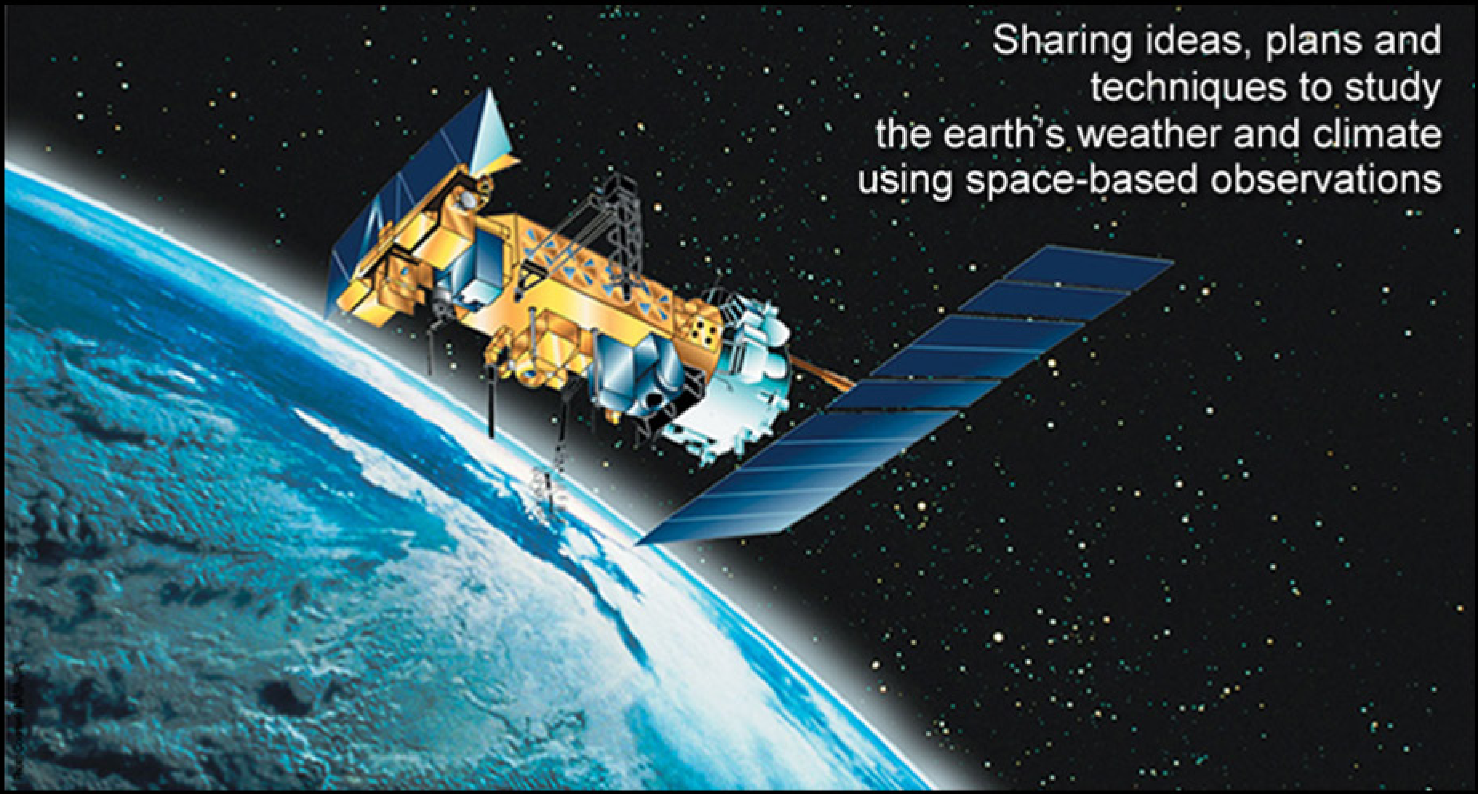
INTERNATIONAL ATOVS WORKING GROUP

21st International TOVS Study Conference (ITSC)

Darmstadt, Germany
29 November - 5 December 2017

Working Group Report from ITSC-21



A Report on
The Twenty-first International
TOVS Study Conference

Darmstadtium
Darmstadt, Germany
29 November – 5 December 2017

Conference sponsored by:	University of Wisconsin-Madison / SSEC ECMWF NOAA/JPSS ABB EUMETSAT Harris Météo France NOAA/GOES-R Orbital Systems SCISYS World Meteorological Organization (WMO)
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FOREWORD

The International TOVS Working Group (ITWG) brings together operational and research users and providers of infrared and microwave satellite sounding data. It is convened as a sub-group of the International Radiation Commission (IRC) of the International Association of Meteorology and Atmospheric Physics (IAMAP) and the Coordination Group for Meteorological Satellites (CGMS). The ITWG organises International TOVS Study Conferences (ITSCs) which have met approximately every 18 to 24 months since 1983. Through this forum, relevant experts exchange information on all aspects of the data processing and use, with a focus on inferring information on atmospheric temperature, moisture, and cloud fields. This includes evaluation of new data, processing algorithms, derived products, impacts in numerical weather prediction (NWP) and climate studies. The group considers data from all sounding instruments that build on the heritage of the TIROS Operational Vertical Sounder (TOVS), including hyperspectral infrared instruments.

This Working Group Report summarises the outcomes of the Twenty-first International TOVS Study Conference (ITSC-XXI) hosted by EUMETSAT in Darmstadt, Germany between 29 November and 5 December 2017. The ITWG Web site contains electronic versions of the conference presentations, posters and publications which can be downloaded (http://cimss.ssec.wisc.edu/itwg/). Together, these documents and web pages reflect a highly successful meeting in Darmstadt.

We wish to thank EUMETSAT for their excellent hosting of the conference, and in particular the local organizing committee, including Sylwia Miechurska, Anne-Marie Andrieux, Julija Mataityte, and Dr Dieter Klaes who ensured a very smooth running of the meeting. The Darmstadtium conference centre provided a brilliant venue for the occasion.

ITSC-XXI was sponsored by industry and government agencies, including ABB, Exelis, Harris, Météo France, NOAA/JPSS Program Office, NOAA/GOES-R Program Office, Orbital Systems, SCISYS, and the World Meteorological Organization (WMO). The German Weather Service (DWD) kindly provided the ice-breaker, very fitting for the first ITSC held in Germany. The EU-project GAIA-CLIM supported and complemented the meeting through a dedicated evening workshop.

The following report encompasses an executive summary highlighting the main developments and conclusions, followed by the detailed working group reports, the conference program, and abstracts of all presentations and posters.

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ITSC-XXI Sponsors

TOVS STUDY CONFERENCE (ITSC-XXI)
Darmstadt, Germany: 29 November – 5 December 2017

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ITSC-XXI Group Photo at the Darmstadtium
Darmstadt, Germany

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1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The twenty-first International TOVS Study Conference, ITSC-21, was hosted by EUMETSAT at the Darmstadtium conference centre in Darmstadt, Germany, between 29 November and 5 December 2017. This time, 180 participants attended the Conference from 49 organizations, providing a wide range of scientific and technical contributions. Eighteen countries and three international organizations were represented: Argentina, Australia, Brazil, Canada, China, Czech Republic, France, Germany, India, Italy, Japan, Norway, Russia, South Korea, Spain, Taiwan, United Kingdom, United States, ECMWF, EUMETSAT, and the WMO. Working Groups were formed for key topic areas, leading to very productive discussions.

Apart from excellent support by the local hosts, EUMETSAT, ITSC-21 was sponsored by industry and government agencies. The industry and government agencies included: ABB, Exelis, Harris, Météo France, NOAA/JPSS Program Office, NOAA/GOES-R Program Office, Orbital Systems, SCISYS, and the World Meteorological Organization (WMO). The great success of ITSC-21 was largely thanks to the excellent work of the local organizing committee from EUMETSAT, Sylwia Miechurska, Anne-Marie Andrieux, Julija Mataityte, and Dr Dieter Klaes, as well as the invaluable administrative and logistical support provided by Leanne Avila, Maria Vasys and Dr Allen Huang at SSEC.

The conference was held only two weeks after two significant polar satellite launches, of FY-3D by CMA and JPSS-1/NOAA-20 by NOAA, and about a year after the launch of the first geostationary satellite carrying a hyperspectral infrared instrument (FY-4A of CMA). First results of the ATMS instrument on NOAA-20 were shown (almost) as they came in from the satellite, suggesting expected good performance, and initial evaluations of the hyperspectral IR instrument on FY-4A gave the community a first chance to appreciate this new capability. Preparations for EUMETSAT's Metop-C (due for launch next year), EPS-SG, and MTG are also providing promising perspectives, as do valuable contributions from Russia, India and Japan. The recent and upcoming launches are testament of a growing diversification of providers, instruments and technology used for passive sounding data, making international coordination of the global satellite observing system all the more important. International coordination to protect relevant microwave frequencies from radio frequency interference (RFI) was also a key topic, prompted by the upcoming World Radiocommunication Conference in 2019.

The group again expressed a strong requirement for state-of-the-art infrared and microwave sounders in at least three complementing orbital planes, and fully supports CMA's efforts to cover the early morning orbit starting with FY-3E. The wide uptake of FY-3 data among international NWP centres establish CMA as a leading provider of satellite sounding data with global reach. Concepts are emerging to provide observations with higher temporal frequency, either through geostationary sounders or through fleets of satellites (e.g., cubesats), and international real-time data exchange and efficient use of such data is essential for optimal exploitation of these resources.

The meeting saw significant progress in enhanced calibration/validation of satellite data and long-term climate data records, not least through fruitful interaction of the NWP and climate communities. The use of metrological approaches combined with reference observations are leading to better quantitative evaluations. These highlight more clearly where better knowledge or reduction of uncertainties is required, for instance in the area of radiative transfer or ocean surface emissivity modelling. Improvements in retrieved products are also more fully appreciated through these calibration-validation efforts. A strong climate session highlighted how well-calibrated data records can be used for trend detections and process studies. A well-attended evening workshop was organised by the EU-funded GAIA-CLIM project to showcase enhanced validation of satellite data through a combination of NWP and reference observations.

Prompted by calibration/validation efforts and new applications in cloudy areas, there was renewed activity regarding improved radiative transfer, recognising the need for improved spectroscopy and better uncertainty characterisation for enhanced quantitative use of sounding data. Initial work towards better uncertainty characterisation was presented, for instance, regarding line mixing in the important 50 GHz temperature-sounding band and the 183 GHz humidity sounding region. Growing accuracy demands, particularly from NWP, are calling for more work on radiative transfer aspects.

Several presentations again demonstrated the critical importance of satellite sounding data for Numerical Weather Prediction and highlighted the growing sophistication of assimilation approaches. The active assimilation of cloud or precipitation affected radiances is becoming a wide-spread operational activity at several NWP centres, particularly for microwave radiances, but promising activities are also emerging for the infrared. Treatment of uncertainties, both random and systematic, continues to be a hot topic, with renewed attention to the role of forecast model bias in adaptive bias correction schemes. Treatment of three-dimensional effects and the actual viewing geometry are starting to receive attention, aimed at reducing errors in the forward calculations for radiance assimilation. The use of reconstructed radiances for the efficient assimilation of the full spectral information contained in hyperspectral infrared radiances is showing promising results. Impact studies also demonstrate that assimilation of passive sounding data provides key 3-dimensional information on wind analyses in modern assimilation systems, for instance through the ability to trace humidity structures in 4D-Var. The optimal exploitation of this will become even more important with the provision of data with high temporal resolution, such as from geostationary sounders or fleets of cubesats.

Critically contributing to the successful data usage are the continued developments of processing packages such as the ATOVS and AVHRR Pre-processing Package (AAPP) and the Community Satellite Processing Package (CSPP). The developments of direct broadcast packages also underpin a continued strengthening of fast retransmission services which uses existing local ground stations to process locally received data and to re-distribute it via the GTS to achieve a timeliness of 30 min or better through the DBNet initiative of WMO. The inclusion of software to process Russian satellite data from the Meteor-M N2 series was encouraged for active exploitation of the promising data source.

Most of the meeting was organized in fifteen sessions of oral presentations and associated poster papers. This comprised of 63 longer format oral presentations and 132 poster papers. Each poster was introduced through a short verbal summary to highlight the scientific content. The range of issues covered in oral presentations and posters included the following:

- Current, new and future observing systems and calibration/validation;
- Operational reports from space agencies and NWP centres;
- Data assimilation applications;

- Climate applications;
- Processing software systems;
- Advanced Sounder science;
- Radiative transfer developments;
- Cloud and precipitation applications; and
- Retrieval science.

Working Groups were formed to consider six key areas of interest to the ITWG, including:

- Radiative Transfer,
- Climate,
- Data Assimilation and Numerical Weather Prediction,
- Advanced Sounders,
- International Issues and Future Systems, and
- Products and Software.

The Working Groups reviewed recent progress in the above areas, made recommendations on key areas of concern and identified items for action. These were further reviewed in a plenary session at the end of the conference. Working Group reviews and recommendations comprise an important part of the ITSC-21 Working Group Report. A summary of the key recommendations and actions arising from the conference is presented below.

Activities that had taken place since ITSC-20 in Lake Geneva, Wisconsin were presented in a dedicated session of Working Group status reports. Technical sub-groups also met during ITSC-21 to discuss developments and plans concerning specific software packages, shared and in common use.

A special oral session honoured the contributions from Paul van Delst, a long-standing member of the ITWG community and co-chair of the Radiative Transfer Working Group, who sadly passed away last year.

The conference agenda and all of the talks and many of the posters can be viewed at the ITWG Web site, located at http://cimss.ssec.wisc.edu/itwg/itsc/itsc21/program/index.html

1.2 SUMMARY OF MAJOR CONCLUSIONS

The ITSC-21 presentations, posters, Working Group meetings and discussions documented significant issues in many areas and identified areas for future activity. The full list of action items and recommendations can be found in the detailed reports from each working group. The main conclusions and recommendations are summarised below.

Observing system evolution:

1. **To CGMS and other satellite agencies:** The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value.
2. **To CGMS and other satellite agencies:** Noting the growing evidence of likely benefits from hyperspectral geostationary soundings, ITWG recommends where possible to work towards the provision of such instruments in plans for future geostationary systems.

3. **To CGMS, other satellite agencies, and users:** ITWG recognises the opportunities arising from the provision of sounder data from small satellites as supplements to the global observing system, particularly for better temporal sampling. ITWG recommends the evaluation of such missions by appropriate agencies, including already planned missions (e.g., TROPICS).
4. **To CGMS and other satellite agencies:** Instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored, in support of maintaining a robust global satellite observing system.
5. **To CGMS and other satellite agencies:** ITWG recommends to develop, test, and implement an SI-traceable radiometric standard in space as soon as feasible.
6. **To satellite agencies:** Consider implementing high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.
7. **To CGMS and other satellite agencies:** Climate applications should be appropriately represented during the planning for new meteorological satellite missions.
8. **To space agencies and all agencies involved in GRUAN/ARM:** ITWG recommends to expand the provision of GRUAN and ARM sites, noting the continued need for and scarcity of ground-based reference measurements.

International coordination, DBNet, frequency protection:

9. **To WMO/CGMS and other satellite agencies:** ITWG recommends to further maintain OSCAR and SATURN, noting the strong positive feedback from ITWG Members. ITWG strongly encourages all agencies to actively contribute information to this portal.
10. **To satellite agencies:** to ensure that provision of Spectral Response Functions for MW instruments is routine practice, particularly for future instruments. This is required to facilitate RFI investigations when needed, and to allow optimal radiative transfer calculations. SRFs should be provided on the SATURN portal, including for current and old sensors.
11. **To the NWP community and other relevant agencies:** in support of continued efforts for frequency protection, national meteorological services should attempt to provide an assessment of the economic value of bands based on an impact assessment, as was done by the Met Office in 2005.
12. **To WMO/stations participating in DBNet:** ITWG continues to support low-cost fast delivery initiatives such as DBNet and welcomes recent extensions to further sensors. ITWG recommends more stations to consider contributing FY-3 sounder data.
13. **To Roshydromet:** Roshydromet are encouraged to release a direct broadcast processing package for the Meteor-M N2 series, including level 1 processing for the MTVZA-GY microwave imager.

Data provision:

14. **To satellite agencies:** For new sensors, pre-launch test datasets should be provided well before launch, in order to allow software development teams (e.g., AAPP, OPS-LRS, CSPP) and other operational users (e.g., NWP centres) to test processing software before satellite launch. New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.
15. **To satellite data providers:** The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.

16. **To satellite agencies:** ITWG recommends open access to new satellite data during the calibration/validation phase (particularly for all NWP centres) to help with calibration and validation.
17. **To CMA:** Consider making available as soon as possible the GIIRS hyperspectral data on FY-4A and of HIRAS on FY-3D to the international user community.
18. **To WMO/CGMS/space agencies:** ITWG supports initiatives to make data from R&D and pre-operational missions available, with a timeliness suitable for operational near-realtime applications. We re-emphasize best practise is to consider timeliness requirements early in the planning stage of new missions, including for research and pre-operational missions, and note that high reliability levels (e.g. >95%) do not need to be a requirement at the pre-operational stage or for short-term research missions.
19. **To CGMS satellite agencies and other data providers:** Advance notifications of processing changes should be an integral component of data provision. If a planned change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.
20. **To CMA:** Consider implementing a subscription-based anomaly/event notification service, similar to that provided by NOAA and EUMETSAT.

Radiative transfer, optimizing return on investments:

21. **To IRC and agencies involved in radiative transfer developments:** ITWG strongly recommends continuous efforts in radiative transfer modelling developments, especially regarding:
    - Line-by-line model development as a fundamental basis for accurate radiative transfer calculations in fast RT models.
    - Development of reference-quality ocean-surface emissivity modeling, specifically Infrared, Microwave, for both active and passive simulations.
    - Extension of the frequency range of scattering models to cover the ranges of current and upcoming sensors, from visible to microwave (i.e., ICI channels).
22. **To IRC and agencies involved in spectroscopy research and radiative transfer development:** ITWG strongly recommends continuous support of theoretical and laboratory spectroscopic studies to improve the accuracy of fundamental parameters required for radiative transfer calculations (e.g., research into spectroscopy of higher frequency microwave channels up to 1000 GHz), as well as efforts to map uncertainties in spectroscopy into radiance uncertainties.
23. **To funding bodies of NWP centres and satellite agencies:** Consider, as part of the cost of satellite sounding programs, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

1.3 FUTURE PLANS

Following the established practice, the group held elections for the future co-chairs of the group after ITSC-21. Anyone who has attended at least three meetings was eligible to vote or stand as candidate. From the five excellent candidates, Liam Gumley (SSEC) and Vincent Guidard (Météo France) were duly elected. ITWG co-chairs are expected to represent and lead the group for the next three conferences.

The next ITSC is expected in 2019. In the meantime, ITWG will continue to inform the infrared and microwave sounding community of the latest news and developments through its Web site (maintained by the University of Wisconsin-Madison/CIMSS) and via the email list (also maintained by CIMSS).

1.4 ACKNOWLEDGEMENTS

This report relied on the active participation of all ITSC attendees and those working group chairs. We acknowledge that writing of this report is possible only through the collective work of ITWG members.

SUMMARY OF ACTIONS AND RECOMMENDATIONS

RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Action RTSP-1 on Benjamin Johnson

To identify specific field campaigns in support of validating fast RT models (specifically RTTOV and CRTM at first).

Action RTSP-2 on Raymond Armante

To give feedback to the RTSP-WG co-chairs on the COMET campaign.

Action RTSP-3 on Jerome Vidot

To provide feedback on cloud scattering validation datasets.

Recommendation RTSP-1 to the aerosol research community

The RTSP working group recommends encouraging research into laboratory measurements of aerosol refractive indices.

Recommendation RTSP-2 to the RT Community

Explore alternative options for the support vibrational temperatures for non-LTE computations.

Recommendation RTSP-3 to RT Model Developers

Fast non-LTE models should include a representation of ozone variability in the upper atmosphere.

Recommendation RTSP-4 to RT Model Developers

We continue to support the previous ITSC-20 recommendation of creating a spectral response function (SRF) repository, to be shared publicly with the RT community. Challenges include export controlled and proprietary information. RTTOV maintains an up-to-date collection of the SRF/passband data used for RTTOV coefficients which may be of interest:
https://www.nwpsaf.eu/site/software/rttov/download/coefficients/spectral-response-functions/

Action RTSP-4 on Benjamin Johnson

To create SRF repository and coordinate inputs from RTWG and other contributors. Will coordinate with Emma Turner (Met Office) to receive updates to SRFs for RTTOV.

Recommendation RTSP-5 to CGMS

Encourage sensor manufacturers and instrument engineering and science teams to provide SRFs with higher quality, consistent format, and with rapid availability.

Recommendation RTSP-6 to Line-by-Line model developers and funding agencies

The RTSP-WG strongly supports continuous line-by-line model development as a fundamental basis for accurate radiative transfer calculations in fast RT models. The RT community also encourages and supports the development of competing line-by-line codes.

Recommendation RTSP-7 to Line-by-Line model developers and spectroscopic database developers

Look at the current continuum absorption models at higher MW frequencies (< 1000 GHz) and promote the use of the MT_CKD model in line-by-line microwave codes. Explore the possibility of using other approaches (e.g., Korshelev 2011) for frequencies below 200 GHz.

Recommendation RTSP-8 to Line-by-Line model developers and spectroscopic database developers

The characterization of LBL model biases should be aimed at identifying spectral regions that can serve as anchor observations. Attempt to map uncertainties in spectroscopy into radiance uncertainties, starting from major lines of a given region.

Action RTSP-5 on Marco Matricardi

To contact RFM group regarding approaches to encourage/enable recommendation RTSP-8.

Action RTSP-6 on Vivienne Payne

To establish and communicate approaches to encourage/enable recommendation RTSP-8.

Recommendation RTSP-9 to Line-by-Line model developers

To include new formulations of the Doppler line broadening line shape (e.g., include velocity dependence in Voigt line shape). This work depends on the availability of relevant data.

Action RTSP-7 on Claude Camy-Peyret

To provide comprehensive communication to the conference co-chairs and to the RTSP-WG regarding a unified model for describing the shape of the relevant atmospheric water vapour lines from the MW to the visible including the very important TIR and SWIR regions.

Recommendation RTSP-10 to spectroscopy researchers

A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. Continuous efforts should be maintained in the generation and improvement of basic line parameters.

Recommendation RTSP-11 to spectroscopy researchers

The RTSP-WG recommends promoting research into spectroscopy of higher frequency microwave channels up to 1000 GHz.

Recommendation RTSP-12 to the surface emissivity modeling community

Develop accurate physical models to support surface emissivity modeling requirements in RT models.

Recommendation RTSP-13 to the surface emissivity modeling community

The RTSP-WG strongly recommends support of developing reference-quality ocean-surface emissivity modeling, specifically infrared, microwave, for both active and passive simulations.

Action RTSP-8 on the RTSP-WG Co-Chairs (Marco Matricardi and Ben Johnson)

Share recommendation with other relevant working groups (e.g., IPWG, Land Surface subgroup, other relevant surface research communities).

Recommendation RTSP-14 to surface-specific spectral library developers

Include broader and more diverse vegetation sampling (e.g., new types), and include the effects of senescence. Also include the impact of the diurnal cycle in spectral emission/reflection databases.

Recommendation RTSP-15 to Atmospheric RT and surface model developers

Improve the interface between land surface model parameters and RT models, and specifically incorporate angular dependence impact on polarized emissivity and reflectivity over all surface types.

Recommendation RTSP-16 to aerosol/cloud/precip microphysical and scattering model developers

For all scatterers, extend the frequency range to cover the ranges of current and upcoming sensors, from visible to microwave (i.e., ICI channels). Extend the range of particulate sizes to be consistent with observed parameters for each particle type.

Recommendation RTSP-17 to aerosol microphysical and scattering model developers

Explore the necessity of using non-spherical aerosol particle scattering properties in fast RT models.

Action RTSP-9 on Ben Johnson

To report on current developments of physical and scattering properties of aerosols, clouds, and precipitation to the RTSP working group.

Recommendation RTSP-18 to RT developers

Extend the comparison of parameterized RT schemes used in fast models. This includes both clouds and aerosols.

Recommendation RTSP-19 to RT developers

We encourage the comparison / validation of full scattering and full polarization solvers. This should include the computational efficiency, specifically including the adjoint model. Analytic adjoint models should be considered.

Recommendation RTSP-20 to aerosol scattering modelers and RT model developers

For aerosol scattering computations, more research is needed to characterize the regimes where fast approximations are effective.

Recommendation RTSP-21 for RT model developers

Look at the importance of simulating radiances in presence of small-scale variability within the FOV. To be done in coordination with model developers.

Recommendation RTSP-22 to RT model developers

Promote the extension of RT models to the simulation of active/passive data (e.g., Radar/LIDAR/Scatterometers), and to UV, visible, and far-infrared portions of the spectrum. A robust treatment of atmospheric, spectroscopic, and surface polarization (linear and circular) should also be considered.

CLIMATE

Recommendation Climate-1 to climate community (including (F)CDR developers)

Consolidate and develop the capacity (expertise, forums, techniques, …) to define the detailed technical requirements for future missions/instruments for climate applications (including climate change detection) & strive to ensure climate requirements are appropriately represented at mission advisory groups.

Recommendation Climate-2 to satellite agencies

Ensure that requirements for climate change applications are appropriately represented for new meteorological satellite missions.

Action Climate 1 on Climate WG Co-Chairs

Establish how requirements from the climate community are collected as input for development of new satellite sensors and provide the information to the group. Establish whether there is a clear role for ITWG-Climate group on definition of climate requirements for new satellite sounding sensors.

Action Climate 2 on data providers/WMO

Links to data, especially FCDR data, recovered data, information on calibration/ inter-calibration of instruments should be fed into a WMO based system. WMO should give a recommendation which of their systems should be used for this purpose.

Recommendation Climate-3 to Satellite Agencies

Climate WG supports efforts to fly SSMIS F-20 to continue the record of upper stratospheric and mesospheric temperatures for climate applications (including climate change monitoring).

Recommendation Climate-4 from ITSC 21 to Reanalysis Groups

Climate reanalysis developing centers shall continue to evaluate the quality of reprocessed/recalibrated data in advance of major new reanalyses, in order to achieve improved consistency in climate reanalysis products, as reprocessed data are better in terms of consistency and accuracy than operational data.

Action Climate 3 on NESDIS

Make climate reanalysis community aware of the reprocessing efforts for SNPP. Lihang Zhou to forward the request within NESDIS.

Recommendation Climate-5 to FCDR developers

The group encourages those engaged in reprocessing FCDRs to make use of techniques developed by the NWP community, based on analysis of departures between observations and models, to improve quality assurance of the FCDRs.

Recommendation Climate-6 on Satellite Data Providers

Satellite data providers should distribute a set of selected channels in parallel to the PC scores. This way users could reconstruct the radiances and compare the reconstructed channels with the distributed channels and check if PCs are done correctly and get a feeling about the potential information loss. The archiving and open availability of full L1C data for climate studies should be preserved and re-processed data should be publicized whenever available.

Recommendation Climate-7 to satellite agencies

Traceable ground calibration and characterization is a necessary (but not sufficient) condition for traceable, low uncertainty, observations on orbit. All space agencies are encouraged to aim to support/develop "ground" calibration strategies which aim at traceability accuracy for all pre-launch characterization and on-orbit calibration - with the aim of reducing radiometric biases over the long term for sounding observations.

Recommendation Climate-8 to satellite agencies

The Climate WG supports free and open data policy and recommends satellite agencies to follow this policy. Satellite agencies should promote / integrate reference in-situ observation from programs such as GRUAN for cal/val activities. The group recommends relevant countries to retain calibration sites even after cal/val campaigns.

Recommendation Climate-9 to satellite agencies/CDR developers

Inter-calibration of hyperspectral sounders is needed for climate applications. The Climate WG supports the mission planning effort for CLARREO which could provide a reference standard for calibration of other hyperspectral instruments.

Recommendation Climate-10

The group supports the establishment of traceability for sensors spanning the electromagnetic spectrum from the microwave to the UV. There had been very effective champions for parts of the spectrum (example visible and IR), while other spectral regions require further support (e.g. microwave, FIR, sub-mm).

DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

Action DA/NWP-1 on ITSC Co-Chairs

To bring relevant recommendations to the attention of CGMS.

Recommendation DA/NWP-1 to all relevant space agencies

The constellation of at least three orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize coverage and include a satellite in early morning orbit.

Recommendation DA/NWP-2 to the satellite agencies

In support of maintaining a robust global satellite observing system, instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored.

Recommendation DA/NWP-3 to space agencies

New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.

Recommendation DA/NWP-4 to space agencies

There should be open and early access to new satellite data for all NWP centres to help with calibration and validation.

Recommendation DA/NWP-5 to funding bodies of NWP centres and space agencies

Consider, as part of the cost of satellite programmes, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

Action DA/NWP-2 on NWP WG members

Send any evidence of RFI to working group chairs for inclusion on the NWP WG RFI web page and forwarding to Jean Pla (jean.pla@cnes.fr) or Richard Kelley (richard.kelley@noaa.gov).

Action DA/NWP-3 on NWP WG members

If you have estimates of revised channel characteristics resulting from post-launch diagnostics, please email these to the radiative transfer working group chairs (Benjamin.T.Johnson@noaa.gov & Marco.Matricardi@ecmwf.int).

Action DA/NWP-4 on NWP centres

Continue to provide information on instrument channels assimilated and their observation errors for inclusion on the NWP Working Group pages in advance of each conference.

Action DA/NWP-5 on WG Chairs

Add information on the notification services from operational data agencies to the working group webpage.

Action DA/NWP-6 on WG members

Review the summary document on different methods of calculation of NEDT compiled by Jörg Ackermann and feedback to the Working Group Chairs by 1st March 2018.

Recommendation DA/NWP-6 to data providers

Agree on a standardized procedure for calculation of NEdT estimates for inclusion within BUFR for microwave data.

Recommendation DA/NWP-7 to data providers

Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Recommendation DA/NWP-8 to space agencies and data providers

When designing new or modified BUFR formats, please circulate drafts to the NWP community via the NWP Working Group for feedback, prior to submission to WMO.

Recommendation DA/NWP-9 to data providers

The transition from NSR to FSR for CrIS data from S-NPP should occur no earlier than six months after CrIS NOAA-20 data becomes available.

Recommendation DA/NWP-10 to data providers

When using PC compression, noise normalisation should be performed using the full noise covariance matrix.

Recommendation DA/NWP-11 to EUMETSAT

Proceed with work on the use of Hybrid PC compression and investigate practical application of this method, including the incorporation of granule-based vectors in BUFR.

Recommendation DA/NWP-12 to data providers

If a change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.

Recommendation DA/NWP-13 to data providers

The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.

Action DA/NWP-7 on WG chairs

Forward Nigel Atkinson's email requesting input on design and features of IRSPP and MWIPP to working group members.

Action DA/NWP-8 on WG members

Review requirements for IRSPP and MWIPP and feed back to Nigel Atkinson and NWP WG Co-Chairs by 1st March 2018.

Action DA/NWP-9 on Wei Han

Distribute a detailed request for data required for his constrained bias-correction study.

Action DA/NWP-10 on WG members

Respond to Wei Han's request.

Action DA/NWP-11 on Working Group chairs

Circulate request for updated information on regional bias correction methods.

Action DA/NWP-12 on WG members

Respond to this request.

Action DA/NWP-13 on DA/NWP WG Co-Chairs

Organise a meeting of a bias correction sub-group to meet at the next ITSC conference.

Recommendation DA/NWP-14 to NWP Centres

Adaptive bias correction schemes are now in wide use and proven to be effective in handling large changes to instrument calibration. Centres should aim to use adaptive bias correction wherever possible.

Recommendation DA/NWP-15 to the research community

The data quality of developmental instruments may be evaluated by the research community, through the use of existing freely available NWP fields and radiance simulators. This is most appropriate where NWP centres are unable to fulfill this role and should be done in close collaboration with the NWP community.

Recommendation DA/NWP-16 to NWP centres

Review whether archived NWP output is sufficient for the purpose of evaluating instrument quality without running the NWP model.

Action DA/NWP-14 on Chris Burrows and Qifeng Lu

Seek expressions of interest on coordinating evaluation of GIIRS and HIRAS data once available to the NWP community.

Action DA/NWP-15 on WG Members

Share impact assessment results for FY-3E with the group and CMA as soon as possible after data becomes available, in particular to provide evidence for support of the early morning orbit.

Recommendation DA/NWP-17 to proposers of research missions

Promote studies from the research community, in particular non-operational centres that run NWP models, to investigate the utility of non-traditional measurement platforms (e.g., small satellites or observations from ISS). Collaboration with operational NWP centres is encouraged.

Recommendation DA/NWP-18 to proposers of research missions

Near-real time dissemination of data is extremely valuable to engage the operational community in mission evaluation, but high reliability levels (e.g., >95%) do not need to be a requirement at the pre-operational stage or for short-term research missions.

Recommendation DA/NWP-19 to WG members

Consider producing timeliness plots similar to those on the NWPSAF website and where possible request they are linked to for comparison.

Action DA/NWP-16 on NWPSAF

Add links on the NWPSAF data timeliness site to monitoring of DBNet stations' data timeliness.

Recommendation DA/NWP-20 to NWP centres

Determine whether existing climatological constraints on stratospheric water amounts are sufficient or whether additional observations (such as the aging Aura-MLS) provide significant information.

ADVANCED SOUNDERS

Recommendation AS-1 to space agencies (CMA)

Consider making available as soon as possible the data of the GIIRS hyperspectral data on FY-4A and of HIRAS on FY-3D to the international user community.

Recommendation AS-2 to space agencies (Roshydromet and Roscosmos)

ASWG recommends to consider the Direct Broadcast capability for the hyperspectral sounder IKFS-2 data on the Meteor-M satellite.

Recommendation AS-3 to Space agencies (Roshydromet and Roscosmos)

ASWG further welcomes the planned development of an improved IKFS sounder and recommends pursuing availability as soon as possible.

Action AS-1 to ITWG Co-Chairs

Bring these recommendations to the attention of Space Agencies at CGMS.

Recommendation AS-4 to space agencies

Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.

Action AS-2 to ITWG Co-Chairs

Bring this recommendation to the attention of space agencies at CGMS.

Recommendation AS-5 to space agencies (NOAA)

Consider implementing a combined imager/sounder instrument approach on future geostationary meteorological satellites.

Action AS-3 to ITWG Co-Chairs

Bring this recommendation to the attention of space agencies via CGMS.

Recommendation AS-6 to space agencies (NOAA & NASA)

a) Make greater use and interpretation of available airborne systems.

This will serve as pathfinders for new systems, and will be a cost effective way to validate the utility of new higher resolution instruments and the applications of their data.

(Primarily to NOAA) Recommend greater field campaign use/exploitation of existing aircraft validation sensors for enhanced measurement system (sensors, algorithms, data products) validation AND data processing/algorithm improvements for handling complex scenes of most meteorological significance (i.e., cold scene retrievals, surface emissivity over snow and ice, aerosols and clouds, etc.).

b) Invest in hardware for next generation sounder specification.

(NOAA and NASA). Recommend investment for developing advanced aircraft sensor system hardware to enable new and improved airborne validation sensors to serve as pathfinders for the development and risk mitigation for the next generation atmospheric satellite sounding system sensors. The aircraft sensor specifications (spatial, spectral, radiometric, and temporal) should far exceed current day state of the art to fulfil the desired pathfinder role.

Action AS-4 to ITWG Co-Chairs

Bring these recommendations to the attention of Space Agencies at CGMS.

Recommendation AS-7 to space agencies

Consider providing non-apodised data to users and having users perform the application related apodisation.

Action AS-5 to ITWG Co-Chairs
Bring this recommendation to the attention of space agencies.

Recommendation AS-8 to space agencies
Consider conducting studies on the utility of sounder measurements from small satellites.

Action AS-6 to ITWG Co-Chairs
Bring this recommendation to the attention of space agencies.

INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Action IIFS-1 on Mikael Rattenborg
To note IIFS comments in next draft of the HLPP.

Action IIFS-2 Action on Christoforos Tsamalis
To provide input to Mikael Rattenborg on item 3.4.1 (new common vocabulary and methodology for the errors associated with validation data).

Recommendation IIFS-1 to IRC
Development of a new unified model for describing spectroscopic and water vapour continuum absorption (Action: IIFS Co-Chairs to discuss with RT Co-Chairs how to communicate).

Recommendation IIFS-2 to ITWG members
ITWG members to become more familiar with the HLPP (Action: IIFS Co-Chairs to suggest to ITWG Co-Chairs to circulate HLPP to ITWG).

Recommendation IIFS-3 to CGMS
Having similar equatorial crossing times is helpful but not sufficient to ensure synergistic opportunities between separate missions. Therefore it is recommended to also take note of projected data coverage when considering opportunities for formation flying of multiple missions (similar to A-train).

Action IIFS-3 on Claude Camy-Peyret
To provide more information to IIFS members on the FORUM proposal.

Action IIFS-4 on IIFS members
To provide science questions to WMO in the first half of 2018 (Lars Peter Riishoejgaard at riishojgaard@wmo.int) and to undertake studies and encourage others to also do so, to support this as a significant theme of the next OSE workshop.

Recommendation IIFS-4 to multiple agencies
Evaluation of TROPICS mission to be undertaken by appropriate agencies in partnership with TROPICS mission (e.g., NWP centres)

Action IIFS-5 on S. English / P. Zhang
To bring this to the attention of major NWP centres and TROPICS mission.

Recommendation IIFS-5 to GODEX-NWP
To organise and oversee agreed sharing of the evaluation of instruments not considered to be “core” by NWP centres.

Action IIFS-6 on Mikael Rattenborg
To discuss with GODEX-NWP members how this initiative could be implemented (next meeting Autumn 2018).

Recommendation IIFS-6 to CGMS
Note the growing evidence of likely benefits from hyperspectral geostationary soundings, and where possible to work towards the provision of such instruments in plans for future geo systems.

Action IIFS-7 on IIFS Co-Chairs
In partnership with NWP WG the IIFS WG Co-Chairs to devise a set of criteria for this CGMS procedure to follow.

Action IIFS-8 on Mikael Rattenborg and the IIFS Co-Chairs
To draft a letter for ITWG Co-Chairs to send to Roscosmos and Roshydromet explaining the importance of access through DB-Net and processing of real time MTVZA-GY and MSU-MR data (Alexander Uspensky to advise full postal address of whom to send to).

Recommendation IIFS-7 to CGMS
Re-emphasize best practise is to consider timeliness requirements early in the planning stage of new missions, including research and pre-operational.

Recommendation IIFS-8 to CGMS
Recognizing the growing need for assessment and on-orbit optimization of the accuracy of operational hyperspectral IR sounders, the traditional approaches for pre-flight SI traceability and post-flight validation should be enhanced by flying a CLARREO-like on-orbit reference standard capability (featuring on-orbit SI verification) with orbits designed to provide inter-calibration capability for refining the calibration of the international fleet of operational sounders.

Action IIFS-9 on Peng Zhang
To check status of reference sites in China and their availability.

Recommendation IIFS-9 to AOPC GCOS
Maintain and where possible expand GRUAN and ARM sites.

Recommendation IIFS-10 to CGMS
Space agencies to develop, where possible, improved capability to detect RFI in level-0 data.

Recommendation IIFS-11 to CGMS
Space agencies to ensure that provision of SRFs for MW instruments is routine practise for future instruments and published on the SATURN portal. Furthermore to obtain wherever possible and practical the SRFs for existing and old instruments, and also to provide on the SATURN portal.

Action IIFS-10 on Steve English

To ask ECMWF if it is willing to host a short workshop (1-2 days) to present updated information with respect to Recommendations IIFS20-14 and IIFS20-15.

Recommendation IIFS-12 to WMO

To continue to pursue SATURN, and all agencies to actively contribute information to this portal (and two associated actions).

Action IIFS-11 on Steve English and Peng Zhang

To bring these suggested changes to WMO teams considering these questions (CGMS, IPETSUP, ICT-IOS…)

PRODUCTS AND SOFTWARE

Action PSWG-1

Nigel Atkinson and Nathalie Selbach to update the list of software packages on the PSWG web page by May 2018.

Action PSWG-2

KMA and SSEC to come up with a plan to make the GK-2A software available to DB users.

Recommendation PSWG-1 to EUMETSAT

EUMETSAT Data Policy be clarified in order to allow distribution of real-time IASI L1 data.

Recommendation PSWG-2 to CSPP team and other DB users

Work with the NPROVS team to allow evaluations of DB-sourced real-time products.

Recommendation PSWG-3 to DB data users

Any DB data users interested in the provision of software to generate their own wind products should contact the CSPP team to register their interest.

Action PSWG-3 on NCEP

To clarify requirements on VIIRS cloud products within the CrIS FOV, and to discuss with the AAPP and CSPP teams the possible implementation in DBNet.

Recommendation PSWG-4 to agencies

In order to allow GEO imager low latency applications, agencies should consider providing GEO rebroadcast geolocation data and other metadata in a format suitable for use during the acquisition of the scan sequence.

Recommendation PSWG-5 to CMA

Provide the Space to Ground Interface document for FY-3D as soon as possible, to allow station manufacturers to prepare their systems in advance of the release of software and data products.

Recommendation PSWG-6 to agencies

Pre-launch test datasets should be provided, well before launch, in order to allow software development teams (e.g., AAPP, OPS-LRS, CSPP) to test Direct Broadcast processing software before satellite launch.

Recommendation PSWG-7 to stations participating in DBNet

Consider contributing FY-3 sounder data to the DBNet system. For FY-3C this means MWHS-2 and IRAS; for FY-3D, it will be MWHS-2, MWTS-2 and HIRAS.

Recommendation PSWG-8 to NOAA and the CSPP team

Support the creation of VIIRS products for nowcasting, similar to the existing MODIS products.

Recommendation PSWG-9 to NOAA

Where possible, provide historical LUTs that are compatible with the latest version of the CSPP SDR processing software.

Recommendation PSWG-10 to NOAA

Consider improving the CLASS interface to allow scripted retrieval of historic data.

Recommendation PSWG-11 to CMA

Consider implementing a subscription-based anomaly/event notification service, similar to that provided by NOAA and EUMETSAT.

Recommendation PSWG-12 to data users

Users should note that L2 profile datasets for validation are available from the NPROVS team, and are encouraged to use them (contact Tony Reale or Lihang Zhou).

Recommendation PSWG-13 to DB station operators

Report instances of RFI (including reception problems) to Richard Kelly. If you are unsure whether specific problems are due to RFI, SSEC is available to help by analysing data samples.

Recommendation PSWG-14 to software providers

Release source code for both L1 and L2 packages, in order to ensure maximum take-up of the software.

Recommendation PSWG-15 to software providers

Provide advance information on plans for implementing new operating system versions and new hardware requirements.

Action PSWG-4

Nigel Atkinson to look at the CrIS PC product and compare the implementation with that used for IASI.

Recommendation PSWG-16 to EUMETSAT

Provide the Metop-SG space to ground interface document, when it is available.

Recommendation PSWG-17 to NOAA

NOAA to provide information to the GRB community on downlink and software requirements for GOES-S (due for launch March 2018). Support for CSPP-GEO should be continued for GOES-S.

Recommendation PSWG-18 to researchers involved in L2 studies

Continue to publish the results of L2 comparisons, particularly those that involve NPROVS, and report to future ITSC meetings.

2. WORKING GROUP REPORTS

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Web site: https://groups.ssec.wisc.edu/groups/itwg/rtsp

Working Group Members: Marco Matricardi (Co-Chair, ECMWF), Benjamin Johnson (Co-Chair, JCSDA), Stephen English, Rory Gray, Emma Turner, Haixia Liu, Yanqiu Zhu, Alex Bobryshev, Heather Lawrence, Eunhee Lee, John Eyre, Pascal Brunel, Jerome Vidot, Pascale Roquet, Wei Han, Cristina Lupu, Sylvain Heilliette, Raymond Armante, Virginie Capelle, Masahiro Kazumori, Yoichi Hirahara, Vivienne Payne, Yasutaka Murakami, Seonki Park, Victoria Galligani, Sanjeev Kumar Singh, Indira Rami S., James Hocking, Nai-Yu Wang

2.1.1 Fast RT Model Intercomparison

The Radiative Transfer and Surface Properties working group (RTSP-WG) agreed to continue RT model intercomparisons and expand it slightly to cover both clear-sky and cloudy RT comparisons, particularly focused between RTTOV and CRTM. One outcome of this intercomparison is to make the input and output datasets publicly available to other RT modelers. In addition to forward modeled radiances, these intercomparisons would also specifically focus on comparing Jacobians.

The initial comparisons would start with a limited set of test cases (profiles) that already exist within the RTTOV testing suite.

For cloudy radiance comparisons, different cloud overlap and cloud physical treatments should be explored, with the goal of identifying deficiencies or areas for future improvements in either modeling approach.

In order to assess the accuracy of RT models, we recommend the use of validation campaign data that has high quality observations of physical and radiometric parameters needed to validate (or partially validate) the forward RT model radiances.

Action RTSP-1 on Benjamin Johnson
To identify specific field campaigns in support of validating fast RT models (specifically RTTOV and CRTM at first).

Action RTSP-2 on Raymond Armante
To give feedback to the RTSP-WG Co-Chairs on the COMET campaign.

Action RTSP-3 on Jerome Vidot
To provide feedback on cloud scattering validation datasets.

Recommendation RTSP-1 to the aerosol research community
The RTSP working group recommends encouraging research into laboratory measurements of aerosol refractive indices.

2.1.2 Fast Model Coefficient Generation

Fast models are crucially important for near real time simulation and assimilation of satellite observations. In this set of recommendations, we seek to improve the availability and quality of spectral responses functions needed to generate accurate coefficients required by fast RT models.

Recommendation RTSP-2 to the RT Community

Explore alternative options for the support vibrational temperatures for non-LTE computations.

Recommendation RTSP-3 to RT Model Developers

Fast non-LTE models should include a representation of ozone variability in the upper atmosphere.

Recommendation RTSP-4 to RT Model Developers

We continue to support the previous ITSC-20 recommendation of creating a spectral response function (SRF) repository, to be shared publicly with the RT community. Challenges include export controlled and proprietary information. RTTOV maintains an up-to-date collection of the SRF/passband data used for RTTOV coefficients which may be of interest:
https://www.nwpsaf.eu/site/software/rttov/download/coefficients/spectral-response-functions/

Action RTSP-4 on Benjamin Johnson

To create SRF repository and coordinate inputs from RTWG and other contributors. Will coordinate with Emma Turner (Met Office) to receive updates to SRFs for RTTOV.

Recommendation RTSP-5 to CGMS

Encourage sensor manufacturers and instrument engineering and science teams to provide SRFs with higher quality, consistent format, and with rapid availability.

2.1.3 LBL Models

Line-by-line (LBL) models are essential to the continued development of fast, accurate radiative transfer models used in NWP and other applications. The current application of LBL models in fast RT models can be further improved through several of the recommendations that we have provided below. In general, we seek to improve the quality of LBL models (including underlying spectroscopic databases), and support diversity and continued development and funding for LBL modelling efforts.

Recommendation RTSP-6 to Line-by-Line model developers and funding agencies

The RTSP-WG strongly supports continuous line-by-line model development as a fundamental basis for accurate radiative transfer calculations in fast RT models. The RT community also encourages and supports the development of competing line-by-line codes.

Recommendation RTSP-7 to Line-by-Line model developers and spectroscopic database developers

Look at the current continuum absorption models at higher MW frequencies (< 1000 GHz) and promote the use of the MT_CKD model in line-by-line microwave codes. Explore the possibility of using other approaches (e.g., Korshelev 2011) for frequencies below 200 GHz.

Recommendation RTSP-8 to Line-by-Line model developers and spectroscopic database developers

The characterization of LBL model biases should be aimed at identifying spectral regions that can serve as anchor observations. Attempt to map uncertainties in spectroscopy into radiance uncertainties, starting from major lines of a given region.

Action RTSP-5 on Marco Matricardi

To contact RFM group regarding approaches to encourage/enable recommendation RTSP-8.

Action RTSP-6 on Vivienne Payne

To establish and communicate approaches to encourage/enable recommendation RTSP-8.

Recommendation RTSP-9 to Line-by-Line model developers

To include new formulations of the Doppler line broadening line shape (e.g., include velocity dependence in Voigt line shape). This work depends on the availability of relevant data.

Action RTSP-7 on Claude Camy-Peyret

To provide comprehensive communication to the conference co-chairs and to the RTSP-WG regarding a unified model for describing the shape of the relevant atmospheric water vapour lines from the MW to the visible including the very important TIR and SWIR regions.

2.1.4 Spectroscopic Parameters

Similar to our support for line-by-line modeling improvements, we also seek to encourage the development of new and improved spectroscopic databases, particularly with respect to those databases that support LBL models. We address a specific need for extending research into higher microwave frequencies that will be used on future sensors.

Recommendation RTSP-10 to spectroscopy researchers

A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. Continuous efforts should be maintained in the generation and improvement of basic line parameters.

Recommendation RTSP-11 to spectroscopy researchers

The RTSP-WG recommends promoting research into spectroscopy of higher frequency microwave channels up to 1000 GHz.

2.1.5 Surface Properties

The RTSP-WG encourages continued development and improvements in both physical surface modeling and radiative transfer interfaces to these models with the explicit goal of increasing the overall accuracy and physical representativeness of emissivity computations. This is applicable to all surface types and includes current and future sensor capabilities. The following recommendations are aimed at strengthening the research aspects and encourages communication and collaboration between and within the physical modeling and RT modeling communities.

Recommendation RTSP-12 to the surface emissivity modeling community
Develop accurate physical models to support surface emissivity modeling requirements in RT models.

Recommendation RTSP-13 to the surface emissivity modeling community
The RTSP-WG strongly recommends support of developing reference-quality ocean-surface emissivity modeling, specifically infrared, microwave, for both active and passive simulations.

Action RTSP-8 on the RTSP-WG Co-Chairs (Marco Matricardi and Ben Johnson)
Share recommendation with other relevant working groups (e.g., IPWG, Land Surface subgroup, other relevant surface research communities).

Recommendation RTSP-14 to surface-specific spectral library developers
Include broader and more diverse vegetation sampling (e.g., new types), and include the effects of senescence. Also include the impact of the diurnal cycle in spectral emission/reflection databases.

Recommendation RTSP-15 to Atmospheric RT and surface model developers
Improve the interface between land surface model parameters and RT models, and specifically incorporate angular dependence impact on polarized emissivity and reflectivity over all surface types.

2.1.6 Optical Properties for Scattering Models

In a similar vein to the surface modeling, the optical properties of scattering particles (e.g., aerosols, clouds, precipitation) also require continued support to improve physical and radiometric accuracy. The accuracy of scattering computations can be significantly affected by errors and uncertainties of the parameterization of optical properties of the scattering particles. Although several methods exist to compute the optical properties of spherical and non-spherical particles, the representation of the optical properties of an ensemble of scattering particles of different sizes and habits is still an outstanding issue. More research is needed into the characterization of these size distributions. This is especially true for ice particles for which a variety of different habits has been observed. In addition, the size distribution of small ice particles is still poorly known.

The following recommendations and action items identify and seek to bring awareness to these deficiencies.

Recommendation RTSP-16 to aerosol/cloud/precip microphysical and scattering model developers
For all scatterers, extend the frequency range to cover the ranges of current and upcoming sensors, from visible to microwave (i.e., ICI channels). Extend the range of particulate sizes to be consistent with observed parameters for each particle type.

Recommendation RTSP-17 to aerosol microphysical and scattering model developers
Explore the necessity of using non-spherical aerosol particle scattering properties in fast RT models.

Action RTSP-9 on Ben Johnson

To report on current developments of physical and scattering properties of aerosols, clouds, and precipitation to the RTSP working group.

2.1.7 Scattering Model Solvers

Scattering approximations used in fast RT models is essential for operational use within simulations involving scattering atmospheres. In that respect, it is crucial that the RT community compares the results from scattering model solvers to both each other, and to external models that may be more robust / accurate. External validation is also an essential component to understanding the systematic errors that may be present in any given model. These comparisons aid in identifying key deficiencies in the models.

Ideally this approach includes aerosols, clouds, and precipitation comparisons, under a wide range of situations. This feeds back into the fast RT Model intercomparison efforts described previously, where the RTSP-WG plans to develop (in the future) additional test cases for fast RT model intercomparisons under scattering conditions.

We also specifically recognize a need for improved accuracy in RT modeling in 3D cloud structures.

Recommendation RTSP-18 to RT developers

Extend the comparison of parameterized RT schemes used in fast models. This includes both clouds and aerosols.

Recommendation RTSP-19 to RT developers

We encourage the comparison / validation of full scattering and full polarization solvers. This should include the computational efficiency, specifically including the adjoint model. Analytic adjoint models should be considered.

Recommendation RTSP-20 to aerosol scattering modelers and RT model developers

For aerosol scattering computations, more research is needed to characterize the regimes where fast approximations are effective.

2.1.8 Future RT Outlook

Part of the challenge of developing fast RT models is to be prepared and responsive to upcoming requirements that will be imposed on RT developers by the NWP or other communities. These recommendations specifically identify areas of potential or upcoming importance that need to have some early attention and discussion. It is expected that these items will move up into other areas as requirements and research progresses.

Recommendation RTSP-21 for RT model developers

Look at the importance of simulating radiances in presence of small-scale variability within the FOV. To be done in coordination with model developers.

Recommendation RTSP-22 to RT model developers

Promote the extension of RT models to the simulation of active/passive data (e.g., Radar/LIDAR/Scatterometers), and to UV, visible, and far-infrared portions of the spectrum. A robust treatment of atmospheric, spectroscopic, and surface polarization (linear and circular) should also be considered.

2.2 CLIMATE

Web site: http://cimss.ssec.wisc.edu/itwg/cwsg/

Nathalie Selbach (Co-Chair, DWD), Cheng-Zhi Zou (Co-Chair, NOAA/NESDIS/STAR), Bill Bell (ECMWF), Claude Camy-Peyret (IPSL), Fabien Carminati (Met Office), Eui-Seok Chung (University of Miami), Cyril Crevoisier (CNRS-LMD), Timo Hanschmann (EUMETSAT), Dirceu Herdies (INPE), Jun Li (SSEC/UW-Madison), Stuart Newman (Met Office), Marc Prange (University of Hamburg), Roger Randriamampianina (Metno), Tony Reale (NOAA), Henry Revercomb (SSEC/UW-Madison), Claudia Stubenrauch (LMD), Bomin Sun (NOAA), Christoforos Tsamalis (Met Office), Lihang Zhou (NOAA)

2.2.1 Introduction

The following topics were discussed in the Climate working group meeting held on 2 December 2017 and 4 December 2017 at ITSC 21:

- Discussion on the Climate WG survey (Cheng-Zhi Zou),
- Review of all open and ongoing actions from ITSC-20,
- Briefing on NOAA reprocessing of SNPP data (Lihang Zhou),
- Specific topics suggested by the ITSC Co-Chairs, and
- Discussion of CGMS HLPP topics relevant for Climate WG.

2.2.2 Climate WG Survey

In spring 2017 a survey has been set up and sent to the 25 members of the Climate WG mailing list. The survey was completed on 15 May 2017 and has been evaluated by the Climate WG Co-Chairs. The results have been distributed to the members of the Climate WG mailing list in summer 2017. The results have also been presented at the ITSC-21 (Report on working group actions from ITSC-20). More information on the results of the survey is available via the Climate WG Co-Chairs.

2.2.3 Review of Actions from ITSC-20

There are three actions from ITSC-20, which could not be closed yet. Two of them are related to updates of the Climate WG subpage, which is currently pending the availability of the new content management system (CMS).

A dedicated mailing list (itwg_climate_wg@ssec.wisc.edu) for the Climate Working Group has been set up and is available since December 2015. For changes in the mailing list or to register a new email address please contact the Climate WG Co-Chairs. Information relevant to the Climate WG will be sent out to members of this mailing list. The mailing list will be updated and attendees of the Climate WG at ITSC-21 will be included in the mailing list.

- **Action Climate20-1 on WG Co-Chairs:** Coordinate the update of the webpage of the Climate WG once the new Content Management System (CMS) is available and the ITWG pages as well as the subgroup pages have been migrated to the new systems.
  Status: Ongoing
  The new system is not yet available and CIMSS is currently working on redesign of the Center's website (for UW-Madison SSEC). The ITWG page and the sub-pages of the different working groups will be moved afterwards. Since ITSC-20 a minor update of Climate WG subpage has been done (e.g. update of contact details, list of group members, update of links and logos, some content changes). The major change will be done on the new system (during 2018). The Climate WG Co-Chairs will

contact the group members once the new system is available. The webpage will be updated with the support from the WG members.

- **Action Climate20-5 on Cheng-Zhi Zou:** NESDIS to look for possibility to merge AIRS/IASI/CrIS with existing Stratospheric Sounding Unit (SSU) CDR for inter-comparisons with the SSU/AMSU merged products
  Status: Ongoing
  This work needs further funding support. A letter of Intent was submitted. A decision on a possible extension of the NOAA CDR work is pending.

- **Action Climate20-6 on Rob Roebeling:** Provide information to the Climate WG webpage on different inter-calibration activities for Level-1 FCDR data, e.g. HIRS, AMSU, AVHRR, etc.
  Status: Ongoing
  Input has been provided by Rob Roebeling, which has been distributed to the Climate WG mailing list. The provision of information to the webpage is pending the availability of the new CMS (see action Climate-1 from ITSC-20).

2.2.4 Tied up to ITSC-21 Discussion topics

Global Observing System Design

It is observed that the current environmental satellite missions are mostly driven by weather requirements. New mission and instrument specifications should take into account the climate community requirements for climate applications (e.g., stability, frequency and radiometry requirements, bias characteristics, *etc*.).

Recommendation Climate-1 to climate community (including (F)CDR developers)
Consolidate and develop the capacity (expertise, forums, techniques, …) to define the detailed technical requirements for future missions/instruments for climate applications (including climate change detection) & strive to ensure climate requirements are appropriately represented at mission advisory groups.

Recommendation Climate-2 to satellite agencies
Ensure that requirements for climate change applications are appropriately represented for new meteorological satellite missions.

New instrument design needs to take into account the need from the climate community for usage of data for climate applications (e.g., stability, frequency and radiometry requirements, etc.).

Action Climate 1 on Climate WG Co-Chairs
Establish how requirements from the climate community are collected as input for development of new satellite sensors and provide the information to the group. Establish whether there is a clear role for ITWG-Climate group on definition of climate requirements for new satellite sounding sensors.

The group discussed that a lot of information on reprocessed data, which should be used in climate monitoring applications and climate reanalysis projects, is available. However, it is sometimes difficult to find the relevant information. The current WMO OSCAR system could serve as a point of information on availability of (reprocessed) data. Other options include the WMO Product Access Guide or the WMO Satellite User Readiness Navigator (SATURN).

Action Climate 2 on data providers/WMO

> **Links to data, especially FCDR data, recovered data, information on calibration/ inter-calibration of instruments should be fed into a WMO based system. WMO should give a recommendation which of their systems should be used for this purpose.**

With support of the Climate WG team members the information will also be added on Climate WG webpage.

Data Archiving

The need for long term archiving of raw data and associated metadata, including documentation and instrument information is well known by satellite agencies and data centres. No further recommendation from the Climate WG is needed.

Data Continuity and Consistency

The group discussed the importance of good calibration/inter-calibration of satellite data for climate applications as well as the importance of sustainability and continuity in observations, particularly the continuity of channel frequencies.

The DMSP F-20 mission was deactivated, but the Naval Research Laboratory Marine Meteorology Division and The Aerospace Corporation have secured the last SSMIS (Special Sensor Microwave Imager/Sounder) sensor that was planned for the F-20 mission for a potential flight on a future mission-of-opportunity. A number of mission options are currently under consideration. This would provide continuity between the currently flown SSMIS units aboard DMSP F16, F17, and F18 and a potential equivalent sensor on a future DoD program.

Recommendation Climate-3 to Satellite Agencies

> **Climate WG supports efforts to fly SSMIS F-20 to continue the record of upper stratospheric and mesospheric temperatures for climate applications (including climate change monitoring).**

Data Reanalysis

The need for reprocessing of level 1 radiances for climate reanalysis and CDR generation has been discussed. There are several European and US activities involved in the generation of FCDRs.

A beta-version of reprocessed ATMS, CrIS, OMPS data are available. Lihang Zhou can be contacted if interested in the data. Reprocessed VIIRS data will become available later.

Recommendation Climate-4 from ITSC 21 to Reanalysis Groups

> **Climate reanalysis developing centers shall continue to evaluate the quality of reprocessed/recalibrated data in advance of major new reanalyses, in order to achieve improved consistency in climate reanalysis products, as reprocessed data are better in terms of consistency and accuracy than operational data.**

Action Climate 3 on NESDIS

Make climate reanalysis community aware of the reprocessing efforts for SNPP. Lihang Zhou to forward the request within NESDIS.

Recommendation Climate-5 to FCDR developers

The group encourages those engaged in reprocessing FCDRs to make use of techniques developed by the NWP community, based on analysis of departures between observations and models, to improve quality assurance of the FCDRs.

Efficient Dissemination of Hyperspectral IR Data (Global and DB)

The group recognizes the importance of efficient access to data for climate studies. As data download from the data providers can become problematic due to the amount of data volume, this could be done via hosted processing, for example. Data providers are encouraged to consider the concept of hosted processing.

Efficient Use of Hyperspectral IR Data

Data volume for hyperspectral IR data is huge and efficient access to data is important. An option to select e.g. selected channels or reduced spatial resolution on data provider side is encouraged.

There is a risk that information relevant for climate change monitoring gets lost if using PCs. For example, MTG-IRS data might only be distributed to the users as PC and users would have to rely on the PCs.

Recommendation Climate-6 on Satellite Data Providers

Satellite data providers should distribute a set of selected channels in parallel to the PC scores. This way users could reconstruct the radiances and compare the reconstructed channels with the distributed channels and check if PCs are done correctly and get a feeling about the potential information loss. The archiving and open availability of full L1C data for climate studies should be preserved and re-processed data should be publicized whenever available.

Biases

There are International standards on the definition of key terms (Guide to the Expression of Uncertainty in Measurement (GUM, see e.g. ISO/IEC Guide 98-3:2008). Data providers are recommended to follow these guidelines, as far as practical and useful. (Noting that this is an area where developments are moving rapidly – due to programs & projects such as: GSICS, X-CAL, FIDUCEO & GAIA-CLIM, …)

NOAA is monitoring SNPP instrument biases by comparing with reference observations as much as possible. The group recommends other agencies to establish online bias monitoring as best practice approach.

Recommendation Climate-7 to satellite agencies

Traceable ground calibration and characterization is a necessary (but not sufficient) condition for traceable, low uncertainty, observations on orbit. All space agencies are encouraged to aim to support/develop "ground" calibration strategies which aim at traceability accuracy for all pre-launch characterization and on-orbit calibration - with the aim of reducing radiometric biases over the long term for sounding observations.

Validation

GAIA-CLIM has produced a set of recommendations which form a basis for consideration by satellite agencies to address gaps in the current capability for cal/val of Earth observations for a wide set of ECVs. These recommendations can be found here: http://www.gaia-clim.eu/page/recommendations

Reference in-situ observations such as GRUAN or ARM are important for cal/val activities to ensure proper characterization of satellite sensors as well as derived climate data records. Additionally dedicated measurement campaigns are often carried out for specific projects. The data from these reference stations and campaigns is an important data source for validation activities and it would be beneficial if this data is available to all interested users.

Recommendation Climate-8 to satellite agencies

> **The Climate WG supports free and open data policy and recommends satellite agencies to follow this policy. Satellite agencies should promote / integrate reference in-situ observation from programs such as GRUAN for cal/val activities. The group recommends relevant countries to retain calibration sites even after cal/val campaigns.**

2.2.5 Tied up to CGMS HLPP

"3. Enhance the Quality of Satellite-derived Data and Products

> *3.1 Establish within GSICS a fully consistent calibration of relevant satellite instruments across CGMS agencies, recognizing the importance of collaboration between operational and research CGMS agencies."*

The group recognizes the efforts within GSICS to provide consistent calibration of relevant satellite instruments. GSICS is encouraged to continue the efforts and cover the full frequency spectrum.

Hyperspectral Sounders

There are multiple hyperspectral sounders currently flying on different satellite missions. Inter-calibration between them could improve the data quality and consistency for their use in climate applications. CLARREO as a Climate Absolute Radiance and Refractivity Observatory could be used as a reference for absolute calibration of other instruments in the inter-calibration effort.

Recommendation Climate-9 to satellite agencies/CDR developers

> **Inter-calibration of hyperspectral sounders is needed for climate applications. The Climate WG supports the mission planning effort for CLARREO which could provide a reference standard for calibration of other hyperspectral instruments.**

Recommendation Climate-10

> **The group supports the establishment of traceability for sensors spanning the electromagnetic spectrum from the microwave to the UV. There had been very effective champions for parts of the spectrum (example visible and IR), while other spectral regions require further support (e.g. microwave, FIR, sub-mm).**

"5. Cross-cutting Issues and New Challenges

5.1.4 Perform case studies linking CDRs to societal applications and informed policy decisions"

The atmospheric temperature CDR derived from microwave sounders were used several times in the US Congressional hearing on climate change debate.

Better calibration/inter-calibration of satellite data resulted in satellite CDRs with improved accuracy and reliability for climate change detection, which helps the society to resolve the climate change debate.

2.3 DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

Web site: https://groups.ssec.wisc.edu/groups/itwg/nwp

Working group members: Fiona Smith (Co-Chair, Bureau of Meteorology/Met Office), Andrew Collard (Co-Chair, NOAA/NCEP/EMC), Jörg Ackermann (EUMETSAT), Thomas August (EUMETSAT), Kristen Bathmann (NOAA/NCEP/EMC), Bill Bell (Met Office), Patrik Benacek (CHMI), Niels Bormann (ECMWF), Chris Burrows (ECMWF), James Cameron (Met Office), Bill Campbell (NRL), Brett Candy (Met Office), Fabien Carminati (Met Office), Keyi Chen (ZAP/CAS), Yong Chen (NOAA/NESDIS/STAR), Hyoung-Wook Chun (KIAPS), Chu-Yong Chung (KMA), Olivier Coopmann (Météo-France), Mohamed Dahoui (ECMWF), Reima Eresmaa (ECMWF), John Eyre (Met Office), Louis Garand (ECCC), Alan Geer (ECMWF), Vincent Guidard (Météo-France), Wei Han (CMA), Sylvain Heilliette (ECCC), Junhyung Heo (KMA), Dirceu Herdies (CPTEC), Tim Hultberg (EUMETSAT), Ben Johnson (JCSDA), James Jung (CIMSS), Jeon-Ho Kang (KIAPS), Masahiro Kazumori (JMA), Meeja Kim (KMA), Christina Köpken-Watts (DWD), Allen Larar (NASA Langley), Heather Lawrence (ECMWF), Eunhee Lee (KMA), Jun Li (CIMSS), Agnes Lim (CIMSS), Haixia Liu (NOAA/NCEP/EMC), Katrin Lonitz (ECMWF), Qifeng Lu (CMA/NSMC), Cristina Lupu (ECMWF), Marco Matricardi (ECMWF), Will McCarty (NASA GMAO), Stefano Migliorini (Met Office), Yasutaka Murakami (JMA), Stu Newman (Met Office), Kozo Okamoto (JMA), Seon Ki Park (EWHA), Roger Randriamampianina (Met Norway), Indira Rani (NCMRWF, India), Kirsti Salonen (ECMWF), Dave Santek (CIMSS), Awdhesh Sharma (NOAA/NESDIS/OSPO), Sanjeev Kumar Singh (NCMRWF, India), Bomin Sun (NOAA/NESDIS), Florian Suzat (Météo-France), Ruth Taylor (Met Office), Bob Tubbs (Met Office), Jérôme Vidot (Météo-France/CMS), Likun Wang (Univ. of Maryland), Nai-Yu Wang (ESSIC/University of Maryland), Pete Weston (ECMWF), Jin Woo (KMA), Qiang Zhao (NOAA/NESDIS/IMSG), Yanqiu Zhu (NOAA/NCEP/EMC)

2.3.1 Scope of the DA/NWP Working Group

The scope of the group with respect to geostationary sounders was discussed. It was decided that it was appropriate to include geostationary sounders (and to some extent imagers) provided the science was within the scope of the conference generally, i.e. it related specifically to passive sounding applications rather than imagery applications (such as AMVs).

2.3.2 Standing Actions and Recommendations

Action DA/NWP-1 on ITSC Co-Chairs

To bring relevant recommendations to the attention of CGMS.

Polar Orbiting Constellation

Over the years, many observation impact experiments have demonstrated benefits from using MW and IR sounding data from three or more polar orbiting systems in NWP, compared to using data from just two orbits. An even spacing of orbits (early morning, morning, afternoon orbit) ensures most homogeneous coverage, with benefits for forecast impact. The WG strongly supports international cooperation to ensure harmonization of orbits. The group would like to recognise that good work has been done in support of this recommendation already over the last few years. It has been agreed that the Chinese satellite FY3E will be placed in early morning orbit, but for future FY satellites the orbit is not yet confirmed. The working group therefore noted the continuing uncertainty around the presence of sounding instrumentation in the early morning orbit.

Recommendation DA/NWP-1 to all relevant space agencies

> **The constellation of at least three orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize coverage and include a satellite in early morning orbit.**

With the discontinuation of the DMSP satellites, the availability of high altitude temperature sounding channels is in doubt. It is therefore recommended that options to continue this capability be explored.

Recommendation DA/NWP-2 to the satellite agencies

> **In support of maintaining a robust global satellite observing system, instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored.**

Cal/val of Future Instruments

The working group believe that the distribution of test data prior to launch is of such importance that the following recommendations should be repeated to ensure that users have adequate test data to fully prepare for future systems.

Recommendation DA/NWP-3 to space agencies

> **New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.**

Furthermore, NWP data has proven to be a critical resource in the Cal/Val process for new instruments.

Recommendation DA/NWP-4 to space agencies

> **There should be open and early access to new satellite data for all NWP centres to help with calibration and validation.**

Investment to Fully Realise Potential of New Satellites in Operational Use

New satellite programmes can cost hundreds of millions of Euros and yet it can take many years to learn to properly exploit the data in numerical weather prediction. Additional investment in operational NWP (which while still expensive is only a few percent of the satellites themselves) therefore represents an efficient path for improving the cost/benefit ratio for satellite observations. This investment should focus on improved computational resources (allowing more sophisticated models to be run and more resources for research); development of new assimilation techniques (many centres are still not running 4D assimilation systems thereby reducing the impact of observations with high temporal frequency) and improvement to the forecast models, as well as methods focused on the particular observations themselves.

Investment in operational NWP is preferred as research conducted in this paradigm from the start is more easily transferred to operational status. It is also noted that the larger the number of operational centres able to conduct cutting-edge research, the more likely that breakthroughs will be made in the use of satellite data.

Recommendation DA/NWP-5 to funding bodies of NWP centres and space agencies

Consider, as part of the cost of satellite programmes, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

Radio Frequency Interference

At ITSC-17, an activity was started to collect evidence from existing Radio Frequency Interference (RFI) or research into potential impacts of RFI in NWP systems. A website has been set up for this task (https://groups.ssec.wisc.edu/groups/itwg/nwp/rfi_and_nwp), including examples for Windsat, SMOS, and AMSR-E. We need to be able to document instances of RFI so that evidence can be presented to the relevant national authorities who may be able to remove offending illegal transmissions.

Action DA/NWP-2 on NWP WG members

Send any evidence of RFI to working group chairs for inclusion on the NWP WG RFI web page and forwarding to Jean Pla (jean.pla@cnes.fr) or Richard Kelley (richard.kelley@noaa.gov).

Updated Channel Characteristics

NWP systems or Simultaneous Nadir Overpass (SNO)-methods have been used to revise channel characteristics such as central pass-band frequencies for microwave instruments or spectral response functions for IR sounders. The group think that it is still useful to collect this information on the channel characteristics web-page of the RT WG, as such updates have been shown to reduce some airmass-dependent biases and therefore aid the assimilation of the affected data.

Action DA/NWP-3 on NWP WG members

If you have estimates of revised channel characteristics resulting from post-launch diagnostics, please email these to the radiative transfer working group chairs (Benjamin.T.Johnson@noaa.gov & Marco.Matricardi@ecmwf.int).

2.3.3 WG Support to NWP Community

The ITSC NWP WG is recognized as an ideal forum to exchange information and inform/update NWP users about new developments, aided by Wiki-pages and a dedicated email list. For several meetings, the survey on the use of satellite data has been capturing the broad developments in the assimilation of sounder data in NWP, with the results posted on the NWP WG web pages. Ahead of ITSC-21, an extra column has been added to allow centres to link in further information (e.g., regarding blacklisting).

Action DA/NWP-4 on NWP centres

Continue to provide information on instrument channels assimilated and their observation errors for inclusion on the NWP Working Group pages in advance of each conference.

The group was pleased by the increased use of the working group mailing list in highlighting problems with operational instruments and members are encouraged to continue to share experiences this way.

It was pointed out that working group members may not be aware of all the notification services available from data providers. The working group chairs will put this information on the working group webpage.

Action DA/NWP-5 on WG Chairs

Add information on the notification services from operational data agencies to the working group webpage.

2.3.4 Provision of BUFR Data

At previous meetings, the group made the recommendation (ITSC-XX/DA/NWP-8) to Data Providers to agree on a standardized procedure for inclusion of NEdT estimates within BUFR for microwave data.

Since the last meeting, NEDT estimates have been added to the ATOVS BUFR data distributed by EUMETSAT.

However, it remains an issue that the calculation of the NEDT differs between NOAA, EUMETSAT and the Met Office. Jörg Ackermann (EUMETSAT) distributed a report detailing the differences between these approaches. For further progress, working group members should review these approaches and make suggestions as to the preferred method for calculating NeDT.

Action DA/NWP-6 on WG members

Review the summary document on different methods of calculation of NEDT compiled by Jörg Ackermann and feedback to the Working Group Chairs by 1st March 2018.

Recommendation DA/NWP-6 to data providers

Agree on a standardized procedure for calculation of NEdT estimates for inclusion within BUFR for microwave data.

The group retained the following two recommendations from previous conferences:

Recommendation DA/NWP-7 to data providers

Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Recommendation DA/NWP-8 to space agencies and data providers

When designing new or modified BUFR formats, please circulate drafts to the NWP community via the NWP Working Group for feedback, prior to submission to WMO.

2.3.5 CrIS switch to Full Spectral Resolution data

CrIS data from NOAA-20 will only be distributed as Full Spectral Resolution (FSR) data, but the decision on when to transition the data dissemination for S-NPP from Nominal (NSR) to FSR needs to be made. Every centre will have a different strategy for making this transition, but it was agreed that the optimal strategy to maximise data usage would be for the transition to FSR for S-NPP to occur when centres are ready to start assimilating CrIS from NOAA-20 (and for some centres it may be necessary to switch both to FSR at the same time). Six months from the start of NOAA-20 data dissemination was considered a reasonable timeframe for this.

Recommendation DA/NWP-9 to data providers

The transition from NSR to FSR for CrIS data from S-NPP should occur no earlier than six months after CrIS NOAA-20 data becomes available.

2.3.6 IASI Non-linearity Correction

Following the change to non-linearity correction on Metop-B IASI, CNES plan to update the non-linearity correction algorithm for Metop-A IASI at the beginning of February 2018, pending any objections from users.

Nobody in the working group expressed any reasons why the change should not be made to Metop-A IASI.

2.3.7 PC Compression of Hyperspectral Data

At the last conference, a recommendation (DA/NWP20-13) was made to data providers and NWP users to agree a mutually acceptable update strategy for the dissemination of PC products. Thomas August and Tim Hultberg (EUMETSAT) closed the associated action (DA/NWP20-13) to circulate a proposal for an update strategy, which in brief proposes an 8-week warning plus test data for a change to the eigenvector basis set (without change to number of eigenvectors).

The working group broadly agreed that this strategy is acceptable but asks data providers to note that it is a change that will require activity by NWP Centres, possibly including updating error covariance matrices. Acknowledging that centres do not currently use PC-compressed data streams in operations, a longer lead time is requested for the first of such changes in order to ensure that 8 weeks is indeed an adequate lead time.

We retained the following recommendation from the last conference:

Recommendation DA/NWP-10 to data providers

When using PC compression, noise normalisation should be performed using the full noise covariance matrix.

Although the full noise covariance matrix is not currently used for IASI compression, the PC basis vectors are in need of updating and the full matrix could be introduced at the same time. This might be a good test case for trying out the 8-week lead time proposed for a change, assuming centres were able to run near-real-time assimilation experiments of PC-compressed data before the switch to new vectors is made.

The group expressed interest in the work being done at EUMETSAT into Hybrid-PC compression (using a few hundred global PCs with 3 granule-based vectors of the residuals added). The use of such an approach should mitigate the requirement for ad hoc changes to PC basis vectors, and instead a planned annual update could be foreseen.

Recommendation DA/NWP-11 to EUMETSAT

Proceed with work on the use of Hybrid PC compression and investigate practical application of this method, including the incorporation of granule-based vectors in BUFR.

2.3.8 Change Management and the NWP Community

There were a number of instances this year where the management of change to the global observing system did not meet the requirements of the NWP community.

There were two planned changes to the calibration of instruments (ATMS on S-NPP and IASI on MetOp-B) where notification via official services should have been more timely and (where applicable) test data should have been provided. In both of these cases, the calibration changes resulted in changes to instrument biases of several tenths of a Kelvin - enough to potentially impact NWP fields.

The group felt strongly that it should be unambiguously communicated by data providers when a significant change such as these are to be made. This should be done at least 8 weeks before the change and, where possible, test data should be provided. An initial definition of a "significant change" is where the brightness temperature changes in the mean by 0.1K or 20% of NEdT (whichever is smaller).

Recommendation DA/NWP-12 to data providers

> **If a change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.**

There was also some disappointment in the group on the very short transition (19 days) from GOES-13 to GOES-16, which was considered too short for NWP centres to introduce new instruments and data products (the International Winds Working Group, IWWG, has previously recommended an overlap of not less than 9 months). In addition, some data products (such as the Clear Sky Radiances) will not be available before Spring 2019, resulting in a fifteen month gap in the products.

It was noted that this transition did not follow WMO guidelines for change management and user consultation.

Recommendation DA/NWP-13 to data providers

> **The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.**

2.3.9 Pre-processing Software

NWPSAF MTG-IRS Pre-Processor (IRSPP)

This software is proposed to be made available in a similar way to AAPP for the polar orbiting sounders. Nigel Atkinson (Met Office) is currently collating a list of requirements for the software. The group had not had time to properly consider this, although one new proposal was made that the package could be configured to automatically download the PC eigenvector basis set required to decode the data if not already available at runtime.

NWPSAF Microwave Imager Pre-Processor (MWIPP)

The NWPSAF are also planning a microwave imager pre-processing package, incorporating features of the current SSMIS-PP Averaging Module and extending to other instruments such as AMSR-2, GMI and the future MWI. A similar request was made for feedback on this proposal.

A suggestion was made that for all-sky assimilation, superobbing is generally onto a fixed (NWP) grid rather than across the scanline. The pre-processor should support averaging onto this kind of grid as well as on the native instrument grid.

Action DA/NWP-7 on WG chairs
Forward Nigel Atkinson's email requesting input on design and features of IRSPP and MWIPP to working group members.

Action DA/NWP-8 on WG members
Review requirements for IRSPP and MWIPP and feed back to Nigel Atkinson and NWP WG Co-Chairs by 1st March 2018.

2.3.10 Provision of Collocated Imager Data from within the Footprint of Hyperspectral Sounders

Action DA/NWP-16 at ITSC-XX was assigned to Andrew Collard to request information from a VIIRS clustering algorithm to be included in the CrIS BUFR data. While this request was made, progress requires delivery of this algorithm from the AAPP group and this is expected in Spring 2018. This action has been taken up by the Software and Products Working Group.

2.3.11 Bias Correction

Constrained Bias Correction

As part of his studies into constrained bias correction, Wei Han (CMA) is investigating forward model and bias correction uncertainty. To do this he requests that members of the ITWG send him first-guess departures and bias correction values for ATMS and AMSU-A at nadir. A more detailed request for exactly what is required and in what format will be sent to the group.

Action DA/NWP-9 on Wei Han
Distribute a detailed request for data required for his constrained bias-correction study.

Action DA/NWP-10 on WG members
Respond to Wei Han's request.

Regional Bias Correction

At ITSC-XX, interested members of the group met to discuss methods for correcting instrument bias in regional models. The working group expressed a desire to monitor progress that has been made in this area, although there is no scope for an additional meeting at this conference.

Action DA/NWP-11 on Working Group chairs
Circulate request for updated information on regional bias correction methods.

Action DA/NWP-12 on WG members
Respond to this request.

Formation of a Bias Correction Sub-group

Other aspects of bias correction were discussed by the group, including the need for better information about RT biases and reinforcement of NWP model bias within VarBC schemes. Extended approaches are needed to handle this. Bias correction schemes for cloudy data are expected to be problematic because in these situations, model biases can be large. The issues are sufficiently numerous and broad that a separate sub-group is proposed.

Action DA/NWP-13 on DA/NWP WG Co-Chairs

> **Organise a meeting of a bias correction sub-group to meet at the next ITSC conference.**

Adaptive Bias Correction and Quality Control

Recent calibration changes have in general been handled well by VarBC, especially combined with VarQC, whilst minimising manual intervention in the data flow.

Recommendation DA/NWP-14 to NWP Centres

> **Adaptive bias correction schemes are now in wide use and proven to be effective in handling large changes to instrument calibration. Centres should aim to use adaptive bias correction wherever possible.**

2.3.12 New and Future Mission Evaluation

Evaluation of Current and Near-to-launch Missions

It is desirable for the data quality of new operational instruments to be evaluated directly by the NWP centres. It is noted however, that there are many instruments that are pre-operational (or failed prematurely) for which evaluation by the NWP centres may be less of a priority that could be evaluated by the wider community. With, for example, tools such as the NWPSAF RadSim and NWP fields freely available from the NWP centres, detailed evaluation of instrument performance can be performed without the need to run an NWP model or data assimilation system.

There was some discussion as to whether the data available in NWP centres' archives is sufficient for this. In particular: the temporal frequency of the fields that are archived may need to be increased to allow sufficiently accurate temporal interpolation; and certain necessary information may be missing for scenarios such as convective cloud (although it was also pointed out that this sort of evaluation should probably avoid cloudy regimes).

Recommendation DA/NWP-15 to the research community

> **The data quality of developmental instruments may be evaluated by the research community, through the use of existing freely available NWP fields and radiance simulators. This is most appropriate where NWP centres are unable to fulfill this role and should be done in close collaboration with the NWP community.**

Recommendation DA/NWP-16 to NWP centres

> **Review whether archived NWP output is sufficient for the purpose of evaluating instrument quality without running the NWP model.**

The recent GAIA-CLIM project has evaluated several new datasets including FY-3 microwave data and MTVZA, and is considered to have been a very successful collaboration.

It is proposed that evaluation of new instruments by NWP centres is carried out in a coordinated and collaborative manner.

Several centres expressed intention to evaluate GIIRS data from FY-4A when made available by CMA. It was proposed that interested centres should therefore coordinate their work.

It was reported that data, including at the interferogram level, could be made available to interested parties during early 2018 for evaluation, though real-time dissemination would take longer. CMA would also be interested for centres to evaluate HIRAS data from FY-3D

Action DA/NWP-14 on Chris Burrows and Qifeng Lu

Seek expressions of interest on coordinating evaluation of GIIRS and HIRAS data once available to the NWP community.

Evaluation of FY-3E data will be critical to support requests for satellites in the early morning orbit, and impact assessments will be sought by CMA.

Action DA/NWP-15 on WG Members

Share impact assessment results for FY-3E with the group and CMA as soon as possible after data becomes available, in particular to provide evidence for support of the early morning orbit.

Support for Future Research Missions

Proposals for new research missions (such as those that may be launched as small satellites or from ISS) often require statements of requirement and evidence of utility in an NWP context, and especially evidence for requirement of near-real time data dissemination which is very costly. However, national NWP centres do not typically have capacity to perform impact studies for missions that are not secure and may be demonstrators of unproven science. However, collaboration with NWP centers would be beneficial so that results from these assessments are readily translatable when the data are available and of sufficient quality.

Recommendation DA/NWP-17 to proposers of research missions

Promote studies from the research community, in particular non-operational centres that run NWP models, to investigate the utility of non-traditional measurement platforms (e.g., small satellites or observations from ISS). Collaboration with operational NWP centres is encouraged.

At the same time, near-real time data supply does increase likelihood of engagement of operational centres. The group acknowledged that this can sometimes add significant cost to a mission. Such near-real time supply does not, however, have to be at a high reliability level.

Recommendation DA/NWP-18 to proposers of research missions

Near-real time dissemination of data is extremely valuable to engage the operational community in mission evaluation, but high reliability levels (e.g., >95%) do not need to be a requirement at the pre-operational stage or for short-term research missions.

2.3.13 Monitoring

An action from ITSC-XX on the definition of a common set of monitoring plots has been dropped, but it was noted at this meeting that the reanalysis community have plans to allow comparison of assimilation systems via the sharing of data in a common format.

The NWPSAF website contains a new page displaying data availability and timeliness, initially from the Met Office and DWD. Working group members are encouraged to visit the page: https://www.nwpsaf.eu/site/monitoring/nrt-availability/data-timeliness/

It was noted that data timeliness is greatly dependent on the mechanism for data dissemination at different centres. Whilst the NWPSAF website is understandably focussed on the member centres, links can be added to plots from other centres outside of the SAF. In particular it would be of interest to see differences in the timeliness from centres outside the EUMETCast network. It was noted that timeliness constraints can differ markedly based on application - in particular regional models have much tighter requirements for this.

Recommendation DA/NWP-19 to WG members

> **Consider producing timeliness plots similar to those on the NWPSAF website and where possible request they are linked to for comparison.**

Action DA/NWP-16 on NWPSAF

> **Add links on the NWPSAF data timeliness site to monitoring of DBNet stations' data timeliness.**

2.3.14 Stratospheric Water Vapour

The question was raised as to whether there is sufficient information available to constrain the stratospheric water vapour in data assimilation, in particular noting the effect of this on heating rates and therefore temperature. It was noted that Aura-MLS would be a good candidate to provide this constraint, and also that this instrument is old and with no replacement planned. It is recommended that studies be conducted to show whether a simple climatological constraint on stratospheric humidity is sufficient for this purpose or whether the assimilation of Aura-MLS data would provide additional information.

Recommendation DA/NWP-20 to NWP centres

> **Determine whether existing climatological constraints on stratospheric water amounts are sufficient or whether additional observations (such as the aging Aura-MLS) provide significant information.**

2.4 ADVANCED SOUNDERS

Web site: http://cimss.ssec.wisc.edu/itwg/aswg/

Working Group members: Dieter Klaes (Co-Chair, EUMETSAT), William L. Smith (Co-Chair, SSEC/UW-Madison and Hampton Univ.), Nigel Atkinson (Met Office, UK), Chris Burrows (ECMWF), James Cameron (Met Office, UK), Keyi Chen (CU2T), Yong Chen (NOAA/STAR UMD), Chu-Yong Chung (NMSC/KMA), Olivier Coopmann (Météo-France), Dorothée Coppens (EUMETSAT), Mohamed Dahoui (ECMWF), Reima Eresmaa (ECMWF), Imane Farouk (Météo-France), Vincent Guidard (Méteo-France), Liam Gumley (CIMSS/SSEC), Stephan Havemann (Met Office, UK), Junhyung Heo (NMSC/KMA), Tim Hultberg (EUMETSAT), James Jung (CIMSS), Norio Kamekawa (JMA), Hyeyoung Kim (NMC/KMA), Allen Larar (NASA LaRC), Zhenglong Li (CIMSS/SSEC), Agnes Lim (CIMSS/SSEC), Qifeng Lu (CMA/NSMC), Will McCarty (NASA GSFC), Kim Meeja (NMC/KMA), Stefano Migliorini (Met Office, UK), A.K. Mitra (I.M.D., MDES, Delhi), Kozo Okamoto (JMA/MRI), Ed Pavelin (Met Office, UK), Alexander Polyakov (SPBSCU), Hank Revercomb (CIMSS/SSEC), Kirsti Salonen (ECMWF), A.K. Sharma (NOAA/NESDIS), Joe Taylor (SSEC), Bertrand Theodore (EUUMETSAT), Robert Tubbs (Met Office, UK), Alexander Uspensky (SRC "Planeta"), Francesca Vittorioso (Météo-France), Likun Wang (Univ. of Maryland), Qiang Zhao (NESDIS/STAR)

2.4.1 Introduction

The Advanced Sounder Working Group (ASWG) focuses on scientific issues affecting the optimal performance of advanced satellite sounder systems. The working group reviews the status of the development of advanced sounder systems and recommends changes pertaining to instrument specification, performance, data processing, and utilisation. For the purpose of this group, "Advanced Sounders" are defined as instruments that present significant new scientific and technological challenges and which require new methods for data processing and utilization. Thus, Advanced Sounders currently include high spectral/spatial resolution passive infrared and microwave sounders and active sensors.

2.4.2 Advanced Sounding from Polar and Geostationary Orbit

Improved sounding from polar orbit has been one of the highly recommended action items from ITWG. The consideration for advancing polar orbiting sounding improvements includes high spatial resolution and denser spatial sampling to increase the density of high quality clear air radiance measurements commensurate with finer grid size of current and future NWP models as well as improvements in absolute accuracy, traceable to radiometric standards, and spectral coverage for the purpose of cross-calibration of instruments of lesser accuracy in geostationary and polar orbits. The ASWG noted with satisfaction the progress towards achieving the availability of hyperspectral infrared soundings in the Polar Orbit: Meteor-M (IKFS-2), FY-3D (HIRAS), JPSS-1, FY-3E in the early morning orbit. The ASWG noted also with satisfaction the arrival of the first geostationary hyper-spectral sounding mission in geostationary orbit on FY-4A (GIIRS). The ASWG expressed the following related concerns and recommendations:

1) In order to make timely and optimal use of the data it is considered important that the availability of the new data and the provision of scientific support to the new Chinese hyperspectral sounders (GIIRS and HIRAS) be ensured. They will provide an important contribution to the global observing system.
2) The Russian Meteor-M satellite is flying a hyper-spectral sounding instrument (IKFS-2) the data of which provide an important contribution to the global observation system. It was noted that no Direct Broadcast capability is available so far, which

reduces the timeliness of the data for international users. It was noted that the orbit for the next Meteor-M satellite is still being discussed.

3) The ASWG noted progress establishing a geostationary ring of hyperspectral sounders to provide global coverage. With the arrival of FY-4A and the planned arrival of MTG-S, important building blocks of such systems will be available. ASWG likes to re-enforce its recommendation for a geo-hyperspectral sounding coverage over the Americas, where a crucial gap in future geo-hyperspectral sounding coverage exists.

Recommendation AS-1 to space agencies (CMA)
Consider making available as soon as possible the data of the GIIRS hyperspectral data on FY-4A and of HIRAS on FY-3D to the international user community.

4) ASWG strongly supports the activities of Roshydromet & Roscosmos of the further development of hyperspectral sounders (of IKFS-2 type) for Meteor-M series satellites as well as encourages providing in Near Real Time (NRT) the data from IKFS-2 to the international community. Along with this the ASWG notes the importance of the work on the development of a new generation of IKFS-sounders with improved spatial and spectral resolution. ASWG noted that the orbit for the Meteor-M satellite to be launched next year (2018) was not specified yet.

Recommendation AS-2 to space agencies (Roshydromet and Roscosmos)
ASWG recommends to consider the Direct Broadcast capability for the hyperspectral sounder IKFS-2 data on the Meteor-M satellite.

Recommendation AS-3 to Space agencies (Roshydromet and Roscosmos)
ASWG further welcomes the planned development of an improved IKFS sounder and recommends pursuing availability as soon as possible.

Action AS-1 to ITWG Co-Chairs
Bring these recommendations to the attention of Space Agencies at CGMS.

2.4.3 Future Hyperspectral Sounders

The ASWG noted with interest and satisfaction that further work has been performed to demonstrate the advantage of increased spatial resolution in order to improve the probability of a uniform scene with the instrument FOV (all clear or all cloudy). Studies were presented to the ASWG that provided a trade-off for smaller FOVs.

Recommendation AS-4 to space agencies
Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.

Action AS-2 to ITWG Co-Chairs
Bring this recommendation to the attention of space agencies at CGMS.

The cost and complexity of hyperspectral instruments are some of the obstacles for their fast and widespread development. If proven and flying technologies (e.g., proven imagers) are used as the basis for a new development, it could be possible to achieve a faster implementation and a wider distribution of this measurement technology.

ASWG noted with interest a presentation discussing these aspects. In particular, because of the use of advanced imagers on US, as well as Japanese and Korean geostationary satellites, the ability to achieve geo-hyperspectral sounding, as well as the current imagery, with an upgrade of the imaging instruments appears to represent a potential for enhancing/upgrading the desired global geostationary sounding system.

Recommendation AS-5 to space agencies (NOAA)

Consider implementing a combined imager/sounder instrument approach on future geostationary meteorological satellites.

Action AS-3 to ITWG Co-Chairs

Bring this recommendation to the attention of space agencies via CGMS.

2.4.4 Use of and Investment in Airborne Systems

ASWG noted the availability of a number of airborne systems, able to carry advanced sounding instrumentation, which can serve as vehicles to foster the development and implementation of advanced space borne instruments and enhanced data processing and application approaches.

Recommendation AS-6 to space agencies (NOAA & NASA)

a) Make greater use and interpretation of available airborne systems.

This will serve as pathfinders for new systems, and will be a cost effective way to validate the utility of new higher resolution instruments and the applications of their data.

(Primarily to NOAA) Recommend greater field campaign use/exploitation of existing aircraft validation sensors for enhanced measurement system (sensors, algorithms, data products) validation AND data processing/algorithm improvements for handling complex scenes of most meteorological significance (i.e., cold scene retrievals, surface emissivity over snow and ice, aerosols and clouds, etc.).

b) Invest in hardware for next generation sounder specification.

(NOAA and NASA). Recommend investment for developing advanced aircraft sensor system hardware to enable new and improved airborne validation sensors to serve as pathfinders for the development and risk mitigation for the next generation atmospheric satellite sounding system sensors. The aircraft sensor specifications (spatial, spectral, radiometric, and temporal) should far exceed current day state of the art to fulfil the desired pathfinder role.

Action AS-4 to ITWG Co-Chairs

Bring these recommendations to the attention of Space Agencies at CGMS.

2.4.5 Data Use

ASWG discussed the pros and cons to distribute apodised or non-apodised data.

Recommendation AS-7 to space agencies

Consider providing non-apodised data to users and having users perform the application related apodisation.

Alternatively users could use reconstructed radiances using Principal Components of the entire radiance spectrum.

Action AS-5 to ITWG Co-Chairs

Bring this recommendation to the attention of space agencies.

2.4.6 Use of Alternative Satellite Technologies and Related Studies

ASWG encourages concept studies and missions utilizing hyperspectral IR instruments with reduced spectral range and higher spatial resolution on constellations of small satellites (including cube-satellites), to evaluate the benefit of high temporal measurements, and retrievals of temperature and humidity. These could provide a baseline for upcoming geostationary missions in terms of: ideal spatial-temporal sampling and spectral tradeoffs for new applications in clear sky and above cloud such as 3D winds (AMVs derived from humidity fields on vertically stacked pressure surfaces in the troposphere) and time rate of change in atmospheric stability (precursors of severe weather). These types of missions have the endorsement of the National Research Council, NASA, and the NWP community as a potential source of global 3D wind information.

There is a general need to study the utility of sounder measurements from small satellites as supplements to the global observing system. This first includes the characterization of the instruments, which are fundamentally expected to be different from the existing global observing system due to their low-cost, small-sized nature. Second, studies should be conducted to determine how these instrument effects translate onto the exploitation of these observations, be it as retrieved products or within NWP data assimilation.

Recommendation AS-8 to space agencies

Consider conducting studies on the utility of sounder measurements from small satellites.

Action AS-6 to ITWG Co-Chairs

Bring this recommendation to the attention of space agencies.

2.4.7 Available Expertise to ASWG

The lack of expertise in the room on microwaves, active sounding etc. was noted. However the WG encouraged the development of higher spatial resolution microwave sounder systems to enable these data to be used with hyperspectral infrared measurements for obtaining convective-scale atmospheric sounding measurements.

2.4.8 Related Software Issues

Questions regarding the development of the MTG-IRS processing software package were discussed in the Working Group. These related to the process of generating reconstructed radiances, conversion from one PC basis set to another, sub-sampling options, apodisation, and output formats. WG members were encouraged to provide feedback to Nigel Atkinson.

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Working Group members: Steve English (Co-Chair, ECMWF), Peng Zhang (Co-Chair, CMA), Pascal Brunel (Meteo-France), Claude Camy-Peyret (IPSL), Mitch Goldberg (NOAA), Stephan Havemann (Met Office), Allen Huang (UW/SSEC), Rich Kelley (NOAA), Dieter Klaes (EUMETSAT), Alexander Polyakov (SPBU), Mikael Rattenborg (WMO), Hank Revercomb (UW-SSEC), Benjamin Ruston (NRL), Bertrand Theodore (EUMETSAT), Christoforos Tsamalis (Met Office), Alexander Uspensky (SRC Planeta)

2.5.1 Introduction

The ITSC-21 Working Group on International Issues and Future Systems (IIFS) convened on Sunday 3 December 2017 and discussed actions and recommendations from ITSC-20 and a number of topics requiring coordination between agencies. The IIFS enjoyed a lively and useful discussion.

2.5.2 Summary of ITSC-19 and 20 Actions and Recommendations

At ITSC-20 the following ITSC-19 action and recommendations remained open:

- **Recommendation IIFS19-1**: Provide examples to the Co-Chairs (Steve English, Jérôme Lafeuille) to show where high frequency soundings proved useful. It was agreed to close this, but to retain IIFS19-2 as a new recommendation.

- **Recommendation IIFS19-2**: Note the growing evidence of likely benefits from hyperspectral geostationary soundings, and where possible to work towards the provision of such instruments in plans for future geo systems (new Recommendation IIFS-6).

- **Action IIFS19-1**: Steve English to request ITWG (involving NWP Group) to provide input to CGMS WG III – via Jérôme Lafeuille – for updating the CGMS Contingency Plan.
  The WG noted that the old draft CGMS contingency plan was discussed at the recent CGMS-45 in June, and agencies and WMO agreed to focus on this topic over the coming months. WMO committed to organize a face-to-face meeting with agencies participating in CGMS WG III to address the plan, and the whole process of CGMS contingency planning. Therefore this action remains open.

- **Recommendation IIFS19-3**: WMO to pursue SATURN, and all agencies to actively contribute information to this portal (and two associated actions).
  This remains open as SATURN is still in an early stage of development.

- **Recommendation IIFS19-4**: CGMS to implement notification process for ITWG recommended events (Stephen English, on behalf of ITWG and in discussion with the NWP WG, to provide list of most relevant events affecting the quality of data, e.g., calibration changes, sensor anomaly, change of operation mode, and indication of the magnitude of the event justifying a notification. CGMS).
  This is closed though the activity continues in the form of action IIFS21-A7, see below.

- **Recommendation IIFS19-5**: Make available pre-processing software for L0/L1 Meteor-M data.

This is closed but there is a new related action IIFS21-A7.

The status of the recommendations from ITSC-20 is as follows:

- **Recommendation IIFS20-1:** Emphasize latency requirement in the HLPP Action 2.3 to increase the use of research and pre-operational satellites. (Action: Mitch Goldberg to propose to CGMS).
Closed. Noted by CGMS.

- **Recommendation IIFS20-2**: When an agency has two or more satellites in the same nominal orbit (e.g., 2pm) that they be staggered by phase (as Metop). With multiple satellites from different agencies it is recommended to stagger them in ECT. (**Action**: Mitch Goldberg to present to CGMS).
Closed. Noted by CGMS.

- **Recommendation IIFS20-3**: IIFS members to investigate optimal staggering to test working assumption that dual Metop configuration separated by about 180° is best option for future missions.(**Action**: IIFS members to provide evidence to IIFS Co-Chairs of advantages of orbit staggering).
Closed. EUMETSAT-led study selected optimal configuration.

- **Recommendation IIFS20-4**: Provision of high temporal frequency MW humidity sounding radiances (alongside cloud and precipitation sensitive observations). (**Action**: Jérôme Lafeuille to present to WMO Vision 2040 workshop).
Closed. Noted by ET-SAT.

- **Recommendation IIFS20-5**: Provision of low-inclination MW humidity sounding to monitor diurnal cycle. (**Action**: Jérôme Lafeuille to present to WMO Vision 2040 workshop).
Closed. Noted by ET-SAT.

- **Recommendation IIFS20-6**: Achieve SI traceability of operational hyperspectral IR sounders, and ultimately MW sounders, recognising growing need for assessment of calibration uncertainties (**Action**: Mitch Goldberg and Peng Zhang to present to GSICS).
Closed. Noted by GSICS.

- **Recommendation IIFS20-7**: Provide more GRUAN and tropical ARM sites, given the need for ground-based reference measurements. (Action: Mitch Goldberg and Peng Zhang to present to GSICS).
Closed. Noted by GSICS.

- **Recommendation IIFS20-8**: Develop best practices in pre-flight characterisation of MW sensors (Action: Mitch Goldberg and Peng Zhang to present to GSICS).
Closed. Noted by GSICS.

- **Recommendation IIFS20-9**: Noting the progress made in characterising observation uncertainty for hyperspectral sounders encourage further characterisation of LBL model error and errors arising from cloud screening, with a view to considering

hyperspectral sounders as an absolute reference. (Action: Mitch Goldberg to ensure this is delivered to IRC and RTWG.)
Closed. Noted by CGMS.

- **Recommendation IIFS20-10**: Clarify reporting procedure for notifying ITU of detected RFI. (Action: Rich Kelley to circulate proposed procedure and ITWG members to follow).
Closed.

- **Recommendation IIFS20-11**: WRC outcomes to be provided to ITWG. (Action: Rich Kelley to email summary to ITWG mailing list).
Closed.

- **Recommendation IIFS20-12**: IIFS and other ITWG members to provide information on current usage of protected bands to Rich Kelley. (**Action**: Stephen English to provide copy of recent ECMWF submission to OFCOM, and to request Met Office to provide copy of their submission as well as encourage other NMSs to provide similar information where it exists).
Open – carried forward to ITSC-22.

- **Recommendation IIFS20-13**: To make MW SRFs available to facilitate RFI investigations when needed. (**Action**: Stephen English to ask co-chairs to combine with Recs from other WGs and communicate to CGMS).
Open – carried forward to ITSC-22.

- **Recommendation IIFS20-14**: Update Steve English's study from 2005 on the value of individual MW protected bands. (**Action**: Sid Boukabara to ask Thomas Auligné to consider making this part of the FSOI intercomparison study and presenting to the WMO impacts workshop in Shanghai in 2016).
Open – carried forward to ITSC-22, supported by new Action IIFS-9.

- **Recommendation IIFS20-15**: NMSs to attempt to provide an assessment of the economic value of bands based on the impact assessment, as was done by the Met Office in 2005. (**Action**: IIFS members to investigate in their countries).
Open – carried forward to ITSC-22, supported by new Action IIFS-9.

- **Recommendation IIFS20-16** WMO and CGMS satellite operators to further maintain OSCAR and SATURN, noting the strong positive feedback from ITWG Members. (Action: IIFS members to review SATURN and provide comments to Stephan Bojinski sbojinski@wmo.int)
Closed. Noted by CGMS and WMO.

- **Recommendation IIFS20-17**: Provide information on best practice for the design phase of new programmes. (**Action**: Dieter Klaes to circulate his paper from the ECMWF satellite seminar, and IIFS members to provide similar information to IIFS Co-Chairs for their agencies if possible.)
Closed. Paper circulated.

- **Recommendation IIFS20-18**: The NWP community to continue to produce and make available Nature Runs to support preparations for, and fair evaluation of,

potential future observations. (Action: IIFS Co-Chairs to bring recommendation to attention of WMO, ECMWF and GMAO.)
Closed. ECMWF are producing new nature run.

- **Recommendation IIFS20-19:** Welcoming the decision of CMA to operate FY-3E on the e-am orbit but noting the current lack of any long-term plan for this orbit, to consider follow-up and back-up missions ensuring continuity of e-am post FY-3E and DMSP. (Action: Nancy Baker and Peng Zhang to pass Rec to DoD and CMA.)
Closed. ISCC is the formal forum for consultation regarding the future Fengyun programme. DoD: Discussion continues, no definitive decision has been taken. Note Paul Menzel, Hank Revercomb, Mitch Goldberg and Steve English are members of ISCC.*

- **Recommendation IIFS20-20**: Continue the SSMIS 60 GHz UAS capability, noting the trend for NWP models to extend higher in the stratosphere and lower mesosphere and the development of thermosphere modelling for Space Weather applications. (Action: Nancy Baker to report to DoD and Jérôme Lafeuille to raise at WMO Vision 2040 workshop.)
Closed. Reported to DoD and raised at ET-SAT Vision 2040 discussions.

- **Recommendation IIFS20-21**: WMO to promote standards to foster interoperability and usability of possible missions from commercial providers. (Action: Jérôme Lafeuille or his successor to provide information when the need arises).
Closed. WMO is developing a position paper on what types of satellite data users consider critical for applications, and which principles should apply to these data (international exchange, transparency, etc.). WMO engages satellite operators in CGMS in this process.

- **Recommendation IIFS20-22**: Secure full government control for observations classed as essential under WMO Res 40. (Action: Mitch Goldberg to Report to CGMS).
Closed, noted by CGMS.

- **Recommendation IIFS20-23**: Noting the strong overlap of interest among the CGMS international science groups for some subjects (e.g., ITWG, ICWG about MTG-IRS) co-chairs to ensure coordination where appropriate of communications to CGMS. (Action: Mitch Goldberg to Report to CGMS).
Closed. This coordination is confirmed to be happening through CGMS working group 2.

2.5.3 The CGMS High Level Priority Plan (HLPP)

The coordination activities of CGMS are reflected in a High Level Priority Plan (HLPP) initially endorsed by the CGMS-40 plenary session in 2012. Items relevant to the IIFS from the HLPP were reviewed. In general the HLPP was again welcomed. Some editorial items were noted. It was agreed that item 3.3.3 should be brought to the attention of Liam Gumley at UW (L2 intercomparisons). The following new recommendations and actions were agreed:

Action IIFS-1 on Mikael Rattenborg
To note IIFS comments in next draft of the HLPP.

Action IIFS-2 Action on Christoforos Tsamalis

> **To provide input to Mikael Rattenborg on item 3.4.1 (new common vocabulary and methodology for the errors associated with validation data).**

2.5.4 Radiative Transfer Standards

The IIFS noted a need for more work on LBL spectroscopic uncertainty and a unified model for describing the shape of the relevant atmospheric water vapour lines from the microwave (MW) to the visible. This should include the thermal (TIR) and shortwave infrared (SWIR) regions. This resulted in the following recommendation to IRC.

Recommendation IIFS-1 to IRC

> **Development of a new unified model for describing spectroscopic and water vapour continuum absorption (Action: IIFS Co-Chairs to discuss with RT Co-Chairs how to communicate).**

Furthermore noting the value of the HLPP, it was felt ITWG members should retain a familiarity with the document to make HLPP discussion at future ITSCs more efficient.

Recommendation IIFS-2 to ITWG members

> **ITWG members to become more familiar with the HLPP (Action: IIFS Co-Chairs to suggest to ITWG Co-Chairs to circulate HLPP to ITWG).**

2.5.5 Orbital Configurations

The WG noted that the synergy arising from concepts like the Aqua A-train can be valuable. When agencies propose new free flyers and research satellites the WG recommends that flying in formation with an operational satellite may be advantageous. This was particularly noted for the FORUM mission with Metop. However because of the different geometry of view and other aspects it is important for CGMS to see actual data coverage plots when proposed to fly in formation to reach an informed judgment.

Recommendation IIFS-3 to CGMS

> **Having similar equatorial crossing times is helpful but not sufficient to ensure synergistic opportunities between separate missions. Therefore it is recommended to also take note of projected data coverage when considering opportunities for formation flying of multiple missions (similar to A-train).**

Action IIFS-3 on Claude Camy-Peyret

> **To provide more information to IIFS members on the FORUM proposal.**

Note that this is not contradictory to the ITSC-20 conclusion that there is significant advantage to staggering satellites of the same nominal orbit (i.e., am, pm, e-am) in order to improve the sampling and coverage. The support for an A-train concept applies when other missions benefit from synergy. When other missions are very similar to the main operational mission then it is more advantageous to introduce a small separation.

2.5.6 Global Design, Characterisation and Calibration of WIGOS

In addition to the long standing support to high temporal resolution hyperspectral infrared sounding, at the previous ITSC-20 meeting the IIFS had concluded that there is evidence for the need for high temporal frequency MW humidity sounding and imagery data.

Science questions for next WMO OSE workshop are being assembled in 2018 where the evidence for this can be critically reviewed, to highlight the need for improved timeliness and temporal repeat cycle.

Action IIFS-4 on IIFS members

> **To provide science questions to WMO in the first half of 2018 (Lars Peter Riishoejgaard at riishojgaard@wmo.int) and to undertake studies and encourage others to also do so, to support this as a significant theme of the next OSE workshop.**

The group noted the upcoming TROPICS mission with a low inclination MW constellation. Such a mission is of potential interest to meet the temporal repeat requirement, but it needs to be critically evaluated by a number of centres.

Recommendation IIFS-4 to multiple agencies

> **Evaluation of TROPICS mission to be undertaken by appropriate agencies in partnership with TROPICS mission (e.g., NWP centres)**

Action IIFS-5 on S. English / P. Zhang

> **To bring this to the attention of major NWP centres and TROPICS mission.**

In addition to initiatives like TROPICS the IIFS noted the increasing number of sounding missions, with programmes in many different countries, and a mixture of research and operational missions. The IIFS noted that new observations that can be considered "core" will be evaluated by all centres as soon as they become available. However more innovative observations, or observations whose quality is uncertain, could be evaluated collaboratively by a group of centres, sharing the workload. This coordination could be achieved by a modest extension of the scope of the existing GODEX group rather than creating a new entity.

Recommendation IIFS-5 to GODEX-NWP

> **To organise and oversee agreed sharing of the evaluation of instruments not considered to be "core" by NWP centres.**

Action IIFS-6 on Mikael Rattenborg

> **To discuss with GODEX-NWP members how this initiative could be implemented (next meeting Autumn 2018).**

Also the recommendation from ITSC-19 (Recommendation IIFS19-2) remains open and important but is renamed for ease of reference:

Recommendation IIFS-6 to CGMS

> **Note the growing evidence of likely benefits from hyperspectral geostationary soundings, and where possible to work towards the provision of such instruments in plans for future geo systems.**

2.5.7 CGMS Change Notifications

Recommendation IIFS19-4 has led to an agenda item for CGMS in 2018. The principal of a CGMS notification procedure to guide satellite agencies may be agreed. It is important that ITWG can provide details when/if this happens.

Action IIFS-7 on IIFS Co-Chairs

In partnership with NWP WG the IIFS WG Co-Chairs to devise a set of criteria for this CGMS procedure to follow.

2.5.8 Data Timeliness Issues

Noting Recommendation IIFS19-5 the Co-Chairs are asked to remind Roscosmos, who are the owner of the existing software package and can modernise to modern OS (linux type), of the requirement for a DB software package to enable use of Russian data in DBNet, to lend support to WMO.

Action IIFS-8 on Mikael Rattenborg and the IIFS Co-Chairs

To draft a letter for ITWG Co-Chairs to send to Roscosmos and Roshydromet explaining the importance of access through DB-Net and processing of real time MTVZA-GY and MSU-MR data (Alexander Uspensky to advise full postal address of whom to send to).

The WG noted that timeliness of CYGNSS does not meet requirements, despite strong real time interest in this mission. This remains typical of research missions.

Recommendation IIFS-7 to CGMS

Re-emphasize best practise is to consider timeliness requirements early in the planning stage of new missions, including research and pre-operational.

This should take into account that the timeliness requirement will depend on the user applications, and there is not a fixed time requirement that must always be met. There needs to be discussion on a mission by mission basis and with specific applications in mind.

2.5.9 Instrument Characterisation

The group went on to consider the absolute calibration of satellite observations, noting efforts such as the Horizon2020 projects GAIA-CLIM and Fiduceo in Europe to establish SI traceability of MW and broadband IR observations to reference observations, as well as CLARREO for hyperspectral observations in the United States. The group welcomed these efforts and encouraged their continuation. The group noted GSICS leadership in this area and encourage GSICS to pay specific attention to SI traceability of hyperspectral sounders.

Noting that whilst pre-flight characterisation is important, instrument are sometimes stored for a long time on the ground, and in any case in-orbit characterisation is needed, the WG made the following recommendation:

Recommendation IIFS-8 to CGMS

Recognizing the growing need for assessment and on-orbit optimization of the accuracy of operational hyperspectral IR sounders, the traditional approaches for pre-flight SI traceability and post-flight validation should be enhanced by flying a CLARREO-like on-orbit reference standard capability (featuring on-orbit SI verification) with orbits designed to provide inter-calibration capability for refining the calibration of the international fleet of operational sounders.

The WG noted the value of the GAIA-CLIM activity and the GRUAN and ARM sites. Such sites are important and should be maintained, and expanded where possible. It was noted that

GRUAN has no resources for such an expansion, so the recommendation is to GCOS to consider how this could be achieved.

Action IIFS-9 on Peng Zhang

To check status of reference sites in China and their availability.

Recommendation IIFS-9 to AOPC GCOS

Maintain and where possible expand GRUAN and ARM sites.

2.5.10 Radio Frequency Interference Issues

The group welcomed recent successes in work carried out by many agencies including NOAA, EUMETNET, EUMETSAT and ESA. However there remains a clear and growing risk to the activities of ITWG from other users of spectrum. The group therefore discussed in some detail ITWG's role in this area.

The WG noted the challenges posed by RFI and the need to, where possible, detect RFI. Some suggested techniques were noted in the presentation by Rich Kelley.

Recommendation IIFS-10 to CGMS

Space agencies to develop, where possible, improved capability to detect RFI in level-0 data.

When RFI is detected MW SRFs are essential to prove its illegal emissions in protected bands. So the need for SRFs is reiterated. The WG noted this is also important for climate and for radiative transfer.

Recommendation IIFS-11 to CGMS

Space agencies to ensure that provision of SRFs for MW instruments is routine practise for future instruments and published on the SATURN portal. Furthermore to obtain wherever possible and practical the SRFs for existing and old instruments, and also to provide on the SATURN portal.

Furthermore the WG noted that the two recommendations to update the current use of MW bands and their economic and social value. Therefore Recommendations IIFS20-14 and IIFS20-15 remain open and in addition there is a new action to try and actively acquire and update this information via a Workshop.

Action IIFS-10 on Steve English

To ask ECMWF if it is willing to host a short workshop (1-2 days) to present updated information with respect to Recommendations IIFS20-14 and IIFS20-15.

2.5.11 Feedback to WMO on Saturn and WMO Contingency Plan

The group continues to strongly support WMO's OSCAR and SATURN facilities and thanked WMO for their continuing strong support to the community through their provision. IIFS members reported that OSCAR is now a very well established source of information in standard working practices and that the SATURN initiative is also very warmly welcomed. The group encourages WMO to continue to support these efforts and to help establish SATURN through constructive feedback. The recommendation from ITSC-19 (IIFS19-3) remains open but is reformulated as Recommendation IIFS-12.

Recommendation IIFS-12 to WMO

To continue to pursue SATURN, and all agencies to actively contribute information to this portal (and two associated actions).

2.5.12 Commercial Satellite Observation Providers

The WG had a lively discussion on the growing role of commercial satellite observation providers, especially in the US. At present there is no single coherent policy within the meteorological community. There are many discussion papers (in agencies, international agencies, WMO). However WMO are attempting to create a policy document. This has key principles. The group agreed with the principles and noted potential additional points:

- Data continuity and long-term planning is critical to operational centres;
- The new notification procedures will need to be respected if adopted by CGMS; and
- New data needs to undergo a thorough scientific evaluation to demonstrate quality and impact for operational users prior to commercial sale.

Action IIFS-11 on Steve English and Peng Zhang

To bring these suggested changes to WMO teams considering these questions (CGMS, IPETSUP, ICT-IOS…)

2.6 PRODUCTS AND SOFTWARE

Web site: http://cimss.ssec.wisc.edu/itwg/pswg

Working group members: Nigel Atkinson (Co-Chair, Met Office), Liam Gumley (Co-Chair, SSEC, UW), Jörg Ackermann (EUMETSAT), Nick Bearson (SSEC, UW), Jessica Braun (SSEC, UW), Chu-Yong Chung (KMA), Dorothée Coppens (EUMETSAT), Geoff Cureton (SSEC, UW), Yoichi Hirahara (JMA), Norio Kamekawa (JMA), Graeme Martin (SSEC, UW), Scott Mindock (SSEC, UW), Ashim Kumar Mitra (IMD), Tony Reale (NOAA-STAR), Pascale Roquet (MétéoFrance), Nathalie Selbach (DWD), Kathy Strabala (SSEC, UW), Jin Woo (KMA), Lihang Zhou (NOAA)

2.6.1 Introduction

The following topics were discussed in the Products and Software group meeting held on 3rd December 2017 at ITSC-21:

- Review of PSWG Action Items and Recommendations from ITSC-20;
- Specific topics suggested by the ITSC Co-Chairs;
- Items for software developers (AAPP/OPS-LRS, CSPP, etc…); and
- CGMS High Level Priority Plan (HLPP) and CGMS-45 actions.

2.6.2 Review of PSWG Action Items and Recommendations from ITSC-20

Action PSWG20-2 to review the list of software packages on the PSWG website. The action was closed as the list has been reviewed. However, a new action is needed to review the list again, and make sure any other outdated software package information is removed.

Action PSWG-1

Nigel Atkinson and Nathalie Selbach to update the list of software packages on the PSWG web page by May 2018.

Action PSWG20-3 on FIDUCEO Framework Document. Nigel Atkinson will ask Martin Burgdorf whether this document is still to be considered for distribution. If not, the action can be closed.

Action PSWG20-6 on GEO-KOMPSAT-2A algorithms. The GEO-KOMPSAT-2A satellite will have an imager similar to ABI and will be at 128°E. The Level 1 data will be transmitted XRIT. KMA is still working on the L2 software, and expect algorithms to be available by June 2019. This could be incorporated into CSPP-GEO, but CSPP-GEO funding has been reduced to maintenance levels. Propose to close the old action and create a new one:

Action PSWG-2

KMA and SSEC to come up with a plan to make the GK-2A software available to DB users.

Action PSWG20-7b on bias correction in IAPP. IAPP is maintained as part of CSPP, but no new developments are planned. No specific requirements or recommendations were made by the group, and DWD (who were originally interested in this action) say they are no longer using IAPP products operationally. *Therefore the action is closed*.

The ITSC-20 PSWG recommendations were reviewed and are discussed in the following paragraphs.

Good progress has been made in making ATMS and CrIS available from DBRTN and other DBNet networks. However, the situation with IASI was unclear. Specifically, distribution of IASI L1 data received by Direct Broadcast may be prohibited by the EUMETSAT Data Policy.

Recommendation PSWG-1 to EUMETSAT

> **EUMETSAT Data Policy be clarified in order to allow distribution of real-time IASI L1 data.**

Tony Reale reported that the GRUAN network would like to foster more collaboration with L2 product developers. There are also valuable collaborations with GSICS. NPROVS is willing to work with L2 product suppliers to evaluate the quality of DB-sourced data. The CSPP team will try to work better with NPROVS to allow evaluations of DB-sourced real-time products. It is recognised that ground sites are also important for CDR evaluation.

Recommendation PSWG-2 to CSPP team and other DB users

> **Work with the NPROVS team to allow evaluations of DB-sourced real-time products.**

Good progress has been made on user readiness for future hyperspectral products with several initiatives having been carried out since ITSC-20, including: (i) EUMETSAT/ECMWF/NWPSAF hyperspectral workshop, and (ii) EUMETSAT MTGIRS level2 dissemination project, for which another phase is planned in 2018.

Good progress has been made on the CSPP VIIRS Flood Product. Software is due to be released in early 2018, and products are available via web map server (https://realearth.ssec.wisc.edu/).

Software to create atmospheric motion vector (AMV) winds from VIIRS and MODIS direct broadcast data could, in principle, be adapted for release as part of CSPP. However, only one prospective user is known at present.

Recommendation PSWG-3 to DB data users

> **Any DB data users interested in the provision of software to generate their own wind products should contact the CSPP team to register their interest.**

The VIIRS cluster analysis in the CrIS footprint was discussed. There are two aspects to this. The first is the provision of a cluster analysis similar to that provided for IASI in which the mean and standard deviation of VIIRS radiances within the CrIS footprint would be computed (for a small number of clusters) and included in BUFR products. This is thought to be reasonably straightforward, pending an AAPP development planned for 2018, and a new BUFR sequence. The second aspect is that NCEP would like to have VIIRS cloud information associated with each CrIS FOV, using the NOAA enterprise cloud algorithm. If NCEP can clarify what is needed, the CSPP and AAPP teams can look at how it would be provided in DBNet data.

Action PSWG-3 on NCEP

> **To clarify requirements on VIIRS cloud products within the CrIS FOV, and to discuss with the AAPP and CSPP teams the possible implementation in DBNet.**

At ITSC-20, a problem was raised with the GOES-16 geolocation and metadata not being transmitted until after the whole of the image data. Harris are aware of the issue, but it is not clear whether a change is feasible for GOES-17.

Recommendation PSWG-4 to agencies

> **In order to allow GEO imager low latency applications, agencies should consider providing GEO rebroadcast geolocation data and other metadata in a format suitable for use during the acquisition of the scan sequence.**

2.6.3 Review of Topics provided by the ITSC Co-Chairs

New and Future Data

The TROPICS mission was discussed. This is a NASA mission comprising a constellation of 6 smallsats with microwave sensors, to measure precipitation, surface properties and winds. UW/SSEC/CIMSS are part of the project. The launch is planned in 2019. The mission is not intended for near-real-time applications: the timeliness is expected to be in the order of 24-48 hours.

The group welcomed the successful launch of FY-3D, and the plans for distribution of products and DB software. However, station manufacturers would appreciate more details on the interfaces.

Recommendation PSWG-5 to CMA

> **Provide the Space to Ground Interface document for FY-3D as soon as possible, to allow station manufacturers to prepare their systems in advance of the release of software and data products.**

Pre-launch Preparations

It was difficult to test processing software for JPSS-1, due to a lack of available pre-launch test datasets.

Recommendation PSWG-6 to agencies

> **Pre-launch test datasets should be provided, well before launch, in order to allow software development teams (e.g., AAPP, OPS-LRS, CSPP) to test Direct Broadcast processing software before satellite launch.**

Extensions to DBNet

The group supports the efforts of the DBNet Coordination Group to ensure consistency between global and local data. Noting that FY-3C sounding data are now used operationally at several centres, and noting the relatively poor timeliness of the global data, there is a strong requirement to extend geographical coverage into the southern hemisphere.

Recommendation PSWG-7 to stations participating in DBNet

> **Consider contributing FY-3 sounder data to the DBNet system. For FY-3C this means MWHS-2 and IRAS; for FY-3D, it will be MWHS-2, MWTS-2 and HIRAS.**

IMD have a strong interest in nowcasting applications. It was noted that the MODIS nowcasting products (overshooting tops, fog, stratus, aerosol) are not yet available for VIIRS.

Recommendation PSWG-8 to NOAA and the CSPP team

> **Support the creation of VIIRS products for nowcasting, similar to the existing MODIS products.**

As well as processing current data, it was noted that some centres have a requirement to re-process historic data – particularly the RDRs. This requires a complete set of look-up tables to be available. This is not the case for Suomi-NPP, because NOAA does not necessarily re-generate old LUTs when something changes.

Recommendation PSWG-9 to NOAA

> **Where possible, provide historical LUTs that are compatible with the latest version of the CSPP SDR processing software.**

It was noted that retrieval of historic data via NOAA CLASS can be a time-consuming process. A group at DWD has developed prototype software that can be used to automate this process (Contact N. Selbach for details), though it would be better if NOAA could do it via the web interface.

Recommendation PSWG-10 to NOAA

> **Consider improving the CLASS interface to allow scripted retrieval of historic data.**

It was also noted that NASA have their own version of archived Suomi-NPP data, available via GESDISC (for ATMS/CrIS) or LAADS (for VIIRS). The format is NetCDF4. Liam or Graeme can give details.

User Notification

EUMETSAT and NOAA have systems for notifying users of anomalies, outages, etc. These are thought to be generally OK. Sometimes anomalies are detected by NWP centres, and in this case the ITSC NWP mailing list is used to circulate information. CMA mainly rely on their web site, plus occasional targeted emails; as CMA data become more widely used, it is recommended that CMA implement a more robust system.

Recommendation PSWG-11 to CMA

> **Consider implementing a subscription-based anomaly/event notification service, similar to that provided by NOAA and EUMETSAT.**

Use of Hyperspectral Data

Although the CSPP SDR processor can work with either full-spectral-resolution (FSR) or normal-spectral-resolution (NSR) CrIS data, currently the level 2 processors only work with NSR. An update for FSR is planned for March-April 2018. Updates for NOAA-20 are also being worked on. It was noted that for NOAA-20 *all* CrIS FOVs will be available on direct broadcast. For S-NPP, only 7 out of the 9 are available, though this is being re-considered. Also VIIRS M7 may be reinstated.

Use of Sounding Data in Cloudy Regions

A question exists as to what is meant by a cloudy region. In the context of NUCAPS sounding specification it is a region where the IR retrieval fails. It can also be an area designated as cloud-free or some minimum cloud fraction. Clarification is needed.

Validation

The group recognised the usefulness of the NOAA NPROVS datasets of co-located sondes. These will be valuable for JPSS. Interested parties should see the NPROVS website (https://www.star.nesdis.noaa.gov/smcd/opdb/nprovs/).

Recommendation PSWG-12 to data users

> **Users should note that L2 profile datasets for validation are available from the NPROVS team, and are encouraged to use them (contact Tony Reale or Lihang Zhou).**

Visualisation

The CSPP web site provides a "Sounder Quicklook" software package for visualising sounder products from NUCAPS, dual regression, IAPP and MIRS. Two-dimensional maps of temperature and moisture at user-selected atmospheric levels; Skew-T plots at user-selected locations; and 2D slices through the atmosphere (along-track) are supported. NPROVS has a visualisation system, called PDISP, for co-location datasets (written in Java).

RFI

This group focused on RFI as it affects reception systems. L-band is liable to interference, as these frequency bands have been sold off, but X-band can also be affected. For example, a station in South Africa cannot receive Aqua, and Honolulu has experienced problems with Terra and Aqua reception.

Recommendation PSWG-13 to DB station operators

> **Report instances of RFI (including reception problems) to Richard Kelly. If you are unsure whether specific problems are due to RFI, SSEC is available to help by analysing data samples.**

2.6.4 Issues for Software Developers

At ITSC-20, there was a recommendation for source code for L1 processors to be released. This still applies (e.g., CMA have not yet released FY-3 source code), and should be extended to L2 software also. Some users are not permitted to run software that they do not build from source. Note that the release of source code does *not* mean that the software provider has to help the user to customise the software to suit their own requirements.

Recommendation PSWG-14 to software providers

> **Release source code for both L1 and L2 packages, in order to ensure maximum take-up of the software.**

Operating systems were discussed. It would be helpful for users to have a better idea of medium-term plans on what type of platform will be needed to run a particular software package (for example, the CentOS6 to 7 migration).

Recommendation PSWG-15 to software providers

> **Provide advance information on plans for implementing new operating system versions and new hardware requirements.**

2.6.5 CGMS High Level Priority Plan (HLPP) and CGMS-45 Actions

1.4.1: Provide for dissemination of satellite derived data and products in one of the four established formats (HRIT, BUFR/GRIB, NetCDF 4 and HDF 5).

BUFR and GRIB are not likely to be superseded any time in the foreseeable future, so products destined for NWP need to be made available in these formats. If products are created only in netCDF4 (for example), some NWP centers may not be able to use them. However, it does not necessarily mean that the products have to be generated *at source* in BUFR/GRIB: the group supports the use of format conversion tools, such as the one proposed as an NWPSAF deliverable for MTG-IRS. At the same time, processing centres should consider support for NetCDF4 as an input format. (The Met Office has this capability).

1.4.2: Develop efficient standardized data handling for high-resolution imaging and hyperspectral instruments, employing novel methods like dissemination of hyperspectral infrared data based on Principal Component Analysis.

Lihang Zhou reported that NOAA does now have a PC product for CrIS.

Action PSWG-4
Nigel Atkinson to look at the CrIS PC product and compare the implementation with that used for IASI.

1.4.3: Facilitate the transition to new direct broadcast systems.

Recommendation PSWG-16 to EUMETSAT
Provide the Metop-SG space to ground interface document, when it is available.

Recommendation PSWG-17 to NOAA
NOAA to provide information to the GRB community on downlink and software requirements for GOES-S (due for launch March 2018). Support for CSPP-GEO should be continued for GOES-S.

1.4.4: Advance the implementation of the CGMS Agency Best Practices.

The DBNet community is aware of the WMO Guide to the DBNet, and supports its recommendations.

1.4.5: Support the evolution of the DBNet services to include new satellites and the extension to advanced sounders for at least half of the globe.

As already mentioned, the group supports the inclusion of advanced sounders in DBNet, and extension to other parts of the globe, particularly in the southern hemisphere.

3.3.3: Conduct an intercomparison study between the different methods to derive level 2 data from infrared hyperspectral sounders, recognising that there are several software packages available that utilize AIRS/IASI/CrIS data.

The NPROVS service helps greatly in this area. The PSWG encourages publication of the results from such intercomparisons.

Recommendation PSWG-18 to researchers involved in L2 studies
Continue to publish the results of L2 comparisons, particularly those that involve NPROVS, and report to future ITSC meetings.

4.2.1: Continue to foster optimum use of satellite data for weather forecasting, climate applications, and environmental assessments including hazardous events such as volcanic ash and flooding.

The CSPP team continues to hold several workshops per year, in different parts of the world, which cover these topics. The PSWG supports these initiatives.

LIST OF ACRONYMS

AAPP: Advanced ATOVS Processing Package
ABI: Advanced Baseline Imager
AHI: Advanced Himawari Imager
AIRS: Atmospheric InfraRed Sounder
AMSR: Advanced Microwave Scanning Radiometer
AMSU: Advance Microwave Sounding Unit
ARM: Atmospheric Radiation Measurement
AROME: Applications of Research to Operations at Mesoscale
ATMS: Advanced Technology Microwave Sounder
ATOVS: Advanced TIROS Operational Vertical Sounders
AVHRR: Advanced Very High Resolution Radiometer
BUFR: Binary Universal Form for the Representation of meteorological data
CDR: Climate Data Record
CGMS: Coordination Group for Meteorological Satellites
CIMSS: Cooperative Institute for Meteorological Satellite Studies
CIRAS: CubeSat Infrared Atmospheric Sounder
CLARREO: Climate Absolute Radiance and Refractivity Observatory
CLASS: Comprehensive Large Array-data Stewardship System
CMA: China Meteorological Administration
CNES: Centre National d'Etudes Spatiales
CrIS: Cross-track Infrared Sounder
CRTM: Community Radiative Transfer Model
CSPP: Community Satellite Processing Package
DB: Direct Broadcast
DBRTN: Direct Broadcast Real Time Network
DMSP: Defense Meteorological Satellites Program
DoD: Department of Defense (US)
DOI: Digital Object Identifiers
DWD: Deutscher Wetterdienst (German Weather Service)
EARS: EUMETSAT Advanced Retransmission Service
ECMWF: European Center for Medium Range Weather
ECT: Equatorial Crossing Time
ECV: Essential Climate Variables
EOS: Earth Observing System
EPS: EUMETSAT Polar Satellite
ESA: European Space Agency
EUMETSAT: European Organization for the exploitation of meteorological satellites
FCDR: Fundamental Climate Data Record
FIDUCEO: Fidelity and uncertainty in climate data records from Earth Observations
FOV: Field of View
FTS: Fourier Transform Spectrometer
FY-3: LEO satellite from China
GAIA-CLIM: Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring
GCOM-W/GCOM-W2: Global Change Observation Missions
GCOS: Global Climate Observing System
GEWEX: Global Energy and Water Cycle Experiment

GIIRS: Geostationary Interferometric Infrared Sounder
GMI: Global Precipitation Measurement (GPM) Microwave Imager
GOES: Geostationary Operational Environmental Satellite
GPM: Global Precipitation Measurement
GPS: Global Positioning System
GRUAN: GCOS Reference Upper Air Network
GSICS: Global Space-Based Inter-Calibration System
GTS: Global Telecommunications System
GUI: Graphical User Interface
HIRAS: Hyperspectral Infrared Atmospheric Sounder
HIRS: High-Resolution Infrared Radiation Sounder
HLPP: High Level Priority Plan
IAMAP: International Association of Meteorology and Atmospheric Physics
IASI: Infrared Atmospheric Sounding Interferometer
IASI-NG: IASI- Next Generation
ICI: Ice Cloud Imager
ICWG: International Cloud Working Group
IDPS: Integrated Data Processing Segment
IPCC: Intergovernmental Panel on Climate Change
IPWG: International Precipitation Working Group
IR: Infrared
IRC: International Radiation Commission
IRFS: instrument onboard Meteor-M N2 satellite
IRSPP: Infrared Sounder Processing Package
ISS: International Space Station
ITSC: International TOVS Study Conference
ITWG: International TOVS Working Group
IWWG: International Winds Working Group
JAXA: Japan Aerospace Exploration Agency
JPSS: Joint Polar Satellite System
LBL: Line By Line
LBLRTM: Line By Line Radiative Transfer Model
LEO: Low Earth Orbit
LTE: Local Thermodynamic Equilibrium
LUT: Lookup Table
MetOp: Meteorological Operational
MHS: Microwave Humidity Sounder
MLS: Microwave Limb Sounder
MODIS: Moderate-resolution Imaging Spectroradiometer
MTG-IRS: Meteosat Third Generation - Infrared Radiometric Sounder
MTVZA: Russian Imaging/Sounding Microwave Radiometer
MVIRI: Meteosat Visible and InfraRed Imager
MW: Microwave
MWHS: Microwave Humidity Sounder
MWI: Microwave Imager
MWIPP: Microwave Imager Processing Package
NASA: National Aeronautics and Space Administration
NEdT: Noise Equivalent Delta Temperature
NESDIS: National Environmental Satellites, Data, and Information Service
NOAA: National Oceanic and Atmospheric Administration

NPROVS: NOAA PROducts Validation System
NRL: Naval Research Laboratory
NWP: Numerical Weather Prediction
OMPS: Ozone Mapping and Profiler Suite
OPS: Operations
OPS-LRS: Operational Software – Local Reception Station
OSCAR: Observing Systems Capability Analysis and Review
PC: Principal Component
POES: Polar Operational Environmental Satellite
PSWG: Products and Software Working Group
QC: Quality Control
RARS: Regional ATOVS Retransmission Services
RDR: Raw Data Record
RFI: Radio Frequency Interference
RO: Radio Occultation
RT: Radiative Transfer
RTM: Radiative Transfer Model
RTTOV: Radiative Transfer for TOVS
SAF: Satellite Application Facility
SAPHIR: Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie
SATURN: Satellite User Readiness Navigator
SDR: Sensor Data Record
SMOS: Soil Moisture and Ocean Salinity
SNO: Simultaneous Nadir Overpass
SRF: Spectral Response Function
SSEC: Space Science and Engineering Center
SSMIS: Special Sensor Microwave Imager/Sounder
SSU: Stratospheric Sounding Unit
STAR: Center for Satellite Applications and Research
Suomi NPP: Suomi National Polar-orbiting Partnership
TOVS: TIROS Operational Vertical Sounder
TROPICS: Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats
VarBC: Variational Bias Correction
VIIRS: Visible/Infrared Imager Radiometer Suite
WG: Working Group
WMO: World Meteorological Organization

ITSC-XXI AGENDA

Tuesday, 28 November 2017

16:00-19:00 **Registration at Darmstadtium**

Wednesday, 29 November 2017

8:00	**Registration (continues to 15:00) Poster setup**	
8:30 – 9:00	**Welcome**	**Mitch Goldberg and Niels Bormann (ITWG Co-Chairs)**
	Welcome by EUMETSAT Overview of EUMETSAT	**Alain Ratier**
	Local arrangements	**Dieter Klaes**
	Review of agenda	**Mitch Goldberg and Niels Bormann (ITWG Co-Chairs)**

9:00 – 10:00 Session 1a: Community software – session dedicated to Paul van Delst (oral presentations - 12 minutes)
Chairs: Andrew Collard and Bill Smith

1.01	Benjamin Johnson	CRTM Development Status and Future Plans
1.02	Quanhua (Mark) Liu	Community Radiative Transfer Model (CRTM) Applications to Support Sensor Cal/Val and EDR Generations
1.03	James Hocking	RTTOV Development Status
1.04	Liam Gumley	CSPP LEO: Recent updates and support for JPSS-1

10:00 – 10:15 Session 1b: Community radiative transfer software (poster introductions - 1 minute: no visual aids)
Chairs: Andrew Collard and Bill Smith

1p.01	Withdrawn	
1p.02	Benjamin Johnson	Radar Simulation in CRTM
1p.03	Pascale Roquet	RTTOV GUI, the graphical user interface for RTTOV.
1p.04	Marco Matricardi	Modeling of nonlocal thermodynamic equilibrium effects in the classical and principal component based version of the RTTOV fast radiative transfer model
1p.05	Cristina Lupu	Evaluation of the radiative transfer model RTTOV-12 at ECMWF

10:15 – 10:45 Break and poster viewing 1b

10:45 – 11:15 Session 1c: Community software (oral presentations - 12 minutes) Chairs: Allen Huang, Vivienne Payne and Guido Masiello		
1.05	Kathleen Strabala	NASA International MODIS/AIRS Processing Package (IMAPP): Current Status and Future Plans
1.06	Nigel Atkinson	NWP SAF software deliverables: 2017 to 2022

11:15 – 11:35 Session 1d: Community software and direct broadcasting (poster introductions - 1 minute: no visual aids) Chairs: Allen Huang, Vivienne Payne and Guido Masiello		
1p.06	Scott Mindock	CSPP SDR 3.0 Support for JPSS-1
1p.07	Geoffrey Cureton	Himawari Support In The CSPP-GEO Direct Broadcast Package
1p.08	Graeme Martin	CSPP Geo direct broadcast software for GOES-16 and Himawari-8: project overview and lessons learned
1p.09	Nick Bearson	CSPP VIIRS Flood Detection
1p.10	Withdrawn	
1p.11	Qiang Zhao (for Walter Wolf)	Planned Updates to the STAR BUFR and GRIB Tailoring System for Satellite Operational Products
1p.12	Gloria Cristina Pujol	Contributions of DBNet South America-Argentina Component for NWP Community
1p.13	Jin Woo	Current Status and Future Plan of Direct-Readout LEO Weather Satellite Operation in NMSC/KMA
1p.14	Jessica Braun	Aqua and Terra Direct Broadcast Processing at CIMSS/SSEC
1p.15	Liam Gumley	NOAA DB Network: Providing advanced sounder data in near real-time for NWP

11:35 – 12:20 Session 2a: Radiative transfer (oral presentations - 12 minutes) Chairs: Vivienne Payne, Guido Masiello and Allen Huang		
2.01	Raymond Armante (for Emilien Bernard)	The 4A/OP model: from NIR to TIR, new developments for time computing gain and validation results within the frame of international space missions
2.02	Raymond Armante	TIR and SWIR level-1 and level-2 products validation: a deeper insight to updated of the 4A line-by-line radiative transfer model
2.03	Niels Bormann	Radiative transfer along a slanted path

12:20 – 12:40 Session 2b: Radiative transfer (poster introductions - 1 minute: no visual aids) Chairs: Vivienne Payne, Guido Masiello and Allen Huang		
2p.01	Stephan Havemann	Improvements to fast radiative transfer modelling of hyperspectral infrared sounders

2p.02	Xavier Calbet	Effects of atmospheric turbulence in radiative transfer modelling
2p.03	Wenguang Bai	Estimation of CO2 column retrieval errors from ignoring 1.6µm polarization calculation in forward modeling for space-borne polarization-sensitive instruments
2p.04	Fuzhong Weng	Simulation of UV Radiance Using UNL-VRTM
2p.05	Raymond Armante	From GEISA-2015 to GEISA-2018
2p.06	Oleksandr Bobryshev	Oxygen line-mixing: Consolidating a spectroscopy for AMSU-A
2p.07	Emma Turner	Quantification of line-by-line parameter errors in the 183.31 GHz water vapour line
2p.08	Domenico Cimini	Sensitivity of microwave downwelling brightness temperatures to spectroscopic parameter uncertainty
2p.09	Heather Lawrence	Uncertainties in the dielectric constant model for seawater used in FASTEM and implications for the calibration/validation of new microwave sounding and imaging instruments
2p.10	Steve J. English	A reference model for ocean surface emissivity from the microwave to the infrared
2p.11	Louis Garand	Accounting for variations of the trial field along the line of sight of the satellite in radiance data assimilation

12:40 – 13:30 Lunch

13:30 – 14:00 Poster viewing 1d, 2b

14:00 – 15:15 Session 3a: Calibration, validation and uncertainty (oral presentations - 12 minutes) **Chairs: William Bell and Tony Reale**		
3.01	Tim Hewison	Global Space-based Inter-Calibration System (GSICS) Infrared Reference Sensor Traceability and Uncertainty
3.02	Gerrit Holl	A new Fundamental Climate Data Record (FCDR) for nearly 40 years of measurements from the High resolution Infrared Radiation Sounder (HIRS) based on a metrologically traceable uncertainty analysis
3.03	Fabien Carminati	Characterisation of numerical weather prediction model biases for improved satellite cal/val.
3.04	Alexander Uspensky	Cal/Val studies for microwave and infrared sounding data from METEOR-M series satellites
3.05	Stuart Newman	An assessment of Meteor-M N2 MTVZA imager/sounder data at the Met Office and ECMWF for GAIA-CLIM

15:15 – 15:35 Session 3b: Calibration, validation and uncertainty (poster introductions - 1 minute: no visual aids) **Chairs: William Bell and Tony Reale**		
3p.01	Stuart Newman	The GAIA-CLIM project

3p.02	Stefano Migliorini	Robust quantification of uncertainty on short-range model forecasts in radiance space based on reference sonde data
3p.03	Brett Candy	Assessment and assimilation of microwave imager observations in NWP global models
3p.04	Heather Lawrence	Assimilation of FY-3C MWHS-2 at ECMWF and evaluation of the microwave imager FY-3C MWRI at ECMWF and the Met Office
3p.05	Marc Prange	Natural and vicarious calibration targets for satellite based microwave sensors
3p.06	Lihang Zhou	Post Launch Calibration and Validation of JPSS-1 Sensor Data Records (SDRs) and Environment Data Records (EDRs) Algorithms
3p.07	Joe Taylor	Current Status of the CrIS Calibration Activities at UW-SSEC
3p.08	Allen Larar	Arctic field campaign inter-comparisons in support of SNPP CrIS validation
3p.09	Ninghai Sun	Advances in Suomi NPP ATMS Data Reprocessing
3p.10	Bomin Sun	Vaisala Radiosonde RS92 to RS41 Transition: Implications for Satellite Data Cal/Val

15:35 Group photo

15:50 – 16:15 Break and poster viewing 3b

16:15 – 17:15 Session 4a: New and current observations (oral presentations - 12 minutes) Chairs: Peng Zhang and Stephen English		
4.01	Qifeng Lu	The status of FY-3C and FY-4A in NWP and the preparation of FY-3D for NWP
4.02	Wei Han (for Peiming Dong)	Study on the simulation and bias characteristics of FY-4A GIIRS observation
4.03	Indira Rani	Impact of the assimilation of water vapor imager radiances from INSAT 3D and 3DR satellites in the NCMRWF Unified Model
4.04	Hyeyoung Kim	Application of Microwave Satellite Data to KMA Local Data Assimilation and Prediction System (LDAPS)

17:15 – 17:30 Session 4b: New and current observations (poster introductions - 1 minute: no visual aids) Chairs: Peng Zhang and Stephen English		
4p.01	Andrew Collard	Plans for the utilization of JPSS and GOES-R satellite systems
4p.02	Yoichi Hirahara	Operational use of Suomi NPP ATMS radiance data in JMA's global NWP system

4p.03	Yasutaka Murakami	Assimilating clear-sky radiance of SSMIS humidity sounding channels in the JMA global NWP system with newly developed cloud detection algorithm
4p.04	Jeon-Ho Kang	Development of the SSMIS processing system and their impacts on the 3DVAR in KIAPS
4p.05	Bryan Karpowicz	Microwave Radiance Assimilation at NRL: Advanced Techniques, Developments, and Future Sensors
4p.06	Bryan Karpowicz (for Steve Swadley)	Salvaging of the Final SSMIS Flight Unit for a Future Flight-of-Opportunity
4p.07	Brett Candy	Recent Improvements to the Assimilation of Microwave Sounders in the Met Office NWP system
4p.08	Stuart Newman (for Amy Doherty)	Investigation into the impact of SAPHIR on humidity analyses at the Met Office

17:45 Icebreaker, supported by DWD (with poster viewing 1b, 1d, 2b, 3b, 4b)

Thursday, 30 November 2017

8:30 – 10:00 Session 5a: Assimilation - clouds (oral presentations - 12 minutes) Chairs: Kozo Okamoto and Christina Köpken-Watts		
5.01	Alan Geer	All-sky assimilation of IASI upper-troposphere water vapour channels
5.02	Kozo Okamoto	Evaluation and assimilation of all-sky infrared radiances of Himawari-8
5.03	Imane Farouk	Towards the improvement of the assimilation of cloudy IASI observations in numerical weather prediction
5.04	Masahiro Kazumori	Development of an all-sky assimilation of microwave imager and sounder radiances for the Japan Meteorological Agency global numerical weather prediction system
5.05	Peter Weston	Assimilation of AMSU-A in the presence of cloud and precipitation
5.06	Stefano Migliorini	All-sky assimilation of microwave sounders at the Met Office

10:00 – 10:15 Session 5b: Clouds: assimilation and radiative transfer (poster introductions - 1 minute: no visual aids) Chairs: Kozo Okamoto and Christina Köpken-Watts		
5p.01	Katrin Lonitz	Matching scales of observed and simulated cloud and precipitation processes seen in the microwave spectrum
5p.02	Yanqiu Zhu	Further developments in the all-sky microwave radiance assimilation and expansion to ATMS in the GSI at NCEP
5p.03	Andrew Collard (for Li Bi)	All-sky infrared radiances assimilation of selected humidity sensitive IASI channels at NCEP/EMC
5p.04	Moved to 5.02	

5p.05	Alan Geer	Scattering from non-spherical frozen particles in all-sky microwave radiative transfer
5p.06	Victoria Galligani	Evaluation and comparison of simulated microwave cloudy radiances using RTTOV-SCAT and ARTS
5p.07	Jerome Vidot	Hyperspectral IR cloudy radiance and Jacobian simulations: comparison between RTTOV and LIDORT

10:15 – 10:45 Break and poster viewing 5b

10:45 – 12:00 Session 6a: Climate (oral presentations - 12 minutes) **Chairs: Hank Revercomb and Claudia Stubenrauch**		
6.01	Claudia J. Stubenrauch	The role of upper tropospheric cloud systems in climate: building observational metrics for Process Evaluation Studies
6.02	Martin Stengel	35 years of cloud observations based on HIRS measurements
6.03	Christoforos Tsamalis	Evaluation of the CM SAF Upper Tropospheric Humidity (UTH) climate data record from AMSU-B/MHS sounders
6.04	Cheng-Zhi Zou	Evaluation of Inter-Sensor Biases between SNPP/ATMS and POES/AMSU-A
6.05	William Bell	The use of satellite radiances in the C3S ERA5 Reanalysis

12:00 – 12:15 Session 6b: Climate (poster introductions - 1 minute: no visual aids) **Chairs: Hank Revercomb and Claudia Stubenrauch**		
6p.01	Eui-Seok Chung	An assessment of the consistency between satellite measurements of upper tropospheric water vapor
6p.02	Nathalie Selbach	The GEWEX water vapor assessment (G-VAP) – results from inter-comparisons and stability analysis.
6p.03	Nathalie Selbach	Climate Data Records and user service of the EUMETSAT Satellite Application Facility on Climate Monitoring
6p.04	Timo Hanschmann	Preparing HIRS radiances as input to Reanalysis within the Copernicus Climate Change Service
6p.05	Cyril Crevoisier	Towards homogeneous reference datasets from Metop-A and Metop-B validated observations
6p.06	Mayte Vasquez	Intercomparisons and Validation of IASI L1 Reprocessed Data of MetOp-A
6p.07	Mohamed Dahoui	Detection of trends and variability of certain atmospheric features by analysing long time series of satellite monitoring statistics
6p.08	Withdrawn	

12:15 – 13:30 Lunch

13:30 – 14:00 Poster viewing 6b

14:00 – 14:40 Session 7: NWP centre reports (poster introductions - 3 minutes, 1 slide) Chairs: Dirceu Herdies and Eunhee Lee		
7p.01	Norio Kamekawa (JMA)	Recent upgrades of satellite radiance data assimilation at JMA
7p.02	Mohamed Dahoui (ECMWF)	Overview of ECMWF NWP changes since ITSC-20
7p.03	Christina Köpken-Watts (DWD)	Developments in satellite data assimilation at DWD since ITSC-XX
7p.04 7p.05	Nadia Fourrie, Florian Suzat (Météo France)	Overview of infrared radiance assimilation in Météo-France models/ Ongoing developments on the use of microwave sounders and imagers at Météo-France
7p.06	Brett Candy (Met Office)	NWP Centre Update: Met Office
7p.07	Fiona Smith (BoM)	Satellite assimilation at the Bureau of Meteorology
7p.08	Indira Rani (NCMRWF)	NCMRWF NWP status
7p.09	Andrew Collard (NCEP, for John Derber)	Progress and plans for the use of radiance data in the NCEP global and regional data assimilation systems

Action Items from ITSC-20
Moderators: Mitch Goldberg and Niels Bormann

14.40-14.50 CGMS report, 5 min (Mitch Goldberg)

14.50-15.30 Working group action items from ITSC-20 (10 minutes)
- **NWP (Fiona Smith and Andrew Collard)**
- **Radiative transfer and surface properties (Marco Matricardi and Benjamin Johnson)**
- **Advanced Sounders (Dieter Klaes and Bill Smith)**

15.30-16.00 BREAK (poster viewing 7)

16.00-16.40 Working group action items from ITSC-20 (10 minutes)
- **Products and Software (Nigel Atkinson and Liam Gumley)**
- **Climate (Nathalie Selbach and Cheng-Zhi Zou)**
- **International and Future Systems (Stephen English and Peng Zhang)**

16:40-17:05 Special topics (10 minutes)
- **World Radiocommunication Conference 2019 (WRC-19) items of interest to ITSC (Richard Kelley)**
- **DBNet implementation status and planning (Mikael Rattenborg)**

17.05-17.15 Technical sub-group report (5 minutes)
- **Direct broadcast packages (Liam Gumley)**

17.30-18.30 Technical Sub-Group meetings
- **RTTOV (James Hocking)**
- **CRTM (Benjamin Johnson)**

- **RARS/DBNet and direct broadcast packages (Liam Gumley, Mikael Rattenborg)**

18.45-20.45 GAIA-CLIM workshop on satellite validation with NWP

Friday, 1 December 2017

8:30 – 9:45 Session 8a: Hyperspectral IR (oral presentations - 12 minutes) Chairs: Nigel Atkinson and Thomas August		
8.01	Tim Hultberg	A global-local hybrid approach to retain new signals in hyperspectral PC products
8.02	Hank Revercomb	Correction to Remove the Residual Responsivity Dependence of Spectral Instrument-Line-Shapes for Fourier Transform Spectrometers
8.03	Yong Chen	Reprocessing of Suomi NPP CrIS SDR and Impacts on Radiometric and Spectral Long-term Accuracy and Stability
8.04	Dorothee Coppens	MTG-IRS L1 processing overview and performances
8.05	Carmine Serio	Determination of the experimental error of high spectral resolution infrared observations from spectral residuals: application to IASI

9:45 – 10:15 Session 8b: Composition (poster introductions - 1 minute: no visual aids) Chairs: Nigel Atkinson and Thomas August		
8p.01	Cyril Crevoisier (for Olivier Membrive)	Retrieval of the 3 main anthropogenic greenhouse gases from IASI: status and lessons learned for validation
8p.02	Guido Masiello	Physically-based simultaneous retrieval for CO, CO2, CH4, HNO3, NH3, OCS and N2O from IASI observations and inter-comparison with in situ observations and AIRS, GOSAT, OCO-2 satellite products
8p.03	Vivienne Payne	Harnessing the power of sounders for atmospheric composition and chemical assimilation
8p.04	Virginie Capelle	A decade of Infrared dust aerosol characteristics (AOD and mean layer altitude) retrieved daily from IASI
8p.05	Alexander Polyakov	Technique and results of retrieving the total ozone content using satellite IR measurements from «Meteor-M» No 2
8p.06	Jonghyuk Lee	Uncertainty of temperature sounding caused by the variation of CO2 concentration
8p.07	Allen Huang (for Chien-Ben Chou)	Using MTSAT-2 Visible Images to Retrieve Aerosol Optical Depth
8p.08	Dirceu Luis Herdies	Estimation of the Aerosols Direct Radiative Forcing in the Amazon region using MODIS

8p.09	Olivier Coopmann	Towards a strengthening of the coupling of Numerical Weather Prediction and Chemistry Transport Models to improve the retrieval of thermodynamic fields from infra-red passive sounders: The ozone case
8p.10	Olivier Coopmann	Greenhouse gases in-situ profiles from the APOGEE campaign in support to satellite infrared sounder assimilation

10:15 – 10:45 Break and poster viewing 8b

10:45 – 12:15 Session 9a: Hyperspectral IR assimilation (oral presentations - 12 minutes) Chairs: Fiona Smith and Louis Garand		
9.01	Vincent Guidard	What is the impact of IASI in global NWP?
9.02	Norio Kamekawa	Assimilation of Suomi-NPP/CrIS radiances into the JMA's global NWP system
9.03	Marco Matricardi	The use of reconstructed radiances to assimilate the full IASI spectrum at ECMWF
9.04	Jun Li	Impact of assimilating the VIIRS-based CrIS cloud-cleared radiances on hurricane forecasts
9.05	Kirsti Salonen	Impact of hyperspectral IR radiances on wind analyses
9.06	David Santek	Feature-tracked 3D winds from hyperspectral infrared sounders: Status and requirements for future missions

12:15 – 12:35 Session 9b: Assimilation of IR observations (poster introductions - 1 minute: no visual aids) Chairs: Fiona Smith and Louis Garand		
9p.01	Reima Eresmaa	The current impact of infrared radiances in the ECMWF NWP system
9p.02	James Jung	Preparing for CrIS Full Spectral Resolution in the NCEP Global Forecast System
9p.03	Euijong Kang	CrIS channel selection for the KMA UM data assimilation based on an iterative method
9p.04	Kirsti Salonen	MTG-IRS level 2 data assimilation into the ECMWF model
9p.05	Young-Chan Noh	Impact of assimilation of a new set of IASI channels on the UM precipitation forecast over East Asia
9p.06	Alain Beaulne	Impact of assimilating multispectral radiances from Himawari and Meteosat satellites on global forecasts
9p.07	Chris Burrows	Assimilation of geostationary radiances at ECMWF
9p.08	Ruth B.E. Taylor	Use of geostationary imager clear-sky radiances in Met Office Global NWP
9p.09	Haixia Liu	Comparison among three cloud-clearing radiance products
9p.10	Seon Ki Park	Assessing Potential Impact of Air Pollutants Observations from Geostationary Satellite on Air Quality Prediction through OSSEs

12:35 – 13:30 Lunch

13:30 – 14:00 Poster viewing 9b

14:00 – 14:45 Session 10a: Land surface studies (oral presentations - 12 minutes) Chairs: Eva Borbas and Ben Ruston		
10.01	Reima Eresmaa	Assimilation of tropospheric-sensitive infrared radiances over land
10.02	Virginie Capelle	Impact of dust aerosols on the retrieval of IR land surface emissivity spectrum: a new simultaneous approach accounting for dust characteristics and surface temperature from IASI
10.03	Rory Gray	A Dynamic Infrared Land Surface Emissivity Atlas based on IASI Retrievals

14:45 – 15:10 Session 10b: Land surface studies (poster introductions - 1 minute: no visual aids) Chairs: Eva Borbas and Ben Ruston		
10p.01	**Withdrawn**	
10p.02	Eva Borbas	The status of the Combined ASTER and MODIS Emissivity Over Land (CAMEL) Product
10p.03	Chawn Harlow	MACSSIMIZE: An upcoming campaign to focus on the development and evaluation of Arctic snow emissivity models suitable for use in assimilation of satellite microwave sounder data
10p.04	Niels Bormann	The current forecast impact of surface-sensitive microwave radiances over land and sea-ice in the ECMWF system
10p.05	Jisoo Kim	The characteristics of the real-time land surface emissivity of the ATMS data for numerical weather prediction model
10p.06	Keyi Chen	Increased use of microwave humidity sounding data from the FY-3 series in the ECMWF assimilation system
10p.07	Cristina Lupu	Surface skin temperature for satellite data assimilation
10p.08	Sylvain Heilliette	Assimilation of land surface skin temperature observations derived from GOES imagery
10p.09	Guido Masiello	Implementation of a real-time Level 2 SEVIRI processor for the simultaneous physical retrieval of surface temperature and emissivity at global scale
10p.10	Hyun-Sung Jang	Use of surface observations as pseudo channels for improving AIRS temperature and moisture retrieval
10p.11	AK Mitra	Assessment of soil wetness variation for extreme events using direct broadcast receiving system at IMD
10p.12	Chunlei Meng	The Joint Land Data Assimilation System (JLDAS)

15:10 – 16:00 Break and poster session for 5b, 6b, 7b, 8b, 9b, 10b

16:00 – 17:00 Session 11a: Retrieval products (oral presentations - 12 minutes) Chairs: Bomin Sun and Kathleen Strabala		
11.01	Thomas August	The EUMETSAT operational IASI L2 products and services, from Global to Regional
11.02	Lihang Zhou (for Antonia Gambacorta)	Status of the NPP and J1 NOAA Unique Combined Atmospheric Processing System (NUCAPS) for atmospheric thermal sounding: recent algorithm enhancements and near real time users applications.
11.03	Sergio DeSouza-Machado	Single Footprint All-Sky Retrievals using a Fast, Accurate TwoSlab Cloud Representation
11.04	William Smith Sr.	Combining Polar Hyper-spectral and Geostationary Multi-spectral Sounding Data – A Method to Optimize Sounding Spatial and Temporal Resolution

17:00 – 17:20 Session 11b: Retrieval products and applications (poster introductions - 1 minute: no visual aids) Chairs: Bomin Sun and Kathleen Strabala		
11p.01	Quanhua (Mark) Liu	Overview of JPSS-1 and Suomi NPP ATMS SDR and EDR Products
11p.02	A.K. Sharma	Exploitation of Hyperspectral Sounder and Microwaves sounder Data Products generated at NOAA/NESDIS
11p.03	F. Di Paola	Retrieval of Temperature and Water Vapor vertical profile from ATMS Measurements with Random Forests technique
11p.04	M. Crapeau	Experimenting different a priori sources for optimal estimation retrievals with IASI
11p.05	Bill Smith (for Elisabeth Weisz)	Hyper-Spectral Sounder Derived Severe Weather Indices
11p.06	Nai-Yu Wang	Combining Imager and Lightning For Enhanced GOES-R Rain Estimates in the NWS Pacific Region
11p.07	Eva Borbas	The Suomi-NPP VIIRS Total Precipitable Water Product
11p.08	Junhyung Heo	Application of Cumulative Probability Distribution Function to Compositing Precipitable Water with Low Earth Orbit satellite data
11p.09	Withdrawn	
11p.10	Wei Dong	Structure Analysis of Heavy Precipitation Over the Eastern Slope of the Tibet Plateau Based on TRMM Data
11p.11	Elisabetta Ricciardelli	Analysis of heavy rainfall events occurred in Italy by using Microwave and Infrared Technique

17:20 – 17:50 Poster viewing 11b

Saturday, 2 December 2017

8:30 – 12:30 Working group meetings (Break at 10:15 – 10:45)

- Advanced Sounders (Dieter Klaes and Bill Smith)
- Climate (Nathalie Selbach and Cheng-Zhi Zou)
- Radiative transfer and surface properties (Marco Matricardi and Benjamin Johnson)

Sunday, 3 December 2017

8:30 – 12:30 Working group meetings (Break at 10:15 – 10:45)

- NWP (Fiona Smith and Andrew Collard)
- Products and software (Nigel Atkinson and Liam Gumley)
- International (Stephen English and Peng Zhang)

Monday, 4 December 2017

8:30 – 9:45 Session 12a: Assimilation studies (oral presentations - 12 minutes) Chairs: Vincent Guidard and Brett Candy		
12.01	John Eyre	The effect of NWP model bias on radiance bias correction schemes
12.02	Wei Han	Constrained variational bias correction for satellite radiances assimilation
12.03	Benjamin Ruston	Radiance Bias Correction from an Alternative Analysis
12.04	Erin Jones	Benefits of Using a Variational Preprocessing Approach for the Assimilation of Satellite Radiances: An Application to Data Assimilation in Environmental Data Fusion
12.05	Sid Boukabara	Exploring Using Artificial Intelligence (AI) for NWP and Situational Awareness Applications. Application to Remote Sensing and Data Assimilation/Fusion

9:45 – 10:15 Session 12b: Assimilation studies (poster introductions - 1 minute: no visual aids) Chairs: Vincent Guidard and Brett Candy		
12p.01	Patrik Benacek	Satellite Bias Correction in Limited-Area Model ALADIN
12p.02	James Cameron	Comparison between global model and VarBC bias corrections in a UK regional model
12p.03	Ed Pavelin	Diagnosis of residual biases in the assimilation of AMSU-A
12p.04	Kristen Bathmann	Assimilating Infrared and Microwave Sounder Observations with Correlated Errors
12p.05	Peter Weston	Accounting for correlated observation error in the assimilation of ATMS
12p.06	William F. Campbell	Posterior Channel Selection for Satellite Radiances with Correlated Observation Error in Hybrid 4DVar System (NAVGEM)

12p.07	Hyoung-Wook Chun	Buddy check for radiance with analysis error variance
12p.08	Stuart Newman	A decade of improved fits to satellite observations at the Met Office
12p.09	Olaf Stiller	Observation impact diagnostics in an Ensemble Data Assimilation System
12p.10	Steve J. English	Data Assimilation Methodology Developments at ECMWF
12p.11	Louis Garand	Toward a coupled ocean-atmosphere data assimilation system: first impact examination from the viewpoint of satellite radiances
12p.12	Reima Eresmaa	Assimilation of satellite data in a coupled ocean-atmosphere system
12p.13	Bob Tubbs	Met Office Convective-Scale Satellite Data Assimilation

10:15 – 10:45 Break and poster viewing 12b

10:45 – 11:30 Session 13a: Sounding science and validation (oral presentations - 12 minutes) **Chairs: Sid Boukabara and Tim Hewison**		
13.01	Tony Reale	Satellite Sounding Product Characteristic Performance and Impact of Satellite Overpass Time
13.02	Alexander Polyakov	Studies using spectral measurements of satellite atmospheric FTIR sounder IRFS-2
13.03	Bjorn Lambrigtsen	Sounding Science at the Jet Propulsion Laboratory

11:30 – 11:35 Session 13b: Retrieved products and validation (poster introductions - 1 minute: no visual aids) **Chairs: Sid Boukabara and Tim Hewison**		
13p.01	Withdrawn	
13p.02	Alexander Polyakov	Validation of temperature sounding of the atmosphere from a board of «Meteor-M» No 2 satellite (IRFS-2 device)
13p.03	Sanjeev Singh	Identifying downburst events using INSAT-3D satellite system

11:35 – 12:15 Session 14: Space agency reports (Space agency poster introductions - 5 minutes: 2 slides) **Chairs: John Eyre and Alexander Uspensky**		
14p.01	Peng Zhang (CMA)	Updates on CMA Meteorological Satellite Programs
14p.02	Dieter Klaes (EUMETSAT)	An update on EUMETSAT Programmes and Plans
14p.03	Mitch Goldberg	NOAA
14p.04	Kozo Okamoto	Status report of space agency: JMA and JAXA
14p.05	Alexander Uspensky	Russian Meteorological Satellite Programs

12:15 – 13:30 Lunch

13:30 – 14:00 Poster viewing 13b, 14

14:00 – 15:30 Session 15a: Future observations (oral presentations - 12 minutes) Chairs: Dorothee Coppens and Fuzhong Weng		
15.01	Cyril Crevoisier	IASI-New generation: scientific objectives and foreseen validation
15.02	Likun Wang	A Study on the Benefits of Spatial Resolution for Next Generation Infrared Hyperspectral Sounder Instruments
15.03	Agnes Lim	Impact Analysis of LEO Hyperspectral Sensor IFOV size on the next generation high-resolution NWP model forecast performance
15.04	Will McCarty	An OSSE Investigating a Constellation of 4-5 µm Infrared Sounders
15.05	Ralf Bennartz	The TROPICS mission's sounding capabilities
15.06	Fuzhong Weng	Future Opportunities of Using Microwave Data from Small Satellites

15:30 – 15:50 Session 15b: Future observations (poster introductions - 1 minute: no visual aids) Chairs: Dorothee Coppens and Fuzhong Weng		
15p.01	Francisco Bermudo	IASI-NG Program: General Status Overview
15p.02	Adrien Deschamps	Overview of the IASI-NG Level 1 Processing
15p.03	Flavia Lenti	Introduction to the IASI-NG principal components and L2 operational processor.
15p.04	Francesca Vittorioso	Preparing the assimilation of IASI-NG in NWP models: a first channel selection
15p.05	Cédric Goukenleuque	Preparing test data for the IRS Level 2 processor
15p.06	Zhenglong Li	Value-added Impact from Geostationary Hyperspectral Infrared Sounder on high impact weather forecasting – demonstration with quick regional OSSE
15p.07	Zhenglong Li	Using CIRAS and MicroMAS-2 to mitigate the data gap of CrIS and ATMS
15p.08	Nigel Atkinson	Level 1 processing for the Microwave Sounder on Metop-SG
15p.09	Fiona Smith	Evaluation of Laser Heterodyne Radiometry (LHR) for Numerical Weather Prediction Applications

15:50 – 16:50 Break and poster session 10b, 11b, 12b, 13b, 14, 15b

16:50 – 17:30 Working groups finalise reports

19:00 Banquet, including

- **Presentation of prizes for best oral and poster presentations**

Tuesday, 5 December 2017

9.00-10.15 Session 15: Working Group Reports (15 minutes)
Co-Chairs: Mitch Goldberg and Niels Bormann

- **Advanced Sounders (Dieter Klaes and Bill Smith)**
- **Climate (Nathalie Selbach and Cheng-Zhi Zou)**
- **NWP (Andrew Collard and Fiona Smith)**

10.15-10.45 BREAK

10.45-12.00 Session 15: Working Group Reports (15 minutes)
Co-Chairs: Mitch Goldberg and Niels Bormann

- **RT (Marco Matricardi and Benjamin Johnson)**
- **International and Future Systems (Peng Zhang and Stephen English)**
- **Products and Software (Liam Gumley and Nigel Atkinson)**

12.00-12.30 Session 16: Technical Sub-Group Reports (5 minutes)
Co-Chairs: Mitch Goldberg and Niels Bormann

- **Direct broadcast packages/DBNet (Liam Gumley and Mikael Rattenborg)**
- **RTTOV and CRTM (James Hocking)**

12:30 – 12:45 Closing Session
Co-Chairs: Mitch Goldberg and Niels Bormann

- **Elections**

ITSC-XXI ABSTRACTS

Session 1a: Community software – session dedicated to Paul van Delst

1.01 CRTM development status and future plans

Presenter: Benjamin Johnson, UCAR/JSCDA @NOAA
Authors: Benjamin T. Johnson, Tong Zhu, Ming Chen, Thomas Auligne, Quanhua Liu, Fuzhong Weng, Ping Yang, Bingqi Yi, Jiachen Deng, Patrick Stegmann, David Groff, Isaac Moradi, Fuqing Zhang, Scott Sieron, Thomas Greenwald, James Rosinksi
The development of the Community Radiative Transfer Model (CRTM) and its subsequent improvements has created a critically important method for NWP models to assimilate satellite measurements made under all weather conditions. The CRTM was primarily developed by STAR and EMC scientists with the support of the Joint Center for Satellite Data Assimilation (JCSDA) to provide fast, accurate satellite radiance simulations and associated Jacobian calculations under all weather and surface conditions, CRTM supports all current operational and many research satellite measurements, covering wavelengths ranging from the visible through the microwave. The model has undergone substantial improvement and expansion, since the first version released in 2004.

The CRTM has been used in the NOAA/NCEP and U.S. Navy operational data assimilation systems and by many other JCSDA partners such as NOAA/NESDIS/STAR, NOAA/OAR, NASA/GMAO, Naval Research Laboratory, Air Force Weather, and within multiple university environments. Over the past 13 years, external research groups and operational centers alike have made essential contributions to CRTM development.

This presentation provides an overview of the current status of CRTM version 2.3.0; and also describes the future planned release of CRTM version 3.0.0, which will represent a major milestone in CRTM development and capabilities.

1.02 Community Radiative Transfer Model (CRTM) applications to support sensor Cal/Val and EDR generations

Presenter: Quanhua (Mark) Liu, NOAA/NESDIS/STAR
Authors: Quanhua (Mark) Liu, Benjamin Johnson, Tong Zhu, Ming Chen, Yong Chen, Lin Lin, and Fuzhong Weng
The Community Radiative Transfer Model (CRTM) operationally supports satellite radiance assimilation for weather forecast, sensor data verifications, and retrievals of satellite products. This presentation will discuss recent improvements of the CRTM and the applications in support of instrumental calibration and validation.

The CRTM serves as a useful tool, greatly support sensor calibration and validation for JPSS and GOES-R missions. By subtracting CRTM simulated radiance from the ATMS measurements, one can reveal and analyze the weak striping in few channels of the SNPP ATMS sensor. With the help of the CRTM, scientists at the NOAA have developed the algorithm for cloud detection based on a pair or a set of pairs of the CrIS channels.

Using the CRTM, we found the root cause in the VIIRS M15 image. The CRTM is also used in radiance monitoring system. This presentation will also demonstrate how the CRTM plays a role in the NOAA Microwave Integrated Retrieval System (MiRS) for the generation of atmospheric profiles of temperature and water vapor, cloud liquid water, ice water content, rainfall rate, snow cover and snow water equivalent, snow fall rate, surface temperature and microwave emissivity, and sea ice concentration.

1.03 RTTOV development status

Presenter: James Hocking, Met Office
Authors: Pascal Brunel, John Eyre, Alan Geer, Stephan Havemann, James Hocking, Cristina Lupu, Marco Matricardi, Pascale Roquet, David Rundle, Roger Saunders, Emma Turner, Jérôme Vidot
A new major release of RTTOV, v12.1, was made available to users in February 2017. The new package includes various developments. New visible/IR coefficients have been generated based on updated trace gas training profiles, and coefficient files are also available allowing SO2 as a variable gas. A new Discrete Ordinates solver for visible/IR aerosol- and cloud-affected radiances has been implemented, and there are updated visible/IR optical properties for ice clouds. There are numerous updates related to the treatment of surface emissivity and reflectance. The non-local thermodynamic equilibrium (NLTE) correction has been updated and new PC-RTTOV coefficients are available optionally including the NLTE correction.

The C++/Python wrapper has been updated so that all direct and K (Jacobian) model clear-sky and scattering capabilities are supported. Finally, it is also now possible to call the HT-FRTC fast radiative transfer model through the RTTOV interface. An overview of the new capabilities will be presented along with a look ahead to planned developments for future versions.

1.04 CSPP LEO: Recent updates and support for JPSS-1

Presenter: Liam Gumley, SSEC/UW-Madison
Authors: Liam Gumley, Allen Huang, Scott Mindock, Graeme Martin, Ray Garcia, Kathy Strabala, Jessica Braun, Nick Bearson, Geoff Cureton, Jim Davies

The CSPP LEO software suite supports processing of data obtained via direct broadcast from SNPP, JPSS-1, Metop-A/B, NOAA-18/19, Terra, Aqua, GCOM-W1, and FY-3B/C. Products include Level 1 (SDRs) from ATMS, CrIS, and VIIRS; atmosphere, land, and ocean geophysical products from imagers and sounders on multiple satellites; and imagery from multiple Level 1 and geophysical datasets. Recent additions to the suite include support for JPSS-1 ATMS, CrIS, and VIIRS, and the addition of full spectral resolution processing for CrIS on both SNPP and JPSS-1. New Level 2 products include a NOAA algorithm for VIIRS active fire detection, and VIIRS flood detection. This presentation will report on the current status of the CSPP suite and describe the support for JPSS-1 processing, along with examples of the new VIIRS fire and flood detection products.

Session 1b: Community radiative transfer software

1p.01 Withdrawn

1p.02 Radar simulation in CRTM

Presenter: Benjamin Johnson, UCAR/JSCDA @NOAA
Authors: Benjamin T. Johnson

The current version of CRTM has the ability to quickly and accurately forward model the passive IR and microwave response to the atmosphere and surface. However, many research and operational centers seek to make better use of active radar data, both ground-based and space-based, in order to better improve on the modeling/assimilation of the complex 3D structure of clouds and precipitation.

This poster describes recent advances in the ability of CRTM to forward model the radar reflectivity and path-integrated attenuation and provides associated tangent linear, adjoint, and K-matrix models. This development is expected to provide an initial capability to directly assimilate radar reflectivities from both satellite and ground-based systems in any assimilation framework using CRTM. It also provides support for non-spherical hydrometeor scattering and extinction calculation. No polarization-by-scattering is included yet, only intensity.

Specific case studies for forward modeling and assimilation will be shown, highlighting the strengths and weaknesses of this new implementation. Also, a section of the poster will highlight the improvements in the cloud and precipitation hydrometeor properties within CRTM.

1p.03 RTTOV GUI, the graphical user interface for RTTOV

Presenter: Pascale Roquet, Meteo-France
Authors: Pascal Brunel, James Hocking, Tony MacNally, Jean-Luc Piriou, Pascale Roquet, Jérôme Vidot

RTTOV GUI is the graphical user interface for RTTOV, the fast radiative transfer model developed in the context of the EUMETSAT NWP-SAF project. Designed for educational purposes, this graphical user interface can be used by researchers, teachers and students to learn about radiative transfer. Users can visualize atmospheric profiles and surface properties, simulate and examine top of atmosphere brightness temperatures and radiances as well as Jacobian profiles for all satellite instruments supported by RTTOV. Users can also modify atmospheric profiles and surface properties, add or remove clouds and aerosols and compare RTTOV simulations. Furthermore, it is possible to use the included 1D-Var feature to visualize temperature and humidity profile retrievals.

The poster presentation will be supported by a live demo of RTTOV GUI.

1p.04 Modeling of nonlocal thermodynamic equilibrium effects in the classical and principal component based version of the RTTOV fast radiative transfer model

Presenter: Marco Matricardi, ECMWF
Authors: Marco Matricardi, Manuel Lopez Puertas and Bernd Funke

The ECMWF 4D-Var data assimilation system has been recently modified to allow the direct assimilation of Principal Component (PC) scores of long-wave IASI spectra. To maximise the exploitation of the IASI instrument, a logical future step is to consider the extension of the PC approach to the extraction of information from the 4.3 µm CO2 absorbing region, which contains excellent temperature sounding channels. Short-wave IASI channels are currently underused compared to similar channels in the long-wave region for a number of reasons, which include day-night variations in data usability due to departures from Local Thermodynamic Equilibrium (LTE) during daytime. In this poster, we document the introduction of Non Local Thermodynamic Equilibrium (NLTE) effects in the PC based version of the RTTOV fast radiative transfer model (PC-RTTOV). This will allow the use of PC-RTTOV for the simulation of daytime IASI short wave PC scores or reconstructed radiances. The inclusion of NLTE effects in PC-RTTOV has required the development of a parameterized scheme that allows the fast computation of a NLTE correction to LTE radiances. The fast NLTE model is based on the use of state-of-the-art vibrational temperatures and is general enough to be applied to any sensor and can be utilised to add a fast and accurate NLTE correction to the polychromatic LTE spectra computed by any general radiative transfer model, including RTTOV, which now incorporates the fast NLTE model developed in this study. The accuracy of the NLTE correction is such that daytime and nigh-time radiances can be simulated to almost the same degree of accuracy. The comparison with IASI observations shows that the fast NLTE model presented here performs significantly better than the fast NLTE model incorporated in the previous version of RTTOV but also that improvements have to be made to the simulation of NLTE effects at winter high latitudes.

1p.05 Evaluation of the radiative transfer model RTTOV-12 at ECMWF

Presenter: Cristina Lupu, ECMWF
Authors: Cristina Lupu, Marco Matricardi, Alan Geer

The use of satellite radiance observations in NWP depends directly on the accuracy of the radiative transfer model, RTTOV, developed within the context of EUMETSAT NWP-SAF activity. This study summarises the evaluation in the IFS of the very latest release of the radiative transfer model, RTTOV-12 with updated surface emissivity models and coefficient databases. The latter includes a move towards using LBLRTM-based coefficients for all infrared sensors and coefficients which better describe the half width of the 183 GHz water vapour line (and its temperature dependency) and with updated values for the oxygen line parameters for microwave sensors. Results show that the new coefficients mainly alter bias characteristics of the assimilated radiances, with one of the largest changes for infrared radiances (e.g., IASI) due to the move to LBLRTM12.2-based RTTOV coefficients from kCARTA-based coefficients. Assimilation experiments conducted in the IFS to evaluate the impact of all components of the RTTOV-12 upgrade show improvements in terms of first-guess departure fits for 183 GHz humidity sensitive observations (e.g., MHS) and lower tropospheric temperature sensitive channels (e.g., ATMS). Studies are ongoing to investigate the performance on medium-range forecasts, and the latest results will be discussed in the poster.

Session 1c: Community software

1.05 NASA International MODIS/AIRS Processing Package (IMAPP): Current status and future plans

Presenter: Kathleen Strabala, CIMSS/SSEC/UW-Madison
Authors: Kathleen Strabala, James Davies, Rebecca Cintineo, Liam Gumley, Allen Huang

NASA's commitment to support global operational environmental satellite users has resulted in the sponsorship of the International MODIS/AIRS Processing Package (IMAPP) for more that 17 years. Since its inception, IMAPP has promoted the local real-time use of Aqua and Terra direct broadcast data through the release of software packages that support the AIRS and MODIS calibration, geolocation and creation of science products for environmental decision makers.

The IMAPP user base now consists of more than 2400 registrants representing more than 90 countries. The extensive suite of supported products now includes MODIS Level 2 Collect 6.1 Atmosphere science software, AIRS Collect 5.0 Level 1 and 6.0 Level 2 software from JPL, two different Air Quality Forecast applications including aerosol pollution trajectories based upon the MODIS AOD MOD04 product, and Stratospheric Ozone Intrusions based upon a University of Wisconsin-Madison AIRS single Field-of-View AIRS retrieval. A set of aviation hazard detection application software which includes lightning and turbulence areal coverage. Other packages include a complete Aqua and Terra direct broadcast processing system that allows uses to take advantage of the entire suite of software freely available to the user community. This package is released in the form of a Virtual Appliance that allows installation on Windows, Macintosh and Linux operating systems.

IMAPP also fosters the education of satellite users through local direct broadcast application workshops. Partnering with organizations including the WMO, IGARSS and GEOSS, IMAPP has co-sponsored 16 local workshops on 6 continents.

This presentation will include a review of the current status of the IMAPP software suite along with scheduled near-term releases, with a focus on expansion of software to support NASA VIIRS, CrIS and ATMS products on S-NPP and JPSS-1 satellites.

1.06 NWP SAF software deliverables: 2017 to 2022

Presenter: Nigel Atkinson, Met Office
Authors: Nigel Atkinson and Chiara Piccolo

The NWP SAF (Satellite Application Facility) aims to improve and support the interface between satellite data/products and European activities in NWP. The NWP SAF is one of several EUMETSAT SAFs, which are dedicated centres of excellence for processing satellite data and form an integral part of the distributed EUMETSAT Application Ground Segment.

The third Continuous Development and Operations Phase (CDOP-3) of the NWP SAF started in March 2017 and runs for 5 years. In addition to monitoring and support functions, the NWP SAF develops and maintains a number of software deliverables, including AAPP, RTTOV, 1DVAR, scatterometer packages, an aerosol and cloud package and a radiance simulator. During CDOP-3, two new software packages will be developed: a Microwave Imager Processing Package (MWIPP) and an Infrared Sounder Processing Package (IRSPP).

The IRSPP will support the hyperspectral sounder on Meteosat Third Generation. Its primary function will be to provide tools to allow users to work with the near-real time data that will be distributed by EUMETSAT, in which the radiances will be compressed using Principal Component (PC) Scores.

The MWIPP will be partly based on the current SSMIS processor, but extended to include several additional sensors – including the microwave imagers on Metop Second Generation, as well as current sensors like SSMIS and AMSR-2. Support for the Microwave and IR sounders on Metop-SG will be included within AAPP.

The NWP SAF seeks to gather input on user requirements for all its packages, but this is particularly true at this time for the two new packages. For example: (i) what instruments should be covered, (ii) what data formats need to be supported (BUFR, NetCDF4, etc.), (iii) what pre-processing is needed (e.g. spatial averaging, PC transformation, etc.).

It is hoped that this talk will prompt discussion in the ITSC-21 working groups, and that the groups will make recommendations which can then be used to develop the product specifications for both the new software packages and the existing ones.

Session 1d: Community software and direct broadcasting

1p.06 CSPP SDR 3.0 support for JPSS-1

Presenter: Scott Mindock, SSEC/CIMSS/UW-Madison
Authors: Scott Mindock, Graeme Martine, Ray Garcia, Kathy Strabala, Nick Bearson, Liam Gumley, Allen Huang

The CSPP SDR team at the University of Wisconsin has been hard at work adding support for JPSS-1 to the CSPP SDR software. CSPP (Community Satellite Processing Package) SDR software has been proving users with dependable SDR generation from SNPP Direct Broadcast data since it's initial launch. The SDR 3.0 software will continue to support SNPP but additionally will support JPSS-1 in one easy to use software package. This poster describes the challenges as well as new features (CrIS FS) to this popular processing suite.

1p.07 Himawari support in the CSPP-GEO Direct Broadcast package

Presenter: Geoff Cureton, CIMSS/UW-Madison
Authors: Geoffrey Cureton

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has a long history of supporting the Direct Broadcast (DB) community for various sensors, recently with the International MODIS/AIRS Processing Package (IMAPP) for the NASA EOS polar orbiters Terra and Aqua, and the Community Satellite Processing Package (CSPP) for the NOAA polar orbiter Suomi-NPP. CSPP has been significant in encouraging the early usage of Suomi-NPP data by US and international weather agencies, and it is hoped that a new package, CSPP-GEO, will similarly encourage usage of DB data from GOES-R, Himawari, and other geostationary satellites. The support of Himawari-8 provides several challenges for the CSPP-GEO-Geocat package, which generally revolve around the greatly increased data rate associated with the subsatellite point footprint approaching 1km. CSPP-GEO-Geocat takes advantage of python shared-memory multiprocessor support to divide Himawari data into managable pieces, which are then farmed out to indvidual cores for processing by the underlying geocat code. The resulting product segments are then stitched together to make the final product NetCDF4 files. CSPP-GEO-Geocat will support high-data-rate HRIT input, as well as the reduced resolution HimwariCast direct broadcast data stream. Products supported by CSPP-GEO-Geocat include the level-1 reflective and emissive bands, as well as level-2 products like cloud mask, cloud type, optical depth and particle size, cloud top temperature and pressure.

1p.08 CSPP Geo direct broadcast software for GOES-16 and Himawari-8: Project overview and lessons learned

Presenter: Graeme Martin, SSEC/UW-Madison
Authors: Graeme Martin, Liam Gumley, Nick Bearson, Jessica Braun, Alan DeSmet Geoff Cureton, Ray Garcia, Tommy Jasmin, Scott Mindock, Eva Schiffer, Kathy Strabala

The Community Satellite Processing Package for Geostationary Data (CSPP Geo) project is funded by the NOAA GOES-R Program to create and distribute software allowing direct broadcast users to process data received from geostationary weather satellites. In the period leading up to the launch of GOES-R (now GOES-16) in November 2016, the CSPP Geo team released several prototype versions of software packages intended to help prepare direct broadcast users for reception of GOES-16 data via the GOES Rebroadcast (GRB) data stream. Since the launch of GOES-R, we have released multiple versions of software that allows users to process the raw GRB stream and generate imagery and geophysical data products. In addition, we have released software supporting the Himawari-8 mission, and interacted with users in the Asia-Pacific region. Both GOES-R and Himawari-8 are part of a new generation of weather satellite missions offering significantly enhanced capabilities, and thus pose a significant new challenge from a processing perspective due to the much higher data rate. In this talk, we provide an overview of the CSPP Geo project and discuss lessons learned while developing direct broadcast software for the GOES-16 and Himawari-8 missions, and through interactions with users.

1p.09 CSPP VIIRS flood detection

Presenter: Nick Bearson, SSEC/UW-Madison
Authors: Nick Bearson, Sanmei Li, Liam Gumley, Mitch Goldberg

Floods are the most frequent natural disasters around the globe. They have caused more loss of life and property in the USA than any other kind of natural disaster. Detecting, monitoring, and mitigating flooding is a challenge that requires a large network of river gauges, human observations, and other data points.

Fortunately, VIIRS is uniquely suited to fill in the gaps. The JPSS Proving Ground & Risk Reduction Program's Proving Ground Initiative for River Ice and Flooding has produced algorithms to detect river ice and flooding. The software runs routinely at SSEC and GINA, which have access to direct broadcast SNPP/VIIRS data, to generate near real-time flood maps for River Forecast Centers in the United States. Their positive response has led NOAA to investigate putting the software into their regular operations.

In the meantime, CSPP has created the CSPP VIIRS Flood Detection package so that other direct broadcast users can produce the same products and create similar partnerships with their local flood managers. In this presentation we introduce the software, answer questions about the implementation, and invite user feedback.

1p.10 Withdrawn

1p.11 Planned updates to the STAR BUFR and GRIB tailoring system for satellite operational products

Presenter: Qiang Zhao (for Walter Wolf), IMSG @NOAA/NESDIS/STAR
Authors: Walter Wolf, Qiang Zhao, and Thomas King

A tailoring software system that converts satellite operational products into Binary Universal Form for the Representation of meteorological data (BUFR) and GRIdded Binary Edition 2 (GRIB2) formatted files has been implemented at NOAA/NESDIS/STAR. This Reformatting Toolkit converts the products from the NPOESS Preparatory Project (NPP)/Joint Polar Satellite System (JPSS), the Global Change Observation Mission 1st - Water (GCOM-W1) Advanced Microwave Scanning Radiometer 2 (AMSR2), the Japanese next generation Himawari-8/9 Advanced Himawari Imager (AHI), and the Geostationary Operational Environmental Satellite data into BUFR and GRIB2 files. The toolkit is running in the NPP Data Exploitation (NDE) system within NOAA/NESDIS/OSPO. OSPO is distributing these tailored products to the NOAA Environmental Modeling Center (EMC) and the European Organisation for the Exploitation of Meteorological

Satellites (EUMETSAT) in near real-time. With the upcoming launch of J1, the toolkit has already been updated for the creation of the JPSS-1 Cross-track Infrared Sounder (CrIS) radiances and Advanced Technology Microwave Sounder (ATMS) antenna temperatures. Additional planned updates to the toolkit include the VIIRS Aerosol Detection BUFR, Ozone Mapping Profiler Suite (OMPS) Limb Profile BUFR, GOES-16 clear and all sky radiances in BUFR, and the VIIRS Land Surface Temperature in GRIB2 format. The planned BUFR and GRIB file contents for each instrument are provided and discussed.

1p.12 Contributions of DBNet South America-Argentina component for NWP community

Presenter: Gloria Cristina Pujol, Argentina National Met. Service

Authors: Gloria Cristina Pujol

DBNet is a network of Direct Readout stations sharing their data in near real time following a set of procedures and best practices to ensure interoperability, global availability and timeliness of DBNet products. The key requirements are the use of current AAPP, the delivery of L1c in BUFR, sending over the GTS (and possibly other means) within 30 minute latency. Identifiers are the Bulletin headings and WMO filename convention.

DBNet South America-Argentina Component are comprise of:
-Córdoba Ground Station is located in the center of Argentina, is operated by Argentina Space Agency (CONAE). As main node for this Component, it is operational since May 2008, processing and distributing ATOVS data and hyperspectral sounders: NOAA/ATOVS, METOP-B/ATOVS, METOP/IASI, S- NPP/CrIS and S-NPP/ATMS.

-Marambio station in Antarctica peninsula, operated by Argentina National Met. Service
-Santiago station (Chile) operated by Chile National Met. Direction.
Both stations contribute with ATOVS data.

-Isla de Pascua station (Easter Island) located in the Southwest Pacific, is operational since August 2015 by agreement between CLS-Argos and Chile, having the ability to extract the ATOVS data, but not their delivery, due to restrictions on communication link with the continent.

Direct Readout stations performance of that Component, as well as processing and dissemination schemes of ATOVS data and hyperspectral sounder products, are shown in the presentation.

1p.13 Current status and future plan of direct-readout LEO weather satellite operation in NMSC/KMA for supporting NWP

Presenter: Jin Woo, NMSC/KMA

Authors: Jin Woo, DaHye Bae, Hyunjong Oh, Yongsang Kim

Nowadays LEO (Low Earth Orbit) weather satellite data is used as a key product in various fields. National Meteorological Satellite Center (NMSC)/Korea Meteorological Administration (KMA) is also utilizing these data for supporting weather forecast analysis and NWP model input. NMSC is receiving LEO weather satellite data directly such as MetOp-A/B, NOAA-15/18/19, Suomi-NPP, Terra/Aqua etc. ATOVS and IASI data is utilized for NWP data assimilation and we are preparing to use ATMS and CrIS for the local NWP model in KMA NWP team. NMSC is processing these data in real time by using AAPP(ATOVS and AVHRR Pre-processing Package), CSPP(Community Satellite Processing Package) and IAPP(International ATOVS Processing Package) and providing for users. NMSC is started DB-Net service for direct-readout IASI data since March 2017 for the first time Asia-Pacific region and preparing CrIS and ATMS data. In this paper, we will present KMA's LEO weather satellite operation status and future plan.

1p.14 Aqua and Terra Direct Broadcast processing at CIMSS/SSEC

Presenter: Jessica Braun, SSEC/UW-Madison

Authors: Jessica Braun, Liam Gumley, Kathy Strabala, Bruce Flynn

The Direct Broadcast (DB) group at CIMSS/SSEC has been processing MODIS, AIRS, and AMSU data from Aqua and Terra direct broadcast data for over 10 years. The processing system uses an overpass prediction method to merge collocated Level 0 PDS files ingested from multiple DB sites across the United States. The resulting PDS files have more extensive coverage and higher quality of data, as the majority of dropouts and bad packets are removed. The merged passes are processed into Level 1 and Level 2 products and distributed to operational sites including the National Weather Service (NWS) and NOAA CoastWatch. With the success of the MODIS, AIRS, and AMSU merged pass processing method, development is in progress to extend this merged method to other DB data including Suomi NPP.

1p.15 NOAA DB Network: Providing advanced sounder data in near real-time for NWP
Presenter: Liam Gumley, SSEC/UW-Madison
Authors: Liam Gumley, Mitch Goldberg, Bruce Flynn, Dave Santek, Jessica Braun
SSEC at UW-Madison owns and operates a network of 5 polar satellite reception sites in Guam, Hawaii, Wisconsin, Florida, and Puerto Rico. Funding for this network was provided by NOAA JPSS in order to provide low latency advanced sounder data from CrIS, ATMS, and IASI for NWP assimilation. Sounder data from the SSEC/NOAA sites, along with data obtained from network partner sites in Alaska, Oregon, California, New York, and Virginia, are ingested at SSEC, processed to Level 1B, and converted to DBNet BUFR format with CSPP, AAPP, and OPS-LRS. The BUFR data are posted for delivery to end users typically within 15 minutes of observation on the satellite. NOAA/NWS/NCEP routinely ingests the BUFR files for NWP assimilation. Starting in mid 2017, EUMETSAT began ingesting the BUFR files and rebroadcasting them on EUMETCAST as a pilot service under an agreement between NOAA and EUMETSAT. Finally, NOAA is preparing to distribute the files via GTS. This presentation will provide an overview of the network technical design, data latency, and data delivery. The presentation will also show a number of other real-time applications of imager and sounder products at the SSEC/NOAA antenna sites for weather forecasting and decision support.

Session 2a: Radiative transfer

2.01 The 4A/OP model: From NIR to TIR, new developments for time computing gain and validation results within the frame of international space missions
Presenter: Raymond Armante (for Emilien Bernard), LMD
Authors: Bernard E , Tournier B , Lezeaux O , Dufour E , Armante R , Capelle V , Scott N , Chédin A , Delahaye T, Deschamps A , Jouglet D , Lafrique P , Jaumouillé E
The Automatized Atmospheric Absorption Atlas (4A) is the fast and accurate line-by-line radiative transfer model developed, improved and validated at LMD (Laboratoire de Météorologie Dynamique) for the computation of transmittances, radiances and Jacobians, (http://ara.abct.lmd.polytechnique.fr/index.php?page=4a). Regularly improved, updated and extended by LMD, NOVELTIS and CNES, the “operational” version 4A/OP is distributed to registered users via the associated website (http://4aop.noveltis.com/).

4A/OP is currently used for radiative transfer simulations on a wide spectral range [e.g. 20 µm – 0.75 µm]. Extension to UV/Vis is in progress. This model is used by several research and operational groups involved in forward and inverse radiative transfer problems. In particular, 4A/OP is the reference software used by CNES for several national or international in-flight (IASI/MetOp) or planned missions (IASI-NG, MicroCarb and MERLIN).

Within the frame of research and operational approaches, validation studies, corrective improvements and corresponding implementations are performed to constantly upgrade the 4A/OP model efficiency in terms of accuracy, computing time and flexibility to users' needs.

Validation studies are performed - on a semi-operational basis in the infrared with IASI (MetOpA and MetOpB, since launch) - and in the near infrared using TCCON stations/observations. They also include the assessment of the impact of the updated version (2015) of the spectroscopic database GEISA (http://ara.abct.lmd.polytechnique.fr/index.php?page=geisa-2).

In order to further reduce the computation time, following improvements have been made:

- The scattering mode in 4A which uses LIDORT/VLIDORT RT software benefits from an acceleration method to significantly reduce the computation time while preserving the accuracy. The Low Stream Interpolation (LSI) method (O’Dell, 2010) implemented in 4A/OP leads to reduce the computing time by 60 with an accuracy < 1%.
- Based on OpenMP API, 4A/OP benefits also from a parallelized mode which makes it possible to compute a large number of atmospheric profiles. In addition, the atlas of the molecular absorption coefficients are now loaded into the memory which reduces the access time to files.

Other new capabilities have been implemented aiming at adding more flexibility to the 4A/OP-User interface and to offer a wider choice of inputs/outputs possibilities:

- infinite resolution versus ISRF convolved Jacobians,
- choice of the emissivity database

- choice of wavenumber or wavelength units, …

These topics will be discussed at the time of the Conference.

2.02 TIR and SWIR Level1 and Level2 products validation: A deeper insight to updates of the 4A line-by-line radiative transfer model
Presenter: Raymond Armante, LMD
Authors: R. Armante, V. Capelle, N.A. Scott, F. Capalbo, L. Crépeau, T. Delahaye, A. Chédin
4A is a fast and accurate line-by-line (LBL) radiative transfer model developed at LMD (Scott and Chédin, 1981). 4A was among the pioneer radiative transfer models to bypass LBL processing time by calculating once and for all a set of compressed Look-Up-Tables (LUT) of monochromatic optical depths, for each absorbing gas and each layer, separately. The LUT are generated by the nominal LBL STRANSAC model (Scott, 1974) fed with any spectroscopic database (GEISA, HITRAN, …). 4A generates transmittances, radiances, Jacobians (Chéruy et al., 1995) for any instrumental, spectral, geometrical configuration. 4A has a long history of validation in the TIR within the frame of the international radiative transfer community. Its efficiency and accuracy have made 4A an essential way to level2 products retrieval: either based on physical approaches – the "3I" method (from Chédin et al., 1985, onwards) - or on Look-up-Tables approaches (from Pierangelo et al., 2004 to e.g Capelle et al., 2014) or on neural networks approaches (from Escobar, 1993 to e.g. Crevoisier et al., 2013). ¬[See also: http://ara.abct.lmd.polytechnique.fr/index.php?page=publications].

Originally developed for the thermal infrared region, the 4A model has been extended to the short-wave infrared region in the framework of new missions proposed by CNES and is currently extended to the Ultra Violet and Visible domains. 4A/OP is the official model chosen by CNES for calibration/validation activities of IASI, IASI-NG, Merlin (https://merlin.cnes.fr) and MicroCarb (https://microcarb.cnes.fr) missions.

All the above mentioned retrieval applications or mission preparations require continuous and robust assessment of the 4A model accuracy, followed by feedbacks to the STRANSAC and/or 4A radiative transfer modeling and/or feedback to the GEISA spectroscopic database content, iteratively.

For many years now (since the TOVS NOAA/NASA Pathfinder Programme in the mid 1990s'), this assessment goes through the statistical study of the "residuals", ie the differences between simulated and observed brightness temperatures. This study is now performed at global scale, in a semi operational way. For the 4A assessment in the TIR, observations are from IASIA or IASIB, since their launch. Atmospheric and surface inputs to the 4A model are either from the ARA/LMD ARSA database or from ECMWF operational data (analyses, reanalyses). Also, a careful characterization of the observed pixels (clear/cloudy , sea/land/day/night, air-mass type, altitude, time-space colocations specs) is performed. The remarkable radiometric stability of IASI and its continuous spectral coverage from 645 to 2760cm-1 provides an effective identification of various sources of errors: inappropriate radiative transfer modeling, spectroscopic parameters, description of the atmospheric or surface states. A recent description of this long-established validation scheme "SPARTE" (Spectroscopic Parameters And Radiative Transfer Evaluation) is given Armante et al., 2016. Based on a similar approach, the 4A assessment in the SWIR is performed through the use of ground-based FTS observations at the Parkfalls TCCON site (Wunch et al, 2011).

At the time of the Conference, several recent improvements will be described and discussed such as the impact of improved spectroscopy (GEISA 2011 vs GEISA 2015, HITRAN, etc…), of better characterization of line mixing (CO2, O2), of the improvement of the modelling of the continuum absorption of H2O and O2 or the H2O/HDO concentration profile separation.

Regularly improved, updated and extended by LMD, CNES and NOVELTIS, the "operational" version 4A/OP is distributed to registered users via the associated website (http://4aop.noveltis.com/).

2.03 Radiative transfer along a slanted path
Presenter: Niels Bormann, ECMWF
Authors: Niels Bormann
This contribution reports on the influence of taking the slanted satellite viewing geometry better into account in the simulation and assimilation of sounding radiances. The traditional approach is to use a vertical profile extracted at the geo-location information provided with the data, and to only take the increased path length into account. The present work instead investigates using a slanted profile, extracted from model fields along the instrument's line of sight.

Taking the viewing geometry better into account leads to significant improvements in the simulation of brightness temperatures from model fields compared to the traditional approach. This is particularly noticeable for larger zenith angles, for channels that peak in the upper troposphere or higher, and for high and mid-latitudes. The finding also suggests that the model fields capture useful information on horizontal gradients, at least on the relevant spatial scales. The improved simulations of the sounder radiances lead to significant reductions in the size of the analysis increments at mid and high latitudes and particularly in the stratosphere during the assimilation. The system shows a statistically improved self-consistency out to the day-3 forecast range.

Session 2b: Radiative transfer

2p.01 Improvements to fast radiative transfer modelling of hyperspectral infrared sounders
Presenter: Stephan Havemann, Met Office
Authors: Stephan Havemann, Fiona Smith and William Bell
The Havemann-Taylor Fast Radiative Transfer Code (HT-FRTC) allows superfast and very accurate simulations for hyperspectral sensors like IASI, IASI-NG and MTG-IRS. It can even run at ultrahigh spectral resolution down to 10-4 cm-1, but it models broadband sensors like MODIS and SEVIRI as well. The underlying concept that makes this possible are principal components at ultrahigh spectral resolution. These principal components which are generated during the code training phase are completely sensor-independent, which means that any number of instruments can be simulated simultaneously in a single run as long as the atmosphere and surface parameters are unchanged.

The HT-FRTC uses the monochromatic gaseous optical properties for the HITRAN gases as provided by LBLRTM. However, the code has its own modules for the monochromatic clear-sky and scattering radiative transfer to model contamination by clouds and/or aerosols. It can be used as a monochromatic code in ultra-high resolution or, alternatively, in its fast code version based on principal components, where only a small number of monochromatic radiative transfer calculations are required to calculate the principal component scores. The fast code version can generate an accurate ultra-highly resolved spectrum and simulate any sensor.

Detailed, global comparisons of LBLRTM, HT-FRTC and RTTOV have been done for IASI. To obtain meaningful results great care has been taken to run the codes under exactly identical conditions. The codes are compared with each other for a global set of 25000 different atmospheric and surface conditions as provided by the datasets supplied by the NWPSAF. In addition to the radiances, the Jacobians are compared, which are essential for retrievals. The importance of a number of other factors that may have a bearing on the results of the simulations has been investigated. Among these is the number and selection of trace gases included in the simulations. The spectral resolution of the monochromatic calculations on the simulations has also been studied. Finally, even when using the linear-in-tau approximation, the finite vertical resolution in the radiative transfer calculation limits the accuracy of the radiance calculations.

Work has started to evaluate the performance of HT-FRTC within the Met Office Observations Processing System (OPS) and Variational Data Assimilation System (VAR).

2p.02 Effects of atmospheric turbulence in radiative transfer modelling
Presenter: Xavier Calbet, AEMET
Authors: Xavier Calbet, Niobe Peinado-Galan, Rob Kursinski, Peio Oria, Dale Ward, Angel Otarola, Pilar Ripodas
In their present state, Radiative Tranfer Models (RTM), offer a high degree of accuracy when compared to actual measurements. Nevertheless, a few discrepancies in the microwave in 183 GHz and in the infrared part of the radiance spectrum have been found. A possible explanation for these discrepancies could be the lack of modelling of the atmospheric turbulence in the RTMs. To test this, the atmospheric turbulence determined from GRUAN radiosondes is integrated into the RTMs to calculate radiances given a measured atmospheric state. These calculated radiances are then compared to real measurements giving an insight as to whether the hypothesis is true. Turbulence does seem to have an important effect on the modelling of the radiances.

2p.03 Estimation of CO_2 column retrieval errors from ignoring 1.6µm polarization calculation in forward modeling for space-borne polarization-sensitive instruments

Presenter: Wenguang Bai, NSMC

Authors: Wenguang Bai, Peng Zhang, Wenjian Zhang, Jun Li, Gang Ma, Chengli Qi

A polarized atmosphere radiative transfer model relied on doubling and adding method was developed to simulate the near-infrared 1.6µm measurements by space-borne instruments. This model solved the radiative transfer equation for a plane-parallel, vertically-inhomogeneous scattering atmosphere with a Lambert reflecting surface. Both gases absorption and scattering by aerosol and molecules were considered. Only the solar source radiation was taken into account because the thermal sources were negligible in this near-infrared band. The model calculation results were verified through comparisons with other well-known models. Based on this model, sensitivity studies have been performed to estimate the errors from neglecting polarization in analyzing spectroscopic measurements. The US standard atmosphere profile loading with aerosols was used as a test case for this study. Solar zenith angle, view zenith angle, surface reflectance and aerosol optical depth were varied one at a time to evaluate the individual errors. The results showed that: except for some situations with very large observation angles, the radiation error made by a scalar approximation became larger with the solar zenith angle, aerosol optical depth increasing and the surface reflecting decreasing; the errors in the line cores were higher than in the window area because they were less affected by the surface depolarization effect. To understand the effect of ignoring the polarization on CO_2 column retrieval, a linear errors estimation research was performed on simulated measurements. It was seen that the retrieval errors from neglecting polarization calculation were largest when the solar zenith angle was high, the aerosol optical depth was large and surface reflectance low. This CO_2 column retrieval error could be as high as 10ppmv, which is much larger than the required precision 1-2ppmv. In order to reduce the errors, the forward model needed to take into account the fully polarized radiation calculations. On other hand, it is too time-consuming to do the full vector retrieval. It is thus imperative to find ways to speed up the complete stokes vector calculation.

2p.04 Simulation of UV radiance using UNL-VRTM

Presenter: Fuzhong Weng, NOAA

Authors: Fuzhong Weng and Shougou Ding

TOA reflected radiances in UV wavelength are simulated using three radiative transfer models: TOMRAD, UNL-VRTM and SCIATRAN. TOMRAD stands for TOMS Radiative Transfer model. It is a vector radiative transfer model and is specifically used for UV region radiance simulation for pure Rayleigh scattering atmosphere with gases absorption. UNL-VRTM is a Unified Linearized Vector Radiative Transfer Model and was specifically designed for the simulation of atmospheric remote sensing observations and for the inversion of aerosol, gas, cloud, and/or surface properties from these observations. It comprises VLIDOSRT for radiative transfer, a linearized Mie and a linearized T-Matrix code for aerosol single scattering, a Rayleigh scattering module, and line-by-line (LBL) gas absorption calculation with HITRAN data base. SCIATRAN is a comprehensive software package for the modeling of radiative transfer processes in the terrestrial atmosphere and ocean in the spectral range from the ultraviolet to the thermal infrared (0.18–40µm) including multiple scattering processes, polarization, thermal emission and ocean–atmosphere coupling.

For simulating the radiances at the OMPS viewing angle, Microwave Limb Sounder (MLS) Ozone profiles are collocated with OMPS radiances and then used as inputs to the forward model. The bias between OMPS observations and simulations is analyzed from each model. It is shown that the UNL-VRTM is the most suitable model for OMPS radiance simulation. Overall, the bias can be attributed to several factors: 1) the scheme of computing the gaseous absorption coefficients gases and Rayleigh scattering in different RTM, 2) surface reflectance, 3) aerosol scattering approximation, 4) the band center wavelength shifts in OMPS, and 5) the errors of input profile to radiative transfer model. The sensitivity studies show that scalar radiative transfer approximation, considering only ozone, and/or the assumption of constant surface reflectance within UV region may cause significant errors to the TOA reflectance. Overall, the differences is less than 5% for OMPS cross-tracking position at all channels. Since SCIATRAN model includes the rotational raman scattering, the difference between measurements and simulations can also be reduced to some extent, particularly for the wavelength larger than 330 nm.

2p.05 From GEISA-2015 to GEISA-2018
Presenter: Raymond Armante, LMD
Authors: N. Jacquinet, R. Armante, A. Perrin, V. Capelle, T. Delahaye, N.A. Scott, A. Chédin
Spectroscopy is at the root of modern planetology, enabling us to determine the physical properties of planets remotely. As a result, standardized spectroscopic databases, were initiated in the early 1970's, such as, GEISA (Gestion et Etude des Informations Spectroscopiques Atmosphériques: Management and Study of Atmospheric Spectroscopic Information), at LMD, in France.

The 2015 release of GEISA [Jacquinet et al, 2016 and references herein], will be presented including significant updates and additions implemented in the three independent sub-databases of GEISA-2015:- the "line parameters database" contains 52 molecular species (118 isotopologues) (spectral range from 10-6 to 35,877.031 cm-1). A new molecule (SO3) has been added. HDO, isotopologue of H2O, is now identified as an independent molecular species. -the "cross section sub-database" has been updated and enriched by the addition of 43 new molecular species in its infrared part. A new section is added, in the near-infrared spectral region, involving 7 molecular species: CH3CN, CH3I, CH3O2, H2CO, HO2, HONO, NH3;-the "microphysical and optical properties of atmospheric aerosols sub-database" has been significantly enriched. It contains more than 40 species originating from NCAR and 20 from the ARIA archive of Oxford University.

Since the time of its creation GEISA has entered a new phase with the advent of high precision spectroscopy, coupling important developments in spectroscopic databases and radiative transfer modelling, to meet the needs of the international space agencies for the exploitation of these remote sensing data. Consequently, GEISA is constantly evolving, taking into account the best available spectroscopic data which are validated using the original and powerful approach of the SPARTE chain [Armante et al, 2016] developed at LMD.

The need to improve and consolidate the spectroscopic parameters is becoming a priority in order to exploit the increased spectral resolution and radiometric accuracy of new atmospheric instruments. In this context, spectroscopic parameters of targeted molecular species will be updated in GEISA-2018, associated with space missions such as: -IASI-NG (H2O, HDO, CO2, O3, N2O, CO, CH4, HNO3, OCS, CFC11,CFC12,CCl4, aerosols, ...), OCO-2 (CO2, O2, H2O), MicroCarb (O2, CO2, H2O), MERLIN (CH4, H2O), TROPOMI (CH4, CO, NO2, SO2, aerosols, ...)

GEISA and associated management software facilities are implemented and freely accessible on the AERIS/ESPRI atmospheric chemistry data center website. It is used on-line by more than 300 laboratories working in various domains like atmospheric physics, planetology, astronomy, astrophysics. GEISA line parameter database is the reference for current or planned TIR/SWIR space missions and it is associated with the work in progress in the frame of the ISSWG scientific group for IASI and its future IASI-NG.

References:
http://ara.abct.lmd.polytechnique.fr/index.php?page=publications

2p.06 Oxygen line-mixing: Consolidating a spectroscopy for AMSU-A
Presenter: Oleksandr Bobryshev, Universität Hamburg
Authors: Oleksandr Bobryshev, Manfred Brath and Stefan Buehler
Advent of new sensors, which allow measurements of radiance intensity in millimeter and submillimeter spectrum (e.g. ISMAR, ICI, ATMS, AMSU-A), set a requirement for appropriate O2 spectroscopy models. Such models should include and correctly represent the effects of the line-mixing and Zeeman effect. The Atmospheric Radiative Transfer Simulator (ARTS), a general software package for long wavelength radiative transfer simulations, now supports most of the up-to-date O2 models that fulfils listed above criteria. The problem with these models is that they were tested only for the narrow range of spectrum. We aim to justify the recommendation of O2 model to use in the radiative transfer models for the millimeter to submillimeter range. Using ARTS, we first examine the differences between the models for the set of pre-defined atmospheric states. We show the differences in absorption, brightness temperatures and Jacobians for different atmospheres. We also examined the quality of agreement between the satellite measurements and simulations using the different models on the radiosonde stations located in polar, mid- and equatorial latitudes. One of the novelties of this study is utilization of Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) processed radiosonde measurements for comparison.

2p.07 Quantification of line-by-line parameter errors in the 183.31 GHz water vapour line
Presenter: Emma Turner, Met Office
Authors: Emma Turner, William Bell, John Eyre
The rotational transition of water vapour at 183.31 GHz is one of the most heavily utilised spectroscopic lines measured by current (and future) satellite instruments. The passbands of channels centred at this frequency typically span a wide frequency range (e.g. 24 GHz for SAPHIR channel 6) in order to profile tropospheric humidity. However, equivalent radiative transfer simulations of these satellite observations show errors that increase further away from the line centre. The Met Office microwave line-by-line model AMSUTRAN uses the Liebe Millimeter-Wave Propagation Model (MPM) to calculate water vapour absorption which utilises six scalar coefficients that are associated with: line strength, air-broadened half-width, self-broadened half width and the temperature dependence of each of these. Recent work has placed updated uncertainties on these parameters drawn from a combination of observational and model-based estimates. This study investigates the impact of these uncertainties, and the correlations between them, on top-of-atmosphere brightness temperature simulations.

2p.08 Sensitivity of microwave downwelling brightness temperatures to spectroscopic parameter uncertainty
Presenter: Domenico Cimini, CNR-IMAA
Authors: Cimini D., P. Rosenkranz, M. Tratyakov, and F. Romano
Atmospheric brightness temperatures are simulated through radiative transfer calculations, which rely on spectroscopic parameters for modelling the atmospheric absorption. The uncertainty affecting the spectroscopic parameters contribute to the uncertainty of the simulated brightness temperatures. This presentation describes the approach to investigate the impact of spectroscopic parameter uncertainties on simulated downwelling microwave brightness temperatures in the 20-60 GHz range. Sensitivities have been computed perturbing each parameter individually and considering six different atmospheric climatologies, for the purpose of identifing the parameters with significant impact. Preliminary results are presented, as well as the approach to map the resulting brightness temperatures' uncertainty on the retrieved atmospheric profile space using the full covariance matrices of uncertainties. The analysis can also be extended to higher frequencies and upwelling brightness temperatures in future work.

2p.09 Uncertainties in the dielectric constant model for seawater used in FASTEM and implications for the calibration/validation of new microwave sounding and imaging instruments
Presenter: Heather Lawrence, ECMWF
Authors: Heather Lawrence, Niels Bormann, Alan Geer, Stephen English
For the surface-sensitive channels of microwave temperature and humidity sounders and imagers, the surface emission can contribute a large portion of the signal. For this reason, the new data from imagers and sounders are typically evaluated over ocean where surface emissivity estimates are expected to be most accurate. Ocean emissivity can be calculated as a function of skin temperature and wind speed and direction using a fast model, such as the commonly-used FAST microwave Emissivity Model (FASTEM). The ocean emissivity is calculated for flat-surface conditions using the standard Fresnel equations, with modifications as a function of wind speed to account for rough surface and foam effects. The Fresnel equations depend on the dielectric constant of seawater, which is modelled in FASTEM for a constant salinity of 35‰, and as a function of temperature, using the equations developed by Liu et al (2011).

When carrying out calibration/validation (cal/val) of new microwave data over ocean, it is important to consider the uncertainties in the ocean emissivity calculation, particularly when identifying potential sources of bias. As a first step, in this poster we present an evaluation of the uncertainties in the dielectric constant model for seawater used in FASTEM, and consider the implications for the calibration/validation of new satellite instruments. We focus on the frequency range of 5 – 100 GHz, which includes measurements for microwave imagers such as GMI and AMSR-2, and temperature sounders such as AMSU-A and ATMS.

Firstly we present a review of the dielectric constant measurements of seawater available in the literature. The measurements available generally have a stated experimental uncertainty of 1 - 3%. However, as we show, at some frequencies there are differences between the published measurement values. Secondly, we compare measurements of the dielectric constant to the model used in FASTEM. Results of this comparison show that at lower temperatures particularly the dielectric constant predicted by

FASTEM is systematically lower than some of the measurements. It is difficult to know whether this difference is due to systematic errors in the measurements or errors in FASTEM. Because of this, we propose new uncertainty values, dependent on the skin temperature, for the dielectric constant terms used in FASTEM. We then transform these uncertainties in brightness temperatures, and review the implications for the calibration/validation of new satellite sounding and imaging instruments.

2p.10 A reference model for ocean surface emissivity from the microwave to the infrared

Presenter: Stephen English, ECMEF

Authors: S. J. English, A. Geer, H. Lawrence, L-F. Meunier, C. Prigent, B. Johnson, S. Newman, W. Bell

Recent developments in fast microwave emissivity modelling such as Fastem or TESSEM2 rely on having a high quality reference ocean emissivity model. Taking the Fastem example the first three versions were based on Geometric Optics model, which is rather simple in design and not applicable to lower frequencies. Therefore from version 4 onwards it was based on a two scale model, run at the Joint Centre for Satellite Data Assimilation. This model is no longer available, and was never a supported deliverable of the JCSDA. Therefore in order to develop future versions of fast models a new reference model is urgently needed, to support missions from low microwave frequencies (SMOS, SMAP) as well as the future EUMETSAT's Ice Cloud Imager.

In this presentation we will discuss the essential components of such a reference model, identifying what exists and what does not. Firstly a dielectric model is needed, with uncertainty estimates. Many such models exist, and the spread between them tends to be larger than the quoted uncertainty, though this may in part reflect errors in some models, rather than real uncertainty. Secondly a representation of waves, both small scale driven by the instantaneous wind, and larger scale ocean swell. For a long time microwave models used the Cox and Munk model, but recently a range of options have become available. However knowledge of the uncertainty is limited. A two scale or similar model to handle surface reflectance and scattering is needed. The third critical area is to represent ocean whitecapping, and foam streaks from breaking waves. In the past this is usually parameterised as a function of instantaneous windspeed, but it is more physically a function of the dissipative wave energy, which can be estimated from a wave model. Consequently there is a very large spread in the models that parameterise foam fraction as a function of windspeed. Investigations of using wave model dissipative wave energy have been carried out. It is also interesting to consider a model that can work from the low microwaves, through the sub-mm region and into the infrared in a seamless way. Such a reference model can also be a focal point for new science, such as improved foam emissivity, impact of rain on ocean surface roughness and foam cover asymmetries.

In this poster we encourage the ITWG remote sensing community to consider how best to address this gap in the radiative transfer model capability and its evaluation, and to support efforts underway to develop the components of such a reference model.

In this poster we encourage the ITWG remote sensing community to consider how best to address this gap in the radiative transfer model capability, and to support efforts underway to develop the components of such a reference model.

2p.11 Accounting for variations of the trial field along the line of sight of the satellite in radiance data assimilation

Presenter: Louis Garand, Environment and Climate Change Canada

Authors: Louis Garand, Josep Aparicio, Maziar Bani Shahabadi, and Stéphane Laroche

For radiance assimilation, the trial field is currently interpolated as a vertical column to the location on the surface of Earth viewed by the satellite. Recently, consideration of the variation of the trial field along the optical path has been implemented at ECMWF. This requires significant modifications to the cost function and its derivative. Here, our approach differs in that differences between calculated radiances using as input nadir and slant path trial fields are estimated offline, and then added to the observation in the input data file in similar fashion to a bias correction. As a result, no modifications to the cost function are required and the added processing costs are small. It is assumed that resulting analysis increments are close to those that would be obtained from minimizing the cost function on the slant path atmosphere explicitly. Recognizing that the correction is negligible for low level sensitive channels, it can be applied to all or selected channels only. The procedure is evaluated first with AMSU-A and ATMS temperature channels. Impact results in assimilation cycles will be presented at the conference.

Session 3a: Calibration, validation and uncertainty

3.01 Global Space-based Inter-Calibration System (GSICS) infrared reference sensor traceability and uncertainty

Presenter: Tim Hewison, EUMETSAT

Authors: Tim Hewison, Dave Tobin, Tom Pagano

The Global Space-based Inter-Calibration System (GSICS) aims to ensure consistent accuracy among satellite observations worldwide for climate monitoring, weather forecasting, and environmental applications. To achieve this, algorithms have been developed to correct the calibration of various instruments to be consistent with community-defined reference instruments based on a series of inter-comparisons. Hyperspectral sounders are considered as potential reference instruments for the inter-calibration of thermal infrared channels on contemporary missions, allowing accurate representation of their spectral response functions. It is essential that these reference sensors are demonstrated to have stable and well-documented radiometric calibration, traceable to community references.

GSICS has initiated a report to support the choice of Metop/IASI, Aqua/AIRS and Suomi-NPP/CrIS as reference instruments and to provide traceability between them by consolidating pre-launch test results, error budgets and a range of in-orbit comparisons. The inter-comparison methods include Polar Simultaneous Nadir Overpasses (SNOs), Quasi SNOs, double differences against geostationary satellite and aircraft instruments as well as Numerical Weather Prediction (NWP) models, and statistics over extended geographical areas. Results from different methods under the same range of conditions are compared to assess the instruments' relative calibration, long-term stability and ultimately, the overall uncertainty as inter-calibration references for GSICS. Together with the error budgets, which are ground-up estimates of calibration uncertainty and associated calibration traceability chain, these results allow us to form a consensus on the uncertainties in their absolute calibration, and increase the confidence in the inter-calibration products derived from them.

The impact of the recent changes to Metop-B/IASI on-board processing will be analysed by comparison with other hyperspectral sounders, and the implications for the generation of Fundamental Climate Data Records discussed.

3.02 A new Fundamental Climate Data Record (FCDR) for nearly 40 years of measurements from the High resolution Infrared Radiation Sounder (HIRS) based on a metrologically traceable uncertainty analysis

Presenter: Gerrit Holl, University of Reading

Authors: G. Holl, J. Mittaz, and C. J. Merchant

We present a new Fundamental Climate Data Record (FCDR) for the High resolution Infrared Radiation Sounder (HIRS), with pixel-level metrologically traceable uncertainties and error covariance estimates. HIRS has flown on 16 polar-orbiting satellites between 1978 and present. It is a 20-channel radiometer with one visible channel and 19 infrared channels, the latter covering a range from 3.7 to 15 µm. The instrument will soon turn 40 years old, but as it was designed to make measurements for weather forecasting, it cannot be immediately applied in climate science. Rather, usage for climate measurements requires (1) a thorough metrological uncertainty analysis for each instrument, and (2) harmonisation to bring all instruments to a common reference. In this paper, we present a detailed metrological analysis and the resulting FCDR. The analysis techniques and FCDR are developed as part of the Horizon 2020 project, Fidelity and Uncertainty in Climate-data records from Earth Observation (FIDUCEO).

We have identified 17 distinct physical effects that cause an error in calibrated HIRS radiances. Starting with the measurement equation, which relates the calibrated radiances to measurands and calibration parameters, we explore the magnitude and correlation structures of some of those effects. The correlation structure affects how errors propagate upon the calculation of averages and other statistics, so this information is critically important for climate applications. Error correlations are present at all timescales, from between neighbouring soundings to the lifetime of a sensor. We will also show significant correlations between channels, with correlation coefficients either positive or negative and in some cases exceeding 0.5.

The result is a new publicly available FCDR designed for appropriately produced Climate Data Records (CDRs) spanning nearly 40 years.

3.03 Characterisation of numerical weather prediction model biases for improved satellite cal/val

Presenter: Fabien Carminati, Met Office
Authors: Fabien Carminati, Bruce Ingleby, Bill Bell and Stefano Migliorini

The characterisation of uncertainties in Numerical Weather Prediction (NWP) models is a major challenge that is addressed as part of the Horizon 2020 GAIA-CLIM project. In that regard, observations from the radiosonde GCOS reference upper-air network (GRUAN) are being used at the Met Office and ECMWF to assess uncertainties associated with model data.

A stand-alone module, decoupled from the NWP systems at the Met Office and ECMWF, is being developed based on a core radiative transfer modelling capability built around two existing open-source software packages (EUMETSAT's NWP SAF RTTOV fast radiative transfer model, and the NWP SAF Radiance Simulator). This software, referred to as the GRUAN Processor, enables the comparison of collocated geophysical fields and simulated brightness temperature between radiosonde and model fields.

A preliminary analysis based on a sample of radiosondes from Lindenberg, Germany, 2013, suggests mean model biases less than 0.1K (0.2K) at frequencies sensitive to tropospheric temperature and less than 0.15K (0.5K) at frequencies sensitive to stratospheric temperature in the Met Office (ECMWF) global model. Biases at frequencies sensitive to tropospheric humidity are less than 0.3K in both models. The analysis will be extended to all GRUAN data available between 2011 and 2017 (15 sites).

The GRUAN processor, at term, will allow robust NWP-based calibration, recalibration, and validation of satellite instruments with channel-by-channel uncertainty estimates. Furthermore, the processor is also expected to serve as a long-term monitoring tool for NWP global models.

3.04 Cal/Val studies for microwave and infrared sounding data from METEOR-M series satellites

Presenter: Alexander Uspensky, SRC Planeta
Authors: A. Uspensky, A. Rublev, D. Gayfulin, and M. Tsyrulnikov

The objectives of Cal/Val system, developed by SRC PLANETA with cooperation, is to ensure accurate and consistent data and products processing from the sensors onboard METEOR-M series satellites, and to prepare for the launch of the next METEOR-M satellites. Moreover the purpose of Cal/Val studies is to deliver space-based observations and products with improved accuracy for climate monitoring, weather forecasting, and environmental applications. The accuracy of space-based observations and output products depend crucially on the reliability of instrument absolute (onboard or post-launch) calibration. The main tasks of Cal/Val system comprise of post-launch instrument calibration/validation and routine validation of output products. Some examples are given illustrating capabilities and efficiency of developed Cal/Val system with respect to calibration/validation of Level 1 data from key sounding instruments onboard METEOR-M №2 satellite (Infrared Fourier Spectrometer – 2 IKFS-2; Imaging/Sounding Microwave Radiometer MTVZA-GY): SEVIRI versus IKFS-2 cross-calibration product; post-launch calibration of MTVZA-GY. Along with this some examples are presented related to validation of temperature & humidity profiles retrieved from IKFS-2 and MTVZA-GY data.

3.05 An assessment of Meteor-M N2 MTVZA imager/sounder data at the Met Office and ECMWF for GAIA-CLIM

Presenter: Stuart Newman, Met Office
Authors: Stuart Newman, Heather Lawrence and Bill Bell

The MTVZA-GY instrument is a conically scanning imaging/sounding microwave radiometer with channel frequencies spanning the range from 10.6 GHz to 183 GHz. It has flown on the Meteor-M N2 satellite since 2014. A data characterisation and validation study is presented, comparing observed brightness temperatures with model equivalents derived from the Met Office and ECMWF NWP systems. The observed minus background brightness temperature departures are analysed to diagnose the spatial variability, geophysical state dependence and instrument state dependence of biases. The utility of NWP systems for characterising new satellite missions, as examined during the EU GAIA-CLIM project, is discussed. Finally, the prospects for operational assimilation of MTVZA selected channels at NWP centres are explored.

Session 3b: Calibration, validation and uncertainty

3p.01 The GAIA-CLIM project

Presenter: Stuart Newman, Met Office
Authors: Stuart Newman, Bill Bell, Fabien Carminati, Stefano Migliorini, Heather Lawrence, Bruce Ingleby, Jacqueline Goddard

The EU-funded GAIA-CLIM project aims to assess and develop our capacity for characterising satellite instrument performance. Robust Earth observation (EO) characterisation relies on traceable uncertainty estimation for the reference as well as an understanding of the additional uncertainties that result from spatial and temporal mismatches in location and scale. In this specific element of the project we focus in particular on assessing and developing the use of NWP as a reference, recognising that high quality (though sparse) reference data such as sondes can be used to sample and estimate model errors and provide a form of metrological traceability for the model fields. We address the challenge of estimating absolute uncertainties in such fields by monitoring reference data with respect to NWP, in terms of temperature and humidity as well as simulated top-of-atmosphere brightness temperatures. Several examples of the utility of NWP systems for identifying bias characteristics of new satellite instruments are shown.

3p.02 Robust quantification of uncertainty on short-range model forecasts in radiance space based on reference sonde data

Presenter: Stefano Migliorini, Met Office
Authors: Stefano Migliorini, Fabien Carminati and William Bell

Robust statistical estimations of numerical weather prediction (NWP) model uncertainties are of crucial importance for maximizing the impact of the data that is operationally assimilated, which is mainly composed of satellite radiance measurements. One of the most direct ways to assess these errors is to compare short-range model forecasts with high-quality radiosonde data such as those from the GCOS Reference Upper-Air Network (GRUAN). The Met Office, as part of its activities within the Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring (GAIA-CLIM) EU-funded project, have been developing the GRUAN Processor designed to compare simulated satellite measurements from model data against simulated radiances calculated from GRUAN sonde data through the use of the RTTOV fast radiative transfer model. The Processor also aims to quantify all known source of uncertainties associated with both simulated satellite and sonde measurements so as to assess the statistical significance of the departures.

This poster discusses the theoretical methodology, based on maximum-likelihood principles, to estimate the errors arising from differences in the vertical grids defined by the NWP model and the sonde levels. It is found that statistical uncertainties also depend on the variability of the atmospheric state on the (higher-resolution) sonde grid. Preliminary estimates of vertical interpolation errors based on an ensemble of sonde measurements will be presented. Finally, a rigorous methodology for assessing the confidence on the departures based on chi-square tests will be discussed.

3p.03 Assessment and assimilation of microwave imager observations in NWP global models

Presenter: Brett Candy, Met Office
Authors: Brett Candy, Fabien Carminati, William Bell , Heather Lawrence and Jacqueline Goddard

The Global Precipitation Measurement (GPM) Microwave Imager (GMI) is a state-of-the-art conical-scanning radiometer. A dual calibration system confers to the instrument the highest standards of radiometric accuracy and stability achieved to date. GMI has nine imaging channels and four sounding channels in the 10-89GHz and 166-183GHz spectral ranges, respectively.

A comprehensive NWP-based validation is being carried out as part of the GAIA-CLIM project, and involves double comparison with the Met Office and the ECMWF models, covering two summer months in 2016 and two winter months in 2016/2017. A shorter 2-week period is also considered (06-20 May 2017) in order to evaluate GMI latest calibration change (GPM V05 GMI L1C). Preliminary results suggest global first guess departures over ocean ranging from -0.2 to 1K when compared to the Met Office model and free of obvious instrument-related bias.

Assimilation experiments of two months duration are being conducted at the Met Office for a) a sub-set of GMI imaging channels and b) the two 183GHz channels, in a low resolution N320 uncoupled full global system. The impact of GMI imaging channels is, to date, neutral on Global NWP Indexes but significantly improves the fit of observations to the model for surface and temperature sensitive channels of independent instruments by up to 2%, while slightly degrading the fit in humidity sensitive channels by 0.2-0.6%.

Benefits from GMI two 183GHz channels are seen both in the forecasts of the 500 hPa height field (up to +0.5%) and in the fit to the model in humidity sensitive channels, which improves by up to 0.6%.

The FY3 series of satellite missions contain the Microwave Radiation Imager (MWRI) instrument. This allows dual frequency observations in the range 10-89 GHz. Studies as part of GAIA-CLIM at both the Met Office and ECMWF have shown that the instrument has different bias characteristics in the ascending and descending parts of the orbit. We will report on the tests of an orbital predictor scheme to correct the biases and look forward to the prospect of assimilation from this new data source. Such a predictor scheme was originally developed for the SSMIS instrument.

3p.04 Assimilation of FY-3C MWHS-2 at ECMWF and evaluation of the microwave imager FY-3C MWRI at ECMWF and the Met Office
Presenter: Heather Lawrence, ECMWF
Authors: Heather Lawrence, Niels Bormann, Qifeng Lu, Alan Geer, Fabien Carminati, Stuart Newman, William Bell, Nigel Atkinson and Stephen English
The Chinese Feng-Yun 3C (FY-3C) satellite was launched in 2013 and carries on-board a number of instruments that are of interest for Numerical Weather Prediction (NWP) and Climate Reanalysis. This includes two microwave instruments: the MicroWave Humidity Sounder -2 (MWHS-2) and the MicroWave Radiation Imager (MWRI). MWHS-2 has traditional humidity sounding channels at 183 GHz as well as 8 new channels at 118 GHz which are sensitive to temperature, cloud and precipitation. MWRI is a microwave imager, with channels in the frequency range of 10 – 90 GHz, which are sensitive to cloud and precipitation as well as total column water vapour.

In this poster we present firstly results of assimilation trials testing the use of MWHS-2 in all-sky conditions at ECMWF. This includes an assessment of the impact of the new 118 GHz channels. As a result of these trials the instrument has been operationally assimilated at ECMWF since April 2016. Secondly, we present an evaluation of the long-term quality of the instrument by analysing observation minus background statistics over 1 year at ECMWF and the Met Office. Finally we present a first evaluation of the MWRI microwave imager at ECMWF and the Met Office by analysing observation minus background statistics at ECMWF and the Met Office.

3p.05 Natural and vicarious calibration targets for satellite based microwave sensors
Presenter: Marc Prange, Meteorological Institute Hamburg
Authors: Marc Prange, Martin Burgdorf, Stefan Buehler
Intercalibration methods for microwave (MW) humidity sounders such as Advanced Microwave Sounding Unit-B (AMSU-B) and Microwave Humidity Sounder (MHS) use in general either Simultaneous Nadir Overpasses or zonal averages. The first method has high accuracy but can only be applied for high latitude data. The second method suffers from significant uncertainties associated with diurnal variations. A more refined approach of using natural calibration targets is investigated here. Natural calibration targets are defined as geographical areas where diurnal variations are minimal, allowing for a high accuracy intercomparison of the MW instruments. To investigate large-scale diurnal variations, a dataset of Upper Tropospheric Humidity from the MW sounder SAPHIR onboard of the Megha Tropiques satellite is used. Multiple natural calibration targets are found over tropical oceans and it is shown that their extent and position depend on season and averaging time. An estimate of uncertainty in the calculated diurnal variations is determined by applying multiple different averaging times. The seasonal and averaging time dependencies motivate an additional approach, which circumvents their explicit investigation. Instead of defining geographical calibration targets the global dataset is used here. The difference between ascending and descending nodes of multiple percentiles of monthly MHS brightness temperatures are calculated. These differences show that the percentiles are insignificantly impacted by diurnal variations and might allow for a multipoint intercalibration of the MW instruments.

3p.06 Post launch calibration and validation of JPSS-1 Sensor Data Records (SDRs) and Environment Data Records (EDRs) algorithms
Presenter: Lihang Zhou, NOAA
Authors: Lihang Zhou, Murty Divakarla, Xingpin Liu, Fuzhong Weng, Ivan Csiszar, Walter Wolf, Arron Layns, and Mitch Goldberg
The Joint Polar Satellite System (JPSS)-1 is on schedule to be launched in late 2017 and will host an array of instruments including the Visible Infrared Imaging Radiometer Suite (VIIRS), the Cross-track Infrared Sounder (CrIS), the Advanced Technology Microwave Sounder (ATMS), and the Ozone Mapping and Profiler Suite (OMPS). These instruments are similar to the instruments

currently operating on the Suomi-National Polar-orbiting Partnership (S-NPP) satellite, a predecessor designed to bridge for the JPSS constellation. Algorithms to process JPSS-1 instrument data into sensor and environmental data products have been developed based on the experiences gained through the S-NPP algorithms, with consideration of mitigating JPSS-1 instrument waivers based on pre-launch instrument testing data. Optimizations are also being performed on JPSS-1 upgrades, which account for science improvements to produce additional or improved data products. The updated algorithms including lookup tables/coefficient files have been developed and tested by science teams using the JPSS-1 instrument testing data and S-NPP proxy data. These JPSS-1 updated algorithms have been delivered to the ground system. To ensure the algorithms can run on JPSS-1 measurements as expected, the science teams have provided independent verification support to a series of JPSS-1 testing activities conducted by the JPSS ground system. As part of the JPSS-1 launch readiness, the calibration and validation (Cal Val) plans for JPSS-1 SDRs/EDRs have been developed, and further updated to ensure the consistency with the flight teams' post-launch testing (PLT) activities. The diagnostic cal/val and monitoring tools have also been tested with the JPSS-1 testing data.

This paper presents an overview of the major JPSS-1 science algorithm updates, with focus on the sounding level 1 and level 2 data products, such as ATMS full radiance calibration, CrIS full resolution with improved calibration; as well as the corresponding sounding EDR retrieval products; The VIIRS and OMPS SDR/EDR updates will also be highlighted. JPSS-1 pre-launch characterization, post-launch cal/val plans and long term monitoring preparations will be addressed.

3p.07 Current status of the CrIS calibration activities at UW-SSEC

Presenter: Joe Taylor, SSEC/UW-Madison
Authors: Joe Taylor, Dave Tobin, Hank Revercomb, Bob Knuteson, Lori Borg, Dan Deslover, Michelle Feltz, Jon Gero, Graeme Martin
The status of the CrIS calibration activities currently being conducted at the UW-SSEC will be presented. Topics include self-apodization correction methods, FIR convolution correction, polarization correction, and airborne calibration validation.

3p.08 Arctic field campaign inter-comparisons in support of SNPP CrIS validation

Presenter: Allen Larar, NASA Langley Research Center
Authors: Allen M. Larar, Daniel K. Zhou, Xu Liu, Jialin Tian, and William L. Smith Sr.
The Suomi NPP (SNPP) Arctic airborne field campaign (SNPP-2) was conducted out of Keflavik, Iceland between 7-31 March 2015. The primary campaign objectives were to focus on SNPP validation and JPSS risk mitigation for cold scene observations and satellite cross-validation in the Arctic region, with a specific interest to investigate radiance differences between CrIS, AIRS and IASI observations for very cold scenes. Since the SNPP launch in late 2011, NASA and NOAA have jointly conducted two airborne field campaigns in support of SNPP instrument and data product calibration / validation: 1) mid-latitude flights based out of Palmdale, CA during May 2013 (SNPP-1), and 2) flights over Greenland during March 2015 while based out of Keflavik (SNPP-2). In addition to under-flying the SNPP satellite, aircraft flight profiles were defined to also obtain coincident observations with the NASA A-train (i.e. AQUA) and EUMETSAT MetOP-A / MetOP-B satellites (i.e. overlapping with the AIRS, IASI, and CrIS infrared advanced sounder instruments), along with radiosonde and ground truth sites. The NASA LaRC National Airborne Sounder Testbed-Interferometer (NAST-I) was one of the key payload sensors aboard the ER-2 aircraft during these campaigns. This presentation will focus on cold scene radiance results from the SNPP-2 campaign with an emphasis on inter-comparisons between NAST-I observations and those from the satellite sounders.

3p.09 Advances in Suomi NPP ATMS data reprocessing

Presenter: Ninghai Sun, NOAA/NESDIS/STAR
Authors: Ninghai Sun, Fuzhong Weng, Wanchun Chen
The Suomi National Polar-orbiting Partnership (NPP) satellite was launched on October 28, 2011 and carries the Advanced Technology Microwave Sounder (ATMS) on board. ATMS is a cross-track scanning instrument observing in 22 channels at frequencies ranging from 23 to 183 GHz, permitting the measurements of the atmospheric temperature and moisture under most weather conditions. The recent major updates on operational processing of ATMS TDR and SDR products include radiance based calibration processing and non-linearity correction update. Both updates have been made into operational JPSS Interface Data Processing Segment (IDPS) since March 8, 2017. To maintain the consistence of NPP ATMS life time datasets (TDR and SDR),

STAR ATMS SDR team reprocesses the ATMS data before March 8, 2017. During the reprocessing, data gaps and operational errors have also been fixed besides the updated calibration algorithm and non-linearity correction coefficients. In this study, a preliminary result on long-term trending of reprocessed ATMS TDR data is given. The change of bias between observation and RTM simulation, based on ECMWF forecast and GPS-RO data, is also demonstrated. It has been proved that ATMS data quality is improved. To provide better quality ATMS data, ATMS SDR team is also developing the operational reflector emissivity correction algorithm. The physical model developed to characterize the flat reflector emission has been used to retrieve the emissivity from ATMS pitch-over maneuver data. It is shown that ATMS reflector emissivity from K, V, W and G bands is within a range of 0.002 to 0.007. Such correction can effectively reduce the distinct scan angle dependent bias in the NWP O-B field, especially at the window channels. STAR ATMS SDR team will plan to perform another reprocessing when such correction is implemented in operational IDPS system.

3p.10 Vaisala Radiosonde RS92 to RS41 transition: Implications for satellite data cal/val
Presenter: Bomin Sun, IMSG @NOAA/NESDIS/STAR
Authors: Bomin Sun and Anthony Reale
Balloon-borne radiosonde observations have played an important role in numerical weather prediction (NWP) forecasting and upper air climate change detection. These observations have also historically been used as a commonly accepted reference dataset in satellite radiance measurements and derived sounding products calibration/validation (cal/val). Vaisala RS92, the major sonde type in the current global conventional upper air network and the reference sonde in the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN), is being gradually replaced by Vaisala RS41. The RS41 includes new technological solutions aimed at providing improvements in measurement accuracy of atmospheric profiles of temperature, humidity and other variables.

In this work, multiple datasets are utilized to characterize the improvements and differences of the RS41 radiosonde compared to the RS92. Special datasets of Vaisala RS41 and RS92 dual launches from campaigns undertaken at a number of global sites with varying atmospheric environments are employed to provide direct comparisons of these two radiosonde instruments. Complimentary comparisons are also presented using the Global Navigation Satellite System (GNSS) radio occultation (RO) and NWP forecast and analysis as the targets, collocated respectively with global conventional radiosondes, to provide the global assessment of these two sondes. All of the above collocation datasets are routinely compiled using the NOAA Products Validation System (NPROVS) operated at the NOAA Center for Satellite Applications and Research (STAR). The impact of using RS92 versus RS41 in the NOAA unique combined atmospheric processing system (NUCAPS)S-NPP CrIS/ATMS and MetOP IASI data cal/val is also discussed in the overall context of the RS92 to RS41 transition.

Session 4a: New and current observations

4.01 The status of FY-3C and FY-4A in NWP and the preparation of FY-3D for NWP
Presenter: Qifeng Lu, NSMC/CMA
Authors: Qifeng Lu, Chunqiang Wu, Chengli Qi, Yang Guo, Shengli Wu, Mi Liao, Heather Lawrence, Fabien Carminati, Nigel Atkinson and Niels Bornman, William Bell, Stephen English
After the third polar-orbit meteorological satellite of China FY-3, FY-3C, was launched in September 2013, the CMA, ECMWF and UKMO cooperate closely to evaluate and improve the data quality, and assess the potential contributions to the NWP operational forecast. To actively support the operational assimilation into NWP, CMA/NSMC especially develops the FY-3 satellite data early warning, monitoring and biases correction system. This talk, would like to generally review the achievements of evaluating FY-3C data from CMA, ECMWF and UKMO, also will cover some details of the FY-3 instrument characterization from the jointly cooperative work of the three parties. FY-4A, the second generation of China geostationary metrological satellite, with high spectral interferometer instrument on board, was launched in Dec 2016, some initial evaluation to FY-4A data quality and the potential contributions to the NWP operational forecast will be reported.

The FY-3D will be launched in September of 2017, we work together to prepare its operation, some early cooperative work on preparing FY-3D in NWP will be introduced as well.

4.02 Study on the simulation and bias characteristics of FY-4A GIIRS observation
Presenter: Wei Han (for Peiming Dong), NWPC/CMA
Authors: Peiming Dong, Wei Han, Ruoying Yin
Satellite hyperspectral infrared observation have been increasingly and widely used in Numerical

Weather Prediction (NWP) and have proved to be invaluable to the improvement of forecast accuracy. The previous hyperspectral infrared sensor, including AIRS, IASI and CrIs, are all flown on the polar-orbiting operational environmental satellites (POES). Geo. Interferometric Infrared Sounder (GIIRS) on board Chinese FY-4A is the first hyperspectral infrared sounding sensor flown on the geostationary meteorological satellite. It is expected to demonstrate the impact of this remote sensing data on NWP. The simulation of FY-4A GIIRS observation is carried out by using rapid radiative transfer model RTTOV with the extension to support this new sensor. The bias characteristics is analyzed and further compared with the matched other hyperspectral infrared data. It is hoped that this work could prompt the use of FY-4A GIIRS observation in NWP.

4.03 Impact of the assimilation of water vapor imager radiances from INSAT 3D and 3DR satellites in the NCMRWF Unified Model

Presenter: Indira Rani S., NCMRWF

Authors: Indira Rani S, Sumit Kumar, Priti Sharma, John P George, E. N. Rajagopal

Both INSAT-3D and 3DR satellites have a six channel imager of same configuration. The scan time difference between the two satellites is 15 min. INSAT-3D scans at every half hour starting from 00 UTC, while the INSAT-3DR scans start from 00.15 UTC and then in every 30 min. The combined resolution of the imager radiances from these two satellites is 15 min. The high temporal resolution data produce good impact in the Hybrid-4DVAR assimilation system. This paper investigates the impact of WV imager radiance assimilation from these two satellites in the NCMRWF Unified Model. Initial results show that the characteristics of humidity analysis increment produced due to the assimilation of INSAT WV imager radiances are similar to the one produced due to the assimilation of MVIRI WV radiances. WV imager radiances assimilation from both INSAT and MVIRI show drying effect in the humidity analysis increment.

4.04 Application of microwave satellite data to KMA Local Data Assimilation and Prediction System (LDAPS)

Presenter: Hyeyoung Kim, KMA

Authors: Hyeyoung Kim, Eunhee Lee, Sangwon Joo and Young Hee Lee

Satellite radiance data assimilation has made a significant contribution to the progress of numerical weather forecasting. Specifically, microwave satellite data is more sensitive to clouds than other data, so it can provide information about the temperature and moisture profiles even in the presence of clouds. The humidity sounding observation at a relatively high horizontal resolution (approximately 17 km at Nadir) has contributed to the improvement of precipitation forecasts through improvement of the dynamical information (Geer et. al, 2014).

The purpose of this study is to evaluate the impact of the microwave humidity sounder (MHS or AMSU-B) on the KMA local area model for the preparation of the operational use of them.

The AMSU-B has been on board the NOAA-18, 19, MetOp-A, and B. Each of these four polar-orbiting satellites visits Korea almost twice a day. It is a cross-track scanning microwave radiometer and has five channels located at 89.0 (channel 1), 157.0 (channel 2), and 183.31 GHz (channel 3, 4, 5). The AMSU-B data used in this study is full-resolution data processed by the Korea Meteorological Satellite Center.

The KMA LDAPS is an extended local model based on the Unified Model (UM) 10.1 Ver. (1.5 km horizontal grid spacing and 70 vertical levels). The data (AWS, Sonde, Scat, Airplane, Radar) within ± 90 minutes is used with the 3-D VAR data assimilation system.

Two experiments were conducted to investigate the impact of AMSU-B radiance assimilation to the local model. The first experiment included AMSU-B radiance with existing criteria (EXP1) in addition to conventional observations (CTL) and the second one used more strict criteria (EXP2) than the EXP1 in the period of July 2016. In EXP2, the bias correction was implemented statically using the scan positions and atmospheric thicknesses. New scattering index of land is introduced to eliminate the strong scattering by rain and cloud over land. Additionally, the threshold of |O-B| is tighter.

As a result of assimilating the AMSU-B satellite data to the local model, the most remarkable point is significant improvements in dynamical forecast scores. Especially at 850 hPa, the RH analysis field of EXP2 over the West Sea is uniformly more humid than that of the CTL, which is considered to affect the precipitation prediction.

Unlike the global model, the data used in the local model is ground-based data. Due to lack of observation data around Korea, it is difficult to understand the precise synoptic condition. In this research, we showed that when improving moisture information in the atmosphere by using microwave humidity channels, the local model prediction ability is further improved.

Session 4b: New and current observations

4p.01 Plans for the utilization of JPSS and GOES-R satellite systems

Presenter: Andrew Collard, IMSG @NOAA/NCEP/EMC
Authors: Andrew Collard, John Derber, Emily Liu, James Jung, Li Bi, Haixia Liu, Kristen Bathmann, Yanqiu Zhu
In 2017 a number of important new data sources became available for assimilation into NWP models. Of these, two are major new operational US satellite platforms: GOES-16 and JPSS.

GOES-16 (known as GOES-R pre-launch) was launched in November 2016 and is at the time of writing undergoing post-launch testing. The primary instrument on GOES-16 is the Advanced Baseline Imager (ABI) which will view the Earth with 16 different spectral bands (compared to five on current GOES) and it will provide three times more spectral information, four times the spatial resolution, and more than five times faster temporal coverage than the current system. The initial major impact from GOES-16 is expected through the use of the Atmospheric Motion Vectors (AMVs) and it is expected that these will be used operationally sometime after the satellite attains its final position toward the end of 2017. Direct assimilation of the radiances will follow once a spatially averaged clear-sky stream becomes available.

The payload on JPSS includes CrIS, ATMS which both flew on Suomi-NPP. The main change will be that CrIS data will now be available at full spectral resolution. Tests are on-going at NCEP to ensure that we can make full use of this increase in the available data. Encouraging progress has been made both on the specification and use of full spectral error covariance matrices and also on the use of cloudy radiances from infrared satellites.

4p.02 Operational use of Suomi NPP ATMS radiance data in JMA's global NWP system

Presenter: Yoichi Hirahara, JMA
Authors: Yoichi Hirahara, Takumu Egawa, Masahiro Kazumori
In March 2017, assimilation of microwave radiance data from the Advanced Technology Microwave Sounder (ATMS) of the Suomi National Polar-orbiting Partnership (NPP) spacecraft was started operationally in the Japan Meteorological Agency (JMA) global Numerical Weather Prediction (NWP) system. For the ATMS data assimilation into the global NWP system, the same approach used for AMSU-A/MHS quality control and variational bias correction in the system are applied. The RTTOV-10 is used as a radiative transfer model for the radiance assimilation.

Preliminary experiments involving the assimilation of ATMS tropospheric channels (6-9, 18-22) and stratospheric channels (10-15) showed a negative impact. The assimilation of ATMS stratospheric channels increased normalized standard deviations (STDV) of the first-guess (FG) departure from AMSU-A stratospheric channels (9-14). Because the cause of this negative impact is not clear at present, only ATMS tropospheric channels are selected for the operational assimilation in the global NWP system. Although slightly increased STDV was observed for AMSU-A tropospheric channels 6 and 7 from the assimilation of ATMS tropospheric channels, generally FG fits to the MHS, AMSR2, GMI/GPM, GNSS-RO and radiosonde temperature observation indicated improved water vapor and temperature fields. The zonal means of the difference in the root mean squared forecast error of the geopotential height showed clear positive impacts in the middle and upper troposphere, especially in the Southern Hemisphere. Improved tropical cyclone track predictions in the experiment periods were also confirmed.

Currently, we are investigating the cause of the negative impact from assimilating ATMS stratospheric channels. From comparison of FG departure of ATMS and AMSU-A for the stratospheric channels, we found different characteristics between corresponding ATMS and AMSU-A channels' FG departure in high latitudes after a variational bias correction in the JMA global system. The latest research results on this issue will be presented in the conference.

4p.03 Assimilating clear-sky radiance of SSMIS humidity sounding channels in the JMA global NWP system with newly developed cloud detection algorithm

Presenter: Yasutaka Murakami, Japan Meteorological Agency
Authors: Yasutaka Murakami and Masahiro Kazumori
Japan Meteorological Agency (JMA) utilizes clear-sky microwave humidity sounding radiance data from the MHS onboard NOAA-18, NOAA-19, MetOp-A and MetOp-B satellite, SAPHIR onboard Megha-Tropiques satellite, and GMI onboard GPM-core satellite in its global data assimilation

system. In March 2017, operational use of clear-sky humidity sounding radiance from Special Sensor Microwave Imager/Sounder (SSMIS) onboard DMSP F-17 and F-18 satellite was started.

It is crucial to detect and discriminate the cloud and precipitation affected data for the clear-sky assimilation of microwave humidity sounding channels, since these channels are affected by cloud liquid water emission and freezing particle scattering in cloudy situations. However, traditional cloud detection approach using microwave window channels is not available for SSMIS onboard DMSP F-17 because its 150 GHz channel is not working at present.

Therefore, a new physically-based cloud detection algorithm was developed for the clear-sky assimilation of SSMIS humidity sounding channels. Since SSMIS has 24 channels covering wide range of microwave frequency, the algorithm using multiple microwave observation channels allows us to detect cloud-affected data effectively by classifying such information into three categories based on hydrometeor types (i.e., cloud liquid particles, snow crystals and ice crystals). The details of the cloud detection algorithm and results of the data assimilation experiment will be presented in the conference.

4p.04 Development of the SSMIS processing system and their impacts on the 3DVAR in KIAPS
Presenter: Jeon-Ho Kang, KIAPS
Authors: Jeon-Ho Kang, Ji-Hyun Ha
Korea Institute of Atmospheric Prediction Systems (KIAPS) has been developing a global model and its data assimilation system. In this presentation, SSMIS (Special Sensor Microwave Imager/Sounder) orbit-angle bias correction and thinning methods in KIAPS are described. For SSIMS data assimilation, the development of the SSMIS processing system and the impact of the assimilation of the SSMIS are presented. For thinning, three methods, such as eqirectangular, equidistance and cubed-sphere element methods are introduced and the improvement using these thinning methods will be mentioned.

4p.05 Microwave radiance assimilation at NRL: Advanced techniques, developments, and future sensors
Presenter: Bryan Karpowicz, US NRL
Authors: Bryan M. Karpowicz, Benjamin C. Ruston, and Steven D. Swadley
Assimilation of passive microwave radiometers has proven useful in Numerical Weather Prediction (NWP), providing temperature sounding information, water vapor information, along with precipitable water information. The focus of this work is how best to incorporate this information into the Naval Research Laboratory Atmospheric Variational Data Assimilation System (NAVDAS), along with recent improvements which enable better use of this information. Some key developments have been: experiments replacing Total Precipitable Water (TPW) retrieved products with direct assimilation of channels sensitive to TPW, addition of correlated observation error for microwave and Infrared sensors, and addition of GMI, SAPHIR, and AMSR2 to NAVDAS. Key among these developments is the ability to assimilate with correlated observation error in NAVDAS, however, the only microwave sensor which is assimilated using correlated observation error is ATMS, currently. In the near future sensors with many water vapor sensitive channels such as SAPHIR and MHS will be added, and the advantages will be discussed. In addition to recent developments, we will discuss future advanced methods such as precipitation affected radiances, and future sensors. With respect to precipitation affected radiances key components to consider are how best to detect precipitation affected radiances, and how to specify the error associated with those observations. Currently, we are exploring options which do not require a retrieval of liquid, or ice water content, and focus on channel relationships. Finally, as part of the calibration and validation of the Compact Ocean Wind Vector Radiometer (COWVR), we will discuss plans for assimilation of products, and direct assimilation of microwave channels (18.7GHz, 23.8GHz, and 34.5 GHz).

4p.06 Salvaging of the final SSMIS flight unit for a future flight-of-opportunity
Presenter: Bryan Karpowicz (for Steve Swadley), U.S. Naval Research Laboratory
Authors: Steven D. Swadley, Donald J. Boucher, Eun-Sung Park, Gene A. Poe, David M. Tratt
The final Special Sensor Microwave Imager/Sounder (SSMIS) that was originally manifested aboard the DMSP F-20 platform became available when that final mission was deactivated. The Naval Research Laboratory Marine Meteorology Division and The Aerospace Corporation have secured the de-manifested SSMIS for potential flight on a future mission-of-opportunity. A number of mission options are under consideration, including installation aboard the International Space Station. The intent is for any such deployment to provide a measure of continuity between SSMIS units currently operating aboard DMSP F-16, F-17, and F-18 and

whatever equivalent sensor may be selected for the next-generation DoD Weather Satellite Follow-on program. We will describe the current status of SSMIS preparations for flight.

4p.07 Withdrawn

4p.08 Investigation into the impact of SAPHIR on humidity analyses at the Met Office

Presenter: Stuart Newman (for Amy Doherty), Met Office

Authors: Amy Doherty, Indira Rani, Stu Newman and William Bell

The Met Office began operational assimilation of SAPHIR data in March 2016. SAPHIR is a microwave humidity sounder with 6 channels centred around the 183 GHz water vapour band. It offers an improvement over similar instruments (e.g. MHS, ATMS) in terms of vertical, horizontal and temporal resolution. A number of investigations were carried out to quantify the impact on humidity analyses. Firstly, 1DVar retrieved humidity profiles from SAPHIR, MHS, ATMS and AMSR-2 were compared. SAPHIR provided a more accurate retrieval than the other humidity sounders and combined use of SAPHIR and AMSR-2 reduced variability in tropical humidity retrieval compared to AMSR-2 alone. Secondly, the effect of a single SAPHIR observation on the humidity increments within the Met Office 4D-Var analysis was investigated and compared to that of ATMS and AMSR-2 alone and also of all three instruments together. It was found that SAPHIR modified the AMSR-2 driven humidity increments to give more realistic vertical humidity structure. Finally, SAPHIR and AMSR-2 were added to a baseline configuration of the Met Office system and assimilation experiments were run for 6 months. The results of these experiments confirmed the complementarity between SAPHIR and AMSR-2 with improvements over a number of metrics, most notably RMSE of high level wind forecasts which improved by 0.2-0.4% when both instruments were assimilated, a remarkable improvement over either instrument alone; and temperature and relative humidity forecasts at 500 hPa which were improved by 1-2%.

Session 5a: Assimilation - clouds

5.01 All-sky assimilation of IASI upper-troposphere water vapour channels

Presenter: Alan Geer, ECMWF

Authors: Alan Geer, Marco Matricardi, Stefano Migliorini

Following the significant benefit to forecast scores that came from the all-sky assimilation of microwave humidity sounding channels, ECMWF is trying the same approach with hyperspectral infrared data. The starting point is seven water vapour sounding channels from IASI, and the aim is to assimilate them in clear and cloudy situations, giving around a 150% increase in available observations, particularly in the storm tracks. However, this is a challenging proposition, partly given the sensitivity of these channels to cirrus cloud. First, it is necessary to deal with inter-channel observation error correlations, as is now done when these channels are used in clear-sky. Hence, an observation error model has been devised that inflates both error variances and error correlations in the presence of cloud. Second, the assimilation system generates poor increments, particularly from observations near the start of the window. ECMWF may finally need to consider adding cloud ice and water control variables, so that increments can be made in the cirrus initial conditions rather than aliasing into temperature or moisture. There are also problems of increments going into the stratosphere. Finally, the quality of the radiative transfer model needs to be improved. The Cfrac Max Simple Streams approach (CMSS) generates systematic errors even for the intended target of these upper troposphere water channels. A more sophisticated treatment of cloud overlap needs to be developed for RTTOV, but without incurring the cost of a multiple-independent stream model.

5.02 Evaluation and assimilation of all-sky infrared radiances of Himawari-8

Presenter: Kozo Okamoto, JMA/MRI

Authors: Kozo Okamoto, Yohei Sawada, Masaru Kunii, Tempei Hashino, Takeshi Iriguchi and Masayuki Nakagawa

This study aims at effectively assimilating all-sky infrared radiances (ASRs) from geostationary satellites in global and regional data assimilation systems. The ASR assimilation is expected to give us beneficial impacts on improving analysis and forecasts compared with the current assimilation system in which limited infrared radiances are assimilated in mostly clear-sky regions.

We have been developing and testing ASR assimilation in a regional assimilation system using a cloud resolving model and LETKF data assimilation system. With a cloud-dependent QC procedure and observation error model, ASRs at humidity bands of Himawari-8 shows Gaussian distribution characteristics. Although we found that assimilating ASRs makes generally reasonable change in cloud and humidity, more careful examination is necessary because excessive increments can occur in some un-observed regions. Revising data usage and data assimilation setting is underway.

Furthermore, we have recently started a new project to assimilate ASR in the global operational data assimilation system. As the first step, we compared simulations and observations for ASR of Himawari-8. To better understand the discrepancy between model and simulations, we are planning to use different radiative transfer models (RTTOV and Joint-Simulator). The preliminary results of assimilation in regional system and comparison in global system will be presented in the conference.

5.03 Towards the improvement of the assimilation of cloudy IASI observations in numerical weather prediction

Presenter: Imane Farouk, CNRM/Meteo-France & CNRS

Authors: Imane Farouk, Nadia Fourrié, Vincent Guidard

Satellite data currently represent the vast majority of observations assimilated into NWP models. However, their exploitation remains suboptimal, only 10% of the total volume is used operationaly in assimilation. Furthermore, about 80% of the infrared data are affected by clouds and it is essential to develop the assimilation of satellite observations in cloudy areas. Météo-France NWP models are using since February 2009 AIRS (Atmospheric Infra-Red Sounder) cloudy radiances and since 2012 IASI (Infrared Atmospheric Sounding Interferometer) cloudy radiances with a simple cloud modelisation. The exploitation of the infrared hyperspectral sounder IASI has already improved weather predictions, thanks to its precision and information content never equalled. Nevertheless, its use in storm areas remains very complex because of the strong nonlinearity of cloud processes in the infrared spectrum.

The method for assimilation of cloudy radiances in the present research work is based on the use of a sophisticated radiative transfer model RTTOV-CLOUD, which takes into account the diffusion, in order to better simulate the brightness temperatures from background in the data assimilation of the ARPEGE global model.

This model will allow the simulation of cloudy infrared radiations from atmospheric profiles and cloud microphysical parameters (liquide Water content (lwc), ice water content (iwc), cloud fraction). This approach has been used by Martinet et al 2013 in AROME.

Firstly, we were interested in the selection of homogeneous scenes using the information of AVHRR clusters to place in the most favorable cases. We used different homogeneity criteria such as the criteria proposed by P. Martinet (2013) and R. Eresma (2014) to select observations.

Then we used this information to identify the situations well simulated with RTTOV CLOUD and thus potentially usable in the data assimilation.

Applying our criteria to day and night data over the sea, we found that the application of the homogeneity criteria has a positive impact on our bias results and standard deviation between our observations and simulations.

By applying the homogeneity criteria of Martinet et al (2013), we have a reduction of bias and standard deviation up to 4% with 63% observations, day over sea, while the criteria based on Eresmaa(2014) even lower our standard deviation down to 2% despite keeping only 20% of observations

To further improve our results, we will use a new cloud parameterization with the PCMT (Prognostic Condensate Microphysics and Transport) convection scheme which is available in the current pre-operational suite of the global model in Météo-France, and we will study the impact of this new parametrization on the simulation of brightness temperature.

Then a new approach for using cloudy IASI observations will be proposed for the assimilation. We test different methods of assimilation, and the first results will be shown.

5.04 Development of an all-sky assimilation of microwave imager and sounder radiances for the Japan Meteorological Agency global numerical weather prediction system

Presenter: Masahiro Kazumori, Japan Meteorological Agency

Authors: Masahiro Kazumori and Takashi Kadowaki

In numerical weather prediction (NWP), the assimilation of cloud- and precipitation- affected radiance is necessary to obtain accurate initial fields in cloudy areas. The cloud and precipitation phenomena exhibit nonlinear behaviors in their formation and dissipation. To consider such nonlinearity in an incremental four-dimensional variational (4D-Var) data assimilation, the outer-loop iteration is an effective method. In this method, the updates of the trajectory and the recomputations of the departures from the observations are performed in the minimizations of the 4D-Var data assimilation. Currently, cloud- and precipitation- affected radiance observations from polar-orbit satellites are not assimilated in the Japan Meteorological Agency (JMA) operational global NWP system. Moreover, in the 4D-Var data assimilation, the outer-loop iteration is not used to reduce the computational costs in the operational system. In this study, we first examined the impacts of introducing the outer-loop iteration into the JMA global NWP system. During the minimization of the 4D-Var data assimilation, a single update of the trajectory and the recomputation of the departure from the observations are performed. The experimental results show that the introduction of the outer-loop iteration resulted in significant improvements in the tropospheric analysis and forecast accuracy, particularly in the temperature, humidity, and wind fields even when only the same observation dataset was used as the operational system. Then, on top of the introduced outer-loop system, microwave imager [Advanced Microwave Scanning Radiometer 2 (AMSR2), Global Precipitation Measurement (GPM) Microwave Imager (GMI) and Special Sensor Microwave Imager/Sounder (SSMIS)] and humidity sounder [Microwave Humidity Sounder (MHS) and GMI] radiance data were assimilated under the all-sky condition instead of the clear-sky assimilation. The all-sky assimilation resulted in further improvements in the lower tropospheric temperature, water vapor, and wind fields in the analysis and forecast. Furthermore, increases in the used data counts of the water vapor-sensitive observations (e.g., clear-sky radiance data from geostationary satellites) in the system were confirmed. The major part of the improvements in the lower troposphere resulted from the all-sky assimilation of the microwave imagers, and the microwave humidity sounder contributed to the improvements in the middle and upper tropospheric humidity and wind fields. The details of the experiments are presented in the conference.

5.05 Assimilation of AMSU-A in the presence of cloud and precipitation

Presenter: Peter Weston, ECMWF
Authors: Peter Weston, Alan Geer, Niels Bormann

AMSU-A has been a pillar of the global observing system for almost 20 years and remains one of the most important instruments for reducing forecast errors in NWP. However, the majority of NWP centres only assimilate AMSU-A observations in clear sky conditions, i.e. without taking into account the effect of cloud and precipitation on the measurements. This is accomplished by applying strict cloud screening tests as part of the quality control procedures prior to assimilation and running a clear sky radiative transfer model to calculate the model equivalent in observation space.

In recent years it has been shown that assimilating humidity-sensitive microwave radiances in the presence of cloud and precipitation can lead to significant increases in forecast skill. This is done by relaxing the cloud screening quality control, running an all sky radiative transfer model taking into account the scattering effects of cloud and precipitation to calculate the model equivalent in observation space and using an adaptive observation error model. In this presentation the impact of extending the existing clear sky assimilation of temperature-sounding AMSU-A radiances to cloudy areas is investigated.

At ECMWF there are several fundamental, technical differences between the system used to assimilate clear sky radiances and the system used to assimilate all sky radiances. Examples of these differences include the treatment of the surface skin temperature and the data thinning algorithm amongst others. The impact of these differences is assessed and some of the inconsistencies between the two systems are eliminated.

Once the impact of these technical differences is understood the impact of assimilating the extra cloud affected AMSU-A observations is assessed. As well as extending the assimilation of channels 5 to 8 that are already assimilated in clear sky conditions, the assimilation of channel 4 which has strong sensitivity to cloud liquid water is tested. The impact of the extra data is assessed by running OSEs and single observation tests.

5.06 All-sky assimilation of microwave sounders at the Met Office

Presenter: Stefano Migliorini, Met Office
Authors: Stefano Migliorini, Brett Candy, William Bell, Andrew Lorenc and Ruth Taylor

According to indicators such as the Forecast error Sensitivity to Observations Impact (FSOI), microwave sounders (particularly AMSU-A) and imagers currently provide more than double the impact of aircraft data, the most important conventional data source within the Met Office data assimilation system. This fact provides a strong motivation to increase the yield of microwave instruments currently used for operational data assimilation. An obvious route to this aim is to avoid discarding data affected by cloud, as currently done at ECMWF and NCEP.

In this talk we will review the current methodology to assimilate moisture-sensitive observations at the Met Office and discuss the recent research aiming to use cloud-affected microwave radiances in operations. First we will discuss the new moisture incrementing operator which partitions increments in total moisture into vapour, liquid and ice phases. The operator is based on empirical relations between these quantities derived from the Office Global and Regional Ensemble Prediction System (MOGREPS). Then we will present the results of a monitoring experiment where AMSU-A channel 4 and 5 radiances were simulated using RTTOVSCATT with input atmospheric profiles on model levels. In particular, statistical results on innovation dependence on observed and simulated liquid water path will be shown. Candidate error models to assimilate AMSU-A channel 4 and 5 radiances in non-raining conditions will also be presented. Finally, an overview of our future work will be discussed.

Session 5b: Clouds: assimilation and radiative transfer

5p.01 Matching scales of observed and simulated cloud and precipitation processes seen in the microwave spectrum

Presenter: Katrin Lonitz, ECMWF

Authors: Katrin Lonitz and Alan J. Geer

With increasing model resolution and, hence, increasing the effective resolution of modelled cloud and rain systems, one has to think which scales are represented by the model in comparison to observations and if those scales match. This is both true for observations of microwave imagers and microwave sounders assimilated under all-sky (clear, cloudy and rainy) conditions. This study focuses on ongoing work of the all-sky assimilation of microwave imagers, however, the basic idea is also true for microwave sounders sensitive to clouds and precipitation. Motivated by the intention to assimilate low frequency channels in the microwave spectrum, e.g. 10GHz, which are very sensitive to land and heavy rain from convective systems the question has been raised if in the current setup of the assimilation of microwave imagers (MWI) at the ECMWF observed scales are matched to simulated scales. For MWI the footprint increases with a decrease in frequency, i.e. the observed scales are broader for 10GHz compared to 89GHz. Up to now all observations of microwave imagers are averaged over an area of roughly r=60km (=superobs), so all observations represent the same scales which is in particular important for cloud and precipitation processes. However, the model resolution of the ECMWF model has increased from 25km to 9km over the past decade, meaning that today's effective resolution of simulated cloud and precipitation processes are higher compared to the superobbed observations. This study explores different strategies to match adaptively scales between microwave observations and their corresponding simulations and to make this consistent for all microwave frequencies. Furthermore, plans are discussed to consider better the subgrid variability in cloud and rain.

5p.02 Further developments in the all-sky microwave radiance assimilation and expansion to ATMS in the GSI at NCEP

Presenter: Yanqiu Zhu, IMSG @NCEP/EMC

Authors: Yanqiu Zhu, George Gayno, Paul van Delst, Emily Liu, Jim Purser, Xiujuan Su, Ruiyu Sun, Jongil Han, John Derber, Jun Wang, Fanglin Yang, Xu Li

Since the implementation of all-sky radiance assimilation of AMSU-A in the Global Forecast System (GFS) at NCEP, significant progress has been made in the all-sky GSI. To facilitate the expansion of the all-sky approach to additional microwave and infrared sensors, the GSI codes for the all-sky capability are generalized with a centralized module and data structure as well as all-sky sensor selection in the sensor information table. Moreover, the all-sky approach is being expanded to radiances of Advanced Technology Microwave Sounder (ATMS). Two other efforts are also under development for the general enhancement for all-sky radiance assimilation. One is the application of the new variational quality control scheme (VQC, Purser 2011) to radiance data, and the other is the treatment of subgrid-scale convective clouds in the GSI. Meanwhile, in the CRTM, fractional cloud coverage (Geer and Bauer 2009) was incorporated.

5p.03 All-sky infrared radiances assimilation of selected humidity sensitive IASI channels at NCEP/EMC

Presenter: Andrew Collard (for Li Bi) IMSG @NOAA/NCEP/EMC

Authors: Li Bi, Andrew Collard, Emily Liu, James Jung, John Derber

All sky infrared radiances assimilation work of selected humidity sensitive Infrared Atmospheric Sounding Interferometer (IASI) channels using National Centers for Environmental Prediction’s (NCEP) Global Forecast System (GFS) will be the main focus of this work. Cloudy radiance simulations are conducted by the latest Community Radiative Transfer Model (CRTM) using the cloud cover option. This version of the CRTM also generates jacobians of liquid-water and ice-water content. In this study, results from parallel experiment for one season will be presented. The experiments are defined as the operational baseline and the operational baseline adding ten selected water vapor sensitive channels from IASI on MetOp-a/b. Cloud cover options will also be discussed. Cloud-dependent quality controls and observation error are evaluated in this study based on the cloud effect. The goal for this preliminary work is to extend NCEP' microwave all sky radiances into the infrared spectrum.

5p.04 Moved to 5.02

5p.05 Scattering from non-spherical frozen particles in all-sky microwave radiative transfer
Presenter: Alan Geer, ECMWF
Authors: Alan Geer
The assimilation of all-sky microwave radiances from imagers and sounders requires an accurate simulation of scattering from non-spherical frozen particles like cloud ice, snow, aggregates and hail. At ECMWF this is done using the RTTOV-SCATT radiative transfer package, and for the past few years this has successfully employed the sector snowflake model (from the Liu 2008 database) to represent all frozen particles except cloud ice: a 'one shape fits all' approach. However, there has been a recent explosion of work on particle scattering databases and there are now many potentially more realistic options available, for example densely rimed aggregates to represent graupel. There are also questions whether the model represents enough scattering from cloud ice. Finally the prospect of the EUMETSAT ice cloud imager (ICI, to be launched in 2022) means that particle orientation may need to be modelled for the first time. This presentation will report on activities to improve the scattering representation in RTTOV-SCATT, along with its testing in the ECMWF all-sky assimilation of microwave sounders and imagers.

5p.06 Evaluation and comparison of simulated microwave cloudy radiances using RTTOV-SCAT and ARTS
Presenter: Victoria Galligani, CIMA-CONICET
Authors: V. Galligani, C. Prigent, P. Salio
Radiative transfer models are used in numerical weather prediction (NWP) as observation operators during assimilation. In order to assimilate passive microwave radiances in an all-sky scenario, an improvement in our understanding of the scattering properties of frozen hydrometeors is essential. At high microwave frequencies, frozen hydrometeors significantly scatter radiation, and the relationship between radiation and hydrometeor populations becomes very complex. The main difficulty in cloudy microwave remote sensing is correctly characterizing this scattering signal due to the complex and variable nature of the size, composition and shape of frozen hydrometeors. These problems make it hard to assimilate microwave observations in NWP models, particularly in situations where scattering effects are most important, like deep-convective areas, over land surfaces or in moisture sounding channels. In the present study, the performance of the very fast radiative transfer for television operational vertical sounder (RTTOV) and its scattering package, RTTOV-SCATT, is compared with the research radiative transfer model, the Atmospheric Radiative Transfer Simulator (ARTS). In RTTOV-SCATT, the bulk optical properties for hydrometeor species are taken from pre-calculated look-up tables, while in ARTS, the bulk optical properties can be defined by the user. In the present study, different real atmospheric scenarios are used to compare the first-guess (FG) departure for both clear and cloudy sky conditions of the GPM microwave imager GMI, with consistency in the input bulk optical cloud properties. In the context of the upcoming launch of the Ice Cloud Imager (ICI) onboard Metop-SG satellites, the present study also compares the performance of RTTOV and ARTS in the sub-millimeter frequencies.

5p.07 Hyperspectral IR cloudy radiance and jacobian simulations: Comparison between RTTOV and LIDORT
Presenter: Jerome Vidot, CMS/Meteo-France
Authors: Jerome Vidot, Laurent C-Labonnote and P. Brunel
Infrared cloudy radiances assimilation is considered as one of the major goal in improving NWP. For such goal, a preliminary step is to include cloud scattering in fast RTM model. The RTTOV model uses the Chou scaling approximation for scattering in order to simulate infrared cloudy observations. This approximation is supposed to be able to simulate IR scattering with few tenth kelvin of error. We compared RTTOV TOA infrared simuled spectra (IASI-like) with simulations made with the full scattering model LIDORT. In order to compare only the cloud scattering model, we used the atmospheric transmittance as well as the

optical properties of clouds as calculated by RTTOV and inputted them in VLIDORT. The comparison of selected simulated jacobians is also provided. A database of many NWP realisitc cloud profiles including ice clouds and water clouds have been used. The effect of different geometries as well as different surface emissivities have been also tested.

Session 6a: Climate

6.01 The role of upper tropospheric cloud systems in climate: Building observational metrics for Process Evaluation Studies

Presenter: Claudia Stubenrauch, LMD
Authors: C. J. Stubenrauch and GEWEX UTCC PROES group

Upper tropospheric clouds, representing about 40% of the Earth's total cloud cover, play a crucial role in the climate system by modulating the Earth's energy budget and heat transport. They often form mesoscale systems. Cirrus emerge as outflow of convective and frontal systems or form in cold air supersaturated with water. Their evolution with climate change and their feedback can only be reliably estimated if these cloud systems are adequately represented in climate models.

Recently GEWEX initiated working groups on Process Evaluation Studies (PROES) to provide observational based metrics for a better understanding of physical processes. One goal of the PROES working group on 'Upper Tropospheric Clouds and Convection' (UTCC) is to gain a better understanding of the role of convection on cloud feedbacks (Stubenrauch and Stephens 2017).

Studies on tropical mesoscale convective systems so far concentrated mainly on the thick cirrus anvils, because radar and visible-infrared imagery either miss or misidentify thin cirrus. However, the thinner cirrus are thought to be a part of the anvils that has a significant radiative impact which might regulate convection itself.

Hence we are creating a synergetic data base of UT cloud systems anchored on IR Sounder observations, because these are sensitive to cirrus down to an optical depth of 0.2, day and night. By merging adjacent measurements with similar cloud height, the horizontal extent of these cloud systems has been determined, and convective cores, cirrus anvils and thin cirrus within these systems could be identified using cloud emissivity (Protopapadaki et al. 2017). The A-Train synergy provides information on the vertical structure and precipitation of these systems, essential to determine their heating rates, and helps to derive proxies for convective strength.

We will present relationships of anvil properties with respect to convective strength and to their surrounding atmosphere. This observational metrics is being used to evaluate different convection / detrainment / microphysical parameterizations in climate models as well as studies of these processes using modelling at finer scale.

Protopapadaki, E.-S., C. J. Stubenrauch, and A. Feofilov, Upper Tropospheric cloud Systems derived from IR Sounders: Properties of Cirrus Anvils in the Tropics, Atmosph. Chem. Phys., 17, 3845-3859, doi:10.5194/acp-17-3845-2017 (2017)

Stubenrauch, C. J., and G. L. Stephens, Process Evaluation Study on Upper Tropospheric Clouds and Convection (UTCC PROES), GEWEX News, vol. 27, no 2, pp 4-6 (2017), available at: http://www.gewex.org/gewex-content/files_mf/1500657263May2017.pdf

6.02 35 years of cloud observations based on HIRS measurements

Presenter: Martin Stengel, DWD
Authors: Martin Stengel, Steffen Kothe, Timo Hanschmann, Viju John

High clouds are of crucial importance for understanding the Earth's climate. High clouds, which are often semi-transparent, can actually have a warming effect on the Earth's energy budget, while low and mid-level clouds usually cool the Earth. Thus, there is a need for detecting high clouds and analysing their spatial and temporal variability, also in the context of a changing climate.

Within the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) a new dataset for cloud amount and cloud top height of high clouds has been generated, making use of a set of CO2 absorption channels of the High-resolution Infra Red Sounder (HIRS) onboard NOAA and MetOp satellites. This dataset allows in-depth analyses of high cloud occurrence and, due to the temporal coverage (1979 to 2013), allows these analyses, including the detection of potential trends, at climate time scales.

In this presentation we sill summarize the most important aspects of the HIRS based cloud property dataset used. We will further use this dataset to analyse the spatial and temporal occurrence of high clouds, investigating their change in more than three decades, and relate these results to changes in sea surface temperature and atmospheric water vapour over the ice free ocean.

6.03 Evaluation of the CM SAF Upper Tropospheric Humidity (UTH) climate data record from AMSU-B/MHS sounders

Presenter: Christoforos Tsamalis, Met Office Hadley Centre

Authors: Christoforos Tsamalis, Viju John, Rob King, Elizabeth Good, Roger Saunders and Rainer Hollmann

Upper tropospheric humidity (UTH) contributes significantly to the atmospheric greenhouse effect by having a strong influence on the outgoing longwave radiation. UTH can be measured either by radiosondes or satellite instruments. However, the radiosonde humidity measurements can suffer from significant biases in the upper troposphere. Satellite observations of UTH are made at both the spectral region of 6.7 µm in the thermal infrared (TIR) and the microwave (MW) channel of 183.31±1 GHz. Although, the former provide longer time-series, they are impacted significantly by the presence of clouds introducing a dry bias in climate data records (CDR) given that cloudy regions are associated with high humidity. The MW observations are less influenced by the presence of clouds in comparison to TIR measurements. In the framework of the EUMETSAT Climate Monitoring Satellite Application Facility (CM SAF), a CDR has been produced based on observations from the MW sounders AMSU-B and MHS aboard NOAA and MetOp satellite platforms. The CDR extends from October 1999 to December 2015 using all of the good quality observations from the available MW humidity sounders on NOAA 15 to 19 and MetOp A and B. The brightness temperature observations have been bias corrected with reference to MHS on NOAA-18, before converting them to UTH. The CDR is consisted of daily NetCDF files, where the ascending and descending orbits are treated separately, and the UTH is given at a spatial resolution of 1 degree globally. The CDR is validated against ERA-Interim reanalysis UTH for the same period. An overview of the UTH CDR is presented together with results from its evaluation.

6.04 Evaluation of inter-sensor biases between SNPP/ATMS and POES/AMSU-A

Presenter: Cheng-Zhi Zou, NOAA/NESDIS/STAR

Authors: Cheng-Zhi Zou and Xianjun Hao

The Advanced Technology Microwave Sounder (ATMS) onboard the Suomi National Polar-orbiting Partnership (SNPP) satellite mission is a new generation of microwave sounder designed to measure the atmospheric temperature and moisture profiles for numerical weather prediction. The ATMS will also be equipped on the NOAA next generation of operational weather satellite series—the Joint Polar Satellite System (JPSS), potentially providing atmospheric temperature and moisture observations for the next two decades. The potentially long-time observations from the SNPP and JPSS ATMS have important climate implication-- it can be merged with its predecessor, the Advanced Microwave Sounding Unit (AMSU-A), to form a long-term climate data record for climate change monitoring and investigation.

Before the merging, it is critically important to understand the inter-sensor biases between the two different instruments. The SNPP was launched on October 2011, having nearly 6 years of overlap at 2017 with the current operational POES satellites. This overlap provides an opportunity to evaluate the inter-sensor biases between ATMS and AMSU-A for future climate applications. We use the recalibrated/inter-calibrated AMSU-A observations for this evaluation. The recalibrated AMSU-A data was based on an Integrated Microwave Inter-calibration Approach (IMICA), which removed or minimized time-varying inter-satellites biases, resulting in inter-satellite biases to be on the order of 0.1K. As a result, the recalibrated AMSU-A data can serve as a reference. The ATMS data may be compared with AMSU-A on any satellites within the recalibrated satellite constellation and the comparison results will be basically same. By comparing ATMS with AMSU-A data on multiple POES satellites, potential issues in the ATMS, if ever exited, may be revealed.

In this presentation, we present and analyze the ATMS-AMSU-A comparison results. We will mainly analyze the ATMS oxygen channels -- channels 5 to 15. Difference time series in global means as well as in simultaneous nadir overpasses (SNOs) are both analyzed to achieve the best judgment on the bias nature between the two instruments. Global inter-sensor bias patterns will also be analyzed to understand the diurnal influence on the biases. Conclusion and recommendation of future directions will be made based on the results.

6.05 The use of satellite radiances in the C3S ERA5 reanalysis
Presenter: William Bell, ECWMF
Authors: William Bell, Paul Berrisford, Gionata Biavati, Per Dahlgren, Dick Dee, Hans Hersbach, Andras Horanyi, Joaquin Munoz-Sabater, Carole Peubey, Raluca Radu, Iryna Rozum, Dinand Schepers, Adrian Simmons, Cornel Soci and Jean-Noel Thepaut.
At the European Centre for Medium-Range Weather Forecasts (ECMWF), reanalysis is a key contribution to the Copernicus Climate Service (C3S) that is implemented at ECMWF on behalf of the European Commission. This presentation provides an overview of the latest ECMWF atmospheric reanalysis ERA5, which is currently in production and will replace the widely used ERA-Interim reanalysis.

ERA5 is the fifth generation of ECMWF atmospheric reanalyses of the global climate, which was pioneered with the FGGE reanalyses produced in the 1980s, followed by ERA-15, ERA-40 and most recently ERA-Interim. Particular attention will be given to the innovative aspects of the use of satellite radiances, which comprises, e.g., the ingestion of a number of reprocessed data sets, data never used before, and required adaptations in the radiative transfer model. The presentation will also provide an outlook on the potential usage of an extended satellite record for the next ECMWF C3S reanalysis, ERA6.

Compared to ERA-Interim, ERA5 incorporates important innovations to maintain the production of state-of-the-art climate reanalysis. ERA5 is based on a recent ECMWF model cycle which uses the 4D-Var assimilation method for the atmosphere, and includes coupling with ocean waves and a land model. Radiative forcing follows the evolution of greenhouse gases, volcanic eruptions, ozone and aerosols as recommended by CMIP5 and consistent boundary conditions are used for sea-surface temperature and sea ice. A number of reprocessed data records are ingested as well as several data sets that have never been re-used before. ERA5 is able to assimilate the latest instruments. Bias correction schemes have been extended and improved.

ERA5 is produced at considerably higher resolution: hourly analysis fields are available at a horizontal resolution of 31 km on 139 levels in the vertical. Data products include information about uncertainties which is provided by a lower-resolution 10-member 4D-Var ensemble. A number of new parameters, such as 100-metre wind speed and direction, are available as part of the output. A database containing all ingested observations, together with detailed information about how they are used, are available to users. In addition, a dedicated ERA5 land component will deliver a land-surface reanalysis product at an enhanced resolution.

Session 6b: Climate

6p.01 An assessment of the consistency between satellite measurements of upper tropospheric water vapor
Presenter: Eui-Seok Chung, University of Miami
Authors: Eui-Seok Chung, Brian Soden, Xianglei Huang, Lei Shi, and Viju John
Consistency of the satellite-based observations of upper tropospheric water vapor (UTWV) is assessed by comparing brightness temperature measurements from the High-Resolution Infrared Radiation Sounder (HIRS) channel 12, the Advanced Microwave Sounding Unit-B/Microwave Humidity Sounder 183.31±1 GHz channel, and spectral radiances from the Atmospheric Infrared Sounder. While all three products exhibit consistent spatial and temporal patterns of interannual variability, noticeable discrepancies in the amplitude of regional trends are observed due to differences in cloud screening. The trends over tropical or near-global spatial scales are however found to be consistent among the three products, suggesting their credibility for documenting long-term changes in UTWV. We also examine the variability of reanalysis-produced and model-simulated UTWV using the HIRS record as a benchmark. While the HIRS record indicates a moistening trend over the climatologically dry regions of the subtropics, both reanalysis data sets and the multi-model mean are found to have difficulty in capturing the observed moistening.

6p.02 The GEWEX water vapor assessment (G-VAP) – results from inter-comparisons and stability analysis
Presenter: Nathalie Selbach, DWD
Authors: Marc Schroeder, Maarit Lockhoff, Lei Shi, Nathalie Selbach
A large variety of water vapour data records is available to date. Without proper background information and understanding of the limitations of available data records, these data may be incorrectly utilised or misinterpreted. The overall goal of assessments of CDRs is to conduct objective and independent evaluations and inter-comparisons in order to point out strengths, differences and limitations and, if possible, to provide reasons for them. The need for such

assessments is part of the GCOS guidelines for the generation of data products. The GEWEX Data and Assessments Panel (GDAP) has initiated the GEWEX water vapor assessment (G-VAP) which has the major purpose to quantify the current state of the art in water vapour products being constructed for climate applications. All atmospheric ECVs associated with water vapour are considered: upper tropospheric humidity, specific humidity (and temperature) profiles as well as total column water vapour. In order to support GDAP and the general climate analysis community G-VAP intends to answer, among others, the following questions:
a) How large are the differences in observed temporal changes in long-term satellite data records of water vapour on global and regional scales?
b) Are the differences in observed temporal changes within uncertainty limits?
c) What is the degree of homogeneity (break points) of each long-term satellite data record?

A general overview of G-VAP will be given. The focus of the presentation will be on observed inconsistencies among the long-term satellite data records as observed by inter-comparisons, comparisons to in-situ observations and the stability analysis. The considered data records are based, among others, on HIRS, AMSU-B, SSM/I, and SSMIS observations as well as reanalyses. On basis of consistently applied tools major differences in state-of-art CDRs have been identified, documented and to a large extend explained. The results and the answers for TCWV are summarized as follows: On global ice-free ocean scale the trend estimates among long-term data records were generally found to be significantly different. Maxima in standard deviation among the data records are found over, e.g., tropical rain forests. These and other noticeable regions coincide with maxima in mean absolute differences among trend estimates. These distinct features can be explained with break points which manifest on regional scale and which typically do not appear in stability analysis relative to ground-based observations. Results from profile inter-comparisons will also been shown and exhibit, among others, that the observed break points are not only a function of region but also of parameter.

6p.03 Climate Data Records and user service of the EUMETSAT Satellite Application Facility on Climate Monitoring

Presenter: Nathalie Selbach, DWD

Authors: Nathalie Selbach, Petra Fuchs, Karsten Fennig, Uwe Pfeifroth, Britta Thies, Diana Stein, Stefan Finkensieper, Jinghong Tan

The EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) generates, archives and distributes widely recognized high-quality satellite-derived products and services relevant for climate monitoring. Several data sets have been released by CM SAF during the last project phase, the Continuous Development and Operations Phase 2 (CDOP-2). In CDOP-3 (running from 2017 to 2022) new editions of climate data records (CDR) will be published. Thus, users have access to many parameters of the water and energy cycle based on operational satellite instruments. The time series of the climate data records range from 8 to more than 30 years with a global coverage for data based on polar orbiting satellites, while those based on geostationary satellite data have a a regional coverage (the METEOSAT disc at 0°for currently available TCDRs),

CM SAF is offering CDRs generated from ATOVS, AVHRR, SMMR, SSM/I and SSMIS on different polar orbiting satellites as well as from the MVIRI, SEVIRI and GERB instruments onboard the METEOSAT series and similar instruments on further georing satellites. Furthermore, CM SAF will focus on precipitation as an additional new parameter in the current project phase.

These CDRs are made available via a web user interface which also allows applying post-processing procedures, such as the extraction of sub-areas or re-projection.

The planned climate data records to be released until the end of CDOP-3 will cover several cloud parameters, surface albedo, radiation fluxes at top of the atmosphere and at the surface, land surface temperature, precipitation as well as different water vapour parameters and fluxes. As for the already released data sets, different areas of the globe will be covered in varying temporal resolution depending on the satellite type.

This contribution will present the new releases of CM SAF climate data records planned for CDOP-3 and will give a general overview of the current and planned re-processing activities at the CM SAF. The concept of providing TCDRs as long term data sets in connection with providing related ICDRs in near real time suitable for climate monitoring applications will be shown. In addition, the offered user services of CM SAF will be presented.

6p.04 Preparing HIRS radiances as input to reanalysis within the Copernicus Climate Change Service

Presenter: Timo Hanschmann, EUMETSAT
Authors: Timo Hanschmann, Gerrit Holl, Viju John, Rob Roebeling, Jörg Schulz

Availability of operational satellite observations on a multi decadal time scale leads to an increased use of them in reanalysis and climate studies, e.g., for the investigation of climate trends and feedbacks. However, to detect and evaluate climate trends and feedbacks, the time series need to have a high temporal stability, accuracy (small bias), and precision (high signal to noise ratio). One objective of the Copernicus Climate Change Service (C3S) is to provide improved global and regional reanalysis data that meet these requirements. In order to achieve this goal, their input observations, must be accurate, stable, and available over long time periods. Serving this need, the Fidelity and uncertainty in climate data records from Earth Observations (FIDUCEO) project reassesses satellite observations of different instruments, in terms of determine the uncertainty, recalibrating the measurements and thus increasing the accuracy.

Within the presented study, we demonstrate an undertaking of preparing such an input satellite dataset for reanalysis in a research-to-operations mode. A Fundamental Climate Data Record (FCDR) of the High Resolution Infrared Radiation Sounder (HIRS) is prepared, based on the latest science including metrological principles. This means not only revising the calibration and harmonising the series, but also determining all the associated uncertainties.

This presentation shows the results of the data quality analysis of the very first HIRS instruments. These were operated on board of NIMBUS-6, TIROS-N, NOAA-6, and NOAA-8 and have been rarely investigated until now. The time series of HIRS is analysed in terms of their stability and variability. Their results are also qualitatively compared to new versions of the HIRS instrument, such as those on board of NOAA 19 and MetOP-A.

6p.05 Towards homogeneous reference datasets from MetOp A and MetOp B validated observations

Presenter: Cyril Crevoisier, CNRS-LMD
Authors: N.A. Scott, L. Crépeau, F. Capalbo, R. Armante, V. Capelle, C. Crevoisier, A. Chédin

For the validation of satellite level1 and level2 products, for our in house applications as well within the frame of the GSICS programme through our cooperation with CNES, we have developed and applied, for a long time, physically coherent quality control tests to detect errors in satellite and atmospheric/surface observations: among many others are errors related to format problems, spurious trends, degradation of the instruments, cross-track asymmetry problems, physically unrealistic values, temporal and vertical inconsistencies in temperature or dew point temperature profiles, … .

Based on one or several instruments on board the same or different platforms, these quality controls as well as the required spatial, spectral, temporal and viewing geometry matchings have been already described in former presentations as part of our "stand alone" and "relative" validation approaches. These quality control and validation activities keep going on for IR and microwave instruments on board satellites operated e.g. by CNES and/or Eumetsat, NASA. Among them, not only IASI, AMSU, HIRS, MHS on board MetOp A and B but also IIR/Calipso, Modis/Aqua, Seviri/MSG.

All these validation activities (satellite observations, ARSA (Analyzed RadioSoundings Archive) data base) have led us to build a robust, global sample of MetOp - clear and not clear-observations collocated in space and time with ARSA. This dataset, so far dedicated to the MetOp – and possibly to post MetOp - era now represents years of information with product updates at approximately 3 month delay from real-time.

The interest for such datasets (e.g. Reale and Thorne, 2004) has been clearly expressed by GSICS/WMO a long time ago. Due to the especially high stability of the IASI radiances and, equally important, to the careful validation of every atmospheric profile accepted in ARSA (more 5,500,000 profiles from 1979 onwards , our dataset may offer a high degree of homogeneity and, as such, be used for assessing the variability of other datasets (satellite observations, raw radiosonde reports, level 2 products).

The goal of this talk is to present how the high stability of IASI radiances (demonstrated from our ongoing work on the validation of IASI/MetOp A and B level1 data) may help the validation of other instruments not only onboard MetOp but also as IIR/Calipso and Modis/Aqua. Characteristics and description of the collocated MetOp/ARSA dataset will be given as well as will be discussed the capability of such a dataset to help homogenizing other simple or composite datasets.

http://ara.abct.lmd.polytechnique.fr

6p.06 Intercomparisons and validation of IASI L1 reprocessed data of MetOp-A
Presenter: Mayte Vasquez, EUMETSAT
Authors: Mayte Vasquez, Dorothee Coppens, Marie Doutriaux-Boucher
EUMETSAT intends to reprocess IASI L1 products covering data starting from July, 2007 in order to account for Day-2 algorithms, format evolution and also the latest configuration improvements. The reprocessed products will specially allow evaluating the content and the improvement of the data and particularly in terms of spectral calibration. Thanks to the Metop-B Cal/Val where the configuration parameters have been revised and are confined to cutoff parameters for algorithms and instrument characteristics. Some of these parameters have been beneficial to IASI on Metop-A from 2013 on. The reprocessing also aims at aligning as much as possible the IASI data measured before 2013 with those parameters.

Comparing the operational quality monitoring statistics and figures of the data is the basis for ensuring the quality of the reprocessed products. Furthermore, related validation activities are presented here through the analysis of intercomparisons to provide an assessment on the stability of the dataset and to discard any reprocessing issues. The validation plan is moreover based on comparisons to revise the general consistency of the reprocessed products, radiances analysis, cloud information, quality flags and on-ground parameters check. These results are of great interest to the users' community and operational L2 products reprocessing since they may lead to a better and homogeneous spectra quality, and a more consistent climate record.

6p.07 Detection of trends and variability of certain atmospheric features by analysing long time series of satellite monitoring statistics
Presenter: Mohamed Dahoui, ECMWF
Authors: Mohamed Dahoui and Tony McNally
The substantial longevity and stability of certain satellite instruments offers a unique opportunity to characterize and study the variability and evolution of certain atmospheric features using long time statistics of observations minus short range forecasts. With nearly 15 years of continuous observations, instruments like AIRS and AMSUA provide a detailed look on long term and seasonal variability of CO_2 concentrations, wildfire driven concentration of certain atmospheric species (e.g. hydrogen cyanide), Sudden stratospheric warming events, orographic gravity waves, etc. Statistics based on fixed analysis systems is very useful to isolate the trends driven by the climate. The impact of instrumental drift and the effects of the evolving observing system need to be taken into account before reaching conclusions. This can be achieved by exploiting redundancies in the observing system (e.g. many AMSUA and GPSRO instruments) and also by comparing statistics from various analysis systems (operational analysis, ERA-Interim and ERA-5).

6p.08 Withdrawn

Session 7: NWP centre reports

7p.01 Recent upgrades of satellite radiance data assimilation at JMA
Presenter: Norio Kamekawa, JMA
Authors: Norio Kamekawa, Masahiro Kazumori, Yoichi Hirahara, Yasutaka Murakami, Yasutaka Ikuta
This poster overviews recent upgrades of satellite radiance data assimilation into the numerical weather prediction (NWP) system at Japan Meteorological Agency (JMA) since the last ITSC-20 in October 2015. Assimilation of microwave radiance data from the Advanced Technology Microwave Sounder (ATMS), Hyper Spectral Infrared Sounder radiance data from the Cross-track Infrared Sounder (CrIS) of the Suomi National Polar-orbiting Partnership (NPP) spacecraft, and humidity sounding channels calibrated with the Unified Preprocessor Package from Special Sensor Microwave Imager/Sounder (SSMIS) onboard DMSP F-17 and F-18 satellite were started. In the ATMS radiance assimilation, tropospheric channels (6 – 9, 18 – 22) have been actively assimilated, while the stratospheric channels (10 – 15) are not used because of an increase of the first-guess departure from AMSU-A in the high latitude areas. In the CrIS radiance assimilation, 27 long-wave temperature sounding channels from 399-channel data set provided from the National Environmental Satellite, Data, and Information Service (NESDIS) were used. For the SSMIS 183 GHz radiance, oceanic SSMIS UPP data are assimilated with a newly developed cloud detection algorithm which utilizes multiple microwave observation channels. The Global Precipitation Measurement Microwave Imager data and Himawari-8 Clear Sky radiance data have been operationally assimilated into JMA's global and meso-scale NWP systems since March 2016. Furthermore, satellite radiance data under clear

sky condition have been operationally assimilated into JMA's local NWP system since January 2017.

7p.02 Overview of ECMWF NWP changes since ITSC-20

Presenter: Mohamed Dahoui, ECMWF

Authors: Mohamed Dahoui and Stephen English

Since ITSC-20, ECMWF implemented three substantial upgrades (41R2, 43R1 and 43R3) of its integrated Forecasting System. The three model cycles had a significant positive impact on forecast skill in the medium range and monthly forecasts. The model cycle 41R2, introduced in March 2016, was marked by a major upgrade of the horizontal resolution that affected all model and data assimilation components. The horizontal resolution of the ocean model (NEMO) increased by a factor of four in cycle 43R1 (November 2016). In addition to the horizontal resolution changes, the three model upgrades included significant observation, data assimilation and model changes. The main observation changes are: Activation of more humidity sounding channels (F-18 SSMIS, MWHS-2, GMI and SAPHIR), extension of all-sky assimilation to snowy land surfaces, harmonisation of microwave sounders usage over land and sea-ice, slant-path radiative transfer for clear-sky sounding observations, situation dependent observation errors for AMSUA, Updated observation error covariance matrices (including inter-channel error correlations) for IASI and CrIS, new channel selection for CrIS, improved aerosol detection for infrared sounders, improved quality control for GPSRO, radiosondes and dropsondes, improved screening of infrared observations for abnormal high concentrations of wildfire Hydrogen cyanide, assimilation of aircraft humidity, activation of Meteosat-8 over the Indian Ocean and assimilation of snowfall from NexRad Radar network. Data assimilation changes included: EDA cycling of its own background errors, improved scale-dependant hybrid background errors using the EDA, improved humidity background error variance, increased resolution of EDA-derived background errors, revised wavelet filtering of background error, reintroduction of model error forcing in the stratosphere. The model changes included: improved freezing rain physics, improved radiation-surface interaction, increased super-cooled liquid water at colder temperatures, new aerosol climatology, efficient radiation scheme, changes to parcel perturbation for deep convection to be proportional to surface fluxes, improvements of linear physics used in the data assimilation. In the ensemble system, an interactive sea-ice model was introduced to dynamically evolve the sea-ice cover in the medium range and monthly time scales.

Apart from model changes a number of operational data incidents occurred and required corrective actions. A timeline of the main data events will be presented.

7p.03 Developments in satellite data assimilation at DWD since ITSC-XX

Presenter: Christina Köpken-Watts, DWD

Authors: Ch. Köpken-Watts, R. Faulwetter, O. Stiller and colleagues

Major upgrades at DWD over the last two years have been the move to ensemble based data assimilation systems with the introduction of the global ICON-EnVAR system early 2016 and the high-resolution COSMO-KENDA system spring 2017 resulting in a marked improvement of forecast scores. For radiance assimilation, the current focus for the global ICON-EnVAR is on enhancing the humidity analysis through implementation of current humidity sounders and MW imagers. Work on hyperspectral data focuses on CrIS data as well as tests using the PC compressed IASI data disseminated by EUMETSAT. To enhance data coverage over land, emissivity retrieval approaches are studied both for the MW and IR, the latter also in preparation of future hyperspectral geostationary data.

For the high-resolution COSMO-KENDA system, the aim is to make use of cloud information from geostationary satellites. The assimilation of WV channels under clear and cloudy conditions is studied as well as the complementary use of visible channel cloud information.

The overview poster will summarize the changes of the operational assimilation system and the satellite data use at DWD and highlight ongoing developments.

7p.04 Overview of infrared radiance assimilation in Météo-France models

Presenter: Nadia Fourrie, Météo-France

Authors: N. FOURRIE, V. GUIDARD, N. BOUKACHABA, O. COOPMANN, P. MOLL, J.F. MAHFOUF

A large part of assimilated observations in the global model of Météo-France comes from infrared radiances. Since Radiances from AIRS, IASI on board Metop A and Metop B, and CrIS are assimilated in the global model. The infrared radiances are also used in the mesoscale model AROME. This poster intends to give an overview of the infrared radiance usage in the French models and the status of the current developments. The IASI channel data set has been increased with 5 ozone sensitive channels. The assimilation density has been increased and one IASI observation is now assimilated in a 100km2 box (instead of 125km). In addition, the surface emissivity atlas from the University of Wisconsin is now used for the simulation of the IASI brightness temperature and the land surface temperature is retrieved with the 1194 IASI channel for clear sky conditions, in both global and mesoscale models. Water vapour and tropospheric channels from Cris have been also added in the assimilation. The clear sky radiances from 5 geostationary satellites are also used in the analysis. Moreover, SEVIRI window channel are now assimilated over sea and channels from HIMAWARI satellites are now assimilated in the global model. The information content of the various observation type is regularly computed and will be presented.

7p.05 Ongoing developments on the use of microwave sounders and imagers at Météo-France

Presenter: Florian Suzat, Météo-France

Authors: F . Suzat, P. Chambon, and J.F. Mahfouf

A large number of satellite radiances from microwave sounders and imagers is assimilated in the operational global and regional Numerical Weather Prediction (NWP) models at Météo-France (ARPEGE and AROME). Currently, microwave instruments represent 15 % of the total number of observations assimilated in the global NWP model ARPEGE, and contribute to 25 % of the analysis information content. Recent developments undertaken over the last two years regarding an improved usage of microwave radiances will be described.

A set of additional radiances from new sensors will be assimilated or monitored in next operational suite, MWHS2 on board FY3-C (3 channels around 183 GHz), GMI on board GPM Core (2 channels around 183 GHz), AMSR-2 on board GCOM-W1 (7 channels between 19 and 80 Ghz) and MTVZA-GY on METEOR-M N2 (monitored). The impact studies conducted for these instruments will be summarized. A number of other changes affecting the simulation of microwave radiances will also be presented: (i) a set of monthly emissivity atlases (complementary to the dynamic emissivity retrieval over continental and sea-ice surfaces) has been set up and tested. The added value of using these atlases taking into account the seasonal variability of surface emissivity against static (annual mean) atlases will be shown. (ii) The RTTOV microwave coefficients have been updated using revised coefficients with band corrections. Finally, the increase in the horizontal resolution of the ARPEGE model planned in the near future has motivated a study on assimilating microwave radiances at higher spatial density (100 km instead of 125 km). Preliminary results of such an horizontal increase will be discussed.

7p.06 NWP centre update: Met Office

Presenter: Brett Candy, Met Office

Authors: William Bell, Anna Booton, James Cameron, Brett Candy, Fabien Carminati, Amy Doherty, Graeme Kelly, Katie Lean, Stefano Migliorini, Stuart Newman, Ed Pavelin, Indira Rani, David Rundle, Andrew Smith, Fiona Smith and Peter Weston

Since ITSC-20 in October 2015, the Met Office have made four major upgrades to their global and regional NWP models, all of which have involved improvements in the assimilation of satellite radiance data: Parallel Suite 37 (PS37, March 2016); PS38 (November 2016); PS39 (July 2017) and PS40 (November 2017).

PS37 included the implementation of variational bias correction (VarBC) in the global model, together with the introduction of radiance observations from several new satellites (MT-Saphir, AMSR-2, F-17 SSMIS and FY-3C MWHS-2). Additionally, the assimilation of AIRS and CrIS data took account of inter-channel error correlations, bringing the treatment in line with that adopted for IASI radiances since January 2013. PS37 delivered significant improvements in forecast quality, amounting to RMS error reductions of 5-10% at Day 3 for SH geopotential heights and PMSL, for example. The benefits are attributed to 70% VarBC, 30% new satellites.

PS38 saw the introduction of dynamic spectral emissivity estimates over land surfaces for AIRS and CrIS in the global and regional models. Dynamic estimation of emissivity in the microwave allowed the assimilation of AMSUA-4 and -5 over land in the global model. FY-3B MWHS-1 data was introduced. Finally, observation errors for humidity sensitive microwave channels were re-tuned, generally resulting in significantly more weight being given to the observations, and delivered improved analyses and forecasts of humidity.

PS39, principally an upgrade to the resolution of the global model (to 10km), included an upgrade to RTTOV-11 (from RTTOV-9).

PS40 included the introduction of GMI observations in the global model, as well as several improvements in the use of microwave sounding radiances from AMSU-A and ATMS. Key channels of NOAA-18 AMSU-A were re-introduced following earlier blacklisting due to drifting biases; more data were assimilated through changes in the thinning of the data; and low peaking channels of ATMS and AMSU-A were blacklisted over sea-ice and high land.

During the last two years several improvements have been made to the assimilation of satellite radiances in the UKV 1.5km regional model: the introduction of ATMS, CrIS and AIRS at PS37; and the dynamic estimation of land surface emissivity for AIRS and CrIS at PS38.

Looking forward, key developments anticipated for the next year include: all-sky treatment of microwave radiances at PS41 (Spring 2018); assimilation of JPSS-1 ATMS and CrIS observations; the assimilation of AMSU, MHS and IASI radiances from MetOp-C; preparations for the assimilation of FY-3C MWRI data, and FY-3D HIRAS, MWTS-2, MWHS-2 and MWRI data; improved assimilation of humidity sensitive radiances over land; and an assessment of Meteor M-N2 MTVZA data.

7p.07 Satellite assimilation at the Bureau of Meteorology (Status Report)
Presenter: Fiona Smith, Bureau of Meteorology (and Met Office)
Authors: Fiona Smith, Chris Tingwell, Jin Lee, John Le Marshall, Peter Steinle and Sergei Soldatenko
This poster will present the current status of satellite data assimilation in the Bureau of Meteorology's NWP systems, including results of recent impact studies and planned DA upgrades.

7p.08 NCMRWF NWP status
Presenter: Indira Rani S., NCMRWF
Authors: E. N. Rajagopal, John P. George, Munmun DasGupta, Indira Rani S
Current status and future plans of NCMRWF's operational NWP is discussed in this paper. Different types of current and future satellite observations used in the NWP system and the data assimilation techniques are discussed in detail.

7p.09 Progress and plans for the use of radiance data in the NCEP global and regional data assimilation systems
Presenter: Andrew Collard, NCEP (for John Derber)
Authors: John Derber, Yanqiu Zhu, Emily Liu, Russ Treadon, Rahul Mahajan, Daryl Kleist, Catherine Thomas, Paul van Delst, Xu Li and Andrew Collard

Since the last International TOVS Study Conference in October 2016, there have been two major operational upgrades to the data assimilation system at NCEP (in May 2016 and July 2017). Most of the significant scientific changes were in the 2016 upgrade, with the 2017 upgrade mostly consisting of a change to the forecast model infrastructure.

The most significant advance in this period were:

1) Assimilation of cloudy radiances for AMSU-A.
2) The 3DEnsVar data assimilation system was extended to 4DEnsVar (thereby allowing the time evolution of the the background error statistics within the assimilation window).
3) The sea-surface temperature is directly analysed in the data assimilation system using a near sea-surface temperature (NSST) model to account for measurements' various penetration depths.
4) The microwave sea-surface emissivity model in CRTM was upgraded to FASTEM-6 (which has the effect of effectively removing a 2K bias seen in AMSU-A channels 1, 2 and 15) and the algorithms that process the azimuthal dependence of the emissivity were revised.

There will be a mini-implementation in the spring of 2018 to introduce JPSS CrIS and ATMS into the assimilation system.

Special Topics

World Radiocommunication Conference 2019 (WRC-19) items of interest to ITSC
Presenter: Richard Kelley, Alion Science for NESDIS
Authors: Rich Kelley and Fred Mistichelli
Representatives from 193 administrations/countries meet every four years to determine the use of the radiofrequency spectrum for the next four years. They will gather in October – November of 2019 to examine future spectrum allocations through careful consideration of needs and impacts on current allocations and uses. This meeting is crucial to the future of our satellites, allocated in three of the radiocommunication services – Earth exploration satellite, Meteorological satellite and Space research. The operating charter for this world radiocommunication conference addresses the future of a major new data downlink and microwave data sensed within or next to some channels used by ITSC members for passive

remote sensing. The presentation will cover the WRC-19 approach to microwave bands of interest to ITSC.

DBNet implementation status and planning
Presenter: Mikael Rattenborg, WMO
Authors: Mikael Rattenborg, Stephan Bojinski and Pascal Brunel
DBNet is a very successful collaborative undertaking of the World Meteorological Organization and its members. The DBNet system provides fast acquisition, processing and delivery of satellite products from direct readout data, primarily for NWP applications with stringent timeliness requirements. Since about 10 years, sounding data from the ATOVS suite has been acquired by receiving stations around the globe, which has improved the availability and impact of satellite sounding data on short-term regional and global Numerical Weather Prediction. DBNet is now extending to cover advanced satellite sounder data such as METOP/IASI and SNPP/CrIS.

The paper will present the DBNet status and implementation plans, with particular emphasis on the numerous areas where feedback is required from the ITSC community.

Session 8a: Hyperspectral IR

8.01 A global-local hybrid approach to retain new signals in hyperspectral PC products
Presenter: Tim Hultberg, EUMETSAT
Authors: T. Hultberg, T. August
Principal Component (PC) compression is the method of choice to achieve band-width reduction for dissemination of hyper spectral (HS) satellite measurements and will become increasingly important with the advent of new HS missions (such as IASI-NG and MTG-IRS) with even higher data-rates than the current instruments IASI, CrIS or AIRS.

We review the current use of PC compression for dissemination, exemplified by IASI, and examine whether improvements can be made. In particular, we investigate the relative merits of using a local dynamic or a global static training set of spectra for the computation of the eigenvectors. We show that local eigenvectors retain a higher amount of noise and a lower amount of atmospheric signal than global eigenvectors, except in rare situations resulting in spectra with new features which have not been observed in the global static training set. To cope with such situations we investigate a hybrid approach which first applies the global eigenvectors and then applies local compression to the residuals in order to identify and disseminate any directions in the local signal which are orthogonal to the subspace spanned by the global eigenvectors. This can rarely happen for instance in case new atmospheric composition events following special volcanic eruption of wild fires.

8.02 Correction to remove the residual responsivity dependence of spectral Instrument-Line-Shapes for Fourier Transform Spectrometers
Presenter: Hank Revercomb, SSEC/UW-Madison
Authors: H. E. Revercomb, D. C. Tobin, J. K. Taylor, R. O. Knuteson, and P. J. Gero
For a Fourier Transform Spectometer (FTS), the Instrument Line Shape (ILS) can in principle be independent of detailed instrument characteristics, only depending on the maximum Optical Path Difference (OPD) observed. This property can simplify radiance assimilation into numerical weather prediction models and avoid a potential source of bias for long term climate records. However, most realistic instruments introduce at least some small responsivity dependence into the ILS, because of the non-flatness of the instrument responsivity and its finite spectral bandpass.

For the current US operational advanced sounder, CrIS, the analysis paradigm to date has been to create calibrated spectra compatible with calculated spectra that, like the observations, are band-limited by the CrIS responsivity at high spectral resolution and then normalized by dividing by the responsivity at the observed resolution. This approach inherently yields an ILS weakly dependent on responsivity, with both observed and calculated spectra containing some ringing (every other point ups and downs) that we refer to as “true” ringing.

We have recently learned about European investigations of a correction for the effects of an expected pixel-to-pixel responsivity variation on the ILS of each pixel for their geostationary imaging high spectral resolution sounder, MTG/IRS. The approach uses (1) a spectrally local de-apodization correction, somewhat analogous to that used for the IASI self-apodization correction, and (2) a weak apodization to narrow the ILS, thereby mainly eliminating un-invertible contributions from out-of-band where the responsivity goes to zero.

In thinking about trying to develop this type of correction for CrIS, we have developed an alternative approach for step (1) that uses a Taylor series of the responsivity to allow the correction to be expressed as a series of Fourier transforms, analogous to the approach used in a new self-apodization correction developed for CrIS. This approach may prove to have some efficiency and accuracy advantages. The need for a weak apodization is also being investigated.

This correction approach will be defined and the status of its development discussed. Both this new approach and that being pursued in Europe will remove the effects of non-flat, in-band responsivity on the spectral ILS, potentially a significant advantage for simplifying applications and avoiding a potential source of bias in climate trends.

8.03 Reprocessing of Suomi NPP CrIS SDR and impacts on radiometric and spectral long-term accuracy and stability

Presenter: Yong Chen, University of Maryland
Authors: Yong Chen, Yong Han, Likun Wang, and Fuzhong Weng

Since early 2012, the Cross-track Infrared Sounder (CrIS) on board the Suomi National Polar-Orbiting Partnership (S-NPP) Satellite has continually provided the hyperspectral infrared observations for profiling atmospheric temperature, moisture and greenhouse gases. The CrIS radiance data are also directly assimilated into global NWP models to improve the medium-range forecasts. The CrIS overall performance in spectral, radiometric, geometric calibrations and noise performance in previous studies demonstrated that the CrIS Sensor Data Record (SDR) data meet calibration requirements, thus making it an exceptional asset for weather applications. However, the operational SDR generated by the Interface Data Processing Segment (IDPS) have undergone several sciences and code changes, thus resulting in inconsistent long-term performance and not suitable for climate applications.

In this study, the CrIS SDR data are further improved for climate applications with its fine-tuning of calibration coefficients in NOAA reprocessing project. One specific code for CrIS SDR reprocessing was developed. This code was updated with calibration algorithm, non-linearity, and geolocation to improve the scientific results. The calibration coefficients are refined with the latest updates based on the work from CrIS science team, and are inserted in the Engineering Packet (EP) in the Raw Data Record (RDR) data stream. The resampling wavelength was updated based on the metrology laser wavelength and resulting in zero sampling error in the spectral calibration. All the SDRs are generated with the same calibration coefficients, resulting in improved consistency during the CrIS life-time mission. The reprocessed SDRs are essential for deriving the long-term climate trending such as tropical sea surface temperature trends and CO2 trends.

Overall radiometric biases (O-S) are small and stable over time, FOV-2-FOV differences are less than ~10 mK, and much better than that from the operational SDR. It is shown that CrIS metrology laser wavelength varies within 3 ppm as measured by the Neon calibration subsystem. The reprocessed SDR have spectral errors less than 0.5 ppm, is much better than the operational SDR with about 4 ppm. The S-NPP CrIS mission-long reprocessing is necessary not only to improve SDR products but also to benefit GSICS inter-calibration capabilities and climate applications, in terms of better radiometric and spectral calibration accuracy, and consistent calibration stability based on the same software and calibration coefficients.

8.04 MTG-IRS L1 processing overview and performances

Presenter: Dorothee Coppens, EUMETSAT
Authors: Dorothee Coppens, Bertrand Theodore

The Meteosat Third Generation (MTG) series of future European geostationary meteorological satellites consists of two types of satellites, the imaging satellites (MTG-I) and the sounding satellites (MTG-S). The Infrared Sounder (IRS) is one of the two instruments hosted on board the MTG-S satellites. The scope of the IRS mission is to provide the user community with information on time evolution of humidity and temperature distribution, as function of latitude, longitude and altitude. Regarding time and space sampling, the entire Earth disk will be covered, with particular focus on Europe, which will be revisited every 30 minutes.

This paper presents a synthetic overview of the mission and the instrument, and will go through the level 1 processing chain which takes instrument raw data to obtain spectrally and radiometrically calibrated and geolocalised radiances, called level 1b products. A discussion will be presented around the radiances uniformisation in space, spectral range and time and its impact for the user community. Also, the last investigations regarding the L1 processing performances will be addressed.

8.05 Determination of the experimental error of high spectral resolution infrared observations from spectral residuals: application to IASI

Presenter: Carmine Serio, Università della Basilicata

Authors: Carmine Serio, Guido Masiello, Elsa Jacquette, Olivier Vandermarcq, Dorothee Coppens

The problem of characterizing and estimating the instrument or radiometric noise of satellite high spectral resolution infrared spectrometers from Earth views is addressed in this paper. Two approaches have been devised and will be compared, which are based on the common concept of spectral residuals (Observations-Calculations). The first approach relies on the Principal Component Analysis with a suitable criterion to select the optimal number of PC scores. The criterion is optimal in that it is based upon the estimation theory of Maximum Likelihood Principle. This first approach is independent of any forward model and/or radiative transfer calculations. The second approach yields the spectral residuals after spectral radiance inversion for atmospheric and surface parameters, therefore it relies on a forward model. The problem of mathematical inversion is solved within the general framework of Optimal Estimation theory. Whatever the method, it will be shown that the use of the spectral residuals to assess the instrument noise leads to effective estimators, which are largely independent of possible departures of the given observational covariance matrix from the true variances-covariances. Application to the Infrared Atmospheric Sounder Interferometer (IASI) has been considered. A series of case studies have been set up, which make use of IASI data in external calibration mode. This mode improves horizontal spatial resolution of the instrument along the nadir view and are particularly suited for the analysis at hand. It is shown that Earth-scene derived observation-errors agree with blackbody in flight calibration. As a major result, the analysis confirms the high stability and radiometric performance of IASI. Finally, the spectral residuals approach also proved to be effective to characterize noise features due to mechanical micro-vibrations of the beam splitter of the IASI instrument.

Session 8b: Composition

8p.01 Retrieval of the 3 main anthropogenic greenhouse gases from IASI: Status and lessons learned for validation

Presenter: Cyril Crevoisier (for Olivier Membrive), CNRS-LMD

Authors: O. Membrive, C. Crevoisier, N. Meilhac, L. Crépeau, R. Armante, H. Chen, F. Danis, M. Ramonet, Céline Lett

Thanks to its continuous spectral coverage of the whole thermal infrared domain, the IASI instrument offers the possibility to retrieve mid-tropospheric columns of the 3 major greenhouse gases influenced by human activities. These are: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The very small seasonal variability of these gases compared to their background values, combined to the strong dependence of IR radiances to atmospheric temperature and the simultaneous sensitivity of the channels to several gases, makes their retrieval challenging.

The non-linear inference scheme developed at LMD delivers mid-tropospheric columns of the 3 gases for both day and night condition, over land and over sea. It strongly relies on careful validation of level1c spectra, characterization of systematic radiative biases and severe cloud and aerosol screening. Almost 9 years of observations from Metop-A and 2 years from Metop-B have now been processed. CH_4 and CO_2 atmospheric columns are delivered in “near real time” (D-1) basis to the Copernicus-Atmosphere Service. Owing to its 20 year-program, IASI also participates to the establishment of long time series in the ESA-Climate Change Initiative-GHG. The retrievals are thus used for a variety of purpose: assimilation to produce CH_4/CO_2 profile forecasts; estimation of surface fluxes using “top-down” atmospheric inversions; characterization of specific emissions such as biomass burnings.

In this talk we will present the latest development of the retrievals of these 3 gases. In particular, we will focus on the lessons learned while going from Metop-A to Metop-B, that will serve as baseline for moving to Metop-C (to be launched in October 2018). We will highlight the importance of a proper radiative characterization of the instruments on both platforms. Finally, we will show the difficulty of properly validating mid-tropospheric column, due to the small but non-negligible impact of an incorrect knowledge of the stratospheric part of the gas vertical distribution. We will show how full measurement of vertical profile, such as those provided by balloon-borne AIrCores air sampler, and data assimilation such as performed within the Copernicus Atmospheric System can offer direct and indirect validation of the gas products.

8p.02 Physically-based simultaneous retrieval for CO, CO2, CH4, HNO3, NH3, OCS and N2O from IASI observations and inter-comparison with in situ observations and AIRS, GOSAT, OCO-2 satellite products

Presenter: Guido Masiello, Università degli Studi della Basilicata
Authors: Guido Masiello, Carmine Serio, Giuliano Liuzzi, Sara Venafra

Recent advances in the random projection approach applied to the inversion of the full IASI (Infrared Atmospheric Sounder Interferometer) spectrum are exemplified with applications to the retrieval of greenhouse gases and pollutants. The case of simultaneous retrieval of CO, CO2, CH4, HNO3, NH3, OCS and N2O is exemplified in this study. Random projections provide a) an unified and coherent treatment of systematic and random errors; b) a compression tool, which can reduce the dimensionality of the data space; c) a noise model which is truly Gaussian therefore, making it possible to apply rigorously Optimal Estimation and derive the correct retrieval error; d) a simplified treatment of the inverse algebra to get the final solution. Many of the methodological aspects above have been shown in a recent paper by the authors (Serio et al. 2016, doi:10.1364/AO.55.006576) in dealing with the retrieval of surface parameters and atmospheric temperature, water vapour and ozone profiles. The present analysis is aiming at showing that we can fully exploit the compression capability of random projections to develop an inverse algorithm capable of dealing with the whole IASI spectrum, therefore with minimal loss of information content. The results is a final retrieval with improved precision and horizontal spatial and temporal resolution. Retrieved parameters and species include, surface temperature and emissivity (spectrum), Temperature, H2O, O3, HDO, CO2, N2O, CO, CH4, SO2, HNO3, NH3, OCS, CF4 atmospheric profiles. The effective vertical resolution of these profiles is depending on the degrees of freedom.

A retrieval case study has been set up, which includes thousands of observed spectra for a two-year period (January 2014 to December 2015) over sea surface in the Pacific Ocean close to the Mauna Loa (Hawaii) validation station. Results obtained until now (see e.g. Liuzzi et al 2016, doi:10.1016/j.jqsrt.2016.05.022 and Camy-Peyret et al. doi:10.1016/j.jqsrt.2017.07.006) show that retrieval of gas species is obtained with unprecedented precision and spatial resolution, which open the way to study and understand regional patterns of greenhouse gases due to anthropogenic activities and/or natural events. In the present study, IASI retrieval for CO2, CH4 and N2O are compared to operational products from different satellites and instruments. These include AIRS (Atmospheric Infrared Radiometer Sounder), GOSAT (Greenhouse Gases Observing Satellite), OCO-2 (Orbiting Carbon Observatory-2). The comparison shows that our retrieval methodology is by far superior to those of existing methods insisting on instruments, which covers the thermal infrared such as IASI, AIRS and GOSAT. Comparison with OCO-2 shows comparable results, but our methodology uses much less a-priori information than OCO-2.

8p.03 Harnessing the power of sounders for atmospheric composition and chemical assimilation

Presenter: Vivienne Payne, JPL/Caltech
Authors: Vivienne Payne, Dejian Fu, Susan Kulawik, Kevin Bowman, John Worden, Jessica Neu, Karen Cady-Pereira, Helen Worden and Matthew Alvarado

Thermal infrared sounders offer a wealth of information on tropospheric composition. Here we review the Level 2 trace gas products currently available from the US TES, AIRS and CrIS instruments. We discuss the potential for continuity of minor trace gas data records from these instruments as well as the scope for development of new infrared and multi-spectral trace gas products, in the context of recommendations from recent NASA and NOAA community workshops.

8p.04 A decade of Infrared dust aerosol characteristics (AOD and mean layer altitude) retrieved daily from IASI

Presenter: Virginie Capelle, LMD/CNRS-Ecole Polytechnique
Authors: V. Capelle, A. Chédin, M. Pondrom, C. Crevoisier, R. Armante, L. Crepeau, and N. A. Scott

Aerosols represent one of the dominant uncertainties in radiative forcing, partly because of their very high spatiotemporal variability, a still insufficient knowledge of their microphysical and optical properties, or of their vertical distribution. A better understanding and forecasting of their impact on climate therefore requires precise observations of dust emission and transport. Observations from space offer a good opportunity to follow, day by day and at high spatial resolution, dust evolution at global scale and over long time series. Infrared observations allow retrieving dust aerosol optical depth (AOD) as well as the mean dust layer altitude, daytime and nighttime, over oceans and over continents, in particular over desert. Therefore, they appear complementary to observations in the visible. In this study, a decade of the Infrared Atmospheric Sounder Interferometer (IASI) on board European Satellite Metop-A observations, from July 2007 to June 2017, has been processed pixel by pixel, using a "Look-Up-Table" (LUT) physical approach. Important improvements have been brought to our former approach in order to extend it to: 1) daytime retrieval, 2) mid-latitude retrieval, 3) retrieval at the IASI pixel resolution, 4) near real time retrieval (day-1). Moreover, over continents, surface characteristics (pressure, temperature, as well as emissivity spectrum) are now better accounted for. Here, a particular attention is given to the validation of the IASI-retrieved AOD through comparisons with the Spectral Deconvolution Algorithm (SDA) 500nm coarse mode AOD observed at 70 ground-based Aerosol RObotic NETwork (AERONET) sites. Even if such a comparison requires converting AOD from infrared to visible, inherently leading to significant uncertainties, the two AOD datasets compare well, with an overall correlation of 0.8. For a large majority of sites, correlation ranges from 0.7 to 0.9. Sites with highest correlation are well distributed within the "dust belt" (Sahara, Arabian Peninsula, Mediterranean basin, India and also the Caribbean). Correlations obtained for East-Asia are in general smaller, which might be due to a more complex dust structure (i.e., impact of pollution) and partly due to an increase of the AERONET coarse-mode AOD uncertainty. Comparisons between IASI aerosol mean layer altitude and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) dust mean altitude have also been carried out. Using all available observations over the dust belt for the year 2010, a bias of -0.26+/-1.02km (IASI minus CALIOP altitude) is obtained. This may be considered as satisfactory given the difficulties of such a comparison: systematic observation time shift of about 4h30, difference in the altitude definition, difference in the spatial resolution as well as in the number of observations provided by each instrument. More generally, this study demonstrates the ability for IASI to retrieve aerosol dust properties, opening a new perspective for a combined IR/Visible approach.

8p.05 Technique and results of retrieving the total ozone content using satellite IR measurements from «Meteor-M» No 2

Presenter: Alexander Polyakov, Saint-Petersburg State University

Authors: A.V. Polyakov A.S. Garkusha, Yu.M. Timofeev, Ya.A. Virolainen, A.V. Kukharsky, D.A. Kozlov

Technique for retrieving the total ozone content (TOC) from spectra of outgoing thermal radiation measured by IRFS-2 from a board of the meteorological «Meteor-M» No. 2 satellite under cloudiness are developed. Comparison of TOCs retrieved using the developed technique with independent data is performed. It is shown that differences between TOCs retrieved from IRFS-2 spectral measurements and satellite (OMI device) and ground-based (Dobson, Brewer, M-124) data, as a rule, are 3–5 %. The greatest differences (up to 10 %) are observed over Antarctica in the presence of an ozone hole in the southern polar latitudes. Using the developed technique and IRFS-2 measurements, ozone mini-holes over Russia detected earlier by other methods in the first quarter 2016 were registered. In separate days during this period almost 2-fold TOC reduction was observed. The study was supported by Russian Science Foundation (project 14-17-00096).

8p.06 Uncertainty of temperature sounding caused by the variation of CO2 concentration

Presenter: Jonghyuk Lee, Yonsei University

Authors: Jonghyuk Lee and Dong-Bin Shin

A fundamental assumption in temperature soundings from satellites is that the concentration of an absorption gas is known and well-mixed vertically. CO_2 absorption bands around 15 µm are typically selected for infrared measurement-based soundings because CO_2 is known to mix well in the atmospheric column. However, atmospheric CO_2 concentrations have increased steadily and regional distributions of CO_2 emissions are not quite homogeneous. If the inaccurate CO_2 concentrations, which cannot reflect the current CO_2 concentration information, are used for the temperature sounding, they may cause the uncertainty of temperature sounding due to a violation of the basic assumption on the vertically homogeneous distribution. This study estimates the uncertainty of the temperature sounding within the framework of the optimal estimation depending on the variation of CO_2 concentration from nine CO_2 scenarios, including realistic and extremely low and high CO_2 concentration. The European Centre for Medium-Range Weather Forecasts (ECMWF) 91-level profile datasets are used to simulate the synthetic measurements for the Atmospheric Infrared Sounder (AIRS) and background fields including atmospheric temperature, humidity profiles and surface variables (2m temperature/humidity and skin temperature etc.). These datasets are also used for the validation of the retrieved sounding results.

This presentation will include (1) an overview of the optimal estimation and methodology to simulate synthetic measurements for the AIRS and background fields, (2) a detailed assessment of the uncertainty of the temperature sounding depending on the variation of CO2 concentration with an emphasis on the channel availability, and (3) an additional investigation of the uncertainty in terms of the intervention of moist conditions.

8p.07 Using MTSAR-2 visible images to retrieve aerosol optical depth

Presenter: Allen Huang, UW-Madison/SSEC (for Chien-Ben Chou, Central Weather Bureau)
Authors: Chien-Ben Chou; Huei-Ping Huang

A geostationary satellite can provide observations at a higher frequency and with greater area coverage than an orbital satellite. This study uses data from geostationary satellite MTSAT-2 to retrieve the aerosol optical depth over eastern Asia. The 6S radiative-transfer model is used to generate a look-up table to facilitate the estimate of surface reflectance and retrieval of the optical depth of aerosols. A comparison of the optical depth retrieved from MTSAT-2 observations with the visibility measured at ground stations reveals a good match in their spatial patterns. The aerosol optical depth from MTSAT-2 is hence useful for monitoring the daily evolution and distribution of aerosols.

8p.08 Estimation of the aerosols direct radiative forcing in the Amazon region using MODIS

Presenter: Dirceu Herdies, INPE
Authors: Dirceu Luis Herdies and Brunna Romero Penna

Every year the Amazon region is heavily affected by heavy loads of atmospheric aerosols from biomass burning, mainly during the dry season (August to September), leading to potential disturbances in the regional climate. In this study 16 years of the direct radiative forcing of aerosols over the Amazon region are analyzed through a trained neural network with the MERRA-2 reanalysis data and the aerosols optical depth values of the MODIS sensor. The neural network model presented an average quadratic error of 1.70 and 0.46 for ARF estimation at surface and top of the atmosphere, respectively. During the dry season, the monthly average for ARF was -25.34 W/m2 ranging from -10.79 W/m2 to -38.55 W/m2 on the surface and -8.52 W/m2 ranging from -4.40 W/m2 to -12 W/m2 at the top of the atmosphere. The ARF values at the top of the atmosphere are small when compared to surface ARF due to the absorption of solar radiation by aerosols. These values are important for predicting weather and climate, providing a better understanding of how the Amazonian ecosystem works. The results of this work were compared with results of other studies, using different methodologies, and presented an excellent concordance.

8p.09 Towards a strengthening of the coupling of Numerical Weather Prediction and Chemistry Transport Models to improve the retrieval of thermodynamic fields from infra-red passive sounders: The ozone case

Presenter: Olivier Coopmann, CNRM-Meteo-France & CNRS
Authors: Olivier Coopmann, Vincent Guidard, Nadia Fourrié

Hyper-spectral infra-red sounding instruments, such as the Infra-Red Atmospheric Sounding Interferometer (IASI), provide 70 % (IASI-A and IASI-B alone account for 50 %) of the data used in the Numerical Weather Prediction (NWP) global model ARPEGE (Action de Recherche Petite Échelle Grande Échelle) of Météo-France. With 8461 channels, this sounder allows to obtain indirect information on temperature and humidity profiles and also on the cloud cover, aerosols, atmospheric compounds such as O3, CO2, CH4, CO, N2O… and surface properties. At Météo-France, 128 IASI channels are assimilated in operation (99 in the LW CO2 band, 4 window channels, 5 ozone channels and 20 in WV band). We identify over 500 ozone-sensitive channels in the IASI spectrum. CO2 and H2O channels are presently used to retrieve temperature and humidity profiles, but O3 channels would enable us to provide additional information on the vertical profile. Ozone is an important chemical compound of the troposphere as regards to pollution, and obviously, of the ozone layer in the stratosphere.

In the current version of the assimilation in the global model ARPEGE, the gases concentrations used for the radiance simulations are considered constant in space and in time. A study conducted in 2015 showed that using realistic ozone information from the Chemistry Transport Model (CTM) MOCAGE (MOdèle de Chimie Atmosphérique à Grande Échelle) of Météo-France as input of the Radiative Transfer Modele (RTM) improved temperature and humidity retrievals from infra-red satellites. The objective of the present study is to select channels among the 500 ozone-sensitive channels in order to improve thermodynamic retrievals from IASI data using realistic ozone information including ozone in the control variable.

8p.10 Greenhouse gases in-situ profiles from the APOGEE campaign in support to satellite infrared sounder assimilation

Presenter: Olivier Coopmann, CNRM-Meteo-France & CNRS

Authors: Olivier Coopmann, Nadia Fourrié, Vincent Guidard, Lilian Joly, Diane Tzanos

Wide parts of the infrared spectrum measured by hyperspectral instruments like IASI or CrIS are sensitive to greenhouse gases such as ozone, CO2 and CH4. A good prior knowledge of the atmospheric profiles for these compounds is needed to compute hyperspectral simulations with a radiative transfer model.

At present, some atmospheric ozone profiles are measured thanks to ozone-soudings, but very few CO2 and CH4 atmospheric profiles are available. The AMULSE (Atmospheric Measurements by Ultra Light SpEtrometer) instrument developed at GSMA measures CO2 and CH4 with diode laser spectrometer. The APOGEE campaign (Atmospheric Profiles Of GreenhousE gasEs) is a project in collaboration between GSMA (Groupe de Spectrométrie Moléculaire Atmosphérique), CNRM – Météo-France & CNRS (Centre National de Recherche en Météorologie) and LSCE (Laboratoire des Sciences du Climat et de l'Environnement) to fly the AMULSE instrument up to 30 km under weather balloons. In addition, ozone-sondes are released at the same time. These atmospheric profiles are acquired in collocation with satellites over-passes, especially IASI and CrIS.

This data allows us to carry out simulations of infrared radiance using CO2, CH4 and O3 in-situ profiles and to compare these with radiances measured by hyper-spectral or geostationary infra-red instruments. These measures are an opportunity to qualify the Chemistry Transport Models (CTM) from which global daily realistic information for greenhouse gases can be routinely extracted.

Session 9a: Hyperspectral IR assimilation

9.01 What is the impact of IASI in global NWP?

Presenter: Vincent Guidard, CNRM-Meteo-France & CNRS

*Authors: V. Guidard, AD. Collar*d, S. Heilliette, F. Smith, B. Ruston, etc.

IASI is assimilated in global NWP models since june 2007. Since while, many NWP centres have made huge efforts to assimilate at most IASI. 10 years later, it is time to assess the impact of IASI on global analyses and forecasts. A intercomparison exercise has taken place among many centres on a 3 months period of 2015. Results will be presented.

9.02 Assimilation of Suomi-NPP/CrIS radiances into the JMA's global NWP system

Presenter: Norio Kamekawa

Authors: Norio Kamekawa, Masahiro Kazumori, JMA

The objectives of this presentation are to introduce the assimilation of CrIS radiance data for the operational global numerical weather prediction (NWP) system at Japan Meteorological Agency (JMA) and to show activities for enhanced use of Hyper Spectral Infrared Sounder (AIRS, IASI and CrIS) data.

Hyper Spectral Infrared Sounder radiance data from the CrIS on Suomi NPP spacecraft have been operationally assimilated into JMA global NWP system since March 2017. JMA obtains the CrIS 399-channel data set from the National Environmental Satellite, Data, and Information Service (NESDIS). 27 long-wave temperature sounding channels were selected for use in the assimilation. As Aqua/AIRS and Suomi NPP/CrIS use almost the same afternoon orbit, data thinning is necessary for the overlap region to reduce overfitting in the analysis. Normally, higher priority in the data thinning is assigned to CrIS because of its wider swath coverage (CrIS: 2,230 km; AIRS: 1,650 km). The priority in the data thinning depends on available channel numbers (i.e., clear-sky condition) and the distance between the observation location and the center of the thinning grid box. CrIS data for particular FOV (field of view) numbers (1, 3, 5, 7 and 9) are rejected for the assimilation due to their different biases from the other FOV data. The method of cloud top estimation and cloud screening for CrIS is based on an algorithm which is already implemented in the operational system for AIRS and IASI data processing.

Results of experiments to evaluate CrIS radiance data assimilation into JMA's global NWP system showed that the addition of CrIS long-wave temperature sounding channels clearly improved temperature analysis for the upper troposphere and stratosphere. Significant improvement in geopotential height forecast for the Southern Hemisphere was also confirmed.

As a future work, the increase of assimilated CrIS channels, update from RTTOV-10 to RTTOV-12 and utilization of water vapor channels of Hyper Spectral Infrared Sounder are planned. The status of these activities will be presented in the conference.

9.03 The use of reconstructed radiances to assimilate the full IASI spectrum at ECMWF
Presenter: Marco Matricardi, ECMWF
Authors: Marco Matricardi
At ECMWF we have tested the exploitation of the full IASI spectrum in the long and medium wave via the assimilation of reconstructed radiances. Six months of assimilation trials carried out using version 42R1 of the ECMWF model shows that in terms of background forecasts, the assimilation of reconstructed radiance produces impressive results above all for humidity sounding in the middle and upper troposphere, temperature sounding in the upper troposphere/stratosphere and ozone sounding. Although these results are extremely significant and encouraging, the temperature sounding in the middle and lower troposphere is still an issue though, the reconstructed radiance system failing to produce better background forecasts than the raw radiance operational system. This is an issue that will be addressed in the medium term starting with the introduction of newly formulated humidity background errors and possibly diagnosing new reconstructed radiance observation errors.

9.04 Impact of assimilating the VIIRS-based CrIS cloud-cleared radiances on hurricane forecasts
Presenter: Jun Li, SSEC/UW-Madison
Authors: Jun Li, Pei Wang, Zhenglong Li, Agnes H. N. Lim, Jinlong Li, Timothy J. Schmit, and Mitchell D. Goldberg
Hyperspectral infrared (IR) sounders have high vertical resolution atmospheric profile information, which improves the forecast skills in numerical weather prediction (NWP). However, IR sounder observations are mostly affected by clouds, usually clear radiances (not affected by clouds) from IR sounders are assimilated. The cloud-clearing (CC) technique, which removes the cloud effects from an IR cloudy field-of-view (FOV) and derives the cloud-cleared radiances (CCRs) or clear sky equivalent radiances (CSERs), is an alternative yet effective way to use the thermodynamic information in cloudy skies for assimilation. This study developed a Visible Infrared Imaging Radiometer Suite (VIIRS) based CC method for deriving Cross-track Infrared Sounder (CrIS) CCRs under partially cloudy regions. CrIS radiances and the collocated high resolution VIIRS cloud mask product and its radiances from IR bands are used together to derive the CrIS CCRs. Due to the lack of absorption bands in VIIRS, two important quality control (QC) steps are implemented in the CC process. The validation with VIIRS clear radiances indicates that the CC method can effectively obtain the CrIS CCRs for FOVs with partial cloud covers. To compare the impacts of original CrIS radiances and CCRs, experiments are carried out on Hurricane Joaquin (2015) and Hurricane Matthew (2016) using Gridpoint Statistical Interpolation (GSI) assimilation system, along with Weather Research and Forecasting (WRF) and Hurricane WRF (HWRF) models. At the analysis time, more CrIS observations can be assimilated in the system with CrIS CCRs than with original CrIS radiances, which leads to improved atmospheric fields than original radiances. Similar improved impacts are also observed in the forecast fields. The comparison of temperature and specific humidity with radiosondes indicates the data impacts are growing larger with longer time forecasts. The results of the hurricane track and intensity forecasts show that the assimilation of CrIS CCRs can improve the track forecast through the impacts on the weather system forecasts.

9.05 Impact of hyperspectral IR radiances on wind analyses
Presenter: Kirsti Salonen, ECMWF
Authors: Kirsti Salonen and Anthony McNally
In 4D-var data assimilation a trajectory of model states is fitted to the available observations. Model variables are linked through the model governing equations and physical parametrizations. Changes made to fit the humidity sensitive observations will result also in adjustment of the trajectory for the other model variables. For example, the wind field can be changed to advect humidity to and from other areas. This process is called wind tracing and it has been demonstrated with clear sky geostationary radiances as well as with microwave instruments in the all-sky framework. The upcoming hyper-spectral infrared instruments on board geostationary satellites will provide information with high temporal and vertical resolution. In order to understand the possibilities of this data from the wind tracing perspective, observing system experiments with the current hyper-spectral IR instruments on board polar orbiting satellites are performed. The presentation will discuss the results.

9.06 Feature-tracked 3D winds from hyperspectral infrared sounders: Status and requirements for future missions

Presenter: David Santek, SSEC/UW-Madison
Authors: D. Santek, D. Posselt, W. McCarty, W. Smith, C. Velden, T. Pagano, J. Taylor, H. Su, G. Matheou

The global measurement of 3D winds is recognized as an important dataset to improve medium- to long-range weather forecasts. At this time, vertical wind profiles through the troposphere are primarily from rawinsondes and aircraft ascents/descents, and are mostly confined to land areas. Wind information over mid- and low-latitude oceanic regions is limited to Atmospheric Motion Vectors (AMVs) from cloud and water vapor feature tracking using imagers on geostationary satellites. A similar technique is used with imagery from polar orbiting satellites over high-latitude regions. However, these geostationary and polar satellite-derived AMVs provide only single-level wind information at a particular geographic location.

To attain a 3D distribution of wind information, an AMV product has been prototyped based on tracking water vapor and ozone features retrieved from hyperspectral sounders. The retrievals produce spatial maps of humidity and ozone concentration on pressure surfaces throughout the troposphere and into the stratosphere, in clear sky and above clouds. An initial 3D AMV product, available in near real-time, is based on retrievals from the Aqua Atmospheric Infrared Sounder (AIRS).

The status of the project will be reported, along with a discussion on: (a) The retrieval algorithm and the 3D wind derivation technique as routinely applied to AIRS, and case studies from other sounders; (b) a detailed study of the sources of uncertainty in feature tracked winds; (c) assimilation statistics, forecast impact, and the outcome of Observing System Simulation Experiments (OSSE) to evaluate the impact of 3D winds in global numerical models. These results will serve to drive the requirements for future hyperspectral infrared instruments and missions, in terms of spatial resolution, instrument performance, retrieval attributes, and characteristics of the 3D AMV product, to realize an improvement in global numerical model forecasts.

Session 9b: Assimilation of IR observations

9p.01 The current impact of infrared radiances in the ECMWF NWP system

Presenter: Reima Eresmaa, ECMWF
Authors: Reima Eresmaa, Cristina Lupu

The European Centre for Medium-range Weather Forecasts (ECMWF) assimilates infrared radiances from four polar-orbiting satellites. There was a major revision to the operational use of Infrared Atmospheric Sounding Interferometer (IASI) and Cross-track Infrared Sounder (CrIS) radiances in November 2016. Substantial changes were made in observation error covariance specification and channel usage to significantly enhance the impact of the radiances on the NWP system performance. We will present an up-to-date assessment of the impact of each infrared sounder, based on standard observing system experiments (OSEs) and adjoint-based sensitivity diagnostics (FSOI).

Additionally to the impact of each sounder, contributions of various channel groups are investigated. Primary channel sensitivities range from mid-stratosphere to surface and they are known to contain useful information to constrain the analysis of temperature, humidity, and ozone mixing ratio. Considering the channel sensitivities, we have formed a total of seven channel groups and run a series of experiments to quantify the impact provided by each group. Among the carbon dioxide -sensitive long-wave channels, a substantial contribution is attributed to each of three groups with primary sensitivities to either stratospheric, upper- to mid-tropospheric, or lower-tropospheric temperature. Similarly among the water vapour -sensitive channels, both upper- and lower-tropospheric channels are found beneficial, even though the number of such channel in the active use is low. The impact contributions from ozone-sensitive channels and short-wave channels are more subtle.

9p.02 Preparing for CrIS full spectral resolution in the NCEP global forecast system

Presenter: James Jung, CIMSS/UW-Madison
Authors: James Jung and co-authors

We will discuss the various changes made to the NCEP Gridpoint Statistical Interpolation (GSI) software to accommodate the new CrIS full spectral resolution data available from the Suomi NPP. Several changes were made to the BUFR table to identify the FSR data and add potentially new capabilities. We will show results from updating the spatial thinning routine from incorporating cloud information from the Visible Infrared Imaging Radiometer Suite (VIIRS), computing the channel correlation matrix and using a new channel selection.

9p.03 CrIS channel selection for the KMA UM data assimilation based on an iterative method
Presenter: Eui-jong Kang, Seoul National University
Authors: Euijong Kang, B.J. Sohn, Hwan-Jin Song, Hyun-Sung Jang, Chu-Yong Chung
The Cross-track Infrared Sounder (CrIS) on the Suomi-NPP satellite launched in October 2011 consists of 1305 channels on three bands in the normal mode. For the efficient CrIS data dissemination, Gambarcorta (2013) proposed 399 selected channels to alleviate problems related to transmission, storage and computation process due to massive channels while preserving full channel capability. However, only 134 channels represent temperature, humidity and surface and are currently used for the data assimilation (DA) in the KMA UM model. Those channels may not be considered optimal for the data assimilation because 399 selected channels are mainly selected to preserve the information as much as resolved by all CrIS channels. Therefore, in this study we suggest a set of new channels relevant for the data assimilation, but with an iterative method of Rodgers (1996) and 1D-VAR approach. The results indicate that the new set of selected channels led to improved RMSE of temperature and humidity fields. Especially temperature in middle and upper troposphere is found to be substantially improved. We also suggest the optimal number of channels that might give best 1-D Var results.

9p.04 MTG-IRS level 2 data assimilation into the ECMWF model
Presenter: Kirsti Salonen, ECMWF
Authors: Kirsti Salonen and Anthony McNally
The Meteosat third generation (MTG) geostationary satellites will carry a hyper-spectral infrared sounder (MTG-IRS) instrument. EUMETSAT has developed a MTG-IRS level 2 (L2) processor to generate temperature, humidity and ozone retrievals. In the testing and evaluation phase, observations from the IASI instruments on METOP-A and B are used as a proxy. The L2 processor uses ECMWF model information as prior information about the atmospheric state and error covariance. In the post-processing stage the temperature and humidity retrievals are transformed into scaled projected state (SPS) observations which according to the theory are independent of the prior information used in the retrieval process. ECMWF is assessing the data quality and performing initial assimilation studies with the new EUMETSAT L2 retrievals. Latest results from the activities will be presented.

9p.05 Impact of assimilation of a new set of IASI channels on the UM precipitation forecast over East Asia
Presenter: Young-Chan Noh, Seoul National University
Authors: Young-Chan Noh, Byung-Ju Sohn, Jihoon Ryu, and Yoonjae Kim
This study attempts to assess the impact of data assimilation with new IASI channels selected by Noh et al. (2017) on the UM precipitation forecast over East Asia. We target to examine rain forecasting capability depending on the heavy rain types; (1) heavy rainfalls frequently observed over East Asia associated with relatively low-level cloud that may contain a small amount of ice crystal (referred to as warm-type rain) and (2) heavy rainfall occurring under convectively unstable conditions linked to the deep convective cloud system (referred to as cold-type rain). In order to assess the effect of a set of new IASI channels in the UM data assimilation system, the data assimilation trials were performed for the summer period from 15 June to 31 July 2015. Using the surface gauge data and cloud-to-ground lightning data, the heavy rainfall events for the summer of 2015 were classified into two rainfall types, based on the characteristics of cloud-rain system of each rain type. The accuracy of precipitation forecast at the experiment run with new IASI channels was found to be improved, particularly in the cases of warm-type heavy rainfall over East Asia. The improvement of the precipitation forecast accuracy is thought to be attributed to the additional water vapor channels sensitive to the tropospheric water vapor in the new set of IASI channels.

9p.06 Impact of assimilating multispectral radiances from Himawari and Meteosat satellites on global forecasts
Presenter: Alain Beaulne, Meteorological Service of Canada
Authors: Alain Beaulne, Louis Garand, Stéphane Laroche, Judy St-James
Water vapour (WV) clear-sky radiances (CSRs) from geostationary satellites are currently assimilated at the Meteorological Service of Canada (MSC) from a single channel (6.2-6.5 micron). Recently, CSR data from JMA's new-generation Himawari-8 in addition to second-generation Meteosat-8 were implemented into MSC data assimilation system in the same manner as previously, as a single water vapor channel. As a next step, the impact of assimilating radiances from three Himawari-8 water vapor channels, and two similar channels from Meteosat-8 and Meteosat-10 is evaluated using the operational

Global Deterministic Prediction System (GDPS) for the 2017 spring-summer season. With primary goal to improve humidity analyses, in a second experiment, a more strict control on humidity observations from radiosondes is also imposed. The observation thinning distance was set to 150 km and hourly CSR were assimilated in both experiments. The impact on forecasts up to five days is assessed against radiosonde observations and global analyses.

9p.07 Assimilation of geostationary radiances at ECMWF

Presenter: Chris Burrows, ECMWF
Authors: Chris Burrows, Julie Letertre-Danczak, Tony McNally

At ECMWF, geostationary radiances are assimilated from SEVIRI (Meteosat-8 and Meteosat-10); the Imager on GOES-13 and GOES 15; and AHI on Himawari-8. Currently, radiances from the water vapour channels are used exclusively, although the window channels are used to detect potentially cloudy scenes. This contribution will summarise various aspects of the assimilation methodology for geostationary radiances, with a particular focus on active lines of research: the impact of more aggressive use of observations at the edge of the disk will be covered, as observations for which the zenith angle is greater than 60 degrees are currently rejected. Also, progress towards an optimal thinning configuration will be presented. Furthermore, an initial investigation of inter-channel observation error correlations will be presented.

9p.08 Use of geostationary imager clear-sky radiances in Met Office Global NWP

Presenter: Ruth Taylor, Met Office
Authors: R.B.E.Taylor and P.N.Francis

Since the introduction of clear-sky radiance (CSR) information from the SEVIRI instrument aboard Meteosat-8 in 2010, the assimilation of geostationary imager radiances in the Met Office's global 4D-Var system has been extended to use cloud-cleared radiance products from an equatorial ring of five platforms. At the same time new instruments such as the Advanced Himawari Imager (AHI) have become operational, providing more detailed spectral information. Typically we now use hourly observations from two or three channels in the 6-7 micron region, providing middle- and upper-tropospheric humidity information, as well as longer-wavelength channels with surface sensitivity. This poster will summarise recent developments in geostationary CSR usage and examine the impacts of these observations.

9p.09 Comparison among three cloud-clearing radiance products

Presenter: Haixia Liu, IMSG @NOAA/NCEP/EMC
Authors: Haixia Liu, Andrew Collard, John Derber

Cloud clearing is the process of computing the clear column radiance (CCR) for each Cross-track Infrared Sounder (CrIS) channel by removing the cloud radiative effects. There have generally been three cloud-clearing methods developed for CrIS. All three methods make the assumption that the surface, atmospheric state and cloud formation characteristics are the same within one field of regard (FOR) or between two fields of view (FOVs) and only cloud fraction varies among adjacent pixels. They all require additional information to estimate a set of cloud-clearing parameters which are assumed to be independent of CrIS channels. The first CCR is from the NOAA-Unique CrIS-ATMS Processing System (NUCAPS). The second method is developed at Wisconsin by Li et al. (2016) to estimate CCR using collocated high spatial resolution imager measurements from Visible Infrared Imaging Radiometer Suite (VIIRS). NCEP has developed an inline cloud-clearing algorithm in their global data assimilation system (GDAS) and the CCRs are estimated together with all other observations. Theoretically the estimated CCRs at NCEP are constrained by all the observations being actively used in the data assimilation system.

In this presentation, the CCRs from the above-mentioned three methods will be compared. In addition, since the second CCR package includes the VIIRS cloud mask, a set of FORs can be identified which contain at least one clear FOV and therefore the three CCRs may be compared with the averaged radiances from the clear FOVs within the same FORs.

A month worth of VIIRS-based CCR data have been provided to be tested in the operational GDAS at NCEP. The impact of these CCR radiances on the global analysis and forecast skills will be reported at the conference.

9p.10 Assessing potential impact of air pollutants observations from geostationary satellite on air quality prediction through OSSEs

Presenter: Seon Ki Park, Ewha Womans University
Authors: Ebony Lee and Seon Ki Park

The Geostationary Environmental Monitoring Spectrometer (GEMS) which is a UV-visible scanning spectrometer is planned to be launched in 2019. The missions of GEMS are to monitor air quality and provide measurements of air pollutants over Asia continuously. It is expected that measurements from the GEMS will provide high spatiotemporal information to improve an air quality prediction. Therefore, we assess potential impact of the GEMS observation on air quality prediction through the observation system simulation experiments (OSSEs).

In this study, we perform the OSSEs using synthetic radiance observation of the GEMS. Based on some target air pollutants of the GEMS (e.g., O3 , NO2 , SO2 , HCHO, and aerosol), we choose several wavelengths to simulate synthetic radiances via a radiative transfer model. Assimilation of synthetic observation is conducted using a coupled meteorology-chemistry model (e.g., WRF-Chem). We will focus on stability of OSSE system and impact of GEMS observations on air quality prediction.

Session 10a: Land surface studies

10.01 Assimilation of tropospheric-sensitive infrared radiances over land

Presenter: Reima Eresmaa, ECMWF
Authors: Reima Eresmaa, Cristina Lupu, Tony McNally

We demonstrate a considerable benefit from assimilating tropospheric-sensitive infrared channels over land surfaces. We have found it useful to make a distinction between those channels that are sensitive to underlying surface and those that are not. With regard to the former, active use continues to be prevented by poor description of surface emission and associated difficulties in detecting clear fields-of-view. In contrast, when it comes to the latter group of channels, we now believe the cloud detection is sufficiently accurate for active assimilation over land. The distinction between the two groups is best done such that local orography and atmospheric state are taken into account.

Motivated by the role of surface-sensitive channels in constraining lower-tropospheric humidity over sea, we are continuing to work towards activating the remaining channels over land. The most promising line of development in this area is through enhanced use of collocated imager data, particularly the visible channel, although this approach is readily applicable only to Infrared Atmospheric Sounding Interferometer (IASI) radiances in the day time. Diagnostic measures suggest some benefit from the approach, but no consistent positive impact has been obtained in extensive assimilation experiments so far. Successful assimilation of land-surface-sensitive channels likely requires improved modelling of skin temperature.

10.02 Impact of dust aerosols on the retrieval of IR land surface emissivity spectrum: A new simultaneous approach accounting for dust characteristics and surface temperature from IASI

Presenter: Virginie Capelle, LMD/CNRS-Ecole Polytechnique
Authors: V. Capelle, A. Chédin, C. Crevoisier, R. Armante, L. Crepeau, and N. A. Scott

Land surface emissivity (LSE) spectrum is a key variable for improving earth surface-atmosphere interaction models, retrievals of meteorological profiles, surface temperature, as well as cloud and aerosol characteristics. An error of 0.05 in emissivity for channels in the thermal infrared may induce an error in the simulated brightness temperature larger than 1.5K, leading to potentially important misinterpretation in the estimation of surface energy fluxes and temperature. However, an accurate estimation of this variable requires precise knowledge of 1) the land surface temperature (LST) and 2) the atmospheric contribution (temperature and water vapour profiles, presence of clouds and/or aerosols). In general, inversion methods are developed for clear sky situations only, where pixels contaminated by clouds or aerosols are supposedly eliminated. The limit of such a procedure is the difficulty, above highly dust contaminated regions such as Sahara or Sahel, to unambiguously identify clear sky condition. First, dusty pixels can be considered as “clear”, leading to large errors in surface properties retrieval (a moderate dust aerosol layer of optical thickness 0.2 not detected leads to an error of more than 1K in LST and 0.05 in emissivity). Second, for such regions and some time periods, every pixel is potentially impacted by dust, preventing the determination of surface emissivity.

Here a new global monthly database of LSE spectrum has been derived from IASI by combining the simultaneous restitution of surface properties (LST&LSE) with the estimation of dust aerosols characteristics. A first estimation of LST and LSE are made applying the MSM method described in Capelle et al., 2012 and based on a physical inversion of the radiative transfer equation, developed for clear sky pixels only. This estimation doesn’t take into account the presence of aerosols. The aerosol properties are then retrieved independently using a Look-up-Table method developed for the simultaneous restitution of dust aerosols characteristics (optical depth, mean altitude) as well as of LST (Capelle et al., 2017, in rev.). The impact of dust on the surface emissivity and temperature restitutions is then parametrized monthly, allowing to reconstruct a gridded monthly emissivity spectrum at resolution 0.25°X0.25°, independent of dust, even for regions and/or seasons without any clear condition. Surface emissivity estimation has also been extended to all latitudes, including ice and snow, and calculated monthly for the entire IASI period (2007-now). Comparisons with other databases such as the UW/MODIS emissivity or the IASI-L2 emissivity will be presented, as well as day and night comparisons with other datasets of surface properties such as soil moisture or NDVI.

10.03 A dynamic infrared land surface emissivity atlas based on IASI retrievals
Presenter: Rory Gray, Met Office
Authors: Rory Gray
The radiative emission from the earth's surface is characterised by its skin temperature and spectral surface emissivity. Uncertainties in these properties limit the use of infrared sounders and imagers over land, for which a more accurate estimate of them is required. This is particularly important in limited area models, where the proportion of land surface is usually higher than in global models.

Hyperspectral IR sounders such as IASI allow exploitation of the spectral structure of surface emissivity. A high spectral resolution, near real-time global atlas of land surface emissivity using spectral emissivity retrievals from IASI has been created. The emissivity is retrieved in the form of a limited number of principal component weights in a 1D-Var pre-processor, simultaneously with skin temperature and atmospheric temperature and humidity profiles. The analysed surface spectral emissivity and skin temperature vary at each assimilation cycle, permitting the capture of more temporal variability than possible with a climatological emissivity atlas. The emissivity product is updated on an observation-by-observation basis, and is produced as a gridded dataset suitable for a range of applications. Verification has been performed against independent data sources.

Test and verification results are presented, and application to SEVIRI is demonstrated. The final product should prove beneficial to observations from other current and future instruments, including SEVIRI, HIRS, MTG-FCI and MetOp-SG.

Session 10b: Land surface studies

10p.01 Withdrawn

10p.02 The status of the Combined ASTER and MODIS Emissivity Over Land (CAMEL) product
Presenter: Eva Borbas, SSEC/UW-Madison
Authors: Eva Borbas, Michelle Feltz, Glynn Halley, Robert Knuteson and Simon Hook
As part of a NASA MEaSUREs Land Surface Temperature and Emissivity project, the University of Wisconsin, Space Science and Engineering Center with the NASA's Jet Propulsion Laboratory have developed a global monthly mean emissivity Earth System Data Record (ESDR) at 0.05-degree spacial resolution with high spectral resolution (between 3.6-14.3 µm). The CAMEL ESDR was produced by merging two current state-of-the-art emissivity datasets: the UW-Madison MODIS Infrared emissivity dataset (UWIREMIS), and the JPL ASTER Global Emissivity Dataset v4 (GEDv4). The dataset is currently being tested in sounder retrieval schemes (e.g. CrIS, IASI) and has already been implemented in RTTOV-12 for immediate use in numerical weather modeling and data assimilation.

10p.03 MACSSIMIZE: An upcoming campaign to focus on the development and evaluation of Arctic snow emissivity models suitable for use in assimilation of satellite microwave sounder data
Presenter: Chawn Harlow, Met Office
Authors: Chawn Harlow
It has been well established that the polar regions are currently undergoing rapid changes in sea ice properties (eg. area cover, thickness, meltpond occurrence, etc.) as well as changes in terrestrial snow and permafost due to Earth's changing climate. The changes in the cryosphere impact the local radiation, moisture, heat and momentum exchange with the atmosphere. Some of these atmospheric changes have been found in previous studies to impact mid-latitude weather and climate but the degree to which this occurs is dependent on currently uncertain cryospheric and PBL dynamical processes in polar regions amongst others. In addition there is uncertainty in the current state of the polar atmosphere and cryosphere due to pausity of conventional observations over these regions. The ability to use microwave and infrared satellite sounder data from instruments such as the AMSU's and IASI's to fill this gap in the conventional observations is limited by understanding of the surface temperature and emissivity, particularly for channels containing information about the lower toposphere where these surface-atmospheric interactions occur. As part of the World

Meteorological Organisation's Year of Polar Prediction (YOPP) project, the Met Office is planning to undertake a joint airborne-ground-based field campaign in late winter of 2018 in order to further constrain some of these uncertainties in the polar climate system. This campaign is called Measurements of Arctic Clouds, Snow and Sea Ice in the Mariginal Ice ZonE (MACSSIMIZE). During MACSSIMIZE, the Met Office hopes to obtain novel observations from the Arctic of surface emissivity, surface and boundary-layer processes, cloud microphysics and aerosols, and orographic flows and their leeside impacts. This presentation will focus on the snow and sea ice emissivity objectives and methodology for MACSSIMIZE. The novel instrumentation available on MACSSIMIZE should allow evaluation of snow microwave emission models in the 20-200 GHz frequency range to degrees of certainty greater than that achieved in the past. The ground-based snow pit measurements will provide snow microstructural and thermodynamic measurements that will be used to improve snow physical models for use in future NWP models. Such models should produce a model formulation able to generate snow stratigraphic sequences typical of Arctic snow conditions for the first time. Coupling such snow emissivity and physical modules into an NWP model will allow the production of a forward model useful for assimilation of microwave sounder data over the polar regions.

10p.04 The current forecast impact of surface-sensitive microwave radiances over land and sea-ice in the ECMWF system

Presenter: Niels Bormann, ECMWF
Authors: Niels Bormann, Cristina Lupu, Alan Geer, Heather Lawrence, Peter Weston and Stephen English

The current forecast impact of surface-sensitive microwave sounder radiances over land and sea-ice has been assessed in the ECMWF system. The assimilation relies on surface emissivities retrieved from window channel observations. Short-comings of the current approach to use the data in specific regions are also highlighted.

Surface-sensitive microwave radiances over land and sea-ice have a significant positive forecast impact (2-3 % reduction in forecast error for the 500 hPa geopotential over the extra-tropics). When added incrementally to an otherwise full observing system, observations over sea-ice, humidity-sounding radiances over land, and temperature-sounding radiances over land all contribute significantly to this positive forecast impact. The impact shows some seasonal dependence, and the Northern Hemisphere impact over land is smaller during winter, most likely related to a more restricted and less optimal use of the observations over snow.

Short-comings are nevertheless apparent in specific areas. Desert regions show diurnal biases, most likely due to biases in the temperature used to specify surface radiation, likely arising from a combination of penetration effects and diurnal model biases. Snow-covered regions show biases that appear consistent with assuming specular reflection when diffuse reflection is prevalent. The quality control currently applied is mostly successful in protecting the analysis from the deficiencies in these areas. Neglected cloud signals can have a significant effect on the retrieved emissivities and the subsequent quality control.

10p.05 The characteristics of the real-time land surface emissivity of the ATMS data for numerical weather prediction model

Presenter: Jisoo Kim, Ewha Womans University
Authors: Jisoo Kim, Myoung-Hwan Ahn, Chu-Yong CHUNG

Assimilation of satellite observation to the numerical weather prediction (NWP) model contributes to reduction of forecast errors. However, there are some limitations in utilizing the microwave observation data over land due to its high variability of the surface characteristics and high emissivity which makes difficulty in distinguishing the land contribution with atmospheric contribution. In this study, we retrieve the real-time land surface emissivity of the Advanced Technology Microwave Sounder (ATMS) data for a better utilization of microwave satellite observation to the data assimilation process. The real-time emissivity is derived from ATMS data with auxiliary information obtained from the radiative transfer model (RTM). The Unified Model of the Korea Meteorological Administration’s operational NWP model provides atmospheric information needed to RTM simulation. The real-time emissivity is characterized by comparison with the prescribed climatological emissivity. As a comparison result, the real-time emissivity shows a significant improvement in the first guess departures; the reduction of bias which means increased number of observation can pass the quality control and can be assimilated. And the variation of the real-time emissivity to frequency and satellite zenith angle is studied. Further, the uncertainty in the calculation of the real-time emissivity was studied. The errors in the data we used and the uncertainties in RTM calculation can propagate to the retrieved emissivity. As a result, the skin temperature and the observation data are the most affective variables in calculation of the emissivity.

10p.06 Increased use of microwave humidity sounding data from the FY-3 series in the ECMWF assimilation system

Presenter: Keyi Chen, Chengdu University of Information & Technology

Authors: Keyi Chen, Niels Bormann, Stephen English, Jiang Zhu

ECMWF has been assimilating the FY-3B MWHS (Microwave Humidity Sounders) data over sea in the operational forecasting system since September 24th, 2014 and the FY-3C MWHS-2 data since April 4th, 2016. Here we study the introduction of more microwave humidity sounding data from these two instruments, namely the introduction of MWHS data over land, and the addition of MWHS-2 data from DBNet.

For assimilating MWHS/FY-3B observations over land, we compare approaches in which the emissivity is retrieved dynamically from MWHS channel 1 (150GHz (V)) with the use of an evolving emissivity atlas from 89 GHz observations from the Microwave Humidity Sounders (MHS) on NOAA and EUMETSAT satellites. The assimilation of the additional data over land improves the fit of short-range forecasts to other observations, notably ATMS humidity channels, and the forecast impacts are mainly neutral to slightly positive over the first 5 days. The forecast impacts are better in boreal summer and the Southern Hemisphere.

To improve the amount of available MWHS-2 data, we also consider the addition of DBNet data with much improved timeliness. This data is currently available from five stations around Europe. After excluding observations for the first and last few scan-lines of an overpass, the DBNet MWHS-2 data are overall consistent with the global data. Due to the improved timeliness, the data coverage is highly improved for the short cut-off assimilation window. It is therefore planned to add the FY-3C DBNet MWHS-2 observations to the ECMWF operational forecasting system in the next version upgrade in late 2017.

10p.07 Surface skin temperature for satellite data assimilation

Presenter: Cristina Lupu, ECMWF

Authors: Cristina Lupu, Tony McNally, Massimo Bonavita

Knowledge of the surface temperature is important to assimilation of radiances providing information on temperature and humidity in the lower troposphere. For the open ocean the sea surface temperature is usually known to within 1K, with low bias and assimilation has proven very successful. However, for land and sea ice areas the uncertainty in the surface temperature can be much higher and can pose a bigger challenge for the assimilation of surface-sensitive data over these regions. In the current data assimilation system the surface skin temperature is retrieved for each satellite sounding during the 4D-Var assimilation and act as a sink variable in the analysis. This estimate is independent from other atmospheric variables in the background error covariance and from the skin temperature at other locations. Work towards improving the handling of skin temperature for satellite data assimilation has started. Different approaches will be discussed, such as using sample statistics from an Ensemble of Data Assimilations (EDA) to estimate background error variances for skin temperature sink variable instead of the constant values currently specified over different surfaces and using the ECMWF model surface temperature instead of skin temperature sink variable.

10p.08 Assimilation of land surface skin temperature observations derived from GOES imagery

Presenter: Sylvain Heilliette, Environment Canada

Authors: Sylvain Heilliette, Louis Garand, Bernard Bilodeau, Marco Carrera, and Stéphane Bélair

Progress was accomplished at ECCC in the assimilation of surface sensitive radiances over land (Dutta et al, 2016, JAMC). However, that assimilation does not influence the analysis of surface skin temperature Ts, i.e. Ts increments are ignored. In view of reducing that inconsistency, the Canadian Land Surface Analysis System (CALDAS) is used to evaluate the impact in forecasts of assimilating GOES-derived Ts observations over land. The resolution of the model is 10 km and the domain covers North America and adjacent oceans. A 1D-var approach is used for the Ts retrieval using up to four infrared channels. GOES-E and GOES-W retrievals are assimilated at 3-h interval over a two-month summer period. The impact in forecasts up to 48-h is evaluated in comparison to the operational system which assimilates SMAP brightness temperatures and 2-m temperature and humidity observations using an ensemble Kalman filter approach. The sensitivity to the Ts observation and model errors is evaluated for optimization of the impact. The next step is to assimilate surface sensitive radiances in the atmospheric analysis together with the Ts observations in CALDAS.

10p.09 Implementation of a real-time Level 2 SEVIRI processor for the simultaneous physical retrieval of surface temperature and emissivity at global scale

Presenter: Guido Masiello, Università degli Studi della Basilicata

Authors: Guido Masiello, Carmine Serio, Giuliano Liuzzi, Sara Venafra, Maria Grazia Blasi

The real-time continuous monitoring of surface parameters is very important for different applications, like risk management, natural hazards and land surveillance. Geostationary platforms allow to provide series of satellite observations with a very high temporal resolution, able to resolve the diurnal cycle and to catch seasonal variability. In this work the development of a very fast multi-temporal and multi-spectral Level 2 processor is described. The processor exploits SEVIRI (Spinning Enhanced Visible and Infrared Imager) infrared radiances (8.7, 9.7, 10.8 and 12 µm) to retrieve surface temperature and emissivity simultaneously by means of a fast forward radiative transfer model (σ-SEVIRI) and an inversion procedure based on the Kalman filter approach. Further details on the adopted methodology are reported in recent works (Masiello et al. 2013 doi:10.5194/amt-6-3613-2013), together with validation exercises at regional and global scale both against in situ, analysis and equivalent satellite observations (Masiello et al. 2015 doi:10.5194/amt-8-2981-2015; Blasi et al. 2016 doi: 10.3369/tethys.2016.13.13). The software is capable to run in real-time also thanks to a code optimization and the usage of parallel computation. In detail, a single SEVIRI full disk slot time (15 minutes) can be processed in about 16 minutes exploiting 20 threads, providing surface temperature and emissivity estimations on land surface.

10p.10 Use of surface observations as pseudo channels for improving AIRS temperature and moisture retrieval

Presenter: Hyun-Sung Jang, Seoul National University

Authors: Hyun-Sung Jang, Byung-Ju Sohn, and Jun Li

Using a linear regression model for AIRS temperature and moisture retrievals, we examined the impact of use of surface observations in the soundings. In doing this, two regression models are constructed. One uses AIRS radiances as predictors for retrieving temperature and moisture profiles, while the other additionally uses temperature and moisture observations from surface weather stations. From the use of surface observations in the regression model, it is noted that contributions by window, lower temperature and lower water vapor channels are all changed, in which contributions from lower water vapor channels are notable. It can be interpreted that the information of lower water vapor channels is relatively unstable and surface observations affect the retrieval performance through modifying the contribution of these channels. Applying surface observations in the AIRS sounding results in improved retrieval performance not only at surface level where surface station is located, but also over the boundary later above the surface station. In other words, the use of surface observations can help better resolve the vertical structure of temperature and moisture near the surface layer by alleviating the influences of incomplete channel weighting functions near the surface on the retrieval. From this experiment which uses Automatic Weather Station (AWS) data over the Korean Peninsula collocated with AIRS measurements, it is noted that root mean square errors of temperature and relative humidity are improved by up to 1 K and 8% point, respectively.

10p.11 Assessment of soil wetness variation for extreme events using direct broadcast receiving system at IMD

Presenter: Ashim Mitra, India Meteorological Department

Authors: A.K. Mitra and Shailesh Parihar

Satellite remote sensing of soil related content for hydrological purposes have been considerably studied and developed over past three decades. This soil estimation by means of remote sensing depends upon the measurements of electromagnetic energy that has either been reflected or emitted from the soil surface and are accessible to remote sensing through measurements at the thermal infrared and microwave wavelengths. Recent advances in remote sensing, in the last few years, have shown that microwave techniques have the ability to measure soil moisture/wetness monitoring under a variety of topographic and vegetation cover conditions quantitatively. This is due to the all-weather and all-time capability of these data, as well as to their high sensitivity to water content in the soil.

The Soil Wetness Estimation (SWE) has been computed from the data acquired by real time direct broadcast (DB) receiving system installed at three places of India Meteorological Department (IMD) using microwave radiometer AMSU (Advanced Microwave Sounding Unit), flying aboard NOAA (National Oceanic and Atmospheric Administration) polar satellites. A multi-temporal analysis of AMSU channel 15 (at 89 GHz) and channel 1 (at 23 GHz) have been used to find the variation of SWE. In the present analysis, the proposed SWE indicator has been very well brought out the soil wetness changes specifically for the flood event which could give some indication of early 'signals' of an anomalous value of soil water content. In order to improve the forecast capabilities over the tropics, SWE approach is found to be promising for operational use.

10p.12 The Joint Land Data Assimilation System (JLDAS)
Presenter: Chunlei Meng, Institute of Urban Meteorology, CMA
Authors: Chunlei Meng; Dongmei Song
An integrated urban land model (IUM) was developed based on the Common Land Model (CoLM), which integrates the urban land model with the common land model, extends the research scales of land models. A joint land data assimilation system was developed based on IUM, which can assimilate the land surface parameters in both urban and non-urban underlying surfaces, improves the model's performance, and expands the theory and application of data assimilation. A simplified variational assimilation method was used to assimilate the soil moisture and the land surface temperature both in natural and urban land surfaces. The atmospheric forcing data from Global Land Data Assimilation System (GLDAS) was used to forcing the IUM. A mosaic scheme was used to assimilate the land cover and land use (LULC) data. The nighttime light data provided by NOAA DMSP/OLS was used to parameterize the spatial distribution of anthropogenic heat release (AHR). A quality control (QC) method was used to assimilate the snow cover fraction (SCF) and snow water equivalent (SWE) data retrieved from Fengyun satellite simultaneously. MODIS leaf area index (LAI) and albedo data was also assimilated into JLDAS as the forcing variables.

Session 11a: Retrieval products

11.01 The EUMETSAT operational IASI L2 products and services, from global to regional
Presenter: Thomas August, EUMETSAT
Authors: T. August, T. Hultberg, M. Crapeau, A. Burini, D. Klaes, C. Clerbaux, P. Coheur
The EUMETSAT operational IASI level 2 (L2) product processing facility (aka PPF) provides single-pixel based products globally, including temperature and humidity profiles, surface skin temperature and land surface emissivity, cloud detection and characterisation (height, coverage) as well as a number of atmospheric composition products. For temperature and humidity sounding, the IASI L2 PPF implements a two-step approach with first a statistical retrieval followed by an optimal estimation (OEM).

We present here the experience made with the products since the release of the version 6 (v6) [August et al., ITSC-20] in September 2014 and in particular since the introduction of the latest revisions v6.2 (June 2016) and v6.3 (June 2017). In the v6, the first step statistical retrieval exploits collocated microwave measurements from the companion instruments AMSU-A and MHS in synergy with the IASI measurements, using a piece-wise linear regression algorithm (PWLR). As a result, temperature and water-vapour soundings are provided in about 85% of the IASI pixels, including cloudy conditions. Since v6.2, the retrieval algorithm exploits measurements in adjacent pixels to take advantage of the horizontal correlation of the atmospheric signals [PWLR3, Hultberg et August, ITSC-20]. The subsequent OEM retrieval is applied in clear sky and is IASI-based only, exploiting most of the spectral information in bands 1 and 2 through reconstructed radiances after principal components analysis. The typical precision reached ranges 0.7-1K in clear-sky for most of the troposphere and of about 1-1.5g/kg for water-vapour depending on the actual moisture content. We show that the sounding products from the PWLR3 perform comparably to the retrievals from the OEM.

In addition, a new land surface emissivity product is available since the introduction of v6.2, which are also generated with the PWLR3 algorithm. We show that observations (OBS) are better fitted with calculated (CALC) radiances by using the PWLR3 temperature, humidity and ozone profiles together with the surface skin temperature and land surface emissivity products than with numerical model fields and static climatological atlas. Finally, the v6.3 consolidates and introduces new atmospheric composition parameters, including CO profiles, SO2 columns and also a dust index which can be used for quality flagging and data selection.

The computational efficiency of the PWLR3 is compatible with regional Users needs to have timely description of the atmosphere. A new regional service extending EARS-IASI to include Level 2 has been running since November 2016. It is based on the joint MW+IR retrievals with the

PWLR3 and provides L2 products within 30 minutes from sensing. We present the EARS-IASI L2 service and introduce the plans and preliminary results of using this service after one year in operations.

11.02 Status of the NPP and J1 NOAA Unique Combined Atmospheric Processing System (NUCAPS) for atmospheric thermal sounding: Recent algorithm enhancements and near real time users applications

Presenter: Lihang Zhou (for Antonia Gambacorta), NOAA

Authors: Antonia Gambacorta, Nick Nalli, Thomas King, Flavio Iturbide-Sanchez, Changyi Tan, Kexin Zhang, Michael Wilson, Bomin Sun, Xiaozhen Xiong, Christopher Barnet, Ashley Wheeler, Nadia Smith, Lihang Zhou, Walter Wolf, Tony Reale, Mitch Goldberg

NUCAPS is the NOAA operational algorithm to retrieve thermodynamic and composition variables from hyper spectral thermal sounders such as CrIS, IASI and AIRS. The combined use of microwave sounders, such as ATMS, AMSU and MHS, enables full atmospheric sounding of the atmospheric column under all-sky conditions. The full suite of retrieval products comprises of skin temperature, cloud parameters and vertical profiles of temperature, water vapor and trace gases such as: ozone, methane, carbon monoxide, nitric acid, nitrous oxide, sulfur dioxide and carbon dioxide. NUCAPS retrieval products are accessible in near real time (about 1.5 hour delay) through the NOAA Comprehensive Large Array-data Stewardship System (CLASS). Since February 2015, NUCAPS retrievals have been also accessible via Direct Broadcast, with unprecedented low latency of less than 0.5 hours.

NUCAPS builds on a long-term, multi-agency investment on algorithm research and development. The uniqueness of this algorithm consists in a number of features that are key in providing highly accurate and stable atmospheric retrievals, suitable for real time weather and air quality applications, as well as long-term climate studies.

Firstly, maximizing the use of the information content present in hyper spectral thermal measurements forms the foundation of the NUCAPS retrieval algorithm. NUCAPS employs a sequential approach of retrieval steps based on an iterated, regularized and weighted optimal estimation approach. The sequential methodology aims at minimizing the dependence on the geophysical a priori and the sources of non-linearity affecting the retrieval problem. This feature is key when it comes to provide an independent measurement of the atmospheric state that can depart from the existing background knowledge, provide additional context to weather forecast and ultimately serve as a test bed for global circulation models. Secondly, NUCAPS is a modular, name-list driven design. It can process multiple hyper spectral infrared sounders (on Aqua, NPP, MetOp and JPSS series) by mean of the same exact retrieval software executable and underlying spectroscopy. This feature plays a critical role in providing additional, yet consistent, atmospheric measurements that can fill in for the temporal and spatial gaps left uncovered by the often-sparse networks of in situ measurements. Third, a cloud-clearing algorithm and a synergetic use of microwave radiance measurements enable full vertical sounding of the atmosphere, under all-sky regimes. This feature is key in removing the clear-sky bias that is typically found in infrared-only retrieval algorithms. It also maximizes the information provided on the atmospheric vertical structure that can complement the measurement acquired in the visible domain.

As we transition towards improved hyper spectral missions, assessing retrieval skill and consistency across multiple platforms becomes a priority. Focus of this presentation is geared towards an overview of the NUCAPS retrieval methodology and improved environmental applications of societal benefits.

11.03 Single footprint all-sky retrievals using a fast, accurate TwoSlab cloud representation

Presenter: Sergio DeSouza-Machado, UMBC

Authors: Sergio DeSouza-Machado, Larrabee Strow

We have developed a fast, accurate package to simulate cloudy radiances, using a TwoSlab cloud representation with our SARTA scattering code. The package is applied toward single footprint retrievals of AIRS L1b radiances, using the Optimal Estimation method. The retrieval is linearized with respect to clouds using nearby ECMWF cloud fields that nominally match the observed radiances. The computed degrees of freedom are shown to vary linearly with window channel observations, demonstrating the retrieval is using the information in the AIRS radiances. Comparisons are made against AIRS L2 and ECMWF model fields. We also use the scattering code to present retrieved geophysical and cloud trends using 15 years of trended AIRS nadir radiance data.

11.04 Combining polar hyper-spectral and geostationary multi-spectral sounding data – A method to optimize sounding spatial and temporal resolution

Presenter: William Smith, SSEC/UW-Madison
Authors: W. L. Smith Sr., E. Weisz, and J. McNabb

A method is developed for combining polar orbiting Direct Broadcast Satellite (DBS) hyper-spectral soundings with geostationary orbiting satellite multi-spectral soundings in order to optimize the spatial and temporal resolution of the derived products. The method is applied to the combination of Direct Broadcast Satellite CrIS and IASI hyper-spectral data and real-time GOES-16 Advanced Baseline Imager (ABI) multi-spectral data. It is shown that the combined sounding products have greater spatial resolution than that provided by either satellite system alone with the temporal resolution of the geostationary satellite multi-spectral imager. The accuracy of the derived products is validated using NASA ER-2 airborne Scanning High-resolution Interferometer Sounder (SHIS) data, which are provided at the horizontal resolution of the ABI and the vertical resolution of the satellite hyper-spectral sounders. The intent of the combined DBS polar and geostationary sounding products is to support real-time severe weather forecast applications.

Session 11b: Retrieval products and applications

11p.01 Overview of JPSS-1 and Suomi NPP ATMS SDR and EDR products

Presenter: Quanhua (Mark) Liu, NOAA/NESDIS/STAR
Authors: Quanhua (Mark) Liu, Hu Yang, Ninghai Sun, Christopher Grassotti, Lin Lin, and Fuzhong Weng

Suomi NPP Advanced Technology Microwave Sounder (ATMS) has been operational since 2012. The ATMS is a cross-track scanner with 22 channels and provides sounding observations for atmospheric temperature, moisture, and clouds, as well as surface temperature, snow and ice. All channels are sampled every 1.1º at 96 scan positions, with a cross track swath width of about 2600 km, significantly wider than AMSU-A or MHS. ATMS channels 1 and 2 have a large beam width (low spatial resolution) of 5.5 degrees; channels 3 to 16 have a medium beam width of 2.2 degrees; and channels 17 to 22 have a small beam width of 1.1 degrees.

In this presentation, we will present the JPSS-1 ATMS performance such as noise, bias, channel noise correction, and others.

We will also show the ATMS products. Using the ATMS data, NOAA Microwave Integrated Retrieval System (MiRS) operationally generates atmospheric profiles of temperature and water vapor, cloud liquid water, ice water content, rainfall rate, snow cover and snow water equivalent, snow fall rate, surface temperature and microwave emissivity, and sea ice concentration. The MiRS is based on 1D-VAR retrieval algorithm which includes the Community Radiative Transfer Model (CRTM) for computing radiances and the gradient of radiance (or Jacobian), and a scheme for minimizing the cost function that weighs the relative contribution of background (a priori) information and satellite observations.

There are a number of recent improvements to the MiRS system. The snow water equivalent retrieval is improved by the implementation of forest fraction emissivity correction. The light rain detection over land is improved by adding cloud liquid water (CLW) and rain water path (RWP) into the rain rate formula. By Implementing new land surface background covariance based on updated CRTM and ECMWF analysis data, the retrieved land surface emissivity are largely improved in comparing with analytical emissivity based on ECMWF data. Both the retrieved temperature and water vapor profiles over ocean are improved by using the atmospheric covariance matrices based on ECMWF 137 level dataset. MiRS is also extended to GPM/GMI. The MiRS retrieval based on GPM/GMI has become operational. TPW retrieval over land based on GPM/GMI data is largely improved by adjusting the MiRS Tuning file.

11p.02 Exploitation of hyperspectral sounder and microwaves sounder data products generated at NOAA/NESDIS

Presenter: Awdhesh Sharma, NOAA/NESDIS
Authors: Dr. A.K. Sharma

Recently, the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite Data and Information Service (NESDIS) has made significant improvements for retrieving atmospheric soundings using the high spectral resolution infrared and advanced microwave sounders data from the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) instrument on board the Suomi-National Polar-orbiting Partnership (S-NPP) and the Infrared Atmospheric Sounding

Interferometer (IASI) which resides on the European Space Agency's (ESA) Metop series of polar-orbiting satellites.

This series of advanced operational sounders CrIS, in conjunction with ATMS, provides more accurate, detailed atmospheric temperature and moisture observations for weather and climate applications. Currently, the level 2 data products from S-NPP and IASI from Metop-A and Metop-B satellites include temperature and humidity profiles, trace gases such as ozone, nitrous oxide, carbon dioxide, and methane, and the cloud cleared radiances (CCR) on a global scale and these products are routinely made available to the operational user community. Higher (spatial, temporal and spectral) resolution and more accurate sounding data from CrIS and ATMS support continuing advances in data assimilation systems and NWP models to improve short- to medium-range weather forecasts.

In an effort to ensure consistent levels of service for product monitoring and data quality assurance of the NOAA Unique Combined Atmospheric Processing System (NUCAPS) data products, the Office of Satellite and Product Operations (OSPO), has developed and implemented new innovative tools (including webpages for displaying analyses) in the ESPC operation that have made significant improvements in the diagnosis and resolution of problems when detected in the operational environment. The OSPO webpages have been extended to include the CrIS/ATMS SKEW-T (Logarithmic Pressure vs Temperature and Dew Point Temperature) sounding plots over the CONUS region. These pages are updated every hour to show the latest soundings from NUCAPS and IASI.

This presentation will showcase several of these tools that have been developed and deployed for the sounding products monitoring and data quality assurance maintenance and sustainment within the Environmental Satellites Processing Center (ESPC) operational environment. The presentation will also include a discussion on the ESPC system architecture involving sounding data processing and distribution for CrIS and IASI sounding products as well as the improvements made for data quality measurements, granule processing and distribution, and user timeliness requirements envisioned from the next generation of JPSS, Metop-C, and GOES-R satellites. There have been significant changes in the operational system due to system upgrades, algorithm updates, and value added data products and services.

11p.03 Retrieval of temperature and water vapor vertical profile from ATMS measurements with Random Forests technique

Presenter: Francesco Di Paola, IMAA-CNR
Authors: F. Di Paola, A. Cersosimo, D. Cimini, D. Gallucci, S. Gentile, S. T. Nilo, E. Ricciardelli, F. Romano, M. Viggiano

The Advanced Technology Microwave Sounder (ATMS) is the polar orbiting microwave sounder currently flying on the Suomi National Polar-orbiting Partnership (NPP) satellite mission. It is a cross-track scanner with 22 channels that provides sounding observations useful to retrieve temperature (T) and water vapor (WV) atmospheric vertical profile in nearly-all-weather conditions, for operational weather and climate applications. Using spatial and temporal coincidences between ATMS observations and the global ECMWF atmospheric reanalysis ERA-Interim dataset (with 0.75° horizontal resolution and 6-hour temporal resolution), a training dataset for machine learning purpose was built for the whole 2016. In detail, for each ATMS acquisition, 37 levels of T (between 1 and 1000 hPa), and 27 levels of WV (between 100 and 1000 hPa), are used to train an algorithm based on Random Forests (RF) regression technique. Considering that the sounding below the precipitation level becomes unreliable, the precipitation-affected observations were removed from the training dataset by means of a pre-screening test based on Brightness Temperatures (BT). A single RF was trained for each level and variable, using a k-fold statistic approach to optimize the input selection and minimum leaf size parameter, to avoid overfitting problem and obtain an accurate retrieval. The algorithm was finally validated against ERA-Interim 2015 dataset, showing profiling performances in line with expectations for both T and WV at all the pressure levels.

11p.04 Experimenting different a priori sources for optimal estimation retrievals with IASI

Presenter: Marc Crapeau, EUMETSAT
Authors: M. Crapeau, T. August, T. Hultberg, A. Burini

We present here different choices of a priori and first guesses as input to an optimal estimation (OEM) retrieval from IASI measurements. The test bed is the EUMETSAT operational IASI Level 2 (L2) processor which implements a two-step retrieval approach to generate the sounding products.

Since the release of the version 6 (v6) [August et al., ITSC-19], a statistical retrieval method is applied, which nominally also exploits IASI observations in synergy with collocated microwave measurements from the companion instruments AMSU-A and MHS on-board Metop. This implements a piece-wise linear regression algorithm [PWLR3, Hultberg et August, ITSC-20] which is applied in clear-sky and in most cloudy situations. The retrieved geophysical parameters include temperature, humidity, ozone, surface temperature, land surface emissivity. They are provided with corresponding quality indicators.

In cloud-free pixels, as assessed with cloud detection functions with the L2 processor, an optimal estimation method [OEM, Rodgers 2000] is subsequently invoked, which exploits IASI measurements only. It is initialised with the first-step statistical retrieval, to update the surface skin temperature and the temperature, humidity and ozone profiles.

In the experiments presented here, the baseline OEM is configured with different inputs in turn, including the above statistical retrieval, numerical model forecasts and also deliberately inaccurate prior information, to evaluate the relative impact of the prior to the posterior state vector, on the convergence and the potential resilience to inaccurate prior estimates. The products evaluation is performed by comparing the temperature and humidity profiles to numerical model analyses and to in situ sonde measurements.

11p.05 Hyper-spectral sounder derived severe weather indices
Presenter: William Smith (for Elisabeth Weisz), SSEC/UW-Madison
Authors: Elisabeth Weisz, William Smith Sr.
Advanced sounding instruments (AIRS, IASI, CrIS) onboard polar-orbiting satellites provide high spectral resolution infrared measurements that can be turned into accurate and high vertical resolution temperature and humidity profiles. This information can be used to evaluate the atmospheric stability in the pre-convective storm environment by investigating severe weather indices such as the lifted index and the convective available potential energy for the use in weather monitoring and forecasting operations. These retrieval products prove valuable in the assessment of atmospheric conditions favorable to severe weather, and are found to complement the information from conventional surface and upper air data networks, satellite imagery and numerical weather prediction models.

11p.06 Combining imager and lightning for enhanced GOES-R rain estimates in the NWS Pacific Region
Presenter: Nai-Yu Wang, University of Maryland/ESSIC, NOAA/NESDIS/STAR
Authors: Nai-Yu Wang, Yalei You, Patrick Meyers
Precipitation estimates from geostationary satellites provide the rapid temporal update desired by the operational meteorologists to capture the growth and decay of precipitating cloud systems on a scale of several kilometers. The launch of the Geostationary Operational Environmental Satellite-R Series (GOES-R) ushered a new era of geostationary satellite withthe 16 channel Advanced Baseline Imager (ABI) and the Geostationary Lightning Mapper (GLM) and the ability to takefull-disk images of Earth at five-minute intervals. A combined IR and lightning convective features and precipitation algorithm for the Pacific Region is being developed using geostationary JMA’s Himawari-8infrared and ground lightning network GLD360 lightning observations. Following the heritage of an IR-lightning combined precipitation algorithm over land (Xu, Adler, and Wang 2013, 2014), the Pacific Ocean region IR and lightning convective feature and precipitation algorithm uses a combination of an IR-based C/S technique (CST), multi-channel cloud information, and lightning information to identify deep convection cores and estimates rainfall rates. This study presents an overview of an oceanic IR-lightning Convective feature and precipitation algorithm, case studies, and provides some thoughts on the next step improvements.

11p.07 The Suomi-NPP VIIRS total precipitable water product
Presenter: Eva Borbas, SSEC/UW-Madison
Authors: Eva Borbas, Zhenglong Li, Paul Menzel and Matyas Rada
The goal of the Soumi NPP VIIRS Moisture Project is to provide total column water vapor (TPW) properties from merged VIIRS infrared measurements and CrIS plus ATMS water vapor soundings to continue the depiction of global moisture at high spatial resolution started with MODIS.

While MODIS has two water vapor channels within the 6.5 µm H_2O absorption band and four channels within the 15 µm CO_2 absorption band, VIIRS has no channels in either IR absorption band. The VIIRS/CrIS+ATMS TPW algorithm being developed at CIMSS is similar to the MOD07 synthetic regression algorithm. It uses the three VIIRS longwave IR window bands in a regression relation and adds the NUCAPS (CrIS+ATMS) water vapor product to compensate for the absence of VIIRS water vapor channels.

This poster presents the evaluation of the S-NPP TPW Level 2 and 3 products with TPW data from ground-based and satellite-based measurements.

11p.08 Application of cumulative probability distribution function to compositing precipitable water with Low Earth Orbit satellite data
Presenter: Junhyung Heo, KMA
Authors: Junhyung Heo
Precipitable water (PW) is used as a leading indicator for severe weather such as heavy rainfall by forecasters. In this study, PWs which are integrated water vapor at boundary layer (BL), middle layer (ML), high layer (HL) and total precipitable water (TPW) are retrieved and analyzed to verify the impact of different layer.

The National Meteorological Satellite Center (NMSC) receives observation data directly from Low Earth Orbit satellite (LEO) data such as NOAA-18, 19 (ATOVS), MetOp-A, B(ATOVS), and Suomi-NPP (CrIS, ATMS) and generates level 2 products in near real time around East Asia. In order to integrate PW retrieved from the five satellite within specific time windows, blending process for PW is performed. The blending algorithm matches the cumulative probability distribution function (CDF) of PW retrieved from the different satellites to reference CDF in order to minimize their differences. For the reference CDF, PW retrieved from Unified Model (UM) Regional Data Assimilation Prediction System (RDAPS) analysis data are used and changed dynamically according to selected time windows. The PWs are composited every 6-hour for 03:00~09:00, 09:00~15:00, 15:00~21:00, and 21:00~03:00UTC time windows. Validation of composited PW is performed during summer and winter season in 2015, 2016, and 2017. Composite results of TPW and BL at Suomi-NPP are improved about 15 % (TPW) and 40 % (BL) in RMSE.

11p.09 Withdrawn

11p.10 Structure analysis of heavy precipitation over the Eastern Slope of the Tibet Plateau based on TRMM data
Presenter: Wei Dong, Lanzhou Central Meteorological Observatory, China
Authors: Wang Baojian, Huang Yuxia, Wei Dong
The horizontal and vertical structure of a heavy rain system happened over the eastern slope of the Tibet Plateau on July 21 2013 has been studied by using tropical measure mission data (TRMM), NCEP-FNL operational global analysis data and ERA-Interim analysis data, in combination with Doppler radar and other surface observational data. The result indicate that: The heavy rain system triggered by unstable stratification with 700 hPa shear line and surface convergence line was consisted of a main stratiform precipitation cloud and several scattered convective precipitation clouds characterized by high precipitation intensity. Although the number of convective rains is less than the stratiform rains, averaged rain rate of convective rains is 4.7 times larger than stratiform rains and contribute 25.6% to the total rain. The horizontal scale is about 20~50 km with a standard of 10 mm/h precipitation rate. The rainfall intensity spectral distributions of convective rains mainly occurred in 1~50 mm/h, and the rains between 20~30 mm/h make the greatest contribute to total. Meanwhile, the rain rate of almost 90% of the stratiform rains concentrated 10 mm/h below. Vertically, the rain top of heavy precipitation system can reach to 12 km from the surface with a low-quality core structure (below 6 km).The most precipitation rate occurred in the atmospheric from ground to the level near 7 km and the distributions of precipitation rate in vertical was inhomogeneous. Upon most occasions, the contribution of total precipitation was inversely proportional to the height, but in certain range of height, convective precipitation profiles show the opposite. As a verification and supplement for TRMM PR , Doppler radar observations show such characteristics as low centroid and adverse wind area.

11p.11 Analysis of heavy rainfall events occurred in Italy by using microwave and infrared technique
Presenter: Elisabetta Ricciardelli, National Research Council of Italy – Institute of Methodologies for Environmental Analysis
Authors: E. Ricciardelli, A. Cersosimo, D. Cimini, F. Di Paola, D. Gallucci, S. Gentile, S. T. Nilo, F. Romano, M. Viggiano
The Precipitation Evolving Technique (PET) [1, 3] and the Rain Class Evaluation from Infrared and Visible observation (RainCEIV) technique [2] use observations from the Meteosat Second Generation –Spinning Enhanced Visible and Infrared Imager (MSG-SEVIRI) to provide information about the rain rate and cloud class. In detail, PET is a multi-sensor algorithm for the continuous monitoring of convective rain cells. This technique propagates forward in time and space the last available rain rate maps obtained from the Advanced Microwave Sounding Unit

(AMSU) and Microwave Humidity Sounder (MHS) observations by tracking MSG-SEVIRI observations. RainCEIV is composed of two modules: a cloud classification algorithm (cloud Classification Mask Coupling of Statistical and Physical methods, C-MACSP) to identify and to characterise the cloudy pixels, and a supervised classifier that defines the rainy areas according to three rainfall intensity classes. Some heavy rainfall events occurred in Italy are analysed by means of PET and RainCEIV. Both these techniques show their ability in the near-real-time monitoring of convective cells formation and their rapid evolution. As quantitative precipitation forecasts by NWP could fail in predicting these heavy rainfall events, tools like RainCEIV and PET shall be adopted by civil protection centres to monitor the real-time evolution of deep convection events in aid to the severe weather warning service.

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[3] Di Paola, F., Ricciardelli, E., Cimini, D., F., Romano, F., Viggiano, M., and Cuomo, V.: Analysis of Catania Flash Flood Case Study by Using Combined Microwave and Infrared Technique, J. Hydrometeorology, 1989-1998,2014.

Session 12a: Assimilation studies

12.01 The effect of NWP model bias on radiance bias correction schemes

Presenter: John Eyre, Met Office
Authors: John Eyre

Observation bias correction schemes are important components of the data assimilation (DA) systems used in operational numerical weather prediction (NWP). They are used at present mainly to correct for biases in satellite radiance observations and their observation operators. These schemes attempt to remove biases in observations relative to the NWP model background or analysis field. The presence of bias in the NWP model itself can substantially complicate this process. Using a very simple scalar forecast model and DA system, this study explores the extent to which model bias leads to biases in the background and analysis states. Theory is presented for systems that attempt to remove observation bias relative to the background or relative to the analysis. It is shown that background and analysis biases are functions of three parameters: the weights given within the DA system to the observations to be bias-corrected and to the other “anchoring” observations, and the rate at which the NWP model state relaxes towards its own climatology. These effects are quantified for “baseline” values of these three parameters intended to be representative of the current Met Office global NWP system, and for large variations around these baseline values. If the baseline values are indeed representative, then background and analysis biases in the range 0.21-0.33 of the model bias are expected. However, substantial variations are expected within the model domain, depending on variations in observation density, in the balance between bias-corrected and anchoring observations, and in the rate at which the NWP model state relaxes towards its own climatology. Moreover, the effect of model bias on background and analysis biases will increase as more observations are bias-corrected and a smaller proportion are used as “anchor” observations. This has important implications for observation bias correction strategies used in NWP and in reanalyses.

12.02 Constrained variational bias correction for satellite radiances assimilation

Presenter: Wei Han, NWPC/CMA
Authors: Wei Han, Niels Bormann, Heather Lawrence

Satellite radiance observations are typically affected by biases that arise from uncertainties in the absolute calibration, the radiative transfer modeling, or other aspects. These biases have to be removed for the successful assimilation of the data in NWP systems. Two key problems have been identified in bias correction: Firstly, bias corrections can drift towards unrealistic values in regions where there is strong model error and relatively few “anchor” observations, i.e., observations that have little systematic error and therefore allow the separation between model and observation bias. Examples where this has been particularly problematic are channels sensitive to ozone or stratospheric temperature. Secondly, there is undesired interaction between the quality control and bias correction for observations where bias-corrected observation departures are used for quality control and where these departures show skewed distributions (e.g., in case of cloud detection).

In this study, we investigated potential solutions to these ill-posed problems by providing further constraints using potential available information, such as constraints on the size of the bias correction and innovative bias correction metrics using uncertainty estimation from calibration and radiative transfer as regularization. This has been studied in CMA's GRAPES (Global/Regional Assimilation PrEdiction System) 3D-Var system and the full ECMWF global 4D-Var system, using data from microwave sounders which are sensitive to stratospheric temperature. The data assimilation experiments showed that this scheme improved GRAPES analyses and medium range forecasts. The resulting enhanced bias corrections in the full ECMWF global 4D-Var was assessed in the context of other assimilated observations (in particular radiosondes and GPS radio occultation measurements), and through comparisons of MLS temperature retrieval data in stratosphere and mesosphere in the full ECMWF global 4D-Var system.

The constrained bias correction of AMSU-A stratospheric sounding channels reduces the biases in stratosphere and improves the medium range forecasts in both stratosphere and troposphere.

12.03 Radiance bias correction from an alternative analysis

Presenter: Benjamin Ruston, NRL
Authors: Benjamin Ruston, Nancy Baker, Rolf Langland, and Craig Bishop

The Naval Research Laboratory (NRL) Marine Meteorology Division (MMD) located in Monterey, CA does the primary development and support of global and regional atmospheric modeling and data assimilation capabilities for the U. S. Navy and broader community. It enjoys a partnership with Fleet Numerical Meteorology and Oceanography Center (FNMOC), which maintains an operational global and regional systems. The global hybrid 4D-Variational data assimilation system for the Navy Global Environmental Model (NAVGEM) is similar to many systems and includes the assimilation of radiances from a variety of radiometers. All of these radiometers use bias correction, which fit the first-guess differences between the observation and NWP model against model thicknesses and quantities derived from scan position. Only the SSMIS sensor adds an additional predictor on orbital position. An examination of the residual biases remaining clearly show systematic patterns for both regions and in some cases diurnal patterns. So the question about how to deal with these residual biases remain. Recently, there has been discussion of this issue from Eyre (2016), and a constrained variational approach proposed by (Chen et al., 2014), and an offline approach using an independent analysis (Buehner et al., 2014). We at NRL are also exploring an offline style approach using dynamic cycling where a parallel DA stream assimilates only observations where no bias correction is applied such as radiosonde and GNSS-RO, to an alternative analysis. This system is just being explored but shows a massive shift in the radiance bias corrections being applied and the verification of the resulting analysis using these bias corrections. Further development is ongoing which further refines the observation error on the observations used in the alternative analysis.

12.04 Benefits of using a variational preprocessing approach for the assimilation of satellite radiances: An application to data assimilation in environmental data fusion

Presenter: Erin Jones, RTi @NOAA/NESDIS/STAR
Authors: Erin Jones, Kevin Garrett, Eric Maddy, and Sid Boukabara

A new approach to environmental data fusion (EDF) is under development as part of a pilot project at the National Oceanic and Atmospheric Administration's (NOAA) Center for Satellite Applications and Research (STAR). This approach is, in a sense, data fusion at the radiometric level: leveraging NOAA's current data assimilation (DA) systems and incorporating satellite remote sensing algorithms in order to create and observation-driven, 4D, global analysis. At the core of this EDF system is a variational preprocessor that allows for the assimilation of satellite observations impacted by cloud and precipitation, and those over non-ocean surface types. The approach relies on the full radiometric information present in the observations, and is therefore able to simultaneously take advantage of the sensing capabilities of both sounding and imaging channels, where they are present. The control state vector includes all geophysical parameters that might impact the radiometric data, and as the method is informed by sensor sensitivities, greater emphasis is put on multiple-scattering forward and Jacobian operators, removing the reliance on moist physics parameterization schemes. The result is a simplified assimilation process that enables the adjustment of the assimilation background, the removal of meteorological feature displacement, and the assimilation of satellite radiance data that might otherwise be rejected by traditional quality control measures.

12.05 Exploring using Artificial Intelligence (AI) for NWP and situational awareness applications: Application to remote sensing and data assimilation/fusion

Presenter: Sid Boukabara, NOAA

Authors: S. A. Boukabara, E. Maddy, K. Ide, K. Garrett, E. Jones, K. Kumar and N. Shahroudi

The volume and diversity of environmental data obtained from a variety of Earth-observing systems, has experienced a significant increase in the last couple years with the advent of high spectral, high- spatial and temporal resolutions sensors. At the same time, users-driven requirements, especially for nowcasting and short-term forecasting applications but also for medium-range weather forecasting, strongly point to the need for providing this data in a consistent, comprehensive and consolidated fashion, combining space-based, air-based and surface-based sources, but at higher spatial and temporal resolutions and with low latency. This trend is expected to continue further with the emergence of commercial space-based data from multiple industry players and the advent of flotillas of small satellites (Cubesats) as well as new sources of data (such as Internet of Things IoT) to complement traditional environmental data. Yet, the data volume presents already a significant challenge. Satellite measurements input to data assimilation algorithms for instance, need to be aggressively thinned spatially, spectrally and temporally in order to allow the products generation, calibration, assimilation and forecast system to be executed. Only a fraction of satellite data gets actually assimilated. Taking full advantage of all the observations, allowing more sources of observations to be used for initial conditions setting, and to do it within an ever shrinking window of assimilation/dissemination, requires exploring new approaches for processing the data, from ingest to dissemination. We present in this study the results of a pilot project's effort to use cognitive learning approaches for numerical weather prediction (NWP) applications. The Google's machine learning open-source tool TensorFlow, used for many Artificial Intelligence (AI) applications, was used to reproduce the performances of remote sensing and data assimilation techniques to fuse data from many sources including satellites, with flexibility to extend to other sources such as IoT. The outcome is a 5D-cubeset of parameters to describe the state of the Environment, useful for multiple applications including NWP. The approach relies on training a deep-layer neural network on a set of inputs from NASA's GEOS-5 Nature Run (NR) and corresponding observations simulated based on it using the Community Radiative Transfer Model (CRTM) and other forward operators. The present study demonstrates the proof of concept and shows that using AI holds significant promise in potentially addressing the vexing issue of computational power and time requirements needed to handle the extraordinary volume of environmental data, current and expected. With dramatically lower execution times, we will compare the AI-based algorithm performances to those of a variational algorithm used to perform data assimilation pre-processing and retrievals, as well as compare the AI-based assimilation system to those of an ensemble/variational hybrid data assimilation system used in NOAA operations (GSI) and explore assessing its potential impact on NWP applications. Comparisons will be based on the NR set up and therefore the truth will be known exactly.

Session 12b: Assimilation studies

12p.01 Satellite bias correction in limited-area model ALADIN

Presenter: Patrik Benacek, The Czech Hydrometeorological Institute

Authors: Patrik Benacek, Mate Mile

Bias correction of satellite radiances is an essential component of data assimilation system in Numerical Weather Prediction (NWP). Variational Bias Correction (VarBC) schemes are widely used by global NWP centres (NCEP, Derber and Wu 1998; ECMWF, Dee 2004), but there are still open questions regrading their use in limited-area models (LAMs). We shall present a study of key VarBC aspects in the limited-area 3D-Var system using the state-of-the-art NWP system ALADIN, which shares its model code with the global system IFS/ARPEGE (ECMWF/Météo-France), and is operationally used at Czech Hydrometeorological Institute. Firstly, we compare the initialization of the VarBC bias parameters using different initialization methods namely a cold-start, a warm-start as well as adopting of the bias parameters from a global model. Secondly, we study the adaptivity of the bias parameters (the VarBC adaptivity) with respect to the limited-area observation sample. Especially polar orbiting satellites provide the data sample that is non-uniform in time and space, leading to the higher sampling variance of the detected radiance bias. Therefore, commonly used settings of the VarBC adaptivity in global models need a revision in LAMs, as pointed out by Lindskog et al. (2012). In order to provide a meaningful satellite bias estimate for LAMs, it is essential to constraint the VarBC adaptivity to reduce the sampling variance. This is achieved by extending of the VarBC stiffness parameter by additional inflation factors considering the limited observation sample and a persistence of the NWP model bias. Finally, the proposed adaptivity approach is evaluated in terms of the bias correction quality and the forecast impact.

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Lindskog, L., Dahlbom, M., Thorsteinsson, S., Dahlgren, P., Randriamampianina, R., & Bojarova, J. (2012). ATOVS processing and usage in the HARMONIE reference system. HIRLAM Newsletter, 59, 33-43.

12p.02 Comparison between global model and VarBC bias corrections in a UK regional model
Presenter: James Cameron, Met Office
Authors: James Cameron
VarBC is used actively in the Met Office's UK regional model since 11 July 2017. In this poster, the effect of applying the most recent global model bias correction in the UK regional model is compared to the performance of running VarBC regionally. The evolution of VarBC coefficients, the statistics of the fit of observations to the forecast background, and the forecast performances are compared.

12p.03 Diagnosis of residual biases in the assimilation of AMSU-A
Presenter: Edward Pavelin, Met Office
Authors: Ed Pavelin, Bill Bell, Andy Elvidge
Variational data assimilation schemes generally assume that observations are unbiased relative to the NWP model background. However, even after the observations are calibrated and quality controlled, there can be residual biases relative to the model when they are presented to the assimilation system. Well-established bias correction schemes are used in an attempt to remove systematic biases, primarily due to radiative transfer model error. Nevertheless, even after standard bias correction methods have been used there are residual biases present in the innovations (observation-minus-background departures). The first of a series of studies has been carried out at the Met Office to document and attempt to explain the residual biases found in sounder radiances, starting with AMSU-A. A number of physical mechanisms have been identified that contribute to residual biases, including residual cloud and surface effects, tropical convection and gravity wave breaking. The initial results of this study will be presented together with a discussion of possible strategies for minimising the effects of these biases.

12p.04 Assimilating infrared and microwave sounder observations with correlated errors
Presenter: Kristen Bathmann, IMSG @NOAA/NCEP/EMC
Authors: Kristen Bathmann, Ricardo Todling, Andrew Collard, Wei Gu, John Derber
Satellite observations are operationally assimilated at the National Centers for Environmental Prediction (NCEP) and are a vital part of the data assimilation system. The Gridpoint Statistical Interpolation (GSI) uses prescribed observation errors for infrared and microwave sounders and assumes that the observation errors of different channels are uncorrelated. To compensate for this, observation errors are inflated, however, in order to produce an optimal analysis, errors and error correlations must be accurately defined. The goal of this study is to enhance the specification of these errors in the operational GSI by improving their estimates and by properly accounting for these inter-channel correlations. The estimation of Infrared Atmospheric Sounding Interferometer (IASI), Atmospheric Infrared Sounder (AIRS), and Advanced Technology Microwave Sounder (ATMS) covariances are detailed in this presentation, as are the impacts of their inclusion in the GSI. The forecast benefits are also assessed after a two month assimilation experiment by verifying against other observations and against ECMWF analyses.

12p.05 Accounting for correlated observation error in the assimilation of ATMS
Presenter: Peter Weston, ECMWF
Authors: Peter Weston, Niels Bormann
The ATMS temperature sounding channels are affected by 1/f gain fluctuations in the low-noise amplifier. This effect causes the observation errors to become correlated along scanlines which can be seen as a striped pattern in first guess departure maps. In practice, at NWP centres, this has led to the assumed observation errors for ATMS being inflated to give the data less weight in the analysis

and to indirectly account for this effect. However, the effect also results in the ATMS temperature sounding channels having stronger diagnosed inter-channel error correlations than the corresponding AMSU-A temperature sounding channels. Hence, another way of indirectly accounting for this effect would be to take account of these non-zero inter-channel error correlations in the assimilation of ATMS data.

In recent years it has been shown that accounting for inter-channel error correlations for the assimilation of infrared sounders is beneficial to NWP analysis and forecast accuracy. Part of this benefit is due to the more aggressive use of the data by using smaller assumed error standard deviations compared to the previously inflated values. Another part of the benefit comes from the situation dependent weighting given to observations depending on which eigenvector the inter-channel structure of the first guess departures maps onto. Both of these benefits should be realised for ATMS too so accounting for correlated observation errors for ATMS has been tested in the IFS at ECMWF.

The error covariance matrix diagnosed using a posteriori methods will be presented and compared to the instrument noise and currently assumed observation errors. It will also be compared to the diagnostics for AMSU-A to highlight the effect of the 1/f noise source. Then the impact of using the full observation error covariance matrix will be assessed by running assimilation experiments.

12p.06 Posterior channel selection for satellite radiances with correlated observation error in hybrid 4DVar system (NAVGEM)

Presenter: William Campbell, NRL

Authors: William F. Campbell

The vertical observation error covariances for a set of IASI and CrIS channels were estimated using the Desroziers method (Desroziers et al., 2005) and an archive of historical satellite and NAVGEM model data. The resulting error covariance matrices have lower error variance (diagonal of R) and strong correlations (off-diagonal terms), especially in the moisture-sensitive channels, compared to the prior diagonal R. The strong correlations lead to a high condition number, which adversely affect the convergence rate of the solver. Before we can use them for practical data assimilation with our system, they must be reconditioned.

Several different reconditioning methods are explored in our paper (Campbell et al., 2017). They can be used independently from, or in conjunction with the new method outlined here. We identify sets of channels that have very high mutual error correlation from the Desroziers-derived error matrices. The high error correlation means that there is significantly less information that can be extracted, and that what is there is significantly more difficult to extract.

In tests with IASI and CrIS in our Hybrid 4DVar DA system (NAVGEM), we replaced sets of channels with high error correlations by a single channel from each set. The resulting condition number of the error covariance matrices was significantly reduced, so the solver converged faster, and there was no negative impact on forecasts. The forecasts were significantly better than the control, which used a diagonal R with inflated variances.

12p.07 Buddy check for radiance with analysis error variance

Presenter: Hyoung-Wook Chun, KIAPS

Authors: Hyoung-Wook Chun and Ji-Hyun Ha

This presentation describes a trial of buddy check for radiance data by using analysis error variances in observation space from Desroziers's diagnostic method. The analysis error variances are calculated as the product of increment and analysis departure, so they should normally be positive value at each observation point. But the analysis error variances are negative when the given observation has different signal from other observations in the vicinity because the analysis does not exist between the background and the observation. The process of eliminating observation with large negative analysis error variance is defined as buddy check in this study. The buddy check is adapted for satellite radiance data such as IASI, CrIS, AMSUA, ATMS, and MHS, after first outer loop in data assimilation process of Korea Institute of Atmospheric Prediction Systems (KIAPS). Preliminary result showed a positive impact on temperature and humidity under 850 hPa in assimilation cycle test. We are currently struggling to find more suitable threshold which is reference point to remove negative analysis error variances.

12p.08 A decade of improved fits to satellite observations at the Met Office

Presenter: Stuart Newman, Met Office

Authors: Stuart Newman, Bill Bell and Nigel Atkinson

The last decade has seen increased volumes of global satellite observations used within NWP and continuous upgrades to the underpinning data assimilation systems. Here long-term trends in background fits to observations are presented, showing examples of improving fits consistent with reduced errors in Met Office short-range NWP forecasts. A focus is given to humidity sensitive channels on microwave and infrared sounders. The contributions to the departures of various sources of observation error, including instrument noise, are considered, shedding light on trends in NWP background error.

12p.09 Observation impact diagnostics in an ensemble data assimilation system
Presenter: Olaf Stiller, DWD
Authors: Olaf Stiller
This study uses observation impact diagnostics developed for ensemble data assimilation systems to diagnose the impact of observations on the analysis of the operational global ICON-EnVAR system of DWD, focusing in a first step especially on observations like radiosondes, radio occultations and AMSU A radiances.

Optimizing the exploitation of observational data, particularly from remote sensing instruments, is not trivial as they can be affected by a large number of influences such as clouds, trace gases and surface properties. Also, some observational and model properties (such as, e.g., biases or correlated error characteristics) often make the assimilation more difficult and require some mitigation. The identification of such detrimental influences or properties is often difficult. To facilitate the investigation of this issue, novel diagnostic variables have been developed over the last decade which (within some approximation) indicate the impact of individual observations on the forecast quality. This allows the generation of statistics over subgroups of observations which can make it easier to identify problems of a particular observation type.

Such diagnostics have been developed both, in the framework of 4D Var systems (using the adjoint model, Cardinali 2009) and the ensemble Kalman filter (EnKF - using covariances diagnosed by the ensemble, Kalnay et al. 2012 and Sommer&Weissmann, 2016). A major challenge in this context is to assess (verify) the forecast impact. While using a model analysis for the verification has the advantage of a good spatial coverage, Sommer et al. used observations as those are less correlated with the original analysis (from which the forecast was started). Particularly for evaluating short forecast lead times this is important. The interpretation of the results requires care, especially when using observation types like radiosondes whose spatial coverage is very inhomogeneous so that impacts on some regions may be overemphasised compared to others.

The work presented here follows in many respects that of Sommer&Weissmann but considers the LETKF/ENVAR system of the DWD's global Icon model. The main differences, however, is that the current work focuses on the impact on the analysis (rather than on the model forecast) which means that the forecast lead time is effectively set to zero. In principal, this represents a consistency check which indicates whether the impacts on the analysis of two different observation types (the chosen one and the observations used for verification) are consistent. While assessing the impact of observations on the model forecast may be seen as the ultimate goal (which is improving the forecast), starting with the analysis impact has the merit of separating the two problems, whether observations lead to a consistent analysis and to which extent the model can profit from a consistent analysis to make a better forecast. Also, as it is explained, for lead time zero the method can be used to indicate the model bias in the observation space of the observations under consideration provided the bias of the verifying observations can be neglected (as it may be appropriate for radio occultations).

In a first step, to demonstrate the possible benefit and the problems of the method, it is applied to well established observations like radio sondes, radio occultations and AMSU A radiances. While the overall consistency is found to be good for these observations, it is shown how regimes where, e.g. AMSU A radiances and radio occultations, seem to pull the analysis into contradicting directions can be identified with this method. Possible explanations in terms of model or observational biases are discussed.

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Sommer, M and Weissmann, M, Ensemble-based approximation of observation impact using an observation-based verification metric. Tellus A: Dynamic Meteorology and Oceanography Vol. 68 , Iss. 1,2016

12p.10 Data assimilation methodology developments at ECMWF

Presenter: Stephen English, ECMWF

Authors: S.J. English, P. Browne, M. Bonavita, M. Chrust, P. de Rosnay, A. Geer, J. Goddard, M. Hamrud, E. Holm, S. Lang, P. Laloyaux, P. Lean, O. Marsden, S. Massart, D. Salmond, D. Schepers

In this poster recent developments of ECMWF's data assimilation will be presented.

ECMWF have developed a C++ code control layer to run the data assimilation in a single executable. This is known as the Object Orientated Prediction System (OOPS). This has previously been applied to data assimilation for simplified models. Over the past two years ECMWF's Integrated Forecast System (IFS) code has been refactored to allow IFS to be called and controlled from OOPS, with a view to using OOPS operationally. The initial goal is to replicate the current atmospheric 4D-Var capability with OOPS. Once this is achieved OOPS will provide a flexible framework that will enable introduction of new data assimilation developments, including the saddle point weak constraint data assimilation formulation. OOPS is also being applied to other components of the IFS, such as the NEMOVAR ocean data assimilation, and will be applied to the land DA system in due course. During the process of this major technical development project the opportunity has been taken to perform a modernisation of the IFS code base, and this allowed some errors and issues in the IFS code to be found and corrected.

Alongside this major infrastructure project a number of important science improvements have been made to the data assimilation methodology, and several others are being researched. Recent improvements include the application of the wavelet background error formulation, from ECMWF's ensemble data assimilation (EDA), to be extended to humidity. Areas of active development include overlapping 4D-Var 12 hour windows, asymmetric re-centred EDA and an augmented control vector. In addition techniques for coupled ocean-atmosphere data assimilation are being developed and impact for sounder radiances, as described in more detail in the poster by Eresmaa, Lupu, Schepers et al.

12p.11 Toward a coupled ocean-atmosphere data assimilation system: First impact examination from the viewpoint of satellite radiances

Presenter: Louis Garand, Environment and Climate Change Canada

Authors: Sergey Skachko, Louis Garand, Jean Marc Bélanger, François Roy, Ervig Lapalme, and Stéphane Laroche

Environment and Climate Change Canada (ECCC) has demonstrated that a significant impact on forecasts is obtained as a result of coupling the atmospheric and oceanic models so that the sea surface temperature as well as the ice cover are evolving in forecasts. The next step is to pass trial fields from that coupled model to the assimilation system. This is the object of this presentation. We will show how observations minus background statistics (O-B) for satellite radiances change (hopefully lower values) as well as sea surface temperature increments proposed by the assimilation system. The impact on forecasts will be evaluated. Next steps toward stronger coupling will be highlighted.

12p.12 Assimilation of satellite data in a coupled ocean-atmosphere system

Presenter: Reima Eresmaa, ECMWF

Authors: Reima Eresmaa, Dinand Schepers, Stephen English, Sean Healy, Patrick Laloyaux, Cristina Lupu

ECMWF has a long record of producing comprehensive re-analyses to provide consistent descriptions of global atmospheric state over extended periods of time. The ongoing trend in the re-analysis is towards increased level of coupling between atmospheric, ocean, land, and sea ice components of the Earth system. At ECMWF, a coupled assimilation system (CERA) has been developed that allows information exchange between different Earth system components at the outer loop level. During development of the CERA assimilation system, the added benefit of the coupling has been demonstrated in the context of improved fit to conventional surface observations and a reduction of initialization shocks in forecasts initialised from a coupled analysis.

Within the ERA-CLIM2 FP7 project, the CERA assimilation is used for the production of a pilot coupled reanalysis for the satellite era (CERA-SAT) spanning 2008-2016. Run with a TL319-L137 atmosphere coupled to a high resolution ocean model, CERA-SAT makes use of the complete available observation system for atmosphere and ocean. Particular focus will be put on analysing the assimilation of sounding satellite observations in the CERA data assimilation framework. With benefits of the coupled assimilation being demonstrated during the project, we expect to implement the coupling in the ECMWF operational system in the next few years.

12p.13 Met Office convective-scale satellite data assimilation
Presenter: Robert Tubbs, Met Office/Exeter
Authors: Bob Tubbs, Graeme Kelly, Gareth Dow, Marco Milan, Bruce Macpherson, Gordon Inverarity, Pete Francis
The Met Office UKV is a convection-resolving operational NWP system which has 1.5-km resolution over the UK land area. Recent changes to the NWP system are discussed: upgrading the data assimilation to hourly 4D-Var; implementation of variational bias correction (VarBC) for the satellite radiance assimilation; increased domain; changes to satellite thinning and data usage; new observation types, new background-error covariances and changes to the adaptive grid settings. This poster gives an overview of the current status of the UKV and an assessment of the performance improvement provided by the recent upgrades, with a particular focus on satellite data assimilation. Also included are future plans for convective-scale satellite data assimilation at the Met Office.

Session 13a: Sounding science and validation

13.01 Satellite sounding product characteristic performance and impact of satellite overpass time
Presenter: Tony Reale, NOAA
Authors: Tony Reale and Bomin Sun
The NOAA Products Validation System has operated at NOAA STAR since 2008 providing routine compilation of collocated conventional radiosonde and environmental satellite sounding products. These observations provide a benchmark for determining the characteristic performance of satellite derived soundings from different satellites based on a common, global sample of observations. In 2013, NPROVS was expanded to target radiosondes synchronized (dedicated) with satellite overpass including reference observations from the GCOS Reference Upper Air Network (GRUAN), referred to as NPROVS+.

This work characterizes the performance of available hyper-spectral IR sounding products, including from the recently sanctioned Full Spectral Resolution (FSR) NOAA Unique Combined Atmospheric Processing System (NUCAPS), and possible impact of local satellite overpass time on perceived performance. Results are primarily based on common samples of collocated conventional radiosonde and satellite observations from NPROVS. Conventional radiosondes typically occur at the 00Z and 12Z synoptic times, with the S-NPP and MetOp satellites having local overpass times of approximately 1330 and 0930, respectively. Results include analysis of systematic time differences (mismatch) between the synoptic radiosondes and respective satellites as a function of global region, diurnal cycle, season and height and respective impacts on perceived characteristic performance. A specific question addressed is how the impact of local overpass is manifested using relatively small (10-day to sub-seasonal) versus larger (multi-seasonal to multi-year) samples. The NPROVS analytic interface provide good tools for "framing" such studies through multiple sampling options that include respective time difference, satellite, region and seasonal segregations, for example, restricting data to polar regions and concurrent cases of MetOp and S-NPP satellites collocated with the same radiosondes. Results are re-enforced with observations from NPROVS + using sets of available synchronized observations from different satellites available at the same site.

Summarizing, this work demonstrates characteristic performance for MetOp and S-NPP hyper-spectral sounding products including from NOAA, EUMETSAT and NASA using collocations of conventional radiosonde and satellite products routinely compiled in NPROVS. The impact of characteristic performance based on local satellite overpass time is investigated. Results are further supported using collocations with available synchronized, reference radiosondes from NPROVS+.

13.02 Studies using spectral measurements of satellite atmospheric FTIR sounder IRFS-2
Presenter: Alexander Polyakov, Saint-Petersburg State University
Authors: A.V. Polyakov, A.S. Garkusha, Yu.M. Timofeyev, A.B. Uspensky, Ya.A. Virolainen, A.V. Kuharsky
The Russian instrument IRFS-2 has been operating on board the satellite "Meteor-M No. 2" for more than 3 years. The spectral data obtained with it are in good agreement with the results of independent measurements; they are stable and characterized by high accuracy. Based on these spectral measurements, a number of results presented in this study have been obtained.

The validation of measurements of vertical temperature profiles by the IRFS-2 instrument (Meteor M N2 satellite) in cloudless conditions based on comparisons with radiosonde measurements and results of NCEP GFS analysis was carried out. For a matched vertical resolution, the average differences in the results of satellite and radiosonde measurements do not exceed 1 K, the root-mean-square differences vary from 1.2 K to 1.8 K, except the lower layer, where they reach -2 K and 4 K, respectively. Above the water surface in the 300-600 hPa pressure range, the root-mean-square difference between the satellite and NCEP GFS data is less than 1K, but above a land it increases up to 1.5-2 K.

A technique for determining the total ozone content (TOC) from IRFS-2 spectra under cloudiness has been developed. The error analysis for the developed technique has shown that the differences between the TOC measured by the IRFS-2 instrument and by independent satellite (OMI) and ground-based (Dobson, Brewer, M-124) instruments are 3-5% as a rule. The greatest differences (up to 10%) are observed in the southern polar latitudes during observations over Antarctica. The results of TOC measurements show the decrease in ozone content of almost 50% during observations of ozone mini-holes over Russia in the first quarter of 2016.

The studies were supported by Russian Science Foundation (project 14-17-00096).

13.03 Sounding science at the Jet Propulsion Laboratory

Presenter: Bjorn Lambrigtsen, JPL
Authors: Bjorn Lambrigtsen, Joao Teixeira, Thomas Pagano, Eric Fetzer

The Jet Propulsion Laboratory (JPL) has become one of the premier centers for atmospheric science based on observations from infrared and microwave satellite sounders such as the Atmospheric Infrared Sounder (AIRS) and the Advanced Microwave Sounding Unit (AMSU) as well as aircraft based microwave sounders such as the High Altitude MMIC Sounding Radiometer (HAMSR). We give an overview of capabilities and areas of active research, highlighting the Atmospheric Physics and Weather group, but we also summarize related activities in other groups at JPL and collaborations with other sounding centers in the U.S. The Atmospheric Physics and Weather group provides science support for AIRS on the Aqua platform as well as the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) on the Suomi-NPP platform and carries out atmospheric research funded through NASA's Research and Analysis (R&A) program. Future sounding systems to address current gaps are also being developed at JPL, such as an IR CubeSat system (CIRAS) and a geostationary microwave sounder (GeoSTAR). We conclude by discussing current and potential collaborations with European organizations.

Session 13b: Retrieved products and validation

13p.01 Withdrawn

13p.02 Validation of temperature sounding of the atmosphere from a board of «Метеор-М» No 2 satellite (IRFS-2 device)

Presenter: Alexander Polyakov, Saint-Petersburg State University
Authors: A.V. Polyakov, Yu.M. Timofeev, A.B. Uspensky, A.V. Kukharsky

The vertical temperature profiles retrieved from spectral satellite measurements of outgoing thermal radiation by the IRFS-2 device («Meteor M No 2» satellite) in cloudless conditions are compared with radiosonde data and results of the NCEP GFS analysis. It is shown that the adjustment of vertical resolutions of various measurements leads to the decrease of a mean square difference between results by 0.2–1 K and more depending on the atmospheric altitude.

In the case of the consistent vertical resolution, average differences between satellite and radiosonde measurements do not exceed 1 K in an absolute value, and mean square differences change from 1.2 K to 1.8 K in free troposphere. In near-surface layer, mean square differences increase up to 4 K. Over the land, mean square differences between satellite measurements and NCEP GFS data (more than 2 K against 1.2–1.8 K for radiosondes) show the worst consent. It is shown that though in the free troposphere over a water surface the mean square difference between satellite and NCEP GFS data less than 1 K, over the land, it reaches 1.5–2 K. In cloudless cases over water surface, the accuracy of IRFS-2 temperature sounding (when comparing with results of the analysis) is close to the accuracy reached for IASI.

The study was supported by Russian Science Foundation (project 14-17-00096).

13p.03 Identifying downburst events using INSAT-3D satellite system

Presenter: Sanjeev Kumar Singh, NCMRWF
Authors: Johny C J, Prasad V S and Sanjeev Kumar Singh

Indian Space Research organization (ISRO) operates INSAT series of geostationary satellites since ninteen eighties and currently operational satellites in this series are INSAT-3D operating at 82° E and INSAT-3DR operating at 74° E. INSAT-3D systems carries 19-channel Sounder and 6-channel advanced Imager can provide images of earth disk at every 26 minutes. The system with features of accurate sea surface temperature estimation, middle infrared band for night time pictures of low cloud and fog and high spatial resolution in visible and thermal infrared bands can be used in various meteorological applications. The combination of INSAT-3D and INSAT-3DR provide the multi-spectral images of the earth and the atmosphere at every 15-minute interval from Imager and 30-minute interval from the Sounder that ensures more accurate and timely detection of weather parameters around the Indian subcontinent. Convective downdraft events and associated outflow of winds are hazardous and major threat especially in aviational sector. Indices like Micoburst wind speed potential index (MWPI) and Dry microburst index are used for identifying these extreme down draft events. Brightness temperature difference between water vapor channel and thermal infrared channel of geostationary satellites also used as indicator for these downdraft events. Lifted index is used for estimating potential of atmosphere for generating extreme thunderstorm events. In this study various indices derived from INSAT-3D satellite system is used to identify these extreme events in atmosphere. Indices computed from INSAT 3D measurements are verified with numerical weather prediction model outputs and surface based observations.

Session 14: Space agency reports

14p.01 Updates on CMA meteorological satellite programs

Presenter: Peng Zhang, CMA
Authors: Peng Zhang

The current status, future program and latest progress are updated on CMA Fengyun meteorological satellites (FY) in this presentation. Currently, there are 3 FY polar satellites and 4 FY geostationary satellites are on the orbit and 5 of them in the operational.

As for the current status, FY-2E and FY-2G constitute the Geo constellation to provide the full disk scan images in 15 minutes maximum while FY-2F provides the images within 6 minutes maximum in fast scan mode. FY-3B and FY-3C constitutes the Leo constellation to provide the global observation of the Earth four times per day on the middle morning and afternoon orbit.

As for the future program, FY program have been integrated into National Space Infrastructure Plan 2015-2025 (NSIP). In NSIP, a number of atmosphere-related satellites are planned in coming decade as three parts. The first part is the CMA led program, such as FY-2 and FY-4 Geo weather satellites, FY-3 Leo climate and environment satellite. The second part is the CMA engaged program, such as High Resolution Earth Observation Satellite series (GF), Atmospheric Environment Monitoring Satellite series. The third part is the joint R&D program, such as Carbon Observation Satellite program (TANSAT).

FY-4A and TANSAT has been launched last Dec. The on-orbit commission tests of both two satellites have been completed by CMA. The latest progress of these two satellites will be given in this presentation. FY-3D is scheduled to be launched this Sept. The news of FY-3D is also expected to be given in this presentation.

14p.02 An update on EUMETSAT programmes and plans

Presenter: Dieter Klaes, EUMETSAT
Authors: Dieter Klaes

The poster will provide information on EUMETSAT mandatory geostationary programmes, mandatory polar programmes. These include current operational programmes (MSG, EPS) and also programmes under development (MTG, EPS-SG). Further more optional and Third party programmes are discussed. These include Jason-2 and Jason-3 and the Copernicus related activities (Sentinel-3, Sentinel-4 and Sentinel-5, Jason-CS (Sentinel-6). Regional missions are discussed as well (EARS).

14p.03 NOAA satellite program update

Presenter: Mitch Goldberg, NOAA

The poster will provide an update on the NOAA satellite program.

14p.04 Status report of space agency: JMA and JAXA
Presenter: Kozo Okamoto, JMA
Authors: Kozo Okamoto, Misako Kachi and Hidehiko Murata
This presentation will provide the status and plan of JMA and JAXA program.

14p.05 Status of Russian meteorological satellite programs
Presenter: Alexander Uspensky, SRC Planeta
This presentation will provide an update on the Russian meteorological satellite programs.

Session 15a: Future observations

15.01 IASI-New Generation: Scientific objectives and foreseen validation
Presenter: Cyril Crevoisier, CNRS-LMD
Authors: C. Crevoisier, F. Smith, C. Clerbaux, V. Guidard, A. Deschamps, T. August and the ISSWG members
In the framework of the EPS-SG program of EUMETSAT, CNES is currently preparing the IASI-NG (IASI-New Generation) mission that will fly on the ESA Metop-SG-A satellite series. The preparation of this mission, which is now in Phase-C, was a long-term process involving research and operational communities, industry and space agencies. Scientists from 3 communities – NWP, atmospheric composition and climate - first defined the goals of the mission and established the scientific requirements to fulfill these goals (what to measure, with which accuracy, and at what spatial/temporal sampling). They then translated these needs in terms of instrumental specifications (what spectral range, which radiometric performance/spectral resolution, what footprint/horizontal coverage). This lead to the selection of an innovative concept proposed by Airbus Defence and Space and based on a Mertz interferometer.

IASI-NG has three main objectives: (i) continuity of the IASI/Metop series that now span more than 10 years, with an envisioned 10 more years to come); (ii) improvement of vertical coverage, especially in the lower troposphere; (iii) improvement of the precision and detection threshold of atmospheric and surface components.

This presentation will detail the studies that have been done by the scientific community, in the framework of the ISSWG (IASI/IASI-NG Sounding Science Working Group), in order to narrow IASI-NG specifications to an improvement of the spectral resolution (factor of 2 as compared to IASI) and the radiometric noise (factor of 2 in the longwave, better in the shortwave and in some spectral regions particularly important for atmospheric composition), and how these choices led to the definition of a baseline for the instrument.

We will also discuss the status of activities that need to be undertaken in order to validate the scientific results that will be achieved by IASI-NG. Forming the IASI-NG validation plan, these activities will built on existing ground-based, airborne (both aircraft and balloons) as well as satellite instruments in order to validate the full suite of atmospheric and surface variables that will be retrieved by IASI-NG.

15.02 A study on the benefits of spatial resolution for next generation infrared hyperspectral sounder instruments
Presenter: Likun Wang, University of Maryland
Authors: Likun Wang, Yong Chen, and Changyong Cao
Hyperspectral infrared (IR) radiance measurements from satellite sensors contain valuable information on atmospheric temperature and humidity profiles, greenhouse gases, clouds, and surface characteristics. These measurements are used not only to retrieve atmospheric temperature and humidity profiles, but more importantly, to be directly assimilated into numerical weather prediction (NWP) models as inputs for weather forecasting. Combined with the microwave sounders together, hyperspectral infrared (IR) sounders, provide basic information on atmospheric temperature and humidity for NWP models, especially at the region where conventional weather observations are not available. The current global NWP and regional models have horizontal resolutions of about 16 km. In the near future, it is under plan to further improve the global model resolution to 3-5 km. Given the fact that current operational IR sounders -Crosstrack Infrared Sounder (CrIS) and Infrared Atmospheric Sounding Interferometer -have an field of view (POV) size of 14 km and 12km at nadir, it is essential to improve spatial resolution of hyperspectral sounder instruments to match NWP model resolutions by reducing the field of view (POV) size to 8 km or below.

From a perspective of data utilization for NWP models, this study report our recent analysis on scientific benefits of spatial resolution for next generation IR hyperspectral sounders (Wang et al. 2016). First, since clear-sky measurements from IR sounders are mainly used for data assimilation, smaller FOV size will provide more clear measurements for NWP models. Second, smaller FOV size increases scene uniformity, which will reduce the spectral calibration uncertainties of IR spectra. Finally, smaller FOV size affects measurements noise for unapodized IR spectra. Specifically, we will use the Visible Infrared Imager Radiometer Suite (VIIRS) and Moderate Resolution Imaging Spectroradioemter (MODIS) radiance measurements and cloud mask products to test different FOV configurations (including the change of FOV size and number) to examine the statistics how the clear and uniform cloudy scene measurements vary. In addition, theoretical analysis and model simulation will be presented to show effects of the smaller FOV sizes on the instrument noise. The study will provide basic scientific information on spatial resolution for future hyperspectral IR sounder instrument design.

15.03 Impact analysis of LEO hyperspectral sensor IFOV size on the next generation high-resolution NWP model forecast performance

Presenter: Agnes Lim, CIMSS/SSEC/UW-Madison
Authors: Agnes Lim, Allen Huang, James Jung, Zhenglong Li, Federick W Nagle, Greg Quinn, Jack Woollen, Sean B. Healy, Jason Otkin, Mitch Goldberg and Robert Atlas

Reduced errors in initial conditions and improved forecast models have led to steady improvements of forecast skill in the past three decades. Some of the reductions in initial condition errors come from increases in the quality and quantity of satellite observations. The spatial resolution of satellite observations must increase to maintain its positive influence on forecast skill as Numerical Weather Prediction (NWP) Centers move to higher resolution forecast models. Increasing the spatial resolution of satellite observations and decreasing spatial inhomogeneity in satellite observations is crucial for satellite radiance assimilation.

Some NWP Centers have begun assimilating cloudy radiance observations, but challenges remain before substantial forecast impact from cloudy radiances could be achieved. Infrared radiance observations are very sensitive to clouds and cloud detection plays an important role in the use of hypersepctral infrared sounders. A smaller field-of-view (FOV) will have a higher probability of being cloud free, increasing the percentage of infrared radiance observations to be assimilated and thus potentially making a larger contribution to the quality of the forecast initialization.

To support the National Oceanic and Atmospheric Administration's Joint Polar Satellite System (NOAA/JPSS) Program in planning for the next generation hyperspectral sounder, the impact of FOV size of the hypersepctral infrared sounder such as Cross-track Infrared Sounder CrIS instrument on NWP will be assessed. The NOAA National Centers for Environmental Prediction's (NCEP) Global Data Assimilation system/Global Forecast System (GDAS/GFS) is used, in the presence of the existing observing network, to assess the impact of the CrIS sensor with a smaller FOV size. Impact assessment is performed in a simulated environment, also known as an Observing System Simulation Experiment (OSSE). Observations from current observing network; CrIS observations at both the current and increased resolution are simulated from a known state of the atmosphere or the Nature Run. The OSSE system is calibrated against the real system to verify that the simulated data impact is comparable to the real data impact. Preliminary results on the impact of increased spatial resolution of CrIS observations will be presented.

15.04 An OSSE investigating a constellation of 4-5 µm infrared sounders

Presenter: Will McCarty, NASA Global Modeling and Assimilation Office
Authors: Will McCarty, John Blaisdell, David Carvalho, Ronald Errico, Ronald Gelaro, Louis Kouvaris, Isaac Moradi, Steven Pawson, Nikki Prive, Meta Sienkiewicz, Joel Susskind

NASA is investigating the utility of a strategically-constructed constellation of infrared sounders onboard small satellites to provide spaceborne measurements of wind. The method proposed by instrument teams is to fly multiple instruments in complementary orbits so that atmospheric motion vector measurements can be made. As part of the investigation of this measurement approach, the Global Modeling and Assimilation Office (GMAO) at NASA Goddard Space Flight Center performed a set of Observing System Simulation Experiments (OSSEs) to demonstrate the value of the wind measurements as well as the corresponding infrared radiance observations that will come from the constellation. This work was an extension of the GMAO OSSE infrastructure and is in the context of the MISTIC(tm) Winds concept. It is noted, though, that this provided insight to the overall measurement strategy. This talk addresses the simulation of the atmospheric motion vectors retrieved via the constellation, the simulation and validation of the radiance observations measured via the constellation, the specification of observation errors for both winds and radiances, and the extension of the data assimilation system to utilize these additional observations on top of a full global observing system. Finally, the results from a set of OSSE experiments are presented.

15.05 The TROPICS mission's sounding capabilities

Presenter: Ralf Bennartz, UW-Madison
Authors: Ralf Bennartz, Bill Blackwell, Scott Braun, Vincent Leslie, Tom Greenwald, James Davies
NASA's 'Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats' (TROPICS) mission will consist of six 3U CubeSats, two CubeSats in each of three orbital planes at 550 km altitude and 30° inclination. Each satellite is equipped with cross-track scanning microwave sounders covering the 118 GHz oxygen and 183 GHz water vapor absorption bands as well as channels at 92 and 204 GHz. TROPICS will demonstrate that a satellite constellation approach to earth science can provide improved resolution, configurable coverage (e.g. tropics, near global, or global), flexibility, reliability, and launch access at extremely low cost, thereby serving as a model for future missions.

TROPICS will enable passive microwave observations of tropical cyclones with an unprecedented temporal resolution. It will also allow for temperature and moisture soundings with accuracy similar to current operational microwave sounders. This presentation will give and overview of the TROPICS mission with special emphasis on its sounding capabilities for both retrievals and data assimilation.

15.06 Future opportunities of using microwave data from small satellites

Presenter: Fuzhong Weng, NOAA/STAR
Authors: Fuzhong Weng, Xiaolei Zou and Zhengkun Qin
Small satellites carrying onboard microwave instruments include Microsized Microwave Atmospheric Satellite (MicroMAS) [1] which was deployed from International Space Station on March 4, 2015; Microwave Radiometer Technology Acceleration (MiRaTA) [2] and Earth Observing Nanosatellite (EON), both of which carries the multi-band microwave sounder onboard; the five-CubeSat constellation Temporal Experiment for Storms and Tropical Systems (TEMPEST) [3]. Recently, a new mission on Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) is developed by NASA. TROPCIS is a constellation with 12 CubeSats. The 12-channel microwave radiometer is designed to provide the atmospheric temperature measurements by seven channels near the 118.75 GHz oxygen absorption line, water vapor measurements by three channels near the 183 GHz water vapor absorption line precipitation measurements by a single channel near 90 GHz and cloud ice measurements by a single channel at 206 GHz. This study aims at using the microwave observations for monitoring the fast-evolving weather systems and improving the prediction of the storms through an optimally-designed small satellite constellation. Hurricane Weather Research and Forecast (HWRF) model is used to conduct the impact studies with assimilation of microwave sounder data from future small satellites. For a direct monitoring of storm development, we propose a three dimensional imaging algorithm using all-available microwave sounder radiance data as demonstrated earlier [4].

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Session 15b: Future observations

15p.01 IASI-NG program: General status overview

Presenter: Francisco Bermudo, CNES
Authors: F. Bermudo, E. Jurado , F. Bernard, C. Lefèvre, A. Deschamps, S Guibert

With notable improvements on spectral and radiometric performances compared with IASI first generation, CNES will develop the New Generation of the Infrared Atmospheric Sounding Interferometer (IASI-NG) key element of the future European meteorological polar system, i.e. the EUMETSAT Polar System Second Generation (EPS-SG).

Within a CNES and EUMETSAT cooperation agreement, CNES has technical oversight responsibility for the development and procurement of the instruments, the definition of instrument in flight operations, the Level 1 data processing software (L1C POP) and the IASI NG Technical Expertise Centre developments. (IASTEC) in charge of the in-flight calibration, validation and continuous performance monitoring. The present paper reports on latest general status overview of IASI NG program

15p.02 Overview of the IASI-NG Level 1 processing

Presenter: Adrien Deschamps, CNES
Authors: A. Deschamps, H. Makhmara, C. Luitot, F. Bernard, E. Baldit, A. Penquer, E. Jurado, F. Bermudo

The development of the IASI-NG System, under responsibility of CNES, includes development and delivery of IASI-NG instruments and Level 0 Processor (ICPU) to be flown on the Metop-SG A Satellites, the development of the Level 1 Processor (L1 POP) as part of the EPS-SG ground segment, and the development of a Technical Expertise Centre (IASTEC) in charge of the in-flight calibration, validation and continuous performance monitoring.

This paper reports on latest scientific developments of the Level 1 Processor concerning both the IASI-NG sounder science data and the internal imager. It presents also the current system performances budget for the main mission requirements.

The Level 1 Processor aims to transform raw interferograms generated by the instrument (L0 products) into geo-located and calibrated spectra distributed to end-users (L1C products). This transformation is divided in several steps such as the Zero-Path Difference detection, the radiometric calibration and the instrument removal. This last function performs in one operation the spectral calibration, the equalization of the Instrument Spectral Response Function (ISRF) and an apodization with a truncated Gaussian function.

This operation consists in estimating the ISRF for each spectrum acquisition, taking into account both the spectral shape and the spectral shift induced by the instrument, then replacing this spectral response function by an easily-modeled function (Gaussian) which is the same for all acquisitions. This part of the Level 1 Processor is named ISRF-EM (for ISRF-Estimation Model) and is very different from the processing of the IASI first generation data. We describe in this paper how this estimation is performed and how this algorithm takes benefits from the devices included in the instrument design, such as the Fabry Perot Interferometer and the five metrology beams.

We present also the functions of the IASI-NG internal imager (IMA) and the main algorithms of the image data processing to perform the pixels geolocation and the scene description within the IASI-NG Field-Of View, based on a radiance classification.

15p.03 Introduction to the IASI-NG principal components and L2 operational processor

Presenter: Flavia Lenti, CLC Space GmbH
Authors: F. Lenti, T. Hultberg, T. August, C. Clerbaux, P. Coheur

The EPS-SG, EUMETSAT Polar System – Second Generation, will provide continuity of observations after EPS in the 2020–2040 time frame. It is Europe's contribution to the future Joint Polar System (JPS), which is agreed to be established together with the National Oceanic and Atmospheric Administration (NOAA) of the United States, following on from the Initial Joint Polar System (IJPS).

The IASI-NG, Infrared Atmospheric Sounding Interferometer - New Generation, is the succesor instrument of the IASI instruments flown on the EPS/Metop satellites. It will provide hyper-spectral infrared soundings of temperature, water vapour, and trace gases with a spectral resolution of 0.25 cm-1 (twice the spectral resolution of IASI) within the spectral range from 645 to 2760 cm-1. The noise figures of the IASI-NG are half the ones of IASI. As for IASI, the footprint at Nadir is about 12km and the observations will be performed at an average spatial sampling distance of 25 km.

Similarly as in EPS, IASI-NG will fly with a microwave sounder (MWS, taking heritage from AMSU and MHS) and a high spatial resolution radiometer (METimage, taking heritage from AVHRR and MODIS).

We introduce here the required products with their required accuracy, and give an overview of the processing chains planned to generate the principal components (Level 1D) and the Level 2 (L2) geophysical parameters (Level 2) products in near-real time. These will include temperature and humidity profiles; surface skin temperature over ocean, land and ice; land surface emissivity; dust detection and cloud detection and characterisation ozone profiles as well as air quality and atmospheric composition products: O3, CO, HNO3 profiles, SO2 characterisation and green-house gases. The IASI-NG L2 processor has a direct heritage from the operational IASI L2 v6 processor, including BRESCIA and FORLI retrieval functions to generate the EUMETSAT AC SAF products.

15p.04 Preparing the assimilation of IASI-NG in NWP models: A first channel selection

Presenter: Francesca Vittorioso, CNRM/Meteo-France & CNRS

Authors: F. Vittorioso, V. Guidard, N. Fourrié, J. Andrey-Andres

The hyperspectral Infrared Atmospheric Sounding Interferometer (IASI), key payload element of the European Meteorological Operational Satellites (MetOp) series, provides since 2007 a huge contribution to Numerical Weather Prediction (NWP), pollution monitoring and climate research with its accurate measurements of atmospheric temperature, humidity and more than 25 other atmospheric components.

As the EUMETSAT Polar System-Second Generation (EPS-SG) is being prepared, a new generation of the IASI instrument has being designed. The IASI New Generation (IASI-NG) instrument will measure at 16921 wavelengths (or channels) in each sounding pixel benefiting of a spectral resolution and a signal-to-noise ratio improved by a factor 2 compared to its predecessor. Measurement precision will be improved as well (1 K for temperature and 10% for humidity). IASI-NG characteristics will lead to huge improvements in detection and retrieval of numerous chemical species and aerosols, and in thermodynamic profiles retrievals.

The high amount of data resulting from IASI-NG will present many challenges, most of all in the areas of data transmission, storage and assimilation. Moreover, the number of individual pieces of information will be not exploitable in an operational NWP context and the choice of an "optimal" data subset will be needed.

For all this reasons, an appropriate IASI-NG channel selection is going to be performed aiming to select the most informative channels for NWP. The work will be carried out on a simulated observation database, containing simulated data for IASI and IASI-NG, produced with specific purpose to serve as a Observing System Simulation Experiments (OSSEs) support.

One-dimensional variational (1D-Var) experiments are used to carry out the channel selection for IASI-NG. As a baseline, retrievals over sea, clear-sky pixels have been realized with the 123 IASI channels used in operational assimilation. However, IASI-NG has a larger channel set and thinner Jacobians. Thus, the best channel selection for this instrument is not necessarily the same as for IASI.

Methodology and results of the channel selection will be described in the presentation.

15p.05 Preparing test data for the IRS Level 2 processor

Presenter: Cédric Goukenleuque, EUMETSAT

Authors: C. Goukenleuque, T. August, B. Théodore

The Meteosat Third Generation (MTG) programme is EUMETSAT follow up of the Meteosat Second Generation (MSG), to guarantee continuity of access to space-acquired meteorological data until at least the late 2030s. It consists of three axes stabilised platforms, allowing instruments to be pointed at the Earth for 100% of their in-orbit time. The satellite series will comprise four imaging (MTG-I) and two sounding satellites (MTG-S). The Infra-Red Sounder (MTG-IRS) is based on an imaging Fourier-interferometer with a hyperspectral resolution of 0.625 cm-1 wave-number. It will deliver hyperspectral infrared measurements over the Full Disk in the Long-Wave InfraRed (LWIR), between 700 and 1210 cm-1 (14.3–8.3 µm) and in the Mid-Wave InfraRed (MWIR), between 1600 and 2175 cm-1 (6.25–4.6 µm) with a half-hour repeat cycle over Europe. The IRS spectra will enable the monitoring of atmospheric temperature, humidity, ozone vertical distributions and some other atmospheric constituents such as SO2, CO, aerosol, as well as the retrieval of surface parameters: sea-and land-surface temperature and land surface emissivity.

There is a large heritage in hyperspectral infrared missions from Polar orbits (e.g. AIRS, IASI, CrIS) with a number a directly applicable experience to the generation of IRS principal components and Level 2 products. Some aspects specific to the geostationary (GEO) acquisition (e.g. viewing geometry from Nadir to quasi limb sounding, very high temporal sampling, data volume) and to this instrument (spectral resolution and coverage coarser than IASI, high spatial resolution) need to be studied to adapt legacy algorithms, develop new ones where needed and exploit the opportunities that the IRS sensing offers in complement to low-Earth orbit missions. Test data are required more generally also to verify and test the implementation of the prototype and future operational processors. We present here early test data development and results, involving high spatial resolution geophysical state from regional numerical models and simulated data with radiative transfer models to evaluate the domain of applicability of heritage algorithms and prepare for the testing and verification of the IRS L2 prototype processor.

15p.06 Value-added impact from geostationary hyperspectral infrared sounder on high impact weather forecasting – demonstration with quick regional OSSE

Presenter: Zhenglong Li, SSEC/UW-Madison
Authors: Pei Wang, Zhenglong Li, Jun Li, Agnes Lim, Timothy J. Schmit, Robert Atlas

Atmospheric water vapor information with high temporal and spatial resolution is one of the key parameters needed in the regional numerical weather prediction (NWP) models for reliable prediction of high impact weather (HIW) events such as tropical cyclones (TCs) and local severe storms (LSS). The high spectral resolution or hyperspectral infrared (IR) sensors from geostationary orbit (GEO) provide nearly time continuous three-dimensional temperature and moisture profiles that allow substantial improvements in monitoring the mesoscale environment for HIW forecasts. These measurements would be an unprecedented source of information on the dynamic and thermodynamic atmospheric fields, an important benefit for nowcasting and NWP based forecasting. In order to demonstrate the impact of GEO high spectral resolution IR sounder radiances on HIW forecasts, a regional quick Observing System Simulation Experiment (R-OSSE) frame has been developed. The first step is to simulate both the GEO and current polar orbit (LEO) satellite based high spectral resolution IR sounder radiances from a suitable high spatial resolution natural runs (NRs). A fast radiative transfer model (RTM) has been developed for radiance simulation, and simulated GEO based hyperspectral IR radiances from NRs are compared with the collocated GOES Imager radiance measurements to examine the quality of the simulation, including channels consistency, diurnal variations, cloud coverage etc. Quick R-OSSEs are performed using the high resolution NRs to investigate the potential value-added impact of a GEO high spectral resolution IR sounder on TC and LSS forecasts. It is found that compared with a LEO based advanced IR sounder, a GEO advanced IR sounder has potential to provide value added impact on both TC and LSS forecasts due to large spatial coverage and high temporal resolution.

15p.07 Using CIRAS and MicroMAS-2 to mitigate the data gap of CrIS and ATMS

Presenter: Zhenglong Li, SSEC/UW-Madison
Authors: Zhenglong Li, Jun Li, Pei Wang, Agnes Lim, Timothy Schmit, Jinlong Li, Frederick W Nagle, Robert Atlas, Sid Boukabara, Thomas Pagano, William Blackwell, and John Pereira

As the Nation's next generation polar orbiting operational environmental satellite system, the Joint Polar Satellite System (JPSS) will continue observing the atmosphere and earth surface in the afternoon orbit (1330 local overpass time) over the next two decades. These observations will provide critical support toward NOAA's goal of the Weather-Ready Nation. Each of the four JPSS satellites will have a designed lifetime of 7 years, resulting in about 2 years of overlap between two consecutive satellites. However, the current constellation is fragile, with the possibility of a data gap in critical sounder data should the S-NPP satellite fail before JPSS-1 is launched; or in the event of a launch failure before NOAA is able to deploy a more robust afternoon polar-orbiting constellation by the 2020's. Should one or more instruments or launch system fails, it could be detrimental to operational weather forecasts. CubeSat based infrared (IR) or microwave (MW) sounders, with the great advantage of being cost effective, could be used to mitigate the risk of the temporary data gap. For example, the Jet Propulsion Laboratory's (JPL's) Cubesat Infrared Atmospheric Sounder (CIRAS) measures hyperspectral IR radiances in the shortwave CO2 region near 5 micron. Despite of fewer channels (625 total) and reduced coverage than the Cross-track Infrared Sounder (CrIS), multiple CubeSats could be launched into one or more orbits to increases data usage, while maintaining an overall low cost. In the loss of the Advanced Technology Microwave Sounder (ATMS), the Lincoln

Laboratory's Micro-sized Microwave Atmospheric Satellite-2 (MicroMAS-2) could be used to mitigate the risk. In this study, quick regional observing system simulation experiment (OSSE) studies are conducted to 1) evaluate the impact of the CIRAS and MicroMAS-2 on local severe storm forecasts over CONUS, 2) determine whether they are capable of mitigating the risk in losing CrIS or ATMS on JPSS, and 3) determine the optimal configuration of the CubeSat orbits, such as how many orbits and how many CubeSats in each orbit. Details about the CubeSat orbit simulator, the radiance observation simulation, the nature run generation, and the results of the impact study will be presented.

15p.08 Level 1 processing for the Microwave Sounder on Metop-SG

Presenter: Nigel Atkinson, Met Office
Authors: Nigel Atkinson, Niels Bormann, Roger Randriamampianina, Fatima Karbou, Clemens Simmer, Jörg Ackermann, Sabatino Di Michele, Sreerekha Thonipparambil, Dirk Schüttemeyer, Ville Kangas

The Microwave Sounder (MWS) will fly onboard the Metop-SG satellite "A", due for first launch in 2021. It is a cross-track scanning microwave radiometer, providing a total number of 24 channels from 23 GHz up to 230 GHz. The instrument is being developed by Airbus in the UK.

In preparation for the mission, ESA and EUMETSAT have established a Science Advisory Group (SAG). One of the tasks of the SAG is the preparation of a Science Plan; within the plan, gaps that might exist in the proposed product processing, product format, archiving, dissemination and reprocessing will be identified.

The SAG has made some specific recommendations on the calibration methodology to be used for MWS. The calibration equations proposed have clear traceability to heritage missions (e.g. AMSU-A, MHS), with a polynomial conversion from counts to antenna temperature similar to that found in NOAA level 1b files. But the equations are modified to take account of the scan-angle-dependent antenna reflectivity, in a way that is physically realistic yet without introducing undue complexity. Also, it has been found that the equation traditionally used for the nonlinear term (due to nonlinearity in the power detector) does not correctly account for changes in gain of the receiver front-end components as the instrument ages. An alternative formulation is presented.

Other aspects of the level 1 processing, including antenna pattern correction and monitoring diagnostics, will also be discussed.

15p.09 Evaluation of Laser Heterodyne Radiometry (LHR) for Numerical Weather Prediction (NWP) applications

Presenter: Fiona Smith, Bureau of Meteorology (and Met Office)
Authors: Fiona Smith, Stephan Havemann, Alex Hoffmann, William Bell, Damien Weidmann and Stuart Newman

Infrared LHRs are very small, very high spectral resolution instruments suitable for launch on small satellites or piggybacking onto larger missions, offering a good alternative to traditional hyperspectral sounders.

In this poster, we explore whether the very high spectral resolution infrared measurements achievable with LHR over narrow microwindows (<1 cm-1) may theoretically be suitable for future nadir-viewing instruments targeting NWP. Appropriate microwindows with CO2 lines apt for temperature sounding are identified, and information content analysis used to study the performance of idealized instruments in an operational NWP data assimilation context.