2. WORKING GROUP REPORTS

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Working Group members: R. Saunders (Co-Chair), L. Garand (Co-Chair) with S. Gu, F. Weng, M. Matricardi, P. Van Delst, P. Brunel, T. Kleespies, F. Chevallier, L. McMillin, J. Li, N. Jacquinet-Husson, S. Turner, R. Armante, T.R. Sreerekha, V. Sherlock, S. English, G. Deblonde, C. Köpken and input from F. Prata and M. Goldberg.

This working group focuses on the issues related to atmospheric radiative transfer (RT) and surface property models which are relevant for radiance assimilation and atmospheric and surface retrievals from current and planned infrared and microwave sounder data.

2.1.1 Atmospheric profile datasets for Radiative Transfer

Radiative transfer (RT) models require a dataset of diverse profiles for training and independent validation. The group is actively using various datasets summarised here. Recent developments include the generation of the TIGR-2000 dataset at LMD, which has 2311 profiles of temperature, humidity and ozone, the latter coming from the UGAMP dataset. Humidity is extrapolated above 300 hPa. The ECMWF profile set selected from the 60 level model analyses, with fully analysed ozone consistent with the temperature and humidity fields is now available. There are 13,000 profiles on model levels with a subset of 80 selected profiles also available for RT model training. In addition to temperature, humidity and ozone there are cloud and surface variables from the model also included with each profile. This dataset is available from the RTTOV web site at: http://www.metoffice.com/research/interproj/nwpsaf/rtm

Other datasets in use are the 48 profiles from the University of Maryland Baltimore County, which are a mix of AFGL, TIGR, and NOAA profiles (contact Scott Hannon, UMBC); the Garand intercomparison set of 42 profiles selected from a larger database which uses SAGE data for upper water and ozone (contact Shawn Turner, MSC). The NOAA-88 profiles that include rocketsondes and SBUV ozone are available from Mitch Goldberg (NESDIS) and there are several versions. The older 43L TIGR-2 dataset (43 water vapour profiles) and the NOAA-88 set (34 ozone profiles) are used for RTTOV and the original 42L 32 profiles from NOAA-88 are also still in use.

The group discussed the number of levels of the profiles required for advanced IR sounder simulations. It was agreed that around 90 levels are optimum based on studies at ECMWF and the Met Office since the last meeting. However it was also felt important to agree on a standard set of levels for everybody as the line by line (LbL) transmittance calculations are so expensive. This could be the AIRS 101 levels as this would allow a sub-sampling or interpolation to any required levels for RT training.

Recommendation

The next definitive LbL transmittance computation for fast RT model training should be on the AIRS 101 levels to facilitate use by all users.

The group noted that diverse profile datasets of trace gases (i.e. CO, CH_4, N_2O, CO_2) are now in preparation at ECMWF and being used for trace gas simulations. The issue of how many profiles are needed to train a statistical regression fast RT model was raised and the general consensus

was about 50 profiles are the minimum number required. The representativity of a profile set was discussed. If the RT model can reproduce results with an independent profile set to an accuracy close to that for the dependent set then it is a reasonable assumption the dependent set is adequate. Members of the group reported problems consistently interpolating profiles on to different levels. There is a potential ambiguity relating layer integrated and level point values. Transmittance datasets should include documentation of any interpolation/integration routines so data can be used consistently.

Recommendation

A standard set of interpolation routines should be provided to optimally convert from level to layers (and vice versa).

The extrapolation of profiles to below the surface (e.g. for Antarctic profiles) was not recommended so that for training RT models the lower levels may have fewer profiles in the regression than the upper levels.

2.1.2 Instrument characteristics required for RT modeling

The group reviewed where there were new requirements or gaps in the instrument data required for RT modeling. The following is a list of the new or existing sensors where the group recognized information is still required for RT simulations:

- HIRS and AVHRR spectral response functions for NOAA-M due for launch in mid 2002.
  Action: T. Kleespies (NESDIS) to make HIRS and AVHRR filter response functions available to ITWG before NOAA-M launch.

- The AIRS channel responses will be updated 6 months after launch. L. Strow (UMBC) will make the updates available.
- GOES imager filter response functions are on a NOAA web site (except for GOES-9). Problems noted with GOES-12 should be documented.
  Action: P. Brunel (CMS Météo-France) to contact Tim Schmidt (CIMSS) to clarify GOES information still required (GOES-9, GOES-12).

- MODIS responses for AQUA are needed
  Action: P. Menzel (NESDIS) to provide contact point for AQUA MODIS response functions.

- Concerns were raised about the lack of detail in the early METEOSAT filter response functions.
  Action: R. Saunders (Met Office, Bracknell) to raise early METEOSAT filter response functions matters with EUMETSAT.

- SSMI(S) channel characteristics are documented by Barbara Burns provided after the last ITWG. Roger Saunders can distribute to ITWG on request.
- For IASI simulations note a minor change in the definition of level 1C radiances has been made (contact Marco Matricardi for details)
- AMSR and WINDSAT channel characteristics are required.
  Action: F. Weng (NESDIS) to inform group of any information on AMSR and WINDSAT channel characteristics.

Recommendation

That instrument builders provide response functions in digital form and at the actual spectral resolution it was measured.

Recommendation

That RT modelers document clearly which filter responses were used in their simulations (e.g. by including them in the output files).

NOAA have recently moved to using the latest set of fundamental constants in their processing. It was emphasized that the same set should be used in the calibration processing as in the RT model simulations.

Action

T. Kleespies (NESDIS) to announce the new NOAA set of fundamental constants to the Working Group.

2.1.3 Line by Line (LbL) model status

The status of IR LbL models used by the group is summarized below:

- GENLN2/GENLN3: new release planned but no new science, just more user friendly and Fortran 90 (contact is Dave Edwards at NCAR email:edwards@ncar.ucar.edu)

- kCARTA is being used for AIRS simulations (contact is L. Strow at UMBC email: strow@umbc.edu).

- LBLRTM: Version 6.01 is available. Some of the new features are:

    - Capability to input atmospheric profile on either altitude or pressure grid, and to output quantities on either altitude or pressure grid.
    - Capability to compute quantities for atmospheric layers which are not in local thermodynamic equilibrium (non-LTE option).
    - Update of universal constants
    - Contact is clough@aer.com

- 4A-2000: Various improvements have been made since the last meeting to be reported in a paper (contact is N. Scott at LMD email: scott@ara01.polytechnique.fr).

A report has recently been published documenting the EUMETSAT sponsored intercomparison of line by line models for IASI simulations. It is available at: http://www.eumetsat.de/en/area2/publications/tm08.pdf
The results of this study, at least for the two airmasses considered, can be used to identify parts of the infrared spectrum where model and/or spectroscopic errors are significant.

Recommendation

The EUMETSAT Line by Line intercomparison is a valuable attempt to document biases in LbL models. It should be extended to more airmass types.

For microwave LbL models:

- MPM 89/92 is used by many groups (i.e. basis for RTTOV and OPTRAN) (contact: Roger Saunders)
- MPM 97: includes updated 23.8 GHz band used at NOAA. (contact: Fuzhong Weng)
- Rosenkranz 1997: updated with a band model used at NOAA. (contact: Fuzhong Weng)
- ARTS a new model developed at Bremen Univ. which aims to be a reference model (contact: Sreerekha Ravindranathan)

There are still biases between measurements and models around the 23 GHz water vapour line. It was noted there are plans for microwave sounders at frequencies up to 500 GHz and so models will need to be able to simulate radiances at these sub-millimeter wavelengths.

Actions

S. Ravindranathan (Univ. of Bremen) to provide web site on new microwave RT model inter-comparison work at Bremen Univ.

R. Armante (LMD, Ecole Polytechnique) to provide information to the Working Group on the STRANSAC-2000 study on microwave simulations.

2.1.4 Assessment of spectroscopic databases

The performance of the new generation of high spectral resolution atmospheric sounders (e.g. AIRS, CrIS and IASI) is dependent upon the quality of the spectroscopic parameters of the active gases since these are used as input to the LbL models. The latest official releases for spectroscopic parameters are GEISA-2000 and HITRAN-2000. Nicole Jacquinet-Husson (LMD) reported on significant efforts to improve the spectroscopy for advanced IR sounders like IASI and AIRS. She commented on the development of the GEISA/IASI spectroscopic database which is an extract, in the IASI and AIRS spectral range (600-3000 cm^{-1}), and a partial update of GEISA. This work is ongoing within the ISSWG (IASI- Infrared Atmospheric Sounding Interferometer- Sounding Science Working Group), and funded by CNES/France, EUMETSAT and the E.C. Environment and Climate Program. These efforts are associated with an international collaboration for IASI required spectroscopy, notably trace gases. The current edition of GEISA is accessible freely via the ARA/LMD group web site, upon prior request for password at *nicole.jacquinet@lmd.polytechnique.fr* The GEISA/IASI spectroscopic database is available at: ftp://ara01.lmd.polytechnique.fr/pub/geisa/iasi2000 (anonymous ftp). An updated HITRAN-2000 database is available. The updates are documented at http://www.hitran.com/hitran/updates.html For the water vapour continuum, CKD 2.4, is the new standard. The EUMETSAT LbL comparison mentioned above is part of the assessment of the accuracy of these datasets.

2.1.5 Fast RT models

Status of fast models:

OPTRAN: Adapted to AIRS. Work underway to improve ozone channel simulations (see papers by McMillin, Kleespies and Van Delst in this conference proceedings).

RTTOV: Version 7 about to be released which includes AIRS and SSMI(S) simulation capability. Details in paper by Saunders et al. (this conference proceedings).

GASTROPOD: Fixed pressure level model for AIRS (see paper by Sherlock et al. in this

conference proceedings).

OSS: Proprietary code developed by AER for CrIS but not yet available to RT community. Is reported to be fast and accurate. The group encouraged AER to include the IR model in the Garand comparison. Contact is Jean-Luc Moncet at AER.

MSCFAST: Implemented at MSC for use in GOES radiance assimilation. Will be adapted to AIRS. (contact Louis Garand).

3R-N: This fast model is based on neural networks and has been developed for TOVS channels at LMD (contact Raymond Armand).

Issues for fast RT models:

- Statistical models

Progress has been made on water vapour and ozone simulations for constant pressure models which for ATOVS channels now give errors well below the instrument noise. Developments are under way for other trace gases to be treated in these models. Water vapour continuum should also be treated as a separate gas from the line absorption to facilitate updates separately from the line datasets. The robustness of the simulations and proper weighting of the predictors requires further investigation. For example, channels in the center of strong lines can be difficult to simulate.

- Physical models

Updating of MSCFAST to AIRS will allow a detailed investigation of the errors versus wavelength for narrow channels. It should be noted that at least one fast physical model has been developed for MW applications (FASMPORT, Weng et al. to appear in *JAS*). This is a polarimetric 2-stream model for SSM/I, SSMI(S) and WINDSAT.

- Neural networks

The performance of these models for forward calculations is promising in terms of speed and accuracy. These models still need to be proven for Jacobian computations.

- Clouds and precipitation

Developments have been made to include cloud in fast radiance simulations. This will serve not only for NWP model validation, but also for research in the assimilation of cloudy radiances (see Chevallier et al. this conference). More work is needed to include precipitation effects in fast RT models.

- Broad channels

Broad band channels can be difficult to simulate with fast models as one central frequency is not a good approximation for the whole channel. RTTOV for instance has errors of almost 2 K for the SEVIRI 3.9 micron channel due to this effect.

- Interferometer channels

These can have negative lobes and so have to be treated correctly for simulation. Currently only apodised radiances with very small negative side lobes have been simulated but work is planned to simulate unapodised IASI radiances.

- RT model biases

An improved understanding of RT model biases as shown by the Garand intercomparison is required. For the use of RT models in NWP data assimilation models it was noted they should be the same in both the global and regional model of each NWP centre but that different bias tuning may be required for each.

Action

The web site maintained by MSC on the fast model intercomparison is a valuable resource for fast model development and should be maintained at least until the next ITWG meeting. (L.Garand, AES/MSC).

Recommendation

The RT community is encouraged to continue to develop and improve fast models for new and existing sensors. It must be recognized however that NWP centers prefer to only have one RT model for all sensors in their assimilation code so new developments should be able to feed through to existing RT models in NWP Centres.

2.1.6 Surface Property Models

2.1.6.1 Microwave emissivity

Ocean surface
For ocean surfaces improvements in FASTEM have been made since the last meeting and this has been integrated in RTTOV-7 (see paper on FASTEM-2 evaluation at: http://www.metoffice.com/research/interproj/nwpsaf/rtm/rtm_reports.html for more details). A two scale model is under development at NESDIS by Fuzhing Weng and will be delivered to NCEP for future polarimetric sensors.

Land surface
At NESDIS the MEM (microwave emission model) has been developed and used in NCEP models. This has allowed more microwave radiances to pass the quality control tests in the assimilation. There are still problems with modeling the emissivity over melting sea-ice, multi-year snow and high topography and more work is planned at NESDIS. Work is underway at Bremen University and Sreerekha Ravindranathan will report back to the group on this work.

Action

S. Ravindranathan (Univ. of Bremen) to report to the Working Group on work on surface models at Bremen.

2.1.6.2 Infrared emissivity

Ocean surface
For the ocean surface no major developments have been made since the last ITWG. Masuda parameterisations are used at several centers (i.e. ECMWF, NCEP) and ISEM-6 (within RTTOV) which is based on Masuda (1988) and Watts et al. (1996)

Issues:
- Accuracy for large viewing angles (>60 deg) required for geostationary radiance assimilation
- Accuracy for high wind speeds. Ship borne interferometer datasets are now available for model validation from Univ. Madison (contact P. Van Delst) and Univ. Miami (contact: pminnett@rsmas.miami.edu).

Land surface
For the land surface some work is underway in order to extend the use of radiance assimilation over land. However this is a difficult problem to reduce the errors to a point where lower peaking channels can be used over land. More channels with only a small sensitivity to the land surface may be able to be assimilated with an improved representation of the land surface emissivity in NWP models.

Issues:
- The link between spectral emissivity resolution and horizontal spatial resolution is important. When averaged over large areas for satellite ifovs the spectral emissivity variation is smoothed making it difficult to use lab and/or in situ measured emissivities without appropriate smoothing.
- Emissivity mixing is *not* linear, the temperature of each element also needs to be accounted for. At night the mixing should be more linear as the temperature contrasts are reduced.
- The emissivity can vary with viewing angle particularly for bare surfaces and uniform grassland.
- Validation is important for land surface emissivity datasets developed. There are several datasets with spectral emissivities measured over different surface types (e.g. see paper by M. Lynch in this conference). In addition MODIS data is being used to improve our knowledge of the IR emissivity.

F. Prata (CSIRO) has drafted a note on issues for surface temperature and emissivity retrieval from satellite sounders.

Action

R. Saunders (Met. Office, Bracknell) to circulate to the group, a draft copy of the note composed by F. Prata (CSIRO) on issues regarding surface temperature and emissivity retrieval from satellite sounders.

2.1.7 Proposal for group web page

It was proposed the working group web page should contain:

- Contact details of WG co-chairs

Links to:

- WG reports, ITSC-XI, ITSC-XII, …
- Links to instrument characteristics for RT calculations
- Links to Line by Line model pages
- Links to fast RT model pages
- Links to surface property models
- Links to fundamental constants
- Links to relevant reports/papers

Action

Co-chairs to prepare a web page for the Radiative Transfer and Surface Property Modelling WG.

All WG members to provide links to co-chairs which can be included on the web pages

2.2 TOVS/ATOVS DATA IN CLIMATE

Working Group members: J. Bates and C. Stubenrauch (Co- Chairs) with M. Goldberg, A. Kaifel, F. Chevallier, T. Phulpin, R. Armante, W. P. Menzel, G. Stephens, M. Prabowo, V. O. John, F. Prata, S. Uppala, and L. McMillin

2.2.1 Contribution of TOVS to climate studies

The use of TOVS data for climate studies has progressed from being experimental to operational. The data sets have proven to be of high value for climate studies. These data sets have been used for regional and global temperature and upper tropospheric humidity trend studies in assessments by the Intergovernmental Panel on Climate Change (IPCC) and various World Climate Research Programs (WCRP). Cloud properties have also been proven reliable and first trend studies have been undertaken. The use of infrared sounding channels allow retrievals both day and night and are less effected by volcanic aerosols than retrievals using visible channels. Further applications of TOVS data, particularly for retrieval of column CO_2, are currently under development and appear promising.

As we eagerly anticipate the next generation of spectrally-resolving infrared sounders, it is now clear that the constellation of operational satellites will be the backbone of the long-term global observing system. A major challenge in moving to the next generation sounding systems, however, is how to maintain a seamless time series of fundamental observations during that transition. This will take a concerted effort by both the instrument scientists and the climate scientists. It will also take a long-term commitment by space agencies to provide resources to achieve the longest possible overlap of the new technology with the old technology.

The following list describes in brief detail some of the latest developments in climate products from TOVS as summarized by those participating in this conference. Further details can be found in the conference abstracts and the conference proceedings.

2.2.1.1. Temperature and water vapor

AMSU-A observations are ideal for monitoring temperature change for two very important reasons. First, microwave observations in the 50 – 60 GHz band are very insensitive to non-precipitating clouds and thereby provides near global coverage. Second, because of the high degree of linearity of microwave observations with atmospheric temperature, linear regression can be used to derive atmospheric temperature from the observed brightness temperatures. AMSU-A temperature datasets are available from NOAA/NESDIS/ORA. The record began in July 1998. The datasets are at 1x1 latitude/longitude resolution, separated into ascending and descending orbits, and averaged for daily, pentad and monthly time periods. The gridded files also include limb adjusted brightness temperatures for all AMSU-A channels, and total precipitable water and cloud liquid water over ocean. There are 40 levels of temperature, from 0.1 to 1000 mb. For additional information go to:
http://orbit-net.nesdis.noaa.gov/crad/st/amsuclimate/amsu.html

HIRS observations have been used to form a long-term climatology of upper tropospheric humidity (UTH) from late 1978 to March 1998. These data have been used to study interannual variability and long-term trends of UTH. These long-term trends are strongly positive in the deep tropics, negative in the Southern Hemisphere subtropics and midlatitudes, and of mixed sign in the Northern Hemisphere subtropics and midlatitudes. The trends are shown to be consistent with

atmospheric circulation changes observed in the past 20 years, including a tendency toward more El Niño-Southern Oscillation (ENSO) warm events and changes in transient eddy activity in the subtropics. This data set has been used in international assessments including the Intergovernmental Panel on Climate Change and in an international assessment by the World Climate Research Program.

2.2.1.2. Ozone

Due to the failure of the launch of QuickTOMS (autumn 2001) and the current problems of EarthProbe TOMS, and GOME1 on ERS2, operational total ozone column monitoring from satellite is not secure for the near future. In the framework of a nationally funded project the ZSW (Center for Solar Energy and Hydrogen Research, Stuttgart, Germany) developed a new method based on neural works (Neural Network Ozone Retrieval Scheme: NNORSY-TOVS) for reliable total ozone monitoring from NOAA-TOVS satellite data. The ZSW recently reprocessed the whole TOVS Level 1b archived data of the satellites TIROS-N, NOAA-6 to NOAA-14 starting Sept. 1979 up to now. So far NNORSY-TOVS wasn't applied to the ATOVS data of NOAA-15 and 16. The RMS on the retrieved long term TOVS total ozone column product is 9 Dobson Units (DU) for monthly mean values compared to ground measurements of Dobson and Brewer stations. This is close to the accuracy of TOMS V7 data with an RMS of about 8 DU for the same time scale. Therefore the TOVS ozone product is well suited for filling the TOMS data gap (May/1993 to July/1996) as well as for global ozone trend analyses.

NNORSY-TOVS has the following advantages:

- Total ozone retrieval can be carried out with the same accuracy also at night time, which is important for data over polar regions during the polar winter in the absence of daylight, in contrast to satellite instruments measuring the backscattered solar radiation (e.g. TOMS, GOME, SBUV).
- At present, with NOAA-14, 15 and 16 in orbit, three satellites are operational in orbit and secure the availability of daily total coverage and enables to get also information of the diurnal cycle of the total ozone column.

Future work will focus on further geophysical validation and comparison of the TOVS ozone product with other satellite ozone data (TOMS, GOME, SBUV/2) as well as the setup of a near-real-time retrieval system for the operational NOAA satellites (NOAA-14, 15 and 16) for global ozone monitoring in order to extend the long term ozone product.

2.2.1.3. Clouds

Infrared sounders on polar orbiters have been shown to have higher sensitivity to semi-transparent high thin clouds than visible and infrared window techniques. They also allow cloud property retrieval both day and night and are less effected by volcanic aerosols than retrievals using visible channels.

For the study of cloud properties, two data sets have been presented at ITSC-12:

1) University of Wisconsin has retrieved cloud properties for the period 1989 – 2001, by using the CO_2 slicing method on sampled HIRS pixels.

   Trends in HIRS cloud statistics, using the CO_2 cloud slicing method, from the last decade reveal that high clouds were stable until 1995 and then gradually decreased below 1989

levels. These decreases are mainly observed over land and especially in higher clouds; ocean cloud cover has been mostly stable. It is found that measured cloud cover trends are sensitive to the orbit overpass times; orbit drifts cause changes that cannot be attributed to decadal cloud trends. For the satellites that did not drift, NOAA 10 and 12, a significant cloud frequency decrease after 1995 is evident. A decrease in tropical cloud cover in the HIRS statistics is similar to that reported by Wielicki et al. (2002) using CERES data and by Chen et al. (2002) using ISCCP data. Such comparisons will continue and will be extended to include the full time span of the polar sounders.

2) The LMD/ARA group has retrieved cloud properties for the period 1987 – 1995, by using a weighted Ψ^2 method on cloudy HIRS radiances averaged at 1° resolution.

   The amount of high clouds (p_{cld} < 440 hPa) over the globe is around 30% and was stable within 1% during the observed period 1987 - 1995 which includes an El Nino event in 1987/88 and the eruption of Mt Pinatubo in 1991. High cloud amount is slightly lower in the SH midlatitudes (25%) than in the NH midlatitudes (32%). In addition to cloud height and effective emissivity, the LMD/ARA group has developed an algorithm to retrieve mean effective ice crystal diameters of medium-thick cirrus clouds. This technique takes advantage of the fact that cirrus emissivity differences between 8 and 11 microns depend on this parameter. A long-term survey of these cirrus properties is being undertaken as part of the European project CIRAMOSA (CIrrus microphysical properties and their effect on RAdiation: survey and integration into climate MOdels using combined SAtellite observations). Another activity at LMD is the intercomparison between TOVS cloud heights and those obtained by LITE, the lidar mission on the space shuttle during six days in September 1994.

2.2.1.4. Trace gasses

Important progress in retrieval of trace gas columnar abundance has been made recently. These are new research results and several investigators are planning to apply these results to the entire TOVS time series.

2.2.1.4.1. Retrieval of CO_2 from TOVS

One of the important advantages of the higher resolution sounders planned in the NPOESS era is the possibility for extracting non-traditional information from the measurements provided by these sounders. It is within this context that we describe the extent to which CO_2 may be directly retrieved from AIRS radiance data or data from similar emission-based spectrometer systems. The analyses conducted is also contrasted against the same analyses applied to ATOVS.

Investigators have shown that the retrieval of CO_2 column concentrations from high spectral resolution infrared sounders looks promising. These retrievals have high enough accuracy (approaching 2 ppmv) to be useful for CO_2 inversion studies that seek to estimate sinks and sources although the information is concentrated mainly in the free troposphere. By contrast, CO_2 information extracted from HIRS is less useful and may approach 4 ppmv accuracy under the most optimal circumstances but more generally can be expected to be at the 6 ppmv level which is just capable of resolving the annual cycle of CO_2. Investigators also have shown how retrieved CO_2 information, at the 2 ppmv level, also benefits temperatures derived from these sounders. The typical assumption of a globally constant CO_2 concentration introduces errors in temperature

retrievals that can be significantly reduced using a variable CO_2 distribution.

Plans exist to augment the data obtained by the high resolution sounders with data from spectrometers designed to measure the spectrally reflected sunlight at ultra-fine resolution in specific CO_2 absorption bands. The CO_2 measurement approach using these measurements is described in O'Brien et al. (2002) and employs radiance measurements in two carefully selected absorption bands located in the near infrared region of the solar spectrum. The complementary nature of these observations and the extent they add information on boundary layer CO_2 is currently under investigation.

2.2.1.4.2. Retrieval of SO_2 from TOVS

Approximately 7-8 Tg of sulphur are believed to be placed into the atmosphere by volcanoes each year. Most of this sulphur arrives in the form of SO_2 gas and at highly variable rates due to the nature of volcanic eruptions. It is estimated that about 30 Mt of SO_2 (~ 2 Tg of S) was emitted by the Pinatubo eruptions of June, 1991. SO_2 in the atmosphere is rapidly converted to sulphuric acid at a rate that depends on environmental temperature and the availability of water vapor. Sulphuric acid causes the stratosphere to warm and the surface to cool. SO_2 and other volcanic effluents (e.g. silicate ash) also cause radiative effects– stratospheric heating–but these are short-lived (days to weeks) and local. Nevertheless both SO_2 and ash are capable of causing changes significant radiative effects that can alter wind circulations.

Currently satellite measurements of SO_2 are made by the TOMS and GOME instruments using UV reflected light, and were also measured by the MLS on UARS. These data have variable and low spatial resolutions and, apart from the MLS, can only make daytime measurements.

The HIRS instruments are capable of measuring SO_2 in the lower stratosphere and upper troposphere through absorption of infrared radiation by $\nu 3$ band situated around 7.34 μm. TOVS has a channel that covers this region and analysis of data for several large eruptions demonstrates that TOVS can retrieve SO_2 concentrations (column) to rms accuracies of 3-6 D.U. Since TOVS provides global data and has been operational for more than 22 years, there is a potentially useful and as yet unexplored data-set of value to the climate community. The synergy of studying radiative effects and O_3/SO_2 coupling from the same data source is attractive and opens up new research avenues.

While it is extremely important to analyze the HIRS data to retrieve SO_2, HIRS data have several limitations. The broadband data are contaminated by water vapour effects and limit the retrievals to upper troposphere and lower stratosphere. These will be overcome once the high spectral resolution data of the advanced FT-IR sounders becomes available. AIRS, IASI, GIFTS and SEVIRI among others will all provide high spectral resolution data that could be used to retrieve SO_2 vertical structure and possibly provide tropospheric SO_2 estimates.

Recommendation

ITWG encourages use of satellite sounder data, including the historical TOVS/ATOVS and the next generation high spectral resolution data sets, for retrieval of column CO_2 amounts.

Recommendation

ITSC scientists are encouraged to prepare a set of comparisons of long term trends and variability from the TOVS long-term archive for specific fields. Comparisons to be prepared include temperature and moisture (Bates), clouds (Stubenrauch, Wylie-Menzel), O_3 (Kaifel), CO_2 (McMillin), SO_2 (Prata).

2.2.2. Relations to international climate programs

Satellite data sets are beginning to have a greater use in international assessments, although increased use is recommended. Notable uses occurred in the IPCC TAR for use of MSU mean layer temperature and HIRS for UTH. Research and TOVS data sets were also used as part of the WCRP Stratospheric Processes and their Role in Climate (SPARC) water vapor assessment. Satellite data sets are more extensively used in climate studies within the WCRP Global Energy and Water Cycle Experiment (GEWEX) program. In particular, the GEWEX radiation program (GRP) uses both imager and sounder data extensively in studies of global cloud, water vapor, precipitation, and earth radiation.

The Global Climate Observing System (GCOS) was established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. It is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU). GCOS provides an operational framework for integrating, and enhancing as needed, observational systems of participating countries and organizations into a comprehensive system focused on the requirements for climate issues. As such, GCOS provides an important point of contact for ITWG in terms of coordinating satellite sounder activities with the climate community. Details about recent GCOS activities can be found on the WMO GCOS web site.

In establishing observing systems for climate, GCOS has identified a number of basic principles that should always be followed. These derive from the so-called Karl principles (which have also been adopted by the Parties to the UN Framework Convention on Climate Change) and can be summarized as:

- ensure overlap whenever instruments are changed;
- fully document data processing methods;
- fully document station histories;
- maintain long continuous records;
- maintain calibration and validation facilities;
- wherever possible, back-up 'high-technology' systems with 'low-technology' ones;
- ensure that any new facilities fill real gaps;
- maintain effective data archive and access facilities;
- ensure there are processes to transfer systems from research to long-term stable operations;
- include GCOS needs in the initial design of networks.

These principles need to be applied to both *in situ* and satellite systems. A recent review by a

USA National Research Council (NRC) Panel highlighted the following issues for the application of satellite data for climate purposes:

- rigorous station keeping;
- overlapping observations;
- launch-on-schedule strategy;
- rigorous pre-launch and on-board calibration;
- formal production of climate products;
- web access to metadata;
- use of functioning baseline instruments on de-commissioned satellites;
- need for complementary *in situ* baseline observations;
- web access to basic climate products;
- need for network monitoring.

Recommendation

An invited presentation to be given to the ITWG on IPCC results and plans at next ITSC meeting.

Recommendation

That Space Agencies/Satellite Operator reports to the next conference include the relationship of plans to the Karl principles.

2.2.3. Pathfinders and re-analysis

Official NOAA/NASA Pathfinder project has ended but individual efforts continue and are encouraged. Since ITSC-XI, production of Path-A has continued at NASA GSFC (Susskind et al.) and processing is complete through the end of 2001. These data are being used by various investigators to study climate processes and trends, including feedback processes.

The Path-B activities (Chedin et al.) since ITSC-XI has focused on producing an extended, coherent radiosonde calibration data set using data from ECMWF and NCEP. This activity is required to provide cross-calibration data for the bias adjustment process for Path-B and should be complete by the Fall of 2002. Once that is accomplished, reprocessing of the entire TOVS data set will begin.

The ERA-40 effort is using 3-d var with TOVS 1b data. The ERA-40 effort has also had success in using the pre-TOVS instruments, the VTPRs, to extend the satellite record back to 1973. This means that we now have a 30-year record of global satellite observations that can be used for climate and global change studies.

ECMWF is currently performing the reanalysis of the global atmosphere for the period 1957-2001. ERA-40 will complement the already existing NWP reanalysis datasets: NCEP (1947-2000) and ECMWF (ERA-15, 1979-1993). In addition to the historical ground-based observations, and to a much larger extent than in ERA-15, ERA-40 makes use of the multi-channel satellite radiances through T159L60/ 3D-variational assimilation starting from the first sounding instrument VTPR in 1972 up to the present SSM/I, TOVS (MSU, HIRS and SSU) and ATOVS instruments. Cloud Motion Winds are used from 1979. Ozone information retrieved

from TOMS (total ozone) and SBUV (layered ozone) is assimilated as well. The reanalyses are progressing in three streams and currently analysed periods are 1957-1961, 1973-1975 and 1989-1996.

Surface and stratospheric analyses show major improvement compared with ERA-15. Among other positive signals, the validation of ERA-40 performed by several institutes associated to the project also indicates a better representation of tropical and extra-tropical cyclones, and better medium-range forecast performance compared with ERA-15.

Among the possible problems identified so far are higher than expected total column water vapour amounts over the tropical oceans and associated higher precipitation amounts. In addition there seems to be a slight tendency towards increased values through years 1989-1996.

Recommendation

Continued production of long-term TOVS climate data sets as envisioned by the NOAA/NASA Pathfinder projects with the goal of achieving a 25 year dataset 'TOVS 25'. The TOVS 25 data set would represent a best effort to use all 25 years of TOVS data for climate studies.

2.2.4. Calibration, validation and quality control monitoring

NOAA NESDIS is continuing efforts to address calibration issues on current and past satellites. Four issues related to calibration of the HIRS instruments are currently under investigation. These include:

1) Currently full calibration of HIRS data is accomplished every 40 scan lines. There is, however, ancillary calibration data included at the start of every scan line. NESDIS is conducting a calibration comparison study to evaluate whether using this additional calibration data leads to an improved calibration of the HIRS instruments;

2) It has been found that some satellites (notably NOAA-15 and NOAA-16) have an issue with the value at zero counts. NESDIS has a procedure to fix this problem;

3) All HIRS instruments that flew with a SSU (i.e., all HIRS instruments prior to the AMSU, except for NOAA-10 and NOAA-12) have SSU-induced noise. This noise can be significant (0.2-0.8C) and its magnitude varies from spot-to-spot and channel-to-channel. NESDIS has a process under way to attempt to correct this and apply it to the entire 1b time series;

4) The non-SSU suite HIRS instruments also have a smaller systematic noise- a process similar to 3) is under way to correct this.

Quality control efforts at numerical weather prediction centers are a very useful source of both calibration and validation information. We appreciate efforts by these centers to make such information available to users via web-based systems. It is not clear, however, that there is a procedure for the long-term archival of this information. We recommend that the long-term archive centers work with the NWP centers to establish a method for saving the important calibration and validation information derived from the assimilation systems.

In situ vertical sounding, both by the operational radiosondes and by research sondes (such as ozonesondes and research-quality water vapor sondes) is critical for satellite calibration and

validation efforts. There are, however, many user communities for these data and the needs of the different user communities can conflict. For example, those who use these data for global and regional climate studies want the launch time to remain constant in order to avoid aliasing the diurnal cycle into longer-term variability. Satellite users would prefer launch times based upon the satellite overpass time to ensure the closest match with the satellite data in time and space. Because of these conflicting needs, requests for changes in radiosonde operations to optimize their use for satellite cal/val must be precisely targeted and well supported to balance conflicts with other user needs.

NESDIS is developing a unified system for satellite validation. This system will include features such as 1) co-location of in situ data with multiple satellites, 2) storage of both the original and final corrected version of radiosonde data, and 3) co-location of radiosonde data with other in situ data types such as ACARS, buoys, GPS, etc.

The current system can be improved. Two opportunities exist for improved coordination between in situ sondes and satellite overpass times: 1) automated ship launches (Hinsman CBS) and 2) research group launches of ozonesondes and water vapor sondes.

In addition, ongoing research field programs offer another opportunity for obtaining calibration and validation data sets. These include both short-term field programs (IHOP, TOGA COARE, Vorcore, ARM IOPs, etc.) and long-term field observation programs (ARM CART sites, WODC/UV sites, GEWEX CEOP sites. etc.).

Recommendation

Past and present calibration issues are currently being addressed. This is a very important activity. These issues should be fully documented, and the related data and software needs to be placed in long term archives. Further software also should be developed and shared (L. McMillin, T. Achtor, D. Klaes, J. Bates)

Action

Develop, archive and make accessible a complete audit trail of all TOVS calibration issues and their resolution (J. Bates, NOAA).

Action

T. Reale (NESDIS) and T. Achtor (CIMSS/SSEC) to compile links from the TOVS/ATOVS Data in Climate Working Group web page to sites containing calibration and validation data, including ARM CART sites, WODC/UV sites, GEWEX CEOP sites, etc.

There is a need to develop a more formal arrangement for enquiring about, reporting and acting on past calibration issues. This arrangement requires development over the next 18 months (D.Hinsman, P.Menzel, J.Bates, L.McMillin).

2.2.5. Data access and archive

We strongly commend the efforts of the operational satellite agencies to make level 1b data sets available at low cost. We appreciate efforts by the WMO to coordinate the access and distribution of satellite data sets from research satellites. We also appreciate various national efforts for climate product processing, archiving, and distribution (such as the NASA DAACS, the French disciplinary centers ETHER for chemistry and ICARE for clouds, aerosols, and

radiation).

The full archival of and access to very large data sets from research satellites, such as Terra, remains a major challenge. In the future the operational satellite operators will face similar challenges. It is important to use the EOSDIS experience to evaluate the benefits and drawbacks of such a system for data distribution and archive.

The request from the coordination group for meteorological satellites (CGMS), that as archive centers transcribe data sets from old, difficult to use data media and formats to new and easier to use media and formats that they add some basic additional metadata to the record at that time, is commended. This metadata should include both details about the format and heritage (or audit trail) of the data as well as simple statistics computed from the data as it is being transcribed. The simple statistics should include, for a full orbit or geostationary satellite scan for each channel, the mean, standard deviation, skewness, kurtosis, maximum, minimum, total number of good observations, and total number of missing and bad observations. Such statistics are relatively easy to compute during data transcription and can be highly valuable to future users.

Action

EOSDIS is the first attempt to deal with the quantum leap in data volume from the next generation environmental satellite sensors. Space agencies/satellite operators should be invited to provide a summary of their plans in relation to this experience in providing data archive and access for next generation satellite instruments (Co-chairs to CGMS).

2.2.6. Data Utilization

There are still several issues which remain to be fully explored but of some importance for climate studies, these include; what are relative tradeoffs in using the shortwave vs longwavelength of water vapor for climate studies, and delineation of the importance of millimeter wave sounding from geosat for water cycle processes. These need to be addressed at ITWG 13.

2.2.7 Future instruments and continuity

There is an urgent need to develop the human resources necessary to take full advantage of the next generation of both research and operational satellite sounders for climate studies. We recommend that the satellite agencies in collaboration with educational institutions and national weather services develop programs such as graduate assistanceships and fellowships, post-doctoral programs, and visiting scientist programs to promote the use of the next generation satellite data.

2.3 THE USE OF TOVS/ATOVS IN DATA ASSIMILATION/ NUMERICAL WEATHER PREDICTION (DA/NWP)

Working Group members: C. Chouinard (Chair), J. Derber (Co-Chair), with N. Baker, W. Bourke, F. Bouttier, G. Deblonde, S. English, E. Gérard, B. Harris, C. Köpken, T. Landelius,, K. Okamoto, J. Paevere, V. Prasard, M. Probowo, S. Ptura, F. Rabier, R. Randriamampianina, J.Sang-Won, N. Servando, H. Schyberg, D.Singh, P. Steinle, E. Sylvestre, V. Tabor, J.-N. Thépault, C. Tingwell, M. Uddstrom, N. Wagneur, K. Whyte, J. Xue

2.3.1 Introduction

There were again many substantive presentations at this meeting that indicated very positive results using satellite data from different instruments although the impact of microwave data appears larger and easier to obtain . Very positive impact of direct assimilation of radiance was reported by still more NWP Centers that were previously using retrievals as their main source of satellite data. Some Centers that were previously using processed level-1d radiances have now started to use raw level-1b radiances with very positive results.

The WG notes that operational use of satellite data over land remains limited. Proper inclusion of the effects of surface emissivity, surface temperature, and cloud variations requires considerable development despite substantial progress in the last several years. Because of these problems, most operational Centers use channels with most of their signal above the surface or retrievals above the troposphere. There are exceptions, but even in these exceptions, the QC tends to be tighter and the weighting of the data less over land. The DAO reports positive impact for short term forecasts using 1D-var retrievals over land. The UKMO is using some lower peaking channels over limited region (Asia). ECMWF is using AMSU-A channel 5 (and above) over land and ice and NCEP in its final testing is using microwave channels over non-snow covered land.

With the release of the latest radiative transfer code (RTTOV-7) at the meeting, it is evident that the exchange of code/results and techniques between groups within the satellite community continues to be very vibrant. The use of the Internet to distribute the new radiative transfer code to users has been very efficient. Overall, the formation of the NWP SAF in Europe has had a very positive impact on satellite data user community all over the world. In the same context, the AAPP and ITPP packages used to calibrate and navigate the satellite data are now extensively used by most NWP Centers in the preparation of data for analysis. Both EUMETSAT and CIMMS have to be commended for the maintenance and distribution of such critical software that have eased the entry of NWP Centers and accelerated the work of others in relation to TOVS and ATOVS data processing.

The experimental use of AMSU-B data which had been reported at the last meeting is now used in daily analysis preparation at some NWP Centers, and others have started experimenting with positive results indicating it is only a matter of time before they implement these data. The WG encourages more studies on the use of AMSU-B to show the impact of this data in other DA/NWP systems. The bias correction procedure for AMSU-B appears to be working as well as with AMSU-A data with somewhat more difficulties apparent over continents in very dry and cold atmospheres. In the context of moisture analysis, at least three NWP Centers have added HIRS-12 moisture channel to AMSU-B with overall benefits.

Work is continuing with the use of cloudy radiance data as indicated in a number of presentations. The DAO has shown that the use cloud-cleared radiances which were so difficult in the past are now feasible provided you can account for their correlated errors in the final analysis step. The use of satellite measured clouds in NWP remains very limited. The only use of cloud data has been the rather crude assimilation of cloud data in limited area models (UKMO, NCEP, MSC). ECMWF is beginning a project to directly assimilate cloud information through their fast RT model. The problem of properly assimilating cloud data remains unsolved and will require at least several years of development.

Several Centers indicated they have developed or are developing mesoscale models and data assimilation systems. The impact of satellite data in regional/mesoscale data assimilation systems is limited by many factors such as: incomplete use of data over land sea/ice; lateral boundary influences; low model top; background error not adequate for regional/meso scales; inadequacies in the data (e.g., clouds and vertical resolution). The WG recognizes that mesoscale data assimilation is in embryonic state and significant development is necessary. Verification of the mesoscale forecasts is difficult and inadequate. Because of the inadequacies of mesoscale DA (MDAS), the full impact of this data cannot be judged at this time. Most Centers have developed and use their MDAS to improve their QPF forecasts and are generally satisfied with improvements in only QPF.

2.3.2 Evaluation and use of TOVS/ATOVS in DA/NWP

Large biases between background and observed radiances (both level 1b and level 1d) still remain and monitoring remains a very important step in the evaluation and preparation of the satellite data for assimilation. Many difficulties have been diagnosed and resolved by monitoring procedures. The WG continues to encourage the development of monitoring procedures as part of any Center's analysis procedure and to post monitoring results on their external web site.

Recommendation (to DA/NWP Centers)

The Working Group recommends the continued exchange of monitoring results and encourages each Center to develop their own Web page to post their results. A master document linking all Web pages has been developed and will reside on the NWP SAF site with a link to the ITWG Web site at CIMMS so everyone can easily examine and compare results from other groups to theirs.

The Working Group further recognizes that the specification of background and observational errors is critical for optimal assimilation of any data type and in particular radiances. Most DA/NWP Centers have recently updated their background and observational error covariances and the Working Group encourages exchanging these results so as to better understand the impact of the a-priori statistics on TOVS data assimilation.

Recommendation (to DA/NWP Centers)

The Group recognizes the difficulty in implementing and validating radiance/retrieval data in a DA/NWP system and recommends that those that have prepared so-called one-observation experiment in the development of their assimilation system post them on their Web page. Since there is more than one fast RTM used, it will indirectly measure the ability of each RTM to project radiance data information onto the atmospheric state variables. Indirectly, this will also indicate what are the effective measures of background and observational error statistics used at each Center. (Action: C. Chouinard to coordinate).

The WG recognizes the importance of Observing System Experiments (OSE's) to quantify the impact of individual sources of data. The results of OSE's are also useful in the decision making process in agencies.

Recommendation (to DA/NWP Centers)

Encourage the preparation of OSE's at various NWP Centers to be presented at the next ITWG meeting and post these results on the ITWG website.

The results of the ITWG survey presented at this meeting and reproduced in the Table 2.3 below, indicates the NWP community still has operational requirements at various levels for NOAA/NESDIS/ATOVS data processing from level-1b through preprocessed (PP) level-1d radiances, to retrieved products.

Table 2.3. Use of ATOVS data in operational NWP. ITWG survey of systems at 01/02/2002.

Institute	Retrievals in Global NWP	Retrievals in Regional NWP	Radiances in Global NWP	Radiances in Regional NWP	WWW Data Monitoring
Australia	NESDIS (above 100)		YES - PP (via 1D-Var)		
Canada (CMC)	NESDIS (ensemble)		YES - 1b (via 3D-Var)	YES - 1b (via 3D-Var)	YES
ECMWF			YES - 1b (via 4D-Var)		YES
France			YES - PP (via 4D-Var)		
Germany (DWD)	NESDIS				
India	NESDIS				
Japan	NESDIS	NESDIS			
Korea			YES - PP (via 1D-Var)		
Sweden					
UK			YES - 1b (via 3D-Var)		YES
USA (NCEP)			YES - 1b (via 3D-SSI)	YES - 1b (via 3D-SSI)	YES
USA (NRL)	NESDIS	NESDIS			

Notes on the survey:

When questioned about systematic blacklisting of data, the most common theme is the very limited use of tropospheric data (radiances or retrievals) over land and ice. This is true for microwave and infrared.

The Working Group and data providers found this study to be very useful. Because the use and the requirement of data are rapidly changing, and in order to better serve the users:

Recommendation (to ITSC)

The Group recommends that the McNally survey summary grid be continued and posted on the ITWG Web site. When changes are made at various NWP centers on the use of data, that McNally be advised, the grid updated accordingly, and the changes be logged on the Web page. (Action: T. McNally to coordinate).

The results of the survey indicate that the majority of DA/ NWP Centers still rely upon NESDIS retrieved products and processed level-1b and level-1d data for their operational forecasting systems. The Group wishes to acknowledge this fact and support the continuing efforts of NOAA/NESDIS and EUMETSAT in their crucial role. This Inter-agency collaboration has been very beneficial. The WG wants to commend the progress at NESDIS in change notification and monitoring of the data since the last meeting.

Recommendation (to NOAA/NESDIS and EUMETSAT)

The Group recommends that the data provider do quality assurance of all data, including level 1b and level 1d. The quality of the data (including e.g. navigation) should be monitored at all stages including the final stage, which may have been reformatted. The provider should attempt to identify and flag questionable or poor quality data. Data providers, e.g. EUMETSAT and NOAA/NESDIS are encouraged to use NWP monitoring results to help them in diagnosing data problems. The Group recognizes that it is easy to identify gross errors, while subtle errors are more difficult to detect. Action: V. Tabor (NESDIS), D. Klaes (EUMETSAT).

There has been some questions raised at this meeting as to the use of uncorrected antenna temperatures of microwave instruments. The WG is concerned that biases are being introduced by the antenna correction and that users may start to use antenna temperature as if they were brightness temperatures.

Action

Evaluate and improve the current procedures to convert antenna temperatures to brightness temperatures (NESDIS and DoD)

There has been indication at this meeting that the data from central data producers may be different to that derived through AAPP, and these may be due to different calibration and navigation algorithms.

Action

Determine why different navigation information is being distributed in comparison with that being used in operations (V. Tabor, NESDIS)

Action

Encourage the collaboration between the local readout software developers and the data producers to minimize the differences between the global and local calibrated and navigated data (AAPP developers, space agencies)

In at least one presentation at this meeting, there was further evidence from sensitivity experiments that forecast errors develop in cloudy regions. This may explain the larger impact

from the AMSU data when compared to the HIRS data and may have implications for future instrument design.

2.3.3 Forward Modelling

The WG is concerned with the development of RT code for new instruments. The RTM codes developed by each group (e.g. IASI/AIRS) does not follow the universal interface policy of RTTOV-6 and its predecessors. The Working Group is worried that these RTM may be difficult to use at DA/NWP Centers. The use of different RT codes in NWP for different satellites is a serious maintenance issue.

Recommendation

We encourage the developers of new instruments to either expand or enhance current RT code, or develop general codes applicable to all instruments and make it available.

2.3.4 Future platforms and real-time access to data

The WG recognizes that the preparations for AIRS were well done, and encourages future satellite programs to take the lead. The Group supports the efforts of M. Goldberg and colleagues at NOAA/NESDIS in disseminating AIRS data (decimated in several different ways) in real time BUFR format and encourages other agencies to continue to support such efforts, especially with regards to experimental data sets.

2.4 ADVANCED SOUNDERS

Working Group members: J.Eyre (Chair), M.Goldberg (Co-Chair), R.Bennartz, H.Bloom, D.Blumstein, N.Chauhan, A.Collard, N.Fourrié, D.Frank, A.Huang, S.Johnson, D.Klaes, J.Le Marshall, J.Li, L.Lavanant, M.Lynch, T.Phulpin, J.Predina, J.Puschell, F.Rabier, G.Rochard, H.Roquet, F.Romano, V.Sherlock, B.Tournier, A.Uspensky, P.Watts, W.Wolf, X.Wu, W.Zhang

2.4.1 Status of plans for advanced sounding instruments

The working group noted progress on plans for five advanced infra-red sounders: AIRS (Advanced Infrared Sounder), IASI (Infra-red Atmospheric Sounding Interferometer), CrIS (Cross-track Infrared Sounder), IRFS-2 (Infra-Red Fourier-transform Spectrometer) and GIFTS (Geostationary Imaging Fourier Transform Spectrometer). Table 2.4-1 summarizes characteristics of these instruments, and Figure 2.4-1 summarizes their planned operating periods. The characteristics of these instruments are described in more detail in the Reports of ITSC-X and ITSC-XI.

The working group also noted progress on plans for advanced microwave sounders. It proposed that comparable information on these instruments should be tabulated and made available, along with information on advanced infra-red sounders, on the ITWG web site.

Action

J.Eyre (Met. Office, Bracknell) to compile summary information on advanced sounders, for posting on ITWG web site.

2.4.2 New initiatives for geostationary sounding

Proposals have been prepared, in both the USA and Europe, to fly millimetre/sub-millimetre radiometers with sounding and imaging capabilities on geostationary satellites. To achieve required horizontal resolutions with reasonable antenna size, these instruments would use high frequencies (bands between 100 and 500 GHz), which are more sensitive to cloud and precipitation than channels used for temperature sounding from polar orbit (i.e. 50-60 GHz). However, the geostationary orbit is particularly well suited to observing time-evolving phenomena related to clouds and precipitation, which can develop rapidly and for which frequent measurements are required to support improvements in nowcasting and short-range forecasting. The working group supported the concept of an experimental mission to demonstrate this technology and suggested that priority be given to channels suited to sensing precipitation, cloud and humidity.

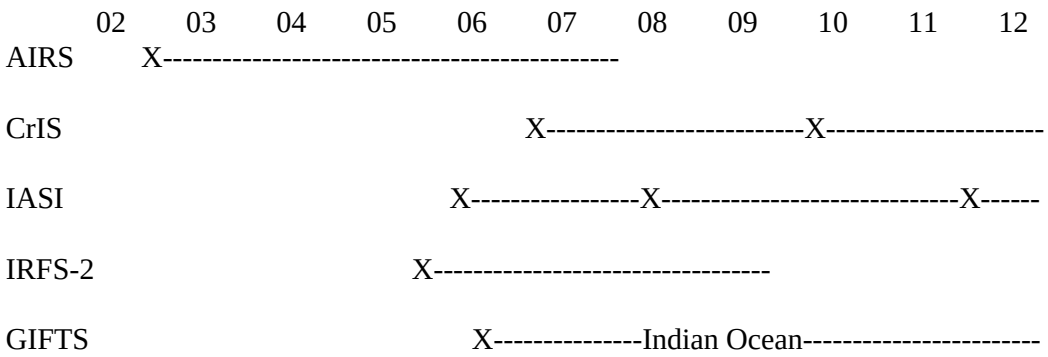
Recommendation (to CGMS)

ITWG recommends that a geostationary millimetre/sub-millimetre radiometer mission should be pursued as a technology demonstrator, with priority towards measurement of precipitation, cloud water/ice and humidity at high temporal frequency in support of nowcasting and short-range forecasting, and as a potential future contribution to the Global Precipitation Mission.

Table 2.4-1 Characteristics of Advanced Infrared Sounders

Name	AIRS	IASI	CrIS	IRFS-2	GIFTS
Orbit	705 km	833 km	824 km	850 km	Geostationary
Instrument type	Grating	FTS	FTS	FTS	FTS
Agency and Producer	NASA JPL/ LoMIRIS	EUMETSAT/ CNES Alcatel	IPO (DoD/NOAA/ NASA) ITT	Russian Aviation and Space Agency	NASA/NOAA / Navy. Space Dynamics Lab.
Spectral range (cm^{-1})	649 –1135 1217–1613 2169 –2674	Contiguous 645-2760	650 –1095 1210 –1750 2155 –2550	665 –2000	685-1130 1650-2250
Unapodized spectral resolving power	1000 – 1400	2000 – 4000	900 – 1800	2000	2000
Field of view (km)	13 x 7	12	14	35	4
Sampling density per 50 km square	9	4	9	1	144
Power (W)	225	200	86	50	255
Mass (kg)	140	230	81	45-50	60
Platform	Aqua	METOP-1,2,3	NPP and NPOESS C1	METEOR 3M N2	Geostationary
Launch date	2002	2005	2006 for NPP 2009 for C1	2005	2006

Figure 2.4-1 Advanced IR Sounder Timeline



2.4.3 Distribution of simulated datasets for advanced sounders

AIRS data, along with AMSU-A and HSB from NASA's Aqua mission, will be provided to several NWP centres in near-real time so that the utilization and impact of high spectral resolution infra-red data in NWP models can be demonstrated prior to the operational missions of IASI and CrIS. The recommendation of ITSC-XI concerning the distribution of near-real time **simulated** data for AIRS/AMSU-A/HSB had been valuable in supporting the case for this service, which was now in place and was playing an important role in allowing NWP centres to make effective preparation for the exploitation of real AIRS data, following the launch of Aqua (planned for April 2002). The meeting commended NASA and NOAA for providing this service and recommended that similar services should be established as part of the preparatory activities for other advanced sounders.

Recommendation (to CGMS)

The ITWG notes the high value of simulated AIRS data, distributed in near-real time, in assisting NWP centres to make effective preparation for real AIRS data, and it recommends that similar services should be established as part of the preparatory activities for other advanced sounders.

Action

M.Goldberg (NOAA/NESDIS/ORA) to draft short paper for CGMS describing the AIRS data simulation system and its use.

2.4.4 Data processing, inversion and assimilation

2.4.4.1 Distribution of ingest and pre-processing code

The working group reaffirmed the importance of the availability of "ingest" code (code to process raw data to level 1b data) and pre-processing code (code to process from level 1b to a point suitable for retrieval or assimilation for NWP or for other applications) to all users who intend to receive and process the raw data, **for all advanced sounders and their complementary imagers**. Instrument combinations for which this will be required (and their responsible agencies) include:

Satellite	Instruments	Agency
METOP	IASI+AMSU-A+MHS+AVHRR	EUMETSAT
Aqua	AIRS+AMSU-A+HSB+MODIS+AMSR	NASA
NPP	CrIS+ATMS+VIIRS	NASA/NOAA
NPOESS	CrIS+ATMS+VIIRS+CMIS	IPO
FY-3	MWTS+MWHS+IRAS	NSMC
Meteor-3M N2	IRFS-2+MTVZA-OK+GLOBUS	RASA/Roshydromet
GIFTS	GIFTS	NASA
GOES-R,…	ABS+ABI	NOAA

(See §2.4.6 for list of acronyms)

For global data, the global processing centres will be the responsible agencies. Plans are in place to deliver the necessary software for this purpose. However, for locally-received, direct read-out data, it will be necessary to distribute suitable ingest code to users for local implementation. This

code should be compatible, in output content and quality, with equivalent code for global processing. With the exception of EUMETSAT plans for IASI/AMSU-A/MHS/AVHRR and NASA/CIMSS plans for AIRS/AMSU-A/HSB/MODIS, plans in this area are not mature, and further developments are needed to ensure timely distribution and implementation. Without such developments, direct read-out data will not be exploited effectively.

In each case, **it will be helpful to establish, for each instrument set, a focal point** responsible for ensuring that ingest and pre-processing code is provided suitable for locally received data and yielding output consistent with global data, and that activities are undertaken to integrate this code into processing packages available for international distribution in a timely manner.

Recommendation (to CGMS)

ITWG recommends that responsible agencies establish focal points to ensure that:

- **ingest and pre-processing code for future advanced sounders (and their complementary imagers) is provided, in a form suitable for use with locally-received direct read-out data, and yielding output consistent with global data, and**
- **activities are undertaken to integrate this code into processing packages available for international distribution in a timely manner.**

The Working Group noted that plans exist to put in place ingest code for NPP instruments (CrIS, ATMS and VIIRS) on the required timeframe, but that there were no mature plans to incorporate this code into a processing package for locally received data.

Recommendation (to IPO and NASA)

ITWG recommends that ingest code for NPP instruments (CrIS, ATMS and VIIRS), to be made available by IPO, should be integrated into a processing package for locally received data.

MODIS data from Terra has provided unprecedented capabilities for observing clouds, the Earth's surface and the atmosphere. International direct broadcast users of Terra-MODIS, and in the near future Aqua-MODIS, will benefit greatly from these well-characterised data.

Recommendation (to NASA)

It is important that NASA continue to provide MODIS instrument status, navigation and frequently-updated calibration information in a timely manner to users and developers, to maximise the benefit of MODIS data for environmental monitoring and weather forecasting.

The Working Group noted progress on establishing the draft specifications for the data records for NPOESS and NPP. The Working Group reaffirmed the value of user feedback on these drafts before they are finalised.

Recommendation (to IPO)

ITWG recommends that the user community be provided with and invited to review the draft specifications (content and format) for the raw data records (RDRs) and sensor data records (SDRs) for NPOESS/NPP instruments.

Action (H.Bloom, NPOESS/IPO)

To inform ITWG members, through the ITWG list server, of the location of draft

specifications of RDRs and SDRs for NPOESS/NPP instruments.

Action (J.Eyre, via ITWG co-chairs)

To co-ordinate feedback to IPO from ITWG members on the draft specifications (content and format) for the raw data records (RDRs) and sensor data records (SDRs) for NPOESS/NPP instruments.

2.4.4.2 Cloud detection and characterisation

At ITSC-XI, it was noted that advanced sounder data are most easily used in NWP when the field of view is free of cloud and when this condition can be recognised with a high degree of confidence. Accurate methods for detecting the presence of cloud are therefore very important. Approaches for improving cloud detection methods included use of coincident high-resolution imagery (e.g. AVHRR with IASI, MODIS with AIRS). ITWG therefore recommended support for the scientific and technical developments required to use coincident MODIS data to improve the cloud detection for AIRS. The Working Group noted that this recommendation had been instrumental in securing the necessary resources for this work and thanked NASA and NOAA for facilitating this work.

For NWP, observations are most important if they help to improve the analysis in "sensitive areas", i.e. regions within baroclinic zones out of which small errors in the analysis grow rapidly to become large errors in the subsequent forecast. It has previously been demonstrated that advanced infra-red sounders will be more successful than current instruments in providing information on the details on the tropospheric temperature structure that are typical in these areas, provided that the effects of cloud are not too great. Research presented at ITSC-XI and confirmed at ITSC-XII has suggested that these sensitive areas are usually cloudy, but in a significant proportion of cases only at low levels. It is therefore important that the NWP data assimilation community makes progress on the assimilation of cloud-affected radiances, and particularly those that are only affected by low cloud.

Recommendation

ITWG encourages research into the assimilation of cloud-affected infra-red radiances, as this may be crucial to the effective exploitation in NWP of advanced sounder data from meteorologically sensitive areas. It encourages investigation of a wide variety of methods including: (1) assimilation of cloudy radiances in "simple" cloud conditions (i.e. homogeneous, low-level clouds), and (2) assimilation of cloud-cleared radiances.

["Cloud-cleared" radiances are clear radiances estimated from cloud-affected radiances.]

The Working Group discussed two important advantages arising from small fields-of-view (fovs) for advanced infra-red sounders:

- to maximise the probability of obtaining clear fovs in partly cloudy areas,
- in the case of interferometric sounders, to maximise the probability of the fov being filled homogeneously (either clear or cloudy), and so to avoid noise contributions arising from artifacts in the derived spectra caused by inhomogeneities in the fov.

Recommendation (to NOAA)

ITWG encourages NOAA to re-examine the requirements on field-of-view size for CrIS.

2.4.5 Characterisation of spectral response

Accurate knowledge of the spectral response of the instrument is crucial to a correct interpretation of the data; errors in the assumed spectral response appear as errors in either the pre-processed measurements or in the forward modelling of the data. Studies have already been performed to characterise the spectral response of IASI such that the associated errors are well below instrument noise level. Studies are needed to characterise the responses of similar instruments in the same way.

Recommendations (to space agencies)

ITWG recommends that the spectral responses of advanced sounders should be characterised:

- **to a level at which the associated error does not cause the total noise budget of the instrument to be exceeded,**
- **and, where achievable at reasonable cost, to a level at which the associated error is a negligible contribution to the total system noise.**

2.4.6 Glossary of instruments

ABS	Advanced Baseline Sounder (for GOES-R+)
ABI	Advanced Baseline Imager (for GOES-R+)
AIRS	Advanced Infrared Sounder
AMSR	Advanced Microwave Scanning Radiometer
AMSU-A	Advanced Microwave Sounding Unit - A
ATMS	Advanced Technology Microwave Sounder
AVHRR	Advanced Very High Resolution Radiometer
CMIS	Conical-scanning Microwave Imager/Sounder
CrIS	Cross-track Infrared Sounder
GIFTS	Geostationary Imaging Fourier Transform Spectrometer
GLOBUS	Multi-channel scanning radiometer
HSB	Humidity Sounder - Brazil
IASI	Infra-red Atmospheric Sounding Interferometer
IRAS	Infra-red Atmospheric Sounder
IRFS-2	Infra-Red Fourier-transform Spectrometer
MHS	Microwave Humidity Sounder
MODIS	MODerate-resolution Imaging Spectrometer
MTVZA-OK	Module for atmospheric temperature and humidity sounding - oceans
MWTS	MicroWave atmospheric Temperature Sounder
MWHS	MicroWave atmospheric Humidity Sounder
VIIRS	Visible/Infrared Imager Radiometer Suite

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Working Group members: D. Hinsman (Chair), J. Bates, H. Bloom, N. Chauhan, C. Chouinard, J. Derber, J. Eyre, A. Gasiewski, M. Goldberg, D. Griersmith, S. Johnson, D. Klaes, J. LeMarshall, M. Lynch, P. Menzel, J. Puschell, T. Reale, G. Reichert, G. Rochard, A. Uspensky, J. Wilson and W. Zhang

2.5.1 Introduction

The Working Group reviewed the progress made since the last ITSC as well as issues raised during the present ITSC. It noted that almost all action items and recommendations had been accomplished and those that remained fell into seven categories: data access, data dissemination, data monitoring, equator crossing times for polar-orbiting satellites, the ITWG web site, radio frequency matters and the need for a new working group for radio occultation soundings. The Working Group noted in particular the efforts by the Co-chairs to take the necessary actions towards the completion of the recommendations and thanked them for their efforts.

It noted that the presentations by the satellite operators, as has been made at previous ITSC, were most informative and generated many useful discussions both during the presentations and afterwards. The purpose of such presentations was to allow ITSC meetings to have a comprehensive perspective of the future for satellite soundings. **Thus, the Working Group strongly encouraged the continuation of such presentation at future ITSC meetings.**

2.5.2 Data access

The Working Group was informed of the discussion at the Advanced Sounders Working Group concerning data access. It was informed that AIRS data, along with AMSU-A and HSB from NASA's Aqua mission, will be provided to several NWP centres in near-real time so that the utilization and impact of high spectral resolution infra-red data in NWP models can be demonstrated prior to the operational missions of IASI and CrIS. The recommendation of ITSC-XI concerning the distribution of near-real time simulated data for AIRS/AMSU-A/HSB had been valuable in making the case for this service, which was now in place and was playing an important role in allowing NWP centres to make effective preparation for the exploitation of real AIRS data, following the launch of Aqua. ITSC-XI had commended NASA and NOAA for providing this service and recommended that similar services should be established as part of the preparatory activities for other advanced sounders. The International Issues and Future Systems Working Group fully supported the findings by the Advanced IR Sounders Working Group and the recommendation and action it generated as recorded in the Advanced IR Sounders Working Group report.

The Working Group also noted the plans by WMO to expand the space-based component of the Global Observing System. It strongly urged that the issue of data access discussed above should also be considered by the R&D space agencies. **Since CGMS was an excellent forum for discussion and implementation of such recommendations, ITWG supported the proposal for an expansion of CGMS to include R&D space agencies contributing to the GOS and further encouraged an expanded CGMS to consider data access issues for R&D satellite missions.**

2.5.3 Data dissemination

The Working Group recalled that it had, at previous ITSCs, made recommendations to WMO to increase the capacity of the Global Telecommunications System (GTS) in order to handle not

only the present volumes of satellite data and products but also the large increase in volume expected by the end of this decade and beyond. It was pleased to note that the capacity of the GTS had been increased in some WMO regions, notably in Europe as well as between the USA and Europe, and that WMO Members should continue their efforts to implement similar system on a global basis.

The Working Group also noted the WMO initiative with regard to direct broadcast from environmental satellites. WMO was in the process of reviewing the data dissemination architecture from operational meteorological satellites and foresaw an evolution from solely direct broadcast to one that included direct broadcast to selected regional sites and alternative dissemination methods that would complement direct broadcast to meet the needs within the region. The need for the review was driven by the plans by the satellite operators to move to X-band direct broadcast which implied a near complete replacement of the present HRPT ground receiving stations worldwide. Such a replacement was felt by WMO to be unachievable. The regional sites would provide sufficient geographic coverage to meet the needs of all applications in the region. The alternative dissemination methods would include the use of Internet or Internet-like capabilities and/or commercial communications services. In acknowledging the expected massive increase in data volume, the Working Group supported the proposed WMO architecture. Furthermore, it encouraged WMO to include R&D satellite missions' dissemination in the architecture. The Working Group suggested that WMO also consider data redundancy without duplication in further developing the architecture. The Working Group noted that the ITWG had requirements for direct broadcast from environmental satellites, which were directly related to requirements for the availability of such data and the proposed WMO architecture had the potential to satisfy future ITWG requirements for data availability.

2.5.4 Data monitoring

The Working Group recalled that it had previously made recommendations related to the monitoring of satellite data and products. In noting the presentations during ITSC-12, the Working Group noted that considerable progress had been made by individual NWP centres in data monitoring. It also noted that the present WMO "lead centre" concept for data monitoring of all types was developed and implemented over 14 years ago. Since then, the monitoring of new satellite instruments as well as the availability of major improvements in Information Technologies had evolved in *an ad hoc* basis. The Working Group agreed that major NWP centres should monitor all data that are used within their system. Due to the varying types of assimilation and forecast systems found within the NWP centres, it may not be appropriate for any one centre to be expected to monitor all satellite data – including the various data levels. Thus, the Working Group proposed the following recommendation to WMO:

Recommendation

WMO should conduct a review of its "lead centre" for data monitoring process. As a initial step in the review, WMO should characterize the scope and intent of data monitoring for its purposes. The review should then be guided by that characterization. (D. Hinsman to inform Chairman OPAG IOS for discussion by CBS Management Group, deadline 1 April 2002)

2.5.6 Equator crossing times for polar-orbiting satellites

The Working Group was pleased to note the satellite operator plans for polar-orbit and that during the second half of the decade there existed the possibility for four polar-orbiting satellite series, NOAA/NPOESS, MetOp, FY-3 and Meteor 3M series. It was informed that both CMA

and ROSHYDROMET had already expressed a willingness to consider moving their satellite series to the PM orbit when nearing nominal configuration. The Working Group noted that this would provide a robust system of two satellites in both the AM and PM orbits each capable of backing-up the other. The Working Group noted that the satellite operators should strive to maintain long-term continuity of equator crossing time for their respective series while seeking to minimize any drift in the crossing time in order to maintain climatological records.

2.5.7 ITWG web site

The Working Group suggested that the ITWG web site include information related to data access for sounding instruments including relevant points of contact and metdata.

2.5.8 Radio frequency matters

The Working Group noted the importance for radio frequency allocations and protection within the International Telecommunications Union (ITU) context. With regard to passive microwave allocation and protection, the Working Group noted the need to provide scientific justification for specific RMS values for radiances observed from space. Thus, the Working Group agreed to the following action item:

Action

A. Gasiewski (NOAA) and G. Rochard (CMS) to prepare a draft two page paper, to be developed through email, containing scientific justification for specific RM values for radiance observed from space. (Deadline: June 2002)

2.5.9 Radio occultation sounding Working Group

The Working Group noted the strength of ITWG in maintaining focus as a passive sounding expert group. It recalled that CGMS 29 had requested that the ITWG take an action to investigate multi-satellite utilization for profile retrieval, specifically radio occultation with high spectral resolution infrared radiometers. At ITSC 12, a few presentations discussed the utility of radio occultation measurements for improving depiction of the tropopause location and estimation of stratospheric temperature profile beyond the information available from high spectral resolution infrared radiometers and microwave sounders. In discussing further action, the Working Group suggested that the broader community of radio occultation experts should be invited to summarize recent progress as a working paper to CGMS at their next meeting. Specifically, EUMETSAT should invite scientists participating in the CHAMP to submit such a report for a future CGMS.

Recommendation (to CGMS)

EUMETSAT should invite scientists involved in atmospheric sounding using radar occultation, in particular those participating in CHAMP, to submit a progress report for a future CGMS.

2.6 SATELLITE SOUNDER SCIENCE AND PRODUCTS

Working Group members: T.Reale and T.Achtor (Co-Chairs), with F.Weng, V. Prasad, L. Hong, E.Borbas, J.Li, S.Buehler, L.Lavanant, J.Carvalho, I.Dyras, J.Predina, E.Silvestre, M.Ahn, W.Zhang, X.Wu, M.Goldberg, F.Romano, M.Uddstrom, A.Apostolou, and D.Griersmith

2.6.1 Introduction

The Working Group on Satellite Sounder Science and Products (SSSP) was formed to promote the development and utilization of meteorological techniques and products from operational and research weather satellites for weather and climate applications. The focus is primarily on polar orbiting satellites, as they provide global coverage, although common measurements and innovative concepts on geostationary satellites are also important to this group. The goals of the SSSP are achieved by providing a central location for information dissemination and exchange related to international scientific activities, data access and validation, with the goal of enhancing communication and collaboration among and between the research and operational communities.

An important mechanism for achieving these goals is the development and maintenance of a SSSP web site, within the current ITWG web site, which provides information on operational and research satellite scientific algorithms, data sources and availability, evaluation, and contact information. In addition, the web site provides a source of ancillary information on operational and research instrumentation status, launches, and primary issues concerning the research and user community.

2.6.2 Discussion

Discussions of the SSSP Working Group at ITSC-12 focused on issues concerning the SSSP web site, including the web site structure and content, attracting additional contributors, guidelines for contributions, providing contact information on data sources and availability, and links to direct broadcast data and software packages. The Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Madison will maintain the SSSP web site.

The SSSP Working Group will also advocate programs to promote measurement and product validation on a regional and global scale in support of current and future operational and research satellites. Programs include studies on the potential benefits of a global network of ground base observations dedicated to polar satellite instrument calibration (i.e. concurrent with satellite overpass), and the promotion of scientific algorithm, product validation and case study intercomparisons among working group members and collaborators.

The SSSP Working Group also agreed to identify and promote important research topics concerning current weather satellites for continued and/or expanded investigation to be developed through interaction with other ITWG working groups.

2.6.3 Actions and Recommendations

NOAA is acknowledged as a primary source of archived operational satellite data and is encouraged to continue to provide archived operational satellite data (level 1b through level 2) and corresponding validation data sets (i.e., data collocated with radiosondes) that are easily accessible on line, to users worldwide, and at no cost when possible, for research purposes. The data should be accessible via various search criteria (i.e. sensor name, time, location, spectral band, etc). The Satellite Active Archive (SAA) operated by the National Climatic Data Center (NCDC) is acknowledged for its outstanding contribution in this area.

In relation to these data holdings we propose:

Action

Promote activity to append level 1b raw satellite observations to existing historical datasets of collocated radiosonde and TOVS and ATOVS observations, and to encourage such methods in current and planned operational systems (T. Reale, NESDIS).

CIMSS is also commended for their initial efforts in creating the SSSP web site, and for continuing to coordinate and manage the ITWG SSSP web site. The SSSP Working Group will be responsible for recruiting contributors (with guidelines for contributions and metadata), providing contact information on data sources and availability, and providing links to direct broadcast data and software packages.

Action

Write and distribute a statement asking Web Site contributors to help broaden participation by contacting others in their country / region or others in their discipline and encouraging them to contribute to the SSSP web site (T. Reale, NESDIS and T. Achtor, CIMSS/SSEC).

Action

Provide information for the SSSP Web Site on NOAA data resources, availability and access information (V. Tabor, NOAA/NESDIS/IPD).

Action

Provide link(s) for the SSSP Web Site to Direct Broadcast software packages and data (T. Achtor, CIMSS/SSEC and L. Lavanant, CMS).

Action

Provide routine information for the SSSP Web Site on current operational and research instrument status (T. Reale, NESDIS).

Action

Divide SSSP Web Site contributors by research (technique) vs. operations (product) (T. Achtor, CIMSS/SSEC).

Ongoing programs dedicated to the global validation of operational and research satellite data are sometimes inadequate. The ITWG SSSP and Climate Sub Groups propose to advocate, initiate and promote studies to define requirements for a permanent, reliable, global ground truth validation programs in support of operational and research polar satellite observations.

Action

Design and conduct studies in conjunction with current and planned calibration/validation experiments (e.g. DOE ARM Sites) to quantify the usefulness of conventional upper air (i.e., radiosonde, profiler, etc) data to monitor polar satellite radiometer performance, their impact on climate and weather applications, and to provide recommendations concerning long term needs for continuous, global monitoring of environmental satellite data (J. Bates, NOAA and T. Reale, NESDIS).

Action

Actively promote product validation and intercomparison studies (e.g., among product and/or software developers) (T. Reale, L. Lavanant and T. Achtor).

Action (to the SSSP)

Take an active role to identify important research topics involving current weather satellites, including topics for continued and/or expanded investigation (to be developed through interaction with other ITWG sub groups) (T. Reale, T. Achtor, and other Working Group Co-Chairs).

In relation to product developers, consideration should be given to expanding the use of gridded formats to facilitate the validation, intercomparison and ultimately the use of derived products in routine NWP and climate analysis, particularly for conventional data sparse and limited accuracy parameters such as upper tropospheric temperature, upper tropospheric moisture and clouds.

Action

Promote consideration of the use of gridded file product formatters in routine operational data processing at NESDIS, including time averaged (monthly) gridded files for selected, conventional data poor parameters (M. Chalfant, NESDIS).