

2. WORKING GROUP REPORTS

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Web site: <http://cimss.ssec.wisc.edu/itwg/groups/rtwg/rtwg.html>

Working Group members: V. Sherlock (Co-Chair), L. Garand (Co-Chair) with R. Bennartz, E. Borbas, P. Brunel, D. CIMINI, S. English, R. Hess, F. Hilton, N. Jacquinet-Husson, F. Karbou, T. Kleespies, X. Liu, P. Marguinaud, J-L. Moncet, C. Ping, R. Rizzi, G. Rochard, B. Ruston, R. Saunders, P. Schluessel, M. Schwaerz, D.S. Turner, P. Wang, F. Weng, H. Woolf.

This Working Group focuses on the issues related to atmospheric radiative transfer (RT) and surface property (SP) models which are relevant for radiance assimilation and atmospheric and surface retrievals from past, current and planned infrared and microwave sounder data. From now on we refer to this Working Group as **RTSP-WG** (previously RTWG).

Unless noted otherwise, action items are to be completed by 15 September 2005.

2.1.1 Atmospheric profile datasets for Radiative Transfer

Radiative transfer models require a dataset of diverse profiles for training and independent validation.

a) Training datasets

The group is actively using various profiles datasets whose characteristics are summarised in Table 2.1-1. This table was reviewed and a revised version of the table will be placed on the RTSP-WG Web pages.

Action RTSP-1

**RTSP-WG Co-Chairs to add revised version of Table 2.1-1 to RTSP-WG Web site.
Revisions listed below to be accomplished by 31 August 2005.**

- 1. Roger Saunders to provide the Web link for the trace gas profile set to add to Table 2.1-1**
- 2. Hal Woolf to put CIMSS data sets on the Web and provide updated information for Table 2.1-1**
- 3. Eva Borbas to provide details of her profile dataset. RTSP-WG Co-Chairs to add entry in Table 2.1-1**
- 4. RTSP-WG Co-Chairs to add a column in Table 2.1-1 indicating data sets the RTSP-WG considers to be standard and only include URLs of datasets we endorse.**

b) Validation datasets

The group indicated willingness to document observational data sets which are available for model validation. If modelers become aware of auxiliary data streams which are missing or documentation which is lacking which limits the exploitation of a given data set, they are requested to raise the problem with the RTSP-WG Co-Chairs.

Action RTSP-2

Fuzhong Weng to inform RTSP-WG when A-train matchup data set is available for RT model validation.

Action RTSP-3

Xu Liu to contact MOZART model group for combined (co-located) temperature, humidity and trace gas profile data sets for independent RT validation and provide RTSP-WG Co-Chairs with details of data set availability (actual and planned).

Diverse Profile dataset	Number of Profiles	Number of Levels	Contact point/Web page
TIGR v3 radiosonde set Sub set from v2	2311 43	40L 43L	http://ara.lmd.polytechnique.fr Marco Matricardi, ECMWF
ECMWF 60L model set Sub set	13495 52	60L 101L	http://www.metoffice.com/research/interproj/nwpsaf/rtn/
ECMWF 50L model set Sub set	13766 117	50L 43L	
UMBC set	49 49	101L 42L	Scott Hannon, UMBC Hal Woolf, CIMSS
NOAA-88 Sub set	8005 32	40L 40L	Larry McMillin, NESDIS
CIMSS	32	40/42/101 L	Hal Woolf, CIMSS
CIMSS Ozone Sub set	380 34	40L 40L/43L	Hal Woolf, CIMSS M. Matricardi for 43L
Trace Gases CH ₄ ,CO,N ₂ O,CO ₂	43	90L	Marco Matricardi, ECMWF http://cimss.ssec.wisc.edu/itwg/groups/rtwg/trace_gases.tar.gz

Table 2.1-1. Summary of diverse profile datasets used to train RT models.

Following a review of ITSC-XIV RTSP-WG recommendation 2.1.3,

Action RTSP-4

Nicole Jaquinet-Husson to document observational datasets available for line-by-line (and fast model) validation and details on how to access these data sets if publically available.

Action RTSP-5 (carried forward)

All members of the group to send information on validation datasets to RTSP-WG Co-Chairs who will post this information on the RTSP-WG Web site.

c) Profile utilities

The RTSP-WG recognizes the importance of standard methods for profile interpolation and integration for RT modeling, and has previously distributed profile interpolation codes. However, associated adjoint (and TL) operators (essential for correct mapping of Jacobians) were not distributed.

Action RTSP-6

Louis Garand to provide his profile interpolation and associated adjoint/TL code to the group.

Action RTSP-7

Louis Garand to survey NWP centres to establish the profile interpolation and adjoint techniques they use. The goal is to seek the best code to map Jacobians from RTM levels to NWP model levels (this implies an appropriate design of the forward interpolation routine).

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 modelling. The following is a list of the new or existing sensors where the group recognized information is still required for accurate RT simulations:

- AVHRR Spectral Response Functions (SRFs): Pascal Brunel indicated he would provide AVHRR SRFs from TIROS-N to NOAA-18 to anyone who requested that information from him.

Action RTSP-8

Tom Kleespies to co-ordinate with Pascal Brunel and post links to all AVHRR SRFs.

- IASI SRF : Claude Camy-Peyret will provide updated SRF to the ISSWG by July 2005.

Action RTSP-9

Nicole Jacquinet-Husson to provide the updated IASI SRF dataset to the RTSP-WG as soon as it is available.

- SRFs for other METOP instruments (HIRS-4, AVHRR ...)

Action RTSP-10

Peter Schluessel will be the point of contact for SRFs for ATOVS on METOP.

- AIRS SRFs and a list of blacklisted channels are maintained on the UMBC ftp site.

Action RTSP-11

RTSP-WG Co-Chairs to update RTSP-WG Web page information on AIRS SRF and channel blacklist referred to above.

2.1.3 Line by Line (LbL) model status

Due to time constraints a comprehensive review of the status of LbL models was not undertaken during the meeting. Rolando Rizzi undertook to contact LbL modellers to invite them to provide a summary of their model developments to the RTSP-WG Co-Chairs who will co-ordinate this material for the RTSP-WG Web pages.

Infrared LbL models to be surveyed include GENLN2, RFM, kCARTA, LBLRTM, 4A, σ -IASI, Hartcode, FLBL. Microwave LbL models to be included in the survey include MONORTM, MPM 89/92, Rosenkranz, ATM, STRANSAC and ARTS.

Action RTSP-12

Rolando Rizzi to contact LbL modelers and invite them to provide a summary of LbL model development status to RTSP-WG Co-Chairs by September 15, 2005. This summary should include model name, version, code access and licensing details, important technical features (including adjoint or analytical Jacobian capability, treatment of scattering) and literature references.

Action RTSP-13

RTSP-WG Co-Chairs to add a summary of LbL model information on RTSP-WG Web page by 15 December 2005.

IR LbL model developments presented at ITSC-XIV are summarized below:

FLBL from Shawn Turner (MSC) now has analytical Jacobian capability (ITSC-XIV poster B42).

Work at Bremen University and at the UK Met Office has recently demonstrated that ozone absorption affects the AMSU 183 GHz channels (brightness temperature changes of the order of 0.5 K).

Recommendation RTSP-1 to RT modellers

The RTSP-WG recommends that ozone absorption demonstrated to affect the AMSU 183 GHz channels is included in radiative transfer models.

2.1.4 Assessment of spectroscopic databases

The 23 GHz water vapor line absorption half widths were recently revised according to the results from the ARM site and models should be revised accordingly.

Action RTSP-14

Stephen English will provide results of a study quantifying the impact for AMSU and SSMI radiances to the group.

It was noted that in some instances there were some discrepancies between the spectroscopic parameters documented in peer-reviewed literature and those actually integrated within official releases of spectroscopic databases. Nicole Jacquinet-Husson highlighted significant differences in water vapour and methane spectroscopic parameters in some specific spectral regions.

Furthermore, the group noted that accurate referencing of subsets of line parameters, and revisions thereof, is also critical in model development and validation.

Recommendation RTSP-2 to spectroscopic database developers

The RTSP-WG urges spectroscopic database developers to adopt a standard and rigorous version control system for spectroscopic databases.

2.1.5 Fast RT models

The Working Group was pleased to note significant advances in super-channel modeling for hyperspectral instruments (e.g. the Principal Component Radiative Transfer Model, PCRTM).

The Working Group commended the Community Radiative Transfer Model (CRTM) framework initiative. A prototype CRTM is undergoing testing and the first official release is planned for June 2005.

OPTRAN: Operational version in CRTM uses polynomial fits to compute transmittances to reduce memory requirements for hyperspectral instruments. Code under development: 1) transmittance correction term and individual transmittances instead of effective transmittances; 2) revised internal vertical coordinate; 3) constraints to assure smooth adjoints; 4) additional gases. CRTM uses interfaces to facilitate swapping of RTM components (transmittance, scattering, surface properties, cloud absorption, etc. Point of contact: Yong Han (Yong.Han@noaa.gov).

RTTOV: RTTOV-8 was released in November 2004. This release includes some of the RTIASI capability and supports carbon dioxide as a variable gas. There have been major changes to code structure with the use of derived data types. More details can be found in the RTTOV ITWG Technical Report, poster B40 and the associated paper. The RTTOV-9 release is planned for February 2007 (will include more variable gases). Point of contact: Roger Saunders.

GASTROPOD: Version v0.3.0 has been released and includes an interface with Met Office 1DVar. Code and coefficients online at <http://gastro.sf.net/>. Point of contact: Vanessa Sherlock.

OSS: Version 1 released and implemented in CRTM. Validation in scattering atmospheres is on-going.

Development/testing of first accelerated version with multi-channel training should be completed for the fall of 2005. Point of contact: Jean-Luc Moncet.

MSCFAST: No new development. Used for assimilation of GOES-10 and 12 water vapor channel radiances at MSC and for retrievals of surface skin temperature. Point of contact: Louis Garand.

LMD fast models: Point of contact: Alain Chedin/Noelle Scott.

SARTA: Version 1.05 of the Stand-alone AIRS Radiative Transfer Algorithm, SARTA, was released in December 2004 and uses the January 2004 coefficient database. It is a clear air fast forward model with variable H₂O, O₃, CO, CH₄, and CO₂ (no Jacobian capability), and is based on HITRAN 2000 spectroscopic database and MTCKD v1.0 water continuum, with some tuning to match validation observations. This implementation of the AIRS-RTA is used in the DAAC version 4 processing and is available online: <http://asl.umbc.edu/pub/packages/>. Work continues on development of the AIRS-RTA algorithm. Several new features and improvements will be implemented for the next official release (December 2005). Point of contact: Scott Hannon.

PLOD/PFAAST: No change to code. Line-by-line data used to train the scheme were updated to LBLRTM-8.4, HITRAN-2000, AER 1.1 updates and UMBC-49. The training set includes an “ultra-cold” atmosphere. Point of contact: Hal Woolf.

RTIASI: The current release of RTIASI is RTIASI-5. In RTIASI-5 the integration of the RT equation is done on 90 levels using the linear in tau approximation to parameterise the Planck function. H₂O, O₃, CO₂, N₂O, CH₄ and CO are treated as profile variables. Solar radiation is included in the interval 2000-2760 cm⁻¹ assuming Lambertian reflectance for land surfaces, and explicit calculation of bidirectional reflectance over sea. RTIASI-5 includes a parameterization of multiple scattering and absorption for water clouds (5 classes), cirrus clouds (9 classes) and aerosols (10 classes). Work is ongoing to develop an emissivity model for a land/sea-ice/snow surface. Point of contact: Marco Matricardi (marco.matricardi@ecmwf.int).

PCRTM: Principal Component based Radiative Transfer Model. Version 1.0 completed in Fortran 90. Supports: NAST-I, IASI, AIRS. Features include Principal Component (PC) scores and analytical Jacobians of PC scores with respect to state vectors. Scattering not included. Variable gases are currently H₂O and O₃. Trained with LBLRTM using HITRAN-2000 spectroscopy. The vertical pressure grid has 101 levels. Point of contact: Dr. Xu Liu (Xu.Liu-1@nasa.gov).

The group agreed that information on the various fast model developments should be co-ordinated on the RTSP-WG Web site.

Action RTSP-15

Modellers to provide fast RT model summary including name, version, code access and licensing details, supported instruments, technical features (including FM/TL/AD or analytical Jacobians, scattering properties, variable gases, spectroscopy, training set, generating LbL, vertical discretisation), literature references to RTSP-WG Co-Chairs.

Action RTSP-16

RTSP Co-Chairs to add a summary of fast models to RTSP-WG Web page by 15 December 2005.

One action, for the RTSP-WG to provide guidance on developing and testing tangent linear and adjoint code, was carried over from ITSC-XIII.

Action RTSP-17

Tom Kleespies and Roger Saunders to collect notes on this topic and post a summary on the ITWG RTSP-WG Web site.

2.1.6 AIRS RT model comparison

The goals of the intercomparison were to:

- Compare the forward model calculations for all the AIRS channels from all the models for 52 diverse profiles and one tropical Pacific profile coincident with AIRS data.
- Assess the Jacobians from each model using the Garand measure of fit for a limited selection of channels.
- Estimate model error covariances.
- Document the time taken to run each model.

Results have been completed, and were presented at ITSC-XIV in poster B41 by Saunders et al. These results will form the basis of a journal publication.

The group noted that additional work is needed before publication, namely

- identify where differences are likely to result from spectroscopic differences or from fast model errors which are not linked to spectroscopy,
- present Jacobian error characteristics (for the selected subset of channels) using box and whisker plots (median, quartiles, minimum and maximum values of the Garand measure of fit).

The issue of the accuracy of Jacobians for weak absorption features should also be addressed or noted in the publication (this is probably not characterized with the current intercomparison channel subset).

In poster B06 Vanessa Sherlock assessed how these RT model differences could impact on retrieval accuracy using a 1D-Var code. This study had been proposed as part of a second phase of the AIRS RT intercomparison during ITSC-XIII. A journal publication is planned.

Action RTSP-18

All AIRS RT modellers should facilitate the publication of the intercomparison results without delay.

Recommendation RTSP-3 to RT modellers

The RTSP-WG recommends that future RT model validation studies be undertaken when collocated A-train sensor data sets become available.

2.1.7 Surface property models

Ben Ruston proposed the formation of a task group representing more specifically the Land Surface Property (LSP) activities of RTSP-WG to co-ordinate research efforts in land surface emissivity modelling.

The RTSP-WG supported this initiative, and in subsequent discussions it was agreed the task group would address surface property modelling for all surface types. The group will focus on co-ordinating research efforts in land surface emissivity atlas and model development in the first instance.

The RTSP-WG noted the SP task group needs to co-ordinate with the ITWG Satellite Sounder Science and Products Working Group (Lydie Lavanant) to provide a summary of existing atlases and surface type classification.

Action RTSP-19

A surface property task group of the RTSP-WG to be set up and co-ordinated by Ben Ruston.

Post Meeting note: Catherine Prigent and Fuzhong Weng have accepted to Co-Chair the SP task group and Ben Ruston and Sid Boukabara will report to RTSP-WG on the SP task group activities.

The SP task group met at ITSC-XIV. At that meeting several working points on land surface emissivity were identified. The SP task group will:

- Document the land emissivity implementation techniques and their impacts on forecasts from different NWP centers.
- Inter-compare retrieval methodologies.
- Standardize the spatial and temporal averaging methodology leading to infrared and microwave emissivity atlases.
- Review the output fields available from land surface modeling systems, and target those fields useful or necessary for forward modeling of emissivity.
- Recommend an aggregation strategy for global soil and vegetation databases for the use of emissivity modeling, and gathering of emissivity statistics.

The RTSP-WG group meeting discussed the current issues and limitations in emissivity modelling. A summary of this discussion follows:

2.1.7.1 Microwave emissivity

Ocean surface

The group agreed efforts should focus on model-model and model-observation discrepancy at low frequencies (below 20 GHz) and polarimetric capability.

Land/sea ice surfaces

The group recommended the SP task group should explore how to specify spectral emissivity at all observed microwave frequencies in absence of adequate emissivity data (extrapolation, modeling, retrieval, climatology).

2.1.7.2 Infrared emissivity

Ocean surface

The group noted modellers need to account for the temperature dependence of the infrared sea surface emissivity, particularly at temperatures less than 10 degrees C. The current consensus is that the effect of ocean salinity is small and is not worth including in the modeling.

Land surface

The RTSP-WG recommends the use of the CERES land classification (including water fraction) and requests the SP task group identify and recommend other relevant databases.

Recommendation RTSP-4 to RT modellers

The RTSP-WG recommends standardization of emissivity model interfaces, e.g. within CRTM framework.

Recommendation RTSP-5 to RT modellers

The RTSP-WG recommends studies into the relationship between retrieved IR and MW skin temperatures (and retrieved/modelled emissivities).

Guy Rochard argued for the need for clear scientific justification for radio frequency protection and requested the RTSP-WG work to identify ITSC-endorsed microwave surface emissivity data and atlases.

The RTSP-WG noted the SP task group should consider this request.

2.1.8 Radiative transfer modeling for cloudy scenes

The group noted significant advances in radiative transfer modelling in the presence of cloud over the past two years.

George Ohring presented the findings of a workshop on the assimilation of satellite cloud and precipitation observations in NWP models at the ITSC-XIV conference. A report on this workshop is available.

Action RTSP-20

F. Weng and R. Bennartz to summarize recent progress on modeling of radiation in cloudy/precipitating atmospheres (including discussion of the effects of FOV and 3D cloud structure).

Claudia Stubenrauch presented the results of CIRAMOS, a European Union study to assess the accuracy of different parameterizations of ice crystal single scattering properties for radiative transfer in cirrus clouds (see poster A05, Eddounia et al.). The CIRAMOS final report will be available online: <http://ww.lmd.polytechnique.fr/CIRAMOS/Welcome.html>, under the results link.

2.1.9 Review of group Web page

In light of the formation of the new Surface Property task group, the RTSP-WG Co-Chairs will review and revise the structure of the RTSP-WG Web site if necessary. The Co-Chairs will update the content of the Web pages to include the new information provided during ITSC-XIV and identified in this report. The RTSP-WG members are invited to propose additions and improvements at any time.

Action RTSP-21

RTSP-WG Co-Chairs to review and update RTSP-WG Web pages by 15 December 2005.

2.2 TOVS/ATOVS DATA IN CLIMATE

Working Group members: J. Bates (Co-Chair), C. Stubenrauch (Co-Chair), S. Ackerman, M. Goldberg, B. Lapeta, M. McCarthy, C. Pierangelo, A. Reale, P. Schliissel, J. Schulz, C. Shi, L. Shi, B. J. Sohn, P. Thorne, H. Zhang

2.2.1 Introduction

The length of the TOVS/ATOVS data record now exceeds 25 years and the quality and number of climate products continues to grow. A sign of the success of these efforts, and the commitment to the importance of climate studies to society, is that there are now efforts emerging to support the routine, operational production of Climate Data Records (CDRs) at several different centers. Although the World Meteorological Organization (WMO) has officially defined the period of climate normals only for the parameters of surface temperature and precipitation (the 30-year average of such fields), there remains no community definition of CDRs derived from satellite data. Recently, a report from the U.S. National Academies has defined several forms of climate data records, with a specific focus on their use of satellite data.

From the National Academies report, we adopt the following definitions of Climate Data Records (CDRs):

- A CDR is a time series of sufficient length, consistency, and continuity to determine climate variability and change.
- Fundamental CDRs (FCDRs) are sensor data (e.g., calibrated radiances, brightness temperatures, radar backscatter) that have been improved and quality-controlled over time, together with the ancillary data used to calibrate them.
- Thematic CDRs (TCDRs) are geophysical variables derived from the FCDRs, specific to various disciplines, and often generated by blending satellite observations, in-situ data, and model output.

In the following sections, we summarize other recent developments in the use of satellite sounding data in CDRs, discuss several continuing challenges, and look forward to the expanded number of products that will become available as hyperspectral infrared sounding moves from research with the AIRS instrument to operations with the IASI and CrIS instruments.

2.2.2 Assessing the maturity of CDRs

As the data records from satellites have become longer and the science of applying these data to climate problems has evolved, best practices for compiling CDRs have emerged. The objectives in compiling these best practices into an assessment model has arisen in order to: 1) reduce difficulty and confusion in the community about what attributes are important in climate data records, 2) produce an easily understood way of identifying maturity of data products and science data stewardship approaches, and 3) help identify areas needing improvement.

In an effort to capture these best practices and assess the maturity of various CDRs, three dimensions for assessing the maturity of a CDR have initially been proposed; scientific maturity, preservation maturity, and societal benefits.

The particular maturity level is assessed by defining the set of key process areas and the level of best practices that characterize each area. The result is a score ranging from 1 (very low) to 5 (very high) that can be used to provide a rating of the total maturity of a specific climate data record.

Action Climate-1

John Bates to provide the ITWG Climate WG with further details of the Climate Data

Record (CDR) measurement maturity index and include their feedback in the further development of the index.

2.2.3 Recent advances in climate data sets

Temperature record MSU-AMSU

There remains controversy over long-term trends in MSU/AMSU climate data records. Structural uncertainty arising through homogenization choices (particularly the intercalibration of overlapping satellites) continues to lead to long-term trend estimates that differ by a similar magnitude to the tropospheric climate signal. New attempts by Fu and colleagues to remove the stratospheric influence do not remove this discrepancy, nor do they fundamentally alter our understanding.

The availability of a range of independently derived datasets has led to a more thorough understanding of the dataset homogenization process. As a result of independent efforts several methodological artefacts have been identified. These help to clarify what the true signal is and lead to better physical consistency between channels. Very recently Remote Sensing Systems produced a 2LT (MSU channel 2 lower troposphere) product and identified a fundamental flaw in the University of Alabama in Huntsville's (UAH) diurnal correction technique for this retrieval that led to a strong spurious cooling in the tropics in their product. Resolving this issue has led to greater vertical consistency within the UAH product.

Water Vapor (HIRS, AMSU, SSMI)

Water vapor profiles

TOVS Path-B provides atmospheric profiles of temperature (9 layers up to 10hPa) and water vapor (5 layers up to 100hPa) for the time period 1987-1995. Water vapor has been evaluated in comparison with radiosonde measurements, SSMI and Meteosat observations. An extension of this dataset, using an improved retrieval is in progress.

NOAA's TOVS Radiance Pathfinder also continues to work on an intercalibrated radiance data set (a TOVS FCDR) as well as a neural network approach to retrieve temperature and water vapor profiles. In this method, the impact of CO₂ increases on the different HIRS channels is being taken into account. Further work, however, is required on the intersatellite calibration.

Integrated water vapor content

SSM/I data have been utilized to derive long temporal records of integrated water vapor in several institutions in Europe, Japan, and the US. Examples of those data sets are the Hamburg Ocean and Atmosphere Parameters and Fluxes from Satellite Data (HOAPS, www.hoaps.org), the J-OFURO (Japanese Ocean Flux data sets with Use of Remote sensing Observations, <http://dtsv.scc.u-tokai.ac.jp/j-ofuro>), or the products provided by Remote Sensing Systems (www.remss.com). Most of them provide the series back to the year 1987 and are keeping processing actual SSM/I data and will continue the series by using SSMIS and later CMIS. Also products from the AMSR- instrument E (~3 years) on the AQUA and TMI (~7 years) on the TRMM satellites are available from Remote Sensing Systems.

One of the major problems encountered during processing SSM/I data was the need for an intercalibration of the different platforms that was solved by using overlapping periods of the DMSP platforms. The algorithms used to derive integrated water vapor from microwave radiometer measurements were comprehensively validated by radiosondes and differences between them are also analysed in the literature. Differences between the derived time series are likely to exist because different techniques for intercalibration of the DMSP platforms have been used, e.g. by choosing different reference satellites.

Ozone (SBUV/HIRS)

NOAA has developed a new total ozone product by combining high resolution infrared radiation sounder (HIRS) upper troposphere and lower stratosphere ozone retrievals with solar backscatter ultraviolet model (SBUV/2) middle to upper tropospheric ozone retrievals. This algorithm uses the best available information from each instrument to create a total ozone product (TOAST). This product from NOAA 16 has been running experimentally since 2002 and is available in near real-time to users. The TOAST product has improved accuracy over HIRS alone and is extremely useful in monitoring total ozone changes in the polar night area where the SBUV/2 instrument does not provide coverage.

Carbon dioxide and dust/aerosol

Carbon dioxide retrieved from HIRS (NOAA10) has been analyzed in terms of biomass burning emissions in the tropics. The monthly difference between the amount of carbon dioxide at 7.30 pm and 7.30 am shows strong signature over Africa and South America during the fire season. Analysis of NOAA12 data is in progress.

A new climate data set has been built with HIRS data (NOAA 10 and 12). It consists in monthly maps of optical depth and altitude of mineral dust aerosol (from 40°S to 40°N). The retrieval is possible both over land (including deserts) and sea, which is a great advantage for monitoring dust sources.

Preliminary work is also occurring at several centers on the direct retrieval of several greenhouse gases from hyperspectral infrared data from the AIRS instrument. This work appears very encouraging but further validation and refinement is needed of these techniques.

Clouds

TOVS Path-B cloud height has been evaluated using collocated LITE data, corresponding in general well to the height of the 'apparent middle' of the cloud system. High-level clouds appear more often in multi-layer systems (about 75%) and are also vertically more extended than low-level clouds. As part of the European CIRAMOSA (final report available), LMD has produced mean effective ice crystal diameters D_e and ice water path IWP of large-scale semi-transparent cirrus for NOAA-10 observations, with global averages (from 60°N to 60°S) of 55 μm and 30 gm^{-2} , respectively. The HIRS instruments of later observation periods do not provide the necessary 8 μm radiances anymore. Even if uncertainties can be up to 25%, this data set revealed in synergy with ERA-40 re-analyses correlations with air humidity and dynamical situations. Other fruitful synergies have been with ScaRaB flux data to determine the best suited D_e parameterization for radiation in climate models and combined use of upper tropospheric relative humidity obtained from TOVS Path-B and effective high cloud amount to study the impact of air traffic on cirrus coverage.

The UW-HIRS cloud data set provides cloud properties from the period December 1978 - December 2001. In this time period, HIRS globally averaged frequency of cloud detection (excluding the poles where cloud detection is less certain) has stayed relatively constant at 75%. High clouds in the upper troposphere (above 6 km) are found in roughly one third of the HIRS measurements; a small increasing trend of ~ 2% per decade is evident. High cloud cover increases of ~10% are found in the western Pacific, Indonesia, and over Northern Australia. The most significant feature of these data may be that the globally averaged cloud cover has shown little change in spite of dramatic volcanic and El Nino events. During the four El Nino events winter clouds moved from the western Pacific to the Central Pacific Ocean, but their global average in the tropics did not change. El Chichon and Pinatubo spewed volcanic ash into the stratosphere that took 1-2 years to fall out, but cloud cover was not affected significantly. The HIRS analysis differs from ISCCP which shows decreasing trends in both total cloud cover and high clouds during most of this period; HIRS detection of upper tropospheric thin cirrus

accounts for most of the difference. GLAS observations of high thin clouds are found to be largely in agreement with the HIRS.

The two cloud climate data sets presented at ITSC-XIV (the 22-year record of UW HIRS and the 8-year record of TOVS Path-B) participate in the GEWEX Radiation Panel global cloud data set assessment. A first meeting was held in Madison, Wisconsin, US, in April 2005. The next is foreseen for April 2006 in Boulder, Colorado, US. They concluded that within the physical uncertainty of the different data sets, no trends on the large scale cloud amount were found. It was further noted that special care must be taken when using the data sets because statistically significant trends are evident in some of the data sets, but those changes are within the uncertainty of the analysis schemes. Some consistency between different data sets on the global scale variations at $\pm 1\%$ were shown leading to the belief that improvements in understanding the uncertainties in the algorithms and their improvement will lead to substantially more accurate estimates of the variations in the next few years. Detailed comparisons between different data sets are now planned to better understand the detectability of small amplitude variations.

Surface properties from infrared and microwave sounders

The retrieval of infrared emissivities at three wavelengths from HIRS has now been applied to the global scale, for NOAA 10 and 12. Emissivities are retrieved simultaneously with surface temperature, with a neural network approach. These emissivities are used to constrain the retrieval of dust properties over land.

Several groups have compiled climatologies and improved models for the microwave surface emissivity. The retrieval of microwave surface emissivity over the oceans is relatively well-understood and well-captured by present radiative transfer models. Over land, the situation is much more complex owing to the highly heterogeneous nature of the surface and strong diurnal cycle of land skin temperature.

Recommendation Climate-1 to agencies/investigators producing climate data records

It is vital to produce multiple independent climate data records for a given atmospheric parameter or satellite instrument to thoroughly understand the effects of methodological choices and better discern the true climate signal. The ITWG endorses the development of criteria to assess the level of capability and maturity of climate data records by defining a set of 'best practices' that would include criteria such as the multiple independent production of CDRs by different groups and their intercomparison.

Recommendation Climate-2 to agencies/investigators producing climate data records

Many CDRs are produced within universities or other science institutions. To provide a continuous treatment and data access of those data sets meeting GCOS climate monitoring requirements, the ITWG climate group recommends continuation of such research efforts as well as the transition of mature products into operational climate activities.

Recommendation Climate-3 to agencies/investigators producing climate data records

ITWG endorses activities that lead to a comprehensive analysis of the existing temporal records either by intercomparison in the framework of the GEWEX Radiation Panel (or its successor, the WCRP Observations and Analysis Program) or their use in applications at operational climate centers.

Action Climate-2

ITWG Co-Chairs to report Recommendations Climate-1-Climate-3 to GEWEX radiation panel and any responses to these Recommendations to the ITWG Climate WG.

2.2.4 Calibration issues

Optimal calibration of individual instruments

Although there are some existing efforts to provide for the intercalibration of GEO and LEO satellites in real-time, there is no co-ordination between these intercalibrations and those made by the climate community looking at longer time series. Calibration and intercalibration of satellite instruments occur in a number of ways and for both raw radiances and retrieved products. All satellites are subjected to some level of pre-launch calibration and instrument characterization, but information about these characterizations is often difficult to find. Once in orbit, raw radiances can be compared between instruments that either overlap or underfly one another as well as through comparison to simulated radiances produced as part of the monitoring programs at major numerical weather prediction centers. Similarly, retrieved products such as temperature and moisture products, ozone, aerosols, and radiation can each be compared with in situ observations of such geophysical variables. These comparisons are done in an ad hoc manner by each agency or center and there is no comprehensive clearing house to coordinate how these comparisons are done or to document the methodology. There are many good efforts, but the entire community needs to benefit from these efforts.

Intercalibration practices

Numerous intercalibration practices have been developed for the generation of homogeneous FCDRs and TCDRs. These include techniques for intercalibrating during the overlap of similar instruments, for accounting for the diurnal drift of the early NOAA satellites, and for the use of long-term quality radiosonde data for a transfer standard.

For the time period of 1987-1995 NOAA provided a collocated radiosonde - TOVS data set (the DSD-5 data set). To extend the TOVS Path-B climate data set back and forward in time, LMD has created bias adjustment constants from collocated radiosonde - TOVS observations which have been identified as clear sky. The collection of radiosonde measurements has been provided by ECMWF and was further processed and subject to additional quality control by LMD.

NOAA has developed a unique, new technique for the intercalibration of polar orbiting satellites by taking advantage of the crossings of the spacecraft in the polar regions. This technique, known as the simultaneous nadir overpass method (see poster A33), holds great promise for an improved intercalibration of satellites, including all polar orbiters. These data are just being evaluated by the community and further work is needed to assess their quality.

Recommendation Climate-4 to WMO Coordinator for satellite observations

Numerous efforts have been made to intercalibrate satellites with each other and against in situ data. Better coordination between relevant agencies and long-term archive and access is required to the various calibration and intercalibration efforts.

Action Climate-3

ITWG Co-Chairs to report Recommendation Climate-4 to WMO and response of WMO to this recommendation.

2.2.5 Reference network

For the purposes of climate monitoring, it is of vital importance to provide strong constraints on the characterization of time-varying biases. This requires the implementation of a ground-based climate reference network. A key component of such a network is the full characterization of all geophysical parameters of interest both for current and future satellite missions. Critical to the success of this is the requirement for measurement redundancy at such sites - each parameter must be measured by two or

more independent instruments and these must be changed so as to provide a continuity of measurements. This requires much more than simply launching a radiosonde to coincide with satellite overpass. Rather the vision is for a suite of ground-based in-situ and upward looking instrumentation (lidar, radar, GPS, microwave scanner etc.). In fact, radiosondes can be launched at irregular overpass coincident times rather than at each overpass.

It is important that efforts are undertaken to prove the concept and learn from previous experiences at, for example, ARM CART sites to optimize network design. It is also vital that the network be accompanied by open access to full data and metadata. Efforts to plan such a network are underway by GCOS and NOAA.

Recommendation Climate-5 to GCOS/NOAA climate observation requirements WG

ITWG strongly supports the vision of a reference network that consists of multiple instruments to fully characterize the atmospheric column, providing a continuous rigorous ground truth, which would have benefits not just to the climate community. GCOS/NOAA are encouraged to continue to strongly pursue this vision and coordinate with other relevant bodies.

Action Climate-4

Peter Thorne to advertise reports and progress from the GCOS/NOAA workshop series to the ITWG list to permit feedback from the ITWG community to ensure that the needs of the satellite community are incorporated.

2.2.6 Status of re-analysis efforts

Since the last ITSC meeting there has been considerable use of the ERA-40 reanalyses system within the climate community. The Japanese have also recently completed a 25 year reanalysis effort over the TOVS/ATOVS era. Within the US there are plans for a set of three reanalyses covering 1860 to present (surface only data), 1958 to present (surface and raobs only) and the TOVS era to present (everything). However, these are unlikely to proceed in the near future. In the meantime, the NCEP frozen reanalysis system continues to be updated in near real-time. Both the Japanese and ECMWF plan further reanalyses and ECMWF plan an interim reanalysis that updates in real-time.

There remain obvious trend discontinuities within both ERA-40 and NCEP reanalyses that mitigate against their use for long-term trend analysis, particularly in the free atmosphere. This relates to the changing use of data over time which leads to changes in characteristics.

Recommendation Climate-6 to reanalysis centers

Reanalyses efforts would greatly benefit from undertaking observing system experiments to understand what input data, particularly the start of different observing systems such as TOVS/ATOVS and hyperspectral sounders, affect the analysis system. This will help future reanalyses mitigate these changes in the observing system and better capture long-term behavior free of biases.

Action Climate-5

ITWG Co-Chairs to report Recommendation Climate-6 to appropriate reanalysis centers and any responses to recommendation to the ITWG Climate WG.

2.2.7 Agency plans for satellite-based climate data records

A common need exists for the long-term preservation of both data and metadata for future generations to be able to exploit the full potential of the space-based observing era. This includes the acquisition, archival, and easy access to both the raw data, products, processing software, and rich metadata. Rich

metadata should be captured and preserved in accordance with national and international standards and include characteristics in the following areas:

- Reference -provides catalog-type data that allows basic search and discovery
- Context - where the data were created and how they related to other similar data
- Provenance -history of processing, any changes to the data, who has had custody of the data
- Integrity -security, vulnerability, etc.

The longer time series provided by the operational satellite data coupled with the continuing importance of climate and global change on societies is leading to the creation of operational programs in the use of these data. Current plans are briefly summarized below.

NOAA plans

The goal of NOAA's Scientific Data Stewardship Program is to provide high quality Climate Data Records of the atmosphere, oceans and land surface. Satellites provide the only technology for achieving truly global coverage. These CDRs will focus on the following societal impact areas:

- Applied Climatology - provide a variety of decision makers with place-based information of known high quality for use in industry, water resources, the energy sector, agriculture, fisheries and other sectors of the economy.
- Climate Monitoring - provide decision makers with reliable information on the state of the Earth's climate.
- Climate Change Predictions - enable researchers to achieve an improved understanding of climate variability and change by providing global observations of forcing and response variables.

NASA plans

NASA has contributed greatly to the efforts on producing CDRs from the Mission to Planet Earth (MTPE), particularly through the large missions of TERRA, AQUA, and AURA. Particularly noteworthy are the efforts for reprocessing of the MODIS data sets and the joint effort by NASA and NOAA to provide AIRS sub-sampled data sets to the operational NWP community in near-real time. These efforts have resulted in rapid use of these research data sets in operations.

NASA and NOAA are now engaged in the transition of these results through the NPOESS Preparatory Project (NPP) to the next generation of operational satellites, the NPOESS series. To accomplish this, NASA has established a NPP Science Data Segment (SDS) and a set of climate analysis research systems (CARS). The science data segment will have no operational responsibilities and will be responsible for assessing the quality of NPP environmental data records (EDRs; the equivalent of level 2 retrieved products) for accomplishing climate research. Five thematic CARS efforts will be supported in the areas of ocean color, land, atmosphere, ozone, and soundings.

EUMETSAT plans

Data Provision

Data from the EUMETSAT Polar System (EPS/METOP) will be available from 2006 onwards. Besides the distribution to near-real time (NRT) users, data products, auxiliary information and meta-data will be archived in the Unified Meteorological Archiving and Retrieval Facility (UMARF). Products generated and archived include AMSU-A, MHS, HIRS, AVHRR level 0 (raw data) and level 1B (geolocated and calibrated radiances), ATOVS level 2 (geophysical products), IASI level 0 and level 1C (geolocated, calibrated and apodised radiances as well as AVHRR radiance analysis inside IASI IFOVs). NRT data will be disseminated via the EUMETCast system to European users, and by NOAA to users in the U.S. A sub-sample of ATOVS, AVHRR, and IASI level 1 and level 2 data will be distributed by the Global Telecommunications System (GTS).

Satellite Applications Facility on Climate Monitoring (CM-SAF)

The Satellite Application Facility on Climate Monitoring (CM-SAF) is dedicated to high-quality long-term monitoring of the climate system and its variability. Currently the CM-SAF is in its Initial Operation Phase (IOP) that aims to set up operational processing of climate data sets mostly for the Meteosat, NOAA, and METOP satellite series. At present the CM-SAF provides macro- and microphysical cloud parameters as well as radiation budgets at the top of the atmosphere and surface over the European region starting from October 2004. A water vapor product (integrated water vapor over five thick layers and total plus relative humidity) will be added during 2005. Details can be found at www.cmsaf.dwd.de.

The Continuous Development and Operation Phase (CDOP) is planned to start in 2007 and will see some substantial upgrades in the products. It is planned to provide water vapor and some of the cloud products globally. For water vapor there will be single sensor estimates from IASI, ATOVS including MHS, and SSM/I (SSMIS). It is also planned to incorporate the existing SSM/I water vapor climatology HOAPS (www.hoaps.org) into the CM-SAF processing to provide a 24-year time series (1987-2011) of total integrated water vapor by the end of the CDOP in 2012.

Additionally, the GRAS-SAF will derive a time series from the occultation measurements of the GRAS instrument that will be shared by the CM-SAF.

CM-SAF is archiving data from level 1 to level 3 including metadata. Presently, locally received AVHRR data, SEVIRI full disk data received via EUMETCast, and global ATOVS level 1c data are archived. This will be extended to global data sets for AMSU-A, MHS, HIRS, AVHRR, and IASI from the METOP and NOAA-N platform in 2006. Level 1 (geolocated and calibrated radiances) and level 2 (geophysical products at satellite resolution) data that are permanently archived within the UMARF at EUMETSAT are held in a rotating archive at CM-SAF for about two years including metadata on software versions used for the retrieval of level 2 data. Level 2 data are not publicly accessible via the internet but are offered offline. User products (level 3 products on grids and integrated over time) and its metadata are permanently archived at DWD and accessible via the internet free of charge. The access is possible via the CM-SAF Web user interface or the UMARF where a metadata catalogue of CM-SAF data and an order handler will be available at the end of the IOP.

Recommendation Climate-7 to space agencies

Space Agencies should ensure archival of and access to all level 0 data along with any metadata for future use by the climate research and monitoring community.

Recommendation Climate-8 to satellite archive centers

Satellite archive centers must ensure the collection, retention, and accessibility of complete and rich metadata. The rich metadata inventory should include compatibility with international standards for metadata and include reference, context, provenance, and integrity information.

Recommendation Climate-9 to reanalysis groups

Reanalysis groups should seek to work with the new operational satellite climate centers on the optimal calibration and processing of archival data sets.

2.2.8 Use of hyperspectral infrared sensors

The success of the AIRS hyperspectral infrared sensor and plans to fly hyperspectral infrared sensors on operational satellites by NOAA and EUMETSAT require us to consider how such data might optimally be used in climate studies in the future. We consider requirements below for both the use of the raw radiances (FCDRs) and geophysical retrievals from those data (TCDRs).

Fundamental CDR issues

As with all sounders, there is a need to provide for quality metadata for hyperspectral sounders including pre-launch calibration, in orbit calibration and validation, processing history, and other relevant information on the instrument performance. Although use of these data in numerical weather prediction often involves a reduction of the data volume in spectral space, we urge all satellite operators to keep the raw data record (level 0) data for climate reprocessing efforts to allow the maximum extraction of information from the data including the ability to update the calibration, navigation, and other processing.

The detailed spectral information in these observations provides for a direct observation of changes in greenhouse gases and their effects on the water vapor and temperature profiles from the surface into the stratosphere. Statistical properties of these spectra and their changes over time will be critical in future climate studies. One way to deal with the high data volume, and to allow wide use of the data, is to provide the data subsampled, or ‘thinned,’ in space. In order to allow for the long-term analysis of hyperspectral data, as well as comparison with filtered radiometer data for the past 25 years, the spectral regions covered by hyperspectral sounders should cover the widest possible range in the short, mid, and long wavelength portions of the infrared spectrum paying particular attention to maintaining coverage of the same spectral regions.

Thematic CDRs - new opportunities

Hyperspectral infrared sounders open the possibility for a suite of new and improved products to be retrieved. To ensure the optimal extraction of retrieved information, researchers require that the full spectral fidelity be retained in the raw data to ensure this can be accomplished. Based upon experience being gathered from research using the AIRS instrument, we encourage climate researchers to exploit opportunities in the following thematic areas:

- Increased vertical resolution for T and q
- Greenhouse gases
- IR surface emissivity
- Aerosols, dust, and cloud microphysical properties

Recommendation Climate-10 to space agencies

Space Agencies should archive and make easily accessible radiances of all spectral channels available including geographically subsampled data sets.

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

Working Group members: S. English (Co-Chair) and J. LeMarshall (Co-Chair), B. Amstrup, D. Anselmo, T. Auligné, N. Baker, N. Bormann, B. Candy, P. Dahlgren, J. George, B. Harris, G. Kelly, C. Köpken, Z. Liu, T. Montmerle, K. Okamoto, R. Randriamampianina, J. San-Woo, R. Souza, M. Szyndel, V. Thyness, C. Tingwell, H. Wei, Y. Zhigang, (part time members: A. Collard, M. Goldberg, R. Hess, T. Kleespies, V. Tabor, F. Weng)

2.3.1 Introduction

There were many substantive presentations at this meeting that indicated very positive results using satellite data from different instruments. The trend towards the use of 1b sounder and imager radiances has continued with most centres now using or preparing to use radiances. OSEs presented at this meeting demonstrate that satellite data has an extremely important impact on weather forecasting and promising new results suggest the potential for future enhancements in the use of satellite sounder and imager data. The microwave data continues to have the largest impact but one centre showed how using a wide diversity of satellite data increased robustness to the loss of any one.

AIRS is now assimilated at three NWP centres and others have plans to exploit AIRS. Most centres have shown a small positive impact arising from a very conservative use of the data. However larger impacts have also been found when more of the data (spatially) has been processed allowing more cloud-free data to be assimilated. As a result new thinned AIRS datasets have been made available by NOAA which should contain more cloud-free data. These are the AIRS warmest FOV dataset in which thinned observations have been selected as the warmest fov in the window region and the AIRS MODIS dataset where the least cloudy FOV has been identified using MODIS cloud flags. A number of presentations were given on fuller use of spectral information (reconstructed radiances, principal components, super-obs). However, the importance of correctly allowing for correlated observation error in so-called reconstructed radiances was also presented.

Initial radiative transfer experiments including the effects of clouds indicate progress has been made towards the potential future assimilation of cloudy radiances. These results indicate that radiative transfer models are now sufficiently accurate to begin the development of theoretically sound assimilation systems for clouds and precipitation. While significant progress has been made, the inclusion of clouds and precipitation remains a very difficult data assimilation problem and a solution should not be expected in the next 5 years.

AMSU-B is assimilated at a majority of NWP Centres and with reports of various levels of positive impacts particularly on the moisture fields and precipitation. This widespread use of the AMSU-B and AIRS data is representative of the general increase in the use of satellite radiance data among the various Centres. Initial work has also begun at a few centres on assimilating the first microwave sounder to use a conical scan geometry and a high noise but oversampling philosophy (SSMIS).

The use of satellite radiances in Limited Area Models continues to progress and there was a significant rise in the number of groups reporting positive impact from ATOVS in regional models. The impact of satellite data in regional/mesoscale (and often for global) data assimilation systems continues to be 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 while significant progress in the use of satellite data in limited area data assimilation has occurred, it is still in the early stages and significant development is still necessary. Note that since the development and use of limited area models is often driven by the expected improvements in QPF and other smaller scale variables, the development of appropriate verification techniques for these models and forecast variables is necessary.

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

The use of satellite data remains very dependent on the monitoring and evaluation procedures for the satellite data. Prior to the use of the data, it is important to diagnose the significant biases between background and radiances (both level 1b and level 1d) which still remain. After implementation, monitoring is necessary to ensure that changes to the data or data assimilation system do not adversely affect the results. Many difficulties have been diagnosed and resolved by monitoring procedures. As more and more Centres get involved in radiance data assimilation, better coordination of the monitoring procedures and more documentation, particularly on the bias correction method should be exchanged between the various data assimilation groups. The WG continues to encourage the development and documentation of monitoring procedures as part of any Centre's analysis procedure and to post monitoring results and documentation on their external Web site. Three more centres have provided monitoring on their Web sites since ITSC-XIII.

The WG acknowledged the continued excellent support to users of AIRS data. The very detailed information distributed and the response to users when possible anomalies are spotted has been very helpful. The WG would like to see support to AIRS as a standard for other missions now and in the future to aspire towards.

Action DA/NWP-1

Mitch Goldberg to enquire (through NESDIS) if the same level of detailed real time information which has been provided for AIRS can be replicated for other instruments and similarly the response to user enquiries.

The WG felt that we do not always know the instrument scientist for each instrument (AIRS, HIRS, AMSU-A, AMSU-B, SSM/I, SSMIS) and requested NESDIS to provide this information.

Action DA/NWP-2

Mitch Goldberg to provide to the ITWG NWP WG a list identifying the most appropriate contact for instrument problems for each instrument.

The WG is not sufficiently aware of existing information on the status of each channel on each instrument and that this information should be linked from the ITWG Web page. Furthermore it would be useful to see what channels the NWP centres considered to not be useable (this can be a larger list than one which is simply instrument problems, e.g. inadequate radiative transfer). The WG members agreed to provide information to a new ITWG Web page and to try to provide updates whenever their usage changed.

Action DA/NWP-3

John Le Marshall with ITWG input to facilitate the establishment of a Web page for instrument status (channel by channel being used where appropriate) and ensure this is linked to the ITWG Web page.

(Post meeting note: an existing page at <http://www.oso.noaa.gov/poesstatus/> exists.)

Action DA/NWP-4

John Le Marshall to ask NWP WG members to provide information to him on their current channel usage for each instrument (used now, used in the past, never used) for input to a summary table which he will put on the ITWG Web page.

The Working Group noted that a new email list server has been established for exchange of information on ATOVS data quality issues and also discussion of other topics relevant to the NWP WG. The address is itwg_nwp@metoffice.gov.uk and the administrator for the list is Stephen English.

The results of the ITWG survey presented at this meeting and reproduced in the Table 2.3-1 below, indicates that the NWP community still has an operational requirement for NOAA/NESDIS ATOVS data processing from level-1b to preprocessed (PP) level-1d radiances, through to retrieved products. The WG again wished to recognise the effort of Tony McNally (ECMWF)) for coordinating the survey and to all centres that responded.

Institute	Retrievals in Global NWP	Retrievals in Regional NWP	Radiances in Global NWP	Radiances in Regional NWP	external WWW DATA MON
<i>Australia</i>	NESDIS		YES-PP (1DVAR)	YES-PP (1DVAR)	YES
<i>Brazil</i>	NESDIS	ICI			NO
<i>Canada</i>			YES-1C (4DVAR)	YES-1C (3DVAR)	YES
<i>Denmark</i>				Yes-1C (3DVAR)	YES
<i>ECMWF</i>			YES-1C (4DVAR)		YES
<i>France</i>			YES-1C (4DVAR)	YES-1C (3DVAR)	YES
<i>Germany</i>	NESDIS				YES
<i>Hungary</i>				YES-1C (3DVAR)	NO
<i>India - IMD</i>		ICI			NO
<i>India - NCMRWF</i>	NESDIS				NO
<i>Japan</i>		NESDIS/JMA	YES-1C (4DVAR)		NO
<i>Korea</i>			YES-PP (3DVAR)		NO
<i>Spain</i>				YES-1C (3DVAR)	NO
<i>Sweden</i>				YES-1C (3DVAR)	NO
<i>UK</i>			YES-1C (3DVAR)	YES-1C (3DVAR)	YES
<i>USA (NCEP)</i>			YES-1C (3D SSI)	YES-1C (3D SSI)	YES
<i>USA (NRL)</i>		NESDIS	YES-1C (3DVAR)		NO

Table 2.3-1. Use of satellite data in operational NWP (ITWG survey of systems at 01 / 05 / 2005).

Notes

- 1) It shows that the NWP community still has operational requirements for all levels of NOAA/NESDIS ATOVS data processing from level-1b radiances to preprocessed radiances (PP), through to retrieved products. However there has been a major move towards direct radiance assimilation (and to 4DVAR).*
- 2) There is still a very limited use of tropospheric data (radiances or retrievals) over land and ice. This is true for microwave and infrared.*
- 3) Many more centres have monitoring information on external Web services (though some are password protected). These are excellent and their use is strongly encouraged.*
- 4) The responses from each NWP centre have provided much more information than is presented here and will be made available in full to all interested parties (hopefully on the ITWG Web site).*

Action DA/NWP-5

DA/NWP Co-Chairs and Tony McNally to provide information from ITWG NWP survey on ITWG Web page.

There continues to be questions raised at this meeting concerning the conversion of antenna temperatures to brightness temperatures for 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. The WG would welcome further studies in this area.

2.3.3 Evaluation and use of AIRS in NWP

The WG agreed NESDIS should be congratulated for past activity in providing AIRS data and be encouraged to continue with the current activity to provide clear fields of view in thinned data sets available to the operational community. The WG discussed options for improved exploitation of AIRS, including new datasets. It was agreed that coordination was necessary in switching from the existing operational dataset to new datasets and that more evaluation of products using MODIS for cloud detection was required. It was also noted that more work is required on developing and testing methods which aim to allow the full spectral information to be used efficiently.

Action DA/NWP-6

Stephen English (Met Office) and Andrew Collard (ECMWF) to coordinate with NOAA the change to warmest fov over the US-Exeter link.

Recommendation DA/NWP-1 to ECMWF/Met Office

ECMWF/Met Office to evaluate AIRS "MODIS" product when it becomes available.

Action DA/NWP-7

Thomas Auligné and Stephen English to present recommendation DA/NWP-1 to ECMWF and Met Office for consideration.

Action DA/NWP-8

John LeMarshall to ask JCSDA to review AIRS 324 channel data set in light of full spectral resolution experiments and recommend any promising additions.

Recommendation DA/NWP-2 to NOAA

Add more MODIS cloud information on AIRS FOVS using existing AIRS BUFR tables rather than additional parameters.

Action DA/NWP-9

John LeMarshall to present recommendation DA/NWP-2 to NOAA, providing full details of what is required in consultation with the WG members.

2.3.4 Forward modelling

The WG welcomed the concept of CRTM where several radiative transfer model options have a common interface. The WG also noted that RTIASI and RTTOV-8 will merge with a common interface in RTTOV-9. The WG encourages developers of RTMs to continue to work towards use of common interfaces wherever possible.

Recommendation DA/NWP-3 to all RT model developers

Where possible use an existing interface (e.g. CRTM, RTTOV) for new models.

Action DA/NWP-10

Stephen English to ask Roger Saunders to communicate recommendation DA/NWP-3 to the wider RT development community.

Recommendation DA/NWP-4 to JCSDA (Paul van Delst) and NWP-SAF (Roger Saunders)

To work towards the same interface for CRTM and RTTOV.

Action DA/NWP-11

Stephen English to present recommendation DA/NWP-4 to the NWP SAF SG.

Action DA/NWP-12

John LeMarshall to present recommendation DA/NWP-4 to the JCSDA SG.

Recommendation DA/NWP-5 to NWP SAF (Stephen English)

To provide information to RTTOV users on sources of emissivity information and emissivity models.

Action DA/NWP-13

Stephen English to discuss with NWP SAF SG whether recommendation DA/NWP-5 can be undertaken by the NWP SAF.

2.3.5 Observing systems and real time access to data

As the use of satellite data matures, the design of observing systems, availability of data, procedures for introducing new data sources and how the data is delivered continue to be major sources of concern for operational NWP Centres. The WG recognizes that the inclusion of NWP early on in the preparation for provision of AIRS data was a positive step, and encourages future satellite programs to have similar programs.

It has been an ongoing concern of the ITWG NWP group that a significant portion of the observations arrive too late for complete inclusion in the data assimilation systems. The operational centres are under pressure to shorten the delivery times of their forecasts to the users and thus are shortening their cut-off times for data delivery. Also, a significant increase in the use of satellite data in limited area systems has been noted. These limited area systems often have shorter time requirements than global systems. Two encouraging advances have been noted. The significant improvement in the delivery time for the NPOESS satellites (20-30min) and the creation of the EUMETSAT EARS system should both allow a significant improvement in the availability of data. The creation of the EARS system has been particularly innovative in providing a low cost system to significantly improve delivery times for the data.

Recommendation DA/NWP-6 to CGMS

Continue to support fast delivery initiatives (EARS, RARS), extending where possible (e.g. Hawaii).

Action DA/NWP-14

Stephen English to communicate recommendation DA/NWP-6 to EUMETSAT and to ask John Eyre to bring it to the attention of WMO and CGMS.

Recommendation DA/NWP-7 to NOAA

To use new global ground stations to mitigate blind orbit problems for NPOESS data.

Action DA/NWP-15

John LeMarshall to present recommendation DA/NWP-7 to NOAA.

The use of research satellites in operational NWP centres has been increasing. The WG strongly welcomed the inclusion of research satellites in the global observing system as a very positive step forward. The availability of research data (e.g., the high spectral resolution data from AIRS) has allowed the NWP centres to develop techniques to use the data more quickly and allowing the monitoring components of the system to feed back to the instrument scientists. However, there continues to be development of satellite programs with no or limited real time access to the data.

The managers of new satellites and satellite programs have often been reluctant to allow outside users to access the data until it has been completely proven. However, NWP centres often have access to data, algorithms and monitoring capabilities which are unavailable to the satellite programs. This makes the NWP centres ideal partners in the initial evaluation process and allows them to begin early development of the infrastructure necessary to use the data.

Recommendation DA/NWP-8 to all satellite agencies

The assimilation community (all major NWP centres) to be part of the cal/val operation for future missions and to receive near real time data before final quality of the data has been established.

Action DA/NWP-16

John LeMarshall and Stephen English to ask ITWG Co-Chairs to ensure recommendation DA/NWP-8 is conveyed to all satellite agencies via appropriate international bodies (e.g. CGMS).

Recommendation DA/NWP-9 to all satellite agencies

While current operational practice and very considerable benefits are based mainly on the use of microwave data and the longwave and midwave IR components of the hyperspectral frequency range, the potential exists for continued gains to be made through additional application of the shortwave IR component of the spectrum. It is recommended that research addressing the problems of solar contamination and surface emissivity be given enhanced emphasis.

Action DA/NWP-17

Stephen English to ask the IASI Sounding Science WG Co-Chairs to note recommendation DA/NWP-9.

The WG welcomed the continuation of the "TOVS" heritage through future missions on METOP, FY-3, NPP and NPOESS. The WG reaffirmed the statement from past meetings that the positive impact of this data on NWP will be largest if satellite agencies choose complimentary overpass times which optimise the data coverage.

The WG is concerned that the instrument specification for ATMS channel noise exceeds current AMSU performance and that the choice of polarisations may not be optimal for sounding the lower troposphere. The WG were keen to do more scientific studies to provide good evidence for the impact of different choices in microwave sounder design on microwave sounder impact in NWP. When these studies are complete, the WG will be in a stronger position to formulate a recommendation to satellite agencies concerning future microwave sounding missions.

Action DA/NWP-18

Nancy Baker to get detailed instrument actual performance figures for ATMS and to then study the relative performance of AMSU-A and ATMS through experiments in the NRL NWP system. Note: JCSDA also plans an OSSE using ATMS this year.

Action DA/NWP-19

Tom Kleespies to repeat Kleespies & Watts MHS study for ATMS compared to AMSU-A.

The WG also noted that the absence of a 6.7 μm channel on VIIRS will prevent a continuation of the MODIS polar atmospheric motion vector product which has been proven to give very positive impact at several centres.

Recommendation DA/NWP-10 to IPO

To add a 6.7 micron water vapour channel to VIIRS.

Action DA/NWP-20

John LeMarshall to present recommendation DA/NWP-10 to the IPO JARG.

The WG discussed data distribution for NPP and METOP products and welcomed the developments for direct broadcast data for both satellites. Whilst the policy for GTS products is clear, the WG needs more information on the policy for distribution of non-GTS products. A specific example is whether the USA can forward METOP non-GTS products to South American countries.

Action DA/NWP-21

John LeMarshall to establish and report to the WG the NPP and METOP non-GTS data distribution policy for countries outside Europe.

Several presentations at ITSC-XIV showed the preparations by satellite agencies and NWP centres for METOP data. The WG considered it important that NWP centres provide input into channel selection for the GTS IASI product and choice of channels etc. for Web based IASI monitoring so that IASI monitoring at different centres can be easily compared.

Action DA/NWP-22

Thomas Auligné to propose and then circulate a monitoring strategy for IASI to be adopted by all NWP centres, to allow easy comparison of monitoring between centres.

Action DA/NWP-23

Stephen English to ask NWP WG members to study the proposal by Andrew Collard for IASI GTS products and provide feedback to Andrew Collard by the end of July 2005 (other IASI GTS questions/comments should be fed to Simon Elliot at EUMETSAT).

During ITSC-XIV NOAA-N was launched. During the meeting it was clarified that NESDIS could provide both NOAA-16 and NOAA-18 in a timely fashion, except when NOAA-16 and NOAA-18 are in conflict when N16 would lose 2 contacts/day because NOAA-18 would be given priority. There are 21 days in conflict, then 23 days out of conflict, then repeat. The data are not lost, just delayed for an orbit.

Recommendation DA/NWP-11 to NWP Centres

NWP centres to provide feedback to NESDIS if NOAA-16 data reception is not acceptable during NOAA-18 commissioning.

Action DA/NWP-24

Stephen English to inform NWP centres of the expected situation for NOAA-16 to NOAA-18 transition and recommendation 14.11.

Recommendation DA/NWP-12 to EUMETSAT

EUMETSAT to provide NOAA-15, NOAA-16, NOAA-17, and NOAA-18 HRPT data as part of EARS where possible.

Action DA/NWP-25

Stephen English to inform EUMETSAT EARS team of recommendation DA/NWP-12.

2.3.6 Other data assimilation issues

The WG welcome the effort of the NWP SAF and ECMWF in particular in organising a bias correction workshop with an open invitation to NWP centres to send observers. This will be held in November 2005 and details can be found at the ECMWF Web site. The WG also said that the bias correction Web based guidance provided by the NWP SAF on its Web site is very helpful.

Action DA/NWP-26

Graeme Kelly to re-advertise details of ECMWF bias correction workshop to ITWG.

Action DA/NWP-27

Stephen English to re-advertise existence of NWP SAF Web based guidance on bias correction on NWP SAF Web page to ITWG and to pass on positive feedback about the Web page to the NWP SAF SG.

The WG noted that considerable progress has been made towards consistent calibration of HIRS in global and direct broadcast data. The effort of CMS Lannion and in particular Pascal Brunel was gratefully acknowledged. The WG requested that NESDIS and CMS confirm whether all possible assistance was being provided from NESDIS to direct broadcast users.

Action DA/NWP-28

Mitch Goldberg to check with CMS (Pascal Brunel) whether NESDIS can provide any information which would allow AAPP processing of HIRS to be even closer to global processing.

The WG noted that re-tuning of AIRS observation errors in combination with a number of other enhancements had a considerable impact e.g., in the NH at JCSDA but little impact at ECMWF. It was agreed we do not know enough about each others observation errors.

Action DA/NWP-29

Stephen English to ask NWP WG members to supply him with information on assumed observation errors for radiance assimilation in order to create a summary Web page for the ITWG NWP WG Web page. This can then be updated as and when necessary.

Action DA/NWP-30

Stephen English to ask NWP WG members to provide him with text (with Web links where appropriate) to describe current techniques used at their centre for estimating observation errors (e.g. Chapnik method).

The WG agreed that there were many ideas and tools but little sharing of information on verification.

Action DA/NWP-31

All WG members to submit information on verification methods (including software tools where available) to Brett Candy, who will create a Web page for the NWP WG Web site.

2.3.7 ITWG NWP WG administration issues

The WG expressed a strong desire to provide a useful Web page under ITWG and noted many items which could or should be provided on it, reflected in many of the actions in this report.

Action DA/NWP-32

Stephen English to get initial information for NWP WG Web page to Leanne Avila.

Action DA/NWP-33

NWP WG Co-Chairs to review the status of the actions and recommendations in September 2005 and at regular intervals before ITSC-XV and email a status report to WG members and ITWG Co-Chairs.

2.4 ADVANCED SOUNDERS

Working Group members: A. Huang (Co-Chair), W. Smith (Co-Chair), with H. Bloom, D. Blumstein, J. Cameron, Z. Cheng, D. Chu, A. Collard, D. Crain, C. Dong, I. Dyras, Z. Fengying, M. Goldberg, F. Hilton, T. King, D. Klaes, B. Lambrigtsen, A. Larar, P. Poli, Y. Qu, F. Rabier, A. Rea, V. Tabor, H. Wei, D. Zhou, L. Zhou, W. Zhou

This Working Group 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 regarding to instrument specification, performance, data processing, and utilization where necessary. 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 infrared and microwave sounders and active sensors.

2.4.1 Sounder field-of-view issue

Considerable discussion was held regarding the intended spatial resolution for the CrIS instrument. It was pointed out that there was never an intent to make the CrIS horizontal resolution poorer than the existing HIRS horizontal resolution (i.e., 10 km).

Recommendation AS-1 to space agencies

It is recommended that trade-off studies be performed to determine the optimal field of view size for the CrIS, considering existing detector noise performance and the desire to increase the density of observations as well as decrease the field of view size. As a first step, a comparison of the yield of NOAA 18 HIRS clear air data versus NOAA 16 HIRS data should be conducted. If the results of these trade-off studies strongly support a change to the CrIS spatial sampling characteristics, a recommendation would be prepared to take to the Joint Agency Requirements Group.

2.4.2 Measurement objectives for Advanced IR Sounders

In order to insure consistency of objectives and adequacy of the capabilities of various international contributions to the global observing system, the ITWG provides the following guidance on the primary measurement objectives and the minimum radiometric measurement thresholds for advanced IR sounders to be carried on future polar and geostationary orbiting satellites.

Advanced IR Sounder Primary Objectives:

Polar Satellite Sounding Observations: The primary measurement objective for polar satellite sounding radiance observations is to infer temperature and water vapor profiles for Numerical Weather Prediction (NWP) model initialization. The radiance spectra, or alternatively the retrieved profile data, to be assimilated need not be spatially contiguous for this application. Simultaneous microwave observations are generally available to assist in the interpretation of clouded hyperspectral IR sounding data.

Geostationary Satellite Sounding Observations: The primary measurement objective of geostationary satellite sounding is the observation of lower and upper tropospheric temperature and water vapor dynamics, as needed to enable the nowcasting (i.e., short-term forecasting) of hazardous weather, and the production of water vapor tracer tropospheric wind profiles, used for regional and global NWP. Spatially contiguous, above cloud, sounding observations are needed to observe the atmospheric processes associated with storm systems and for tracing cloud and altitude resolved water vapor motion winds used for NWP.

Channel cm ⁻¹	$\delta\nu$ cm ⁻¹	Purpose	Polar		Geostationary			Remarks
			P	δS^1 km	P	δt^2 min	δS^3 km	
660-680	0.6	Strat. Temp.	1	100	-	-	-	Polar satellite only
680-800	0.6	Trop. Temp	1	15	1	30	5	Fundamental Band ⁴
800-1000	0.6	T _s , H ₂ O, Cld	1	15	1	15	5	Fundamental Band ⁵ Cls, Sfc., T/Eemis. & H ₂ O
1000-1100	0.6	O ₃	1	15	3	30	5	O ₃ , Stratospheric Wind
1100-1590	1.2	T _s , H ₂ O Aerosol/Dust	1,2	15	2,1	15	5	Water Vapor Flux Trop. Wind Profiles ⁶
1590-2000	1.2	H ₂ O, T _s , Cld	2,1	15	1,2	15	5	Water Vapor Flux Trop. Wind Profiles ⁶
2000-2200	0.6	CO, T _s , Cld	3	15	2	60	5	Trace Gas/Air Quality ⁷
2200-2250	2.5	Trop. Temp	2	15	2	15	5	Clear Ocean Day and Land/ Ocean Night Utility ⁸
2250-2390	2.5	Strat. Temp.	4	100	-	-	-	Night-time Utility ⁸
2386-2400	2.5 ⁹	Trop. Temp	4	15	-	-	-	Night-time Utility ⁸
2400-2700	2.5 ¹⁰	T _s , Cloud	3	15	-	-	-	Clear ocean and Night Land Utility ⁸

Table 2.4-1. Measurement Threshold for Future Advanced IR Sounders

Table definitions: $\delta\nu$ (spectral resolution, unapodized for the case of an FTS, assuming an instrument self apodization of less than 5%), P (priority), δt (refresh rate), δS (footprint linear resolution). The values given are the threshold requirements with objectives being better by as much as practical from a technology and cost point of view. Priority 1 measurements are required to fulfill advanced sounding primary objectives.

¹ For cloud clearing, the highest spatial resolution is desired

² Refresh rate for regional (3000 km x 3000 km) area coverage at full spectral resolution as desired for convective storm applications of the data (i.e., thermodynamic stability and water vapor flux measurement). Broader area coverage (e.g., 9000 km x 9000 km), with 30 to 60 minute refresh rates, is desired for temperature, moisture, and wind profile measurements for NWP applications, but these can be performed at lower spectral resolution (e.g., $2 \times \delta\nu$).

³ Spatial contiguity is required to observe atmospheric dynamical processes

⁴ This band is fundamental for day/night high vertical resolution temperature profiles required for determining atmospheric constituent profile and cloud parameters from hyperspectral radiance emission measurements

⁵ High spectral resolution is needed to resolve on-line/off-line radiance determinations of surface reflectance/emissivity and to separate water vapor/cloud/dust contributions

⁶ High spectral resolution provides shortwave window observations, near the edges of these bands, as needed for cloud clearing. Either longwave (1100-1590 cm⁻¹) or shortwave (i.e., 1590-2000 cm⁻¹) sides of water vapor band can be priority 1. Having measurements covering both longwave and shortwave sides of the water vapor band will optimize the water vapor profile accuracy throughout the atmospheric column. Thus, if one side is chosen as Priority 1 then the other side becomes a Priority 2.

⁷ Spectral resolution resolves CO lines and provides shortwave window observations near 2000 cm⁻¹ desired for cloud clearing, surface temperature, and cloud property estimation.

⁸ Reflected sunlight limits the daytime utility of these data for cloudy sky and/or land surface conditions

⁹ A spectral resolution of 0.05 cm⁻¹ is desired to resolve the contribution from in-between the absorption lines.

¹⁰ The AIRS 2616 cm⁻¹ channel, with 2.5 cm⁻¹ resolution, has been found useful for cloud detection and sea surface temperature measurement.

Common Advanced IR Sounding Measurement Requirements:

- ***NEdT***: A spectrally random noise level of less than 0.2 K, for a US Standard Atmosphere scene temperature at the δt and δS specified above, is desired to optimize sounding vertical resolution. A spatially random noise level of less than 0.4 K, for a US Standard Atmosphere scene temperature at the δt and δS specified above, is desired to minimize the noise in the spatial gradients of the retrieved profiles.
- ***Co-registration***: Co-registration means the degree to which different channels see the same scene taking into account optical alignment, field of view response, diffraction, etc. This co-registration error is generally referred to as the Cij error. Hyperspectral radiances are observed within measurement bands (e.g., as provided by a single detector for a FTS instrument or provided by a focal plane array detector module for a dispersive instrument). It is desired to co-register all the fields of view of the tropospheric sensing spectral channels observed within a measurement band, (e.g., 600-1100cm⁻¹, 1100-2000cm⁻¹, and 2000-2700 cm⁻¹) to within 1% of the window channels (i.e., $C_{ij} \geq 0.99$) within that band (further refinement of the co-registration threshold requires further study). The window channels are used for cloud clearing and for accounting for surface emissivity and surface temperature contributions to the observed radiance as needed for atmospheric profile retrieval. The fields of view of all spectral channels within each measurement band should be spatially contiguous and co-registered as closely as practical with all spectral channels within all other measurement bands. Ideally, one would want all spectral channels to be co-registered to within 2% ($C_{ij} \geq 0.98$).
- ***Absolute radiometric accuracy***: An absolute accuracy better than 0.3 K is desired for weather and climate applications of the data.
- ***Temporal stability***: A temporal stability of the calibrated radiance measurements that is better than 0.1 K is desired for climate applications of the data.
- ***Spectral instrument line shape***: A knowledge and stability of better than 3 part / 10⁶ is desired to achieve the high spectral precision needed for high vertical resolution atmospheric profiling, as well as for meeting the desired spatial and temporal stability of the radiance measurements desired for weather and climate applications of the data.

Recommendation AS-2 to the space agencies

In order to ensure consistency of objectives and adequacy of the capabilities of various international contributions to the global observing system, it is recommended that space agencies follow the ITWG guidance on the minimum radiometric measurement requirements for advanced IR sounders to be carried on future polar and geostationary orbiting satellites.

2.4.3 Calibration and validation of Advanced Sounder data

The importance of calibration/validation (Cal/Val) activities associated with future advanced atmospheric sounders was discussed, and concern was expressed over a perceived lack of emphasis being placed in these areas in planning for upcoming missions (i.e. METOP, NPP, and NPOESS). Post-launch Cal/Val activities are critical for verifying the quality of the entire measurement system for advanced sounders (i.e. the sensor, processing algorithms, and direct/derived data products), and is a prerequisite step for

optimising post-measurement data usage by the operational weather, climate research, chemistry, and broader scientific communities. The 1 K / km layer and 15 % / 2 km layer product accuracy, coupled with the very high radiometric accuracy and precision requirements imposed on the hyperspectral sounding spectrometers, makes adequate Cal/Val for these instruments problematic (i.e., the use of radiosondes and NWP model forecasts alone cannot provide sufficient validation to the levels of accuracy and precision required).

Recommendation AS-3 to the space agencies

Cal/Val for advanced sounders needs to be an activity which receives sufficient resources. While radiosondes and NWP fields can provide a basic validation, high-altitude airborne sensors, such as those associated with the NAST and ARIES airborne sensors, and upper air reference networks (see Climate WG Report) need to also be included in order to validate the radiances, and derived products, to the very high accuracy, and precision, specified for advanced sounding instruments.

2.4.4 Distribution and optimal use of Advanced Sounder radiance data in NWP

The current use of advanced sounder data in NWP is very conservative. The limitations are the cost of radiative transfer modeling and the transfer of large observation datasets from the satellite agencies. Full use of these data requires the efficient use of all the information in a compressed form. Candidates include Principle Component (PC), reconstructed radiances, and retrievals. In choosing the optimal strategy to use, consideration must be given to the specification of the observation error covariance matrix, quality control, cloud detection and monitoring.

In the day-1 METOP system, EUMETSAT cannot distribute the full IASI dataset on the GTS in near-real-time. A subset of 300-500 channels will therefore need to be distributed. A method for choosing such a subset using C. Rodger's selection method based on degrees of freedom for signal has been described in the poster presented at ITSC-XIV, by Collard and Matricardi.

Action AS-1

NWP centers should review the channel selection method proposed at ITSC-XIV to ensure that the channels selected will meet their initial requirements for NWP applications and provide any comments to the ITWG Co-Chairs.

Recommendation AS-4 to advanced sounder research community

The advanced sounder research community needs to consider issues such as: (1) the ability to detect cloud such that the impact of undetected cloud on the observed radiances is less than 0.2K, (2) the correct usage of Principal Components (PCs), (3) effective and efficient quality control (particularly for PCs), (4) the continued development of fast models in super channel or PC space, that are robust, fast and sufficiently accurate, and (5) the quantification of the observational and forward model error covariance matrices.

2.4.5 New initiatives for geostationary sounding

The progress, since ITSC-XIII, of advanced MW sounder/imagers for geostationary orbit was reviewed. In particular, the progress made with the synthetic aperture approach was reported at the meeting. The IGeoLab initiative to promote international cooperation to place a MW sounder/imager in orbit was also noted. As a result of these discussions the following recommendation was formulated.

Recommendation AS-5

It is recommended that relevant organizations conduct studies to identify the functions of microwave sounders, identify users, and develop consensus measurement requirements for future systems. This should be done for LEO as well as GEO sounders. It is recommended

that this information be consolidated in a table similar to that presented above for the IR sounder.

Recommendation AS-6

For future microwave sounders, it is recommended that efforts be devoted to improving radiometric sensitivity and horizontal spatial resolution. It is further recommended that scattering models, which will enhance rain rate estimates and enable retrieval of vertically resolved rain, be further developed.

2.4.6 MW Sounder deployment with future IR Sounders

Examples were shown at ITSC-XIV of how microwave sounders provide data that can assist the interpretation of cloudy IR observations and provide valuable information for filling gaps in advanced sounder information below opaque cloud levels. It is desirable to fly microwave sounders with future IR sounders configured in such a way as to enable simultaneous observations (i.e. collocated in space and time). Cloud-clearing will be enhanced and sub-cloud level information will be provided for continuity. Such MW observations are desired for future advanced IR sounders.

Recommendation AS-7 to space agencies

Microwave sounders should be considered to be flown with future advanced IR sounders, to provide simultaneous observations at the same time and at the same location.

2.4.7 IR Imagers with sounding channels to support future IR Sounders

High spatial resolution imaging radiometers which possess one, or more, lower tropospheric IR sounding channels (e.g., MODIS) provide valuable data for cloud-clearing and for the quality control of cloud-cleared radiances from advanced IR sounding instruments. Furthermore, for the case of complex partly cloudy scenes, where cloud clearing is unsuccessful, the imager sounding channel radiances provide valuable information for filling gaps in advanced sounder information otherwise incurred below clouds. It is desirable that imaging radiometers fly with future IR sounders and that they possess sounding channels in addition to their “window” channels.

Recommendation AS-8 to space agencies

Future imaging radiometers to be flown with advanced IR sounding instruments should possess lower tropospheric IR sounding channels to support the interpretation and enhanced utilization of advanced IR sounding spectrometer observations obtained for cloudy sky scene conditions.

2.4.8 ATMS noise performance compared with actual AMSU performance

The current ATMS specification is consistent with the AMSU performance specification, which is significantly inferior to actual AMSU performance. The polarization of the ATMS in all channels is horizontal while it is vertical for most AMSU channels.

Recommendation AS-9 to space agencies

A study should be undertaken to determine the impact of horizontal and vertical polarization for future MW sounders, taking into account the impact on “clear sky” information content as well as the ability to detect clouds and precipitation. The goal of this study should be to compare the AMSU and ATMS systems to determine what is best for future microwave sounders. The study will also inform users what they can expect from the ATMS data.

2.4.9 Low inclination orbit for satellite cross calibration

A high accuracy spectrometer in a low inclination orbit (i.e. $<20^\circ$) would have the ability to cross-calibrate all polar orbiting satellites several times per day as well as geostationary satellites in different longitudinal sectors. These cross-calibrated radiances would be useful in the determination of biases between different satellite platforms and applying single station in-situ calibration to the entire constellation of satellites by linking cross-calibrated radiances with high temporal frequency. This may complement the existing and planned in-situ calibration campaigns for many separate satellites if the radiances from several can be cross-calibrated with a single 'standard' satellite.

Recommendation AS-10 to science community

The utility of applying the SNO (Simultaneous Nadir Observation) technique for an equatorial (inclination $<20^\circ$ degrees) LEO platform for the purpose of radiometric cross-calibration should be examined. Optimal orbital parameters (attitude and inclination), as well as sensor type, should be determined so that recommendations for possible sensors on future equatorial satellites can be put forward.

2.4.10 Move to single contractor's responsibility for satellite Sounder systems

Historically, environmental satellite systems have been developed by a partnership of government (NASA, NOAA, & EUMESAT), industry and university science communities. While the technological expertise of industry is a key part of the entire system, industry is not well suited to supplying the broad perspective on the use of these future systems nor is it well suited to developing the necessary pre-launch simulations, ground data processing science algorithms, and associated data application approaches. The ITWG believes that the single contractor approach to the development of future satellite systems (e.g., the GOES-R system), would tilt the resource balance so that it would undermine the ability of government to provide continuity into the future and would place much of the science community under the financial control of industry, inhibiting the science community from acting as an objective, commercially neutral, body in the development and application of future satellite systems.

Recommendation AS-11 to space agencies

ITWG strongly recommends that certain elements of future satellite systems (e.g., the data processing, algorithm and product development system, the evaluation and validation, and the training program), be led by government agencies, together with its academic teams, in partnership with industry. It is also recommended that the users of the satellite system play a role in the definition of the characteristics of this system.

2.4.11 Transmission of Recommendations

Action AS-2

Advanced Sounders WG Co-Chairs to forward recommendations to specified groups by end of 2005.

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Working Group members: P. Menzel (Co-Chair), G. Rochard (Co-Chair), T. Achtor, S. Elliott, J. Eyre, D. Griensmith, L. Jian, D. Klaes, F. Romano, J. Purdom, P. Wilczynski

The Working Group discussed issues in four areas:

- Enhancing local access to satellite data and fostering global retransmission
- Evolving the Global Observing System
- Frequency protection
- Opportunities for input to education programs for satellite sounder science

2.5.1 Enhancing local access to satellite data and fostering global retransmission

Concerning data access, formats and dissemination for education and research, the Working Group noted that both the education and research communities need access to near real time and retrospective satellite data in digital format. Ease of access and browse capability to the data sets, as well as common formats, are important for users.

Recommendation IIFS-1 to research and operational satellite operators

Make data available in a form and browse display similar to that done by NASA on their rapidfire sites (e.g. <http://rapidfire.sci.gsfc.nasa.gov/realtime/>) that provide access to MODIS and AIRS data. While some providers may have specialized formats, all providers should strive to make their data also available in standard formats (e.g. hdf for images, BUFR for soundings).

Action IIFS-1

ITWG Rapporteur to take Recommendation II-1 forward at CGMS 2005.

In order to make IASI level 1 data available on the GTS, the Working Group noted that EUMETSAT plans to distribute a reduced data set in BUFR format. The reduction will be accomplished by selecting a subset of the available channels where the selection mainly serves NWP users outside of Europe. Informed consultation with potential users took place at ITSC-XIV.

Recommendation IIFS-2 to WMO Space Program Office and CGMS

Establish a process for similar data set distribution from other instruments whereby users can formally express their need for such data sets and conduct a dialogue with the data providers on issues of content and format.

Further regarding BUFR, the Working Group expressed support for the process agreed upon between the WMO Expert Team on Data Representation and Codes and CGMS for the specification of BUFR descriptors for satellite data. As part of this process, classes of element descriptors (BUFR Table B) and sequence descriptors (BUFR Table D) have been set aside for the representation of future satellite data. Proposals for the definition of these descriptors will be coordinated by a working group of CGMS, and then passed via a rapporteur to the WMO Expert Team for approval via the existing process. This will allow the WMO Expert Team to concentrate on data representation issues, rather than the details of the satellite data themselves.

Concerning direct read-out, the Working Group considers the direct broadcast for future polar orbiting satellites (i.e., METOP, NPP, NPOESS, and FY-3) as a paramount issue. The Working Group is encouraged by the planned first International Direct Broadcast Conference in Benevento, Italy in October 2005.

Recommendation IIFS-3 to the direct broadcast community

An International Direct Broadcast Working Group should plan meetings like the forthcoming Benevento, Italy meeting on a regular basis to provide a forum for the international direct broadcast users to exchange vital technical planning information regarding achieving access to and maintaining consistency of level 0 and level 1 data. Annual plenary meetings would suffice, however, more frequent sub-groups should be considered. Failure to do so may put at risk the continuity of data access at some NWP centers and synergy within the international user community. All international DB users should plan to be represented at the October workshop.

Action IIFS-2

The ITWG rapporteur to encourage consideration for establishing an IDBWG within CGMS in the near future.

Concerning timeliness of satellite data (Global NESDIS, RARS, NPP, NPOESS plans), the Working Group noted the success of the EUMETSAT Advanced Retransmission Service (EARS) in enabling NWP assimilation of more data within cutoff times. The first workshop on leveraging EARS to form a global rapid ATOVS data exchange system was held in Darmstadt, Germany in December 2004 and it furthered plans for the establishment of a number of coordinated RARS (Regional Advanced Retransmission Service) around the globe. This system will likely expand to many other satellite data types (as in Europe) and will provide key components of future meteorological data dissemination systems. Realizing this system will require considerable coordination and support by relevant agencies, including National Meteorological and Hydrological Services (NMHS), the Working Group congratulated EUMETSAT for sharing their EARS knowledge to prospective RARS partners in the recent WMO organized workshop.

Recommendation IIFS-4 to the WMO Space Program Office

The WMO, with CGMS assistance, should continue to promote the implementation of a globally coordinated system of RARS. The 6th Asia-Pacific Satellite Data Exchange and Utilization (APSDEU-6) meeting in Seoul in June 2005 will seek to reach agreement on implementation of an Asia-Pacific RARS. The WMO Space Program Office should organize a further global RARS meeting thereafter.

Recommendation IIFS-5 to the WMO Space Program Office

To coordinate the development of backbone reception stations and dissemination nodes, contacts and implementation standards, including quality, formats, and processing software requirements. A Web site should be established as a central reference for all global RARS information.

2.5.2 Evolving the Global Observing System

The Working Group discussed at length polar orbit coordination and optimization among space operators. Concerning equator crossing times of planned polar orbiting satellites, it was noted that insertion of satellites into similar orbital planes should be coordinated so that data reception problems are minimized (e.g. two satellites should not appear simultaneously above the local horizon) and contribution to the Global Observing System be optimized (e.g. continuity of ageing instruments).

Recommendation IIFS-6 to CGMS

To continue to provide a forum for discussion and coordination among satellite operators to avoid orbit overlap as much as possible.

Action IIFS-3

ITWG Rapporteur to CGMS to present Recommendation 14.6.

Recommendation IIFS-7 to IPO

To consider placing NPP into a 1430 local time ascending orbit (instead of the planned 1030 descending orbit) in order to complement the pending METOP/IASI with NPP/CrIS and to provide continuity with Aqua/AIRS.

Action IIFS-4

Goldberg to present Recommendation 14.7 to the IPO/JARG.

Recommendation IIFS-8 to NOAA NESDIS

To pursue added support from the new IPO/NESDIS antenna located in Svalbard, Norway to eliminate the blind orbits and hence significantly improve data timeliness for existing polar orbiting international users.

The Working Group also discussed strategies for achieving an optimized space based component of the Global Observing System that is integrated for NWP and climate. It was concluded that there is a strong need for enhancing the capabilities of the space based component of the GOS and as much as possible a distributed approach amongst the space operators and R&D agencies should be taken toward achieving new remote sensing capabilities (i.e., agencies agree for each to emphasize different development tasks to achieve maximum capability growth in the GOS with the available resources).

Recommendation IIFS-9 to CGMS

To add discussion of the distribution of development tasks to their agenda in November 2005.

Action IIFS-5

ITWG Rapporteur to CGMS to present Recommendation 14.9.

The Working Group noted the “Implementation Plan for Evolution of the Space and Surface- based Sub-systems of the GOS” that was endorsed by the CBS and recently published as WMO TD 1267. It was felt that this document provided a suitable list of those remote sensing capabilities that are missing or need improvement.

Recommendation IIFS-10 to ITWG members

To review WMO TD 1267.

Action IIFS-6

ITWG Co-Chairs to seek volunteers to review the WMO TD 1267 who will provide their comments to P. Menzel by end of July 2005.

The Working Group noted the WMO Space Program initiative to draft a strategy for Intercalibration of the space based component of the GOS. Space operators will be convened in the summer of 2005 to discuss possible short term initiatives and long term commitments. The Working Group strongly endorsed this initiative and requested that the WMO Space Program Office provide an update on the progress at the next ITSC.

2.5.3 Frequency protection

The Working Group noted the considerable progress made in awareness of the importance of frequency protection for environmental remote sensing and the continuing need for protective vigilance. It further noted the need for a document containing the scientific use of each of the frequencies to be protected.

Recommendation IIFS-11 to the WMO Space Program Office

To organize the production of a WMO Technical Document containing the characteristics,

environmental utility, and need for each requested frequency.

2.5.4 Opportunities for input to education programs for satellite sounder science

The Working Group noted that WMO and CGMS have developed the Virtual Laboratory for Training in Satellite Meteorology (VL). The VL is on track with its implementation plan and in several cases had surpassed expectations. Major successful training events have been held in Nanjing, Melbourne, Barbados and Costa Rica. In Costa Rica the VL achieved a major milestone in introducing the electronic notebook concept as a component of the training activity. A major global training event is planned for late 2006.

Action IIFS-7

(a) ITWG Members to review and provide guidance for VL Materials on VRL Electronic Notebook to help assure updated materials for VRL (Available through WMO Space Program Web site for Virtual Lab and linking to CIRA VRL site). (b) ITWG to establish an outreach and education focal point to serve as liaison between ITWG and VL focus group.

2.6 SATELLITE SOUNDER SCIENCE AND PRODUCTS

Web site: <http://cimss.ssec.wisc.edu/itwg/sssp/>

Working Group members: T. Reale (Co-Chair), L. Lavanant (Co-Chair), T. Achtor, N. Atkinson, E. Borbas, I. Dyras, S. Elliot, F. Romano, D. Griersmith, B. Lapeta, E. McKernan, G. Rochard, D. Singh, G. Songyan, R. Souza, H. Wei, H. Woolf, F. Zhang

2.6.1 Background

The SSSP was formed to report and promote the science of derived meteorological products from environmental satellite measurements. The importance of such work is manifested in improving our understanding of the utility of satellite borne radiometric data to depict the atmospheric weather state. The rich learning environment associated with such work, both operational and research (global and HRPT), is fundamental to achieving optimal use and understanding of these data.

The wide variety of applications worldwide, the multiple parameters measured and derived, evolving opportunities for cross calibration and validation, and numerous programs for coordinating the expanding global observing systems challenges SSSP to facilitate full access and dissemination of this information.

2.6.2 HRPT Facility Inputs

Inputs from HRPT facilities concerning status for current processing and plans are not yet complete. These inputs for the SSSP Web site will continue to be solicited through the existing survey and HRPT sites list. The existing topic area will be restructured to provide a tabular/listing which identifies all registered sites, and for the subset of sites for which inputs have been received, a link which identifies the satellites, instrument data, processing packages, measurements and products available, validation and distribution practices, and a link to the site.

Action SSSP-1

Lydie Lavanant to continue HRPT survey and collect data and Leanne Avila to put the information on the ITWG/SSSP Web page.

2.6.3 Local and Global data output format differences

Current local (HRPT) and global data output formats are not always the same (e.g. AVHRR METOP). This makes it difficult for users of Level 1 and Level 2 data from HRPT and Global systems to interface with these data. Also the archive format may be different from the near-real time dissemination format.

Recommendation SSSP-1 to space agencies and direct readout package developers

Future NPP, METOP, FY-3 and NPOESS programs should provide data and products in a standard reference format. If not, then global centres should provide an interface routine (i.e., in FORTRAN and/or C languages which converts the data into a reference format such as HDF and/or BUFR). Local packages for direct readout should also use these formats or provide an appropriate interface similar to the global centres.

Action SSSP-2

SSSP Co-Chairs to forward these recommendations to space agencies and identified direct readout package developers.

2.6.4 Access to near-time simulated IASI data

The capability to get near-time simulated IASI data from national agencies (NOAA, EUMETSAT) through an automatic routine (CRONTAB) and for a selected area is important for the preparation and operational availability of local, direct readout processing packages.

Recommendation SSSP-2 to NOAA and EUMETSAT

Make available simulated IASI measurements (from NWP) in a routine manner, for example through ftp, to facilitate ITWG user access. It is recommended that such data be archived and accessible through interfaces to define time period and if possible geographic windows (i.e., similar as for ECMWF archived data) to help manage the high volume of these data.

Action SSSP-3

SSSP Co-Chairs to forward this recommendation to NOAA and EUMETSAT.

2.6.5 Local and Global processing package coherence

The coherence between local and global processing packages is important for the simultaneous assimilation of both products in NWP systems.

Recommendation SSSP-3 to space agencies

When defining their global processing systems, space agencies (EUMETSAT, NOAA) should consider the portability and availability of their software on standard platforms (e.g. Linux PCs). This would facilitate comparisons of local and global processed data that would be mutually beneficial to data providers and users alike. These comparisons should be routinely conducted by identified centres (e.g. NWP-SAF), and results made available to all users (i.e., via the SSSP Web site).

Action SSSP-4

SSSP Co-Chairs to forward these recommendations to space agencies and direct readout package developers.

2.6.6 Cross validation

Opportunities for the cross validation among existing (and past?) satellite products and sensors exists, across operational and research communities. Coordination is needed to compile baseline datasets and protocols for providing such information from respective platforms and programs including, as available, in conjunction with evolving standardized upper-air reference programs for climate. Existing activities at NOAA-NESDIS to define protocols for compiling real-time collocations of satellite sensor and product data from ATOVS, AIRS and GOES with global radiosonde observations are recognized as a good starting point. Validation results from such efforts will be reported in a designated "Validation" topic area of the SSSP Web site.

Action SSSP-5

Hal Woolf/A. Reale to include some "global" ATOVS products from IAPP (available from CIMSS) in the cross-validation studies.

2.6.7 Standardized, multi-platform software for historical TOVS 1b data

The need for standardized software (on multiple computer platforms) to read historical TOVS 1b-level datasets that are executable on a variety of computer platforms is needed. There is also a need for the recovery and documentation of available metadata records with respect to TOVS concerning, format

(i.e., 1b-level) changes, calibration and offsets, systematic bias, etc.

Action SSSP-6

The SSSP Co-Chairs shall forward these concerns to appropriate NOAA agencies in an effort to locate sources of information and software concerning the status of available meta-data and processing software for 1b-level TOVS from 1979-2001.

2.6.8 GPS RO + ATOVS

Studies on combining GPS radio occultation (RO) and ATOVS radiometric measurements showed that the combination yields improved tropospheric temperature and moisture profiles over those inferred from either system alone. Currently three GPS receiver satellites operate and in the near future a 6 GPS satellite configuration (COSMIC) will be launched.

Action SSSP-7

Eva Borbas to provide information on the SSSP Web site under agency planning for RO-GPS. Specifically provide links to respective programs (NASA, UCAR, EUMETSAT) with respect to GPS data, and associated sites where such data and software (i.e., SAF GRAS) are available.

2.6.9 SSSP agency survey

Inputs from Agency surveys concerning the status for current and future satellites, data distribution and plans are not yet complete.

Action SSSP-8

SSSP Co-Chairs to identify contact points for agencies from China and Russia, contact them, gather information and include them on the SSSP Web site.

2.6.10 Scientific Product inputs on SSSP Web site

Inputs for scientific products as reported on SSSP Web site have in some cases not been updated (for several years) and new inputs are requested from those who have not yet registered their work.

Action SSSP-9

SSSP Co-Chairs and their collaborators will write a letter requesting that information on the SSSP Web site be updated and maintained. They will also solicit new inputs (including from non-ITWG members).

2.6.11 SSSP Web site upgrade

The SSSP Web site has undergone a significant upgrade over the past 18 months and now includes the original topic area of product reports, and new areas describing agency plans, HRPT sites and data distribution (EARS), sources of global satellite data, helpful ancillary data sources (i.e. topography atlas), and operational and research instrument status and metadata. We recognize the tremendous support of our WG members and in particular from CIMSS and Ms Leanne Avila.

Action SSSP-10

The site needs to be reviewed by ITWG members with suggestions, recommendations and in particular areas of concern provided to the SSSP Co-Chairs.