

## 2. WORKING GROUP REPORTS

### 2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Web site: [cimss.ssec.wisc.edu/itwg/groups/rtwg/rtwg.html](http://cimss.ssec.wisc.edu/itwg/groups/rtwg/rtwg.html)

Working Group members: R. Saunders (Co-Chair), L. Garand (Co-Chair) with F. Weng, M. Matricardi, P. Brunel, T. Kleespies, L. McMillin, J. Li, N. Jacquinet-Husson, D.S. Turner, V. Sherlock, G. Deblonde, C. Köpken, J. Grove-Rasmussen, H. Woolf, J-L. Moncet, M. Vesperini, C. Crevoisier, P. Schlüssel, D. Klaes, Y. Han, E. Weisz, M. Schwaerz, X. Wu, A. Uspensky, R. Knuteson, P. Wang, A. Dybbroe, A. Collard, T. Auligné, M. Szczech-Gajewska, D. Anselmo, L. Strow (provided inputs during ITSC-XIII).

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

#### 2.1.1 Atmospheric profile datasets for Radiative Transfer

Radiative transfer (RT) models require a dataset of diverse profiles for training and independent validation. The group is actively using various profiles datasets whose characteristics are summarised in Table 2.1-1. A Fortran 90 code for interpolating a profile from one level to another and extrapolation above the top level has been provided to the group as an action from the last meeting. One of the developments since ITSC-XII has been the use of NWP model based profile datasets that have a more consistent treatment of humidity in the upper troposphere and lower stratosphere.

#### Action

**Roger Saunders to post profile interpolation code on ITWG-RTWG Web page.**

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

Diverse Profile dataset	Number of Profiles	Number of Levels	Contact point/Web page
TIGR v3 radiosonde set	2311	40L	Raymond Armante/LMD Marco Matricardi, ECMWF
Sub set from v2	43	43L	
ECMWF 60L model set	13495	60L	<a href="http://www.metoffice.com/research/interproj/nwpsaf/rtm/">http://www.metoffice.com/research/interproj/nwpsaf/rtm/</a>
Sub set	52	101L	
ECMWF 50L model set	13766	50L	Scott Hannon, UMBC Hal Woolf, CIMSS
Sub set	117	43L	
UMBC set <sup>1</sup>	49	101L	Scott Hannon, UMBC Hal Woolf, CIMSS
	49	42L	
NOAA-88	8005	40L	Larry McMillin, NESDIS
Sub set	32	40L	
CIMSS	32	40/42/101 L	Hal Woolf, CIMSS
CIMSS Ozone	380	40L	Hal Woolf, CIMSS M. Matricardi for 43L
Sub set	34	40L/43L	
Trace Gases CH <sub>4</sub> , CO, N <sub>2</sub> O, CO <sub>2</sub>	43	90L	Marco Matricardi, ECMWF

<sup>1</sup>One profile in the upper levels in the UMBC set has stratospheric temperatures that are too cold.

Recent developments include a consideration of the units conversion for water vapour. A report on this is available on request from Peter Rayer (peter.rayer@metoffice.com) at the Met Office.

**Action**

**Roger Saunders to put trace gas profiles on ITWG-RTWG Web site.**

**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:

- ATOVS filter responses for NOAA-N due for launch in September 2004.

**Action**

**Tom Kleespies to inform ITWG before NOAA-N launch.**

- MTSAT IR channel characteristics are available from Jeff Puschell (Raytheon) subject to approval by JMA.
- AMSR-E Paul Van Delst (NCEP) has the channel responses.
- SSMIS channel characteristics are available. S/N02 is the sensor in orbit.

**Action**

**Tom Kleespies to provide SSMIS channel characteristics.**

- WINDSAT channel characteristics are required.

**Action**

**Tom Kleespies to obtain and provide WINDSAT measured channel responses.**

**2.1.3 Line by Line (LbL) model status**

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

- **GENLN2**: No new developments were reported. **RFM** is a faster more user friendly version of GENLN2 available from Oxford University.
- **kCARTA** has been updated based on AIRS validation. Code available on UMBC Web site. (contact is Larrabee Strow at UMBC email: strow@umbc.edu).
- **LBLRTM**: A new version 8.2 is now available from AER Web site at <http://rtweb.aer.com>
- **4A** in its operational version is now distributed by NOVELTIS but is still free for research groups. It uses GEISA-2001 at <http://ara.lmd.polytechnique.fr>
- **$\sigma$ -IASI** is available from EUMETSAT based on LBLRTM but optimised for IASI.
- **Hartcode** from R. Rizzi/F. Miskolczi
- **FLBL** from Shawn Turner (MSC) for research in MSC and used to train MSCFAST.

**Recommendation**

**Infrared line by line models can now be validated using AIRS data with collocated profiles for a wide range of atmospheric situations. Model developers should be encouraged to update their models and/or spectroscopic databases in the light of this new dataset.**

For microwave LbL models:

- **MONORTM** is a simplified version of LBLRTM for the microwave and can be obtained from the same Web site as LBLRTM.
- **MPM 89/92** continues to be used by many groups (i.e., basis for RTTOV and OPTRAN)
- **Rosenkranz** model last updated in 2002.

- **ATM** from Juan Pardo.
- **STRANSAC** from LMD.
- **ARTS** a model developed at Bremen University which is being extended to cover the infrared. A poster was presented on ARTS.

#### 2.1.4 Assessment of spectroscopic databases

The performance of the new generation of high spectral resolution atmospheric sounders (e.g., AIRS, CrIS and IASI) is dependent upon the quality of the spectroscopic parameters of the active gases since these are used as input to the LbL models. The latest official releases for spectroscopic parameters are GEISA-2003 and HITRAN-2000+ and there is code available to convert from GEISA into HITRAN format. It was noted that there are plans to change the format of HITRAN in the future. A warning about the treatment of CFCs in HITRAN was discussed where all the negative absorption values have been suppressed. Nicole Jacquinet-Husson (LMD) reported on the draft of a 'road map' for the HITRAN and GEISA databases.

##### Action

**Nicole Jacquinet-Husson to send Roger Saunders copy of 'road map' document for distribution to the group.**

LMD has also continued support for the aerosol dataset for IASI.

The role of this group to help provide information through the Web site of useful validation datasets (e.g., ground based, airborne, satellite) was proposed.

##### Action

**All members of the group to send information on validation datasets to RTWG Co-Chairs for posting on the ITWG-RTWG Web site on a new validation page.**

#### 2.1.5 Fast RT models

The working group noted the continuing progress on fast RT models, especially for simulating AIRS data. The group reviewed the status of fast models:

**OPTRAN:** Version 6 is available and is the operational code. Version 7 uses a corrected transmittance term in place of the effective transmittances. Version 8 is under development and uses a polynomial fit to represent the coefficients along the absorber path. The point of contact is Yong Han (NESDIS). Plans are to merge versions 7 and 8 and to use it for cloudy radiance simulations. Other plans include additional variable gases. Papers on OPTRAN have been submitted to Applied Optics.

**RTTOV:** Version 7.1 is the latest version. Version 8 will be released in Feb 2004 and the paper in the proceedings by Saunders *et. al.* gives more details. Users were reminded to feedback any problems to rttov.nwpsaf@metoffice.com. RTTOV-71 can simulate cloudy radiances.

**GASTROPOD:** An AIRS fast model based on kCARTA. This is an open source project and code can be downloaded from gastro.sourceforge.net. Regression coefficients for pre-launch and the latest post-launch AIRS ISRF are available.

**OSS:** The code is working for AIRS, CrIS, NAST-I, AMSU and CMIS. The training on LBLRTM and possibly kCARTA will be redone to include the CFCs. Cloudy radiance simulation is planned. The code may be available on request to Jean-Luc Moncet (AER).

**MSCFAST:** The code is being used at Met. Service Canada for GOES radiance assimilation. It also

supports AIRS, but currently only the 324 channel subset.

**LMD fast models:** A Neural Net model has been developed for AIRS and IASI simulations. A Jacobian model has also been developed for AIRS. A poster on the LMD fast models was presented at the conference. In addition, the 3R and 3R-NN models from LMD have demonstrated their capability in simulating TOVS channels (Chédin *et al.* JQSRT, **77**, 2003).

**SARTA:** AIRS fast RT model from UMBC based on kCARTA.

**PLOD/PFAAST:** Hal Woolf has developed code for HIRS, MODIS, GOES and other IR sensors. It is trained on the UMBC 48 profiles with LBLRTM. Plans are to update with cleaned up training set and latest version of LBLRTM.

**RTIASI:** Fast RT model for simulating IASI radiances. Version 4 is available from EUMETSAT with variable trace gases and reflected solar radiation. Version 5 will be released in June 2005 with scattering, aerosols and clouds.

### **Issues for fast models**

- Trace gases

Fast models are now beginning to have the capability to treat trace gases as variable in the same way as water vapour and ozone have been in the past. This allows for retrieval of trace gas concentrations. However a trace gas climatology is still required for retrievals which require a climatological first guess. The models should have the ability not to compute trace gas transmittances if they are not required.

- Number of levels and predictors

Increasing the number of layers for fast models may be required for advanced sounders but it also slows the model run times for ATOVS. Fast models need to be flexible to allow different number of levels for different sensors as required. Increasing the number of predictors for higher accuracies needs to be balanced against the increased model run times. It was thought 40-50 levels is enough for ATOVS but ~90 levels may be needed for AIRS simulations.

- Broad channels

Broadband channels can be difficult to simulate with fast models as one central frequency is not a good approximation for the whole channel. Planck weighted transmittances have been used in the past (e.g., Weinreb and Hill, *NOAA Technical Report NESS 80*, 1980) with some success and more recently with RTTOV (see poster at ITSC-XIII by Pascal Brunel and Shawn Turner). Also a Planck function correction which uses the central frequency as a free parameter rather than setting it to the mean value can extend the range over the usual 2 parameter (band correction factors) solution.

- Model diagnostics

Several users asked for the option to be able to output profile layer mean quantities which were used in the regression. Outputting the various emission terms (surface, upwelling, and downwelling) was also requested.

- Fast model testing for Tangent Linear and Adjoint codes.

This is an area where it was felt some guidance to the users is required. Both Tom Kleespies and Paul van Delst have some lecture notes on TL/AD testing. They made the point each module should be tested individually. Vanessa Sherlock noted inner products could be used to test tangent linear and adjoint codes.

### **Action**

**Tom Kleespies and Roger Saunders to collect notes on this topic and post a summary on**

the ITWG-RTWG Web site.

## 2.1.6 AIRS RT model comparison

At the workshop for Soundings from High Spectral Resolution Observations in May 2003, an AIRS radiative transfer model comparison was proposed and Roger Saunders is now coordinating this activity under the auspices of the ITWG. Results from 9 models have already been submitted and about 15 participants have indicated they will provide results. An initial analysis of the differences was presented as a poster at ITSC-XIII. It was emphasised the importance of having results from the LbL model dependent set for each of the fast models so that the difference between the LbL models can be excluded from the analysis. Error correlations from the model differences were also requested to be documented in the results. Larabee Strow offered to provide profiles from the ARM W. Pacific site, together with AIRS data to provide a comparison between the models and measurements. The method of Louis Garand will be adopted to assess the Jacobian differences. A reference Jacobian will have to be selected which could be the dependent set, where possible, for each fast model. It was agreed any comparison of model run times (e.g., for 1000 profiles) would only be approximate but it was felt this was still useful information. To summarise the aim of the first phase is:

- 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.
- To estimate model error covariances.
- Assess the Jacobians from each model using the Garand measure of fit for a limited selection of channels.
- Document the time taken to run each model.

The plan is to have all the results submitted by January 2004 and provide a report by April 2004. The results would be posted on the RTWG Web site at:  
<http://cimss.ssec.wisc.edu/itwg/groups/rtwg/rtairs.html>

As a second phase it was suggested to provide a line by line transmittance dataset to all participants for training so the uncertainties due to the different profiles and spectroscopy could be eliminated. However data volumes may make this difficult to achieve at least for all the AIRS channels. It was also suggested to do studies on the impacts on AIRS retrievals of the RT model errors derived from phase one. Vanessa Sherlock will address this by assessing how the RT errors feed through to the retrievals using a 1D-Var code. The response of the models to surface emissivity was also a parameter of interest which may be added.

### Recommendation

**All AIRS RT modellers should be encouraged to participate in the AIRS RT model comparison to assist in the estimation of forward model error covariances.**

### Action

**Roger Saunders to obtain profiles and AIRS data from Larrabee Strow and provide to modellers.**

## 2.1.7 Surface property models

### 2.1.7.1 Microwave emissivity

#### *Ocean surface*

FASTEM-2 is being updated by Stephen English (Met Office) to improve the simulations and add a polarimetric capability so all 4 components of the Stokes vector are computed. It will be released as part of RTTOV-8.

NRL is developing a polarimetric model for WINDSAT.

Paul Chang at NESDIS is preparing a field campaign during 2004 to make microwave sea surface measurements at high wind speeds to validate the models.

#### *Land surface*

A new snow model by Fuzhong Weng (NESDIS) will soon be tested on AMSU channels. Stephen English presented results showing that data assimilation trials using the microwave surface emissivity atlas had not been successful suggesting an implicit retrieval of surface emissivity might be more successful.

#### **2.1.7.2 Infrared emissivity**

##### *Ocean surface*

The sea surface emissivity model from Wu and Smith (*Applied Optics*, **36**, 1997) is now being used for developing fast IR surface emissivity models (e.g., at NCEP) due to the more complex treatment for larger viewing angles and higher wind speeds although their results agree with Masuda et. al. for normal wind speeds and close to nadir view angles.

For RTIASI an alternative to the Cox and Munk slope variance for the ocean surface has been developed using a surface wave model in an attempt to provide more realistic computations of reflected downwelling radiation. This allows the emissivity model to be initialised by a wave model in an NWP system. Shaw and Churnside (*Applied Optics*, **36**, 1997) have published measured statistics of sea-surface slope. In the era of advanced sounders it would be worth updating the IR sea surface emissivity models with newer datasets.

##### *Land surface*

Several talks were presented during the conference on this topic. There are now several MODIS atlases of land surface emissivity and in a few years there will be global atlases of surface emissivity in all the AIRS window channels. Retrievals of surface emissivity have been demonstrated from AIRS over the ARM Oklahoma site. There is a University of Washington study making measurements over snow. The current efforts in NWP centres to use more IR radiances over land should encourage more research into land surface emissivity.

#### **2.1.8 Review of group Web page**

The Web pages will be updated to include the new information provided during ITSC-XIII.

#### **Action**

**Co-Chairs to update Web pages and ITWG-RTWG to propose additions and improvements.**

## 2.2 TOVS/ATOVS DATA IN CLIMATE

*Working Group members: P. Thorne (acting Co-Chair) with T. Achtor, S. Ackerman, G. Aumann, P. Ciren, E. Fishbein, L. Horrocks, M. McCarthy, C. Mears, G. Rädcl, B. Rossow, S. Serrar, L. Zhou, [in absentia: M. Goldberg, G. Kelly, T. Reale]*

### 2.2.1 Introduction

Weather satellites can be useful for climate monitoring purposes and, as an example satellite climate datasets from MSU have been used in a number of recent papers, including two in *Science*. However, recent developments in our understanding of the MSU calibration have highlighted the requirement for caution in interpretation of satellite climate records, and for Global Climate Observing System (GCOS) climate monitoring principles to be adhered to. Satellites will always require a degree of surface and satellite based validation, and this could and should be better optimised and targeted in space and time. The relative cost of such a program is small and the potential benefits significant for climate applications. TOVS data continue to be used in reanalysis products and provide very useful information, particularly over otherwise data-sparse ocean and high latitude regions.

NOAA NESDIS has recently published a white paper relating to future plans for its polar orbiting satellites under the Climate Change Science Program. This Paper is available for comment on the ITWG Web site. Mitch Goldberg can provide further details regarding the review process. The working group broadly supports this paper which builds on recommendations from previous ITSC meetings and external bodies such as GCOS. However, the WG believes that the paper could be improved in certain respects. Individual members of the Working Group (and ITWG more generally) can make comments on different aspects of the white paper. Feedback from this group on the white paper is welcomed. In particular there was concern voiced that the definition of “Climate Data Record” within the white paper was not specific enough. We hope to pool together the feedback from this group via Mitch Goldberg and John Bates as we feel that feedback as a group would be more powerful than as individuals.

#### Recommendation

**We recommend that ITWG broadly supports the white paper.**

#### Action

**The NOAA NESDIS white paper is available on the ITWG Web site. All members of the Climate Working Group (and other interested parties) should provide feedback and comments on the white paper to Mitch Goldberg and John Bates.**

#### Action

**Mitch Goldberg and John Bates to provide summary of responses and report back via the ITWG email list.**

Rather than repeat the ground covered by the white paper, we have chosen to concentrate on other work not explicit in it for the remainder of this WG report. Furthermore we concentrate entirely on applications from the (A)TOVS MSU and HIRS sounders as these are the areas of group expertise.

### 2.2.2 Recent advances in the use of TOVS / ATOVS data in climate studies

Since ITSC-XII a number of peer-reviewed climate datasets have been constructed and / or documented:

- 2 new realisations of the long-term (A)MSU tropospheric record from Channel (5)2 and an update to the previously published version.
- A HIRS based CO<sub>2</sub> dataset.
- Potential new datasets and transfer capability from AIRS.

MSU, HIRS UTH, and SST datasets continue to be widely used in climate research applications. The MSU record is being used to try to help evaluate the causes of recently observed changes in the vertical structure of atmospheric temperatures. This is an important topic in climate change studies and MSU data have the potential to contribute to understanding physical processes. In particular, the MSU record is truly global in coverage whereas available radiosonde data are primarily a Northern Hemisphere continental record. The change in frequency of channel 12 on HIRS with the ATOVS platform instrumentation means that the UTH product has been discontinued from 1998 onwards.

Work also continues to be undertaken by investigators in the WG to prepare other climate-quality satellite datasets.

### 2.2.3 Issues related to long-term homogeneity

Ensuring long-term homogeneity in satellite datasets is essential for climate studies, and the group noted lessons learned from a number of instruments (HIRS, CERES). In this report we use the example of MSU to highlight some of the key issues, which are generic to all satellite instruments if they are to be useful in climate research.

Discrepancies between three independently produced MSU datasets (Christy *et al. J. Atmos. and Oceanic. Tech.* **20** 613-629, 2003; Mears *et al. J. Clim.* **16** 3650-3664, 2003; Vinnikov and Grody, *Science* **302**, 269-272, 2003) have raised serious concerns regarding long-term homogeneity of satellite-based climate records. Pessimistically, they can imply that satellite data may not be useful for climate change studies at all (although they are useful for climate variability) as in terms of global-mean trends these three datasets do not overlap within their respective published uncertainty estimates. Alternatively, one or more of the datasets might be physically unrealistic. Each group has tried to minimise errors associated with satellite platform changes, diurnal drift etc. Although the likely sources of non-climatic noise in the MSU measurements are generally agreed upon, the groups undertake very different approaches to correct for these. In the absence of an agreed transfer standard it is difficult to conclude unambiguously which approach is more likely to be correct. Tony Reale presented in the climate session a potential radiosonde baseline network (SUAN). An agreed transfer standard should be put in place for future reference to reduce uncertainty in the size and pattern of non-climatic effects for both MSU and other satellite datasets. SUAN would provide such a standard at relatively small cost and have potential benefits operationally as well as for climate monitoring. However efforts should explicitly be made to minimise the impact on records from long-term stations, especially from the GUAN (150 stations) and Lanzante *et al.* (87 stations) datasets, which can provide a complimentary viewpoint and extend back further than the satellite period.

#### Action

**Tony Reale to pursue SUAN funding and agreement through relevant bodies (NOAA, NASA, WMO, GCOS etc.). This needs to be effectively targeted which will require research and further collaboration with interested parties before being presented.**

Key in establishing and maintaining a climate data record using spaceborne sensors is the regular intercomparison between the sensors on different satellites in a statistically representative sample of global positions. An inter-calibration satellite (ICS) in a medium earth orbit (MEO) at 10,000 Km altitude can be useful in supporting this requirement, when equipped with suitable high spatial and spectral resolution VIS, IR and MW radiometers. The MEO concept is being evaluated at NASA and NOAA. Having two independent sources of calibration for polar orbiters (ground based SUAN and a suitable MEO) would greatly enhance our understanding of non-climatic noise characteristics in their products. An additional benefit of such a MEO instrument would be the accurate characterization of the diurnal cycle in the IR and MW. The diurnal cycle is currently not well-represented in polar satellite and radiosonde observations, due primarily to coarse spatial/temporal sampling, or in NWP/climate models.

**Recommendation**

**ITWG encourages an inter-calibration sensor to be considered for the first medium earth orbit evaluation payload.**

It has been found that most of the discrepancy in trends between the MSU time series relates to a single platform - NOAA-9 and the treatment of its overlap periods, particularly that with NOAA-6. The periods of overlap are very short and so the choice of an inter-satellite bias correction approach has a disproportionately large effect. Carl Mears' analysis shows that this single satellite's transitions account for approximately half of the long-term trend difference between two of the datasets. This highlights the importance of future satellite missions adhering to the GCOS observing system principles as articulated in the white paper and elsewhere.

Future planned NOAA platforms will be different from the (A)TOVS systems. There will be a critical need to maintain backward compatibility with existing records to ensure continuity in climate data records. New instruments should explicitly demonstrate that they maintain this backward compatibility. Climate monitoring considerations should be borne in mind whenever instruments are modified or replaced. There is a climate requirement for a cross-track MW scanner with the same channels as AMSU going forward into the future. Similarly, HIRS channel 12 frequency should be returned to the original specification - allowing for a continuation of the UTH series, albeit with an undesirable break of several years. Alternatively such a channel should be reconstituted from high resolution sounder data. The combination of AMSU and HIRS can provide information on changes to the hydrological cycle, an area of uncertainty in climate model predictions. If climate models can be shown to capture observed changes in the hydrological cycle, then we will have greatly increased confidence in their projections of future climate change.

**Recommendation**

**ITWG should promote the GCOS observing principles to satellite agencies.**

**Recommendation**

**When changing instrumentation satellite agencies should try and ensure that the new sensor has backward compatibility to ensure long-term climate monitoring can continue.**

The effect of uncertainties in the MSU dataset is important as the choice of climate data record version can fundamentally affect our understanding of climate change. We need to understand the true evolution of the MSU time series and the reasons for discrepancies between the current versions. This is likely to provide lessons for other satellite based climate record construction. The continuing uncertainty about the trend greatly reduces confidence of the climate community in the veracity and value of satellite based climate records.

**Recommendation**

**ITWG members should help to resolve the observed MSU dataset trend discrepancy for the climate community by providing their expertise and guidance gleaned from other applications of MSU.**

There are a number of additional issues relating to long-term satellite dataset consistency which are likely to become increasingly important in the future for all TOVS products:

- Re-examination of calibration on long time-scales to identify and remove seasonal and interannual effects not evident in real-time quality control.
- Better metadata availability (addressed through CLASS - see white paper).
- More complete sampling of the diurnal cycle.

A major consideration regarding sampling of the diurnal cycle is the choice of equator crossing times for future polar-orbiters. If at all possible, consistency of crossing times both in-orbit, and with previous

platforms would be advantageous. NOAA plans for NPOESS have specified crossing times of 1030, 1330, and 1730LT.

**Action**

**Evan Fishbein and Carl Mears to assess the optimal choice of equator crossing times for climate applications and report back to ITWG.**

**2.2.4 Reanalysis datasets**

ECMWF have recently completed a new ERA-40 reanalysis product that has directly assimilated radiances from (A)TOVS. Initial analysis and comparison with observed ground-based and satellite datasets suggests that this is an improvement over the previous much shorter ERA-15 product, both at the surface and aloft. The reanalysis provides us with tools to assess satellite climate datasets. However, the timing of model stream start dates has been unfortunate with regard to the NOAA-9 MSU problem. A stream started in 1987 when only NOAA-9 data were available shows an initial 0.5K warm bias in its MSU2 brightness temperature.

**Recommendation**

**ITWG to ask ECMWF to try rerunning a 2-year segment from early 1986 to remove the early NOAA-9 platform warm bias and allow potential analysis of true NOAA-9 platform bias in MSU2.**

With each generation of reanalysis, lessons are learned which increase the physical realism of the next generation product. However, there is little money currently available to either ECMWF or NCEP to undertake such work. Continued development of high quality reanalyses may be useful in guiding choices required in homogenising long-term satellite records (and surface based records) to construct climate quality datasets.

**Recommendation**

**ITWG should reaffirm to funding bodies the potential benefits of new high quality reanalysis products.**

**2.2.5 Relations to international climate programs and other bodies**

Individuals from within ITWG continue to interact with other groups and programs on an ad hoc basis. This collaboration is likely to increase in the coming years as satellite records are better exploited by both the satellite and climate communities.

Mitch Goldberg has received a formal request from AOPC (WMO Atmospheric Observation Panel for Climate) for information as to what the key IR and MW frequencies are which need to be maintained for continuity. There were no members of the group who felt qualified to address this at the meeting.

**Action**

**ITWG climate group to form a sub-group to discuss this issue and report back.**

Given plans for polar orbiting satellites from agencies other than NOAA/NASA/EUMETSAT, it is felt that it would be useful to place AMSU and HIRS sensors on some of these platforms. This would permit a better characterisation of the diurnal cycle and more robust coverage.

**Recommendation**

**ITWG to promote using standardised sensors on non-NOAA platforms as a way to increase spatial and temporal coverage for climate records.**

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

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### **2.3.1 Introduction**

There were many substantive presentations at this meeting that indicated very positive results using satellite data from different instruments. There continues to be a move towards the use of level 1b sounder and imager radiances. Observing System Experiments (OSEs) presented at this meeting demonstrate that satellite data have 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 currently produce most of the impact. More centres that were previously using processed level-1d radiances have now started to use raw level-1b radiances with very positive results.

At this meeting, first impact experiments of high spectral resolution instruments (i.e., AIRS) were shown. As expected by NWP centres, the conservative use of these has produced at best small positive impact. However, in the development of the systems to assimilate these data, many innovative improvements at the various centres have been introduced. These improvements have positioned the centres to begin experimentation on additional improvements directed towards extracting more information from the high resolution data.

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 now assimilated at a majority of NWP centres and with reports of various levels of positive impacts particularly on the moisture fields and precipitation. At the last ITWG meeting, the AMSU-B data were only assimilated operationally at a few centres with experimental use of AMSU-B data at several others. This widespread use of the AMSU-B data is representative of the general increase in the use of satellite radiance data among the various centres.

The use of satellite radiances in Limited Area Models continues to progress and some groups have now successfully implemented the use of radiances with similar results as observed in global systems. 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 Data Assimilation/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.

**Recommendation (to DA/NWP Centres)**

**The Working Group recommends the continued exchange of monitoring results and encourages each centre to develop their own Web page to post their results. A master document linking all Web pages has been developed and linked on the NWP SAF site and a similar link will be set on the ITWG Web site to enable easy examination and comparison of results between groups. Centres are encouraged to share pre-submitted papers and any valuable material on the following topics:**

- 1. Bias correction procedures for regional and global systems**
- 2. Scan-dependent biases**
- 3. Thinning procedures for regional and global systems**
- 4. Background error correlation and variance studies**
- 5. Mesoscale verifications**

**Action**

**C. Chouinard will coordinate the development of the NWP Web page until June 2004 after which S. English will take responsibility.**

The Working Group further recognizes the importance of day-to-day monitoring procedures in rapidly identifying problems related to the data particularly when they originate from instrument problems and there is need to intervene quickly.

**Recommendation (to DA/NWP Centres)**

**That an e-mail list be set up and used to quickly alert each other of potential problems and their severity so actions can be taken in a timely manner. (Action: J. Derber to setup the e-mail list) Note: this e-mail list is intended as an informal exchange between NWP centres not a formal communication with data providers. The original list is made up of NWP WG members but will likely be extended to others.**

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

**Recommendation (to DA/NWP Centres)**

**The Group recognizes the difficulty in implementing and validating radiance/retrieval data in a DA/NWP system and recommends that those that have prepared so-called single observation experiments in the development of their assimilation system post them on their Web page with sufficient details on the Web site for another to replicate these independently.**

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

agencies. Some centres have presented recent OSEs at this meeting with their systems and continue to update these when their analysis systems undergo critical updates.

**Recommendation (to DA/NWP Centres)**

**Encourage the production of OSEs at various NWP centres to be presented at the next meeting and most importantly post these results on the ITWG Web site.**

The results of the ITWG survey presented at this meeting and reproduced in 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.

**Recommendation (to ITSC)**

**The Group recommends that the McNally survey summary grid be continued and posted on the ITWG Web site. When changes are made at various NWP centres on the use of data, that McNally be advised, the grid updated accordingly, and the changes be logged on the ITWG Web site. The WG noted that the table and survey should be expanded and include more information on how the data are prepared and used at various centres. This would be reflected by a more complete summary with additional columns and/or notes. (Action: T. McNally to coordinate).**

The results of the survey indicate that the majority of DA/ NWP centres still rely upon processed level-1b and level-1d data and retrieved products for their operational forecasting systems. The Group wishes to acknowledge this fact and support the continuing efforts of NOAA/NESDIS and EUMETSAT in their crucial role in providing these products. This inter-agency collaboration has been very beneficial. The WG wants to commend the progress at NESDIS in change notification and monitoring of the data and the recent detection of the problems with NOAA-17.

**Recommendation (to NOAA/NESDIS and EUMETSAT)**

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

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.

**Recommendation**

**To document, evaluate and improve the current procedures to convert antenna temperatures to brightness temperatures. (NESDIS and DoD)**

**Action**

**To collect documentation of the current status of antenna correction procedures for current microwave instruments from DoD, NESDIS, EUMETSAT and NASA and present at next ITSC meeting. (G. Deblonde)**

**Table 2.3-1. Use of satellite data in operational NWP (ITWG survey of systems at 01 / 09 / 2003)**

Institute	Retrievals in Global NWP	Retrievals in Regional NWP	Radiances in Global NWP	Radiances in Regional NWP	external WWW DATA MON
<i>Australia</i>			YES-NP (1DVAR)	YES-NP (1DVAR)	NO
<i>Canada</i>	NESDIS (ensemble)		YES-1B (3DVAR)	YES-1B (3DVAR)	YES
<i>ECMWF</i>			YES-1B (4DVAR)		YES
<i>France</i>			YES-1B (4DVAR)		NO
<i>Germany</i>	NESDIS				NO
<i>India</i>	NESDIS				NO
<i>Japan</i>		NESDIS + LOCAL	YES-NP (3DVAR)		NO
<i>Denmark</i>				YES-1B (3DVAR)	NO
<i>UK</i>			YES-1B (3DVAR)	YES-1B (3DVAR)	YES
<i>USA (NCEP)</i>			YES-1B (3D SSI)	YES-1B (3D SSI)	YES
<i>USA (NRL)</i>	NESDIS	NESDIS			NO

*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.

2) Blacklisting of data results in 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 internal Web services, but many are still not posted on the external (WWW) Web.

4) The ITWG needs to decide what to do with (i.e., how to document) the (sometimes very comprehensive) responses from each NWP centre. (e.g., upload to Web site?). They are a valuable reference for users.

**2.3.3 Forward modelling**

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

different RT codes in NWP models for different satellites is a serious maintenance issue.

**Recommendation**

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

**2.3.4 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 are 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 was reported at this meeting that the use of 3 polar satellites has been shown to provide better and more extensive cover of satellite radiances which increases the impact in NWP models. There was also a report on improvement with a fourth sounder on the Aqua platform.

**Recommendation**

**That satellite agencies and the WMO GOS WG consider 3xAMSU or equivalent in orthogonal orbits as minimum requirement to maximize global coverage for operational NWP.**

NWP Centres spend a large part of unproductive and duplicative effort on data formatting and management. The group is worried that rather than converging on the use of a single WMO standard format some agencies are proposing new data formats complicating the use of the data and unnecessarily increasing the cost of the development.

**Recommendation**

**That satellite agencies support the use of the WMO standard and produce data in a common format (e.g., BUFR). Also, the agencies should collaborate early and often on definitions and provisions of test data sets.**

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**

**That EARS be continued and where possible, extended to include more of NH and possibly SH.**

**Recommendation**

**The data providers should continue to strive to speed up delivery of data and eliminate blind orbits. (Action EUMETSAT, NESDIS)**

The use of research satellites in operational NWP centres has been increasing. The availability of these 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.

**Recommendation**

**Real-time access to the observations by NWP centres should be considered for all satellite observation programs which may be useful for NWP. (All satellite agencies)**

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 the NWP centres to begin early development of the infrastructure necessary to use the data.

**Recommendation**

**Both operational and research programs should develop collaborative efforts with NWP centres to evaluate the new data and allow the earliest possible access to the data for the NWP centres.**

The WG is concerned that the instrument specification for ATMS channel noise exceeds current AMSU performance.

**Recommendation (NOAA, EUMETSAT)**

**Specification for future instruments at least matches or improves upon the capabilities of current instruments.**

## 2.4 ADVANCED SOUNDERS

Working Group members: W. Smith (Co-Chair), A. Huang (Co-Chair) with T. Auligné, P. Antonelli, H. Bloom, D. Chao-hua, A. Collard, C. Crevoisier, D. Crain, R. Dedecker, E. Fishbein, A. Gasiewski, M. Goldberg, L. Horrocks, G. Kelly, D. Klaes, T. Kleespies, B. Knuteson, B. Lambrigtsen, A. Larar, J. Li, X. Liu, M. Matricardi, M. Pavolonis, J. Predina, J. Puschell, Y. Qu, F. Rabier, T. Reale, G. Rochard, F. Romero, H. Roquet, P. Schlüssel, M. Schwaerz, A. Sharma, V. Sherlock, D. Singh, A. Uspensky, E. Weisz, F. Weng, W. Wolf, H. Woolf, X. Wu, D. Zhou

### 2.4.1 Review of the scope of the Advanced Sounder Working Group

Meetings of the Advanced Sounder working group will focus on scientific issues affecting the optimal performance of advanced satellite sounder systems. The working group will review the status of the development of advanced sounder systems and recommend changes regarding to instrument specification, performance, data processing, and utilization where necessary. For the purpose of this working 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.

### 2.4.2 Status of plans for advanced sounding instruments

The working group noted the successful implementation of the first U.S. advanced Atmospheric Infrared Sounder (AIRS) and significant progress on the development of the IASI (Infra-red Atmospheric Sounding Interferometer), CrIS (Cross-track Infrared Sounder), IRFS-2 (Infra-Red Fourier transform Spectrometer), and the GIFTS (Geosynchronous Imaging Fourier Transform Spectrometer) advanced sounding instruments. Table 2.4-1 summarizes characteristics of these instruments, and Figure 2.4-1 summarizes their planned operating periods. The characteristics of these instruments are described in more detail on the ITWG Web site. The working group also noted progress on plans for advanced microwave sounders and their characteristics are listed on the ITWG Web site.

#### Action

**J. Eyre to update IR and MW sounder tables on ITWG Web site before ITSC-XIV.**

#### Action

**A. Huang to implement a Web page for the Advanced Sounders Working Group on the ITWG Web site.**

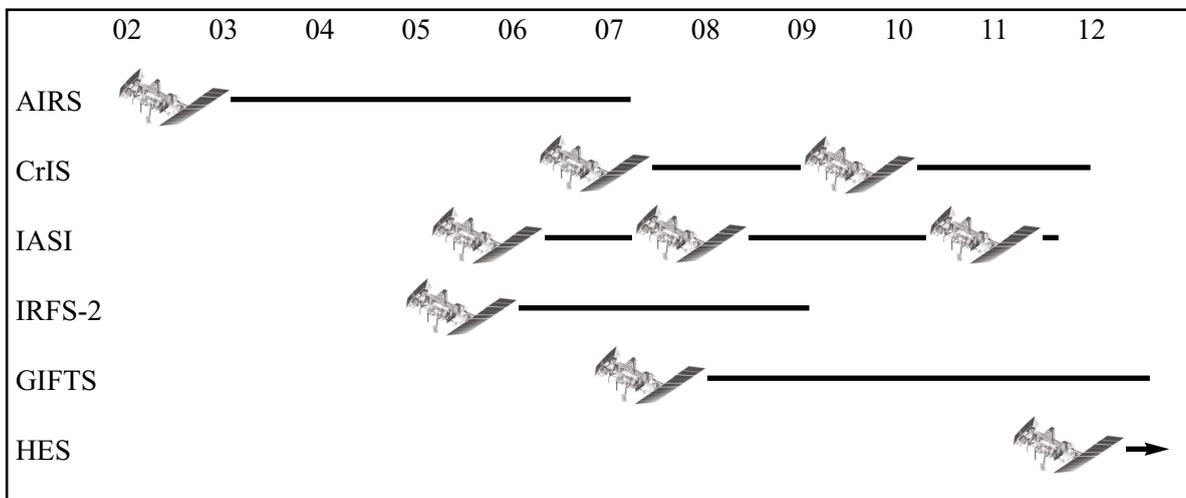


Figure 2.4-1. Current and Future Advanced IR Sounder Timeline.

Table 2.4-1. Advanced Infrared Sounding Instrument Characteristics

Name	IMG	AIRS	IASI	CrIS	IRFS-2	GIFTS	HES
Orbit (km)	800	705	833	824 (NPP) 828 (NPOESS)	850	Geo-synchronous	Geo-synchronous
Instrument	FTS	Grating	FTS	FTS	FTS	FTS	TBD
Agency and Producer	MITT JAROS	NASA JPL BAE	EUMETSAT/ CNES Alcatel	IPO (DoD/NOAA/ NASA), ITT	Russian Aviation & Space Agency	NASA/NOAA/ Navy Space Dynamics Lab (Utah St. U.)	NOAA/ NASA
Spectral range (cm <sup>-1</sup> )	700- 3000	649-1135 1217-1613 2169-2674	645-2760	650-1095 1210-1750 2155-2550	665-2000	685-1130 1650-2250	650-1200 1650-2150 or 1210-1740 2150-2250
Unapodized spectral resolution (cm <sup>-1</sup> )	0.05	0.5-2.25	0.35-0.5	0.625 1.25 2.5	0.6	0.6	0.6-2.5
Field of view (km)	10	13 x 7	12	14	35	4	4-10
Sampling density/50 km square	1	9	4	9	1	144	25-156
Power (W)	150	256	200	124	50	325	TBD
Mass (kg)	115	156	230	152	45-50	135	TBD
Platform	ADEOS -1	Aqua	METOP-1, 2,3	NPP and NPOESS C1	METEOR 3M N2	Geostationary	GOES R+
Launch date	1996	2002	2005	2006 for NPP 2009 for C1	2005	2008-2010	2013

### 2.4.3 New initiatives for geostationary sounding

The working group discussed developments since ITSC-XII in sensors for sounding of the atmosphere from geostationary orbit.

#### Recommendation (to Space Agencies)

**The ITWG recommends that system design simulations and other studies be completed for the purpose of identifying optimized performance/cost/risk/benefit approaches for candidate geostationary and MEO microwave sensors. This microwave system would supply data for temperature and moisture soundings and time-resolved precipitation mapping.**

### 2.4.4 The use of the NPOESS requirements change process

Recommendations for NPOESS requirements updates or changes can be facilitated through a U.S. Dept. of Defense (DOD) process. This process requires members to make a performance/cost/benefit presentation to the Joint Agency Requirements Group (JARG) which may be an interactive process. Users are then polled to determine if the proposed requirement change is beneficial to their respective agency. Once consensus is reached, JARG members from NOAA and DOD ask their respective agency

to fund the change. Once funding has been identified and the requirements approval by the JARG and the Senior Users Requirements Group (e.g., weather and oceanography service directors from agencies), the proposed change is handed to the NPOESS executive committee for approval. Once approved, the NPOESS IPO executes the change. Recommendations for NPOESS requirements changes or updates should use the above process, which for the ITWG can be facilitated by Mitch Goldberg, the NESDIS liaison to the JARG.

#### **Recommendation to ITWG**

**Any recommendation concerning NPP and NPOESS advanced sounding instruments' requirements change should use this process by presenting the relevant study results to the JARG through Mitch Goldberg.**

#### **2.4.5 Implementation of advanced sounders**

The working group discussed improvements which could be made to the CrIS instrument on NPOESS. Several recommendations are made below:

##### **Recommendation (to NPOESS Joint Agency Requirements Group (JARG))**

**ITWG recommends that the entire interferogram be sampled and transmitted to the ground for all three spectral bands of the NPOESS CrIS instrument. This will allow full spectral resolution to be achieved for the midwave and shortwave N<sub>2</sub>O/CO<sub>2</sub> bands as well as for the longwave bands. Full spectral resolution in all three bands is important for improving boundary layer temperature and upper tropospheric water vapor sounding as well as for extraction of trace gas profiles for climate data records. In addition the longwave extent of the shortwave band of the CrIS should be extended to include the 4.7 μm band of CO lines. Measurement of tropospheric CO is important for monitoring and forecasting air quality and for associated impacts to atmospheric chemistry climate.**

##### **Recommendation (to NPOESS Joint Agency Requirements Group (JARG))**

**ITWG recommends that the 0530LT and 1330LT NPOESS platforms retain full CrIS and ATMS measurement capability. These two satellites together with the 0930 METOP satellite will be able to provide 4-hour frequency high resolution soundings that are important for improved global weather predictions (see recommendation in 2.3.4 related to this).**

##### **Recommendation (to NASA)**

**ITWG recommends that the orbit of the NPP satellite be changed from 1030 to a time that better complements the 0930 orbit of the METOP satellite. This is important to improve the global sampling of high vertical resolution soundings for global weather prediction.**

Experience with AIRS data has revealed that 90% of the AIRS 15 km FOVs contain cloud which limits the accuracy and vertical resolution of tropospheric soundings. The proper combination of instantaneous FOV and radiometric sensitivity should be defined so as to optimize CrIS sounding performance for the most generally occurring partly cloudy scene condition. Specifically, FOVs with a linear dimension of 8 km, or smaller (as suggested by the Huang et al. study presented at ITSC-XIII) should be considered after investigation of the spatial sampling impacts of the smaller FOV sizes on the accuracy of the retrieval results.

##### **Recommendation (to NPOESS Joint Agency Requirements Group (JARG))**

**The Field-of-View size for CrIS should be redefined so as to optimize sounding performance under partly cloudy sky conditions.**

#### **2.4.6 Data processing, inversion and assimilation**

NOAA has started to make available some of the NPOESS documentation to selected members of the ITWG for review. This is to be welcomed. However, further documents for all sensors are still required. Several recommendations and actions given below were agreed during these discussions.

##### **Action (Hal Bloom)**

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

##### **Recommendation (to IPO and NPOESS Joint Agency Requirements Group (JARG))**

**ITWG recommends that the user communities be invited to assess and comment on the performance of NPOESS/NPP sensors and processing algorithms, especially calibration data and algorithms, in a timely fashion to enable suitable preparation for processing and interpretation of data from the flight mission.**

##### **Action (Allen Larar / Chair of SOAT)**

**Interact with the NPOESS IPO to facilitate a mechanism for ITWG members to obtain NPOESS ground processing and field terminal design parameters, including draft input data file formats, draft processing design documents, draft interface control documents and draft hardware specification documents through collaborations with the NPOESS SOAT.**

##### **Recommendation (to CGMS)**

**ITWG recommends that responsible agencies establish focal points to ensure that ingest and pre-processing code for future advanced sounders (and their complementary imagers) is provided, in a form suitable for use with locally-received direct read-out data, and yielding output consistent with globally processed data. Furthermore, activities are to be undertaken to integrate this code into processing packages available for international distribution in a timely manner.**

##### **Recommendation (to IPO and NASA)**

**ITWG recommends that ingest code for NPP instruments (CrIS, ATMS and VIIRS) be made available by IPO to the external scientific community, and that such algorithms should be integrated into a processing package for locally received data available for international distribution.**

#### **2.4.7 Characterization of spatial response**

The spatial responses of some sensor fields of view are still not being measured pre-launch to the required accuracy.

##### **Recommendation (to Space Agencies)**

**ITWG recommends that the spatial responses of advanced sounders should be characterized to a level at which the associated error does not cause the total noise budget of the instrument to be exceeded, and, where achievable at reasonable cost, to a level at which the associated error is a negligible contribution to the total system noise.**

#### **2.4.8 Validation of data and products**

To accelerate the full and early utilization of advanced sounders' data and products, validation of both data and products must be made as soon as possible. High quality global in-situ measurements are

required to help achieve this goal.

**Recommendation (to NOAA and NASA)**

**The Advanced Sounder working group strongly supports the Satellite Upper Air Network (SUAN) initiative proposed by the Satellite Sounder Science and Products working group (see action in 2.6.11).**

The SUAN effort will provide a large quantity of in-situ measurements early in the lives of these satellite missions, potentially shortening validation times and accelerating the utilization of validated data and products.

**2.4.9 Workshop for Soundings from High Spectral Resolution Sounders**

A 3-day workshop for soundings from High Spectral Resolution Sounders was recently hosted by ITWG members from University of Wisconsin-Madison and demonstrated useful scientific exchanges and established shared resources and knowledge that may enable the optimal processing and future utility of advanced sounding data. These more in-depth workshops than are possible during the ITSC meetings would aim to accelerate the use of, and optimize the information provided by, high spectral resolution measurements from advanced sounders. The workshops would actively seek to involve young scientists in the field.

**Recommendation (to ITWG)**

**The Advanced Sounders working group recommends that ITWG organize periodic Advanced Sounding workshops to be held independently of the main ITSC meetings and plans should be made to hold a workshop in Europe before ITSC-XIV.**

**2.4.10 Glossary of instruments**

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

## 2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

*Working Group members: G. Rochard (Acting Chair) with T. Achtor, E. Borbas, A. Dybbroe, G. Fournier, A. Gasiewski, D. Griersmith, D. Klaes, B. Lambriksen, T. Reale, R. Saunders, P. Schlüssel, D. Steenbergen and A. Uspensky (with additional inputs from D. Hinsman and J. Eyre after the meeting).*

### 2.5.1 Introduction

Working Group discussions included the following topics: data access and dissemination; timeliness of satellite data; software and documentation, equator crossing times; frequency protection; education, training and promotion; GPS/RO; and the satellite upper air network (SUAN).

Due to the absence of Don Hinsman, Paul Menzel and John Eyre from ITSC-XIII, it was agreed that the report should be reviewed by them as well as Bill Smith, Jim Purdom and the ITWG Co-Chairs before the final preparation of the report.

### 2.5.2 Data access and dissemination

Concerning data access, ITWG recognized the outstanding efforts by space agencies to provide access to satellite data and encourages all space agencies to continue such efforts. Access to satellite data had been instrumental in the major improvements in weather forecast, synoptic meteorology, meso-scale modelling and climate monitoring as described by the other ITSC Working Groups.

The Working Group agreed it was essential for both operational NWP centres and research users to have access to global, real-time, satellite data in a timely and efficient manner. The Working Group acknowledged the efforts by satellite operators to provide these data to the global user community through direct broadcast as well as accessible databases. Maintaining data access standards and principles had resulted in improved utilization of satellite data at enormous cost benefit to many user communities, e.g., agriculture, industry and transportation.

The Working Group noted the recent incorporation of appropriate Research and Development (R&D) satellite missions into the space-based component of the Global Observing System (GOS). This was seen as a new mechanism to further enhance access to satellite data in order to meet the requirements of international users including National Meteorological and Hydrological Services and at NWP centres. Many of those requirements had not previously been totally met by the operational meteorological satellite systems. Hence, continuing efforts to add further R&D satellites to the GOS were encouraged. While it was too early to assess the full impact of enhanced access to R&D satellite data, the Working Group expressed its strong support for the initiative and efforts of satellite operators to make their data more available, especially for real-time or operational users and by direct broadcast where possible. ITWG also noted the expansion of the CGMS membership to include R&D space agencies contributing to GOS.

### 2.5.3 Timeliness of satellite data

ITWG recalled that the WMO timeliness goal for global NWP was at present 1 hour with a threshold within 4 hours of observation. It noted that the new EUMETSAT EARS provided data nominal within 30 minutes and most all data within 1.5 hours. ITWG recognized that the goal for global NWP would most probably become 30 minutes in the near future.

#### **Recommendation (to WMO/CGMS)**

**It was recommended that WMO review the requirement for timeliness of satellite data for global NWP in the light of NWP centres changing requirements.**

The Working Group was of the opinion that in the near future timely access to both global and local direct readout data would be required for the NWP assimilation systems, at least for regional and fine mesh/short range models. Pre-processing software should be made available by the satellite operators where possible, such as software packages for new satellites (NPP, NPOESS, METOP, FY-3, METEOR-3M etc.) to the same pre-processed level as made by NASA, NOAA, EUMETSAT, CMA/NSMC, PLANETA etc. for the global data.

#### **2.5.4 Software and documentation**

The Working Group noted that software and its associated documentation was becoming increasingly critical for efficient and accurate data processing, including the need for instrument and measurement metadata as well as software for direct broadcast processing from the raw signal (level 0) to calibrated, navigated radiances (level 1b).

##### **Recommendation (to Space Agencies)**

**The Working Group recommended that the satellite operators continue their excellent efforts to provide documentation and software to support optimal use of environmental satellite data with the view to have complete compatibility between global and local geophysical parameters (at least to level 1b).**

In the same way, the Working Group encouraged comparisons between fast radiative transfer models not only for scientific progress but also to encourage the use of common software to achieve fully compatible use of radiances.

The Working Group noted that the software pre-processing topic would also be discussed in the Working Group on Advanced Sounders (see section 2.4.6).

#### **2.5.5 Equator crossing time**

The Working Group noted that CGMS currently maintained a list of equator crossing times for all sun-synchronous satellites and that it would be useful to maintain a link to the table on the ITWG Web site. The Working Group reaffirmed the need to maintain a robust system in both AM and PM orbits optimally spaced including minimal drift for preservation of long time series of observation for climate monitoring.

##### **Action (D. Hinsman)**

**Provide link to CGMS table to ITWG Webmaster.**

#### **2.5.6 Frequency protection**

With regard to frequency protection, the Working Group agreed that one priority was to finalise the WMO draft table for users' needs between 1 to 1000 GHz and also to consider 1000 to 3000 GHz. The WMO draft table is available on the ITWG Web site at: (<http://cimss.ssec.wisc.edu/itwg/groups/frequency/>). The table will be updated by December 2003 and the complete update of the WMO draft table should be accomplished before mid 2004. The Working Group noted the considerable information already contained on the WMO Satellite Activities Web site and in the CEOS/WMO database. The Working Group noted that work remained to define the Delta T for noise not attributed to man-made interference.

##### **Recommendation (to National Radiofrequency Agencies)**

**Given the current levels of uncertainty in the studies for potential interference to EESS applications within the 23.6-24.0 GHz band by proposed automobile collision avoidance radars it was recommended that:**

- 1) automobile radar manufacturers make efforts to develop systems that operate outside this band**
- 2) any interference study of the impact of automobile radars on EESS applications using this band incorporate margins of at least 13 dB (20x) below the necessary EESS sensitivity levels to account for the uncertainties.**

### **2.5.7 Education, training and promotion**

The Working Group noted the extensive international efforts, particularly through WMO, concerning education and training in satellite meteorology. It recognized that these efforts were contributing greatly to better utilization and impact of satellite data on countries throughout the world. The Working Group therefore encouraged participants at ITSC-XIII and their associated agencies to provide resources and information or Web site links that may contribute to the WMO-coordinated efforts in education and training including the Virtual Laboratory concept to utilize resources globally.

#### **Action (to ITWG)**

**All members of ITWG to consider contributing to ITWG training Web page.**

### **2.5.8 GPS/RO**

The WG reviewed recent progress to investigate the complementary information content of data from passive (IR and MW sounders) and active (GPS/RO) systems on tropospheric temperature and moisture profiles. Studies confirm that the two systems are indeed highly complementary, with the GPS/RO data providing improved temperature information near the tropopause and improved moisture information in the lower troposphere.

### **2.5.9 Satellite Upper Air Network**

The Working Group noted a proposed approach to monitoring data from polar orbiting satellites with radiosondes. In particular, the Working Group reviewed the proposal to establish a satellite upper air network (SUAN) in order to provide monitoring of operational polar orbiting satellites through a carefully defined network of reference coincident radiosondes with polar satellite overpass. The Working Group also noted the ongoing activities within WMO/CBS on the redesign of the GOS in which the radiosonde networks and their launch times for the whole range of applications for which WMO was responsible were under discussion. The Working Group was of the opinion that as those WMO activities evolved one possible outcome could be the need for a network such as SUAN. Thus, the Working Group encouraged continued development of the SUAN concept. The Working Group also noted that the need for collocated data was not universally accepted for all applications and that continued investigations in this area were still required. Additionally, the Working Group also suggested that it would be appropriate to carefully evaluate the scientific justifications for SUAN taking into consideration the existing requirements for the GCOS Upper Air Network (GUAN).

## 2.6 SATELLITE SOUNDER SCIENCE AND PRODUCTS

Web site: [cimss.ssec.wisc.edu/itwg/sssp/](http://cimss.ssec.wisc.edu/itwg/sssp/)

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### 2.6.1 Introduction

The Working Group (WG) on Satellite Sounder Science and Products (SSSP) discussions focused on the role of the SSSP to facilitate the access to data by users (global and HRPT) of current operational and research satellites, and information concerning planned data access capabilities for future satellites (over the next two years). It was agreed that the SSSP page on the ITWG Web site should be expanded to provide information on research satellite health, and the status of pending, future satellite preparation and launch schedules (out to two years), in addition to the current operational satellite health (which is already provided).

Discussion also addressed topics such as the role of the SSSP Web site to provide information (via Web site links) concerning current and planned scientific algorithms from satellite providers (i.e., NOAA, EUMETSAT, NSMC, etc.) for global and local processing systems. The group discussed the possibility of developing user surveys on current and future uses of the data. Participants also agreed that it was important for the WG to define key areas of research concerning current and future data processing and applications, and to facilitate validation studies involving the various satellites, instruments, scientific products and algorithms available from the scientific community.

It was agreed that the current Web site structure has progressed significantly and provides a strong resource for users to access information on international scientific activities involving polar satellite data. For example, over the past 18 months the site has matured to provide categorization of products, applications, and facilities, resulting in efficient and user-friendly access to information from over 40 individual contributors who provide scientific input. Possible areas of expansion, in addition to those discussed earlier, include the addition of a global data and HRPT information directory, and of course the continued solicitation of scientific inputs from users both within and outside the ITSC community. Ms. Leanne Avila, the ITWG Webmaster, is recognized for her outstanding support in this area.

Finally, the WG acknowledged and encouraged activities to provide historical data sets of raw satellite (TOVS and ATOVS) and radiosonde (GTS and Special) collocated observations, and the need to expand current operational systems to provide such data routinely. The WG endorsed plans for a dedicated Satellite Upper Air Network (SUAN) to provide coincident satellite and reference radiosonde observations in support of current and future validation of polar satellite, radiosonde, and associated scientific applications, acknowledging the evolving requirements for such data in the processing, validation and utilization of (past, present and future) global satellite data. The success of this project will eventually need broad agency support that can best be focused through the WMO.

### 2.6.2 Working Group interaction and scientific contributions

The WG on Satellite Sounder Science and Product's primary function is to demonstrate the scientific achievements and current developments in our field, both within ITWG, and from the international scientific community. Unlike other ITWG Working Groups that were formed to address specific scientific issues, an important function of SSSP is to interact with the other groups and support their efforts to inform our user community about what they are doing. This is achieved through interactive links between the SSSP Web site and the other WGs, and most importantly, through the individual scientific contributions by individuals to the SSSP site.

**Action (all WG Members)**

**The WG Co-Chairs and individual members will promote the synergy between SSSP and other ITWG Working Groups, continue to seek scientific contributions from members and from the international community, and enhance the SSSP and ITWG Web site to meet these goals. The group will also seek to identify sources of information on the use of sounding data through questionnaires.**

**2.6.3 Access to global data from current polar satellites**

Improved access to global satellite data and products in real-time and for historical data is needed from current operational and research satellites operated by NOAA (U.S.), NASA (U.S.), NSMC (China), METEOR (Russia) and IRI (India). It is understood that routine access to all observations is not always feasible; however, in many cases routine data access appears unduly limited (to selected portions of the data stream) and/or cumbersome.

**Recommendation (to Satellite Agencies)**

**All satellite operators providing global polar satellite observations are encouraged to make their data routinely available to the international user community. In each case, procedures (and necessary protocols) for users to gain routine access to global, operational and research data sets should be identified and made available to users via links on the SSSP Web site. This will include complete listings of the data available (measurements and products), data formats, metadata and software for reading data files.**

**Action (to SSSP Co-Chairs)**

**The Co-Chairs will request information from space agencies through ITWG members (AK Sharma, Devendra Singh, Dong Chaohua, Alexander Uspensky) and provide links to the information on Web site).**

**2.6.4 Access to HRPT data and software from current polar satellites**

Documentation and information concerning the availability and access to direct broadcast (HRPT) data from operational and research polar satellites is often not readily available to users. Software packages to ingest and process the data are also needed by the user community to create navigated, calibrated data sets. Programs such as the EUMETSAT ATOVS Retransmission Service (EARS), which provide expanded coverage of level 1a and 1c HRPT sounding data, represent an improvement to user access to such data, albeit for a limited area. A more complete approach is needed to create a near-global, real-time data set of polar HRPT data, along with associated software packages for global and regional processing.

**Action (to SSSP Co-Chairs)**

**The Co-Chairs will request information from space agencies and provide links on the Web site. WG members will collect needed information on operational and research satellites and instruments for which direct broadcast (HRPT) data and associated software processing packages are available (and not currently included on the SSSP Web site). Appropriate data links will be provided to the Webmaster for inclusion in the HRPT area of the site.**

**Recommendation (satellite agencies and HRPT reception stations)**

**It is recommended that satellite data providers and HRPT reception stations consider programs for expanded HRPT and associated imager data coverage similar to EARS, but with more complete global coverage.**

### **2.6.5 Instrument health and future instrument status**

The SSSP Web site currently provides operational polar satellite instrument health status for NOAA operational satellites. Similar information is needed for the other operational and available research satellites, including those operated by China, India and Russia. Similarly, access to information on the status of preparations for near-term future satellites, for example, NOAA-N, NPP/NPOESS, METOP and EOS-3, is also needed to facilitate timely planning for processing these data.

#### **Action (to SSSP Co-Chairs)**

**The Co-Chairs will request information on instrument health from satellite providers through ITWG members (Dieter Klaes, Devendra Singh, Dong Chaohua, Alexander Uspensky, Paul Menzel, Hal Bloom) to identify sources of information (e.g., Web sites) covering the health of current instruments and the status of future satellites and instruments. This information shall be provided to the SSSP Webmaster to include on the Web site.**

### **2.6.6 Access to information on data plans for future satellites**

Users need to be better informed about satellite provider plans concerning access to global and direct broadcast data from future weather satellites. In particular those U.S. missions planned within the next few years (e.g., NOAA-N, EOS-3 and NPP/NPOESS) and from other nations, including Europe (METOP), China (FY), India and Russia, who plan to operate polar satellites.

#### **Action (to SSSP Co-Chairs)**

**The Co-Chairs will request information on future satellite systems from satellite providers through ITWG members (A.K. Sharma, Dieter Klaes, Devendra Singh, Dong Chaohua, Alexander Uspensky, Hal Bloom). Information shall be provided to the SSSP Webmaster to include on the ITWG site.**

### **2.6.7 Scientific algorithm information from global satellite providers**

Improved information dissemination concerning the current scientific algorithms being used by government agencies that are processing operational and experimental satellite data is needed. We believe users are not aware of the details surrounding such processing and thus cannot use the data most effectively. This information should include the uncertainty about the measurements and processed data.

#### **Action (to SSSP Co-Chairs)**

**The Co-Chairs will request information from satellite providers through ITWG members (Dieter Klaes, Peter Schlüssel, Thierry Phulpin, Devendra Singh, Dong Chaohua, Alexander Uspensky, Tony Reale, Walter Wolf, Tom Kleespies). They will identify sources of information (e.g., Web sites) describing the scientific methods for processing polar satellite data, beginning with measurement calibration (i.e., instrument filter functions, etc.) and including derived product algorithms. This information will be provided to the ITWG Webmaster for inclusion on the SSSP Web page.**

### **2.6.8 Information on useful datasets for satellite data processing and simulation**

Access to training datasets for new platforms 1-2 years before launch (e.g., METOP, NPP) such as the simulated orbit available for AIRS before launch will facilitate the preparation of new processing chains and this activity should be encouraged.

The mapping of global parameters such as SST, albedo, terrain types, surface elevation, emissivity, etc have become widely produced from polar satellites, serving as important input parameters for users who

are processing satellite data. For example, a fine description of the land surface emissivity IR spectrum depending on a land surface classification will enable the use of more tropospheric sounding channels from IR hyperspectral sounders. Also, the use of information for cloud top emissivities allows the simulation of cloudy spectra. Efforts to identify such data products and to facilitate access to them on the SSSP Web site should be pursued.

**Action (Lydie Lavanant)**

**A list of parameters and associated data atlas volumes available within the international community from operational and research satellites will be identified, and links to scientific documentation, formats and data will be established within the SSSP Web site to facilitate their access by users.**

### **2.6.9 Global HRPT directory**

A directory of HRPT facilities worldwide that are actively receiving, ingesting, processing and archiving polar satellite data is recognized as a potentially valuable mechanism for identifying system and scientific processing methodologies across the international community. Such a directory could help broaden participation in ITWG. For example, individuals from each facility could be solicited for information concerning their work (i.e., register on the SSSP Web site) and future participation in ITWG.

**Action (Lydie Lavanant, Elizabeth Silvestre, Tom Kleespies)**

**WG members should seek information concerning actively working HRPT sites. Available government licensing and/or other listings will be sought to aid in creating a directory. Once established, the SSSP Co-Chairs shall contact these facilities and solicit inputs to SSSP and, where appropriate, encourage ITWG participation.**

### **2.6.10 Collocated radiosonde and satellite observation dataset**

Real-time and historical datasets of collocated radiosonde and polar satellite observations have been compiled by a number of agencies and provide important information to monitor the radiosondes, satellite measurements and products, and ultimately to validate and “tune” the underlying scientific algorithms and applications. However, existing strategies for their compilation typically do not include “special” experimental radiosondes, and often lack sufficient raw data (i.e., level-1a and 1b observations) and meta-data (i.e., quality control, data adjustments, etc.) which can compromise their usefulness. It is critical that all strategies for compiling collocation data sets, for example, the processing stage(s) of the data, spatial and temporal windows, QC, etc., be clearly documented. Those groups identified will be encouraged to provide access to their data and metadata via the SSSP Web site, for example, to facilitate inter-comparison studies across various scientific algorithms and satellites (i.e., AIRS vs. ATOVS).

**Action (Tony Reale, Lydie Lavanant, Hank Revercomb, Mitch Goldberg, Graeme Kelly)**

**Efforts to compile real-time and historical datasets of collocated radiosonde (GTS and special experimental observations) and operational polar satellite (Global and HRPT) data are encouraged. The SSSP Web site will be expanded to identify groups compiling such data, and facilitate better awareness of and access to special experimental radiosondes (and other in situ ground truth observations) which are not routinely available.**

### **2.6.11 Satellite Upper Air Network (SUAN)**

Since the onset of polar satellite operational systems in 1979 (TIROS -N) and through the current ATOVS sensors, the problem of monitoring satellite radiometers and derived weather products from satellite to satellite has been a major problem for the climate community. This has resulted in a less than optimal impact of these data, particularly on climate applications. A standard reference set of ground

truth (i.e., radiosonde) measurements launched close to satellite overpass times as proposed through the Satellite Upper Air Network (SUAN) would help to minimize such problems. Such a network and ensuing historical record would potentially benefit all applications that depend on satellite and radiosonde observations.

**Action (Tony Reale, with Guy Rochard, Don Hinsman, Peter Thorne, Mitch Goldberg, John Bates, Dave Steenbergen, Dieter Klaes)**

**A proposal describing the Satellite Upper Air Network will be developed and provided to the WMO for international discussion and recommendation. This proposal would identify candidate site selection, expected benefits, network protocols (i.e., launch schedules) and resource requirements.**

#### **2.6.12 Identification of key research topics**

The international research community conducts research investigations and develops scientific algorithms in support of a broad spectrum of user requirements. Although it is never the intention of this WG to downplay the importance of any particular scientific development activity, it is recognized that certain issues, given their immediate potential impacts, have significant potential impact. Identifying a list of key topics relevant to ATOVS and advanced sounder applications that is consistent with ongoing and expected research and development programs can play an important role in scientific planning and resource allocation.

**Action (Tony Reale, Lydie Lavanant, Tony McNally, Thierry Phulpin)**

**SSSP WG members will establish a list of key scientific topics in conjunction with ongoing user needs. ITWG members are requested to provide inputs to the SSSP WG Co-Chairs, who will review and forward this information to the Webmaster for inclusion on the SSSP site.**