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REPORT FROM
THE INTERNATIONAL TOVS WORKING GROUP

A report from the ITOVS Working Group for CGMS consideration.

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I. Introduction

The Twelfth International TOVS Study Conference (ITSC-XII) was held in Lorne, Australia from 27 February – 5 March 2002. One hundred and four participants attended the Conference and provided scientific contributions. Twenty one countries, four international and many national organizations were represented: Australia, Brazil, Canada, China, France, Germany, Hungary, India, Indonesia, Italy, Japan, Kenya, New Zealand, Norway, Philippines, Poland, Russia, Switzerland, the United Kingdom, the United States of America, ECMWF, EUMETSAT, WMO, the IRC, NASA and NESDIS.

Most of the meeting was occupied with scientific presentations on a range of issues: radiative transfer modeling; the application of TOVS and ATOVS data in numerical weather prediction (NWP) and climate studies; preparations for advanced sounders; and relevant plans of operational satellite agencies and international issues. The corresponding papers are published separately as the *Technical Proceedings of The Twelfth International TOVS Study Conference*, available through the co-chairs of the International TOVS Working Group (ITWG).

Working Groups were formed to consider five key areas identified prior to the Conference: Radiative Transfer and Surface Property Modeling; TOVS and ATOVS in Numerical Weather Prediction; TOVS and ATOVS in Climate Studies; Advanced Sounders; and International Issues Future Systems; and Satellite Sounder Science and Products. The Working Groups reviewed recent progress in these areas, made recommendations on key areas of concern and identified items for action. Several technical sub-groups also met during ITSC-XII to discuss developments and plans concerning specific software packages, shared and in common use in TOVS, ATOVS and Advanced Sounder processing centres.

2. Summary of major conclusions

Overall, the meeting documented significant gains in many areas and noted areas for future activity. In particular, it noted that:

1. Considerable benefits have been demonstrated from ATOVS in NWP and other applications;

2. Continuing excellent results are being demonstrated from advanced data assimilation techniques;

3. Firm evidence continues to emerge of the utility of the TOVS/ATOVS data over land in NWP;

4. Preparations for Advanced Sounder have progressed markedly since ITSCXI.

5. Although a significant amount of work has been done since ITSC-XI in the area of radiative transfer modelling - radiative transfer modelling (including clouds), surface property modelling and calibration are areas still requiring attention;

6. The intercomparison of radiative transfer calculations is important and needs to be continued;

7. There is a continued need to emphasise climate activity and establish links with climate community;

8. NASA is to be complimented for their continued support of an advanced geostationary sounder. This sounding system provides an opportunity for operational agencies to include information

from this system in the development of their plans;

9. There is a need to develop further, the interface between ITWG and the CBS of WMO;

10. The development of community software for ATOVS processing has progressed well. The free distribution of ATOVS processing software has been essential in the use of ATOVS in the meteorological community;

11. The development of community software for AIRS is proceeding well with a requirement for ingest software still outstanding. The development and distribution of this software is essential for the effective use of AIRS data in the meteorological community;

12. The requirement for near real time AIRS and MODIS data remains important;

13. The GTS/DDS bandwidth needs to be increased to carry advanced sounder data.

14. The SSMI/S will provide significant upper atmospheric observations. Access to SSMI/S data and the related data archive is important; and

15. Easy access to radiance data after the transition to NPOESS needs to be established.

3. Response to CGMS XXIX actions

CGMS XXIX requested that ITWG, at its March 2002 meeting, should (a) summarise the successful characterisation of problems with AMSU-A & B direct broadcast (DB) data (e.g. humidity profiles derived with AMSU-B) and post these on a web site for DB users, (b) characterise the DB profile retrieval packages (three are known to CGMS – AAPP, IAPP, ISDAP), (c) provide an update on the status of using satellite data over land for retrievals and other products, (d) explore the quantitative use of cloud products, (e) discuss the necessity for CO2 profile measurements for improving atmospheric temperature profile retrieval, and (f) investigate multi-satellite utilisation for profile retrieval, specifically radio occultation with high spectral resolution infrared radiometers.

3.a Summarizing the problem solving encountered AMSU-A & B

This is underway at NESDIS.

3.b Documenting DB Packages

The ITOVS community is making progress in this area. Documentation of packages will be posted on the ITOVS web site http://cimss.ssec.wisc.edu/itwg/.

3.c Retrievals over Land

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

Surface property models are necessary for effective use of satellite data over land. ITSC XII summarized the status of microwave and infrared emissivity models.

3.c.1 Microwave emissivity

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

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

3.c.2 Infrared emissivity

Ocean surface
For the ocean surface no major developments have been made. Masuda parametrisations are used at several centers (i.e. ECMWF, NCEP) and ISEM-6 (within RTTOV) that are based on Masuda (1988) and Watts et al. (1996). Remaining issues are:

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

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

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

3.d Cloud Parameter Utilization

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

3.d.1 In NWP

Work is continuing on the use of cloudy radiance data. The NASA DAO has shown that the use cloud-cleared radiances which were so difficult in the past are now feasible provided you can account for their correlated errors in the final analysis step. The use of satellite measured clouds in NWP remains very limited. The RUC has successfully used cloud top pressure and effective cloud amount in their assimilation cycle to better forecast the location and height of clouds in the next three hours. Otherwise, the only use of cloud data has been the rather crude assimilation of cloud data in limited

area models (UKMO, NCEP, MSC). ECMWF is beginning a project to directly assimilate cloud information through their fast RT model. The problem of properly assimilating cloud data remains largely unsolved and will require at least several years of development.

3.d.2 In Climate Studies

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

* University of Wisconsin has retrieved cloud properties for the period 1989 – 2001, by using the CO_2 slicing method on sampled HIRS pixels.
* The LMD/ARA group has retrieved cloud properties for the period 1987 – 1995, by using a weighted ^{2} method on cloudy HIRS radiances averaged at 1° resolution.

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

3.e CO2

Regarding CO2, investigators have shown that the retrieval of CO_2 column concentrations from high spectral resolution infrared sounders looks promising. These retrievals have high enough accuracy (approaching 2 ppmv) to be useful for CO_2 inversion studies that seek to estimate sinks and sources although the information is concentrated mainly in the free troposphere. By contrast, CO_2 information extracted from HIRS is less useful and may approach 4 ppmv accuracy under the most optimal circumstances but more generally can be expected to be at the 6 ppmv level which is just capable of resolving the annual cycle of CO_2. Investigators also have shown how retrieved CO_2 information, at the 2 ppmv level, also benefits temperatures derived from these sounders. The typical assumption of a globally constant CO_2 concentration introduces errors in temperature retrievals that can be significantly reduced using a variable CO_2 distribution.

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

3.e GPS

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

for a future CGMS.

Recommendation (EUMETSAT): EUMETSAT should invite scientists participating in CHAMP to submit such a report for a future CGMS.

4. Other Conclusions and Recommendations from the ITSC XII Working Groups

4.1 Radiative Transfer and Surface Property Modeling

A data set of 13,000 profiles that include temperature, humidity and ozone as well as model generated cloud and surface variables are available from the RTTOV web site at: http://www.metoffice.com/research/interproj/nwpsaf/rtm. Other datasets in use are the 48 profiles from the University of Maryland Baltimore County, which are a mix of AFGL, TIGR, and NOAA profiles Garand intercomparison set of 42 profiles selected from a larger database which uses SAGE data for upper water and ozone. The NOAA-88 profiles that include rocketsondes and SBUV ozone are available from NESDIS/ORA and there are several versions. The older 43L TIGR-2 dataset (43 water vapour profiles) and the NOAA-88 set (34 ozone profiles) are used for RTTOV and the original 42L 32 profiles from NOAA-88 are also still in use.

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

To avoid ambiguity relating layer integrated and level point values, transmittance datasets should include documentation of any interpolation/integration routines so data can be used consistently.

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

4.1.1 Instrument characteristics required for RT modeling

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

Recommendation (Space Agencies): Instrument builders be required to provide response functions in digital form and at the actual spectral resolution it was measured.

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

4.1.2 Line by Line (LbL) model status

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

- GENLN2/GENLN3: new release planned but no new science, just more user friendly and Fortran 90 (contact is Dave Edwards at NCAR email:edwards@ncar.ucar.edu)
- kCARTA is being used for AIRS simulations (contact is L. Strow at UMBC email: strow@umbc.edu).
- LBLRTM: Version 6.01 is available. Some of the new features are:
  - Capability to input atmospheric profile on either altitude or pressure grid, and to output quantities on either altitude or pressure grid.
  - Capability to compute quantities for atmospheric layers which are not in local thermodynamic equilibrium (non-LTE option).
  - Update of universal constants
  - Contact is clough@aer.com

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

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

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

For microwave LbL models:

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

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

4.1.3 Assessment of spectroscopic databases

The latest spectroscopic parameters are found in GEISA-2000 and HITRAN-2000. The GEISA/IASI database is available at: ftp://ara01.lmd.polytechnique.fr/pub/geisa/iasi2000 (anonymous ftp). HITRAN-2000 database updates are documented at http://www.hitran.com/hitran/updates.html. For the water vapour continuum, CKD 2.4, is the new standard. The EUMETSAT LbL comparison mentioned above is part of the assessment of the accuracy of these datasets.

4.1.4 Fast RT models

With the release of the latest radiative transfer code (RTTOV-7) at the meeting, it is evident that the exchange of code/results and techniques between groups within the satellite community continues to be very vibrant. The use of the Internet to distribute the new radiative transfer code to users has been very efficient. Overall, the formation of the NWP SAF in Europe has had a very positive impact on satellite data user community all over the world. In the same context, the AAPP and ITPP packages used to calibrate and navigate the satellite data are now extensively used by most NWP Centers in the preparation of data for analysis. The status of fast models follows:

OPTRAN: Adapted to AIRS. Work underway to improve ozone channel simulations.
RTTOV: Version 7 about to be released which includes AIRS and SSMI(S) simulation capability.
GASTROPOD: Fixed pressure level model for AIRS.
OSS: Proprietary code developed by AER for CrIS but not yet available to RT community. Is reported to be fast and accurate. The group encouraged AER to include the IR model in the Garand comparison.
MSCFAST: Implemented at the Canadian MSC for use in GOES radiance assimilation. Will be adapted to AIRS.
3R-N: This fast model is based on neural networks and has been developed for TOVS channels at LMD.

An improved understanding of RT model biases as shown by the Garand intercomparison is required. For the use of RT models in NWP data assimilation models it was noted they should be the same in

both the global and regional model of each NWP centre but that different bias tuning may be required for each.

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

4.2 TOVS/ATOVS data in Climate Studies

4.2.1 Contribution of TOVS to climate studies

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

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

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

These principles need to be applied to both *in situ* and satellite systems. A recent review by a USA National Research Council (NRC) Panel highlighted the following issues for the application of satellite data for climate purposes:

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

Recommendation (Space Agencies): ITSC XII recommended that Space Agencies report at the next conference on plans to respond to the Karl principles.

4.2.2 Pathfinders and re-analysis

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

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

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

ECMWF is currently performing the reanalysis of the global atmosphere for the period 1957-2001. ERA-40 will complement the already existing NWP reanalysis datasets: NCEP (1947-2000) and ECMWF (ERA-15, 1979-1993). In addition to the historical ground-based observations, and to a much larger extent than in ERA-15, ERA-40 makes use of the multi-channel satellite radiances through T159L60/ 3D-variational assimilation starting from the first sounding instrument VTPR in 1972 up to the present SSM/I, TOVS (MSU, HIRS and SSU) and ATOVS instruments. Cloud Motion Winds are used from 1979. Ozone information retrieved from TOMS (total ozone) and SBUV (layered ozone) is assimilated as well. The reanalyses are progressing in three streams and currently analysed periods are 1957-1961, 1973-1975 and 1989-1996.

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

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

Recommendation (NESDIS and NASA): ITSC XII recommended continued production of long-term TOVS climate data sets as envisioned by the NOAA/NASA Pathfinder projects with the goal of achieving a 'TOVS 25' data set. The TOVS 25 data set would represent the TOVS communities' best effort to use all 25 years of TOVS data for climate studies.

4.2.3 Calibration and validation quality and monitoring

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

In situ vertical sounding, both by the operational radiosondes and by research sondes (such as ozone-sondes and research-quality water vapor sondes) is critical for satellite calibration and validation efforts. There are, however, many user communities for these data and the needs of the different user communities can conflict. For example, those who use these data for global and regional climate studies want the launch time to remain constant in order to avoid aliasing the diurnal

cycle into longer-term variability. Satellite users would prefer launch times based upon the satellite overpass time to ensure the closest match with the satellite data in time and space. Because of these conflicting needs, requests for changes in radiosonde operations to optimize their use for satellite cal/val must be highly targeted to avoid conflicts with other user needs.

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

Recommendation (NESDIS): Past and resent calibration issues are being addressed, but these need to be better documented, placed in long-term archives, and software needs to be developed and shared. Develop, archive and make accessible a complete audit trail of all TOVS calibration issues and their resolution.

Recommendation (CGMS): There is a need to develop an official international mechanism for reporting and acting on past calibration issues. The current system is ad hoc. Two opportunities exist for improved coordination between in situ sondes and satellite overpass times: 1) automated ship launches and 2) research group launches of ozone-sondes and water vapor sondes.

4.2.4 Data access and archive

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

Recommendation (Space agencies): Space Agencies should strive to benefit from lessons learned from EOSDIS, a first attempt to deal with the quantum leap in data volume from the next generation environmental satellite sensors.

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

4.3 TOVS/ATOVS data in Assimilation and Numerical Weather Prediction

There is considerable evidence of very positive results using satellite data from different instruments; positive impact with microwave data has been readily apparent. Very positive impact of direct assimilation of radiances has been achieved by a growing number of NWP Centers; some Centers that were previously using processed level-1d radiances have now started to use raw level-1b radiances with very positive results.

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

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

4.3.1 Evaluation and use of TOVS/ATOVS in NWP

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

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

The ITWG 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.

Table 1. ITWG survey on the Use of ATOVS data in operational NWP systems at 01/02/2002

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

The results of the ITWG survey reproduced in Table 1 indicate the NWP community still has operational requirements at various levels for NOAA/NESDIS/ATOVS data processing from level-1b through preprocessed (PP) level-1d radiances, to retrieved products. The results of the survey indicate that the majority of NWP Centers still rely upon NESDIS retrieved products and processed level-1b and level-1d data for their operational forecasting systems. ITSC XII acknowledged this fact and supported the continuing efforts of NOAA/NESDIS and EUMETSAT in their crucial role. This Inter-agency collaboration has been very beneficial. The ITWG wants to commend the progress at NESDIS in change notification and monitoring of the data since the last meeting.

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

There were some questions raised as to the use of uncorrected antenna temperatures of microwave instruments. The ITWG 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 (NESDIS and IPO): To evaluate and improve the current procedures to convert antenna temperatures to brightness temperatures. There have been indications that the data from central data producers may be different to that derived through AAPP, and these may be due to different calibration and navigation algorithms.

Recommendation (NESDIS): To determine why different navigation information is being distributed in comparison with that being used in operations.

Recommendation (Space Agencies): Encourage the collaboration between the local readout software developers and the data producers to minimize the differences between the global and local calibrated and navigated data

In at least one presentation at this meeting, there was further evidence from sensitivity experiments that forecast errors develop in cloudy regions. This may explain the larger impact from the AMSU data when compared to the HIRS data and may have implications for future instrument design.

4.4 Advanced Sounders

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

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

4.4.1 New Initiatives for Geostationary Sounding

Proposals have been prepared, in both the USA and Europe, to fly millimetre/sub-millimetre radiometers with sounding and imaging capabilities on geostationary satellites. To achieve required horizontal resolutions with reasonable antenna size, these instruments would use high frequencies

(bands between 100 and 500 GHz), which are more sensitive to cloud and precipitation than channels used for temperature sounding from polar orbit (i.e. 50-60 GHz). However, the geostationary orbit is particularly well suited to observing time-evolving phenomena related to clouds and precipitation, which can develop rapidly and for which frequent measurements are required to support improvements in nowcasting and short-range forecasting. The ITWG supported the concept of an experimental mission to demonstrate this technology and suggested that priority be given to channels suited to sensing precipitation, cloud and humidity.

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

Table 4.4-1: Characteristics of Advanced Infrared Sounders

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

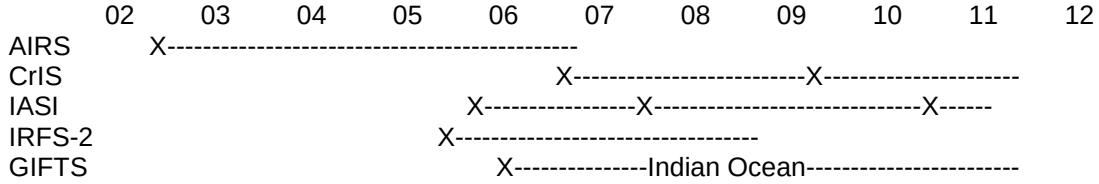

Figure 4.4-1: Advanced IR Sounder Timelines

4.4.3 Distribution of simulated datasets for advanced sounders

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

Recommendation (CGMS): The ITWG notes the high value of simulated AIRS data, distributed in near-real time, in assisting NWP centres to make effective preparation for real AIRS data, and it recommends that similar services should be established as part of the preparatory activities for other advanced sounders. M.Goldberg of NESDIS was volunteered to draft short paper for CGMS describing the AIRS data simulation system and its use.

4.4.4 Data processing, inversion and assimilation

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

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

(See below for list of acronyms)

For global data, the global processing centres will be the responsible agencies. Plans are in place to deliver the necessary software for this purpose. However, for locally-received, direct read-out data, it will be necessary to distribute suitable ingest code to users for local implementation. This code should be compatible, in output content and quality, with equivalent code for global processing. With the exception of EUMETSAT plans for IASI/AMSU-A/MHS/AVHRR and NASA/CIMSS plans for AIRS/AMSU-A/HSB/MODIS, plans in this area are not mature, and further developments are needed to ensure timely distribution and implementation. Without such developments, direct read-out data will not be exploited effectively.

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

Recommendation (CGMS): ITWG recommends that responsible agencies establish focal points

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

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

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

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

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

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

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

Recommendation (IPO): IPO inform ITWG members, through the ITWG list server, of the location of draft specifications of RDRs and SDRs for NPOESS/NPP instruments. The ITWG co-chairs will co-ordinate feedback to IPO from ITWG members on the draft specifications (content and format) for the raw data records (RDRs) and sensor data records (SDRs) for NPOESS/NPP instruments.

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

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

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

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

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

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

In the light of these issues the following recommendation was addressed to IPO.

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

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

Recommendations (Space Agencies): ITWG recommends that the spectral responses of advanced sounders should be characterised: (a) to a level at which the associated error does not cause the total noise budget of the instrument to be exceeded, and (b) where achievable at reasonable cost, to a level at which the associated error is a negligible contribution to the total system noise.

Glossary of instruments

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

4.5 International Issues and Future Systems

The ITWG reviewed the progress made since the last ITSC as well as issues raised during the present ITSC. It noted that almost all action items and recommendations had been accomplished and those that remained fell into seven categories: data access, data dissemination, data monitoring,

equator crossing times for polar-orbiting satellites, the ITWG web site, radio frequency matters and the need for a new working group for radio occultation soundings. The ITWG noted in particular the efforts by the Co-chairs to take the necessary actions towards the completion of the recommendations and thanked them for their efforts.

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

4.5.1 Data access

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

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

4.5.2 Data dissemination

The ITWG recalled that it had, at previous ITSCs, made recommendations to WMO to increase the capacity of the Global Telecommunications System (GTS) in order to handle not only the present volumes of satellite data and products but also the large increase in volume expected by the end of this decade and beyond. It was pleased to note that the capacity of the GTS had been increased in some WMO regions, notably in Europe as well as between the USA and Europe, and that WMO Members should continue their efforts to implement similar system on a global basis.

The ITWG also noted the WMO initiative with regard to direct broadcast from environmental satellites. WMO was in the process of reviewing the data dissemination architecture from operational meteorological satellites and foresaw an evolution from solely direct broadcast to one that included direct broadcast to selected regional sites and alternative dissemination methods that would complement direct broadcast to meet the needs within the region. The need for the review was driven by the plans by the satellite operators to move to X-band direct broadcast which implied a near complete replacement of the present HRPT ground receiving stations worldwide. Such a replacement was felt by WMO to be unachievable. The regional sites would provide sufficient geographic coverage to meet the needs of all applications in the region. The alternative dissemination methods would include the use of Internet or Internet-like capabilities and/or commercial communications services. In acknowledging the expected massive increase in data volume, the ITWG strongly supported the proposed WMO architecture. Furthermore, it encouraged WMO to include R&D satellite missions' dissemination in the architecture. The ITWG suggested that WMO also consider data redundancy without duplication in further developing the architecture. The ITWG noted that while ITWG had no specific requirements for direct broadcast from environmental satellites, it did have requirements for the availability of such data and the proposed WMO architecture had the potential to satisfy future ITWG requirements for data availability.

4.5.3 Data monitoring

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

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

4.5.4 Equator crossing times for polar-orbiting satellites

The ITWG was pleased to note the satellite operator plans for polar-orbit and that during the second half of the decade there existed the possibility for four polar-orbiting satellite series, NOAA/NPOESS, METOP, FY-3 and Meteor 3M series. It was informed that both CMA and ROSHYDROMET had already expressed a willingness to consider moving its satellite series to the PM orbit when nearing nominal configuration. The ITWG noted that this would provide a robust system of two satellites in both the AM and PM orbits each capable of backing-up the other. The ITWG noted that the satellite operators should strive to maintain long-term continuity of equator crossing time for their respective series while seeking to minimize any drift in the crossing time in order to maintain climatological records.

4.5.5 ITWG web site

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

4.6 Satellite Sounder Science and Products

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

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

Discussions of the SSSP sub-group at ITSC XII focused on issues concerning the SSSP web site, including the web site structure and content, attracting additional contributors, guidelines for contributions, providing contact information on data sources and availability, and links to direct

broadcast data and software packages. The Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Madison will maintain the SSSP web site.

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

The SSSP sub-group also agreed that identify and promote important research topics concerning current weather satellites for continued and/or expanded investigation to be developed through interaction with the rest of the ITWG.

4.6.1 Actions and Recommendations

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

Recommendation (NESDIS): Promote activity to append level 1b raw satellite observations to existing historical datasets of collocated radiosonde and TOVS and ATOVS observations, and to deploy such methods in current and planned operational systems (making such actions unnecessary in the future).

Recommendation (IPO): Ongoing programs dedicated to the global validation of operational and research satellite data are not routinely available. The ITWG is offering to be a mechanism to initiate and promote studies to define requirements for a permanent, reliable, global ground truth validation program in support of operational and research polar satellite observations.

ITWG made an action on itself to design and conduct studies in conjunction with current and planned calibration/validation experiments (e.g. DOE ARM Sites) to quantify the usefulness of conventional upper air (i.e., radiosonde, profiler, etc) data to monitor polar satellite radiometer performance, its impact on climate and weather applications, and to provide recommendations concerning long term needs for continuous, global monitoring of environmental satellite data.

Recommendation (NOAA, EUMETSAT and other product developers): Product developers and providers should expand the use of gridded formats to facilitate the validation, intercomparison and ultimately the use of derived products in routine NWP and climate analysis, particularly for conventional data poor parameters such as upper tropospheric temperature, upper tropospheric moisture, clouds, and in regions of thermal advection.

Recommendation (NESDIS): Promote activity to utilize gridded file product formatters in routine operational data processing at NESDIS, including as feasible, time averaged (monthly) gridded files for selected, conventional data poor parameters. Eumetsat and other product developers should be contacted to encourage their participation in this activity

5. ITSC XIII

New Co-Chairs Tom Achtor (CIMSS) and Roger Saunders (Met Office) will be convening ITSC XIII in Beijing in October 2003.