Working Group 1: Observation Pre-processing

T. Kleespies (co-chair) , S. English (co-chair), L. Lavanant, G. Kelly, D. Klaes, P. Schussel, N. Atkinson, G. Prangsma, A. Thoss, F. Tveter, G. Deblonde, G. Rochard

1.1. Calibration and instrument characterisation

The characterisation of the AMSU and HIRS for NOAA-15 has been done well. The biases are smaller and more stable compared to earlier instruments and the experience with NOAA-15 is considered to be a good example of how to characterise instruments for the future. A minor geo-location error in the AMSU-A data and some small differences found between NESDIS level-1b data and level-1b data produced by AAPP (from direct read-out) will be reported to NESDIS (Tsan Mo). The UKMO (Atkinson) has shown some scan dependent signals in AMSU-B radiance data that were attributed to polarisation changes. It is not known if this effect is also an issue for the AMSU-A instrument. It is known that the HIRS scan mirror coating was changed some time ago to minimise or eliminate such a problem.

The HIRS spectral response functions for earlier satellites are in question as many NWP centres with different radiative transfer models (based upon different spectroscopy) observe similar systematic departures. NESDIS has hired a full time employee who will address infrared calibration, although his time will be split among several instruments. It is unclear whether he will be able to deal with older HIRS instruments, but it is very encouraging that the resources have been applied to the crucial issue of infrared calibration.

The historic MSU thermal vacuum measurements are in the process of being recovered and archived on a stable medium. This work should be completed in the winter of 2000. The majority of the historic MSU antenna range data have already been recovered, converted to ASCII, and placed on a stable medium.

It was noted that work by Bates regarding SSU microphonic interference on the HIRS shows that it can be of significant amplitude on some satellites. Bates is working on a fix to the problem with McMillin and Uppala. This interference may explain some of the irregularities that have been observed in the scan dependent bias of the HIRS data.

The calibration process and instrument characterisation is not a solved problem and there is clearly much work to be done. However, the work done with NOAA-15 is a big step forward.

1.2. Systematic error

There are at least five generic sources of biases that have been identified: characterisation and calibration of the instrument, spectroscopy, radiative transfer, and systematic error in the NWP models against which the data are compared. The first two error sources are the responsibility of the data provider and the last three are the responsibility of the data user. These biases are not completely understood, nor are the relative magnitudes of the biases among the five sources known. The best approach for any corrections to be made by the data provider depends upon the type of data. For raw radiance users, the best available correction should be included with the level 1B data, and it is up to the user to apply them. For processed radiance or retrieval users, changes should only be based upon sound physics and not "blind tuning". Consultation should be made with the users before any change to the data processing is made, including changes that are not expected to have any effect. Users of both raw and processed radiances should receive adequate prior notification and a period of parallel processing should be implemented before any change becomes final.

1.3. Cloud and precipitation detection as a pre-processing step

Over the ocean clouds can be detected most of the time in both infrared and microwave data. However, the negative impact of undetected cloud using the best state of the art cloud detection has not been fully quantified. Cloud detection over land and ice is more difficult. While some situations are straightforward (for example cold clouds over a warm land background), cloud detection over land and ice generally presents more marginal situations than over ocean such that that more mistakes are likely to be made. The consensus is that the best current solution is to use due caution and discard potentially cloudy data conservatively.

Much more work needs to be done on cloud detection, including improved emissivity and skin temperature specification.

1.4. ATOVS retrieved products

Both METEO-FRANCE and NESDIS have noted a marked improvement in retrieval quality using ATOVS data. The broader community should be encouraged to use the new wide frequency range of the AMSU channels for surface and precipitation retrievals. For example, there is some evidence of useful data from the 150 GHz scattering index for precipitation.

Other recommendations:

- NESDIS should establish a specific mailing list of processing experts for users to submit problems and discrepancies.
- NESDIS should be complemented on the quality of the NOAA-15 data and encouraged to apply this attention to detail to future satellites.
- ECMWF should work with the UKMO to establish a complete SSU archive.
- Radiance O-B monitoring plots from the various centres should match the ECMWF latitude zones.

Working Group 2: Assimilation Issues

J. Derber (co-chair), J. Eyre (co-chair), E. Andersson, C. Chouinard, B. Harris, J. Joiner, K. Okomoto, F. Rabier, R. Renshaw, H. Schyberg

2.1 The use of ATOVS

The users of level 1b/1c/1d ATOVS data have expressed great satisfaction with the quality and impact of the data. Operationally these data are assimilated at the NCEP, ECMWF, and UKMO (experimentally at the NASA DAO). The incorporation of these data into operational systems has been rapid after the initial availability in the summer of 1998. The 500km SATEM users have reported less consistently positive results, but have still generally found a positive impact on their assimilation systems. These data (which have been available since April 1999) are being used operationally at the JMA and BOM. The 120km BUFR data have only been available since August 1999. Format problems have been reported and no group has yet reported positive impact from using this data.

The AMSU-A data is a significant improvement over the MSU/SSU instruments carried on previous satellites. This improvement has not only resulted from the expected increase of information provided by AMSU-A channels, but also from practical aspects such as low and stable biases and the ease of quality control. This is identified as an important reason for the relatively quick operational use of ATOVS data following the launch of NOAA-15.

The NOAA-15 HIRS-3 appears to be better calibrated and characterised than earlier HIRS instruments. The working group suggests that it would be desirable to determine exactly what was done differently for this instrument to ensure similar levels of quality in the future. The monitoring information generated by NWP centres for the AMSU-A and HIRS-3 instruments should be provided to the calibration group at NESDIS to enhance their own monitoring capabilities. The working group recommends improving the antenna correction algorithms. However, since a change in the antenna corrections would substantially impact current users of the data the working group also suggests improvements in the antenna corrections be made only with the launch of a new instrument.

In the stratosphere the AMSU-A appears to be providing good information and the working group feels that the AMSU-A data may even be useful for estimating systematic errors between different radiosondes. However, there is a lack of cross-validation data available for the upper stratosphere making verification difficult. Tony McNally presented his proposal to estimate the bias correction needed for old HIRS/SSU stratospheric channels in the ERA-40 project. The working group was unsure whether a process of "back-correction" making use of the current AMSU-A observing system and periods of overlap between satellites would work, but could not suggest a better approach.

The working group discussed the specification of radiance observation errors. There appears to be a discrepancy between the values suggested by observation minus background statistics (that may be considered an upper bound on the observation error) and the (generally larger) tuned values that give the best impact results. Some of this discrepancy may be explained by the presence of correlated radiance error and problems in the specification of the background error statistics. The working group feels this subject merits further study.

The AMSU-A quality control over sea appears to be relatively straightforward. To maximise the usage of the data, signatures of surface or cloud liquid water should be separated from precipitation.

The priorities for ATOVS development (in order of importance) were considered as follows

- Improve quality control and channel selection over ocean
- Improve use of data over sea-ice (and the better-known land surfaces)
- Improve use of HIRS data, including humidity channels (and channels significantly affected by humidity). Reconsider humidity control variable and/or background error specification. Improve cloud detection, including use of short wave channels (HIRS ch. 18-19, 20). Exploit AVHRR data to improve cloud detection.
- Extended use of data over land through improved treatment of surface emissivity and temperature.

The use of Advanced IR sounders (IASI, AIRS, NPOESS)

Work to provide fast forward modelling capabilities has started and should be continued. In particular, the model developed at ECMWF for IASI should be extended to AIRS. The assimilation of AIRS/IASI should build on approaches and structures developed for HIRS. However, exploitation of HIRS is not a "solved problem" and much more attention is needed to improve:

- cloud detection to accuracies approaching instrument noise
- exploitation of IR sounder data in cloudy areas.

Some basic research is needed in both areas.

Exploitation of advanced sounder data will also benefit from improved background error covariances, particularly with regard to humidity and synoptically dependent structures.

Whilst the short-term priority should be improved exploitation of ATOVS, it is important that the scientific and technical basis for advanced IR sounders should be put in place. Urgent work is needed here in parallel with ATOVS activities, and both areas require adequate resources.

Working Group 3: Radiative Transfer

R. Saunders (co-chair), J. Bates (co-chair), P. Brunel, F. Chevallier, G. Deblonde, L. Garand, T. Hewison, M. Matricardi, V. Casse

3.1. Status of RT models

3.1.1 Infrared Line-by-line models

Simulations of a selection of HIRS channels by infra-red line-by-line models all agree within the HIRS instrument noise and so for HIRS are consistent with each other. A line-by-line model intercomparison for the spectral range covered by IASI, including measured radiances, is being co-ordinated by the IASI Sounder Science Working Group (ISSWG) and will report in March 2000.

The main uncertainty of these models continues to be the water vapour continuum. These models are very expensive to run both in CPU and data volumes and so all centres should co-ordinate model runs before creating a new database in order that they can all benefit. It is only proposed to update these model runs when i) a significant change in the spectroscopy and/or improvement in model parameterisation is available or ii) transmittances on a different set of pressure levels are required (e.g. more levels for AIRS/IASI models).

3.1.2 Microwave line-by-line models

The agreement between the models is good except for the AMSU window channels, possibly due to uncertainties in the water vapour continuum, and the highest stratospheric channel (AMSU-A channel 14). Measurements exist for the window channels to validate the models. It was proposed to carry out a more detailed comparison for the channels where there are discrepancies to identify which component of the absorption mechanisms is responsible for the differences.

3.1.3 Fast models

No fast infra-red models seem to perform well for all cases. For the models which participated in the intercomparison of Garand et. al. RTTOV-5 was poor for water vapour, OPTRAN for ozone and AESFast for stratospheric temperatures. The poor performance may not be inherent to the basic model itself but to the particular implementations which were included in the tests.

Infra-red models mainly reproduced the line-by-line results to within the HIRS instrument noise and it was also noted biases for HIRS/3 on NOAA-15 are less than for HIRS/2 on NOAA-14. The group welcomed the appointment at NESDIS of an infra-red instrument scientist. Microwave fast models reproduce the line-by-line results to well within the instrument noise.

The comparisons of Jacobians from the fast and line-by-line models proved to be a useful diagnostic that showed up anomalies not seen in the forward model comparisons. Differences in fast model Jacobians from the line-by-line models can lead to the radiances having a significantly different impact on the radiance assimilation process. The group also noted that the layer mean profile quantities must be consistent within the line-by-line, fast RT model and NWP model profiles.

Developments for improving fast models (both radiance simulation and Jacobians) include:

- A new diverse profile set using model fields with a few extreme radiosonde profiles to ensure the full range of variability is captured.
- Increase the number of levels for the fixed pressure level models in preparation for AIRS/IASI.
- Better knowledge of instrument spectral responses
- Improved profile predictors to improve the accuracy of the models
- Investigate the feasibility of a neural net approach
- Investigate the feasibility of more physical models

3.2. Status of fast RT model comparisons

The GEWEX Global Water Vapour project has recently completed a comparison of NOAA-12 HIRS channel-12 radiances and Jacobians. The results are about to be published in the Bulletin of the American Met. Soc. by *Soden et. al.*

A more comprehensive comparison of ATOVS channels initiated at the last ITSC is underway co-ordinated by AES. Initial results were presented to this workshop (see paper by Garand) and are summarised above. It is planned to continue this comparison with a more diverse profile set, with no super-saturation, and complete by end of Jan 2000. To date there are 9 participants (3 line-by-line, 4 fast and 2 narrow band models). The definitive results will be published and presented to the next ITSC in 2000. They can be used as a benchmark for future ATOVS fast model developers. A fast model comparison is also underway for IASI radiance simulations and Jacobians. First results will be presented at the next ISSWG meeting in March 2000.

3.3. Modelling of the surface

3.3.1 Ocean

Fast infra-red sea surface emissivity models now use the Masuda tabulation in place of an assumption of unit emissivity for the sea-surface. The inclusion of non-unit emissivity led to improvements in the assimilation of GOES and HIRS radiances at NCEP. Airborne interferometer measurements have indicated some errors to Masuda are still present for large zenith angles.

Fast microwave sea surface emissivity models are now available but still in need of evaluation. Their accuracy is typically 0.5% at nadir to 2% for a zenith angle of 50 deg. Feedback from the NWP centres on their O-B stats to the emissivity model developers is now required. The AMSU window channels are not yet assimilated due to the surface model errors. High wind speed situations (due to foam) and high viewing angles give the largest errors. Above 100GHz there is no sea water permittivity data and so the models are extrapolated for AMSU-B channels. One possible development in the NWP context is to provide the large scales from the wave model and the small scales from the first guess wind speed.

This needs further investigation. If the AMSU window channels were assimilated they would potentially provide another measure of lower tropospheric water vapour (similar to SSM/I).

3.3.2 Land/sea-ice

To make real progress in radiance assimilation over land and sea-ice the radiative properties of the various surface types need to be estimated a priori and then updated using information from the HIRS and AMSU radiances. A surface type atlas, with around 20 classes, is thought to be required to encompass both the infra-red and microwave emissivity regimes. Atlases are now becoming available (e.g. the NASA/GISS dataset). The recent rainfall history from the NWP model may also be another useful variable. The variation of emissivity with wavelength is normally slow making it easy to model the complete spectrum. The variability of the surface in the infra-red is less than for the microwave particularly over snow/ice surfaces. The best area for microwave radiance assimilation over land is thought to be over forests where the emissivity is more stable.

Independent data-sets such as SSM/I radiances and AVHRR NDVI may help to refine or update the atlases. A COST 712 report has just been published which has considered the status of microwave surface and cloud models in some detail.

3.4. Clouds and precipitation

The philosophy for incorporating clouds into fast models is well developed with the NWP model providing the cloud fraction and liquid/ice water content on each level. Parameterisations exist to relate the water content to transmittance at both infra-red and microwave frequencies. However parameterisations for ice cloud are still subject to large errors. Recent interest in simulated satellite imagery from NWP model fields will provide an incentive to improve the fast modelling of NWP model clouds. When more fast RT models which include cloud are available comparisons between them should be made for both infra-red and microwave channels.

Precipitating clouds affect the microwave channels through scattering. The current models are too expensive and complex for direct radiance assimilation. The need to build a database of rain-rate, cloud water/ice on model levels co-located with AMSU, SSM/I and TMI radiances was recognised to see what the correlations are. Key areas of uncertainty for RT models are the permittivity of supercooled water, the ice and melting phase extinction, and 3D/beam filling effects. It was noted the Global Precipitation Monitoring Mission may provide useful radiance data beyond the current TRMM satellite.

3.5. Validation data sets

3.5.1 Validation for profiles of temperature, moisture, ozone, and other trace gasses

There is still a strong need for high-quality radiosonde data with improved water vapour data, particularly in the upper troposphere. There is an increased need for temperature profile information above 100 hPa (i.e., above the limits of radiosondes) to validate AMSU stratospheric channels.

With regard to radiative transfer modelling, there is a need to continue to research and document the behaviour of the infrared water vapour continuum and, for broadband and cooling rate computations, the behaviour of the pure rotational band (18-26 microns). Analysis of spectra obtained at long-term monitoring sites (e.g. ARM CART) may be useful for studying the water vapour continuum.

Attempts should be made to document past and current HIRS channels with large biases to identify and correct suspect filter response functions.

NWP systems need to allow for variable ozone (NCEP have successfully implemented this) and O-B statistics for channels sensitive to ozone should be used to improve the treatment of ozone in radiative transfer models.

3.5.2 Surface emissivity over land and oceans

Over the oceans, additional research is recommended on the behaviour of microwave emissivity models at high viewing angles (greater than 50 degrees) and at high frequencies (greater than 100 GHz). Operational NWP centres should monitor and provide O-B statistics to the radiative transfer community to identify problems in this area. Similarly, O-B statistics for microwave data over land should be used to improve emissivity information from sources such as the NASA/GISS tables.

3.5.3 Clouds and precipitation

Use of multi-sensor campaigns and process studies is recommended for validation (e.g. TRMM validation campaigns and the GEWEX co-ordinated extended observation program, CEOP). Incorporation of information on hydrological cycle variables, including water vapour, clouds, and precipitation, has been particularly difficult due to the indirect and sometimes negative impact of such information on the forecast cycle. In order to translate research studies into positive model impact, additional resources at the NWP centres are required to improve the assimilation of hydrological variables and the treatment of moist physics.