A report on
The Eleventh International ATOVS Study Conference

Budapest, Hungary
20 - 26 September 2000

Conference sponsored by

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World Meteorological Organization

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ITT Aerospace / Communications Division

Matra Marconi

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Published and distributed by
Bureau of Meteorology Research Centre
GPO Box 1289K
Melbourne VIC 3001 Australia

July 2001

FOREWORD

The International TOVS Working Group (ITWG) is convened as a sub-group of the International Radiation Commission (IRC) of the International Association of Meteorology and Atmospheric Physics (IAMAP). ITWG continues to organise International TOVS Study Conferences (ITSCs) which have met every 18-24 months since 1983. Through this forum, operational and research users and providers of TIROS Operational Vertical Sounder (TOVS), Advanced TOVS (ATOVS) and other atmospheric sounding data have exchanged information on data processing methods and on the impacts of the derived atmospheric temperature and moisture fields on numerical weather prediction (NWP) and climate studies.

The Eleventh International TOVS Study Conference (ITSC-XI) was held at the Agro Hotel, Budapest, Hungary, from 20 - 26 September 2000. This conference report summarises the scientific exchanges and outcomes of the meeting. A companion document – *The Technical Proceedings of The Eleventh International TOVS Study Conference* – contains the complete text of ITSC-XI scientific presentations. Together, these documents reflect the conduct of a highly successful meeting in Budapest. An active and mature community of TOVS and ATOVS data users now exists, and considerable progress and positive results were reported at ITSC-XI in a number of areas, including many related to the new ATOVS system.

ITSC-XI was sponsored by NASA, NESDIS, EUMETSAT, the World Meteorological Organization, the Australian Bureau of Meteorology, Météo-France, Matra Marconi and ITT Industries. Their support is gratefully acknowledged. We wish to thank the local organising committee: Ms Eva Borbas, Ms Magdolna Pusztaine and Ms Marta Dioszeghy. We also thank the staff of the Agro Hotel for their assistance during the Conference. Finally, we acknowledge the contribution of Bureau of Meteorology Research Centre staff, particularly David Jasper and Terry Adair, who assisted with the preparation and publication of this report.

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THE ELEVENTH INTERNATIONAL TOVS STUDY CONFERENCE (ITSC-XI)

Budapest, Hungary: 20 - 26 September 2000

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ITSC-XI

Budapest, Hungary, 20–26 September 2000

Members of the International TOVS Working Group at ITSC-XI

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1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Eleventh International TOVS Study Conference – ITSC-XI – was held in Budapest, Hungary from 20-26 September 2000. Eighty-seven participants attended the Conference and provided scientific contributions. Twenty countries, four international and many national organisations were represented: Australia, Brazil, Canada, China, France, Germany, Hungary, Iceland, Italy, Japan, New Zealand, Norway, Romania, Russia, Senegal, Sweden, Switzerland, Taiwan, the United Kingdom, the United States of America, ECMWF, EUMETSAT, WMO, the IRC, NASA and NESDIS.

The agenda for ITSC-XI can be found at Appendix A. Most of the meeting was occupied with scientific presentations on a range of issues: Radiative Transfer Modelling; 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.

Section 4 of this report records the abstracts of all scientific contributions. The corresponding papers are published separately as the *Technical Proceedings of The Eleventh 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 Modelling; TOVS and ATOVS in numerical weather prediction; TOVS and ATOVS in climate studies; advanced infrared sounders; and international issues and future systems. The Working Groups reviewed recent progress in these areas, made recommendations on key areas of concern and identified items for action. Working Group reviews and recommendations comprise Section 2 of this report. A new Working Group, which met for the first time at this Conference, provided the summary given in Section 2.6.

During the Conference, a session on Status Reports considered summaries of allied meetings and activities that had taken place since ITSC-X. It also reviewed progress on the Action Items identified by ITSC-X Working Groups. Many of these items formed the basis for further discussion by Working Groups at ITSC-XI.

Several technical sub-groups met during ITSC-XI to discuss developments and plans concerning specific software packages shared and in common use in TOVS and ATOVS processing centres. Brief reports on these sub-group meetings are recorded in Section 3.

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

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

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

- Firm evidence is emerging of the utility of the TOVS/ATOVS data over land in Northern Hemisphere NWP;

- The contribution of satellite sounding data to the integrated global observing system is vital and increasing;

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

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

- There is a need to emphasise climate activity and establish links with climate community;

- NASA is to be complimented for their plan to launch an advanced geostationary sounder. This sounding system provides an opportunity for operational agencies to include information from this system in the development of their own plans;

- There is a need to develop further the interface with the CBS of WMO;

- 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;

- 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;

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

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

- The SSMIS will provide important upper atmospheric observations. Access to SSMIS data and the related data archive is important; and

- Easy access to radiance data at NOAA/NESDIS after the transition to NPOES needs to be established.

Conclusions and recommendations are summarised below.

1.2 CONCLUSIONS AND RECOMMENDATIONS

As a result of the activities of the Working Groups and their reports to the Conference, the following actions and recommendations were adopted during the ITWG meeting at ITSC-XI. More details related to specific technical recommendations and actions are given in the Working Groups' full Reports in Section 2 and the Reports of Technical Sub-Groups in Section 3.

ACTIONS AND RECOMMENDATIONS

RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING:

Review of RT Model Intercomparison (section 2.1.1)

Actions

L. Garand (AES/MSC) to submit the draft report to a refereed journal summarizing the intercomparison (24 co-authors);

D. S. Turner (AES/MSC) should make available the more specific report on IR LBL intercomparison to all members of Working Group after completion of internal review;

L. Garand (AES/MSC) will maintain the web site on the intercomparison until the next ITSC (atmospheric profiles and all model results can be downloaded from the site).

Diverse profiles (section 2.1.2)

Actions

F. Chevallier (ECMWF) to inform the ITWG when the 60-level water vapour/ozone profile dataset is available;

R. Saunders (UKMO) / M. Matricardi (ECMWF) to make available, to the ITWG, the 117 profile GENLN2/LIEBE transmittance dataset for independent validation of fast RT models for ATOVS and IASI.

Instrument characteristics required for RT modelling (section 2.1.3)

Recommendation

Space agencies should measure and characterise the total system spectral response of future IR and MW radiometers, spectrometers and interferometers to an accuracy such that changes in modelled radiances due to uncertainties in the response are well below the instrument noise.

Actions

T. Kleespies (NESDIS) to put AMSU band pass filter frequency characteristics in Annex D of the NOAA-KLM users guide and to provide a link to M. Chalfant's web site for more detailed HIRS filter responses;

T. Kleespies (NESDIS) to investigate if AMSU-A band pass filter shapes are available and, if they are, to investigate their impact on the measured radiances;

T. Kleespies (NESDIS) to provide a 'one stop' page giving links to sites for NOAA instrument characteristics;

B. Burns (Aerojet) to make available the SSMIS band pass filter characteristics to the ITWG.

LBL model status (section 2.1.4)

Action

R. Saunders (UKMO) to make the IASI LBL intercomparison report available to ITWG.

Recommendation

All centres creating LBL model transmittance datasets to coordinate activities with other centres to enable as wide as possible use of these datasets which are expensive to create.

Fast RT model status (section 2.1.5)

Recommended areas for fast RT model future developments:

- Improve accuracy of water vapour and ozone transmittance and Jacobian simulations;
- Include solar reflection term in IR models;
- Improve representation of surface scattering in models;
- Pursue work on neural networks (noting difficulty is obtaining accurate Jacobians);
- Pursue development of fast physical models;
- For newly developed ATOVS fast models, a comparison should be made with the Garand dataset;
- Extend model capabilities to include aerosols, clouds (liquid and ice) and precipitation;
- Fast models should have a specific transmittance for all variable gases, including CO_2 and the water vapour continuum;
- More work required on how to combine gas transmittances such that the product of individual transmittances equals the total transmittance is recommended as with more variable gases, it will be more complex to combine transmittance ratios;
- Future intercomparisons should be able to compare each variable gas transmittance in order to better understand the cause of differences;
- The optimal number of levels (pressure or absorber space) for advanced sounder RT models should be investigated ;
- Fast RT models for advanced sounders should be further optimised to allow a flexible combination of channels and/or 'super channels' to be computed fast enough to allow real time data assimilation of >200 channels for every AMSU-A FOV.

Surface property models (section 2.1.6)

Recommendations
To further improve microwave emissivity estimation, it is important for the community to:

- Compute a dry land surface emissivity atlas and then convolve with the water amount based on river/lake area and, perhaps later, recent precipitation from the model;
- Compare the various emissivity atlases now being produced to identify where there are significant differences between them;
- Encourage the various efforts for developing better land and sea surface models which are not specific to one instrument only;
- In addition, aircraft measurements of microwave surface emissivity are required over land and over sea for higher wind speeds; and
- Physical polarimetric emissivity models should be developed for future instruments.

Action
R. Saunders (UKMO) and P. Van Delst (NESDIS) to investigate if ship interferometer data exist for high surface wind speeds.

Recommendations
To further improve the estimation of IR emissivities, the community needs to:

- Develop fast IR surface emissivity models (codes) for generic land surface types;
- Obtain measurements of IR surface emissivity over land and over sea for higher wind speeds.

TOVS/ATOVS DATA IN CLIMATE STUDIES:

Status of Pathfinder long-term data sets from satellite-borne sounders (section 2.2.1)

Recommendation (to NESDIS and EUMETSAT):
The ITWG again expresses its appreciation for dissemination of 1b data to Pathfinder and re-analysis groups and encourages continued low-cost, efficient dissemination of data from future instruments, including METOP, NPOESS, and ATOVS.

Recommendations (to Satellite Agencies, in particular):
Future infrared sounding instruments should observe radiances covering the same spectral bands as HIRS to ensure that its data record will be continued for as long as possible.

Recommendation
Overall, the Group advocates continued support of Pathfinder activities into the AMSU and HIRS/3 era and beyond, with the goal of establishing the longest possible data record for climate research.

Re-analysis data sets (section 2.2.2)

Recommendation
The Group advocates a program to intercompare existing climate data sets, such as Pathfinder Path A, B, C and P; Spencer and Christy's MSU 2R and MSU 4; and NCEP and ECMWF reanalyses; especially from the point of view of global and regional interannual variability and trends.

Contributions from ATOVS (section 2.2.3)

Recommendation
Efforts should be focussed on relationships between microwave brightness temperatures and view angle, defining land surface characteristics in terms of spectral and polarization behavior, and combining data from conical scanners with those from cross-track scanners.

Calibration, validation, and continuity issues (section 2.2.4)

Recommendation
Information regarding bias corrections and tuning should be documented and made available to the community. In particular, the following specific information is useful:

- Radiance bias corrections summarized (by time, latitude, etc.) in digital form;
- QC and rejection statistics in digital form;
- A standard climatological radiosonde data set should be assembled and distributed;
- Radiance biases from reanalysis and Pathfinder projects should be intercompared to reveal changes in observing systems, data processing algorithms, sensors, and orbits.

Action : Bates, Scott, Saunders

USE OF TOVS/ATOVS IN DATA ASSIMILATION / NWP:

Evaluation and use of TOVS/ATOVS in DA/NWP (section 2.3.2)

Recommendation (to DA/NWP Centers)
The Working Group recommends the continued exchange of monitoring results and encourages each Center to develop their own Web page on which to post their results. A master document linking all Web pages will be developed and reside on the NWP SAF site with a link to the ITWG Web site so everyone can easily examine and compare results from other groups to theirs. As agreed

upon at the workshop on the use of ATOVS data in NWP held at ECMWF in 1999, the latitude bands to average will be 90-70N, 70-20N, 20N-20S, 20-70S, and 70-90S (*Action: S. English to coordinate*).

Recommendation (to DA/NWP Centers)
The Group recognizes the difficulty in implementing and validating radiance/retrieval data in a DA/NWP system and recommends that so-called one-observation experiments, which most Centers must do in order to verify the theoretical and measured impact of one datum, be posted on their Web page. Since there is more than one fast RTM used, it will indirectly measure the ability of each RTM to project radiance data information onto the atmospheric state variables. Indirectly, this will also indicate what are the effective measures of background and observational error statistics used at each Center. *(Action: C. Chouinard to coordinate).*

Recommendation (to ITSC)
The Group recommends continually updating the data usage survey (*Action: T. McNally to coordinate*).

Recommendation (to NOAA/NESDIS and EUMETSAT)
The Group recommends that the data providers do quality assurance of all data, including level 1b and level 1d. The quality of the data (including e.g. navigation) should be monitored at all stages including the final stage, where data 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 and/or to compute radiance differences from NWP models to more quickly and effectively identify data quality problems. The Group recognizes that it is easy to identify gross errors, while subtle errors are more difficult to detect. *Action: V. Tabor (NESDIS), (EUMETSAT)*

Recommendation: (to Space Agencies)
The Group recommends that NOAA/NESDIS investigate collaboration with Météo-France/CMS to transmit data from blind orbits (*Action: V. Tabor*)

Forward modelling (section 2.3.3)

Recommendation
The Working Group recognizes that the work in RTM for future instruments is progressing rapidly at various Centers. The RTM codes developed by each group (e.g. IASI/AIRS) does not follow the universal interface policy of RTTOV-6 and its predecessors. The Working Group is worried that these RTMs may be difficult to use at DA/NWP Centers.

Recommendation (to RTM developers)
The Group recommends the use of a common interface for radiative transfer modules (as much as possible). *Action: NWP SAF, P. van Delst, other RT developers.*

Future platforms and real-time access to data (section 2.3.4)

Recommendation (to WMO)
WMO/NESDIS/EUMETSAT should develop and publicize procedures for handling real-time data requests for external users.

Recommendation (to NASA NPP)
The Working Group requests more information on the decision to switch polarization on ATMS near-surface sounding channels from V to H (as compared to AMSU);

Recommendation (to Space Agencies)
The Working Group recommends the exploration of an additional 226-230 GHz channel to future microwave humidity sounders (AMSU-B, MHS follow-on) to assist with processing of ice water effects at 183 GHz.

ADVANCED INFRA-RED SOUNDERS:

New initiatives for geostationary sounding (section 2.4.2)

Recommendation
ITWG recommends that operational agencies make use of present and forthcoming information from the GIFTS mission in studies of user requirements for possible future operational systems.

Distribution of AIRS datasets (section 2.4.3)

Recommendation (to NOAA)
The ITWG recommends that data transfer links needed for routine transfer of AIRS radiance and retrieval products be established many months prior to the launch of Aqua so that simulated AIRS data can be used to develop and improve data processing and assimilation procedures for AIRS.

Data processing, inversion and assimilation (section 2.4.4)

Recommendation (to satellite agencies)
ITWG recommends that ingest code for advanced sounder data should be made available to user community, to permit effective exploitation of direct read-out data.

Recommendation (to EUMETSAT)
ITWG recommends that EUMETSAT considers the integration of IASI level 1 ingest code into an extended version of the AAPP software via activities in the EUMETSAT SAF for NWP.

Recommendation (to IPO)
ITWG recommends that IPO plan for initial distribution of CrIS ingest code to users 1-2 years before the launch of the NPP satellite.

Recommendation
ITWG encourages its members to participate in the co-operative development of common pre-processing and retrieval packages for advanced sounders. It recommends the evolution and extension of existing ATOVS pre-processing and retrieval packages to provide processing capability for advanced sounder data.

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

Recommendation
ITWG encourages its members to develop faster radiative transfer models with adequate accuracy in both the direct calculation and its Jacobian.

Recommendation
ITWG encourages its members to continue to focus efforts on improving cloud detection for advanced sounder data.

Recommendation
ITWG supports the scientific and technical developments required to use coincident MODIS data to improve the cloud detection for AIRS.

Recommendation
ITWG encourages research into the assimilation of cloud-affected radiances, as this may be crucial to the effective exploitation in NWP of advanced sounder data from meteorologically sensitive areas.

Recommendation (to NASA/Langley)
ITWG encourages the compilation and distribution of a data set of advanced sounder data covering a wide and representative range of cloud conditions, to assist research on the retrieval of cloud parameters from advanced sounder data.

Characterisation of spectral response (section 2.4.6)

Recommendations (to space agencies)
ITWG recommends that the spectral responses of advanced sounders should be characterised to a level at which the associated error is tolerable within the total noise budget of the instrument.

ISSUES AND FUTURE SYSTEMS:

Review (section 2.5.1)

Recommendation (to CGMS and WMO)
ITWG encourages CGMS and WMO to consider coordination of polar-orbiting equator crossing times to optimize satellite utilization while minimizing potential conflicts in data reception.

Recommendation (to NASA and RASA)
ITWG encourages NASA to consider placing the NPP sounder in a PM orbit. ITWG also encourages RASA to finalize manufacturing of the very high spectral resolution IFRS and launch it on METEOR 3M N2 in 2003.

Action (co-Chairs)
ITWG co-Chairs to contact SFCG to initiate the process for ITWG becoming an observer at SFCG meetings. Co-Chairs should also act as the focal point to identify the appropriate ITWG member to attend SFCG meetings and to find the necessary financial resources.

Action (co-Chairs)
ITWG to augment its present web site to contain education and training information and relevant links and to forward the links to the WMO specialized "centres of excellence".

Action (co-Chairs)
ITWG co-Chairs to initiate action to augment the ITWG web site to include information on relevant software system updates and changes as well as on information and contact points for groups beginning to work in the sounding area.

Action (co-Chairs)
ITWG co-Chairs to write to the President of CBS to express ITWG's appreciation for inclusion in the work of past OPAG IOS Expert Teams and its willingness to continue to provide its expertise on future Expert Teams.

Recommendation (to WMO)
ITWG encourages WMO to send Statements of Guidance from the OPAG IOS Expert Team Meetings to ITWG with the expectation that any feedback would serve as input to the following Expert Team Meeting.

Action (co-Chairs)
ITWG co-Chairs to solicit feedback from an adequate number of ITWG members and provide it to WMO within four months.

Action (co-Chairs)
ITWG co-Chairs to inform the Chairman of the GCOS Steering Committee and its relevant discipline Panel Chairmen (AOPC, OOPC and TOPC) of ITWG's available expertise and willingness to assist in climate monitoring activities.

Recommendation (to CGMS and WMO)
ITWG encourages CGMS and WMO to review the monitoring procedures and practices for satellite data and products placed on the GTS with a goal towards improving them. The review should also identify the future monitoring policy once the Initial Polar System of NOAA/NESDIS and EUMETSAT becomes operational.

Recommendation (to WMO)
ITWG encourages WMO to increase the GTS capacity including through the implementation of the Distributed Database System Concept.

Action (co-Chairs)
ITWG co-Chairs to seek information from CGMS as to plans for production and distribution of International Polar System (IPS) products to be distributed over the GTS.

Recommendation (to CGMS)
ITWG requests CGMS seek clarification from the NPOESS Integrated Program Office (IPO) as to the availability of radiance products as part of the suite of NPOESS SDRs.

Action (co-Chairs)
ITWG co-Chairs to write and express its appreciation to NASA for activities that established direct readout access as well as software processing packages for AIRS, AMSU-A (and HSB), and MODIS. These will allow timely use of the data for operations and research. The addition of ingest software for AIRS and software for processing AMSR-E should also be requested. Finally, a similar activity for the NPP mission should be suggested.

Recommendation (to CGMS)
ITWG requests CGMS clarify the situation concerning the availability of SSMIS data.

2. WORKING GROUP REPORTS

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING[1]

Working Group members: R. Saunders and L. Garand (Co-Chairs) with P. Brunel, B. Burns, F. Chevallier, G. Deblonde, A. Doherty, S. English, S. Gu, T. Kleespies, C. Koepken, A. Korpela, M. Matricardi, L. McMillin, M. Mueller, G. Rochard, V. Sherlock, A. Thoss, M. Uddstrom, P. Van Delst, P. Wang, F. Weng, H. Woolf, X. Wu, W. Zhang and G. Zhao.

2.1.1 Review of Radiative Transfer (RT) Model Intercomparison

One of the recommendations from the ITSC-X meeting of the technical sub-group on fast RT models was a fast model intercomparison of ATOVS channels (see Section 3.4.4 of the ITSC-X report). This followed on from the successful comparison of HIRS-12 radiances carried out by B. Soden during the GEWEX water vapour project (GVaP) which was published in BAMS (Vol. 81, 2000). L. Garand has coordinated this new study with 29 models compared, some line-by-line (LBL) some fast models for a subset of 7 HIRS and 4 AMSU channels. Not only were the forward model brightness temperatures compared but also the Jacobians (analytical or brute force) for the radiances with respect to temperature, water vapour and ozone. The results were presented to the ITWG during ITSC-XI. The ITWG thanked L. Garand for this extremely valuable study which will benefit all fast RT model developers and users. The main conclusions were:

- IR line by line (LBL) models typically agree to within 0.1 K, but up to 0.2 K (standard deviation) for some channels such as HIRS-12. Some differences (up to 0.6 K) still exist, some systematic (HIRS-5), others with a dependence on air-mass. It is recommended that differences in excess of 0.15 K be studied.

- No one IR fast model reaches the desired accuracy of 0.25 K in all channels but that accuracy is achieved by at least one model in all channels. Largest differences are seen in water vapour channels. The amplitude and sign of the differences are often a function of the type of air mass. Fast models need to be tuned in some way to an accurate LBL reference. Using a less accurate narrow-band model (such as Modtran) for that purpose is not recommended.

- The Jacobian study revealed subtle forward model errors which otherwise were difficult to detect. Secondly, it provided clues on the causes of differences. It was observed that models which appear accurate for brightness temperatures (BT) may still have deficiencies in their Jacobians. It is believed this is the first dataset of LBL Jacobians against which fast models can be compared.

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[1] This is a new Working Group established to focus on issues related to atmospheric radiative transfer (RT) and surface property models which are relevant for radiance assimilation and retrievals from sounder data. The technical sub-group on fast RT models was amalgamated with this group.

- Fast IR models which use a physical formulation of transmittances (as opposed to regression) appear promising. At the moment no attempt has been made to develop a fast physical MW model.

- MW fast modeling appears to be relatively easy with accuracies of 0.1 K or better obtained against the LBL used to develop the fast model. The main issue in microwave modeling is that significant differences were found among LBL models.

- If possible, both LBL and fast models were corrected as a result of this intercomparison. Since errors were not obvious to the same degree in all channels, the variety of analysed channels was important.

Actions

(a) L. Garand (AES/MSC) to submit the draft report to a refereed journal summarizing the intercomparison (24 co-authors);

b) D. S. Turner (AES/MSC) should make available the more specific report on IR LBL intercomparison to all members of working group after completion of internal review;

(c) L. Garand (AES/MSC) will maintain the web site on the intercomparison until the next ITSC (atmospheric profiles and all model results can be downloaded from the site).

2.1.2 Diverse profiles

Radiative transfer models require a dataset of diverse profiles for coefficient generation and independent validation. Several radiosonde based datasets exist (e.g. NOAA-88, TIGR-3) supplemented with UARS data above the radiosonde measurements. F. Chevallier (ECMWF) presented plans to generate a dataset of 2 million diverse profiles from the 60-level ECMWF forecast model analysed fields for temperature, water vapour and ozone. The working group encouraged this activity but made the following comments:

- The top level of this dataset will be at 0.1 hPa. For some channels this is not high enough and so there is still a need to extend the profiles above this level. UARS data may be of use for this. L. McMillin reported that rocket sonde and SBUV data had been added to the NOAA-88 profile dataset. B. Burns also informed the group that she has a dataset which may provide some idea of the temperature variability at these low pressures.

- It was agreed that profiles with low surface pressures (e.g. over Antarctica) should still be included in the dataset so long as there were no more than 10% in the dataset and the profile is still extrapolated to the maximum pressure.

- The WG recommended that about 80 profiles are sufficient for creating the LBL transmittance datasets from which the fast model coefficients for fixed gases, water vapour and ozone are computed, however more may be required for minor gases.

- Diverse profile datasets of variable minor gases (e.g. CH_4, CO, N_2O, CO_2) should also be generated soon to allow the new advanced IR sounders to retrieve their profile concentrations and also to improve the retrieval of temperature, water vapour and ozone.

Actions

(a) F. Chevallier (ECMWF) to inform the ITWG when the 60-level water vapour/ozone profile dataset is available;

(b) R. Saunders (UKMO)/M. Matricardi (ECMWF) to make available to the ITWG the 117 profile GENLN2/LIEBE transmittance dataset for independent validation of fast RT models for ATOVS and IASI.

2.1.3 Instrument characteristics required for RT modelling

T. Kleespies reported to the group that comparing RT model results using the NOAA 15 AMSU-A1 specified band pass filters with the actual measured values gave differences of greater than 0.1K for AMSU channels 12 and 14. The corresponding NOAA-16 differences were smaller, indicating that the AMSU-A1 instrument on this satellite is closer to the specified band pass filters.

A poster presented at ITSC-XI by B. Burns also showed differences in simulated radiances for the SSMIS instrument as specified and as measured. Information on the AMSR-E bandpass filters was requested from NASA.

There was some discussion on which recommended values of the fundamental physical constants to use in both instrument calibration and RT models. The latest (1998) values are at: http://physics.nist.gov/cuu/Constants/ . T. Kleespies reported that he had found no significant differences between the latest values and the 1986 values in terms of RT model calculations.

The WG was also tasked by CGMS to report on the quantification of the required accuracy for spectral response specifications to reduce errors in the forward modelling of satellite radiances. The WG recommended:

Recommendation

Space agencies should measure and characterise the total system spectral response of future IR and MW radiometers, spectrometers and interferometers to an accuracy such that changes in modelled radiances due to uncertainties in the response are well below the instrument noise.

Actions

(a) T. Kleespies (NESDIS) to put AMSU band pass filter frequency characteristics in Annex D of the NOAA-KLM users guide and to provide a link to M. Chalfant's web site for more detailed HIRS filter responses;

(b) T. Kleespies (NESDIS) to investigate if AMSU-A band pass filter shapes are available and, if they are, to investigate their impact on the measured radiances;

(c) T. Kleespies (NESDIS) to provide a 'one stop' page giving links to sites for NOAA instrument characteristics;

(d) B. Burns (Aerojet) to make available the SSMIS band pass filter characteristics to the ITWG.

2.1.4 LBL model status

An intercomparison of twelve IR LBL models (some runs of the same model at different centres) was carried out by the IASI Science Sounder Working Group coordinated by S. Tjemkes (EUMETSAT). The study focused on high spectral resolution channels by simulating IASI spectra for model and real atmospheres. The latter have co-incident aircraft or ground-based intereferometer measurements with which the simulated spectra can be compared. A report on the results will be presented shortly.

It was reported that the most recent water vapour continuum correction is CKD version 2.4. New versions of the spectral line databases (HITRAN and GEISA) are about to be released in the coming year and will include enhancements such as the improved water vapour line parameters. The 4A and kCARTA approach is being more widely adopted as a way to efficiently store the LBL transmittances.

Action

R. Saunders (UKMO) to make the IASI LBL intercomparison report available to ITWG.

Recommendation

All centres creating LBL model transmittance datasets to coordinate activities with other centres to enable as wide as possible use of these datasets which are expensive to create.

2.1.5 Fast RT model status

2.1.5.1 Status

The current status of the fast RT models was reviewed by the group:

- **RTTOV-6:** This is now adapted to support simulations for many instruments (i.e. ATOVS, SSM/I, TMI, MVIRI/SEVIRI, GOES (imager and sounder) and AVHRR). It includes cloud water in the MW and the simulation of AMSU-B water vapour channel transmittances has been significantly improved;

- **OPTRAN:** Supports ATOVS, AVHRR, SSM/T, SSM/T-2, GOES (imager/sounder), GMS, and MVIRI. Two versions are now being developed one for optimal use within the NCEP model and one for more general use outside the model.

- **PLOD/PFAAST:** used with success for AIRS simulations. No analytical Jacobian routines available. PLOD is based on LBLRTM and PFAAST on kCARTA.

- **MSC-FAST:** Physical model adapted to a limited number of NOAA and GOES platforms. Allows cloud layers and analytical Jacobians. Specific transmittances for all gases. Operates on any vertical coordinate.

- For AIRS and IASI simulations, **PFAAST, OPTRAN** and **RTIASI** are under development and for CrIS a fast model developed by AER (**OSS**) with analytic Jacobians is being used.

2.1.5.2 Recommended areas for fast RT model future developments

- Improve accuracy of water vapour and ozone transmittance and Jacobian simulations;

- Include solar reflection term in IR models;
- Improve representation of surface scattering in models;
- Pursue work on neural networks (noting difficulty is obtaining accurate Jacobians);
- Pursue development of fast physical models;
- For newly developed ATOVS fast models, a comparison should be made with the Garand dataset;
- Extend model capabilities to include aerosols, clouds (liquid and ice) and precipitation;
- Fast models should have a specific transmittance for all variable gases, including CO_2 and the water vapour continuum;
- More work required on how to combine gas transmittances such that the product of individual transmittances equals the total transmittance is recommended as with more variable gases, it will be more complex to combine transmittance ratios;
- Future intercomparisons should be able to compare each variable gas transmittance in order to better understand the cause of differences;
- The optimal number of levels (pressure or absorber space) for advanced sounder RT models should be investigated ;
- Fast RT models for advanced sounders should be further optimised to allow a flexible combination of channels and/or 'super channels' to be computed fast enough to allow real time data assimilation of >200 channels for every AMSU-A FOV.

2.1.6 Surface property models

2.1.6.1 Microwave emissivity

For land surfaces, dynamically updated maps of surface emissivity are now available from the NESDIS web site (http://orbit18i.nesdis.noaa.gov/html/day2_datatab.html) for AMSU channels 1-3. Modelling surface emissivity at higher frequencies is more problematic. Better scattering models are required above 10 GHz. The use of the AVHRR NDVI product may be a useful input to the models. The Southern Great Plains project may provide some useful validation of these models.

For the sea surface, FASTEM2 and the Hollinger model have been developed for AMSU and the model from L. Phalippou is used for SSM/I. Attempts are being made to unify these models for both instruments. Uncertainties in the Bragg scattering and foam cover exist for windspeeds above 7 m/s. Polarimetric emissivity models are now under development although they are semi-empirical.

Recommendations

To further improve microwave emissivity estimation, it is important for the community to:

> **Compute a dry land surface emissivity atlas and then convolve with the water amount based on river/lake area and perhaps later recent precipitation from the model;**
>
> **Compare the various emissivity atlases now being produced to identify where there are significant differences between them;**
>
> **Encourage the various efforts for developing better land and sea surface models which are not specific to one instrument only;**
>
> **In addition, aircraft measurements of microwave surface emissivity are required over land and over sea for higher wind speeds; and**
>
> **Physical polarimetric emissivity models should be developed for future instruments.**

2.1.6.2 Infrared surface emissivity

The Masuda model has been parameterised by several groups for use with fast RT models, some of which include a wind speed dependence. For high windspeeds (>5 m/s) and large zenith angles uncertainties still exist and so as - with the microwave models - more validation measurements are required for high wind speeds.

Action

> **R. Saunders (UKMO) and P. Van Delst (NESDIS) to investigate if ship interferometer data exist for high surface wind speeds.**

Datasets exist of measured surface emissivity for a variety of different land surface types and are available as an ASTER CDROM (http://speclib.jpl.nasa.gov/).

The CERES dataset of a 10 arc-minute atlas of surface type is also available at (http://tanalo.larc.nasa.gov:8080/surf_htmls/SARB_surf.html). As with the microwave, the recommendation (above) to compute a dry surface emissivity is equally applicable to the IR. MODIS data may also contribute in defining the atlas of surface types necessary for this work. Some limited surface emissivity measurements are available (e.g. down-looking AERI).

Recommendations

To further improve the estimation of IR emissivities, the community needs to:

> **Develop fast IR surface emissivity models (codes) for generic land surface types;**
>
> **Measurements of IR surface emissivity are required over land and over sea for higher wind speeds.**

2.2 TOVS/ATOVS DATA IN CLIMATE STUDIES

Contributors : J. Bates, P. Menzel, J. Le Marshall, G.Rochard, ITWG Plenary

2.2.1 Status of Pathfinder long-term data sets from satellite-borne sounders

As a result of there being several fundamentally different approaches to the retrieval of climate information from the TOVS data, the TOVS Pathfinder Working Group recommended that at least three approaches be pursued. As noted at ITSC-X, these three approaches differ in their use of model dynamical constraints and *a priori* data. *Path-A* is model dependent and *a priori* data dependent, *Path-B* is model independent and *a priori* data dependent, and *Path C* is model independent and *a priori* data independent. These distinctions are important, since the dependencies on model constraints and/or on *a priori* data can lead to complex error structures in the retrieved data.

In addition to these original TOVS Pathfinder studies, several other Pathfinder approaches have evolved. These include a Path-P polar pathfinder using the Path-B approach but with adjustments specifically tailored for the Arctic, an Ozone Pathfinder using a neural network approach, a Radiance Pathfinder specifically examining the radiance data set and performing comparisons in radiance space, and a Stratospheric Pathfinder examining the long term data set from the SSU. A brief summary of the activities of these Pathfinders follows.

2.2.1.1 Pathfinder Path-A (NASA/Goddard Space Flight Center - GSFC)

The TOVS Pathfinder Path-A dataset covers the fourteen year period 1985 - 1998. Products include global surface skin temperature; surface air temperature and mandatory level temperatures from 1000 hPa - 30 hPa; surface specific humidity and mandatory level specific humidity to 300 hPa; fractional cloud cover and cloud top pressure; outgoing long-wave radiation (OLR) and clear sky OLR, which are computed from the soundings, including and excluding cloud effects; and a precipitation estimate. The soundings are gridded daily on a 1 deg. x 1 deg. latitude/longitude grid separately for ascending and descending orbits and for each satellite. Intercomparison of monthly mean values measured at different times of day by the same and/or by different satellites during the 14-year period shows clear signals related to diurnal variability and orbit drift for all products. This drift must be accounted for before the data can be used to study interannual variability and possible trends. A methodology has been developed to account for differences between observations taken by different satellites based only on observing time changes. Spurious signals arising from different satellite instrumentation are small.

2.2.1.2 Pathfinder Path-B (Laboratoire de Meteorologie Dynamique- LMD)

Eight years (January 1987 - August 1994) of the Path-B data set have been processed using the Improved Initialization Inversion ("3I") algorithm at the LMD. Products include temperatures and virtual temperatures in nine layers between 1000 and 10 hPa, mean temperatures in four deep layers between the surface and 30 hPa, precipitable water above 5 tropospheric pressure levels, surface skin temperature, a variety of cloud parameters, and several additional quantities. These variables are computed separately for morning and afternoon orbits for each satellite and are gridded to 1 deg. x 1 deg. latitude/longitude globally at daily, five-day, and monthly temporal resolutions.

Numerous important improvements have been made to the 3I algorithm, and extensive product validation has been performed. The primary updates include an expanded Thermodynamic Initial Guess Retrieval (TIGR) library to include more tropical situations with high moisture content; a new method to compute the empirical radiance corrections; a new water vapor retrieval method that employs a neural network approach; and significant improvements to the algorithm for cloud property retrievals. In addition, a new neural-network-based fast radiative transfer code has been developed for computing longwave flux profiles.

A comprehensive paper describing the Path-B data set and algorithm modifications appeared the *Bulletin of the American Meteorological Society* in December 1999.

2.2.1.3 Pathfinder Path-C MSU (NASA/NOAA)

Path-C activities have concentrated on the use of MSU data for monitoring the temperature in deep layers. Considerable interest and debate continue following the use of the MSU for detecting global lower tropospheric temperature trends. Temperature soundings from the NOAA polar-orbiting satellites remain the only truly global observations of the earth's temperature structure. The MSU channel 2 data have been used more than the HIRS data because of the near all-weather capabilities of the microwave and the considerably lower data volume in comparison to those from the HIRS. Another advantage of the microwave is that the radiance observations are linear with temperature. Noting this, observations near nadir and at the limb have been combined into a new weighting function peaking in the lower troposphere.

Numerous adjustments, however, must be made to the observational record in order to obtain long, continuous time series. Within the context of the use of TOVS in numerical weather prediction (NWP), the subject of radiance bias tuning has a long history. For the NWP problem, identification of the sources of bias were not critical, only that they could be removed. For long-term climate studies, the sources of bias include all those traditionally identified for the NWP problem, including radiative transfer model errors, use of inexact response functions and in orbit calibration drifts.

Other important considerations, particularly for climate studies, include drift of the satellite orbital time, changes in the satellite altitude, and, for the microwave, secular changes in the surface emissivity. A data set containing MSU temperatures and rainfall has been produced by the NASA Marshall Space Flight Center.

2.2.1.4 Radiance Pathfinder and Path-C HIRS (NOAA/ERL Climate Diagnostics Center and NOAA/NESDIS Office of Research and Applications)

The philosophy of the TOVS radiance Pathfinder is simple: all information from the operational temperature and moisture sounders is contained in the raw radiance data. What is needed is easy access at a variety of different user experience levels, full documentation, and tools that allow users to effectively compare data and climate models. The TOVS radiance Pathfinder is modelled on the very successful International Satellite Cloud Climatology Project and will provide a reduced volume data set of climate observations using the operational sounding instruments on the NOAA polar orbiting satellites. The TOVS radiance Pathfinder activities involve documenting and improving understanding of the TOVS instruments, including the end-to-end instrument response, studying and documenting the in-orbit performance of the TOVS instruments, producing an all-sky and clear-sky radiance data set, using these data, particularly the water vapor channel data, in studies of climate and global change, and applying techniques to retrieve mean layer temperature, OLR, cooling rates, and cloud information using the HIRS.

2.2.1.5 Pathfinder Path-P (University of Washington/Rutgers University)

Eighteen years of the NASA/NOAA TOVS Polar Pathfinder data set, the so-called Path-P, was completed in late 1998. The 3I algorithm, with some special modifications for polar environments, was used to process HIRS and MSU radiances at 100 km resolution across the region north of 60 degrees N latitude. The data set contains a suite of atmospheric and surface products, including temperature at ten levels below 50 hPa, moisture in five layers below 300 hPa, surface skin temperature, cloud parameters, boundary layer variables, and an assortment of other information. Daily fields from 1979-1996 are available from the National Snow and Ice Data Center (NSIDC). Extensive validation of the data set has been performed. Temperature and moisture profiles have been compared to radiosondes from Russian meteorological stations drifting on the Arctic sea ice. Root mean square errors are generally about 3K for temperatures and 30% for precipitable water. Biases are near zero. Comparisons with surface observations show that clouds are identified with high accuracy and the annual cycle of cloudiness in the Arctic is properly captured. This result is in contrast with other satellite-derived cloud climatologies, such as the ISCCP D series, which appear to have difficulty in detecting clouds over sea ice. Surface temperatures show little bias, and have r.m.s. errors of approximately 4.5 K.

2.2.1.6 Ozone Pathfinder Data Set Path-O_3 (Germany)

A TOVS pathfinder project (Path-O3) has been funded by the German Government (BMBF) as a part of the German Ozone Research Program (OFP). The TOVS project started in July 1997 with the development of a new neural network total ozone retrieval scheme to compute ozone amounts from the entire TOVS level 1b data record. The goal is to produce a consistent, global, 0.5 degree resolution, 20-year total ozone dataset. The advantage of the TOVS data for ozone retrieval, compared to other satellite instruments (e.g. TOMS, SBUV, and GOME) that rely on measurements in the solar spectrum, is that ozone can be retrieved during the night as well in daylight. This is particularly important in polar regions during winter. An additional advantage of this method is the availability of a global 20-year record of TOVS data with concurrent temperature and moisture profile retrievals, which provides a good basis for analysing dynamic and anthropogenic effects on the ozone layer.

All NOAA-12 data have been processed and compared to ground truth measurements from the World Ozone and UV-radiation Data Center (WOUDC). The RMS error in all atmospheric conditions (clear, cloudy, day, night) is about 10 Dobson units.

2.2.1.7 Recommendations in relation to Pathfinder Activities

In relation to Pathfinder activities in general, the following recommendations are provided to NESDIS and EUMETSAT.

Recommendation (to NESDIS and EUMETSAT)

The ITWG again expresses its appreciation for dissemination of 1b data to Pathfinder and re-analysis groups and encourages continued low-cost, efficient dissemination of data from future instruments, including METOP, NPOESS, and ATOVS.

Recommendations (to Satellite Agencies, in particular):

Future infrared sounding instruments should observe radiances covering the same spectral bands as HIRS to ensure that its data record will be continued for as long as possible.

Recommendation

Overall, the Group advocates continued support of Pathfinder activities into the AMSU and HIRS/3 era and beyond, with the goal of establishing the longest possible data record for climate research.

2.2.2 Re-analysis data sets

Summaries for all re-analysis activities were provided in the ITSC-IX Climate Working Group Report. This report updates plans for the use of satellite data in the ECMWF 40-year re-analysis project, ERA-40.

2.2.2.1 ERA-15 and ERA-40

The ECMWF 15-year (1979-1993) re-analysis data sets are available to the scientific community either from ECMWF directly or for the U.S. research community from NCAR. The ECMWF has now started a 40-year reanalysis (1958-1998) using the 3Dvar assimilation system. VTPR and TOVS 1b radiances will be directly assimilated. It should be noted that this working group at ITSC-X recommended that the radiance monitoring statistics be retained in electronic form for the VTPR and TOVS radiances.

Recommendation

The Group advocates a program to intercompare existing climate data sets, such as Pathfinder Path A, B, C and P; Spencer and Christy's MSU 2R and MSU 4; and NCEP and ECMWF reanalyses; especially from the point of view of global and regional interannual variability and trends.

2.2.3 Contributions from ATOVS

The addition of microwave channels from the AMSU-A and AMSU-B instruments on ATOVS greatly expands the number of climate parameters that can be observed. Also, interest has expanded in the use of the infrared data for climate studies of clouds and radiation.

2.2.3.1 Clouds and radiation

The NESDIS sounding systems (RTOVS/ATOVS) produces an array of climate products, including cloud-top pressure, cloud amount, cloud-top temperature, outgoing longwave radiation (OLR), layer radiative cooling rates, and ozone amounts. These products are created for each HIRS field of view. The RTOVS system also interpolates these products onto a 1-degree square latitude/longitude grid and a 512 x 512 pixel grid. These grids are archived.

2.2.3.2 Surface characteristics

Radiances from AMSU can be used operationally to measure a variety of surface properties, including sea ice extent and type, surface temperature, and vegetation/soil type. In particular, its sea ice monitoring capability will be valuable owing to its relatively high resolution, wide swath, and low sensitivity to clouds. AMSU-A has five surface-sensitive channels with 48 km resolution at nadir in the 23 to 89 GHz band. The AMSU-B 89 GHz and 150 GHz channels have a resolution of 16 km at nadir. These data will extend the 20-year record available from the SSM/I, SSM/T and SSM/T-2 instruments.

While the SSM sensors measure horizontal and vertical polarization in certain channels and have a conical scan with a constant view angle of 53 degrees, AMSU radiances have mixed polarisation and are measured at varying view angles. AMSU data from successive days and the location, however, contain different amounts of vertically and horizontally polarised radiation owing to the different look angles, thus polarisation-dependent information can be derived from AMSU data. Differentiation of sea ice and vegetation types, for example, depends on differences in polarization properties and emissivities of the surfaces. Emissivity values have been derived for SSM channels; additional research is needed to transfer these values to AMSU channels and verify their accuracy. One advantage of AMSU data is that IR imagery and soundings are available coincidentally, so that accounting for surface temperature and atmospheric effects is easier.

Recommendation

Efforts should be focussed on relationships between microwave brightness temperatures and view angle, defining land surface characteristics in terms of spectral and polarization behavior, and combining data from conical scanners with those from cross-track scanners.

2.2.4 Calibration, validation, and continuity issues

Calibrating our observations of the Earth's climate state remains a significant issue in using satellite data, conventional measurements, and model output in climate research. This research includes not only the detection of trends, but also studies of climate processes and large-scale patterns associated with climate change. The latter may not be as sensitive to calibration problems, but it is desirable to minimize the potential effects of observing system calibration problems and prevent the introduction of spurious climate signals that may result from orbit drift and decay, biases in model output, radiosondes, and/or inversion algorithms.

One solution to some of these issues is to cross-calibrate observations from similar instruments flying on low Earth orbit (LEO) platforms and those on geostationary orbit (GEO) satellites. Synergistic use of these similar instruments (e.g. HIRS channel 12 and water vapor channels on GOES Meteosat and GMS) could overcome some of the problems encountered in using data from one platform. For example, corrections for orbital drift and diurnal sampling are required in LEO data, while calibration and use of data taken with large view angles are issues for GEO data.

Recommendation

Overall, in relation to these issues, the following actions are recommended:

Information regarding bias corrections and tuning should be documented and made available to the community. In particular, the following specific information is useful:

- **Radiance bias corrections summarized (by time, latitude, etc.) in digital form;**
- **QC and rejection statistics in digital form;**
- **A standard climatological radiosonde data set should be assembled and distributed;**
- **Radiance biases from reanalysis and Pathfinder projects should be intercompared to reveal changes in observing systems, data processing algorithms, sensors, and orbits.**

Action : Bates, Scott, Saunders

Note : Due to an IPCC related meeting in Washington at the time of ITSC-XI, much of the work of the group was done by telecommunications.

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

Working Group members: C. Chouinard (Chair), J. Joiner (co-Chair), T. McNally (co-Chair) with J. Ackermann, T. Böhm, G. Deblonde, S. English, Z. Francesco, A. Gaye, B. Harris, G. Kelly, C. Köpken, T. Landelius, L. Lavanant, K. Okamoto, R. Randriamampianina, A. Sarr, R. Schraidt, H. Schyberg, A. Smith, V. Tabor, S. Thorsteinsson, F. Tveter, M. Uddstrom and W. Wolf.

2.3.1 Introduction

There were many substantive presentations at this meeting that indicated very positive results using satellite data. The very positive impact of the direct assimilation of radiance was reported by three NWP Centers that were previously using retrievals as their main source of satellite data.

During the last few years, there were a number of exchanges of code/results and techniques between groups, indicating that the satellite community continues to be very active. The formation of the NWP SAF in Europe is a good indicator of how well organized the exchanges of codes are between satellite data users/groups. The Working Group supports exchanges between groups, and encourages the use of either the Internet or other means of communication for this activity.

Preliminary results obtained at the UKMO (English et al.) indicate that RFI-corrected AMSU-B data can substantially improve humidity analyses. The Working Group encourages more studies on the use of AMSU-B to show the impact of this data in their DA/NWP systems. The bias correction appears to be working well in all channels with the exception of AMSU-B 4. In the same context, the recent implementation of the HIRS-12 moisture channel has proven very positive in the ECMWF analysis system, much as it has in the UKMO and NCEP systems where, for the last two years, they have been using it to improve their moisture analyses. Thus, even though the combined value of HIRS and AMSU-A is being questioned for temperature analysis, it appears that the combined value of AMSU-B and HIRS moisture channels is now very promising in DA/NWP.

There is renewed interest in the use of cloudy radiance data as indicated by the number of presentations focused on improving and understanding their use. Various approaches were used in these studies, 1) using a CO_2 slicing approach to increase IR data usage above cloud, 2) assimilation of cloud parameters (both microwave and IR), and 3), cloud-clearing. A few Centers are now performing forward calculations with cloud and are monitoring cloudy radiance innovations. This is the first step towards the assimilation of cloudy radiance data, and it provides a means to assess their usefulness and at the same time provides *a priori* estimates of errors.

There were a number of presentations on the use of, and/or retrieval and specification of, surface emissivity for both the microwave and infrared channels. This is very important work that will lead to better and particularly more extensive use of surface sensitive and window channels. The use of mid to upper peaking channels has been shown to be very positive at most DA/NWP Centers; however, the use of lower peaking and window channels is becoming critical in the large continental data void areas e.g. the Arctic and Antarctic. Similarly, large deserted areas could be better simulated with improved knowledge of surface emissivity.

Several Centers indicated they have developed or are developing mesoscale models and data assimilation systems. With the current and future availability of high-temporal-resolution satellite data, most DA/NWP groups would like to increase the utilization of satellite data in these systems. However, the Working Group realizes that the assimilation of higher resolution data, be it radiance or any other type in higher resolution analysis systems, is still a difficult problem. Generally, these systems also have shorter data cut off times and data needs to be delivered more rapidly (e.g. by direct readout) in order to be useful. The GIFTS compressed spectral data at 40 km, if available in one hour may be useful for both global and regional DA/NWP.

2.3.1.1 Reanalysis

There has been a considerable effort at a few major Centers in the preparation of conventional and particularly satellite data from historical data sets. Some of the Centers involved in reanalysis are willing to share these valuable datasets with the scientific community for experimentation. Given the limited resources available at most Centers, this is more than welcome.

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

Large biases between background and radiances (both level 1b and level 1d) still remain and it is crucial that Centers exchange monitoring results of biases and standard deviation of errors as estimated by their DA/NWP systems. As recommended at the last meeting, many Centers have developed internal or external monitoring websites to rapidly share these valuable results. However, because there are various technical difficulties in publishing these web pages (e.g. language, clearance) the exchange of monitoring results has mostly taken place on an informal basis.

Recommendation (to DA/NWP Centers)

In order to facilitate this type of exchange, the Working Group recommends the continued exchange of monitoring results and encourages each Center to develop their own Web page on which to post their results. A master document linking all Web pages will be developed and reside on the NWP SAF site with a link to the ITWG Web site so everyone can easily examine and compare results from other groups to theirs. As agreed upon at the workshop on the use of ATOVS data in NWP held at ECMWF in 1999, the latitude bands to average will be 90-70N, 70-20N, 20N-20S, 20-70S, and 70-90S (Action: S. English to coordinate).

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

Recommendation (to DA/NWP Centers)

The Group recognizes the difficulty in implementing and validating radiance/retrieval data in a DA/NWP system and recommends that so-called one-observation experiments, which most Centers must do in order to verify the theoretical and measured impact of one datum, be posted on their Web page. Since there is more than one fast RTM used, it will indirectly measure the ability of each RTM to project radiance data information onto the atmospheric state variables. Indirectly, this will also indicate what are the effective measures of background and observational error statistics used at each Center. Progress has been made in formulating such experiments since the last meeting. Due to rapid changes in analysis systems and other technical issues, the group recognizes the difficulties in

carrying out this type of experiment. However, we will continue to pursue this activity. (Action: C. Chouinard to coordinate).

At the last meeting, survey results on the usage of TOVS data at Centers was presented. The Working Group and data providers found this study to be very useful. Because the use and the requirement of data are rapidly changing, and in order to better serve the users, the following recommendation is provided.

Recommendation (to ITSC)

The Group recommends continually updating the data usage survey (Action: T. McNally to coordinate).

Preliminary results indicate that the majority of DA/ NWP Centers still rely upon NESDIS retrieved products and processed 1b and 1d data for their operational forecasting systems. The Group wishes to acknowledge this fact and support the continuing efforts of NOAA/NESDIS in this crucial role. In the future, EUMETSAT will also be involved in similar activities. There were questions of data integrity that were brought up at this meeting and the Working Group feels that Inter-agency collaboration in this capacity would be very beneficial.

Recommendation (to NOAA/NESDIS and EUMETSAT)

The Group recommends that the data providers do quality assurance of all data, including level 1b and level 1d. The quality of the data (including e.g. navigation) should be monitored at all stages including the final stage, where data 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 and/or to compute radiance differences from NWP models to more quickly and effectively identify data quality problems. The Group recognizes that it is easy to identify gross errors, while subtle errors are more difficult to detect. Action: V. Tabor (NESDIS), (EUMETSAT)

Some DA/NWP Centers have reported receiving irregular volumes of data during the course of one day; the data from NOAA-15 on occasion has a large fraction of orbits missing. It is possible that this problem may be related to blind orbits.

Recommendation: (to Space Agencies)

The Group recommends that NOAA/NESDIS investigate collaboration with Météo-France/CMS to transmit data from blind orbits (Action: V. Tabor)

2.3.3 Forward Modelling

Despite the substantial work on fast radiative transfer models in recent years, the Working Group notes that substantial errors in the forward models still exist. While some of the effects of the errors can be removed by bias correction, the removal of the errors by improving the forward model is a more satisfactory solution. While it is difficult to determine the source of all the errors, the Working Group believes that substantial improvements can be made in several areas. Substantial progress in the area has been made since the last meeting. The study of Garand et al. has been extremely valuable in identifying differences in transmittances and Jacobians of both line-by-line and fast radiative transfer models (RTM). The Group recognizes the need to continue work in this area. In particular;

Recommendation

The Working Group recognizes that the work in RTM for future instruments is progressing rapidly at various Centers. The RTM codes developed by each group (e.g. IASI/AIRS) does not follow the universal interface policy of RTTOV-6 and its predecessors. The Working Group is worried that these RTMs may be difficult to use at DA/NWP Centers.

Recommendation (to RTM developers)

The Group recommends the use of a common interface for radiative transfer modules (as much as possible). Action: NWP SAF, P. van Delst, other RT developers.

2.3.4 Future platforms and real-time access to data

The accessibility and format of data from future platforms was a major concern of the Working Group. This is particularly a concern from non-operational or experimental instruments. The transfer of large volumes of data, which will be produced by future platforms, cannot be handled by the current communication systems e.g. GTS. Several data compression techniques were discussed at the meeting, including channel and principal component decimation.

The Group supports the efforts of M. Goldberg et al. in disseminating AIRS data (decimated in several different ways) in real time BUFR format and encourages other agencies to continue to support such efforts, especially with regard to experimental data sets.

The Working Group wishes to commend WMO for making BUFR formats flexible so that changes can be made quickly. However, there are still no established mechanisms for data requests to data providers.

Recommendation (to WMO)

The WMO/NESDIS/EUMETSAT should develop and publicize procedures for handling real-time data requests for external users.

Current plans for future satellites represent a large increase in instruments and data types. Also, a substantial percentage of current satellite data is not being used at present. To use each new type of data, a substantial workload increase (person-years) is required. The Working Group is concerned that resources at NWP and DA Centers are currently insufficient to properly utilize these data.

Because of limited resources, it is not possible for every group to develop the necessary procedures to use new data types. For that reason, the exchange of techniques and software between groups has been extremely important. The Working Group also notes that there has been substantial informal cooperation/exchange between users at various Centers, agencies and instrument designers. Two particular points require attention.

Recommendation (to NASA NPP)

The Working Group requests more information on the decision to switch polarization on ATMS near surface sounding channels from V to H (as compared to AMSU);

Recommendation (to Space Agencies)

The Working Group recommends the exploration of an additional 226-230 GHz channel to future microwave humidity sounders (AMSU-B, MHS follow-on) to assist with processing of ice water effects at 183 GHz.

2.4 ADVANCED INFRA-RED SOUNDERS

Working Group members: J. Eyre (Chair), M. Goldberg (Co-Chair), A. Huang (Co-Chair), H. Bloom, R. Buell, F. Chevallier, A. Collard, A. Kaifel, G. Kelly, T. Labrot, J. Le Marshall, J. Lerner, T. McNally, G. Monnier, C. Philpot, J. Predina, F. Rabier, F. Romano, P. Schluessel, R. Schraidt, C. Schueler, M. Schroedter, V. Sherlock, A. Uspensky, K. Whyte.

2.4.1 Status of plans for advanced infra-red sounding instruments

Progress was reported on plans for five advanced infra-red sounders: AIRS (Advanced Infrared Sounder), IASI (Infra-red Atmospheric Sounding Interferometer), CrIS (Cross-track Infrared Sounder), IRFS (Infra-Red Fourier Spectrometer) and GIFTS (Geostationary Imaging Fourier Transform Spectrometer). AIRS is a cross-dispersed grating spectrometer. The other four instruments are Fourier transform spectrometers based on Michelson interferometers. Table 2.4-1 summarizes characteristics of these instruments, and Figure 2.4-1 summarizes their planned operating periods.

2.4.2 New initiatives for geostationary sounding

Information in Table 2.4-1 on instruments for polar sounders represents an update on instruments described in more detail in the Report on ITSC-X. The addition of an advanced infra-red sounding mission planned for geostationary orbit represents an important new initiative. Since ITSC-X, the USA's NASA, NOAA and Navy have approved the Geostationary Imaging Fourier Transform Interferometer (GIFTS) as a proof-of-concept demonstration under the NASA New Millenium Program (NMP) Earth Observer (EO) –3 mission, planned for launch in 2004.

GIFTS will demonstrate both SWIR/MWIR and LWIR 128x128 HgCdTe detector arrays in an FTS to cover the spectral ranges 2250 to 1650 cm^{-1} and 1130 to 685 cm^{-1} respectively at 0.3 cm^{-1} nominal resolution, coupled with a 512 x 512 visible CCD array for coincident imaging. Advanced mechanical cryogenic cooling, on-board processing and compression are among other aspects of the technology demonstration. The system will be placed in a series of geostationary orbit locations, starting with East and West USA placements, each for one of the first two years, with the remaining mission life over the Indian Ocean. Australia has offered to provide the ground-station and processing for the latter portion of the mission. As NMP is intended to demonstrate advanced technologies with significant technical risk, the GIFTS mission is an appropriate application of NMP, which should pave the way for low risk operational large focal plane array (FPA) applications to follow.

GIFTS will provide temperature and humidity profile information with a vertical resolution and accuracy comparable with advanced sounders on polar satellites, but with higher horizontal and temporal resolution. Its frequent multi-spectral imagery will also permit the extraction of wind information through the tracking of height-resolved water vapour tracers. GIFTS will provide an opportunity to demonstrate the potential benefits of advanced infra-red soundings of high temporal frequency in global and regional NWP and in very short-range forecasting.

The experimental GIFTS is expected to make an important contribution to studies of requirements for future operational systems, as GIFTS performance is pushing the state-of-the-art not only in spectral content and resolution, but also in spatial and temporal sampling.

Recommendation

ITWG recommends that operational agencies make use of present and forthcoming information from the GIFTS mission in studies of user requirements for possible future operational systems.

2.4.3 Distribution of AIRS datasets

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. Near-real time simulation of AIRS/AMSU-A/HSB is now routine. These datasets include the effect of clouds and surface emissivity and can be valuable for developing/improving algorithms for cloud detection, data compression, channel selection and retrieval/assimilation. Sample AIRS datasets with readers have been made available to NWP centres. The distribution of the data cannot become routine until a dedicated communication line is established between the NESDIS computer located at GSFC and NESDIS (Suitland, Maryland). Early development of AIRS data assimilation procedures will accelerate the utilization of real AIRS observations.

Recommendation (to NOAA)

The ITWG recommends that data transfer links needed for routine transfer of AIRS radiance and retrieval products be established many months prior to the launch of Aqua so that simulated AIRS data can be used to develop and improve data processing and assimilation procedures for AIRS.

2.4.4 Data processing, inversion and assimilation

Discussion of options and issues in this important area were the primary focus of this working group at ITSC-XI.

2.4.4.1 Distribution of ingest code

A general issue of relevance to all advanced sounders is the availability of "ingest" code (code to process raw data to level 1b data) to all users who intend to receive and process the raw data. For global data, the processing centres will be the responsible agencies, e.g. NASA/NOAA for AIRS, EUMETSAT for IASI, NASA/NOAA for CrIS. 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. Plans in this area are not mature, and further developments are needed to ensure the necessary distribution and implementation. Without such developments, direct read-out data will not be exploited effectively.

Recommendation (to satellite agencies)

ITWG recommends that ingest code for advanced sounder data should be made available to user community, to permit effective exploitation of direct read-out data.

Recommendation (to EUMETSAT)

ITWG recommends that EUMETSAT considers the integration of IASI level 1 ingest code into an extended version of the AAPP software via activities in the EUMETSAT SAF for NWP.

Recommendation (to IPO)

ITWG recommends that IPO plan for initial distribution of CrIS ingest code to users 1-2 years before the launch of the NPP satellite.

Table 2.4-1 Characteristics of Advanced Infrared Sounders

Name	AIRS	IASI	CrIS	IRFS	GIFTS
Orbit	705 km	833 km	824 km	1000 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	625 -2000 2200 -5000	685-1130 1650-2250
Unapodized spectral resolving power	1000 – 1400	2000 – 4000	900 – 1800	1200 - 4000	2000-6000
Field of view (km)	13 x 7	12	14	20	4
Sampling density per 50 km square	9	4	9	1	50
Power (W)	225	200	86	120	255
Mass (kg)	140	230	81	70	59
Platform	AQUA (EOS PM1)	METOP-1,-2,-3	NPP and NPOESS C1	METEOR 3M N2	Geostationary
Launch date	May 2001	2005	2006 for NPP 2009 for C1	2003	2004
Primary assets	best noise performance, especially for SW	most versatile spectral coverage and resolution with embedded imager	smallest polar sensor with combination of spatial and spectral resolution tuned to meet operational user requirements	best spectral coverage	Best horizontal and temporal resolution (30 minute full-disk coverage)

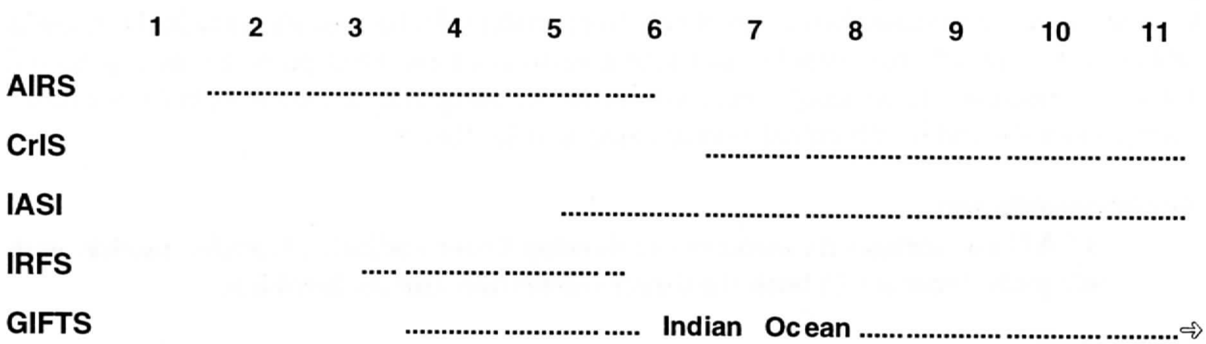

Figure 2.4-1 Advanced IR Sounder Timeline

2.4.4.2 Common preprocessing and retrieval packages

The effective exploitation of advanced sounder data will also be greatly facilitated by the availability within the user community of common pre-processing software packages, as has been demonstrated for TOVS (e.g. ITPP and 3I packages) and ATOVS (e.g. AAPP, IAPP and ICI packages).

The International ATOVS Processing Package (IAPP) has been modified by University of Wisconsin to provide an International MODIS and AIRS Processing Package (IMAPP) available on the web at http://cimss.ssec.wisc.edu/~gumley/IMAPP/IMAPP.html. This common preprocessing package provides a platform to combine the use of advanced imaging spectroradiometry and infra-red sounding, which will enable improved sounding over land as well as substantially improved cloud-clearing in partly cloudy areas. IMAPP will be updated over the next two years to produce the International NPP and NPOESS Processing Package (INPP), which will enable ingest and processing of AIRS, CrIS, MODIS and VIIRS data.

The EUMETSAT SAF for NWP plans to developed pre-processing and retrieval packages for IASI (with AMSU-A, MHS and AVHRR) through evolution of the current ATOVS processing software, AAPP and ICI.

Recommendation

ITWG encourages its members to participate in the co-operative development of common pre-processing and retrieval packages for advanced sounders. It recommends the evolution and extension of existing ATOVS pre-processing and retrieval packages to provide processing capability for advanced sounder data.

The utility of common software packages may be improved by the adoption of common data interfaces at different levels of processing. These interfaces should be designed based on experience from current sounders and with input from the user community.

Recommendation (to IPO)

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

2.4.4.3 Fast model considerations

Fast and accurate radiative transfer models are required for use in physical retrieval schemes and in NWP data assimilation systems. Such schemes are already in widespread use for TOVS and ATOVS, but the greatly increased number of channels of advanced sounders represents a problem for operational systems: how to make use of even a fraction of the channels available without excessive increases in the cost of radiative transfer calculations. Faster radiative transfer models would be of great benefit, and neural networks have been proposed as a potential approach. However, to be acceptable, models must be adequately accurate, both for the direct calculation itself and for the calculation of associated Jacobians.

Recommendation

ITWG encourages its members to develop faster radiative transfer models with adequate accuracy in both the direct calculation and its Jacobian.

It is common practice at present to treat some atmospheric gases, namely water vapour and ozone, as "variable" gases with other gases treated as "fixed". With advanced sounders there will be an increasing need to treat some of the current "fixed" gases (e.g. CO_2, CH_4, N_2O) as variable. This will be needed for the retrieval of these gases, but it could also improve accuracy of retrievals of temperature, water vapour and ozone. There is also a need to study and specify the accuracy requirements for transmittance models of such gases.

2.4.4.4 Cloud detection and characterisation

2.4.4.4.1 Cloud detection Advanced sounder data is 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, and their accuracy (i.e. the degree of residual cloud contamination that they cannot detect) needs to be characterised. The following approaches to improving cloud detection methods have been proposed:

- identifying the characteristic signatures caused by residual cloud or aerosol contamination in the multi-channel radiance spectra,
- use of coincident high-resolution imagery (e.g. AVHRR with IASI, MODIS with AIRS),
- improved NWP modelling of surface skin temperature, particularly over land.

Recommendation

ITWG encourages its members to continue to focus efforts on improving cloud detection for advanced sounder data.

Recommendation

ITWG supports the scientific and technical developments required to use coincident MODIS data to improve the cloud detection for AIRS.

2.4.4.4.2 Use of cloudy radiances 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. Recent research, presented at ITSC-XI, has suggested that these sensitive areas are often free of high level cloud but are usually heavily clouded at low levels. It is therefore important that the NWP data assimilation community makes progress on the assimilation of cloud-affected radiances, and particularly those that are only affected by low cloud.

Recommendation

ITWG encourages research into the assimilation of cloud-affected radiances, as this may be crucial to the effective exploitation in NWP of advanced sounder data from meteorologically sensitive areas.

2.4.4.4.3 Retrieval of cloud parameters Advanced sounder data will offer the opportunity not only to improve the detection of cloud but also to improve the characterisation of cloud properties and the retrieval of cloud parameters. This will be possible either using the advanced sounder data only or together with coincident imagery. Further research is required to develop effective and efficient methods, and such research would be greatly aided by the availability of a datasets from test bed instruments (e.g. NAST-I) together with collocated in situ data and covering a representative range of cloud conditions.

Recommendation (to NASA/Langley)

ITWG encourages the compilation and distribution of a data set of advanced sounder data covering a wide and representative range of cloud conditions, to assist research on the retrieval of cloud parameters from advanced sounder data.

2.4.4.5 Data compression

Data compression is expected to be needed or desirable in one or more of the following stages of advanced sounder data processing:

- on board the satellite, to reduce the load on the downlink;
- for data distribution from the central ground segment to users;
- within processing systems and databases used for operational NWP (and probably other applications).

The downlink problem is a major issue for GIFTS because of its extremely high data rate. Work is in progress to explore how the maximum information can be transmitted to the ground in the available bandwidth, and ideas from the community would be welcome.

For the second and third problems, EOF-based techniques are being explored and results using simulated data are promising. However more work is needed to test these techniques on real data, and on a wider range of simulated data.

2.4.4.6 Channel selection

The huge number of channels of advanced sounders has stimulated research on "channel selection" to answer the following questions. Can we select a subset of channels that contains almost all the information (on the variables to be retrieved) from the full set? How big should this subset be? What is the optimal method to select this subset? What is the optimal trade-off between information retained and computational expense? Considerable progress has been made, and methods based on linear optimal estimation theory appear promising; optimal methods available in the literature have been tested for specific advanced sounder scenarios and appear to perform well. However, more work is required on "robust" channel selection, i.e. to select a subset that is not only adequate for a given set of conditions (atmospheric profiles, scan angles, measurement and forward model error covariances, and prior error covariance) but is also satisfactory over a wide range of expected conditions.

2.4.4.7 Error covariances

Research presented at the conference illustrated how retrieval/assimilation performance can be substantially degraded if relevant error covariances are not adequately specified. For radiance assimilation, it is important to characterise the errors–both their magnitudes and inter-channel correlations - arising from various sources: measurement errors, pre-processing errors (e.g. residual cloud effects) and forward modelling errors. Similarly, when assimilating retrievals, it is important to have a good characterisation of the error covariance of the retrieved products.

In practice, it will usually not be possible to compute and distribute full error covariance matrices. Further research is required to understand how the full matrices can be approximated (as diagonal or otherwise) whilst retaining tolerable levels of accuracy.

2.4.5 Characterisation of spectral response

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

Recommendations (to space agencies)

ITWG recommends that the spectral responses of advanced sounders should be characterised to a level at which the associated error is tolerable within the total noise budget of the instrument.

2.4.6 Instruments for new spectral regions

The conference noted two new initiatives for advanced sounding instruments in the far infra-red:

- the Radiation Explorer in the Far Infra-red (REFIR) instrument, proposed for the ESA Earth Explorer programme; and

- the CIRRUS instrument, proposed for the NASA Space Station.

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Working Group members: D. Hinsman (Chair), H. Bloom, J. Eyre, M. Goldberg, D. Klaes, J. Le Marshall, P. Menzel, T. Reale, G. Rochard, P. Schlüssel, C. Schueler, A. Uspensky and W. Zhang.

2.5.1 Review

ITSC-XI agreed that the Working Group for "International Issues and Future Systems" should discuss several topics including: a review of recommendations and action items from the previous ITSC; satellite operators' plans for future instruments and missions; the protection of frequency allocations; interactions with WMO's Commission for Basic Systems (CBS) Open Programme Area Group for Integrated Observing Systems (OPAG IOS) and the Global Climate Observing System (GCOS); direct read-out; education and training; software availability; satellite data and product monitoring; and the capacity of the GTS to handle future satellite data and products.

The Working Group reviewed the status of recommendations and action items from ITSC-X and agreed that all had been completed (except the few that are refined below).

It recalled that at previous ITSCs the satellite operators had made presentations covering their plans for missions and instruments. The purpose of such presentations was to allow ITSC meetings to have a comprehensive perspective of the future for satellite soundings. The Working Group was unanimous in agreeing that the presentations at ITSC-XI were most valuable and should be continued at future meetings.

The Working Group noted that the presentation by each satellite operator (NOAA/NESDIS, EUMETSAT, China, the Russian Federation and NASA) included plans to launch polar-orbiting satellites but that coordination of their equator crossing times was not apparent. The Working Group was informed that the WMO Executive Council had agreed to hold "Consultative Meetings on High-Level Policy on Satellite Matters" on a yearly basis and that both the operational and research and development satellite operators would be participants in such meetings. Thus, the Working Group encouraged CGMS and WMO, through its "Consultative Meetings" to consider contingency plans that would be comparable and consistent for all three polar orbits (early a.m., a.m. and p.m.).

Recommendation (to CGMS and WMO)

ITWG encourages CGMS and WMO to consider coordination of polar-orbiting equator crossing times to optimize satellite utilization while minimizing potential conflicts in data reception.

With regard to the present plans which include only one operational advanced sounder (IASI) before 2009, the Working Group was updated on NASA's NPOESS Pathfinder Project (NPP) which had the potential to make available a second advanced sounder prior to 2009. It also heard about the plans of the Russian Aviation and Space Agency (RASA) to fly its high spectral resolution advanced sounder (IRFS) on METEOR 3M N2 in 2003. However, the Working Group noted that both advanced sounders were planned to fly in an AM orbit and suggested that consideration be given to placing the NPP sounder in the p.m. orbit.

Recommendation (to NASA and RASA)

ITWG encourages NASA to consider placing the NPP sounder in a PM orbit. ITWG also encourages RASA to finalize manufacturing of the very high spectral resolution IFRS and launch it on METEOR 3M N2 in 2003.

The Working Group was briefed on WRC 2000 held in Istanbul, Turkey. The results of WRC 2000 were very positive for the protection of microwave frequencies. A compromise had been obtained for both the 18.6 – 18.8 GHz and 55.78 – 56.9 GHz bands to protect remote sensing of the Earth/Atmosphere. Between 71 GHz and 275 GHz, all the requested frequencies were allocated as primary for passive remote sensing. The goal for the next WRC will be to achieve allocations that recognize the need for less than 0.01% contamination in each band as has been achieved in the 50 – 60 GHz band for example. The Working Group noted however, that some satellite operators still had plans to utilize frequencies where appropriate allocations did not exist; it strongly urged those satellite operators to conform to the ITU allocations. The Working Group also noted the excellent work of the Space Frequency Coordination Group (SFCG) in preparing for each WRC; it recommended that ITWG seek to participate in meetings of the SFCG as an observer.

Action (co-Chairs)

ITWG co-Chairs to contact SFCG to initiate the process for ITWG becoming an observer at SFCG meetings. Co-Chairs should also act as the focal point to identify the appropriate ITWG member to attend SFCG meetings and to find the necessary financial resources.

With regard to education and training and the use of small workstations, the Working Group was pleased to learn of recent developments by WMO in defining a Virtual Laboratory for Education and Training in Satellite Meteorology. The Working Group recalled the ITWG commitment to make available, where possible, its expertise for education and training activities. The Working Group also noted that the Virtual Laboratory enabled direct participation of specialized science groups through links to the WMO's specialized "centres of excellence" (the RMTCs for Costa Rica, Barbados, Niamey, Nairobi, Nanjing and the BMTC in Melbourne). Thus, the Working Group agreed that the ITWG web site should be augmented to contain information and links related to education and training for sounding instruments and that links be provided to the six centres of excellence as well as other interested entities.

Action (co-Chairs)

ITWG to augment its present web site to contain education and training information and relevant links and to forward the links to the WMO specialized "centres of excellence".

The Working Group suggested that ITWG initiate activities that would provide for software system updates and changes through the use of an augmented ITWG web site. The web site should also contain information and contact points for groups beginning to work in the sounding area.

Action (co-Chairs)

ITWG co-Chairs to initiate action to augment the ITWG web site to include information on relevant software system updates and changes as well as on

information and contact points for groups beginning to work in the sounding area.

The Working Group was also informed of the latest structure for the CBS and its OPAG IOS. The Working Group noted that expertise from the ITWG community had been adequately represented within the OPAG IOS and wished to reconfirm to CBS its willingness to continue to provide such expertise.

Action (co-Chairs)

ITWG co-Chairs to write to the President of CBS to express ITWG's appreciation for inclusion in the work of past OPAG IOS Expert Teams and its willingness to continue to provide its expertise on future Expert Teams.

Similarly, the Working Group expressed ITWG's willingness to provide feedback on Statements of Guidance regarding how well satellite capabilities meet WMO user requirements. The Working Group noted that Statements of Guidance were normally issued after an OPAG IOS Expert Team Meeting and that feedback to WMO would be useful as input to the following Expert Team Meeting.

Recommendation (to WMO)

ITWG encourages WMO to send Statements of Guidance from the OPAG IOS Expert Team Meetings to ITWG with the expectation that any feedback would serve as input to the following Expert Team Meeting.

Action (co-Chairs)

ITWG co-Chairs to solicit feedback from an adequate number of ITWG members and provide it to WMO within four months.

The Working Group also noted the possibility of the close of the Global Observing Systems Space Panel (GOSSP) with regard to climate observations. The Working Group felt it important to have a mechanism for ITWG interaction with the climate communities to make ITWG's climate monitoring expertise available. Thus, it was suggested that the co-Chairs inform the Chairman of the GCOS Steering Committee and its relevant discipline Panel Chairmen (AOPC, OOPC and TOPC) of ITWG's available expertise.

Action (co-Chairs)

ITWG co-Chairs to inform the Chairman of the GCOS Steering Committee and its relevant discipline Panel Chairmen (AOPC, OOPC and TOPC) of ITWG's available expertise and willingness to assist in climate monitoring activities.

With regard to the monitoring of satellite data on the GTS, the Working Group reconfirmed the importance of such activities, but felt that they should include quality control of the content of BUFR messages on the GTS. The Working Group suggested that CGMS and WMO review current procedures and practices with a goal towards improve the monitoring. Additionally, it was noted that the review should identify the future monitoring policy once the Initial Polar System of NOAA/NESDIS and EUMETSAT becomes operational.

Recommendation (to CGMS and WMO)

ITWG encourages CGMS and WMO to review the monitoring procedures and practices for satellite data and products placed on the GTS with a goal towards improving them. The review should also identify the future monitoring policy once the Initial Polar System of NOAA/NESDIS and EUMETSAT becomes operational.

The Working Group recalled that concern had been expressed for the capacity of WMO's present Global Telecommunication System (GTS) to handle large volumes of satellite data. In particular, the Working Group noted that the volume of data from AIRS in 2001, IASI in 2003 and GIFTS in 2004 would greatly exceed the present GTS capacity. Thus, the Working Group strongly encouraged WMO to seek means to greatly increase the GTS capacity including through the implementation of its Distributed Database System Concept. The Working Group also reaffirmed the sounding community's need for continuation of broadcast of satellite data either directly from the satellite or by other telecommunication means that would ensure near real-time reception.

Recommendation (to WMO)

ITWG encourages WMO to increase the GTS capacity including through the implementation of the Distributed Database System Concept.

With regard to satellite products to be distributed via the GTS within the Initial Polar System (IPS) of NOAA/NESDIS and EUMETSAT (Metop AM satellites and NOAA PM satellites), the Working Group agreed that there should be a consistent policy as to production and distribution on the GTS of IPS products in order to avoid duplication.

Action (co-Chairs)

ITWG co-Chairs to seek information from CGMS as to plans for production and distribution of International Polar System (IPS) products to be distributed over the GTS.

With regard to the need for radiances, the Working Group was informed that NPOESS Sensor Data Records (SDRs) would include radiance products but that they would not be available as part of the suite of NPOESS Environmental Data Records (EDRs). The Working Group requested clarification regarding availability of radiance products.

Recommendation (to CGMS)

ITWG requests CGMS seek clarification from the NPOESS Integrated Program Office (IPO) as to the availability of radiance products as part of the suite of NPOESS SDRs.

The Working Group noted the important potential contribution of the AIRS instrument on the EOS PM (Aqua) satellite to be launched in 2001 to WMO's World Weather Watch. In particular, Aqua's AIRS would provide advanced sounder data in synergy with AMSU-A (and HSB), AMSR-E and MODIS data to the meteorological community to allow preparations for the operational advanced sounders. The Working Group was pleased to note NASA's activities to establish direct readout access as well as software processing packages for AIRS, AMSU-A (and HSB) and MODIS to allow timely use of the data for operations and research. The Working Group also noted the need for the processing software package to include the ingest software for

AIRS and to expand to AMSR-E. The Working Group also recommended that a similar activity be started for the NPP mission.

Action (co-Chairs)

ITWG co-Chairs to write and express its appreciation to NASA for activities that established direct readout access as well as software processing packages for AIRS, AMSU-A (and HSB), and MODIS. These will allow timely use of the data for operations and research. The addition of ingest software for AIRS and software for processing AMSR-E should also be requested. Finally, a similar activity for the NPP mission should be suggested.

The Working Group reconfirmed the need for free software for ingest and processing from new instruments. Such free software would ensure a broad distribution and provide for more validation and data usage.

The Working Group noted that the availability for data from the SSMIS was unclear. It suggested that CGMS confirm if such data would be available similar to the SSM/I and SSM/T1 and SSM/T2 over Shared Processing.

Recommendation (to CGMS)

ITWG requests CGMS clarify the situation concerning the availability of SSMIS data.

2.6 SATELLITE SOUNDER SCIENCE AND PRODUCTS

Working Group members: T. Achtor (Co-chair), A. Reale (Co-chair), E. Borbas, R. Buell, M. Chalfant, A. Diamandi, A, Kaifel, L. Lavanant, J. Le Marshall, L. McMillin, M. Mueller, K. Okamoto, C. Philpot, G. Rochard, J. Sakuragi, A. Sarr, M. Schroedter, B. Stankov, V. Tabor, A. Thoss, M. Uddstrom, P. van Delst, F. Weng, X. Wu, W. Zhang, C. Zou.

2.6.1 Background

A new Working Group (WG) on Satellite Sounder Science and Products (SSSP) was proposed and met during the later part of ITSC-XI. The main purpose of this Group was to examine the current range of scientific algorithms and associated derived products from operational and research satellites and to promote scientific exchange among product developers.

A requirement for this WG originated from two basic premises. An important component of ITSC activity is to provide a forum for satellite data providers and users to facilitate an exchange of scientific information about environmental products from operational sounding satellites, with the goal of optimizing their application in weather and climate. Second, it appeared that considerable attention was being given to the numerical weather prediction and climate application areas, along with preparations for advanced (infrared) interferometers; however the area of current, derived satellite products was being given less attention than they required and needed greater prominence.

The SSSP WG was formed to review and make recommendations for the derived products area, and to facilitate the continuation of the important work being done on the problem of deriving useful scientific products from operational and research satellite measurements.

2.6.2 Agenda

The SSSP WG held its initial (and only) meeting on Monday, September 25th. The meeting was very well attended (by over 25 people), and the following ideas were generally agreed upon as starting points for the Group; the initial action was to define some broad categorization of available products, radiometer(s) used, researchers and a brief description of the scientific algorithms and product characteristics. The initial categorization of included products related to: Radiometric Measurements; Atmospheric Temperature; Atmospheric Moisture; Wind; Clouds; Surface; Radiation and Gases.

The action of matching researchers within the categories of derived products will be facilitated through the formation and maintenance of a new SSSP WG web site, available through the ITSC web server and Internet **(Action: Stankov, Achtor, Reale).**

The SSSP WG web site will serve as the focal point for promoting correspondence and comparisons among scientists working in the product derivation area. The attending members would provide inputs on their work, and encourage other scientists to enlist their contributions (and perhaps attend ITSC-XII). The goal is to establish a home base, and mechanism for the dissemination and exchange of information across the international community, and the spectrum of available science techniques and products. **Action: Attending SSSP WG Members.**

The longer term goals of the SSSP WG will be to report to the ITSC on:

- *the current status of derived products and scientific algorithms;*
- *the progress made since the last ITSC meeting; and*
- *perceived areas of strengths and weaknesses.*

The SSSP WG would also recommend actions to be pursued, for example, in response to a perceived weakness, case study comparisons, validation strategies and software exchange.

3. REPORTS OF TECHNICAL SUB-GROUPS

3.1 TECHNICAL SUB-GROUP ON THE ATOVS AND AVHRR PROCESSING PACKAGE: AAPP

3.1.1 Background

AAPP was a joint development of a number of European institutions, under the coordination of EUMETSAT, for the pre-processing of HRPT direct read-out data from NOAA polar-orbiting satellites. AAPP produces, in a suite of processing steps, level 1B, 1C and 1D output files.

AAPP has been distributed worldwide by EUMETSAT and successfully installed by the users. The current version of AAPP is V2.4 which includes some minor updates to CD-ROM version V2.0.

3.1.2 Bugs and Problems

During the beta-testing period of AAPP several bugs and portability problems have been discovered and resolved. The corrections have been integrated into release V2.0. Solutions for some remaining portability problems are proposed on EUMETSAT's webpage:

http://www.eumetsat.de/en/area4/aapp/bugs.html

These portability problems require individual adaptations to the platform used. It was not recommended to spend additional effort in the removal of the portability problems.

3.1.3 Information Exchange

The current scheme for exchanging information between all involved parties was regarded as sufficient:

- EUMETSAT distributes new major releases (Vn.0) of AAPP on CD-ROM on a yearly basis. Temporary updates (Vn.i) are distributed via EUMETSAT's ftp server (ftp.eumetsat.de). EUMETSAT informs the users of new releases and updates and any other AAPP related subject via EUMETSAT's AAPP Internet Forum:

  L-AAPP@eumetsat.de

- The users can pass requests and information to EUMETSAT via EUMETSAT's User Service ops@eumetsat.de or to the AAPP helpdesk kwhyte@meto.gov.uk

- The AAPP Internet Forum allows users to communicate to each other via email and automatically addresses all forum participants.

3.1.4 New Modules

- NOAA-16 parameters will be made available to users.

Action (Meteo France/CMS/Lannion)

Provide the NOAA-16 parameters to EUMETSAT to make them available on the ftp server.

- MAIA V2.1 will be made available to the users by the end of November 2000. Note that MAIA V2.1 does not require external forecast data and is therefore usable by any user. It will be integrated into AAPP V3.0.

- AAPP V3.0 is expected to be distributed in February 2001.

- AAPP V3.0 will include a second method of AMSU to HIRS convolution.

- ICI V2.5 will be distributed as a separate package on CD-ROM in November 2000.

3.1.5 Data Visualisation

EUMETSAT has prepared a simple data visualisation tool based on the freely available packages GMT and GhostView. EUMETSAT will make this tool available via EUMETSAT's ftp server and invites users to enhance it and report improvements back to EUMETSAT for distribution.

Tom Achtor/CIMSS/University Wisconsin reported that the satellite data visualisation and processing package McIDAS is being prepared for free distribution. It was proposed to include a link to Wisconsin's McIDAS webpage into EUMETSAT's AAPP webpage when the MCIDAS webpage is ready.

Action (Tom Achtor)

Inform EUMETSAT in due time.

Action (EUMETSAT)

Install the link.

3.1.6 New Platforms

AAPP has been successfully installed on SUN, HP, SGI, DEC and IBM platforms.

The installation of AAPP on LINUX PCs is not supported by the current releases. It was noted that it is not feasible to compile AAPP with the Fortran compiler provided with LINUX. It was further noted that AAPP could be compiled under LINUX using a commercial compiler.

AAPP has been successfully installed on PC under WINDOWS at Planeta Roshydromet / Moscow. This installation can be made available to users ‘as is’.

Action (Alexander Uspensky)

Make the WINDOWS AAPP installation available.

3.1.7 AAPP Licence

A new licence for AAPP can be requested via EUMETSAT's AAPP webpage:

http://www.eumetsat.de/en/area4/aapp/get-aapp/get-aapp.html

3.2 TECHNICAL SUB-GROUP ON THE INTERNATIONAL ATOVS PROCESSING PACKAGE (IAPP) - FURTHER DEVELOPMENT

3.2.1 General Summary

The International ATOVS Processing Package (IAPP) has been developed to retrieve the atmospheric temperature profile, moisture profile, total ozone and other parameters in both clear and cloudy atmospheres from ATOVS radiance measurements. The IAPP algorithm retrieves the parameters in 4 steps: 1) cloud detection and removal; 2) bias adjustment; 3) regression retrieval; and 4) nonlinear iterative physical retrieval. A recent publication by Li, Wolf, Menzel, Zhang, Huang and Achtor, *Journal of Applied Meteorology* (August 2000) provides details on the algorithms.

3.2.2 IAPP Versions 1.0, 1.1 and 2.0

IAPP v1.0 was released to the international community in April, 1999. Version 1.1, consisting primarily of small improvements and software fixes, was released in June, 2000.

Since that time, a number of significant upgrades have been completed, which will be incorporated in Version 2.0, to be released in Spring 2001. Key features include:

(a) AMSU/B radiances are used in moisture retrieval. For clear sky conditions, HIRS/3 plus AMSU/A plus AMSU/B temperature and moisture profiles are created. In the case of non-precipitating clouds, an AMSU/A plus AMSU/B only temperature/moisture profile is created.

(b) A non-linear regression retrieval procedure is used instead of the linear one. This procedure better deals with water vapor nonlinearity and accounts for the effects of zenith angle, surface elevation and latitudinal variation of the atmosphere. Since the regression scheme employs the local zenith angle (in the form of its secant) as a predictor, the NOAA-16 HIRS/3 pointing problem does not create difficulties, as long as the navigation is done properly. This problem has been taken care of by NESDIS, EUMETSAT (AAPPv2.8), and UW/CIMSS.

(c) Cloud top pressure (height) and effective cloud amount are derived from the CO_2-slicing technique, if forecast profiles are available for the retrieval process.

3.2.3 IAPP: Future development

Future work on the IAPP will include:

(a) improved bias adjustment using the NOAA/NESDIS monthly radiosonde – radiance matchups over all seasons;

(b) incorporation of an AVHRR cloud mask algorithm for improving cloud detection;

(c) development of AMSU/B derived moisture and water cloud products;

(d) capability to create and use a surface analysis from a blend of METAR observations with a model background field; and

(e) comparison of IAPP results with other ATOVS retrieval packages;

(f) a set of powerful visualization / data manipulation tools for ATOVS and IAPP output has been created within the Man-computer Interactive Data Access System (McIDAS). Basic imaging capability is available for all bands of AVHRR, HIRS and AMSU. Any NOAA AVHRR or ATOVS radiance value and/or IAPP field can be plotted or contoured over the imagery.

McIDAS also includes the potential to display many other types of satellite and conventional data, based on the user's access to the data.

3.3 TECHNICAL SUB-GROUP ON SOUNDING SOFTWARE FROM LMD/ARA

3.3.1 Background

This overview summarizes the status of the Improved Initialization Inversion (3I) system at LMD. Since the previous ITSC, no new 3I version has been released. However, intensive work has been carried out to extend and validate algorithms or databases which are important to the 3I system itself. This is the case for the forward model 4A (Automatized Atmospheric Absorption Atlas) as well as for databases such as TIGR (Thermodynamic Initial Guess Retrieval) and GEISA (Gestion et Etude des Données Spectroscopiques de l'Atmosphère).

Research and development has been undertaken, including important feedbacks. The development of more and more powerful (forward, inverse) radiative transfer tools is in progress, to further increase accuracy and rapidity. All aim to improve the 3I processing of instruments such as TOVS, ATOVS, AIRS, and IASI in order to serve the climate and meteorological community particularly through contributions to:

(a) the retrieval of the main greenhouses gases;
(b) the study of clouds and their radiative properties; and
(c) the study of the stratosphere and of the troposphere-stratosphere exchanges.

3.3.2 The 4A-Line by Line model

Within the last few months, a number of validation exercises determining accuracy (three, to our knowledge) have taken place related to well identified measurement campaigns or international synthetic programmes. LMD has participated in these intercomparisons using, in a first stage, the 4A line by line model (1993 version) referred to as 4A-93. During these validation exercises, updates and revisions (see below) have been effected; these have led to the 4A-00 version.

A memorandum has been written to summarize and widely disseminate the status of the 4A model at LMD in order to - unambiguously - present how the model performs in simulating radiances as well as transmittances and Jacobians under various observational conditions (radiometric or interferometric experiments mainly within the frameworks of TOVS, ATOVS, IASI and AIRS experiments). This document is available upon request.

3.3.3 The TIGR database

Thermodynamic profiles: The TIGR has evolved from the previously-available TIGR-2 (1761 situations) to a 2312 situation database. The mid-lat 1 and 2, as well as the polar 1 and 2 components, have been left unchanged while the tropical air-mass has been enriched in terms of more humid situations. Very recently (December 2000, not yet published), ozone profiles from the UGAMP 5-year climatology have been introduced, resulting in a more realistic representation of this constituent.

Radiance and transmittance profiles: Using the newly-improved 4A-2000 model (see above), TOVS radiances and transmittances have been generated for all the 2312 thermodynamic profiles, and, as in the previous version, for ten viewing angles, two sets of emissivity, and 19 surface pressures (above 1013 hPa). Also, updated values of the constant gases mixing ratios have been used for CO_2, N_2O, CO, CH_4, and so on. Regenerating AMSU-A and B radiances and transmittances is in progress based on the microwave version of our in-house LBL code

(Stransac) and using the newly-derived emissivities computation FASTEM-2 (S. English, pers. comm.). This version will be referred to as TIGR-2000.

3.3.4 The GEISA/IASI-2000 spectroscopic database

As a subset of the nominal GEISA database, and within the framework of the high spectral resolution instruments (AIRS, IASI), the GEISA/IASI-2000 database is both an extraction (spectral range 600 - 3000 cm^{-1}) and a partial update of the GEISA97 spectroscopic database. It comprises the following sub-databases:

(a) A sub-database on line parameters for 15 molecules (53 isotopic species) representing 573,942 transitions. Since the GEISA97 edition, the spectroscopic line parameters of H_2O (Toth et al. 1999), NO (Mandin et al. 2000a) and C_2H_2 (Mandin et al. 2000b) have been updated for GEISA/IASI-2000 and the upcoming GEISA-2001 issues.

(b) A sub-database on absorption cross-sections of 4 molecules: CFC-11 and CFC-12, from GEISA97 and updated for GEISA/IASI-2000 (Li and Varanasi 1994 ; Varanasi and Nemtchinov 1994 ; Varanasi, Private Communication, 1999), CFC-14 (from GEISA97), CCl_4(Varanasi, Private Communication, 1999). This sub-database, with its management software, is available from the anonymous ftp site : ara01.polytechnique.fr, in the sub-directory /pub/geisa/iasi/cross.

(c) A sub-database on micro-physical and optical properties of atmospheric aerosols. Four datasets on microphysical properties of atmospheric aerosols have been archived, related respectively with:

- Refractive indices of basic atmospheric constituents compiled by Massie (NCAR, CO,USA, Private Communication, 2000);
- A database on atmospheric aerosols compiled by A.A. Rublev, 1994 ;
- The database and associated software package OPAC (Optical Properties of Aerosols and Clouds), by Hess et al. 1998. OPAC allows the computation of very different radiative properties of aerosols by the combination of pre-calculated values and makes it possible to consider one's own mixture of selected components;
- The Global Aerosols Dataset (GADS) computed by Köpke et al. 1997. GADS, a revised version of d'Almeida, et al. 1991, provides data of individual aerosols component mixtures, which are assumed to be valid for the Earth's surface, on a 5° by 5° grid, for winter and for summer, with both their microphysical and radiative properties.

3.3.5 The 3I system

Within the framework of the NOAA/NASA Pathfinder programme and based on the use of our Path-B reanalysis of the TOVS, research actions have been undertaken . They concern

- Clouds as seen by satellite sounders (3I) and imagers (ISCCP)
- Seasonal, interannual, and zonal temperature variability of the tropical stratosphere based onTOVS satellite data, 1987-1991
- Signatures of annual and seasonal variations of CO2 and other greenhouse gases from comparisons between NOAA/TOVS observations and model simulations
- Retrieval of cirrus ice crystal sizes from 8.3 and 11.1 μm emissivities

Also, within the framework of ATOVS, AIRS, and even more so of the IASI ISSWG, developments based on neural network approaches are being developed for forward and inverse modelling. Validation is in progress based upon the various validation intercomparison campaigns of the working groups.

3.4 INTERNATIONAL MODIS/AIRS PROCESSING PACKAGE: IMAPP

3.4.1 General

An International MODIS/AIRS Processing Package (IMAPP) has been developed for processing of EOS MODIS data for weather, climate, nowcasting, NWP, cloud properties, and radiation budget studies. Future system capabilities will encompass EOS Aqua AIRS (Atmospheric Infrared Sounder) data reception and processing. Here, we briefly address the details of system configuration, MODIS product requirements, and expectations of the International TOVS community.

3.4.2 Background

The MODIS and AIRS instruments onboard the EOS Terra and EOS Aqua platforms will provide greatly enhanced remote sensing capabilities for the observation of planet Earth. The ability to receive the data stream in a timely manner and accomplish fundamental processing to transform sensor measurements to radiances and geophysical products will be a key to utilizing these data. For this purpose, the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison and other groups in the United States, along with international groups around the globe, are installing X-band ground stations to receive the direct broadcast data stream from the EOS Terra and EOS Aqua platforms.

3.4.3 Processing Strategy

Upon reception, the direct broadcast data stream may be processed to derive calibrated, geo-located MODIS and AIRS radiances (Level-1B data). In order to conduct interdisciplinary studies with MODIS and AIRS data, the international EOS direct broadcast community and, of course, the ITWG has expressed a strong desire for a software package which uses well-established algorithms to process MODIS and AIRS data to Level-1. In addition, there are also several geophysical products (e.g. cloud mask, temperature and moisture profiles) that would directly facilitate the use of MODIS and AIRS direct broadcast data by the international science community, such as in the field of numerical weather prediction.

3.4.4 Goals

The IMAPP software provides the international multi-disciplinary science community with the capability to process direct broadcast MODIS and AIRS data into calibrated, geo-located radiances and to create derived products utilizing the capabilities of both instruments.

The specific goals of IMAPP are:

(a) To develop a software package for international distribution which allows any X-band ground station capable of receiving direct broadcast data from the EOS Terra and Aqua platforms to produce calibrated and geo-located MODIS and AIRS radiances, and selected geophysical products, in near real-time (within 1 hour of satellite overpass).

(b) By providing a freely available software package to process MODIS and AIRS direct-broadcast data, to promote and support the worldwide use of EOS data, and to directly involve the international community in the validation of EOS data sets.

(c) To develop and implement a synergistic MODIS/AIRS algorithm for direct-broadcast data that utilizes the high spatial resolution of MODIS data and the high spectral resolution of AIRS data.

(d) To allow, using the SSEC X-band ground station (using IMAPP), the routine reception of EOS direct broadcast data over the central and Eastern United States and generation of a suite of MODIS and AIRS products within one hour of overpass. The Level-1 and Level-2 near real time regional data can be shared with international TOVS community users to broaden the scopes of EOS earth science initiative.

3.4.5 Package Information

The IMAPP is freely available at the web address

http://cimss.ssec.wisc.edu/~gumley/IMAPP/IMAPP.html

Additional information is available from the paper "International MODIS/AIRS Processing Package - Package Information and Science Objectives" by Hung-Lung Huang, Liam Gumley, Tom Rink, and Jun Li is contained in the Technical Proceedings of the Eleventh International TOVS Study Conference. It summarises differences between IMAPP and GSFC/DAAC Operational Software, Language, Data Formats used and the Supported Platforms. It describes the functions for MODIS, IMAPP, Reformatting (Level-1A), Geolocation and Calibration (Level-1B). It also describes the Level-1A File Contents, Geolocation File Contents and Level-1B File Contents are also described.

3.4.6 Science Objectives

Key science products and objectives are listed below.

(a) ***Cloud Mask*** A cloud detection product will be produced by IMAPP (based on Ackerman et al. 1998).

(b) ***Total Precipitable Water (TPW)*** An IMAPP MODIS TPW model has been completed.

(c) ***Sea Surface Temperature (SST) and Land Surface Temperature (LST)*** An IMAPP MODIS SST/LST product has been completed.

(d) ***Total Column Ozone*** An IMAPP MODIS-derived total column ozone product has been completed.

(e) ***Temperature Profile*** An (example) IMAPP MODIS 500 hPa temperature retrieval product has been developed.

(f) ***Water Vapor*** An IMAPP MODIS water vapor product has been developed.

(g) ***Surface Emissivity*** An IMAPP MODIS shortwave infrared surface emissivity product is available.

(h) ***Future MODIS/AIRS Synergistic Products*** Future Synergistic Level-2 products will also be derived when both MODIS and AIRS data are available through direct broadcast of the Aqua satellite.

3.4.7 Summary

The IMAPP processing capabilities in terms of Level-0 to Level-1, Level-1 to Level-2 have been summarised. Package information has also been summarised. The availability of information concerning language, data format, tool kit, calibration accuracy, navigation accuracy and efficiency, internal file contents and format has also been noted. Scientific objectives of achieving Level-2 products are also outlined, and products such as cloud mask, TPW, SST/LST, total ozone column concentration, shortwave infrared surface emissivity, and sounding profiles of temperature and water vapor are noted.

A new release of IMAPP in March 2001 will include an enhanced Level-1 calibration procedure using B-side electronics and an improved navigation scheme. New cloud and surface type classification algorithms without using the statistic threshold approach are also being developed and further improvements in cloud mask products are expected. Comparisons of IMAPP MODIS Level-2 products with other operational satellite retrieval products are also underway. With all these ongoing efforts and the strong support from NASA and International TOVS Working Group (ITWG), it is expected that IMAPP will continue to rejuvenate itself for the challenges of new research and operational polar orbiting satellite systems.

Acknowledgement

The IMAPP project is currently funded by NASA grant NAG5-9389.

4. ABSTRACTS OF ITSC-XI PRESENTATIONS

Collocation of HIRS/2 and AVHRR data sets

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Collocated HIRS/2 and AVHRR Products (CHAPS) combines observations from the AVHRR and HIRS/2 instruments with NMC forecast model temperature and moisture profiles to generate: global distributions of cloud altitude and amount; the spectral radiative forcing of clouds; and the spectral greenhouse effect. CHAPS collocation and analysis of the NOAA AVHRR and HIRS/2 instruments is conducted in real-time each day.

The HIRS/2 was designed for atmospheric sounding and has a field of view at nadir of approximately 17 km For cloud studies, the CO2 slicing technique approach is often applied to the HIRS/2 observations to determine cirrus cloud top pressure and effective emittance. The CO2 technique for deriving cloud top pressure takes advantage of the differing partial CO2 absorption in several of the HIRS/2 infrared channels. Due to the weighting functions of the CO2 channels, this technique works best for upper and mid-tropospheric clouds, and is least successful for low level clouds.

AVHRR observations are collocated within the HIRS/2 to overcome the horizontal resolution deficiencies of the HIRS/2 and improve the detection of low level clouds. The 4 km Global Area Coverage (GAC) is used to determine cloud amount within the HIRS/2 footprint, using a combination of spatial coherence type tests and histogram analysis. The AVHRR collocated points are also used to determine the scene homogeneity within the HIRS/2 footprint. By independently determining the cloud amount within a HIRS/2 footprint, a better estimate can be made of the cloud emissivity in HIRS/2 fields of view that are partially filled with cloud. By combining the AVHRR and HIRS/2 observations, we make optimum use of each instrument for detecting clear and cloudy regions.

This paper presents results of the CHAPS analysis, including global cloud amount, cloud height and, for high cloud, cloud type (e.g. convective core, thick cirrus). Comparison of cloud products from CHAPS will also be compared with ISCCP, ground based observations and MODIS.

Interannual variability and long-term trends in upper tropospheric humidity

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Water vapor is the most radiatively active greenhouse gas and the water vapor feedback is a process that significantly amplifies global warming induced by anthropogenic greenhouse gases. Satellite radiance observations, sensitive to the water vapor and temperature of the upper troposphere, from the past 20 years provide the first global observations of trends in upper tropospheric humidity. These trends are strongly positive in the deep tropics, negative in the southern hemisphere subtropics and mid-latitudes, and of mixed sign in the northern hemisphere subtropics and mid-latitudes. Large regional trends are related to changes in transient eddy activity. The trends are shown to be consistent with atmospheric circulation changes observed in the past 20 years including a tendency toward more El Niño-Southern Oscillation warm events and a high index of extra-tropical circulation annular modes.

The TOVS Radiance Pathfinder and ISCCP Enhanced Dataset

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The TOVS radiance Pathfinder has a foundation in the very successful International Satellite Cloud Climatology Project (ISCCP), namely, to provide a reduced volume data set of climate observations using the operational sounding instruments on the NOAA polar orbiting satellites. The objectives of the TOVS radiance pathfinder activity include 1) to document and improve understanding of the TOVS instruments including the end-to-end instrument response, 2) to study and document the in-orbit performance of the TOVS instruments, 3) to produce all-sky and clear-sky radiance data set, and 4) to use these data, particularly the water vapor channel data, in studies of climate and global change. Progress in these objectives will be presented.

We have also begun a program to provide significant enhancements to the ISCCP data set. These enhancements include: 1) adding the upper tropospheric water vapor channel from the geostationary satellites, 2) adding the TOVS radiance data set, and 3) adding radiance data from the SSM/T2 moisture sounder. Samples of these significant enhancements to the ISCCP data set will be discussed.

Optimal convolution of AMSU-B to AMSU-A

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In order to find an optimal convolution of the Advanced Microwave Sounding Unit (AMSU)-B to AMSU-A resolution the scan characteristics of AMSU-A and AMSU-B onboard NOAA-15 are examined. A set of coefficients for this degradation is derived using the Backus-Gilbert technique. A 7 x 7 set of adjacent AMSU-B pixels is used where the center pixel is the one closest to a given AMSU-A observation. The error characteristics of the convolution are investigated and, except for the two outermost footprints, a good reproduction of the spatial sensitivity of the AMSU-A by the convolved AMSU-B is obtained. For a NOAA-15 overpass over inhomogeneous terrain we compared AMSU-A data at 89 GHz to convolved AMSU-B data at the same frequency. The root mean square deviation between the so-convolved AMSU-B data and the AMSU-A data was on average 1.7 K including a systematic deviation of -1 K of AMSU-B to AMSU-A. In comparison, simple, equally weighted averages of AMSU-B data produce rms-errors in the order of 4 K and large deviations in regions where gradients in the brightness temperatures occur.
To apply the Backus-Gilbert technique, the AMSU's effective field of view (EFOV) as a function of the scan position was determined. For the continuously scanning AMSU-B the integration time of 18 ms per observation in conjunction with the sensor's rotation leads to a considerable broadening of the antenna pattern in cross-track direction and thus to an increase of the EFOV as compared to the instantaneous field of view (IFOV). This does not occur for the stepwise scanning AMSU-A where the IFOV equals the EFOV (neglecting the second-order effects induced by the approximately 1 km movement of the sub-satellite point during AMSU-A integration). Analytical expressions to calculate the AMSU-A and AMSU-B footprint sizes as functions of their respective scan positions were derived. These expressions exhibit rms-deviations to the actual footprint size of 0.5 km with maximum deviations of less than 1 km.

AVHRR data in support of nowcasting applications

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Within the framework of EUMETSAT's Nowcasting Satellite Application Facility (SAF) new satellite- based applications for nowcasting and very short range forecasting are being developed. We describe a method to remotely sense precipitation and classify its intensity over water, coasts, and land surfaces. This method is intended to be used in an operational nowcasting environment. It is based on data obtained from the Advanced Microwave Sounding Unit (AMSU) onboard NOAA-15 and AVHRR. Each observation is assigned a probability of belonging to four classes: precipitation-free, risk of precipitation, precipitation between 0.5 and 5 mm/h and precipitation higher than 5mm/h. Since the method is designed to work over different surface types, it relies mainly on the scattering signal of precipitation-sized ice particles received at high MW frequencies. After performing a precipitation retrieval from AMSU, the AVHRR data is used to screen out remaining false precipitation echoes in both cloud-free and cloudy areas with very small precipitation likelihood according to AVHRR.
For the calibration and validation of the method we use an eight month dataset of combined weather radar, AMSU and AVHRR-data obtained over the Baltic area. We compare results for the AMSU-B channels at 89 GHz and 150 GHz and find that the high frequency channel at 150 GHz allows for a much better discrimination of different types of precipitation than the 89 GHz channel. While precipitation-free areas, as well as heavily precipitating areas (>5mm/h) can be identified to high accuracies, the intermediate classes are more ambiguous. This ambiguity stems from the ambiguity of the passive microwave observations as well as from the non-perfect matching of the different data sources and suboptimal radar adjustment. In addition to a statistical assessment of the method's accuracy, we present case studies to demonstrate its capabilities to classify different types of precipitation and to seamlessly work over highly structured, inhomogeneous surfaces.

NPOESS Preparatory Project (NPP): an opportunity for data fusion technology demonstration

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In the 2005 time-frame the National Aeronautics and Space Administration (NASA) and the National Polar Orbiting Environmental Satellite System (NPOESS) Integrated Program Office (IPO) will fly a technology demonstration suite of sensors. This mission is to serve two purposes: (1) to bridge the NASA mission objectives of the Earth Observing System (EOS) for climate monitoring, and (2) to provide risk reduction for sensors/ground system and products for the NPOESS mission scheduled to begin in the 2009 time-frame. The NPP mission will carry three meteorological sensors designed to provide real time weather information, and aid near- and long-term numerical weather forecasts. These sensors include the Cross-Track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), the Visible-Infrared Imager Radiometer Suite (VIIRS) and one TBD sensor, possibly an Ozone Monitoring sensor. The CrIS combined with the ATMS constitutes a suite of cross-track sensors capable of taking high spatial and spectral resolution radiometric measurements to produce vertical temperature and humidity profiles globally under a variety of weather conditions. The VIIRS is a cross-track instrument capable of taking high spatial imagery and radiometric data to produce a variety of products including clouds, earth radiation budget, sea surface temperature, ocean color and low-light visible imagery.
Traditionally, each sensor is designed to produce specific products to a specified level of accuracy and precision. However, the opportunity exists to combine the information from all the sensors aboard NPP to produce and demonstrate improved and robust products. This paper will highlight the specifications of the NPP instruments, the specific opportunities for data fusion, the algorithms and theory used in data fusion, and simulation results from specific data fusion examples.

Impact of NOAA/NESDIS-SATEM data in the DWD global NWP system

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Since the last summer the new global model (GME) has been running in the NWP suite of the DWD. During last winter some bad 24h-forecasts of extreme storm events over Europe occurred whereas longer range forecasts for those situations came up with good results. It could be demonstrated that using asynoptic data in the assimilation with a too-large time distance from the analysis time tends to "smear" fine structures of the atmosphere. Therefore, the time range window which allows for the inclusion of asynoptic data like SATEMs had to be tuned. Tightening the window led to improved short-range forecasts of deep lows. Results will be presented to demonstrate this effect. Furthermore it has to be demonstrated that for longer time periods the average score of the model forecasts are higher using the new tighter time window in comparison to the old one. Results of these studies will also be presented.
The examplary impact of positive or negative SATEM-data on the model performance will be demonstrated on the basis of case studies in detail.

Perspective on the operational use of TOVS and ATOVS data at the Hungarian Meteorological Service

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Since mid-1998, the ATOVS and AVHRR Processing Package (AAPP) and the inversion model ICI (Inversion Coupled with Imager) have been used to process (A)TOVS data and retrieve temperature profiles at the Hungarian Meteorological Service. The HAWK (Hungarian Advanced Weather worKstation) visualization tool was upgraded in order to provide a better comparison of the retrieved temperature profiles with ones measured by radiosondes and others forecast by the ARPEGE/ALADIN model. In this paper we give an overview of the development of (A)TOVS retrievals and an introduction to the results of the comparison.

ICI operational package for local ATOVS retrievals: status of the code

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ICI has been developed at the Centre de Météorologie Spatiale of Meteo-France and is now part of the SAF NWP deliverables. This Fortran package is able to produce ATOVS retrievals in an AAPP (ATOVS AVHRR Processing Package, EUMETSAT) environment, with a full set of commands to monitor the quality of the results. We will present the functional scheme of the code for the current operational CMS version, the auxiliary meteorological data, and the different formats for output. We will focus on the graphic postscript capabilities generated with GMT (Generic Mapping Tool), which are converted to image format for web visualization. The cooperation with other ICI places is shown through the same web site where they have their own graphics and areas, that they can maintain off-line. Finally, the future of the code will be presented.

Radiative transfer modeling for SSMIS temperature sounding channels

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The Special Sensor Microwave Imager Sounder (SSMIS) is the latest microwave sensor developed by Aerojet for the Defense Meteorological Satellite Program (DMSP). It combines the functions of the current SSM/T1, SSM/T2, and SSM/I instruments, and additional channels in the 50-60 GHz band provide temperature soundings from the surface to ~ 70 km altitude. In preparation for the launch of the first SSMIS (late 2000), Aerojet's radiative transfer code (ATRAN) has been updated to incorporate recent spectroscopic measurements of O2 line widths, interference parameters, and nonresonant absorption. Comparisons with other absorption models currently used, as well as the effects of instrument passband shape on the predicted brightness temperatures, will be presented. In addition results of a full tensor calculation of brightness temperatures in the presence of a magnetic field are compared to approximate expressions. As the latter form the basis for the SSMIS upper air temperature retrieval algorithm, this comparison provides a critical component needed to estimate the retrieval error.

Experimental cloud products from ATOVS onboard NOAA-15

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The National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite Data and Information Service (NESDIS) currently produces a suite of experimental cloud products from the Advanced-TOVS (ATOVS) High-resolution Infrared Radiometer Sounder (HIRS/3) instrument onboard the NOAA-15 polar orbiting satellite. These products include a global Cloud Top Temperature, Cloud Top Pressure and Cloud Amount in support of operational sounding products, and are generated at each HIRS/3 field-of-view as well as on 1.0-degree gridded fields. NESDIS experimental cloud products are currently under evaluation by the National Weather Service (NWS) for direct use in regional and global Numerical Weather Prediction (NWP) forecasts. This report outlines the scientific algorithms for deriving cloud products (including automated quality control), evaluation results concerning their usefulness in NWP, and pending status for operational implementation by NESDIS.

Comparison between ATOVS data and the ECMWF model in the presence of clouds

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During recent decades, the skill of weather prediction has undergone dramatic improvements. Modellers have concentrated mainly on the validation of temperature and geopotential height, however the improvements in these quantities have increased the interest towards other variable validation: water vapour, winds, cloudiness, radiation, rain, and so on. This gives insight into the model deficiencies and guides corresponding improvements.
Operational comparison of the ECMWF model with TOVS/ATOVS data makes it possible to evaluate the model cloud variables. Firstly, both infrared and microwave cloud absorption has been introduced in the RTTOV radiation scheme in order to compute the radiances from the model. The model radiances are then compared to the observed ones. Secondly, the CO_2 slicing technique is used to derive the cloud top pressure and the cloud effective emissivity of a radiatively effective cloud layer from the HIRS channels. These two variables, either derived from the observed radiances or derived from the model radiances, are also compared together. Results are presented and analysed. From them, prospects for the assimilation of cloud information in the forecast system are discussed.

Recent results with TOVS data in the new CMC 3D-var analysis system: the combined and separate impact of microwave and IR radiance observations, the interaction with aircraft data

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The CMC is about to implement a new higher vertical resolution 3D-var analysis system operating directly on the model's terrain-following coordinate. It will be used by both the regional and global models for the preparation of daily 2 and 10 day forecasts. In preparation for the implementation of this new analysis system, a series of assimilation cycles have been prepared to measure and adjust the impact of various data sources. In particular, the impact of TOVS radiance observations has been studied carefully so as to maximize their impact when run separately and in combination with all other data types. Comparisons with the operational suite and other experimental suites will be presented and the quality of analyses and 10 day forecasts evaluated.

A simple cloud-detection in operational applications of infrared satellite data

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Cloud contamination is one of the most general problems in operational applications of infrared satellite data. Many cloud detection algorithms are based on ancillary data, microwave radiances, simulated or forecast information and visible-infrared radiances coming from other instruments (AVHRR for instance). In any case it is easy to introduce some errors due to the different instrument resolutions and due to the forecast or simulated accuracy data.
Cloud detection depends on the clouds' contrast to the cloud-free environment. Luckily, this contrast varies with wavelength, so that a multispectral approach gives reliable results. Cloud-free and fully cloudy pixels differ considerably in their spectral properties and allow for simple threshold techniques. Partially cloudy pixels vary continuously from cloud-free to fully cloudy and always require a decision on their cloud cover. The cloud detection presented here is based on infrared HIRS/3 data only. In particular it is based on the correlation between the selected channel temperatures and the correspondence level of peak energy contribution. The preliminary results show that the cloud detection algorithm developed is applicable to IASI data also. In order to understand the robustness and reliability of the cloud detection algorithm, the developed software has been validated with both simulated data (CDS-HIRS and CDS-IASI cloud data set) and measured data (ATOVS and IMG). The validation is carried out using a set of global area coverage, which is representative of the spatial and seasonal variability of geophysical parameters. Clear-sky and cloudy-sky have been diagnosed with a high degree of accuracy by means of coincident METEOSAT and AVHRR imagery.

FASTEM, FASTEM2

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RTTOV-5 includes a fast model for the effective microwave surface emissivity of the ocean surface called FASTEM which was developed by S. English from the UKMO. Recently, he developed a much more accurate fast microwave module (named FASTEM2) that takes into account the complex ocean surface effects. FASTEM2 computes both an effective surface emissivity and a path correction factor for the downwelling brightness temperature. This allows for a considerably more accurate parameterization of the interaction between the downwelling brightness temperature and the surface. FASTEM, FASTEM2 and a simplified version of FASTEM2 (for easy implementation in RTTOV) models were implemented in a general line by line microwave radiative transfer model (named MICLBL) developed at the Meteorological Service of Canada. MICLBL can also be run in the same mode as SSMI1DVAR (or RTSSMI) developed at ECMWF by L. Phalippou (Phalippou 1996) or as RTM. RTM is a full geometric optics model that uses the same setup as that used to develop FASTEM and FASTEM2.
Results will be presented that compare the different geometric models with FASTEM and FASTEM2 for the SSM/I and AMSU channels. The impact of how various parameters affect the computed brightness temperatures will also be discussed. The set of parameters includes sea foam, the dielectric constant of the ocean water, Bragg scattering effects and the specification of multiple reflections. The sensitivity of the brightness temperatures with respect to surface wind speed will also be presented.

Towards improved assimilation of ATOVS radiances over land

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ATOVS observations have proven value in enhancing the accuracy of numerical weather prediction (NWP). Despite this, the use of ATOVS observations over land is still very limited compared to the use over the sea at all centres for global NWP.
Recent experiments have shown that increasing the use of ATOVS over a data-sparse land area (30E-130E, 50N-70N) can give rise to small but significant improvements in the accuracy of NWP, especially in that region at short range. These experiments will be described. More general assimilation of ATOVS data over land is limited by large errors in the modelling of emissivity, high background skin temperature errors, problems with precipitation and cloud detection and the possibility of inappropriate bias correction. A semi-empirical technique for modelling emissivity has been coupled to emissivity atlases derived from SSM/I at NASA/GISS. This provides emissivity information to an accuracy of 1-2% away from areas of open water. The merits of this approach and the broad design of its practical implementation will be presented. By combining this information with the information in the window channels through a variational analysis of emissivity model parameters alongside rigorous quality control it is possible to assimilate lower tropospheric temperature information from ATOVS over land. Lower tropospheric humidity may also be possible. Results of observation system experiments using these improved tools for processing ATOVS over land will be shown.

Current status in the assimilation of TOVS and ATOVS radiances at the UK Met. Office

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There have been four upgrades in the assimilation of ATOVS and SSM/I radiances at the UK Met. Office since the beginning of 1999: March 1999: assimilation of 1D-var retrievals from AMSU channels 4 to 14 and HIRS channels 1-8 and 10-15 on NOAA-15. Complete profile assimilated over sea. Only altitudes above 400 hPa assimilated over land. July 1999: assimilation of complete 1D-var profiles over the land area defined by 30E-130E 50N-70N. September 1999: Radiances re-computed from retrieved profiles assimilated in place of 1D-var retrievals and 10 m windspeed analysed from SSM/I brightness temperatures assimilated. May 2000: Observed radiances assimilated in place of radiances recomputed from retrieved profiles.

The introduction of ATOVS in March 1999 and the assimilation of radiances in place of retrieved profiles both gave substantial improvements in the accuracy of the NWP forecasts. The largest improvements were at high altitude and in the southern hemisphere. Total precipitable water from SSM/I has been assimilated experimentally with mixed results. Negative impacts could be resulting from inconsistent or incorrect bias correction, limitations of the assimilation method or interactions with the model physics. In the year since ATOVS radiances were first assimilated the accuracy of the forecasts as verified against both the analysis and observations has improved very rapidly. Forecast root mean square errors in the southern hemisphere in March 2000 have been typically 25% lower than in March 1999, the month in which ATOVS data was first assimilated. This improvement exceeds the gain in accuracy for the whole period March 1992 to March 1999.

Flood area classification and flood-monitoring by AMSU data

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In this paper, the potential of using AMSU window channels data for flood area classification and flood-monitoring over the Changjiang River Basin of China in 1998 is investigated. Recent studies have shown that useful information can be abstracted from AMSU window channels by using a new soil wetness index (NSWI). We built the NSWI following the form of the BWI (Bassisti 1998). But the window channels we used here (AMSU CH2, CH3 and CH15) were very different from the BWI and these channels all are vertical polarization. Our NSWI has the form of: NSWI(CH2)=a*Tb(CH15)+b*Tb(CH3)+c*Tb(CH2). VDISORT radiance transform model was used when we derived the coefficients in the equation of NSWI.

In accord with the new concept of water body percentage, we can get the threshold of NSWI for flood classification. Then the flood area can be classified into three kinds: flood area, muddy area (over wet area) and wet soil area. The analysis results indicated that, we can get the accuracy of 80% in flood area classification over the Changjiang River Basin of China in1998 in contrast with the data of China plane L-SAR data and Canada Radarsat SAR data over Changjing River Basin in the summer of 1998, and the flood-monitoring algorithm is easy to use in operational flood-monitoring. Future work will investigate possible improvement to the flood area classification and the flood-monitoring algorithm using AMSU-B (CH16 and CH17), and extending the testing of the algorithm to the other regions.

An overview of the results from the HIRS-AMSU intercomparison of radiative transfer codes

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The HIRS-AMSU intercomparison (an ATOVS initiative from the radiative transfer sub-group) provided results from 19 infrared and 11 microwave models, ranging from fast monochromatic to detailed line-by-line models, as applied to 7 HIRS and 4 AMSU channels. Brightness temperatures, transmittances and Jacobians (of temperature, water vapor and ozone) were compared. The weaknesses and strengths of the fast models, notably those meant to be used in radiance assimilation into NWP, are analysed. Similarly, the smaller, but still significant differences among line-by-line models are studied. In general, fast models do well in most channels, but none is fully satisfying in all channels. For some channels, results depend strongly on the line-by-line reference used to develop the fast model. Results are available on a web site and a formal report should be ready for distribution at the time of the conference.

On the utility of high spectral resolution Jacobians

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Vertical profiles of Jacobians with respect to temperature and specific concentrations for eight gases were computed at high spectral resolution (0.005 cm-1) with the AESLBL model for the US standard atmosphere and for most of the infrared spectrum. These plots synthesize the information content of narrow channels. They represent a basic tool for the optimum selection of narrow (~0.25-1.0 cm-1) channels available from AIRS or IASI. The plots also allow one to identify channels which can best be modeled by fast radiative transfer models, as less precision is in general obtained in areas of rapidly varying Jacobians. Examples of this latter application will be shown.

Observed influence of precipitable water on convective activity in tropical West Africa

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For the improvement of climate and weather prediction in the tropics it is important to understand the main characteristics of convective systems (CS) and how they relate throughout the behavior of physical parameters with their environment. CS may provide disturbances that sometimes can intensify into tropical cyclones. The convective activity (genesis and decay of convective systems) is generally modulated by external factors such as orography, surface heating, synoptic weather systems like easterly waves and monsoon fluxes.

Over West Africa, areas of important convective systems activity are mountainous regions and monsoon regions. Very low convective activity was found around 0 deg. longitude in the equatorial upwelling region associated with a Walker-type circulation between there and the Ethiopian region. Then genesis and decay of Mesoscale Convective Systems (MCSs) depends largely upon thermodynamic and dynamic mechanisms.

In this study we specially focus on the influence of precipitable water vapor in MCS activity. We use NASA Water Vapor Project (NVAP) data (1985-1988), SSM/I and PIRATA soundings to determine precipitable water data sets (1988-1999). Intercalibration has been done between HIRS/2 and Meteosat Water Vapor Channel.

Seasonal maps or precipitable water give global features of water vapor spatial distribution. These patterns have similar spatial distribution to the MCS activity.

The Crosstrack Infrared Sounder (CrIS)

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The Crosstrack Infrared Sounder (CrIS) is one of the sensors now under development for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program, which is the follow-on to the current DMSP and POES meteorological satellite systems. CrIS is an interferometric sounding sensor which accurately measures upwelling earth radiances at very high spectral resolution, and uses this data to construct vertical profiles of atmospheric temperature, moisture and pressure. ITT Industries was recently awarded a contract from the NPOESS Integrated Program Office to build at least three flight sensors for upcoming NPOESS satellite missions, with a first flight planned for 2006.

The purpose of this paper is to describe the CrIS system design developed by ITT Industries. This includes a discussion of the key trade studies that led to selection of optimum design approaches for the sensor and retrieval algorithms. The designs of the sensor and algorithms are also discussed in detail. We also describe numerous risk reduction demonstrations that were performed to confirm the readiness of the technologies used in the CrIS design. Finally, we summarize the projected performance of the CrIS sensor and its retrieved data products.

Climate data sets from the Advanced Microwave Sounding Unit-A

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Atmospheric temperatures, limb adjusted brightness temperatures, total precipitable water and cloud liquid water (the latter two over ocean-only) have been derived from AMSU-A using a fixed algorithm without periodic tuning.

Daily, pentad, and monthly data sets are available. Validation of the temperature retrievals using collocated radiosondes in the troposphere and lower/mid stratosphere and HALOE-derived temperature in the upper stratosphere show excellent agreement. Temperature errors are mostly below 1.5 K. Total precipitable water shows very good agreement with collocated radiosondes (about 10%). AMSU-A retrievals currently provide the best information on temperature in the mid to upper stratosphere, with respect to both global coverage and accuracy. Methodology and validation of the products will be presented as well as the description of available data sets.

Operational processing and distribution of AIRS

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The Atmospheric InfraRed Sounder (AIRS) will provide the first high spectral resolution dataset available for routine NWP assimilation. The near-real-time processing and distribution of AIRS will occur at NESDIS. Processing of the data will include the generation of temperature and moisture retrievals and the detection of clear radiance field of views. Both clear and non-clear radiances will be distributed to NWP centers to allow direct assimilation of radiances. The AIRS data sets also include microwave instrument data from the Advanced Microwave Sounding Unit (AMSU) and the Humidity

Sounder Brazil (HSB). The talk will include description of the instruments and methodologies for cloud detection, retrieval of geophysical products and data distribution/compression.

Assimilation of AMSU-A observations in HIRLAM 3D-VAR

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A 3D-Var assimilation scheme has been developed as part of the HIRLAM (High-Resolution Limited-Area Model) cooperation. An important part of the work with the scheme has been to include observation operators for satellite data in the scheme, including direct use of ATOVS radiances. The system is able to assimilate locally received near-real-time NOAA data for use in limited-area modelling with short cut-off-time, and radiance data received from NESDIS can also be utilized.
The ATOVS preprocessing is performed with the EUMETSAT AAPP package. The use of ATOVS-data in the system is described, including bias correction, quality control, thinning and observation error modeling. An example using AMSU-A-data in the North-Atlantic is presented. The experience so far is discussed, and the impact of the AMSU-A data is evaluated.

Use of ATOVS radiances in the 1DVAR/GASP data assimilation system

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The Global Assimilation and Prediction System (GASP) at the Bureau of Meteorology Research Centre (BMRC) has previously shown good positive impact in the Southern Hemisphere and the Tropics, and neutral impact in the Northern Hemisphere, using one-dimensional variational retrievals (1DVAR) with TOVS radiances from the NOAA-11 and NOAA-14 satellites. We show that that inclusion of ATOVS radiances from NOAA- 15 significantly increases the information content of the 1DVAR retrievals, and as result produces an improved analysis and consequently an improvement in the forecast scores.

This configuration was tested at a resolution of T79L29 before extensive parallel testing at the operational resolution of T239L29 culminating in the operational implementation of the 1DVAR system in August 2000.

International MODIS/AIRS Processing Package - Package Informationa and Science Objectives

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The Space Science and Engineering Center at the University of Wisconsin-Madison with support from NASA has installed an X-band ground station to receive direct broadcast from the EOS Terra and Aqua satellites in near realtime. Image data from MODIS (MODerate resolution Imaging Spectro-radiometer) are received and processed to Level-1B within 60 minutes of reception. The system includes commercially available antenna hardware; a data receiving front end; ingest software; and reformatting, calibration, navigation, image processing, and atmospheric product generation software.

An International MODIS/AIRS Processing Package (IMAPP) has been developed for processing of EOS MODIS data for weather, climate, nowcasting, NWP, cloud property, and radiation budget studies. Future system capabilities will encompass EOS Aqua AIRS (Atmospheric Infrared Sounder) data receiving and processing. This paper will address the details of system configuration, MODIS product requirements, and expectations of the International TOVS community.

Assimilation of (A)TOVS data at the NASA Goddard Data Assimilation Office

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At the NASA Goddard Data Assimilation Office (DAO), a 1D variational radiance assimilation system has been developed. This system, called DAOTOVS, uses (A)TOVS level 1b radiances. It has been implemented within the DAO's semi-operational system as well as within the next generation data assimilation system that uses a finite-volume dynamical core. We will show results from (A)TOVS assimilation, including stratospheric analyses and validation. We will also describe our systematic error correction scheme which is based on collocated radiosondes.

Results of TOVS ozone retrieval with neural networks

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We will present the results of a recently finished project concerned with total ozone retrieval on a global scale from HIRS and MSU brightness temperatures. The project encompasses processing TOVS data ranging from1990 to 1999 by means of a neural network technique utilizing information from all thermal spectral channels. Comparisons with WOUDC ground station measurements yielded a day and night average RMS accuracy of about 12 D.U. for all atmospheric conditions, including broken clouds. Some further validation with gridded TOMS data revealed structures in the difference pictures suspected to stem from dynamical effects and/or TOMS cloud treatment, leading to somewhat higher TOMS-TOVS RMS values. However, we conclude that TOVS has qualified as a suitable instrument for accurate and fast ozone retrievals, especially since it is currently the only orbital sensor capable of measuring ozone in the polar night.

Future work will be directed towards application of neural network techniques to other sensors including ATOVS, which promises to yield even higher accuracy due to its increased number of channels. Encouraging results are currently found from a running project with ERS-GOME data total ozone and ozone profile retrievals.

The use of AMSU_A surface channels to obtain surface emissivity over land,snow and ice for Numerical Weather Prediction

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At ECMWF, the operational use of the lower troposphere sensing AMSU-A channels 5 and 6 has been limited to the oceanic regions and to a limited extent over sea-ice. This work uses a parametric model using AMSU-Achannels at 23.4,31.8, 50.3, 89.0 GHz to estimate values of surface emissivity over land, snow and ice. In addition the model provides estimates of rain and cloud (over water only) that are useful for quality controlling AMSU-A radiances in NWP. Data assimilation has been carried out for a period of six months to validate the emissivity model.

Comparison of temperature retrieval performance of the IASI interferometric and the GRAS occultation sensor

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The interferometric sensor IASI (Infrared Atmospheric Sounding Interferometer) and the Global Navigation Satellite System (GNSS) radio occultation sensor GRAS (GNSS Receiver for Atmospheric Sounding) are part of the core payload of the European Polar System MetOp satellite series (MetOp-1 launch scheduled 2003).

Both IASI and GRAS furnish temperature profiles as a key data product and share the goal of providing them with an accuracy of < 1 K at a vertical resolution of ~1 km. Such potential performance is currently unique to high-resolution IR spectroradiometry and occultation sounding, respectively, just the techniques represented by the two sensors.

Using ensembles of 300 globally distributed co-located soundings for IASI and GRAS, which were realistically simulated based on an ECMWF T213L50 global analysis field (Sep 15, 1999, 12UT), we comparatively analyzed the temperature retrieval performance of the sensors in terms of biases, rms errors, and correlation functions, respectively. We also studied other properties including vertical resolution and dependence on prior knowledge.

Results are presented in the form of a direct comparison of performance measures and evaluated in light of the specific characteristics of each of the sensors and their associated retrieval methodologies. The co-existence of IASI and GRAS on MetOp is highly valuable for rigorous mutual validation.

Land infrared emissivity for Numerical Weather Prediction

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Radiative transfer models are becoming so accurate that the departure of infrared emissivity from unity and local variations of emissivity are now important. In the context of Numerical Weather Prediction, emissivity is required for accurate cloud detection and clearing, and to determine land skin temperature for surface energy flux calculations. The problem is that emissivity is bound with skin temperature in the surface term of the radiative transfer

equation. There are additional difficulties with inhomogeneities in the field of view, and variations of the emissivity of some materials with wavelength. Further, the emissivity can change with time as vegetation cover grows and decays with the seasons. This paper will present some discussion of this problem, and suggest a simple method for dealing with infrared land emissivity, and present preliminary results from the HIRS instrument.

A method for correlated noise modeling in satellite radiance simulation

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One of the major difficulties in simulation of realistic satellite radiances for Observation Systems Experiments and other purposes is modeling the correlated inter-channel noise. In this paper we present a method that accurately simulates this correlated noise. Given a noise covariance matrix, the algorithm produces multi-channel noise which statistically matches the original matrix. Examples of this technique will be given for the High Resolution Infrared Sounder carried on the NOAA satellites.

The Special Sensor Microwave Imager / Sounder

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The SSMI/S is scheduled for launch on a DMSP satellite in November 2000. This new instrument is a conically scanning microwave instrument with all channels viewing a common field of view. It includes imaging channels similar to the SSM/I, as well as temperature and water vapor sounding channels, and channels sensitive to mesospheric thermal emissions. This paper will discuss some of the basic features of this instrument, and review the product list of the operational processing software.

ICI retrieval package: towards version 3

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The ICI sounding scheme developed at CMS/Météo-France for the processing of local HRPT data is interfaced with the 'ATOVS and AVHRR Preprocessing Package' level1d files and has performed retrievals for TOVS and ATOVS channels since summer 1998. The results of the two first years in the operational context are shown.

An ICI version 2 processing HIRS/AMSUA, has been delivered to EUMETSAT at the end of 1999 in the frame of the NWP SAF. This version has also been implemented in other HRPT stations in different areas of the world. A graphic package inside ICI based on the freeware GMT graphic package is used by each of the different users to display in near real time, on the ICI website, the accuracy of their retrievals when compared to collocated radiosonde and analyses. An evaluation of the package exportation will be given. It appears that at each new implementation of the software, the access to NWP outputs for running ICI in similar conditions to those in CMS is difficult and we present a study which we expect could solve this problem.

An update of the package is planned for January 2001. The main evolutions concern the processing of the water vapor channels (HIRS and AMSUB) for retrieving the humidity profile, a improved use of the surface and of the stratospheric microwave channels, the implementation of a quality control at each step of the software together with the improvement of the tuning approach. Temperature and humidity statistics will be presented with the new version.

Regional Sounding

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Detailed sounding of the atmosphere at regional scales depends on the use of high spatial temporal and spectral resolution satellite observations. In the area of temperature and moisture sounding VTPR then TOVS and ATOVS have contributed to forecast skill particularly over the southern hemisphere. Recently direct readout ATOVS data from NOAA-15 has been used in a data impact study over the Australian region and demonstrated positive impact at all levels examined. In relation to preparation

for future Advance Sounders, results are presented showing temperature profiles derived from synthetic AIRS data using a one-dimensional non-linear full physical retrieval scheme. Work is also described, based on the use of aircraft Advanced Sounder data (both HIS and NAST-I data) in combination with a high resolution (1km) 4D-Var. assimilation scheme, to study the influence of sequential Advanced Sounder data on initialised temperature, moisture and wind fields. These experiments are precursors, to the definition of a new scheme to use observations from sounders such as GIFTS to provide geophysical data.

Retrieval of water vapor from IASI measurements: methodology and case study application

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An optimal estimation retrieval technique is applied to a subset of simulated radiances from the Infrared Atmospheric Sounding Interferometer (IASI). Approximately 500 of the original 8000 channels are chosen based on the peak contribution height and information content of each channel. Radiances and weighting functions are simulated using the RTIASI fast forward transmittance model which has a vertical sampling of less than 1 km in most of the troposphere and 1-2 km in the lower stratosphere where the retrievals are made.

Retrievals of water vapor are applied to a latitude-height cross section from an ECMWF analysis field on 15 September 1999 at 1200 UTC. Typically, 3-5 iterations are necessary to attain convergence in the retrieval algorithm. Humidity features associated with Hurricane *Floyd* and a Southern Hemisphere extratropical cyclone at 79 degrees west longitude are analyzed. The retrieval noise, forward model and smoothing error characteristics are presented to reveal at which levels confidence in the retrieved quantities is greatest and/or least.

Further development of the International ATOVS Processing Package (IAPP)

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The International ATOVS Processing Package (IAPP) has been developed to retrieve the atmospheric temperature profile, moisture profile, total ozone and other parameters in both clear and cloudy atmospheres from ATOVS radiance measurements. The IAPP algorithm retrieves the parameters in 4 steps: 1) cloud detection and removal; 2) bias adjustment; 3) regression retrieval; and 4) nonlinear iterative physical retrieval. A recent publication by Li, Wolf, Menzel, Zhang, Huang and Achtor, *Journal of Applied Meteorology,* August 2000, provides details on the algorithm.

IAPP v1.0 was released to the international community in April, 1999. Version 1.1, consisting primarily of small improvements and software fixes, was released in June, 2000. In October, 2000 a significant upgrade will be released. Key features of the upgrade include:

1. AMSU-B radiances are used for moisture retrieval.

2. The regression first guess is now based on zenith angle classification.

3. All regression routines are applicable to NOAA-L ATOVS data.

4. A technique to calculate cloud top pressure (height) from the CO_2 absorption technique has been added. In addition, a new technique to use the AMSU -A O_2 absorption band over land to determine cloud heights has been completed.

In the coming year, future work on the IAPP will include: 1) improved bias adjustment; 2) incorporation of AVHRR for improving cloud detection; 3) development of AMSU –B derived moisture and cloud products; and 4) capability to create and use a surface analysis from METAR observations and a model background field.

Finally, a set of powerful visualization / data manipulation tools for ATOVS and IAPP output has been created within the Man-computer Interactive Data Access System (McIDAS).

Rapid transmittance algorithm improvements

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Atmospheric transmittance calculations are necessary for analyzing radiance observations from infrared and microwave sounders on satellites. For the NOAA series of satellites, these are the HIRS and AMSU instrument. Since it takes so long to calculate the exact transmittances using line-by-line techniques, rapid algorithms are employed to calculate the transmittances for single channels. A number of comparison have been made to determine the effects of different line-by-line models, the constant pressure or the constant absorber spacing, and the effects of the number of levels on the accuracy of the rapid algorithm. Results will be presented. For example, the different line-by-line data sets include the operational data from LBLRTM used by NESDIS, GENLN2 data used by the ECMWF, and data from LBLRTM provided by Jean-Luc Moncet of Atmospheric and Environmental Research. The operational data uses the 32 profiles (which have become to be known as the NESDIS profiles). The other two are based on the set of 43 (34 for ozone) profiles used by the ECMWF. The ones from Jean-Luc Moncet also contain additional levels in the upper atmosphere. Results from these comparisons will provide guidance for future improvements to the model.

Carbon dioxide retrievals

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Carbon dioxide is an important greenhouse gas. We are examining the feasibility of detecting the variability of carbon dioxide in the atmosphere using the TOVS instruments. Although the signal for the annual increase and the annual cycle in many parts of the globe is below the expected noise levels, in the northern hemisphere (Point Barrow), the annual cycle of about 15 ppmv produces a signal of about 0.7 K in the more responsive channels. A sensitivity study will be performed using simulation to determine the accuracy to which the total column carbon dioxide can be retrieved. This study will be completed by August 15. Results will be presented at the meeting.

The NESDIS unified validation system

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NESDIS is developing a unified system to validate atmospheric soundings from satellite sensors. Larry McMillin is responsible for validating soundings from the AIRS instrument on the EOS platform. McMillin, Tom Kleespies, Ralph Ferraro, and Fuhzong Weng are responsible for validating products from the SSMIS instrument. There are several satellites planned for the future (for example METOP, NPP, and NPOES) that will need to be validated and monitored. Much of the work in validating consists of formatting the validation data in a form that can be easily accessed. Processing all the data on a common platform with a common format makes the validation of additional instruments much easier. In addition, it offers the opportunity to cross-validate instruments. Tools are being developed for the validation process using the TOVS as the prototype instrument. Examples are a plot of the accuracy as a function of solar zenith angle, and accuracy as a function of time and distance to access the effect of time-coincident launches. Plans for the validation system and results of some of the comparisons will be presented.

Recent developments in the use of satellite data at ECMWF and preparations for advanced sounders

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An overview of recent developments at ECMWF will be presented with emphasis on the operational use of TOVS/ATOVS raw radiance data in 4DVAR. Areas were good progress has been made and the areas where significant problems remain will be discussed. Finally, preparations for the assimilation of radiance data from advanced sounders (AIRS/IASI) will be described.

Comparison of University of Wisconsin HIRS and ISCCP D2 cloud studies

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Cloud statistics from the University of Wisconsin (UW) analysis of High resolution InfraRed Sounder (HIRS) data were compared to the International Satellite Cloud Climatology Project (ISCCP) D2 statistics. The comparison included monthly averages of the frequency of total cloud cover, high clouds, and cloud properties (optical depths and IR emissivities) measured by each cloud detection system. The comparison focused on the months of January and July over five years. The UW HIRS analysis reported more total cloud cover and more high cloud cover than the ISCCP D2 in both January and July. ISCCP D2 detected clouds in 65 to 67% of their observations while the UW HIRS averaged 71 to 73%. The largest differences were in the ITCZ and the polar winter. High clouds were found in 18% of the ISCCP data and 33% of the UW HIRS data. High cloud detection differences were greatest in the ITCZ. Cloud radiometric properties were compared by converting the ISCCP visible optical depth measurements to equivalent infrared emissivities. The monthly averaged emissivities were similar; the ISCCP ranged from 73 to 76% while the UW HIRS ranged from 68 to 69%. The largest cloud emissivity differences were in the ITCZ and the summer hemisphere.

Towards the adaptation of the ICI retrieval software to IASI data

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In the framework of the MASSIF contract, involving EUMETSAT, Météo-France and LMD, work is currently performed at CMS to adapt the ICI inversion software to the future IASI data. The ICI algorithm implies two main steps: choosing a guess profile, among an updated rolling library of analyses profiles, and then performing the 1-DVar inversion itself. The present paper focuses on the use of IASI data for improving the first stage. The guess profile is found by minimizing a distance between its associated calculated radiances and the observed radiances. This distance should account for the radiances covariances, evaluated over the whole profile library. The calculation, storage and manipulation of the corresponding covariance matrix obviously requires the selection of a reasonable subset of the 8461 IASI channels. Direct calculations performed over 300 profiles from the TIGR database allow one to gather channels having similar behaviours into about 100 to 600 classes. One radiance only from each class takes part in the radiance-based distance calculation. The efficiency of this technique is evaluated for an increasing number of classes, several scanning angles and various ways of defining the best radiance for each channel class. The improvement of the guess selection due to the use of IASI instead of HIRS channels is underlined.

Recent developments in assimilation of TOVS and ATOVS at JMA

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The TOVS 1-Dimensional Variational (1DVar) system was introduced operationally into the global assimilation system of Optimal Interpolation at the Japan Meteorological Agency (JMA) in March 2000. RTOVS provided by the National Environmental Satellite Data, and Information Service (NESDIS) is processed only over sea in the TOVS 1DVar system. As for ATOVS, we use temperature profiles from BUFR and thickness profiles from SATEM retrieved by NESDIS.

The ATOVS 1DVar system is under development. One problem of the moment is a large difference between measured brightness temperatures (TBBs) and calculated TBBs for surface sensitive microwave channels.

A 3-Dimensional Variational (3DVar) system is being developed. It will be operational about half a year after replacement of a supercomputer in March 2001. It is planned to assimilate ATOVS radiances directly in the 3DVar. The top height of JMA global forecast model will be extended to 0.4 hPa. It will improve the accuracy of calculating TBBs for ATOVS upper stratospheric channels.

Self-adaptive algorithms for change detection: OCA (the One-channel Cloud-detection Approach) — an adjustable method for cloudy and clear radiances

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Many algorithms, have been up to now proposed, which are devoted to detect local abrupt changes, in the satellite multi-spectral radiance fields, possibly associated, from time to time, with different atmospheric or superficial phenomena (e.g. clouds, forest fires, volcanic eruptions, etc.). Their application to the global scale often gives generally poorer results mainly because of the high-variability of local (i.e. punctual in the space-time domain) atmosphere and surface parameters whose knowledge is frequently lacking or insufficient. A new, self-adaptive approach (RAT- Robust AVHRR Techniques), to Earth surface and atmosphere monitoring by satellite, at the same time reliable and fully exportable (as it is based only on satellite data) has been recently proposed and its application to several environmental emergencies suggested. Preliminary, but very encouraging results have been already achieved by using NOAA/AVHRR data in the fields of fire detection, monitoring of volcanic eruptions as well as stratospheric aerosols increase due to major eruptive events.

In this paper the application of RAT to the problem of cloud-detection and clearing will be presented using as test-package NOAA/AVHRR. The One-channel Cloud-detection Approach (OCA) will be described and results coming from its application to more than ten years of NOAA/AVHRR imagery presented by comparison with traditional multi-spectral techniques.

The main aim of this work was to verify an alternative (i.e self-consistent) way for cloud(y radiance)s-detection and clearing also in the presence of radiometers (e.g. GERB/MSG) with very low-spectral resolution. Positive impacts expected also for multispectral VIS-IR sounders, will be discussed with reference to present and future meteorological satellite missions.

A new neural network approach including first-guess for over-land microwave retrieval of atmospheric water vapor, cloud liquid water path, surface temperature and emissivities from SSM/I observations

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The use of microwave observations over land for retrievals of atmospheric and surface parameters is still limited, due to the complexity of the inverse problem. Neural network techniques have already proved successful in the development of time-effective retrieval method for nonlinear cases. However, a first-guess estimate is often very important and up to now, neural network methods did not take into account such *a priori* information.

In this study, a neural network approach is developed that includes the use of a first guess. It retrieves the surface skin temperature, the integrated water vapor content, the cloud liquid water path and the microwave land surface emissivities between 19 and 85 GHz, from SSM/I observations. A simulated data base is designed to train the neural network; it is derived from a global collection of coincident surface and atmospheric parameters, extracted from the US National Centers for Environmental Prediction reanalysis, from the International Satellite Cloud Climatology Project data and from microwave emissivity atlases previously calculated.

The results of the neural network inversion are very encouraging. The r.m.s. error of the surface temperature retrieval is 1.3 K in clear sky conditions and 1.6 K in cloudy scenes over the globe. Water vapor is retrieved with a r.m.s. error of 3.8kg/m2 in clear conditions (4.9 kg/m2 in cloudy situations). The r.m.s. error in liquid water path is 0.08 kg/m2. The surface emissivities are retrieved with an accuracy of better than 0.08 in clear conditions. The respective merits of the neural network and the variational approaches are compared.

Comparison of two methods to estimate the cloud-top temperature and pressure for NOAA-AVHRR and HIRS data

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Within the SAF in support of Nowcasting and Very Short Range Forecasting (SAF NWC), software has been developed to extract cloud parameters (cloud mask and types, cloud top temperature and height) from MSG SEVIRI imagery.

Part of this work is the choice of the most appropriate method to estimate the cloud top temperature and pressure. For this reason test calculations were made for NOAA and GOES data comparing the results of different methods. This paper focuses on the comparisons made for NOAA data.

We used two methods to estimate the cloud top temperature and pressure: the AVHRR histogram method and the radiance ratioing method. The AVHRR histogram method uses AVHRR measurements. After detecting the opaque and semi-transparent clouds it calculates a mean opaque and semi-transparent cloud top temperature for the HIRS spots but using the corresponding AVHRR 11 mm and 12 mm channel measurements. The radiance ratioing method uses the HIRS measurements itself. It calculates the cloud top pressure in HIRS spots using measured brightness temperatures in pairs of HIRS channels. The retrieved cloud top pressures extracted from different channel pairs were compared to each other and with the results of the AVHRR histogram method, as well. Both methods need NWP vertical temperature and humidity profiles for data simulations. The French NWP model

ARPEGE was used. The results of the methods were routinely compared by analysis of statistics of their differences separately for opaque and semi-transparent clouds and different underlying surface types for a several month period. The results were validated by comparing with lidar measurements performed in Lannion, France.

The analysis and evaluation of the retrieving results of IAPP in NSMC

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Since early 1999, the ATOVS and AVHRR Processing Package (AAPP) has been operating in the National Satellite Meteorological Center (NSMC) and providing a real data base for retrieving the atmospheric profile and surface parameters from ATOVS observation. The International ATOVS Processing Package (IAPP) developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin-Madison was also introduced to NSMC in late 1999 and was installed in a SGI workstation with IRIX operating system version 6.4. After a small correction to the software, IAPP has run successfully with the input of ATOVS level 1D data from AAPP and is available to produce retrievals of atmospheric temperature, water vapor and dew point temperature profiles, total ozone, precipitable water, cloud top pressure, rainfall, surface skin temperature and microwave surface emissivity. In this paper, some results of IAPP operating in NSMC compared with atmospheric profiles obtained from radiosonde and an NWP model will first be provided, then the analysis will be made to estimate the effects of different input data except ATOVS level 1D data on retrieval accuracy and finally an evaluation to the running of IAPP in NSMC will be given.

Comparison of channel selection methods for IASI

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IASI is an Infrared Atmospheric Sounding Interferometer developed by CNES and EUMETSAT to be on board the polar-orbiting METOP satellites. The large volume of data (8461 channels) and amount of computations required to treat them is prohibitive, unless a reduction of the number of channels is achieved. In the numerical weather prediction context of a one-dimensional inversion (retrieval) procedure, four methods selecting the most informative channels are compared. The four methods are: an iterative method (from C. Rodgers), a Singular Value Decomposition (SVD) method (from P. Prunet), a data resolution matrix method and a weighting function method. The four methods are compared for a few profiles representative of extremely sensitive weather events, and for a set of meteorological conditions representing the overall temporal and spatial atmospheric variability.

Monitoring and assimilation of ATOVS data at Meteo-France

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The operational variational analysis at Meteo-France uses pre-processed radiances from NESDIS. A 1D-Var scheme is used as a pre-processor for quality control, adjustment of surface temperature and of temperature above the top of the model. Then, the radiances are directly assimilated in the 4D-Var assimilation system. TOVS radiances have been assimilated since March 1999, and ATOVS radiances since mid-2000. Results of pre-operational monitoring and assimilation show a positive impact on the forecasting system. Monitoring has also been performed for raw radiances processed via the AAPP system within the Lannion reception area and a comparison with NESDIS pre-processed data has been made.

Operational sounding products from ATOVS onboard NOAA-15

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The National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite Data and Information Service (NESDIS) currently produces operational sounding products from five polar orbiting satellites, including the Advanced TOVS temperature and moisture sounding products from NOAA-15. This report describes the scientific algorithms for deriving soundings, including adjustments to the radiometric observations, cloud detection, and the suite of products available to users. Evaluation results against collocated radiosonde, numerical weather prediction forecast (and analysis), and existing NOAA and Defense Meteorological Satellite

Program data are presented. The report concludes with future plans for the simultaneous retrieval of sounding products from combined Advanced Microwave Sounding Unit (AMSU)-A, AMSU-B and High-resolution Infrared Radiation Sounder (HIRS/3) measurements.

A program for combining radiosonde and polar satellite observations from theNOAA Science Vessel *RONALD H BROWN* for weather guidance over remote oceans

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The National Oceanic and Atmospheric Administration (NOAA) currently operates a fleet of ocean vessels to support scientific research over remote ocean regions, including the premier NOAA Research Vessel *RONALD H. BROWN* (RHB). Ongoing collaborative efforts between NESDIS and NOAA's Environmental Technology Laboratory (ETL) include expanding NOAA's mission for the RHB to include routine radiosonde launches coincident with Advanced-TOVS (ATOVS) polar satellite overpass, and a demonstration of their impact on NESDIS global sounding products, and locally processed sounding product systems onboard the RHB. This includes support for PACJET: Pacific Landfalling Jets Experiment (www.etl.noaa.gov/programs/pacjet), to develop and test methods for improving short-term (0-24 h) forecasts of damaging weather on the US West Coast emerging from the data-sparse Pacific Ocean (scheduled from January through March, 2001). PACJET joins several agencies across NOAA, including ETL, the Office of Marine and Aviation Operations, NESDIS (including Cooperative Institute for Meteorological Satellite Studies (CIMSS)), the National Weather Service, the US Navy, several University and Joint Institutes, and the RHB. The following report summarizes planned collaborative activities between NESDIS and ETL in support of NOAA polar satellites, and planned activities in conjunction with PACJET.

On the planetary emission between 100 and 600 cm-1 in presence of clouds

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Extending the global spectral information that will soon be available from AIRS and IASI to the far- infrared (FIR) region, from 100 to 600 cm-1, is important for at least the following two reasons: • The terrestrial emission in the FIR is peculiar since radiance arises mainly from the mid and upper troposphere, while the bulk of the emission monitored by spectrometers and broad-band radiometers comes from the underlying surface and lower troposphere.
• Most broadband radiometers used to measure the Earth Radiation Budget (ERB) are sufficiently well characterised only up to 350 cm-1. That is, even if their sensitivity extends to 100 cm-1 (CERES) or 50 cm-1 (ERBE), the far infrared component is known with insufficient accuracy. In the GERB (Geostationary Earth Radiation Budget) experiment on board Meteosat Second Generation (MSG) there is a limitation in the sensitivity of the detectors and therefore the range below 35 microns is unmeasured.

We have therefore started an analysis of the quantitative role of the still unmeasured range with respect to the total planetary emission to space. In particular we have extended the study to account for the emission in the presence of realistic clouds.

We will present the simulation technique adopted and describe the selected atmospheric profiles and the properties of the cloud types used for the computations. The results show clearly that the unmeasured portion of the Earth's spectral radiant emission is important also from a quantitative point of view when compared to the total. This result has been pointed out for computations involving standard profiles with no clouds present. The results with clouds presented in this note indicate that their effect is to make the range below 600 cm^{-1} still more important. The fact that broadband radiometers that measure, or infer, the total longwave radiant emission, are sufficiently well characterised only up to 350 cm^{-1}, clearly indicates one further motivation to perform accurate spectral radiance measurements in the FIR.

Status about microwave frequency protection

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The World Radio Conference (WRC 2000) of the ITU (International Telecommunications Union) held last spring has been successful in protecting our frequencies up to 275 GHz. Some difficulties still exist in the windows below 20 GHz. It is now necessary to consolidate the scientific use of all our frequencies, because new attacks could come in 2003 from the next World Radio Conference (WRC 2003). The pressure of the commercial and military telecoms is growing so much that they will try to "share" all our bands. It should also be useful to test some possible noise in the windows by appropriate methods . Furthermore, it's also time to express the needs above 275 GHz for limb sounding and for near-nadir geostationary sounding.

AAPP V2.0 first results and future plans for the ATOVS sounding processing practices using ICI in Brazil

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The objective of this paper is to present the AAPP first results obtained in Brazil. AAPP V.2 was implemented at DSA/INPE (Environmental Satellites Division/Brazilian Space Research Institute). In the AAPP processing, numerical weather prediction products, from the CPTEC/INPE (Center for Weather Prediction and Climate Studies) Global Model, as well as SST (Sea Surface Temperature) data, produced by DSA, are used. The AAPP implementation is the first step of the CPTEC ATOVS Project. In cooperation with CMS (Centre de Météorologie Spatiale), CPTEC is installing the ICI in order to retrieve atmospheric information from the ATOVS sounding radiances acquired in real time by the DSA/INPE TIROS-N receiving station. The first guess is obtained from the CPTEC Global Model analysis data.

RTTOV - 6: New features and validation results

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The fast radiative transfer model, RTTOV, used by several NWP centres for ATOVS radiance assimilation, has recently been upgraded to include several new enhancements. This work has been carried out as part of the EUMETSAT NWP-SAF activities. The new features are (i) addition of cloud liquid water concentration profile to affect microwave channel transmittances, (ii) addition of infrared surface emissivity model for ocean and more realistic constant values specified for land, and (iii) modification to water vapour transmittance calculation for AMSU-B water vapour channels (AMSU channels 18-20) to give much improved accuracy in computed radiances. Several new instruments are now supported by RTTOV-6 in addition to (A)TOVS and Meteosat. They are MSG, SSM/I, TMI, AVHRR and the GOES imager. Finally several minor bugs were rectified which has improved the Jacobians computed. The paper will also describe the extensive validation performed for RTTOV-6 and comparisons with the previous RTTOV-5 model.

Retrieval of temperature and water-vapour from IASI measurements in partly cloudy situations

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and

Mitch Goldberg

NOAA/NESDIS/ORA

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The Infrared Atmospheric Sounder Interferometer (IASI), that will be flown on Metop, is a nadir sounding instrument for the measurement of high-resolution atmospheric temperature and water-vapour profiles as well as other trace gases. IASI covers the infrared spectrum in 8461 channels between 3.6 and 15.5 micrometres and is suited to resolve temperature and water vapour profiles at a vertical resolution of 1 km with high accuracy. Due to the opacity of clouds, partially filling the field of view of the instrument, the profile retrievals are likely to be perturbed by undetected clouds. However, using the huge amount of spectral information of IASI will allow us to

account for this effect. Radiative transfer simulations are carried out in the IASI channels for a large set of atmospheric profiles, representing global variability. The simulations are analysed showing the effect of undetected clouds on the retrieval accuracy and retrieval schemes are presented that account for the effect of undetected clouds.

Amalgamation of geostationary and polar orbiting satellite sounder data for atmospheric profiling

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The new Geostationary Operational Environmental Satellite (GOES) system significantly advances the U.S. atmospheric sounding capability. Operational hourly sounding products over North America and adjacent oceans are now possible with the GOES-8 and GOES-10 sounders. The GOES sounder, consisting of 19 spectral channels, plays an important role in weather forecasting and nowcasting. In particular, sounder data has improved monitoring of hourly temperature and moisture changes over the eastern Pacific Ocean, the Gulf of Mexico, and the western Atlantic Ocean. All are critical in numerical weather prediction over North America and for local aviation and marine forecasts.

The Advanced Microwave Sounding Unit (AMSU), with a total of 20 channels in the microwave on the NOAA-15 polar orbiting satellite, measures information in the upper troposphere and stratosphere, and is less sensitive to clouds. AMSU represents a dramatic improvement in microwave technology over the Microwave Sounding Unit (MSU) from the TIROS- N Operational Vertical Sounder (TOVS).

Two separate radiometers (AMSU-A and AMSU-B) comprise the AMSU platform. The primary function of the 15-channel AMSU-A (channels 1-15) is temperature sounding of the atmosphere, although three of the channels will also provide information on tropospheric water vapor, precipitation over ocean, sea-ice coverage, and other surface characteristics. The five channels of the AMSU-B (channels 16-20) mainly measure water vapor and liquid precipitation over land and sea. In a clear atmosphere, the major absorbing constituents in the AMSU channels are oxygen and water vapor. An algorithm for retrieval processing, employing the complementary nature of the two instruments, has been developed. AMSU-A and B observations are limb adjusted and remapped to the GOES sounder field of view. Retrieval results based on simulated and observed radiances from the GOES sounder and AMSU-A and B measurements will be shown.

Water vapour from TOVS/ATOVS - Value-added products and applications

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The paper deals with the generation of level 3 water vapour maps and our projects where we use this kind of product (atmospheric correction, solar energy, input calculation, aerosol retrieval etc.)

Some experiments with observation error modeling for assimilation of AMSU-A observations

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The degree of positive impact of ATOVS observations in data assimilation depends on the realism of the observation error model used. Usually the various channels have been assumed uncorrelated in the assimilation, since many assimilation schemes are coded under the assumption of uncorrelated observations. In this poster we present an attempt to take into account error correlations between the AMSU-A channels.

The effect of correlated channels is most as independent observations. We present results from using methods easily incorporated, by first projecting the channels onto the eigenvectors of an estimate of the observation channel error covariance matrix. These projections can then be treated by this method in a 1D-Var retrieval scheme using HIRLAM (High-Resolution Limited Area Model) forecasts as background fields, we present comparisons with the results from assuming uncorrelated channels and comparison of the retrievals with independent reference data.

Estimation of fast radiative transfer forward model errors and their impact on retrieval accuracy for the Infrared Atmospheric Sounding Interferometer, IASI

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An intercomparison of existing fast models for IASI (RTIASI, PFAAST) has been undertaken to assess their suitability for use in NWP. As it is anticipated that Level 1C radiances will be assimilated directly within a variational framework, both the forward model error covariances and the accuracy of the modelled Jacobians are considered. Results from this study are summarised briefly. Forward model error covariance estimates are then used to examine the impact of correlated forward model errors on retrieval accuracy. The error introduced by a diagonal forward model error covariance matrix assumption is addressed specifically. A similar analysis is performed to assess the impact of errors in modelled Jacobians. Results indicate that in some situations radiative transfer forward model errors can have a significant impact on retrieval accuracy. The implications for future forward model and data assimilation developments are discussed.

ISEM_6: Infrared surface emissivity model for RTTOV_6

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The Version 6 release of the NWP fast radiative transfer operator RTTOV_6 includes a revised default infrared surface emissivity model, ISEM_6. ISEM_6 default emissivities depend on surface type classification (sea/land/snow /sea_ice). A critical survey of models and studies appearing in the literature has been undertaken to select model parameterisations for each surface type. This paper summarises the current emissivity model parameterisation and model error characteristics for the four surface type classifications. The expected impacts of the new surface emissivity models in NWP data assimilation schemes and future developments are also discussed.

The Geostationary Imaging Fourier Transform Spectrometer - GIFTS

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The Geostationary Imaging Fourier Transform Spectrometer (GIFTS) is designed to provide temperature and moisture soundings with very high spatial resolution. By observing the flux of water vapor as a function of altitude, wind profiles can be derived. GIFTS was selected for flight as NASA's Earth Observing-Three (EO-3) technology validation mission with a scheduled launch in the late 2004. The Office of Navel Research (ONR) joined the program with funds to harden the GIFTS instrument for extended lifetime with the intent providing multi-spectral high resolution imagery over the Indian Ocean in support of naval operations. After an 18 month technology and measurement concept validation period, with the satellite in view of the North American region, the GIFTS will be moved to a position over the western Indian ocean for an additional five to seven year period of operation. The Bureau of Meteorology in Australia will receive the raw data stream and process the radiometric data into temperature, water vapor, and wind profiles. Here we provide a description of the instrument and demonstrate expected measurement capabilities with results obtained from an airborne interferometer which possesses the same spectral and spatial resolution as the GIFTS.

Humidity profiling using satellite and ship-based remote sensors: NAURU-99

B. Boba Stankov 1, A.L. Reale 2, B. Weber 1, G. Feingold 3, J. Hare 4 and E.R. Westwater 4

1 NOAA/ETL, 2 NOAA/NESDIS, 3 NOAA/CIRA, 4 NOAA/CIRES

USA

NAURU99 was an international research collaboration conducted on and around the island of Nauru in the Tropical Western Pacific during the summer of 1999. This international research campaign involved the US Department of Energy, the U.S. National Oceanographic and Atmospheric Administration (NOAA), and the Japan Marine Science and Technology Center (JAMSTEC). A variety of ship-based instruments were available on board

the R/V *RONALD H. BROWN* (RHB) to gather first-ever data on oceanic and atmospheric processes to better understand the influence of the tropics - our world's "heat engine."

Humidity profiles are retrieved with the Multi-sensor Retrieval of Atmospheric Parameters (MRAP) method from 449 MHz wind-profiling radar, microwave radiometer, ceilometer, radiosonde temperature, NOAA-15, and surface measurements. MRAP humidity profiles are compared with the humidity profiles from DIAL lidar, aircraft, and radiosondes.

The launch and implementation of SSMT-1 and SSMT-2 from DMSP-15

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The National Oceanic and Atmospheric Administration (NOAA) currently produces sounding products from 5 satellites. Three of these satellites are Defense Meteorological Satellite Program (DMSP) spacecrafts. The latest of these being DMSP F-15, which is the last in the series to fly the Special Sensor Microwave Temperature-1 (SSM/T-1) and Special Sensor Microwave Temperature-2 (SSM/T-2) instruments. This report will describe F-15 bring up, unique F-15 features, comparisons to F-13 SSM/T-1 and F-14 SSM/T-2 and the implementation and distribution of these products.

Generation of sounding products from TOVS data: recent algorithm developments and application in real-time data processing

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V.I.Soloviev, A.V.Kuharsky

SRC Planeta, Roshydromet,

Moscow, Russia

Efforts are continuing at SRC Planeta on the development and implementation of the TOVS/ATOVS data processing system for operational generation of atmosphere sounding products (regional coverage). The algorithm and software development and updates were focused towards: 1) improvement of the tuning scheme (radiance adjustments, accounting for residuals arising in inversion procedure); 2) retrieval of the first guess; 3) interface arrangement with NWP data base at the Hydrometeorological Center (Moscow); 4) operational evaluation and validation of sounding products.

The processing of locally received HRPT TOVS data is performed using Updated TOVS data Software Package (UTSP). The UTSP runs once per day and generates sounding products from NOAA - 14 TOVS real time data for each HIRS pixel (total number of soundings is about 4000); moreover, the sounding products are regularly embedded into NWP data base. The last version of UTSP, released in January 2000, represents a suite of FORTRAN 77 based program modules. Future plans include several code updates in order to provide interface with AAPP level 1d files. A short description of UTSP is presented.

Results of the evaluation of UTSP - derived temperature and humidity profiles are under discussion. Included are error statistics for various samples as well as results of TOVS data information contents analysis that were obtained through comparisons of retrieved profiles against "ground truth" data, i.e. collocated radiosonde soundings and first guess profiles. Plans for the next developments are presented.

Cloud detection using high spectral resolution IR sounder data: a simulation study

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**SRC Planeta, Moscow*

*** RRC Kurchatov Institute, Moscow*

The design of advanced IR sounder IASI intended to be a key payload on the forthcoming EPS-METOP promises significant improvements in global scale remote sensing. The high resolution radiance spectra to be measured by IASI can reveal valuable information about atmospheric constituents and clouds. Since the cloud contamination of the IASI FOV have evident impact on the measured radiance spectrum, the cloud detection and derivation of cloud properties (e.g. estimation of cloud top height and fractional cloud cover) represents a mandatory and important stage of IASI data analysis.

The goals of the current study are threefold: 1) to evaluate the capabilities to distinguish cloud contaminated radiance using advanced IR sounder data; 2) to develop an approach for cloud detection and possibly cloud properties derivation based on the analysis of IASI data alone; 3) to apply the developed technique to the sample of simulated IASI measurements and to validate the cloud detection results.

A cloud detection scheme is developed that uses a threshold technique and analysis of "spectral signatures" for different types of clouds. The suggested approach has been examined for different combinations of IASI channels and scenes with various types of cloud using simulated IASI measurements. Theoretical calculations of IASI measured spectra for clear and cloudy conditions have been performed using FRTM developed in frame of our previous investigations. The original sample of input data relating to various cloudy scenes, was generated from an ensemble of radiosonde soundings. For each radiosonde the estimates of cloud amount, base and tops have been derived. The comparison of IASI based cloud detection results with "ground truth" demonstrates the efficiency of the proposed methodology.

Optimisation of OPTRAN for use in the GDAS

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The OPTRAN code used in the EMC GDAS model is in the process of being upgraded. This paper details the requirements and architecture specification of OPTRAN and the radiative transfer module for use in the GDAS. Some of the changes being incorporated are for future upgrades (e.g. more absorber species) and some address current issues such as the use of layer vs. level specification of the input profile. The tangent linear and adjoint model components are also discussed.

A high-resolution IR sea surface emissivity database for satellite applications

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This paper details the generation of a high resolution IR sea surface emissivity database based on the Wu-Smith model. The Wu-Smith approach improves upon the Masuda model by including the reflected sea surface emission into the emissivity model. The database spans the frequency range 600-3000cm-1 for wind speeds 0-30m/s and viewing angles from 0-80deg. Comprison of the calculated sea surface emissivities with MAERI measurements is made. The construction of a emissivity regression model is also discussed.

Effect of atmospheric aerosols on land surface temperature determination with IR window channel measurements

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To retrieve land surface temperature, the AVHRR window channels can be utilized, but even though the channels are located in atmospheric window region, the atmospheric effect is still unavoidable. For clear sky, atmospheric temperature, moisture and aerosol are three main factors affecting the radiative transfer in infrared window regions. We have already investigated the effects of atmospheric temperature and moisture on our retrieval algorithms of land surface temperature. In this work, the effects of aerosols on radiative transfer of infrared window channels and on the accuracy of land surface temperature retrieval with infrared window channel measurements have been studied further. Unlike atmospheric temperature and moisture, for which reasonably accurate profiles could be produced from ATOVS/TOVS data, there is no real time aerosol measurement data available on land, so that, larger uncertainty may exist in considering the aerosol effect. In such case, is the retrieval algorithm of land surface temperature still of practical use? The results of simulation tests show that the uncertainty in atmospheric aerosol may have significant effect on retrieval accuracy of land surface temperature. But it is still possible to use proper aerosol model to take the atmospheric aerosol effect into consideration in retrieving land surface temperature with infrared window channel measurements and to get land surface temperatures of reasonable accuracy.

The study of precipitation effects on AMSU and the application of AMSU to typhoon monitoring

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AMSU clear and cloudy forward model is developed, which includes absorption and scattering effects of raindrops and ice clouds. The validation of microwave forward model is presented also. The parameters of cloud were introduced from hurricane cloud model which was developed by SSEC (Space Science and Engineering Center, UW). Verification results show that this is a reliable microwave radiation forward model. The effects of rainfall and limb correction on AMSU 20 channels are discussed, it is possible using AMSU data to retrieve precipitation. Three Typhoons in west Pacific Ocean were

examined from the perspective of AMSU. Precipitable water is derived from AMSU-B by regression method.

The effects of clouds' liquid water derived from global AMSU-B data

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The AMSU-B data from the NOAA-15 satellite have been corrected for RFI and have been adjusted to the nadir position. Then, using the algorithm of Grody, the cloud liquid water is derived and regressed against the deviations of each channel from cloudless conditions derived separately. The algorithm then is used to adjust a set of measurements to cloudless skies.

Global liquid water and cloud-cleared channels are displayed. Each set of cloud-cleared data may then be used to derive the vertical water vapor profile. The use of AMSU-B in place of AMSU-A brings out the effects of ice clouds.

Developments of a fast and accurate microwave land emissivity model for satellite data assimilation and remote sensing applications

Fuzhong Weng

Assimilation of satellite microwave sounding data over land poses greater problems because the surface emissivity at microwave frequencies displays larger variability compared to the infrared wavelengths and presently cannot be accurately simulated. This study develops a fast and accurate emissivity model that simulates the microwave emissivity spectra for various surface conditions. The volumetric scattering and the interface reflection are taken into account using various physical models. For canopy leaves, geometric optics is used to derive the optical parameters because leaf size is typically greater than the incident wavelength. For media containing a higher fraction volume of scatterers such as snow and desert sand, the optical parameters are derived using a small perturbation method that takes into account the coherent scattering of closely populated scatterers. It is shown that the simulated emissivity spectra agree with in-situ measurements under various surface conditions.

Lidar for calibration/ validation of microwave sounding instruments

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Five lidar campaigns have been performed in support of calibration/validation for DMSP microwave sensors. Radiative transfer calculations based on lidar water vapor profiles agreed with collocated SSM/T2 atmospheric channel measurements to better than 1K RMS, whereas discrepancies were greater than 2 K for collocated AIR and Vaisala radiosondes. The improved capability is attributed to the new ability to measure water vapor from 8 to about 17 km altitude. Conventional radiosondes are unresponsive to water above 8 km. The new measurements frequently revealed one or more highly moist layers in the vicinity of the tropopause. The layers are dynamic and are often associated with sub-visual cirrus clouds. The clouds can alter 183 GHz brightness temperatures by 1-4 K. Prominent layer structure was observed on most evenings at San Nicolas Island (SNI, 33.5N, 119.5W, June to November 1998), from Table Mountain Observatory (TMO, 34.4N, 117.7 W, July and August 1999), and from the Hawaiian Islands (HI, 22N, 159.8W, January to April, 2000). Conventional mid-latitude oceanic climatology underestimates water vapor by a factor of four from 14-17 km altitude for the SNI and TMO campaigns, whereas HI measurements are consistent with climatology. Currently, we are applying lidar to temperature calibration for SSM/T1 and SSMIS and are investigating the influence of upper tropospheric water on the microwave measurements.

Further development of the European AAPP

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The ATOVS and AVHRR Processing Package is a software package for the processing of ATOVS and AVHRR data from the NOAA polar orbiting spacecraft, and has been developed jointly by EUMETSAT, Meteo-France, The Met. Office and KNMI. Following the release of version 1.0 of AAPP in late 1998, a number of improvements and bug fixes were made available in versions 1.1 to 1.3. In particular a number of portability issues were resolved, and advice and information was published on EUMETSAT's AAPP webpage. Further bug fixes and code improvements, together with improved portability and updated documentation, were included in the integrated version 2.0, released in February 2000. Since then, further incremental releases have been made to take account of instrumental calibration changes and updated bias corrections. The ICI retrieval package has also been added. There are currently about 120 licensed AAPP end-users worldwide. The development of AAPP now forms part of EUMETSAT's Numerical Weather Prediction Satellite Application Facility, co-ordinated by The Met. Office at Bracknell, and release of the integrated version 3.0 of AAPP is planned for early in 2001.

A near real time simulated AIRS processing system

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To test the functionality of the real time distribution of the AIRS calibrated and navigated radiances and retrieval products by NOAA for model assimilation, a system has been developed to simulate AIRS/AMSU/HSB data on a real time basis. Ephemeris and attitude data are simulated to define the AIRS orbit. The simulated orbits are used with the NCEP Aviation Model forecast data to produce atmospheric profiles on an AIRS field of view basis. Level 1B AIRS radiances along with AMSU and HSB brightness temperatures are calculated from the forecast profiles using a fast radiative transfer model, and are used to generate both radiances and retrieval profiles in HDF and BUFR formats which are subsequently distributed by NOAA/NESDIS to NWP centers. Details of processing and distribution of AIRS products will be presented.

Using ICI at the National Satellite Meteorological Center of China

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The AAPP was installed successfully on a HP workstation of CMA/NSMC at the beginning of 1999. The near real time HRPT data from the 3 receiving stations (Beijing, Guangzhou and Urmuqi) have been processed by AAPP since July of last year. ICI Version2.0 was developed by Meteo-France/CMS and its adaptation has been implemented in CMA/NSMC. The analysis of Chinese regional NWP model HLAFS is utilized to create a rolling library and its winds forecast is also used for estimating the microwave emissivity of the sea surface. Since last autumn, this adaptation package has been running in near real time on a daily basis for NOAA-15 data from the 3 HRPT stations in China. The free display software GMT is used to display the output retrieval results and their statistics. Currently the retrieval results are placed on the Meteo-France ICI Website and updated on a regular basis, and the results with their statistics will be presented in this paper. Some preliminary results from the PC-ATOVS Window display system of CMA/NSMC will also be shown. Many Chinese meteorologists are very interested in the satellite retrievals for nowcasting and environmental monitoring, etc. The retrieval products are also needed to enable the assimilation of satellite data in the NWP impact scheme in China.

Land surface temperature retrieval from satellite IR window channel measurements over non-uniform land surface

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The land surface temperature (LST) is a key parameter in many land surface processes, and of fundamental importance for climate change studies. Compared with an ocean surface, the most significant characteristic of land surface is its non-uniformity. The land surface is constructed from various different and often mixed types of land cover, it is varied not only from region to region, but also from time to time; not only varied with the field of view (FOV) of satellite, in FOV, it is also non-uniform; furthermore, the land surface emissivity has different spectral variations for different land cover types. All these make the split-window algorithms successfully used in sea surface temperature retrieval unable to be generalized and applied in LST retrieval. In fact, the non-uniformity of land surface is the fundamental cause of difficulties in LST determination from satellite infrared window channel measurements. In the case of uniform land surface, to deal with the coupling problem between the land surface temperature and emissivity, we have presented two algorithms to retrieve LST and emissivities, simultaneously, and have investigated the effects of atmospheric temperature and moisture on the retrieval algorithms of land surface temperature. For non-uniform land surface, the situation is much more complex, but the land surface in FOV could be considered as composed of several different uniform parts, and can be treated as a uniform land surface of some equivalent temperature and channel emissivities, then the similar retrieval algorithms as used for uniform land surface could be applied, the results of simulation tests show that equivalent land surface temperatures of non-uniform land surface could be obtained with rather good accuracy.

Zonal wind retrievals from satellite soundings for climate studies over the Southern Ocean

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Precipitation estimates over Antarctica and the Southern Ocean have become an important component of studies on the influence of Antarctic ice sheets in global climate change. Direct rain-gauge measurements of precipitation, however, are extremely difficult due to the lack of weather stations, large errors caused by small rainfall amounts, and drifting snow. Because of these difficulties, an indirect method that uses the atmospheric moisture budget has been developed for high southern latitudes. In this method, moisture fluxes are first estimated using radiosonde-observed or model-calculated atmospheric moisture and wind profiles, then long-term net precipitation is computed as the convergence of the moisture fluxes. Three types of data have been used in moisture flux estimates: (1) Radiosonde observations (RAOBs). This method, however, was limited by the sparseness of the radiosonde stations over the Antarctic continent and the surrounding ocean. (2) Secondly, ECMWF (European Centre for Medium-Range Weather Forecasts), NMC (National Meteorological Center) and ABM (Australian Bureau of Meteorology) analyses were used, but these resulted in broad disagreement in the estimates of net precipitation and moisture fluxes. (3) The third type of study used satellite data to estimate the moisture fluxes. Recently, Slonaker and Van Woert (1999) and Zou and Van Woert (2000a,b) sought to use TOVS temperature and moisture data to estimate the meridional moisture fluxes and net precipitation over Antarctica and the Southern Ocean. Slonaker and Van Woert (1999) used the thermal wind equation plus the surface wind fields obtained by Atlas et al. (1993) as the tie-on wind. Zou and Van Woert (2000a,b) further extended the method by applying conservation of mass to the wind obtained by Slonaker and Van Woert (1999)and produced mean meridional winds and moisture fluxes comparable to the radiosonde observations and reanalysis data. This study is an extension of Zou and Van Woert (2000a,b). In Slonaker and Van Woert (1999) and Zou and Van Woert (2000a,b), only meridional wind and moisture fluxes were derived from the satellite soundings. With meridional moisture fluxes, only zonally-averaged net precipitation can be inferred. In order for the satellite method to estimate the distribution of net precipitation, three-dimensional zonal winds are also needed. In this study, the wind derivation approach of using thermal wind plus a mass conservation constraint developed in Zou and Van Woert (2000a,b) is applied to the zonal wind derivation. The zonal wind obtained is compared with ECMWF and NCEP/NCAR reanalysis data and RAOB data from Macquarie Island.

Wednesday 20 September 2000

0800 - 0900 **REGISTRATION**

0900 - 1000 **INTRODUCTORY SESSION (Chairs: Rochard/ Le Marshall)**
Welcome
Opening
Presentation and discussion of agenda

1000 - 1030 **BREAK**

1030 - 1210 **SCIENTIFIC PRESENTATIONS (Chair: Le Marshall)**

SESSION 1a: ATOVS

1a1 **Bennartz,Thoss, Dybbroe and Michelson**
Precipitation analysis using AMSU and AVHRR data in support of nowcasting applications

1a2 **Chalfant**
Experimental cloud products from ATOVS onboard NOAA-15

1a3 **Reale**
Operational sounding products from ATOVS onboard NOAA-15

1a4 **Weng**
Developments of a fast and accurate microwave land emissivity model for satellite data assimilation and remote sensing Applications

1a5 **P.K.H. Wang**
The study of precipitation effects on AMSU and application of AMSU on typhoon monitoring

1210 - 1400 **LUNCH**

1400 - 1540 **SCIENTIFIC PRESENTATIONS (Chair: Rochard)**

SESSION 1b: ATOVS/SSM

1b1 **Chevallier, Bauer, Kelly and McNally**
Comparison between ATOVS data and the ECMWF model in the presence of clouds

1b2 **Deblonde**
FASTEM, FASTEM2

1b3 **Korpela and Uddstrom**
The use of ATOVS and radar data for development and validation of rain-rate algorithms

1b4 **Gao, Gu and Zhu**
Flood area classification and flood-monitoring by AMSU data

1b5 **Garand and Turner**
An overview of the results from the HIRS-AMSU intercomparison of radiative transfer codes

1540 - 1610 **BREAK**

1610 - 1710 **SCIENTIFIC PRESENTATIONS (Chair: Eyre)**

SESSION 1c: ATOVS/SSM

1c1 **Prigent, Aires, Rossow and Rothstein**
A new neural network approach including first-guess for over-land microwave retrieval of atmospheric water vapour, cloud liquid water path, surface temperature and emissivities from SSM/I observations

1c2 **Tabor**
The launch and implementation of SSMT-1 and SSMT-2 from DMSP-15

1c3 **Kleespies and McMillin**
The Special Sensor Microwave Imager/Sounder

1730 **RECEPTION**

Thursday 21 September 2000

0850 - 1030 SCIENTIFIC PRESENTATIONS (Chair: Menzel)

SESSION 2a: TOVS/ ATOVS in NWP

2a1 **Böhm and Wergen**
Impact of NOAA/NESDIS SATEM data in the DWD global NWP system

2a2 **Chouinard and Hallé**
Recent results with TOVS data in the new CMC 3-DVAR analysis system: the combined and separate impact of microwave and IR radiance observations, the interaction with aircraft data

2a3 **English and Poulsen**
Towards improved assimilation of ATOVS radiances over land

2a4 **Harris, Steinle and Paevere**
Use of ATOVS radiances in the 1-D Var./GASP data assimilation system

2a5 **Joiner, Rokke, da Silva, Partyka and Todling**
Assimilation of (A)TOVS at the NASA Goddard Data Assimilation Office

1030 - 1100 BREAK

1100 - 1220 SCIENTIFIC PRESENTATIONS (Chair: Chouinard)

SESSION 2b: TOVS/ ATOVS IN NWP

2b1 **McNally, Andersson, Bauer, Chevallier, Kelly and Matricardi**
Recent developments in the use of satellite data at ECMWF and preparations for Advanced Sounders

2b2 **Okamoto**
Recent developments in assimilation of TOVS and ATOVS at JMA

2b3 **Rabier, Puech and Benichou**
Monitoring and assimilation of ATOVS data at Meteo-France

2b4 **Gustafsson, Landelius, Lindskog, Schyberg, Thorsteinsson and Tveter**
Assimilation of AMSU-A observations in HIRLAM 3-D Var.

1220 - 1400 LUNCH

1400 - 1540 SCIENTIFIC PRESENTATIONS (Chair: Joiner)

SESSION 3a: TOVS/ATOVS IN CLIMATE STUDIES

3a1 **Goldberg**
Climate data sets from the Advanced Microwave Sounding Unit-A

3a2 **Zou**
Zonal wind retrievals from TOVS soundings for climate studies over the southern oceans

3a3 **Menzel**
Comparison of University of Wisconsin HIRS and ISCCP D2 cloud studies

SESSION 4a: PREPARATION FOR ADVANCED SOUNDERS

4a1 **Goldberg**
Operational processing and distribution of AIRS

4a2 **Lerner, Weisz and Kirchengast**
Retrieval of water vapour from IASI measurements: methodology and case study application

1540 - 1610 BREAK

1610 - 1640 WORKING GROUP FORMATION
Radiative Transfer and Surface Property Modelling
ATOVS/TOVS in Climate Studies
ATOVS/TOVS data in NWP
Advanced Infrared Sounders
International Issues and Future Systems
Satelllite Sounder Science and Products

1640 - 1730 POSTER INTRODUCTIONS (Chair: Reale)
(Each 1 minute duration, 1 viewgraph maximum)

1730 - 2000 POSTER SESSION
(See list of posters following all session details)

FRIDAY 22 SEPTEMBER 2000

0850 - 1030 AGENCY STATUS REPORTS (Chairs: Le Marshall/ Rochard)

Relations with other bodies:
IRC (Menzel, 5 min)
CGMS (Menzel, 5 min)
WMO (Hinsman 5 min)
Reports on issues raised at ITSC-X
Frequency protection (Rochard, 5 min)
Re-analysis at NCEP (van Delst / Derber, 5 min)
Re-analysis at ECMWF (Kelly, 5 min)
Re-analysis at GSFC (Joiner, 5 min)
TOVS Pathfinder (Goldberg/ Scott/ Susskind/ Jackson, 5 min)
Review of actions from ITSC - X (30 min)
Any other items /discussion

1030 - 1100 BREAK

1100 - 1215SCIENTIFIC PRESENTATIONS (Chair: Kleespies)

SESSION 4b: PREPARATION FOR ADVANCED SOUNDERS

4b1 Sherlock, Matricardi, Collard and Saunders
Estimation of fast radiative transfer forward model errors and their impact on retrieval accuracy for the Infrared Atmospheric Sounding Interferometer, IASI

4b2 Huang, Gumley, Rink, Li and Menzel
International MODIS and AIRS Processing Package - IMAPP: First package for direct broadcast user and MODIS Level 1 and Level 2 products

4b3 Monnier, Lavanant, Brunel, Labrot and Rochard
Towards the adaptation of the ICI retrieval software to IASI data

4b4 Schluessel and Goldberg
Retrieval of temperature and water vapour from IASI measurements in partly cloudy situations

4b5 Wolf, Goldberg, Zhou, Qu and Divakarla
A near-real-time simulated AIRS processing system

1215 - 1400 LUNCH

1400 - 1515 SCIENTIFIC PRESENTATIONS (Chair: Hinsman)

SESSION 5:FUTURE SYSTEMS

5-1 Menzel / Purdom
NOAA's plans for polar satellites: 2000 and beyond (15 min - invited paper)

5-2 Joiner/Smith/Dodge
NASA's plans for future sounding systems (15 min - invited paper)

5-3 Klaes
EUMETSAT future plans (15 min - invited paper)

5-4 Zhang / Dong
Considerations on sounding instruments for future Chinese satellites (15 min - invited paper)

5-5 Uspensky
Sounding instruments for future Russian meteorological satellites (15 min - invited paper)

1515 - 1545 BREAK

1545 -1625 SCIENTIFIC PRESENTATIONS (Chair: Kelly)

SESSION 5a: SCIENTIFIC STUDIES AND DEVELOPMENT - FUTURE SYSTEMS

5a1 Bloom and Huang
NPOESS Preparatory Project (NPP) : An opportunity for data fusion technology demonstration

5a2 Predina and Glumb
The Crosstrack Infrared Sounder (CrIS)

1625 - 1730 PRESENTATION ON SOFTWARE PACKAGES (Chair: Rochard/ Le Marshall)

AAPP (Klaes)
IAPP (Achtor)
ICI (Rochard)
RTTOV/ RTATOV (Saunders)
MODIS/ AIRS (Menzel)
3I/3

... continued

PRESENTATION ON SOFTWARE PACKAGES (Chair: Rochard/ Le Marshall) continued **Technical sub-groups: formation / organisation** AAPP ICI APP RTATOV MODIS/AIRS 3I/3R **EVENING: WORKING GROUP MEETINGS**	

SATURDAY 23 SEPTEMBER 2000

WORKING GROUP MEETINGS

SUNDAY 24 SEPTEMBER 2000

WORKING GROUP MEETINGS

MONDAY 25 SEPTEMBER 2000

0900 - 1015 **SCIENTIFIC PRESENTATIONS (Chair: Uddstrom)**

SESSION 6a: SCIENTIFIC STUDIES AND DEVELOPMENTS - Cloud and Moisture

6a1 **Putsay, Derrien, Le Gléau and Monnier**
Comparison of two methods to estimate the cloud top temperature and pressure for NOAA-AVHRR and HIRS Data

6a2 **Rizzi and Mannozzi**
On the planetary emission between 100 and 600 cm^{-1} in the presence of clouds

6a3 **Schroedter**
Water vapour from TOVS/ATOVS - value-added products and applications

6a4 **Saunders**
A global comparison of AVHRR and HIRS 10 radiances

6a5 **Wessel and Farley**
Lidar for calibration/validation of Microwave Sounding instruments

1015 - 1045 **BREAK**

1045 - 1215 **SCIENTIFIC PRESENTATIONS (Chair: Saunders)**

SESSION 6b: SCIENTIFIC STUDIES AND DEVELOPMENTS - SOUNDING AND APPLICATIONS

6b1 **McMillin, Kleespies and van Delst**
Rapid transmittance algorithm improvements

6b2 **Le Marshall, Seecamp, Kuleshov, Kelly, Leslie, Harris and Choi**
Regional sounding

6b3 **Pietrapertosa, Pergola, Lanorte and Tramutoli**
Self-adaptive algorithms for change detection: OCA (the One-channel Cloud-detection Approach) - an adjustable method for cloudy and clear radiances detection

6b4 **Uspensky, Kopylov, Rublev and Trotsenko**
Cloud detection using high spectral resolution IR sounder data: a simulation study

6b5 **Lavanant, Brunel, Gendrier and Rochard**
ICI retrieval package: towards version 3

6b6 **van Delst**
Optimisation of OPTRAN for use in the GDAS

1215 - 1400 **LUNCH**

1400 - 1500 **SCIENTIFIC PRESENTATIONS (Chair: Rizzi)**

SESSION 6c: SCIENTIFIC STUDIES AND DEVELOPMENTS - SOUNDING AND APPLICATIONS

6c1 **Kelly**
Satellite data impact on ECMWF forecasts

6c2 **Zhao and Wang**
Land surface temperature retrieval from satellite IR window channel measurements over non-uniform land surface

6c3 **Kaifel and Müller**
Results of TOVS ozone retrieval with neural networks

6c4 **Uddstrom, Korpela, Andrews, Oliver, Gray and Falvey**
Advances in data assimilation and weather prediction in New Zealand

1500 - 1515 **FREQUENCY PROTECTION (Rochard)**

1515 - 1535 **BREAK**

1535 - 1700 **WORKING GROUP MEETINGS**

1700 - **CONFERENCE DINNER**

TUESDAY 26 SEPTEMBER 2000

0845 - 1015 SCIENTIFIC PRESENTATIONS (Chair: Goldberg)

SESSION 6d: SCIENTIFIC STUDIES AND DEVELOPMENTS - SOUNDING AND APPLICATIONS

6d1 **Gaye and Citeau**
Observed influence of precipitable water on convective activity in tropical West Africa

6d2 **Sakuragi and Barbedo**
AAPP V2.0 first results and future plans for the ATOVS sounding processing practices using ICI in Brazil

6d3 **Wu, Lavanant, Brunel and Zhang**
Using ICI at the National Satellite Meteorological Center of China

6d4 **Qiu and Zhang**
The analysis and evaluation of the retrieving results of IAPP in NSMC

6d5 **Whyte, Klaes and Schraidt**
Further development of the European AAPP (ATOVS and AVHRR Processing Package)

1015 - 1030 BREAK

SCIENTIFIC PRESENTATIONS (Chair: Garand)

SESSION 6e: SCIENTIFIC STUDIES AND DEVELOPMENTS - SOUNDING AND APPLICATIONS

6e1 **Brunel**
Operational package for local ATOVS retrievals: status of the code

6e2 **Borbas, Randriamampianina and Szenyan**
Perspective on the operational use of TOVS and ATOVS at the Hungarian Meteorololgical Service

1100 - 1230 ITWG PLENARY

SESSION (Chair: Le Marshall/ Rochard)
Working Group Reports

1230 - 1400 LUNCH

1400 - 1530 ITWG PLENARY SESSION
Technical subgroup reports
Executive summary, major recommendations and actions

1530 - 1600 BREAK

1600 - 1700 ITWG PLENARY SESSION (Chair Rochard/ Le Marshall)
Review of progress
Future Plans
Next meeting
Issues/ Working Groups

1700 CLOSE

ITSC-XI POSTERS

ACKERMAN AND FREY
COLLOCATION OF HIRS/2 AND AVHRR DATA SETS

BATES AND JACKSON
INTERANNUAL VARIABILITY AND LONG-TERM TRENDS IN UPPER TROPOSPHERIC HUMIDITY

BATES, ROSSOW AND JACKSON
THE TOVS RADIANCE PATHFINDER AND ISCCP ENHANCED DATA SET

BENNARTZ
OPTIMAL CONVOLUTION OF AMSU-B TO AMSU-A

BURNS AND STOGRYN
RADIATIVE TRANSFER MODELLING FOR SSMIS TEMPERATURE SOUNDING CHANNELS

GARAND AND TURNER
ON THE UTILITY OF HIGH SPECTRAL RESOLUTION JACOBIANS

KLEESPIES
LAND INFRARED EMISSIVITY FOR NUMERICAL WEATHER PREDICTION

KLEESPIES AND CROSBY
A METHOD FOR CORRELATED NOISE MODELLING IN SATELLITE RADIANCE SIMULATION

KORPELA
XTOVS-ATOVS DATA VISUALISING TOOL, APPLIED TO QUALITY MONITORING OF DIRECT READOUT DATA

LI, HUANG, WOOLF, WOLF AND ACHTOR
FURTHER DEVELOPMENT OF THE INTERNATIONAL ATOVS PROCESSING PACKAGE (IAPP)

MCMILLIN AND GOLDBERG
CARBON DIOXIDE RETRIEVALS

MCMILLIN, KLEESPIES AND DING
THE NESDIS UNIFIED VALIDATION SYSTEM

PRIGENT, AIRES, ROSSOW AND ROTHSTEIN
A NEW NEURAL NETWORK APPROACH INCLUDING FIRST-GUESS FOR OVER-LAND MICROWAVE RETRIEVAL OF ATMOSPHERIC WATER VAPOUR, CLOUD LIQUID WATER PATH, SURFACE TEMPERATURE AND EMISSIVITIES FROM SSM/I OBSERVATIONS

RABIER, PUECH AND BENICHOU
MONITORING AND ASSIMILATION OF ATOVS DATA AT METEO-FRANCE

REALE AND STANKOV
A PROGRAM FOR COMBINING RADIOSONDE AND POLAR SATELLITE OBSERVATROINS FROM THE NOAA SERVICE VESSEL *RONALD H. BROWN* FOR WEATHER GUIDANCE OVER REMOTE OCEANS

RIZZI AND MANNOZZI
ON THE PLANETARY EMISSION BETWEEN 100 AND 600 CM^{-1} IN THE PRESENCE OF CLOUDS

SCHREINER, LI, MENZEL, SCHMIT, WOOLF AND NAGLE
AMALGAMATION OF GEOSTATIONARY AND POLAR ORBITING SATELLITE SOUNDER DATA FOR ATMOSPHERIC PROFILING

SCHYBERG AND TVETER
SOME EXPERIMENTS WITH OBSERVATION ERROR MODELLING FOR ASSIMILATION OF AMSU-A OBSERVATIONS

SHERLOCK AND SAUNDERS
ISEM-6, INFRARED SURFACE EMISSIVITY MODEL FOR RTTOV-6

SMITH, HARRISON, REVERCOMB, BINGHAM, HUANG, REGEON AND LE MARSHALL
GIFTS - THE GEOSTATIONARY IMAGING FOURIER TRANSFORM SPECTROMETER

STANKOV
HUMIDITY PROFILING USING SATELLITE AND SHIP-BASED REMOTE SENSORS: NAURU-99

USPENSKY, PLOKHENKO, SOLOVIEV AND KUHARSKY
GENERATION OF SOUNDING PRODUCTS FROM TOVS DATA: RECENT ALGORITHM DEVELOPMENTS AND APPLICATION IN REAL-TIME DATA PROCESSING

VAN DELST
A HIGH RESOLUTION INFRARED SEA SURFACE EMISSIVITY DATABASE FOR SATELLITE APPLICATIONS

WANG AND ZHAO
EFFECT OF ATMOSPHERIC AEROSOLS ON LAND SURFACE TEMPERATURE DETERMINATION WITH IR WINDOW CHANNEL MEASUREMENTS

WARK
THE EFFECTS OF CLOUD LIQUID WATER DERIVED FROM GLOBAL AMSU-B DATA

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JPL AIRS Project	http://www-airs.jpl.nasa.gov/ Enter AIRS in the NASA Search Window
Mike Chalfant	http://poes.nesdis.noaa.gov/ 1) HIRS filter functions 2) HIRS/3, AMSU-A and AMSU-B limb adjustment co-ordinates 3) AMSU-B RFI corrections 4) DMSP, RTOVS, ATOVS raw data products, including non-sounding products 5) HIRS Limb corrections 6) NOAA climate products 7) Sea Surface Temperatures
NASA Goddard Data Assimilation Office (Reanalysis, etc.)	http://hera.gsfc.nasa.gov/
NAST Aircraft Spectra, Ancillary Data, Forward Models, Visualisation Software, etc.	http://danspc.larc.nasa.gov/NAST/ (Note: NAST must be in UPPER CASE)
NCEP Reanalysis	http://wesley.wwb.noaa.gov/Reanalysis.html
NIST CODATA recommended and latest values of physical constants	http://physics.nist.gov/cuu/Constants/
OPTRAN Code	ftp orbit-net.nesdis.noaa.gov pub/crad/sit/kleespies/optran/source
OPTRAN Coefficients	ftp orbit-net.nesdis.noaa.gov pub/crad/sit/kleespies/optran/coeff
Ozone/Probe/CZE	http://www.chmi.cz/meteo/sat/ozon/
POLAR PATHFINDER SAMPLER CD	nside @kryos.colorado.edu http://www-nsidc.colorado.edu/CATALOGENTRIES/nsi-0069.html

Surface emissivity:
dynamically updated maps
(see section 2.1.6, page 13)

http://orbit18i.nesdis.noaa.gov/html/day2_datatab.html

Surface emissivity:
measured values for different
land surface types (CD)
(see section 2.1.6.2, page 14)

http://speclib.jpl.nasa.gov/

TOVS Pathfinder Data Set -
Joel Susskind

http://faster.gsfc.nasa.gov/srt.html
Click on TOVS

TOVS Polar Pathfinders

http://psc.apl.washington.edu:80/pathp/

UKMO TOVS Monitoring report

http://www.met-office.gov.uk/sec5/NWP/TOVS_monitoring/*mmmyy*
where *mmm* is the 3-character month name : JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC and *yy* is the last 2 digits of the year number.
(NWP/TOVS MUST be in UPPER CASE. 'monitoring' MUST be in lower case.)

WMO home page

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- Satellite operation status reports
- Global Observing System (GOS) status reports
- Online data base information
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- Y2K information
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- Education and Training
- Publications : download
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- Satellite receiving equipment
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- Satellite system information
- Data requirement