A report on The Tenth International ATOVS Study Conference

Boulder, CO, USA
27 January - 2 February 1999

Conference sponsored by

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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 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 Tenth International TOVS Study Conference, ITSC-X, was held at the 'Regal Harvest House', Boulder, Colorado, USA, from 27 January to 2 February 1999. This conference report summarises the scientific exchanges and outcomes of the meeting. A companion document – *The Technical Proceedings of The Tenth International TOVS Study Conference* – contains the complete text of ITSC-X scientific presentations. Together, these documents reflect the conduct of a highly successful meeting in Boulder. An active and mature community of TOVS and ATOVS data users now exists, and considerable progress and positive results were reported at ITSC-X in a number of areas, including many related to the new ATOVS system.

ITSC-X was sponsored by NASA, NESDIS, EUMETSAT, the World Meteorological Organization, the Australian Bureau of Meteorology, Météo-France and ITT Industries. Their support is gratefully acknowledged. We also thank the staff of the Regal Harvest House 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 TENTH INTERNATIONAL TOVS STUDY CONFERENCE (ITSC-X)

Boulder, Co, USA: 27 January - 2 February 1999

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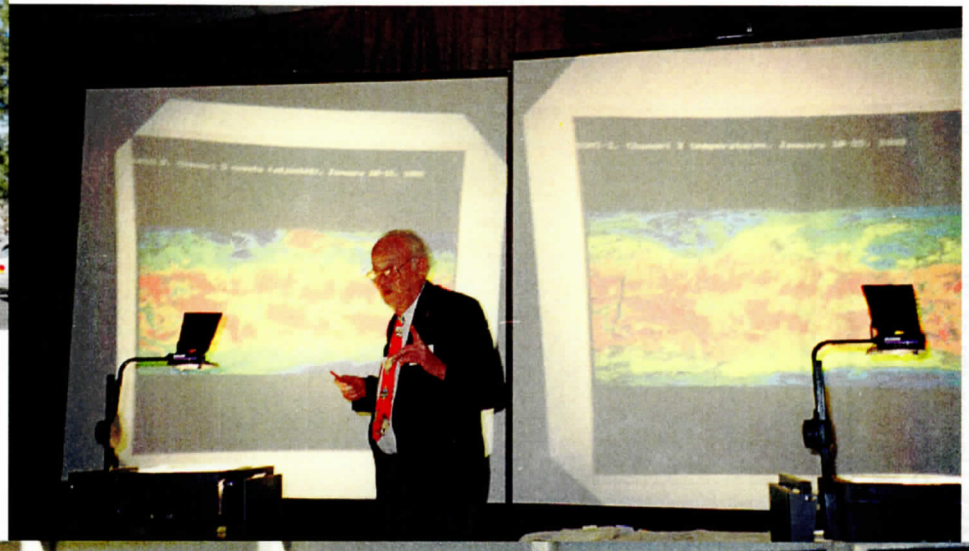
ITSC-X Boulder, Colorado January 1999

Venue: Regal Harvest House



Dr David Wark (NOAA/NESDIS) during the conference dinner address.

Members of the International TOVS Working Group at ITSC-X

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1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Tenth International TOVS Study Conference – ITSC-X – was held in Boulder, Colorado, USA, from 27 January to 2 February 1999. One hundred and thirty-four participants attended the Conference and provided scientific contributions. Twenty-three countries, four international and many national organisations were represented: Australia, Austria, Brazil, Canada, China, the Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Republic of Korea, Mongolia, Netherlands, New Zealand, Norway, Russia, Spain, Sweden, Taiwan, the United Kingdom, the United States of America, ECMWF, EUMETSAT, WMO, the IRC, NASA and NESDIS.

The agenda for ITSC-X can be found at Appendix A. Most of the meeting was occupied with scientific presentations on a range of issues: TOVS and ATOVS data characteristics and processing; 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 Tenth International TOVS Study Conference, ITSC-X*, available through the Co-chairs of the International TOVS Working Group (ITWG).

Working Groups were formed to consider five of the main issues/areas identified prior to the Conference: ATOVS data access, processing and validation; 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.

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

Several technical sub-groups met during ITSC-X 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 further activity. In particular, it noted that:

- HIRS/3, AMSU-A and AMSU-B are now providing atmospheric monitoring, with great potential for NWP;
- Continuing excellent results are being demonstrated from advanced data assimilation techniques;
- There is still a need to pay attention to fundamentals; for example, accurate forward radiative transfer modelling, use of accurate spectral response functions and calibration;
- A survey of NWP users noted that the majority still use retrievals.
- Sufficient resources should be allocated in relation to future satellite programs to ensure proper use of the data at NWP and DA centres;

- There is a requirement to further emphasise climate activity and improve relations with the climate community;
- ITWG encourages the continuance of support for Pathfinder activities into the AMSU and HIRS/3 era and beyond, to establish the longest possible data record for climate research;
- The ITWG advocates a program to intercompare existing climate data sets (e.g. Pathfinder A, B, P; Spencer and Christy's MSU 2R, MSU 4; NCEP and ECMWF reanalyses);
- Encouragement should be given to national space agencies to implement advanced infrared sounding capabilities on future GEO satellites;
- CGMS should consider means to provide for well-resourced activities towards the protection of frequency allocations;
- There is a need to interface with the restructured World Meteorological Organization's Commission for Basic Systems (CBS);
- The development of community software for the processing of ATOVS data is proceeding well, with the AAPP preprocessing software already available to ITWG members and several other packages for further processing of ATOVS data nearing completion; and
- The ITWG expressed a strong requirement for (near) real-time access to AIRS and MODIS data via direct readout and through NOAA/NESDIS.

The 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 major conclusions and recommendations were adopted as a summary of the ITWG meeting at ITSC-X. More details and specific technical recommendations and actions are given in the Sub-Groups' full reports in Section 2 and the reports of the Technical Sub-Groups in Section 3.

ATOVS data access, processing and validation

Issue	*Recommendation or action*	*Person / group involved in recommendation or action*	*Cross - reference: see section:*
ATOVS data characteristics	**Users should be informed of all significant changes to the ATOVS instrument by NESDIS via the ITWG list server**	**E. Brown**	**2.1.2**
AMSU-B	**A report on the AMSU-B problems should be compiled and distributed via the ITWG list server**	**M. Chalfant**	**2.1.2**

AMSU-B	**Software solutions to AMSU-B problems to be included in the AAPP**	**P. Dibben and D. Klaes**	**2.1.2**
AMSU-B	**A check should be performed on the consistency of the AAPP corrected radiances and the NESDIS global 1b dataset**	**P. Dibben and P. Brunel**	**2.1.2**
AVHRR/3	**Further test periods with channel 3a 'on' should be considered, to allow a full scientific evaluation of the channel 3a data in the morning orbit**	**NESDIS**	**2.1.2**
Status of ATOVS processing software	**A document should be made available to the ITWG describing the scientific aspects of the NESDIS ATOVS processing**	**A. Reale**	**2.1.3**
Status of ATOVS processing software	**Feedback on AAPP problems should be posted on the AAPP web page**	**D. Klaes**	**2.1.3**
Status of ATOVS processing software	**A requirements document to be written for visualisation tools for IAPP**	**ITWG members to submit requirements to CIMSS**	**2.1.3**
Dissemination of ATOVS related information	**In relation to instrument characteristics, a single web page should be provided at NESDIS to provide links to all relevant instrument data for ATOVS (including AMSU antenna patterns) and AVHRR**	**T. Kleespies**	**2.1.4**
Ancillary data files	**The new collocation dataset at NESDIS, the MDB, should be made available to the ITWG**	**E. Brown**	**2.1.7**
ATOVS case studies	**When requirements are confirmed and participant commitment affirmed, case study dates and areas should be defined and announced via the ITWG list server**	**ITWG Co-chairs**	**2.1.8**

TOVS/ATOVS data in climate studies

Stratospheric retrievals	**In support of Pathfinder activities, document the characteristics of current and past IR sounding channels and recommend necessary characteristics for future instruments.**	**Pathfinder Working Group Co-chairs**	**2.2.1.7**
Pathfinder activities	**Agencies encouraged to continue low-cost, efficient dissemination of data from future instruments, including METOP, NPOESS and ATOVS**	**NESDIS and EUMETSAT**	**2.2.1.8**

Pathfinder activities	**Continuance of support for Pathfinder activities into the AMSU and HIRS/3 era and beyond, to establish the longest possible data record for climate research**	**NESDIS and EUMETSAT**	**2.2.1.8**
ERA-15 and ERA-40	**Radiance monitoring statistics should be retained in electronic form for the VTPR and TOVS radiances**	**R. Saunders and G. Kelly**	**2.2.2.1**
ERA-15 and ERA-40	**Reports to be provided on the characteristics of the filters flown on early satellites**	**R. Saunders**	**2.2.2.1**
Pathfinder and reanalysis activities	**Advocacy of a program to intercompare existing climate data sets (e.g. Pathfinder Path A, B, P; Spencer & Christy's MSU 2R, MSU 4; NCEP & ECMWF reanalyses) especially from the point of view of global and regional interannual variability and trends**	**ITWG**	**2.2.2.1**
ATOVS - AMSR	**Offer to AMSR team of ITWG expertise in calibration and validation of satellite-based sounders such as AMSU, as well as in the selection of additional sounding channels targeted towards climate monitoring**	**Co-chairs**	**2.2.4.3**
Calibration, validation and continuity	**Information on radiance bias corrections and forward model tuning should be documented and made available to the community. Specifically, information is needed on: radiance bias corrections; QC and rejection statistics; use of input data**	**J. Bates, J. Susskind, N. Scott and R. Saunders**	**2.2.5**
Calibration, validation and continuity	**A standard climatological radiosonde data set should be assembled**	**J. Bates, J. Susskind, N. Scott and R. Saunders**	**2.2.5**
Calibration, validation and continuity	**Radiance biases from reanalysis and Pathfinder projects should be intercompared**	**J. Bates, J. Susskind, N. Scott and R. Saunders**	**2.2.5**
Calibration, validation and continuity	**Additional work on TOVS calibration should be undertaken to establish consensus and reconcile differences**	**ITWG**	**2.2.5**
Calibration, validation and continuity	**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**	**Satellite agencies**	**2.2.5**

General action items	Provide input to the Intergovernmental Panel on Climate Change's Third Assessment Report	ITWG Co-Chairs/ Working Group Co-chairs	2.2.6

The use of TOVS/ATOVS in data assimilation / numerical weather prediction (DA/NWP)

Evaluation and use of TOVS/ATOVS in DA/NWP	Exchange of monitoring results should continue; also, each center to be encouraged to develop their own web page on which to post results. A master document to be developed on the ITWG site linking all web pages	C. Chouinard and B. Harris	2.3.2
Evaluation and use of TOVS/ATOVS in DA/NWP	The so-called 'one observation experiment' should be posted on the web page of each center	C. Chouinard & E. Andersson to coordinate	2.3.2
Forward modelling	Strong support should be given to further improve the modelling of the radiative transfer problem. Specifically, close attention should be given to: surface emissivity modelling; improved LBL models; improved specification of instrument characteristics; improved fast RTM through larger dependent data bases and gradient comparisons of LBL and fast RTM models	ITWG	2.3.3
Future platforms and real-time access to data	WMO/NESDIS/EUMETSAT should develop a communication system with sufficient bandwidth to allow real-time data transfers from current and future platforms. Also, the development of a common format (e.g. BUFR) is strongly encouraged	WMO/NESDIS/ EUMETSAT	2.3.4
Future platforms and real-time access to data	NESDIS/EUMETSAT should further develop and publicise procedures for handling real-time data requests for external users	NESDIS/ EUMETSAT	2.3.4
Future platforms and real-time data usage	Sufficient resources should be allocated in relation to future satellite programs to ensure proper use of the data at NWP and DA centers	NWP and DA centers	2.3.4
Future platforms and real-time data usage	A web-based list of information and software available for exchange should be developed; the exchange of expertise should be encouraged through short-term visits	NWP and DA centers/ ITWG/ C. Chouniard	2.3.4

Advanced IR sounder Working Group

Importance of GEO satellite advanced infrared sounders	**Encouragement should be given to national space agencies to implement advanced infrared sounding capabilities on future GEO satellites**	**WMO**	**2.4.4**
Importance of GEO satellite advanced infrared sounders	**A detailed study of regional user requirements for advanced infrared sounder data should be undertaken**	**Geostationary satellite data providers**	**2.4.4**
Importance of GEO satellite advanced infrared sounders	**A program should be established to train regional users on the use of GEO wind and sounder data in nowcasting**	**Geostationary satellite data providers**	**2.4.4**
Use of new technology for improving spatial resolution of soundings	**National space agencies should investigate the use of large focal plane array technology for enhancing the spatial resolution and clear air sampling capabilities of advanced infrared sounders**	**Space Agencies**	**2.4.5**
Use of new technology for improving spatial resolution of soundings	**Cloud scene airborne measurement data sets and analysis methods should be established to provide a common basis for assessing sounder performance**	**Space Agencies**	**2.4.5**
Use of new technology for improving spatial resolution of soundings	**An immediate study of the installation of HIRS/4 aboard NOAA/M should be undertaken, to provide an earlier opportunity to evaluate and benefit from the effects of reduced IFOV size**	**NOAA**	**2.4.5**
New spectral regions	**Investigations should be undertaken into including far infrared wavelengths (15 - 1000 μm) in future advanced infrared sounders**	**Space agencies**	**2.4.6**
Use of advanced infrared sounder data in NWP	**Further work be undertaken to establish the best method(s) for extracting information from advanced infrared sounder data for NWP**	**Space agencies**	**2.4.7**
Use of advanced infrared sounder data in NWP	**Additional research should be undertaken to improve the efficiency of ground processing systems in using advanced infrared data for operational soundings**	**Space agencies**	**2.4.7**
Use of advanced infrared sounder data in NWP	**The facility should be created to make global AIRS data available in near-real-time to the international operational weather forecasting community**	**NOAA/ NASA**	**2.4.7**

Fast model considerations	**Recommended steps to increase the impact of fast models: establish & quantify potential error sources; review and improve ground calibration procedures; improve use of essential spacecraft information; support programs to define and correct errors in spectral parameters; support efforts to validate rapid algorithm performance; standardise vertical spacing of LBL calculations**	**NOAA/NASA/ EUMETSAT/ ESA**	**2.4.8**
Data compression studies	**Detailed study of lossy data compression techniques for advanced infrared sounders should be undertaken. Performance of lossy compressions should be evaluated and largest errors documented and transmitted to users**	**Space agencies**	**2.4.9**
Airborne and ground truth validation studies	**Airborne measurement campaigns, covering a wide range of climatological and meteorological conditions, should be conducted and should employ well calibrated in situ and ground-based sensors**	**Space agencies**	**2.4.10**
Radiance assimilation and retrieval assimilation	**Data producers should provide the NWP community with error covariance matrices of both radiances and retrievals**	**NOAA, EUMETSAT and JMA**	**2.4.11**
Climate applications of Advanced Infrared Sounders	**Detailed studies of advanced infrared sounders should be carried out to document and assess the utility of these instruments for providing accurate data products for climate studies**	**Space agencies**	**2.4.12**
Other uses of Advanced Infrared Sounders in NWP	**Detailed study should be undertaken of the performance and assimilation of Advanced Infrared Soundings over land. In addition, development and distribution of an accurate, high resolution surface characterisation should take place**	**NOAA and EUMETSAT**	**2.4.13**
Other uses of Advanced Infrared Sounders in atmospheric chemisry	**Detailed study should be undertaken of the uses of advanced infrared sounders in atmospheric chemistry**	**ITWG**	**2.4.14**

International issues and future systems

Polar-orbiting satellite coordination	**CGMS should consider cooordination of polar-orbiting equator crossing times to optimise satellite utilisation**	**CGMS**	**2.5**
Advanced sounder deployment	**NASA should consider placing the NPP sounder in a PM orbit**	**NASA**	**2.5**
Relations with SOAT	**The USA Integrated Programme Office should be informed that ITWG is ready to participate on the Sounder Operational Algorithm Team when requested**	**ITWG Co-chairs**	**2.5**
Frequency protection	**CGMS should consider means to provide for well-resourced activities towards the protection of frequency allocations**	**CGMS**	**2.5**
Relations with CBS	**OPAG IOS should consider a mechanism, similar to that between ITWG and CBS WGSAT, for providing guidance and assistance between ITWG and OPAG IOS**	**OPAG IOS**	**2.5**
Communication with OPAG-IOS	**Co-chairs of ITWG should develop an ITWG process to provide guidance and assistance to the OPAG IOS**	**ITWG Co-chairs**	**2.5**
Communication with GOSSP	**The Chairman of the GOSSP should be informed of ITWG's willingness to provide guidance, assistance and expertise with the expectation that a mechanism, similar to that between WMO and ITWG be developed**	**ITWG Co-chairs**	**2.5**
Status of the GTS	**WMO should inform meetings of the ITWG of the latest status and plans for improvements to the GTS**	**WMO/ D. Hinsman**	**2.5**
NPOESS Environmental Data Records	**The NPOESS IPO should include radiance products as part of the suite of NPOESS EDRs, as a matter of urgency**	**NPOESS IPO**	**2.5**
Direct readout of AIRS and MODIS	**NASA should consider support for activities with the ITWG community towards the establishment of direct readout software packages for AIRS (and MODIS) allowing timely use of the data for operations and research**	**NASA**	**2.5**
Real-time AIRS and MODIS data	**ITWG encourages provision, by NASA and NESDIS, of near real-time data from AIRS (and MODIS).**	**NASA and NESDIS**	**2.5**

2. WORKING GROUP REPORTS

2.1 ATOVS DATA ACCESS, PROCESSING AND VALIDATION

Working Group members: R. Saunders (Chair), D. Klaes (Co-Chair) with V. Achard, T. Achtor, R. Allegrino, T. Bohm (part-time), E. Borbas, E. Brown, P. Brunel, M. Chalfant, D. Chaohua, G. Deblonde, P. van Delst, P. Dibben, S. English (part-time), J. Eyre (part-time), P. Fritz, L. Garand, M. Goldberg, K. Hlavaty, T. Kleespies (part-time), A. Korpela, T. Labrot, L. Lavanant, Yong-Seob Lee, J. Li, M. Muller, P. Pellegrini, C. Pietrapertosa, G. Prangsma, V. Prasad, G. Rochard , F. Romano, M. Schroedter, L. Shi, Y. Takeuchi, A. Thoss, F. Travaglioni, V. Tabor, F. Tveter, M. Uddstrom, K.H. Wang, D. Wark, W. Wolf, H. Woolf, F. Zauli, Wenjian Zhang, Gaoxiang Zhao.

2.1.1 Progress since ITSC-IX

The recommendations and actions from the ITSC-IX meeting of the Working Group were reviewed. All were completed.

AAPP – and documentation for it – is available on the EUMETSAT AAPP web page and on CD-ROM. A more detailed document on the AAPP software provided by Météo-France is planned to be distributed to AAPP users after the clarification of copyright issues. Tom Kleespies has made the TOVS instrument parameters accessible on a server:

ftp: ORBIT-NET.NESDIS.NOAA.GOV (140.90.197.137)
cd pub/crad/sit/kleespies/itsc/atovs.txt

NOAA-15 1b file formats and many other useful NOAA-K information can be found on the NOAA Web Page in the NOAA-KLM Users guide at:

http://www2.ncdc.noaa.gov/docs/klm/index.htm

and the NESDIS ATOVS web page at:

http://poes.nesdis.noaa.gov/atovs

S. English has made the ATOVS products file format in BUFR available on the web at:

http://www.meto.gov.uk/sec5/NWP/ATOVS_product_file_contents.html

The Working Group was pleased to see that this comprehensive documentation is now available, partly as a result of the recommendations from the last ATOVS Working Group report.

2.1.2 ATOVS data characteristics

Recommendation

The Working Group recommended that users should be informed of all significant changes to the ATOVS instrument performance by NESDIS on the ITWG list server (Action: E. Brown)

HIRS/3

No anomalies or problems have been reported. The Group noted the changes in filter functions of channels 12, 15, 16, and 14 (slightly), compared to HIRS/2 on NOAA-14. All HIRS filter functions can be downloaded from the NOAA web site:

http://poes.nesdis.noaa.gov/rtovs

The reason for the large bias between measured and simulated NOAA-14 channel 15 radiances seen by several centres is still not fully understood.

AMSU-A

The Group noted the switch of channels 7 and 15 which is now allowed for in the NESDIS and AAPP ingest software. Radiometer calibration is working well, as demonstrated by a sudden change in gain of channel 14, but which had no effect on brightness temperatures. The Group noted that the large limb adjustments, necessary for some AMSU-A channels, need to be better understood. The issue of whether Zeeman splitting needs to be taken into account in the radiative transfer models for the higher peaking channels (12-14) was discussed. A study showed that the effect was only 0.2K. Comparing AMSU with PLOD indicated that more careful comparisons need to be made between simulated and measured radiances for channel 14 to determine if there is a detectable effect. The radiance monitoring at different centres showed all the measured radiances were stable in time. Only small biases were observed, in contrast to some of the HIRS channels.

AMSU-B

The radio frequency interference problem observed in some AMSU-B channels was discussed. The initial interference observed was stable and correctable until October 1998 when a new source of interference was seen which makes two sets of corrections necessary. Correction tables are available on the NESDIS web page for HRPT users and are provided in the header records of the level 1b data. Corrections for the blackbody and space views will be added soon.

Recommendation

The Group recommended that a report on the AMSU-B problems should be compiled and distributed via the ITWG list server. (Action: M. Chalfant)

Some information is already available in Appendix M of the NOAA-K polar orbiter users guide on the web (see above for address).

Action

The Working Group agreed that the correction needs to be included into the AAPP software. P. Dibben has an updated version and will make the modified modules available to EUMETSAT. D. Klaes will post these modules on the AAPP update server by the end of February 1999. (Action: P. Dibben and D. Klaes)

Action

A check on the consistency of the AAPP corrected radiances with the same NESDIS global 1b dataset should be performed (Action: P. Dibben and P. Brunel)

The Group acknowledged the excellent work done to establish the AMSU-B correction scheme by N. Atkinson (UKMO) and D. Wark, M. Weinreb and M. Chalfant (NESDIS).

AVHRR/3

The Working Group discussed the use of the AVHRR channel 3a (1.6 μm) and 3b (3.7 μm) radiances. NESDIS intend keeping channel 3b 'on' all the time for the morning satellite (NOAA-15). On the afternoon satellite a switch will be performed between channels 3a and 3b when crossing the terminator; the switch will be made when the centre of a line crosses the

terminator. The whole line will then be switched. One or two lines may be lost due to the ambiguity. Several test periods have taken place when the switch to channel 3a has been made for users to assess the utility of this new channel.

Recommendation (to NESDIS):

The Group recommended that further test periods with channel 3a on should be considered to allow a full scientific evaluation of the channel 3a data in the morning orbit.

A problem was reported with the AVHRR level 1b format with the second order calibration coefficient.

2.1.3 Status of ATOVS processing software

During the plenary session there were presentations on the current status of three processing systems for ATOVS data, and the Working Group reviewed these in more detail.

The NESDIS ATOVS software for processing ATOVS data is a development of their operational RTOVS processing system, used to process data up to NOAA-14. The ATOVS system has new science to address the new microwave channels on AMSU-A. It is planned to become operational in March 1999.

Recommendation

The Working Group recommended that a document be made available to the ITWG describing the scientific aspects of the ATOVS processing. (Action: A. Reale)

The European groups developing the ATOVS and AVHRR Processing Package (AAPP), co-ordinated by EUMETSAT, have released version 1.0 which supports ATOVS. AAPP V1.0 is now available for distribution to the user community for test purposes. It comprises ingest and pre-processing for TOVS and ATOVS data as well as AVHRR data. The AVHRR pre-processor includes the generation of a cloud mask and a processor for TBUS orbital predicts. Retrieval modules currently planned to be compatible with AAPP are IAPP (CIMSS), ICI (Météo-France), 1DVAR (ECMWF) and 3I (LMD). Visualisation packages are under consideration.

Recommendation

The Working Group recommended that feedback by e-mail on problems be posted on the AAPP Web Page. (Action: D Klaes).

CIMSS is planning to release Version 1 of the IAPP (International ATOVS Processing Package) in April 1999. This version will be able to process HIRS and AMSU-A data from the AAPP level 1d file. It is planned to add AVHRR and AMSU-B at a later date. Documentation will be delivered with the package. Delivery will be on CD-ROM or via ftp. The release will be announced on the ITWG list-server. It is planned to add visualisation tools to the package.

Action

A requirements document for visualisation tools for IAPP will be written and ITWG members should submit requirements to CIMSS. (Action: ITWG)

The ECMWF 1DVAR package for TOVS has been made available since the last ITWG. The ATOVS version is planned to be included within the next year.

The ICI package from Météo-France is processing HIRS and AMSU-A data with AVHRR information. It is planned to include AMSU-B soon. The first guess can be climatology or NWP fields. The ICI takes the input from AAPP and puts the results in the AAPP level 2 file format. The MAIA cloud mask module will be upgraded for world-wide use.

The 3I ATOVS retrieval package is also under development at LMD. Release is planned in the near future. Empirical radiance corrections (deltacs) are planned to be created for pre-NOAA-9 and NOAA-14 data. Collocation files used are DSD5 files. Extraction of collocated radiosondes from the ECMWF ERA-15 archive has started. The ATOVS retrievals use neural networks for airmass classification and selection of first guess. Neural network techniques are also under development for IASI/AIRS. A simulated ATOVS dataset using the TIGR-3 datatset is also being prepared.

2.1.4 Dissemination of ATOVS related information

NESDIS is planning to continue the GTS dissemination of ATOVS products, as for TOVS. The 120 km ATOVS BUFR format will use a different BUFR encoder which is now available to users for test and to allow feedback to NESDIS. Once the ATOVS product file format has been agreed, NESDIS will announce the replacement of the NOAA-11 RTOVS file with the NOAA-15 ATOVS file on the GTS. Two months notice will be given before the change is implemented. A file with AVHRR parameters for each HIRS field of view is also nearly ready for dissemination from NESDIS to Bracknell.

The 500 km SATEMS for NOAA-15 will continue as before, with some consideration being given to increasing the spatial sampling. The NOAA-15 SATEMS will have a different bulletin header to define the geographic sampling. Level 1B TOVS/ATOVS data are transmitted to the UKMO via the dedicated Washington-Bracknell link. The UKMO already distributes the level 1B products to ECMWF, Météo-France and other European meteorological services on request. If users outside Europe wish to receive level 1B radiances or products they should submit their request directly to NESDIS. E. Brown is the point of contact.

Recommendation

In relation to the instrument characteristics, the Working Group recommended the provision of a single web page at NESDIS to provide links to all the relevant instrument data for ATOVS (including AMSU antenna patterns) and AVHRR (Action: T. Kleespies).

2.1.5 Radiative Transfer Models

The Group recognised that the following Radiative Transfer models for ATOVS are available: OPTRAN (NESDIS), RTTOV5 (ECMWF), PLOD (Univ. Maryland), AES-FAST (AES) and 3R (LMD).

A technical sub-group session related to fast RT models was held during the conference and a separate report is given in Section 3.

2.1.6 Validation

The Working Group gratefully acknowledged the efforts of the University of Wisconsin to validate ATOVS radiances with several interferometers and microwave radiometers on the

NASA ER-2 aircraft. The Group encourages the user community to extend and continue the efforts in radiance validation. NESDIS expressed an interest to see a validation of their ATOVS retrievals when they become available through in-situ measurements and comparisons with other retrieval schemes.

2.1.7 Ancillary data files

NESDIS maintains an archive of all radiosonde collocation files from RTOVS and ATOVS processing. The format of the dataset has changed with RTOVS and it is now called the MDB which is a replacement for the DSD5 files.

Recommendation

The Working Group recommended that the new collocation dataset, the MDB, be made available to the ITWG. (Action: E. Brown).

An overlap period is available for the transition from NOAA 11 RTOVS to NOAA-15 ATOVS.

Météo-France archives all collocations within the Lannion reception area. The region around La Reunion is planned to be added within the next six months. The University of Wisconsin also has a global data set with collocated radiosonde data. In relation to surface field datasets the Working Group acknowledged the availability of the MM5 surface type data set for global applications. The NESDIS microwave surface precipitation analysis from N. Grody's scheme can be obtained from NESDIS as a product. The dataset of land surface microwave emissivity in preparation by C. Prigent at NASA GISS may also be of interest for AMSU radiance assimilation over land.

2.1.8 ATOVS case studies

During the development of the TOVS packages, the ITWG identified several meteorologically interesting case studies, which allowed ITWG members to compare the results of their TOVS processing and improve their processing systems.

There is currently an action item against the ITWG co-chairs to organise the distribution of case studies. This is contingent upon full implementation of AMSU-B corrections and finalisation of ITWG requirements.

After some discussion, the Working Group proposed to collect the requirements for such case studies from the ITWG and to obtain firm commitment from interested participants.

Recommendation

When the requirements are confirmed and participant commitment affirmed, it was recommended that case study dates and areas be defined and announced via the ITWG list server. (Action: ITWG Co-Chairs).

2.2 TOVS/ATOVS DATA IN CLIMATE STUDIES

Working Group members: J. Bates and J. Francis (Co-chairs) with R. Allegrino, H. Billing, F.M. Breon, H. Chung, J. Citeau, A. Kaifel, W. P. Menzel, M. Rieder, L. Rokke, R. Saunders, A. Schweiger, C. Sear, J. Susskind, Y. Takeuchi, R. Teixeira, S. Tjemkes, D. Wark.

2.2.1 Recent advances in relation to long-term data sets from satellite-borne sounders

In recognition that there were 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. 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 this original concept for the TOVS Pathfinders, several other Pathfinder approaches have more recently 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 latest activities of each of these Pathfinders follows.

2.2.1.1 Pathfinder Path-A (NASA/GSFC)

The TOVS Pathfinder Path-A dataset presently covers the fourteen year period 1985 - 1998. The 1979-1984 period is expected to be completed shortly. 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. A CD-ROM containing monthly mean values for 10 parameters, adjusted to a common observing time, is planned.

2.2.1.2 Pathfinder Path-B (LMD)

To date, nearly eight years (January 1987 - August 1994) of the Path-B data set have been processed using the Improved Initialization Inversion ("3I") algorithm at the Laboratoire de Meteorologie Dynamique (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.

During the past two years, 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 (deltacs); 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 these recent algorithm modifications was submitted to the *Bulletin of the American Meteorological Society* in December 1998.

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 that 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. An appraisal of the MSU temperature trend studies is currently being conducted.

As with all satellite information, however, most information is contained in the spatial fields and their time evolution. In addition, other estimates of the long term evolution of the atmospheric temperature profiles will be available as the various Pathfinders are completed.

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 is intended to

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 include:

- 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. (An initial processing of all HIRS and MSU data has been completed and is currently being evaluated.)

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 presented in HDF and will be available from the National Snow and Ice Data Center (NSIDC) early in 1999, along with sample read programs. 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. Cloud fractions look especially encouraging. 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 new TOVS pathfinder project (Path-O3) is 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. While this project is still in research mode, 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.

To date, 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. Future activities include processing all TOVS Level 1b data including extensive work on inter-satellite calibration.

2.2.1.7 Stratospheric Retrievals

Since the launch of TIROS-N in October 1978, constant and consistent emission measurements from the ν_2 band of CO_2 at 15 μm have been made. The stratospheric sounding units (SSU) are a series of pressure-modulated radiometers that were supplied by the UK Meteorological Office. Eight SSUs were incorporated as part of all but two TOVS instrument packages on board the NOAA polar-orbiting satellites.

Each SSU contains three cells of CO_2 at nominal fill pressures of 108.0, 35.6, and 10.8 hPa. The pressure in each cell determines the part of the spectral line that is sampled. As the cell pressures change through outgassing, the weighting function peak rises. A temperature profile can be derived from these measurements because it is a known function of the intensity and spectral distribution of the infrared radiation at 15 microns.

It is hoped to encourage the use of the SSU data set by addressing four key areas of uncertainty. The first is documentation of the instrument performance, calibration, and identification of any instrument anomalies. The second is to employ the substantial improvements that have been made in the accuracies of line-by-line radiation codes at 15 μm. This monochromatic information can be used to model each individual instrument spectral response and corresponding transmittance functions over time. Third is to address systematic errors that can be present, including instrument and satellite drift and changes in the ambient CO_2 concentrations. The fourth goal is to provide this documentation, fast forward models, and retrieved stratospheric temperatures for use in re-analysis and for use in climate studies of the stratosphere. This activity will be undertaken by Pathfinder scientists including J. Bates and F.M. Breon. In support of these current Pathfinder activities, it is necessary to document the characteristics of current and past IR filter response functions, recommend necessary characteristics for future instruments and define total-system responses, including effects such as mirror emissivity changes as a function of wavelength.

2.2.1.8 Additional recommendations relative to Pathfinder Activities

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

Recommendation

The ITWG 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.

Action

The ITSC notes that, in support of Pathfinder activities, it is necessary to determine the characteristics of current and past IR filter response functions, recommend necessary characteristics for future instruments and define total-system responses, including effects such as mirror emissivity changes as a function of wavelength. (Action: Pathfinder Working Group Co-Chairs)

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 Advances in 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 working group encourages comparisons between the ERA-15 and pathfinder data sets. ECMWF plans to start a new 40-year reanalysis (1958-1998) in the near future using the 3Dvar assimilation system. VTPR and TOVS 1b radiances will be directly assimilated. The working group recommends that the radiance monitoring statistics be retained in electronic form for the VTPR and TOVS radiances.

Recommendation

As a result of the strong community interest in this reanalysis activity, it is recommended that reports be provided concerning the characteristics of the filters, flown on early satellites. (Action : R. Saunders)

Recommendation

The Group strongly 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 Regional studies

The nearly 20-year-long TOVS data record can give researchers and forecasters useful information to identify and study regional characteristics of energy budgets and moisture cycles.

2.2.3.1 The Atlantic Basin Hydrological Cycle

France (IRD, Météo- France) and Brazil (FUNCEME) have set up informal collaboration through the development of a Satellite and Tropical Atmospheric Profile network. The goal is to assess the utility of climatic parameters retrieved from TOVS/ATOVS over the Atlantic basin either for climate studies (water vapor fluxes of the African monsoon), led by IRD, and climate monitoring over the N.E. of Brazil, conducted by FUNCEME. The availability of a longer TOVS Pathfinder A time series will improve diagnostic analyses in the area, as will real-time data from the Pilot Research Moored Array in the Tropical Atlantic (PiRATA) array buoys giving subsurface and SST, wind, air temperature and humidity (http://www.pmel.noaa.gov/pirata) and radiosonde data collocated with NOAA-15 overpasses from cruises. These data may be particularly useful for investigating variability of the monsoons and their related energy and moisture patterns.

2.2.3.2 Polar climate applications

With the completion of the 18-year NASA/NOAA TOVS Polar Pathfinder (Path-P) data set, numerous opportunities arise for investigations of interannual and decadal polar climate variability, air/ice/ocean interactions, and feedback mechanisms involving snow and sea ice. Several applications of the data set are already in progress, including the calculation of surface radiation fluxes, horizontal advection of sensible and latent heat, precipitation, and surface wind velocities. An Arctic Ocean modelling project at Rutgers University is already ingesting Path-P-derived wind fields to force sea ice motion and to compute turbulent fluxes.

In addition to these applications, Path-P data are being combined with AVHRR brightness temperatures to retrieve cloud properties in the polar night for the NASA CERES project. Products from the AVHRR and passive microwave Polar Pathfinder groups have been combined with TOVS Path-P data into a common 100 km grid - the Pcube - to foster the inter-use of these complementary data sets.

2.2.4 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.

2.2.4.1 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 being archived.

2.2.4.2 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.

Future efforts will focus 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.

2.2.4.3 Precipitation

A precipitation index, based on a difference between AMSU-A channels 1 and 15, is used over land. Over ocean, there is a rain/no rain flag. Efforts are underway to improve and refine these products.

In addition to the operational microwave instruments, research microwave instruments will also be available for use in climate studies. The AMSR – to be launched in 2000 by NASDA – is a unique microwave imager because it has two sounding channels and a lower frequency channel, so that surface characteristics and heavy precipitation can be monitored simultaneously. In relation to this, the following recommendation is made to the AMSR Science Team.

Recommendation

The ITWG offers to the AMSR team its expertise in calibration and validation of satellite-based sounders such as AMSU, as well as in the selection of additional sounding channels targeted toward climate monitoring.

2.2.5 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 combine 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 latitude, time etc.)**

in digital form;

- **QC and rejection statistics in digital form;**
- **Use of input data (locations, times);**
- **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, Susskind, Scott, Saunders

In addition, the following recommendations are made :

Recommendations

To ITWG in general :

- **Additional work on TOVS calibration should be undertaken to establish consensus and reconcile differences.**

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.**

2.2.6 General action items

Action

To ITWG Co-Chairs and Climate WG Co-Chairs: Provide input from the material presented at ITSC-X to the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR).

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

Working Group members: C. Chouinard (Chair), J. Derber (Co-Chair) with E. Andersson, N. Baker, T. Böhm, B. Burns, D. Chaohua, G. Deblonde, P.Dibben, S. English, L. Garand, B. Harris, J. Joiner, T. Kleespies, R. Munro, V.S. Prasad, R. Renshaw, H. Schyberg, S. Tjemkes, S. Turner, M. Uddstrom, S. Wadley, W. Zhang

2.3.1 Introduction

There were many substantive presentations at this meeting that indicated very positive results using satellite data either directly as radiances or as retrievals. The controversy over the preferred use of radiances or retrievals has not been resolved. The new data from the AMSU-A instrument is already showing great potential as indicated from the preliminary impact studies presented by two NWP Centers. The AMSU-B RFI problem is serious but it appears that the data will be usable after a series of corrections.

The Working Group feels that there will be some degree of difficulty with the microwave sounders in the modeling and specification of surface emissivity and in the detection of precipitation which has a large impact on the window channels and lower tropospheric channels (channels 1-5).

During the last few years, there were a number of exchanges of code/results and techniques between groups, indicating that the satellite community is vibrant and very active. It was decided to encourage and support such exchanges and try to improve communications between groups by using the Internet more effectively.

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

Large biases between background and radiances 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.

Recommendation

In order to facilitate this type of exchange, the group recommends the continued exchange of monitoring results and encourages each Center to develop their own Web page to post these results. A master document linking all Web pages will be developed and reside on the ITWG Web site so everyone can easily examine and compare results from other groups to theirs (Action: C. Chouinard and B. Harris to co-ordinate).

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. A few background error covariance exchanges have occurred in the past for conventional data.

Recommendation

The Group recognizes the difficulty in implementing and validating radiance/retrieval data in a DA/NWP system and recommends that so-called one-observation experiment, which most Centers have or will have to do in order to verify theoretical and measured impact of one datum, be posted on their Web page. Since there are 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 and E. Andersson to coordinate).

At the last meeting it was decided to conduct a survey on the current use of TOVS data in operational DA/NWP Centers. T. McNally of ECMWF was responsible for this action and promptly summarized the results in the form of the following Table.

Table 2.3.1 Current Use of TOVS data in DA/NWP Centres

PARTICIPANTS		NESDIS RETRIEVALS			RADIANCES	
		500	250	120	DIRECT	1DVAR
AES	(CAN)	G/R				
BOM	(AUS)			G		R^+
DWD	(GER)	G				
ECMWF				*	G	
JMA	(JAP)			G/R		
METEO	(FRA)	G				
NASA	(USA)			G		
NCEP	(USA)			R	G	
NRL	(USA)			G/R		
UKMO	(UK)					G/R
NCMRWF	(INDIA)	G/R				

G = GLOBAL DA/NWP R = REGIONAL DA/NWP * = OTHER USES
+ USES RAW CLOUDY RADIANCES

Given the survey results, the Working Group recognizes the important role of NESDIS as a data producer and wishes to make the following statement: *The results of a recently conducted survey indicate that the majority of DA/ NWP Centers still rely upon NESDIS retrieved products (in some way, see Table 2.3.1) for their operational forecasting systems. The Group wishes to acknowledge this fact and support the continuing efforts of NOAA/NESDIS in this crucial role.*

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. In particular;

1. The use of near surface radiance data over land and ice are greatly influenced by surface emissivity estimates. While reasonable estimates of the surface emissivity of oceans exist, over land, snow and ice they are inadequate.

2. The basis for all radiative transfer models are the line-by-line (LBL) models. These models are imperfect, and without substantial improvements in them, new higher spectral resolution data cannot be properly used. The fast RTM, themselves based on the LBL models, also need further examination and improvement. It was noted that it is important for the fast radiative transfer models to be valid over the entire range of potential atmospheric profiles and that the sensitivity of radiances to various input parameters such as temperature and humidity (e.g. the gradient) to be properly modeled.

3. Improved specification of instrument characteristics is required. Errors have been noted recently which can be traced to the specification of the filter functions for the various channels. Without the accurate specification of the instrument characteristics, it is clearly difficult to fully utilize the information in the data.

Recommendations

The Working Group notes that the radiative transfer problem is not solved and recommends strong support for the further improvement of its modeling. Specifically, the Working Group recommends strong support for surface emissivity modeling, improved LBL models, improved specification of instrument characteristics, improved fast RTM through larger dependent data bases and gradient comparisons of LBL and fast RTM models. Finally the Working Group notes that the radiosonde remains the basis for intercomparisons and supports the maintenance and improvement of the current radiosonde network.

2.3.4 Future platforms and real-time access to data

The accessibility of data from future platforms was a major concern of the Working Group. The transfer of large volumes of data, which will be produced by future platforms, cannot be handled by the current communication systems. Also, the variety of data formats for current and future datasets will result in substantial overhead in the production and use of these datasets.

Recommendation

The WMO/NESDIS/EUMETSAT should develop a communication system with sufficient bandwidth to allow real-time data transfers of current and future platforms. Also, the development of a common format (e.g. BUFR) with the users is strongly encouraged.

Problems were noted in acquiring new datasets by users external to the organizations producing the data. While the Working Group acknowledges that there is a resource limitation on these requests, it became clear that there is not a well-defined procedure for communicating and

prioritizing the requests.

Recommendation

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 currently not being used. 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.

Recommendation

The Working Group strongly encourages that sufficient resources be allocated in relation to future satellite programs to ensure proper use of the data at NWP and DA centers.

Because of limited resources, it is not possible for every group to develop the necessary procedures to use new data types. For that reason, it is important to exchange techniques and software between groups. The Working Group also notes that there has been substantial informal cooperation/exchange between various Centers. However, not all groups have had access to this invaluable information.

Recommendation

The Working Group recommends the development of a Web based list of software and information available for exchange and encourages the exchange of expertise through short-term visits.

2.4 ADVANCED INFRARED SOUNDER WORKING GROUP

Working Group members: W. Smith (Co-Chair), J. Susskind (Co-Chair), H. Billings, H. Bloom, D. Ceckowski, V. Cuomo, J. Eyre, M. Goldberg, A. Huang, G. Kirchengast, G. Kelly, B. Lambrigsten, S. Lee, J. Lerner, J. Li, L. McMillian, T. McNally, Y. Plokhenko, J. Puschell, F. Rabier, A. Uspenski, D. Wark, W. Zhang

2.4.1 Progress on Recommendations from ITSC-IX

At its recent meeting in Nagoya, the IRC accepted this Group's recommendation to expand the scope of the ITWG to include passive sounders other than TOVS, that is, ATOVS, high spectral resolution advanced infrared sounders and geostationary sounders.

2.4.2 Advanced infrared sounder instrument status

Work is progressing on four advanced infrared sounders: AIRS (Advanced Infrared Sounder), IASI (Infrared Atmospheric Sounding Interferometer), CrIS (Cross-track Infrared Sounder) and IRFS (Infra Red Fourier Spectrometer). One of these instruments (AIRS) is a cross-dispersed grating spectrometer. The other three instruments are Fourier transform spectrometers based on Michelson interferometers. Table 2.4-1 summarizes characteristics of these instruments.

The AIRS instrument has been built and will fly on EOS PM-1 that is currently scheduled for December 2000.

The first IASI instrument is being fabricated under a recent contract to Alcatel. It is scheduled for launch aboard METOP-1 in mid-2003.

The CrIS development is in a Risk Reduction Phase with teams led by Raytheon Santa Barbara Remote Sensing and ITT Industries competing for an award to complete the design and build the first set of instruments. Downselection to one contractor team is expected in July 1999, following Preliminary Design Review in April and follow-on phase proposals submitted in May.

2.4.3 Research advanced sounder plans

The Russian MTVZA instrument is a multichannel scanning MW radiometer that is designed for atmospheric temperature/humidity sounding as well as for remote measurements of some ocean parameters. It has twenty channels in the range 19-183 GHz (including vertical and horizontal polarization) and conical scanning at an incident angle of 65 degrees. The spatial resolution varies between 16 and 70 km, depending on channel wavelength. The swath width is ~2600 km, resulting in 12 hour global coverage from one satellite. MTVZA will function as an experimental instrument aboard METEOR 3MN1. It is planned for launch in 1999 and will become operational for METEOR 3MN2, planned for launch beyond 2001.

China is investigating development of a Michelson interferometer-based sounder, called MIRAS and an improved microwave sounder, for Phase II of the FY-3 Program of polar orbiting satellites. These instruments would fly in the 2008-2016 time period.

The US continues to develop innovative microwave technology for future sounders, based on MMICs (monolithic microwave integrated circuits) technology. As part of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP), NASA plans to fly the Advanced Technology Microwave Sounder (ATMS) with possible channels in the 23 GHz, 31 GHz, 50 GHz, 89 GHz, 166 GHz and 183 GHz bands. FOV size is expected to be as small as 10 km at 183 GHz with signal-to-noise as good as AMSU in the notional NPOESS CrIS 10 km IFOV. Channels in the 118 GHz and 58 GHz bands are also being explored. The NPP platform is currently scheduled for launch in 2005.

Table 2.4-1 Characteristics of Advanced Infrared Sounders

	AIRS	IASI	CrIS (notional)	IRFS
Approach	grating	FTS	FTS	FTS
Agency and Producer	NASA JPL/LoMIRIS	EUMETSAT/ CNES Alcatel	IPO TBD	Russian Space Agency
Spectral range (cm^{-1})	LW: 649 -1135 MW: 1217 -1613 SW: 2169 -2674	contiguous 645-2940	LW: 635 -1095 MW: 1210 -1600 SW: 2155 -2800	LW: 625 -2000 SW: 2200 -5000
Unapodized spectral resolving power	1000 - 1400	2000 - 4000	900 - 1800	1200 - 4000
Spatial footprint (km)	13 x 18	12	10	20
Altitude (km)	705	833	824	1000
Sampling density per 50 km square	9	4	9	1
Power (W)	225	200	91	120
Mass (kg)	140	160	81	70
Platform	EOS PM-1	METOP-1	NPP or NPOESS C1	METEOR 3MN2
Launch date	Dec 2000	2003	2005 for NPP 2008 for C1	2001
Primary assets	best noise performance, especially for SW and demos. new technology	most versatile spectral coverage and resolution	smallest sensor with best spatial sampling for mitigating cloud effects	best spectral coverage

2.4.4 Importance of GEO satellite advanced infrared sounders

Advanced infrared sounders are needed in geostationary earth orbit (GEO) satellites to meet the WMO hourly sounding requirement and to observe the transport of water vapor, especially in the tropics. High vertical resolution advanced infrared sounders in GEO can provide measurements of wind profiles above clouds, by using water vapor as a tracer of wind velocity. These wind profile measurements are needed with high spatial and temporal resolution, particularly in the highly convective tropics, the source of heat and moisture of both tropical and extratropical storms. The flexible, repeat sampling possible from GEO enables detailed capture of the

4-dimensional behavior of temperature, moisture and clouds on time scales as short as minutes and leads to dense fields of water-vapor tracked winds that can be created at hourly intervals with high vertical resolution and 15 minute temporal resolution.

GEO advanced infrared sounders are required to support improvements in nowcasting by capturing the wide temporal and spatial characteristics of atmospheric and surface phenomena that are unavailable from current and planned polar orbiting systems. In addition, GEO advanced infrared sounders can provide cloud-free views of atmospheric and surface conditions at different times of day, thereby improving the probability of clear soundings to more locations. GEO sounders can improve sounding and therefore weather forecasting performance by offering better combinations of sensitivity, spatial resolution and spectral resolution than polar sounders, because of the long dwell times possible from GEO.

An increasing number of regional users (US NWS, US military, US state and local governments) use GEO sounding data. However, improvements are needed in communicating how to obtain these data and use it in nowcasting. To avoid similar delays in implementing full operational use of advanced infrared GEO sounder data, assessment of regional user requirements for advanced infrared GEO sounders needs to start immediately.

Recommendation (to the WMO)

Because of the importance to meet the WMO one hour temporal resolution sounding requirement and because of the need to measure the transport of moisture and wind velocity and because of the unique ability of GEO sounders to improve mesoscale weather forecasting performance, the ITWG strongly recommends that the WMO encourage national space agencies to implement advanced infrared sounding capability on their future GEO satellites.

Recommendation (to Geostationary Satellite Data Providers)

The ITWG recommends a detailed study of regional user requirements for advanced infrared sounder data. The ITWG also recommends establishing a program to train regional users on how to use GEO wind and sounder data in nowcasting.

2.4.5 Use of new technology for improving spatial resolution of soundings

New Mercury Cadmium Telluride detector arrays using active cooling are sensitive to wavelengths out to 16 mm and enable high spatial resolution and contiguous samples of advanced infrared sounder data. Considering recent work (presented at ITSC-X by Pietrapertosa and Cuomo et al.) which shows that the probability of sensing clear air radiances in an IFOV increases with a decrease in linear IFOV dimension for broken clouds, this technology could greatly enhance the value of advanced infrared soundings of the lower troposphere. In addition, for the detector array sizes envisioned for future advanced sounders, this technology reduces overall instrument development cost by shifting the alignment of detectors in focal planes from a labor intensive manual process to a highly developed microelectronics manufacturing process. For GEO sounders, new detector arrays can provide more efficient earth coverage, thereby enabling longer dwell times which lead to better instrument sensitivity and better soundings.

However, given that insertion of new technology into sounders or any other system is an iterative process that requires continuous consideration of both mission requirements and technology availability and cost, more detailed study is required to optimize the selection of

detector parameters for advanced infrared sounders. Trades between spatial resolution/sampling and radiometric sensitivity needs to be made very carefully and should be based on a comprehensive set of real cloud scenes that include cirrus clouds and other important cases.

Early evaluation of the effect of reduced field of view size on sounding performance is possible with the 10 km IFOV HIRS/4. This instrument has been delivered and is currently scheduled for flight aboard NOAA-N.

Recommendations (to Space Agencies)

Given the promise of new detector technology for dramatic improvement in the critically important application of lower troposphere sounding, the ITWG recommends that national space agencies investigate use of large focal plane array technology for enhancing the spatial resolution and clear air sampling capabilities of advanced infrared sounders. Furthermore, to enable trade studies between field of view size and instrument sensitivity on overall sounding performance, the ITWG recommends that cloud scene airborne measurement data sets and analysis methods be established to provide a common basis for assessing sounder performance.

Recommendation (to NOAA)

The ITWG also recommends immediate study of installing HIRS/4 aboard NOAA-M, to provide an earlier opportunity to evaluate effects of reduced IFOV size. It is further recommended that this study include an assessment of whether the last remaining HIRS/3, currently intended for launch aboard NOAA-M, be retrofitted as a HIRS/4 for flight on NOAA-N in order to maintain best possible performance enhancements available in the latest HIRS design.

2.4.6 New spectral regions

Advanced infrared sounders, to date, have been limited to spectral regions below 15μm, because sensitive detectors suitable for operational sounders have not been available at longer wavelengths. However, almost half of the Earth's radiant energy to space emerges from wavelengths beyond 15 μm. Furthermore, water vapor emission from the middle and upper troposphere occurs at wavelengths beyond 20 μm. Far-infrared measurements also offer the ability to remotely sense physical properties of cirrus clouds and measure ozone concentrations in the upper troposphere. New bolometer detectors are now becoming available for observing far-infrared wavelengths with high sensitivity.

Recommendations (to Space Agencies)

Considering the need in weather forecasting and climate studies to observe the optical properties of cirrus clouds and water vapor emission and water vapor profile in the upper troposphere, the ITWG recommends that national space agencies investigate including far infrared wavelengths (15 - 1000 μm) in future advanced infrared sounders.

2.4.7 Use of advanced infrared sounder data in NWP

Due to the large volume of radiance data expected from advanced infrared sounders and practical constraints on NWP processing facilities, there is a need to reduce these data to their information

content before using them in NWP. Recent work shows that an eigenvector analysis can vastly reduce the volume of data assimilated into NWP models, with little information loss. At least two possible approaches can further reduce the data set size used in NWP:

- Model-independent retrievals: Use of temperature and humidity retrievals in NWP can be difficult if the background information cannot be removed during the NWP analysis. Hence, only retrieval methods with easy-to-characterize errors are suggested. Library search methods are difficult to use with current NWP analysis methods;
- Use of radiances from super channels in 1-DVAR, 3-DVAR or 4-DVAR. Selection of a small number of super channels may provide a simple way of extracting the information content from advanced sounder data and allows those radiances to be used by current NWP systems.

Approaches for dealing with the challenges of processing advanced infrared sounder data for assimilation into NWP and to produce high quality products within operational time constraints can be explored prior to IASI and CrIS by operational utilization of AIRS data. It is vitally important that AIRS data be made available to the international NWP centers in near real time to facilitate the transition to operational advanced infrared sounders.

Recommendations (to Space Agencies)

The ITWG recommends further work to establish the best method(s) for extracting the information from advanced infrared sounder data for NWP. The ITWG also recommends additional research to improve efficiency of ground processing systems in using advanced infrared data for operational soundings.

Recommendation (to NOAA/NASA)

To reduce risk and avoid delays in full operational utilization of operational advanced infrared sounder data, the ITWG strongly recommends that NOAA and NASA create a facility to make global AIRS data available in near real time to the international operational weather community.

2.4.8 Fast model considerations

Rapid transmittance models are used in retrievals and radiance analysis to define the relationship between atmospheric state and measured radiance. Currently, adjustments are necessary to remove systematic differences between calculated and measured values. Before measured radiances can achieve their full impact on forecast models, a detailed understanding of the causes of these biases must be developed and the size of the adjustments needs to be reduced.

These biases have several potential causes, including errors in:

- atmospheric parameters used to calculate radiances;
- knowledge of instrument spectral response;
- line-by-line models used to generate rapid models;
- rapid models themselves; and
- instrument calibration.

Recommendation (to NOAA/NASA/EUMETSAT/ESA)

To increase the impact of fast models, the following steps are recommended:

- **Establish and quantify the potential sources of error;**

- **Review and improve ground calibration procedures and provide the resources required to perform essential measurements;**
- **Improve use of essential spacecraft information that can have significant impact on instrument data. Examples of such spacecraft-related information include orbit altitude, spacecraft attitude and temperatures of emitting surfaces in the detector fields of view;**
- **Support programs to define and correct errors in spectral parameters;**
- **Support efforts to validate performance of currently available rapid algorithms;**
- **Standardization is required in the vertical spacing of line-by-line calculations and in the profile sets used for coefficient generation and validation. In addition, spectral regions where fast models are safe to use need to be identified and documented. Fast model requirements and differences between single sample sounding and climate studies must be considered in this validation process.**

2.4.9 Data compression studies

Data compression techniques offer the prospect of reducing requirements and therefore cost for communication and ground processing systems while retaining the capability of advanced infrared instruments for providing much improved soundings of atmospheric state and calculation of surface properties. Data compression methods with no loss of information (so-called 'lossless' methods) provide roughly a factor of two reduction in downlink data rate requirement. However, lossy techniques can provide reductions of 10x or more in data rate, leading to significant cost savings in future operational systems. Further study is required to determine whether loss of information due to compression methods degrades sounding performance unacceptably.

Recommendations (to Space agencies)

The ITWG recommends detailed study of lossy data compression techniques for advanced infrared sounders. Performance of lossy compressions needs to be evaluated for a wide variety of individual vertical sounding profiles. In addition, the largest error associated with the data compression process needs to be documented and transmitted to users.

2.4.10 Airborne and ground truth validation studies

Data sets need to be obtained which can validate forward radiative transfer models and retrieval algorithms, in preparation for the launch of advanced infrared sounders. Airborne high spectral resolution instruments covering the full spectral range and spectral resolution of anticipated advanced infrared sounders now exist. These instruments need to be used in airborne campaigns along with best available in-situ and ground-based remote sensors to characterize the atmospheric state. Similar airborne measurements campaigns will be invaluable for validating space-based radiance measurements and products produced from them.

Recommendations (to Space agencies)

Considering the importance of validating remote sounding radiance observations, forward and inverse algorithms and derived products, to the

success of operational advanced infrared sounders, the ITWG recommends that airborne measurement campaigns be conducted which include sophisticated and well-calibrated in-situ and ground-based remote sensors for characterizing the atmospheric state. These campaigns should cover a wide variety of climatological and meteorological conditions and should be conducted prior to and after launch of operational advanced infrared sounders.

2.4.11 Radiance assimilation and retrieval assimilation

Assimilating radiances and/or retrievals requires observation error covariance.

Recommendation (to NOAA/ EUMETSAT/ JMA)

The ITWG recommends that data producers provide error covariance matrices of both radiances and retrievals to the NWP community.

2.4.12 Climate applications of advanced infrared sounders

Advanced infrared sounders can provide accurate, high resolution products for climate studies.

Recommendation (to Space Agencies)

The ITWG recommends detailed studies of climate applications of advanced infrared sounders to document and assess their utility for providing accurate high resolution cloud, cloud optical property, ozone, earth radiation budget and other products for climate studies. This study should determine spectral range, spectral resolution, sensitivity and calibration performance required in advanced infrared sounders to support climate studies.

2.4.13 Other uses of advanced infrared sounders in NWP

Reductions in deployment of radiosondes over land increases the importance of using advanced infrared soundings of temperature and humidity over land.

Recommendation (to NOAA/EUMETSAT)

The ITWG recommends detailed study of performance and assimilation of advanced infrared soundings over land. In addition, given that the accuracy of surface emissivity has been demonstrated to influence the accuracy of soundings, the ITWG recommends development and distribution of an accurate, high resolution surface characterization database that includes emissivity.

2.4.14 Other uses of advanced infrared sounders in atmospheric chemistry

Spaceborne advanced infrared sounders such as AIRS, IASI and CrIS can provide significant improvement in remote measurement of atmospheric gas composition, in particular tropospheric gas constituents such as CH_4, CO_2 and N_2O. Global scale measurements of trace gas concentrations are required to improve overall understanding of atmospheric chemistry and to assess possible radiative forcing of climate due to changes in trace greenhouse gases. The measurement of global budgets for these species and others in terms of sources and sinks provided by forthcoming nadir-viewing advanced infrared sounders are of great importance for atmospheric chemistry, especially when used in conjunction with ground-based sensor networks

and chemical transport models.

Recommendation (to ITWG)

The ITWG recommends detailed study of uses of advanced infrared sounders in atmospheric chemistry.

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Working Group members: D. Hinsman (Chair), with G. Rochard (Co-chair), J. Le Marshall (Co-chair), E. Brown, D. Ceckowski, J. Eyre, P. Menzel, G. Prangsma, V. Tabor, A. Uspensky and D. Wark.

2.5.1 Background

ITSC-X agreed that the Working Group for "International Issues and Future Systems" should discuss several topics including satellite operators' plans for future instruments and missions, the protection of frequency allocations, the restructuring of WMO's Commission for Basic Systems (CBS), direct read-out, education and training and workstations.

The Working Group also reviewed the status of recommendations and action items from ITSC-IX. 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-X were most valuable and should be continued at future meetings.

When discussing the ITSC-IX recommendation to CGMS to develop a mechanism for an overarching strategy to best address individual country needs as well as international requirements, the Working Group felt that while the short- and medium-range satellite operator plans were well coordinated, the long-range plans could benefit from better coordination, especially with regard to gaps and overlaps in missions and instruments. In this regard, the Working Group noted that WMO's CBS Working Group on Satellites had prepared a preliminary statement of guidance regarding how well satellite capabilities met WMO user requirements in several application areas. It felt that such guidance provided a valuable input to the satellite operators in developing long range plans and it was pleased to note that the CBS Open Programme Area Group for Integrated Observing Systems - OPAG IOS (the successor to the Working Group on Satellites) would prepare a second iteration of the statement of guidance.

The Working Group noted that some CGMS satellite operators (NOAA/NESDIS, EUMETSAT, China and the Russian Federation) have plans to launch polar-orbiting satellites and that coordination of their equator crossing times was necessary. Additionally, it was suggested that CGMS take into consideration the plans of non-CGMS satellite operators who have plans to utilize the present frequency allocations for HRPT downlinks. Finally, the Working Group encouraged CGMS to consider contingency plans that would be comparable and consistent for all three polar orbits (early AM, AM and PM).

Recommendation (to CGMS)

ITWG encourages CGMS to consider coordination of polar-orbiting equator crossing times to optimize satellite utilization while minimizing potential conflicts in data reception; to consider non-CGMS satellite operator plans to utilize the present downlink frequency allocations; and to consider comparable contingency plans for all polar orbits.

With regard to the present plans which only include one operational advanced sounder (IASI) before 2009, the Working Group was pleased to note NASA's NPOESS Pathfinder Project (NPP) which had the potential to make available a second advanced sounder prior to 2009. 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 PM orbit.

Recommendation (to NASA)

ITWG encourages NASA to consider placing the NPP sounder in a PM orbit.

The Working Group agreed that international participation on the Sounder Operational Algorithm Team (SOAT) by members of the ITWG would be mutually beneficial. Thus it suggested that the USA's Integrated Programme Office be informed.

Action (co-chairs)

The USA Integrated Programme Office should be informed that ITWG is ready to participate on the Sounder Operational Algorithm Team (SOAT) when requested.

While the Working Group felt the action item for further information concerning access to direct readout data from MODIS and AIRS had been obtained, it encouraged a continuing update of such information. A planning group was nominated to do this.

With regard to promoting well-resourced national activities towards protection of frequency allocations, the Working Group also suggested that CGMS consider means to provide for such dedicated resources. The Working Group also agreed that the new ITU/WMO Handbook on the use of frequency for meteorological applications would be a most valuable reference for use by National Meteorological and Hydrological Services (NMHS).

Recommendation (to CGMS)

ITWG encourages CGMS to consider means to provide for well-resourced activities towards protection of frequency allocations.

The Working Group reiterated the need for instrument designers to utilize only those frequencies for which approved allocations existed. The use of non-approved allocations would be detrimental to the sounding community for several reasons.

With regard to education and training and the use of small workstations, the Working Group was pleased to learn of recent decisions to make the AAPP software widely available and hoped that such decisions could be extended for wider use on workstations by the meteorological community in general. Thus, it felt it appropriate to note the need for the availability of AAPP software capable of running on small reception systems as well as on workstations. The Working Group also noted the work program for the OPAG IOS that included an expert team dedicated to improve satellite system utilization. Expected improvements were through the use of improved education and training techniques (in particular, the use of a virtual laboratory) and through the provision of guidance to manufacturers of satellite ground receiving equipment. A standard portfolio of applications as well as specific methods for presentation as defined by WMO would form the basis for the design of satellite ground receiving equipment.

The Working Group, in summarizing the progress to date on recommendations and action items arising from ITSC-IX, agreed all had been completed except where refined as above.

The Working Group also reviewed the restructuring of CBS. While agreeing with the goals and purposes of such restructuring, it felt it important that such restructuring also provide a mechanism for providing guidance and assistance from ITWG to CBS as had been the established in the old CBS structure. Thus, it suggested that the OPAG IOS consider establishing

a similar mechanism.

Recommendation (to OPAG IOS)

ITWG encourages the OPAG IOS to consider a mechanism, similar to that between ITWG and CBS WGSAT, for providing guidance and assistance between ITWG and OPAG IOS.

Similarly, it was recognized that ITWG needs a process to forward its recommendations to WMO. It suggested that the ITWG Chairs could identify appropriate expertise to provide such recommendations. In this regard, it felt it appropriate for ITWG to provide to WMO a response to the preliminary statement of guidance regarding how well satellite capabilities meet WMO user requirements in several application areas. Thus, it agreed to form an ITWG subgroup to review and comment on the statement of guidance:

Action (co-Chairs)

ITWG co-Chairs to develop an ITWG process to provide guidance and assistance to the OPAG IOS. As a first step, the process should provide to WMO a response to the preliminary statement of guidance regarding how well satellite capabilities met WMO user requirements in several application areas by the end of May 1999 (before the first meeting of an OPAG Expert Team Meeting in June 1999).

The Working Group also noted the development of the new Global Observing Systems Space Panel (GOSSP) with regard to climate observations. It felt it important to develop a mechanism similar to the WMO connection but to the GOSSP. This would allow ITWG's considerable expertise in climate monitoring to be available. Thus, it was suggested that the co-Chairs inform the Chairman of GOSSP of ITWG's available expertise as well as inviting GOSSP representatives attend and provide input on climate application of satellite-borne sounders to future ITSCs.

Action (co-Chairs)

The Chairman of the GOSSP should be informed of ITWG's willingness to provide guidance, assistance and expertise with the expectation that a mechanism, similar to that between WMO and ITWG, be developed.

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. The Working Group was informed of WMO's initiatives in upgrading the present GTS from a 'store and forward system' to one of a distributed database, similar in operation to the Internet. It noted that WMO Members had already agreed upon TCP/IP specifications to enable Internet-like communications. It also was informed that many European meteorological services were starting to use a new satellite-based GTS. The Working Group commended these developments and requested the WMO to keep ITWG informed of further developments at future ITSCs. It also suggested that WMO undertake an activity to make its Members aware of the availability of existing satellite products through use of the WWW Operational Newsletter and the WMO Satellite Activities Home Pages.

Recommendation (to WMO)

ITWG encourages WMO to inform meetings of the ITWG of the latest status and plans for improvements to the GTS. It also encouraged WMO to inform its Members of the availability of existing satellite products through use of the WWW Operational Newsletter and the WMO Satellite Activities Home Pages.

With regard to the need for radiances, the Working Group strongly endorsed the inclusion of radiance products as part of the suite of NPOESS EDRs.

Recommendation (to the NPOESS IPO)

ITWG encourages the NPOESS IPO to include radiance products as part of the suite of NPOESS EDRs as a matter of urgency.

The Working Group reaffirmed its requirement for the provision of direct readout on operational meteorological satellites. It further noted the important potential contribution of the AIRS instrument on the EOS PM satellite to WMO's World Weather Watch. In particular, it would provide advanced sounder data to the meteorological community to allow preparations for the operational advanced sounders to be tested as well as providing data for potential operational use. Thus, the Working Group encouraged NASA to consider activities with the ITWG community towards the establishment of a direct readout software package for AIRS (and MODIS) allowing timely use of the data for operations and research.

Recommendation (to NASA)

NASA to consider support for activities with the ITWG community towards the establishment of a direct readout software package for AIRS (and MODIS) allowing timely use of the data for operations and research.

In order to ensure the effective use of AIRS (and MODIS) data by the meteorological community, it is important for NASA and NESDIS to provide for the transfer of such data in near real-time.

Recommendation (to NASA and NESDIS)

ITWG encourages the provision of near real-time data from AIRS (and MODIS) by NASA and NESDIS. In particular, it recognizes the importance of the global provision of radiance and derived products in near real-time.

The Working Group noted the positive results of the 1997 World Radio Conference (WRC-97) concerning the better protection of the band 50-60 GHz for temperature sounding as well as the consolidated protection of the 31.3 to 31.8 GHz window. However, it was noted that the commercial and military pressures to obtain portions of the microwave spectrum continue to grow without a comparable activity by the meteorological community.

A draft ITU/WMO Handbook on the use of frequencies in meteorological applications will be available in March 1999. The Handbook will be distributed to all WMO Members with the expectation that each NMHS would actively encourage its national Post, Telegraph and Telecommunication Administrations (PTT) to protect the frequencies needed for meteorological operations at the WRC-2000. The Working Group noted that most of the preparatory work

needed to be accomplished within the next six months. It was hoped that several NMHSs would send representatives to their respective ITU regional organizations in preparing for WRC-2000 (CITEL for the Americas, CEPT for Europe and Africa and APT for Asia and the Pacific).

The Working Group noted three specific issues of high and immediate priority:

1. Protection of 50-60 GHz from high density fixed links to respect the 0.01% maximum of contaminated pixels;
2. Protection of 18.6-18.8 GHz with a world-wide allocation; and
3. Appropriate allocations around 118, 150 and 183 GHz for atmospheric sounding.

The Working Group also noted that the new 500 MHz allocation between 31.3 to 31.8 GHz should be fully utilized to avoid losing it. Thus, it strongly encouraged satellite operators to modify existing instrument plans and use a center frequency of 31.55 GHz with a bandwidth of 500 MHz in this atmospheric window.

3. REPORTS OF TECHNICAL SUB-GROUPS

3.1 TECHNICAL SUB-GROUP ON THE AVHRR AMSU PREPROCESSOR PACKAGE: AAPP

3.1.1 General

AAPP is a joint development of a number of European institutions, under the coordination of EUMETSAT. It is the first development of its kind and has clearly demonstrated the benefits of international cooperation.

3.1.2 Status

AAPP V1.0 was available in November 1998 for distribution to an extended community for testing. It comprises ingest and pre-processing software for TOVS and ATOVS data, as well as for AVHRR data. The AVHRR pre-processor includes the generation of a cloud mask and a processor for TBUS orbital predicts.

A deposit of the Intellectual Property rights for AAPP (the components of V1.0) has been filed with the "Agence pour la Protection des Programmes" in Paris. Consequently, distribution is achieved under a license procedure. The license currently covers AAPP testing until January 2001. A license for all types of use, except commercial re-distribution and for an unlimited time period will be distributed to the registered users for signature in the next few weeks, pending signature of a license agreement between EUMETSAT and the owners.

A license for commercial re-distributors has been proposed and is currently under consideration by involved parties. This license will allow free distribution to re-distributors under the condition that the owners are asked, in advance, for permission.

As at 25 January 1999, 66 test users had obtained AAPP V1.0. This number included: 7 developer testers, 11 beta testers, 24 institutes, 13 meteorological services and 13 commercial companies. Thirty-one parties have indicated their interest and will receive AAPP V1.0 after the signature of the license.

Machines known to support the package include: HP, SGI, DEC alpha, SUN sparc 20, SUN Epoc 5.5.1, SUN Ultra 2 and IBM RS6000.

3.1.3 Known problems

No major problems were reported by users during AAPP installation. Those of a less serious nature included: imake-related problems (mostly non-adapted configuration files (xxx.cf) or the unavailability of imake), compiler-related problems (they could be mostly solved by the appropriate compiler option flags), script-related problems (related to path, typos, and shell), UNIX version related problems (some successfully installed AAPP would not function properly after upgrade of the operating system), some bugs in the code and problems with the test files are mostly related to little/big endian recognition and the front-end to the receiving equipment.

Recommendation

It was recommended that all AAPP user feedback be posted on the EUMETSAT AAPP home page (Action D. Klaes).

3.1.4 Documentation

In addition to the documentation provided with the package and the AAPP home page, the documentation presented by Météo-France at ITSC-X is expected to be made available (as .pdf or .ps files).

3.1.5 Information exchange

A List server has been established to allow for easy information exchange between AAPP users.

To register:	Send a message to (listserv@eumetsat.de subscribe l-aapp)
To send a message:	Send to (l-aapp@eumetsat.de)
To list members:	Send message to (listserv@eumetsat.de review l-aapp)
To give feedback:	Several possibilities: • through the EUMETSAT AAPP home page (http://www.eumetsat.de/area4/aapp/index.html), or • go to (http://www.eumetsat.de)

There is a page feedback interface and a bug report interface and a list of known and corrected bugs will be maintained on the home page.

To request AAPP, a request should be sent to ops@eumetsat.de. The EUMETSAT User Service will process the request.

3.1.6 Improvements

The immediate update planned is the correction for AMSU-B interference correction. Paul Dibben will provide the correction modules to EUMETSAT; they will be made available to the User Community through the ftp update server. Smaller fixes and urgent updates are planned via the ftp server. One major upgrade on CD-ROM is planned per year.

3.2 TECHNICAL SUB-GROUP ON THE INTERNATIONAL ATOVS PROCESSING PACKAGE: IAPP

3.2.1 General summary

The IAPP will be available from CIMSS via FTP or on CD-ROM in April 1999. The IAPP will be provided as shareware/freeware to interested ITWG members for research and educational purposes. Operational and commercial users are required to obtain a separate license.

3.2.2 ITPP issues

ITPP V5.12 is the most recent version of TOVS processing software. It operates on satellite data streams from TIROS-N to NOAA -14. Current ITPP users should upgrade to version 5.12.

There are a few small Y2K problems with the ITPP. Y2K compliance will be achieved by June 1999 and released to users via FTP or CD-ROM.

Technical issues from ITSC-IX have either been addressed or incorporated into the IAPP.

3.2.3 IAPP : Version 1.0

The first release will occur in April 1999 and will be delivered by CD-ROM or via FTP. The package will include a benchmark data set, beginning with the raw HRPT data stream.

Requests were made at ITSC-X for detailed algorithm description, technical documentation, and validation results. It was noted that the IAPP is very well documented. Additionally, a journal article will be prepared on the IAPP, covering mainly the IAPP algorithm development and validation. The draft (together with technical documentation) will be posted to the CIMSS IAPP Web site, as they become available.

It was recommended and agreed that retrieval using 2x2 or 3x3 FOVs for retrieval processing will be enabled. The current procedure is based on 3x3 FOV retrieval, and the 2x2 procedure will be included as an option as soon as possible.

3.2.4 IAPP: Future development

It was recommended that IAPP be enabled for use with historical NOAA satellite data (TIROS -N through NOAA -14). This issue will be investigated as time and resources permit.

It was requested and agreed that limb adjusted data be included as part of the output.

Several users asked about visualization capability with IAPP. Platform specific visualization requirements have historically made visualization software difficult to create. With the advent of the Web and Java programming, platform independent visualization and data manipulation software is easier to achieve. It was noted that CIMSS is investigating such a capability and will report on progress to users through the ITWG listserver. ITWG members are encouraged to send their recommendations for visualization requirements to the ITWG and/or CIMSS.

Users asked about the availability of IAPP within a LINUX operating system (i.e. on a PC platform). The development of IAPP for LINUX will be investigated and reported to users through the ITWG listserver. This development has a strong likelihood of being achieved sometime in 1999.

General support for ITWG case studies was noted by the sub-group as a beneficial means to discuss methods and results, leading to improvement in all retrieval algorithms.

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

The Atmospheric Radiation Analysis group at the Laboratoire de Météorologie Dynamique in Palaiseau, France, has made numerous improvements and modifications to software for processing TOVS/ATOVS radiances (3I, neural network algorithms), to forward radiative transfer models (4A, 3R), and to the data bases that are used for both forward and inverse calculations (TIGR, GEISA).

The updated GEISA97 data base was released in April 1998 to over 110 users worldwide.

The 4A line-by-line forward model incorporates these data, and also includes a new formulation for the water vapour continuum and temperature dependence of the line coupling. The updated 4A will be available in winter 1999.

The fast version of 4A (called 3R) has also been modified to incorporate these changes.

The TIGR data set has been augmented for moist tropical conditions and has been distributed worldwide as TIGR3. TIGR3 constitutes the core of the TOVS/ATOVS 3I processing algorithm as well as the IASI neural network algorithm.

The 3I algorithm for TOVS has an improved neural-network-based water vapour retrieval scheme as well as an improved method for retrieving cloud properties.

The 3I/ATOVS software is compatible with the AAPP package and is presently undergoing validation.

All retrieval algorithms are continually being validated for a variety of environmental conditions by comparison to measurements from international field programs.

A more thorough description of updates to TIGR3 and 3I will be published in fall 1999 in the AMS Bulletin, and other modifications have been widely published. A list of these publications is available from Noelle Scott (see Appendix B).

3.4 TECHNICAL SUB-GROUP ON FAST RADIATIVE TRANSFER MODELS

3.4.1 Background

A meeting of this technical sub-group was held during ITSC-X and a summary of the discussions is given here. R. Saunders chaired the meeting, supported by S. Tjemkes. Presentations during the conference were given to update the ITWG on the status of fast radiative transfer models for TOVS and ATOVS: RTTOV-5 (Saunders *et al.*, QJRMS 1999), OPTRAN (Kleespies, Tech. Proc. ITSC X, 1999), PLOD (Woolf and Van Delst, Tech. Proc. ITSC X, 1999) and AES Fast (Garand et. al. Tech. Proc. ITSC IX, 1997). All models have the capability of simulating both TOVS and ATOVS data and OPTRAN and RTTOV-5 also support other satellite radiometers.

(An RTTOV-5 users email group has been set up co-ordinated by R. Saunders (rwsaunders@meto.gov.uk) which alerts users to bugs and upgrades. The code can be obtained from the data services section at ECMWF (data.services@ecmwf.int). OPTRAN is available from T. Kleespies at NESDIS (tkleespies@nesdis.noaa.gov).)

Several issues (summarised below) were addressed in the meeting.

3.4.2 Profile and transmittance databases

There are several diverse profile datasets available, the 43 set from TIGR-2, the 32 set from NESDIS, the 528 set from SODA (Météo-France) the 189 set from AES, and the NOAA 88 & 89 sets. It is believed that existing diverse profile datasets do not capture the complete dynamical range of temperature and water vapour variability found in NWP models as radiosondes are not necessarily in locations where extreme profiles occur. They need enhancing, especially with respect to the description of ozone. One option is that the observed radiosonde temperature, water vapour and ozone profiles will be replaced by model profiles. As a first step, P. Brunel will investigate if the SODA profiles – consisting of 528 diverse radiosonde/ozonesonde profiles – could be made available to the group at their original levels. The aim should be to have a common dependent and independent set of profiles which developers of fast models can all use to compute their transmittance coefficients and assess model performance.

The group discussed possible enhancements to transmittance databases generated by line-by-line models. These differ in their internal transformation of the point values to layer quantities and the fast models differ from the line-by-line models. To make comparisons the complete layer description (including pressure, temperature and anything else of relevance) must be given. As a first step, the layer-average molecular burden, layer-average temperature, and layer-average pressure used by the model should be recorded. The preferred units for absorber amount were recommended to be molecules.cm^{-2}. The minimal combination of line-by-line transmittances required for fast models was recommended to be {all gases; water vapour; ozone; water vapour plus ozone}.

Regarding the number of atmospheric levels required for the simulation of future high resolution sounders, the AIRS team have agreed on a figure of one hundred. This should be adequate. More work on determining the optimal number for AIRS, IASI and CrIS is recommended.

3.4.3 Fundamental constants

The group recommended that one set of fundamental constants be used in their models. These will be posted by T. Kleespies. It is important that the brightness temperatures from NESDIS are computed using the same constants as those in the fast models. For NOAA-15, NESDIS updated

the fundamental constants used for the brightness temperature computation.

A common algorithm used to calculate band correction coefficients for radiometer channels from the filter response function will be posted by P. Brunel. The members of the group are encouraged to use this in order to facilitate a better comparison between the different models.

The work of T. Kleespies and H. Woolf on whether different transmittance coefficients are needed for different AMSU-A instruments due to changes in frequency of the channels should be reported back to the group.

3.4.4 Fast model intercomparisons for ATOVS channels

The group recommended the continuance of the intercomparison of radiative transfer codes for the TOVS channels (IRTASO is the acronym proposed) initiated, for HIRS channel 12, within the GVaP project. The latter work will be documented shortly by B. Soden in a BAMS paper. L. Garand will define and coordinate this new comparison which will extend the GVaP comparison to other ATOVS channels. It was suggested that a few temperature, water vapour and ozone channels be included. Where possible, line-by-line calculations should be included to provide a reference. Both the computed top-of-atmosphere brightness temperatures and – where possible – Jacobians with respect to temperature, water vapour or ozone, depending on the channel, should be compared.

3.4.5 Preservation of old instrument data

The group identified the need to conserve system information of old "retired" instruments (e.g. spectral response functions, calibration methodology) in the light of their potential use in future re-analysis projects. For instance, it is planned to assimilate VTPR radiances in the next ECMWF re-analysis. Some instruments which were identified to be of potential interest were VTPR, SIRS, IRIS, ITPR, SCR on the NOAA and NIMBUS satellites as they cover the late 60s to late 70s. SSU and MSU are other instruments about to enter this "retired" category.

3.4.6 Surface emissivity

The group felt that knowledge of the surface emissivity over land was insufficient and recommended more *in-situ* and airborne measurements especially for the AMSU channels to enhance the use of these observations in assimilation schemes over land. Over the ocean the infrared model from T. Kleespies is available, as is the microwave model (FASTEM) from S. English.

4. ABSTRACTS OF ITSC-X PRESENTATIONS

An evaluation of IAPP retrieval products

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The International ATOVS Processing Package (IAPP) is an entirely new sounding retrieval processing package, designed for ATOVS applications. IAPP includes a non-linear physical retrieval algorithm using AVHRR, HIR/3 and AMSU radiances to retrieve the atmospheric temperature profile, moisture profile and other parameters in clear and cloudy atmospheres. Evaluation of the retrieval results are conducted by processing global ATOVS data from NOAA -15 and accumulating statistics through comparison of ATOVS retrievals with collocated radiosondes. Individual case studies are also being examined in greater detail.

Application of limb adjustment techniques for polar orbiting sounding data

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The National Oceanic and Atmospheric Administration (NOAA) operates a series of polar orbiting satellites which contains the TIROS Operational Vertical Sounder (TOVS) platform for measuring temperature and moisture values at different levels of the atmosphere. Data retrieved from the cross-track scanning of TOVS instruments passes through increasing amounts of atmosphere at higher scan angles. Hence, radiance values at the edge of the swath differ than those at the nadir position over a homogenous surface.

The National Environmental Satellite, Data, and Information Service (NESDIS) applies limb adjustments to all scan measurements to the nadir field of view to facilitate the scientific processing of operationally derived sounding products. This process uses linear regression to define the relationships between channel values for a given beam position and channel values for a common field of view. The method has been applied to data from the NOAA-11, NOAA-12, NOAA-14, and NOAA-15 satellites. One of the assumptions of this solution is that a single set of coefficients produced near the time of the solstice will adequately account for a vast majority of meteorological conditions.

The European Centre for Medium-Range Weather Forecasts' (ECMWF) evaluation of NESDIS sounding products has revealed a noticeable scan bias occurring in the NOAA-14 HIRS and, to a lesser extent, in the MSU. Experiments conducted by NESDIS to re-compute the limb -adjusted coefficients using more current radiometric observations significantly reduced the scan bias for many of the channels, in particular, the infrared longwave. This paper presents plots of scan bias before updating coefficients in May, 1998 and after updating coefficients, in August, 1998 for NOAA-11 and NOAA-14 HIRS and MSU instruments.

With the launch of NOAA-15, AMSU-A replaced MSU and SSU and HIRS was slightly modified. The limb correction software was also upgraded. The results of the new procedure were reviewed via image analysis comparisons with the older method and through the computation of scan angle residuals. Comparisons yielded similar or slightly better results overall. However, a bimodal temperature distribution appears across a scan for the new microwave surface data. Graphs, images and explanations are presented and discussed.

A cloud-detection approach for IASI data

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The Infrared Atmospheric Sounding Interferometer (IASI) is part of the core payload of the EUMETSAT Polar System (EPS) METOP-1 and will contribute to the primary mission objective of EPS which is the assessment of meteorological parameters. The IASI instrument covers the range from 645 to 2760 cm^{-1}, with a spectral resolution of 0.25 cm^{-1}.

The presence of clouds in the thermal infrared over the observed area influences the retrieval 'cleared field'. Consequently, the role of the cloud-detection algorithm appears essential. The cloud-detection scheme developed here is based on the spectral tests which rely on the temperature thresholds in the infrared and it is assessed using Interferometric Monitor for Greenhouse gas (IMG) data. The IMG detects infrared rays from the atmosphere and the earth. The IMG

views an 8 km x 8 km area of the earth's surface. The measurements are performed every 86 km along the satellite orbit, and they cover all over the world in about four days. The IMG instrument covers the spectral range from 715 to 3030 cm^{-1} with a spectral resolution of 0.04 cm^{-1}.

The IASI test results (clear/ cloud flag) obtained using IMG data have been compared with TOVS and METEOSAT images.

A study of TOVS and ATOVS background errors in radiance space in a variational analysis scheme

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In any analysis scheme, the ratio between background error and observation error fundamentally determines the weight given to the observations. Analysis schemes that use observed radiances have observation errors specified directly in terms of radiances (brightness temperatures). The background errors, on the other hand, are specified in terms of those quantities required by the background term (*viz.* vorticity, unbalanced temperature and surface pressure, specific humidity and divergence). Their correspondence to radiance errors is implied, and for example depends on the atmospheric state and the Jacobian of the radiative transfer model.

An accurate method to diagnose the implied background errors for TOVS and ATOVS radiances has been developed. The method can be used to help improve the background error formulation or to adjust the specified observation errors. This could be especially useful in the stratosphere where there are few conventional data to compare against. It also gives an indication of the information contained in new data types such as AMSU-A and AMSU-B radiances. Maps can show the relative contribution from temperature, humidity and surface background errors for each of the radiance channels.

Simulation studies of advanced infrared and microwave sounders

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Simulation studies to assess the relative performance of advanced multispectral (infrared and microwave) sounders with regard to meeting environmental sounding requirements of the National Aeronautics and Space Administration (NASA) and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) will be presented.

These studies utilized advanced retrieval techniques to capture the information content of high resolving power instruments. A brief overview of salient features of the retrieval algorithm is presented. Results of soundings of temperature, moisture and ozone within partially cloudy conditions (50 km footprints with up to 80% cloudiness) are shown for the NASA/AIRS, the notional NPOESS/CrIS and the notional European meteorological satellites (EUMETSAT) IASI instruments. Trade studies involving spectral resolution and signal-to-noise will also be shown.

Use of TOVS upper tropospheric water vapor channel data in climate and global change research

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The use of TOVS upper tropospheric water vapor (UTWV) channel data has grown substantially in the past several years. We have produced an intercalibrated data set of HIRS channel 12 data that now covers 20 years.

This data set is being used in a variety of World Climate Research Program activities including SPARC, GEWEX, and CLIVAR. Within the SPARC program, the UTWV data are being used to assess the role of water vapor in climate change for inclusion in the IPCC 2000 assessment process. Within the GEWEX program, the TOVS UTWV data will be used as part of a water vapor data set development project. Within CLIVAR, TOVS UTWV data are being used in process studies of the Austral-Asian monsoon and Pan-American climate. Examples of the use of TOVS data in each of these programs will be given.

In addition, these data will be used to hypothesize on the role of tropical water vapor variability in anthropogenic global change and in millennial-scale global change.

Precipitation identification and retrieval from the Advanced Microwave Sounding Unit (AMSU) at mid- and high-latitudes

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Based on three-dimensional radiative transfer simulations of typical frontal and convective precipitation events, the response of the AMSU to mid- and high- latitude precipitation is investigated.

It is shown that variations in precipitation intensity, cloud top height, beam-filling, and freezing level reveal a distinct but highly variable signature in the observed brightness temperatures, which is likely to be misinterpreted by algorithms designed for global use. It is further shown that the scattering intensity of precipitation-sized ice particles is a sensitive indicator for the presence of precipitation. However, the relation between the scattering intensity and surface rain rate is highly variable and depends on the type of the precipitation event as well as on the precipitation intensity itself. Based on these investigations, a multi-frequency precipitation retrieval algorithm for AMSU is currently being developed.

The algorithm as well as first validation results from collocated AMSU and radar observations will be presented at the conference.

AMSU surface channels in comparison with infrared data

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Data from NOAA satellites have been received regularly in Berlin for 20 years. The MSU-data are used in Berlin to investigate the ice edge in the polar region. Due to a mapping of data of successive days with different orientations, the pattern of the ice edge can be mapped with a higher resolution than is given by the instrument characteristic. This method shall be adapted to the surface channels of AMSU at the same frequency (channel 3, 50.3 GHz) and the other ground sensitive channels of AMSU (channel 4 at 52.8 GHz). Channels 1 and 2 at 23.8 and 31.4 GHz are sensitive to precipitation. From these channels the ice boundary may be detected at a resolution of 15 km. With channels 15 and 16 in AMSU/A and AMSU/B the effect of the precipitation on the channels may be determined. Thus we hope to use the 89 GHz/ 15 km resolution channel to yield a very exact mapping of the ice edge and ice flows in the north polar region.

Current status of operational processing of TOVS data in the Hungarian Meteorological Service

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As it was reported at the ITSC-IX, the operational use of TOVS data is an integral part of the data processing system of the Hungarian Meteorological Service. Data from NOAA 14 satellite overpasses are processed in real-time at the Satellite Research Laboratory's HRPT satellite receiving station, using the ITPP5 software. Since mid-1998, data have also been processed with a test version of the ATOVS and AVHRR Processing Package (AAPP) software (development coordinated by EUMETSAT) in conjunction with an inversion model called the Inversion Coupled with Imager (ICI) developed at the Centre de Météorologie Spatiale (CMS) of Météo France. Under a cooperation agreement and collaboration with CMS we were able to participate in the testing phase relevant to the installation and operational runs of the AAPP and ICI software on our local HP workstation. This paper presents, firstly, the results of those tests, and secondly, a comparison of an ICI validation made at Lannion (CMS) and Budapest (HMS).

Using TOVS and ATOVS profile information at the Norwegian Meteorological Institute

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This paper describes the development and results from the work undertaken at the Norwegian Meteorological Institute (DNMI) to exploit data from the new ATOVS instrument. These data may prove an important additional source of upper-air information, in particular in near-Arctic regions where these instruments have good data coverage, and where DNMI also has forecasting responsibilities. These measurements have only been in limited use in high-resolution regional numerical weather prediction models, and a project has been initiated to obtain optimal impact of these data in limited area modeling. This work is coordinated with other efforts in the European HIRLAM (High Resolution Limited Area Modeling) cooperation, and DNMI has the coordination responsibility for this work.

The main task in the project is to incorporate the satellite sounding observations in the data assimilation system of the operational numerical weather prediction model HIRLAM which runs at DNMI. The project has the following milestones:

- beta testing and implementation of the EUMETSAT AAPP package;
- implementation of a 1D-Var package for deriving fast nowcasting products; and
- inclusion of ATOVS data in the HIRLAM 3D-Var, and later in the HIRLAM 4D-Var scheme.

We discuss our experiences with using the AAPP package operationally on TOVS data at DNMI and the implementation of a 1D-Var scheme. Furthermore, we discuss the further plans and outlooks for dealing with the problems related to the assimilation of these data. This includes the coarse vertical resolution of the instrument, how the special accuracy characteristics of the ATOVS are taken into account, the problem of cloud contamination and the modeling of the influence of the underlying surface.

NESDIS products and the Year 2000

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The Year 2000 (Y2K) issue is a very serious concern at NESDIS and work is well underway to ensure that the satellite data from NESDIS will flow smoothly throughout 2000 and beyond. This report will discuss the efforts undertaken to date to prepare the sounding products and the 1b data for Y2K. Data formats and software modifications will be discussed. Availability of test data for users will also be addressed.

Distribution and archive of sounding products from NOAA-15

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The National Oceanic and Atmospheric Administration (NOAA) -15 satellite provides many new opportunities for the use of satellite sounding data. The new and improved suite of sounding instruments represent the first significant modifications in instrument payload aboard a NOAA satellite since the TIROS (Television and InfraRed Operational Satellite) -N in 1979. The National Environmental Satellite Data and Information Service (NESDIS) has been preparing products for operational use since the launch of NOAA-15 in May 1998. The sounding products generation system for NOAA-15 is significantly different from the operational system for NOAA-11 and NOAA-14. The following report describes the products from the NOAA-15 sounding system and how they differ from the current operational products. Projected implementation dates and procedures will also be discussed.

Quality control of the NESDIS sounding products

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The National Environmental Satellite Data and Information Service (NESDIS) performs quality control checks at many stages throughout the generation of the sounding products. These checks are performed on the satellite data as well as the ancillary data. This report will describe the many checks performed in the NESDIS sounding operation on all of the sounding products, including the Revised TIROS-N Operational Vertical Sounder (RTOVS), the Special Sensor Microwave/ Temperature-1 (SSM/T-1), and the Special Sensor Microwave/ Temperature -2 (SSM/T-2 for moisture). The Advanced TOVS (ATOVS) and Atmospheric Microwave Sounding Unit -B (AMSU-B) systems will also be discussed.

Simulation of ATOVS temperature profiling errors due to uncertainty in microwave land surface emissivity

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One of the major advances of AMSU over previous microwave sounders is its higher spatial resolution. This will improve delineation of temperature and humidity fronts and features associated with storm events under both clear and cloudy conditions. However, with this improvement also comes greater sensitivity to variations in surface emissivity, especially over land. With previous sensors (MSU, SSM/T1) these variations averaged out over the relatively large footprint such that a "mean" emissivity for all land surfaces and an empirical limb-correction could be applied. In the case of AMSU, the presence of water bodies, topography, and transitions between land-use types within the footprint will have greater impact on measured brightness temperature. The purpose of this paper is to quantify the expected error in temperature profile retrievals due to errors in estimating the microwave surface emissivity. Simulated AMSU brightness temperatures and HIRS radiances are used with the variational inversion approach of Eyre (1990) to retrieve temperature and water vapor profiles simultaneously. Different methods currently in use to account for surface emissivity prior to or within the

retrieval process are evaluated by comparing resultant rms temperature errors. Preliminary results for microwave-alone retrievals assuming a constant emissivity of 0.95 show rms errors of 13 K at 1000 mb and 3 K at 500 mb. Suggestions for improved methodologies will also be discussed.

Implementation of the assimilation of TOVS radiances at Météo France

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The current global data assimilation system at Météo France uses a three dimensional variational analysis (3D-Var). This method allows the direct assimilation of TOVS 120 km pre-processed radiances. It is planned to use radiances in the following way:

(a) Firstly, 1D-Var is run to perform a quality control check, ensuring data consistency, to extend the temperature profile above the top of the model (10 hPa) and to provide a radiative surface skin temperature to 3D-Var; and

(b) Secondly, the 3D-Var analysis of all data including TOVS radiances is performed.

Results of pre-operational tests, including a comparison between the direct use of radiances and the previous use of SATEM retrievals will be presented.

The IASI program in the framework of Météo-France

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Météo France

Météo France is involved in preparations for the IASI mission. Our main goals are to be in the best position to operationally assimilate IASI data as soon as they are made available and to improve our knowledge of the atmosphere with IASI data. To do that we need an observation operator (a very fast radiative transfer model + a modelisation of the instrument (ISRF)) with its adjoint (the Jacobians at least of temperature, humidity and ozone), a matrix of model errors (to characterize errors of the very fast radiative transfer model) and a matrix of observational errors (provided by IASI project to characterize the instrument). Then, we can estimate the information content of IASI spectra, determine the channels which bring most of this information and the atmospheric features which can be described with such data. We have developed some tools to quantify the improvement from TOVS data to IASI spectra, to define optimal vertical resolution and to select subsets of channels. After a brief presentation of the main results obtained, the plans for the next two years are presented.

Preparing for the next generation operational LEO sounder - the NPOESS CrIS

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CrIS, the Cross-track Infrared Sounder, is one component of the NPOESS Cross-track Infrared/Microwave Sounding suite of sensors. This suite will be used to generate global Environmental Data Records (EDRs) of temperature, humidity and pressure profiles for Numerical Weather Prediction (NWP).

CrIS will provide high spectral resolution radiance data in the IR spectral bands using a Michelson type interferometer. It is currently in its preliminary design phase.

A summary will be provided of the SRD and anticipated temperature, pressure and moisture products as defined by the Integrated Program Office. Graphic illustrations will be included to visualize the comparison of current HIRS products to the projected CrIS threshold compliant products.

Application of AVHRR data to a one-dimensional variational retrieval scheme for cloudy TOVS data

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A one-dimensional variational method is adopted to derive a profile of atmospheric temperature and humidity from TIROS Operational Vertical Sounder (TOVS) radiance data for use in data assimilation. Reasonable initial estimates of cloud parameters are useful to accelerate convergence, and in some cases can even be essential to obtain convergence (Eyre 1989). Advanced Very-High-Resolution Radiometer (AVHRR) pixels coincident with each High-resolution Infrared Radiation Sounder(HIRS) field of view can be analyzed to improve the accuracy of cloud parameters.

The purpose of this work is to understand the impact on retrieval of cloudy TOVS radiances with a one-dimensional variational method, when using initial estimates of cloud parameters having improved accuracy from AVHRR data.

Results indicate that 76% of samples were convergent and less than five iterations were generally

required in the calculation. AVHRR data are useful for deriving reasonable cloud parameters from this analysis, but no significant benefit was found for the analysis of profiles of temperature and humidity.

Utilizing AVHRR data yielded more accurate analyses of cloud parameters, so cloudy scenes can be classified according to cloud conditions. Profiles of temperature and humidity retrieved from cloudy scenes in the following situations are as good as those from clear scenes:

(1) cloudy case with cloud top under 900 hPa;
(2) partly cloudy case with cloud top under 800 hPa;
(3) partly cloudy case with cloud top above 800 hPa, but cloud proportion smaller than 0.3.

Improvement is slight for temperature, for which r.m.s. error is decreased about 0.2 K in the low and middle troposphere. The mixing ratio (g/kg) on a logarithmic scale shows 0.06 improvement in the middle and upper troposphere.

The impact of cloud-cleared TOVS radiances in the CMC 3D variational analysis system

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In June 1997, the CMC implemented its first global 3D-var analysis system for the preparation of daily 10 day forecasts. In the fall of the same year, this incremental 3D-var was introduced for the preparation of the 35-km regional model analyses. Both the global and regional systems produce increments on a 16 pressure level grid with the top level at 10 hPa. In their first implementation, because geopotential is used as mass variable and not temperature, it was decided to retain SATEM thickness as the main source of satellite data for analysis.

In preparation for the next analysis system that has been in development for the last 3 years, research in radiative transfer modeling for the purpose of assimilating radiances directly has progressed significantly and a complete system using TOVS radiances has been tested extensively and compared to the system using SATEM data. Monitoring has been integrated into the analysis system serving to control the quality and correct the biases of a dataset used to estimate the observational errors of TOVS radiances. Results clearly indicate that the assimilation using radiances consistently produces better analyses as indicated by improved 5-day forecasts.

The current operational 3D-var system is about to be completely upgraded.

The global model providing trial fields will be a 28-level hybrid coordinate system run on a 0.9 degree global grid where the top level will gradually be raised to levels more compatible with the top of the radiative transfer model, thereby reducing extrapolation errors of temperature and moisture. In this new system the mass variables are temperature and the logarithm of specific humidity as opposed to geopotential and dewpoint depression currently used. Comparisons with the operational system will be presented with emphasis on the response to radiance data.

ITPP-5.12 retrievals in a McIDAS system

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Satellites play important roles in monitoring trends of temperature distribution on a large scale basis. The International TOVS (TIROS Operational Vertical Sounder) Process Package (ITPP-5.12), developed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison, has been installed at the Meteorological Research Institute (METRI) in Korea. ITPP-5.12 diagnoses vertical profiles of atmospheric temperature and humidity from the radiance measurements of the NOAA polar orbiter. Also, the retrieved TOVS output is displayed on the McIDAS (Man-computer Interactive Data Analysis System). The McIDAS application was developed at the University of Wisconsin-Madison Space Science Engineering Center to allow satellite data, output from NWP models and observational data to be processed and displayed. McIDAS-X 7.3 has been installed at METRI and the TOVS data retrieval scheme is embedded in the METRI/MCIDAS-X.

The principal aim of these efforts is to retrieve TOVS-derived meteorological fields and to superimpose these on AVHRR imagery with NOAA/HRPT using McIDAS-X 7.3. In this study, results of the evaluation of ITPP-5.12-derived temperatures are presented. Several cases of temperature distributions are chosen for intercomparisons with retrieved fields.

Relationships between the water vapor above the Atlantic and Western Africa and climate in Western Africa (1985-1992): Introduction to the FLUVAP project

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Atmospheric water vapor, a key parameter for climate studies, remains one of the less well known in intertropical areas. The multiple causes of this situation (the economies of developing countries, weakness of the synoptic network, coverage of oceanic areas . .) lead to an extended use of satellite observations as an alternative to conventional ones.

This opportunity has been developed by the NASA/NVAP project, based on all available conventional and spatial data (1988-1992), and providing a global knowledge of the variability of the atmospheric humidity.

Focusing over the intertropical region of Africa and the Atlantic Ocean, NVAP data displays two relative maxima of humidity (integrated water vapor) localized in the Eastern and Central regions of the equatorial Atlantic Ocean. The maximum of variability of this parameter remains localized in the West of the basin (0, 40W).

The present contribution also deals with the variability of water vapor over the area 20N-20S, 60W-20E, using TOVS data from DACC/GSFC (NASA's Mission to Planet Earth); these data provide vertical profiles of atmospheric humidity, in 5 levels from the surface to the top of the atmosphere and are currently available over the period 1985-1992.

The time series of integrated water vapor, analyzed by reference to the major climatic episodes of the period 1985-1992 in West Africa, indicates that:

- in the Sahelian and Gulf of Guinea areas, the variability of integrated water vapor in all layers reflects the locally observed variability of rainfall (the two first lower layers being the most important);
- the series corresponding to the driest (or wettest) episodes envelop all the other observations;
- a simple analysis (EOF) of these data and their anomalies leads to the following preliminary conclusions:
  - the integrated water vapor is a seasonal signal, which is explained for 57% of the variance by the water vapor over the oceanic domain and for 30% of the variance by water vapor standing over the Western Africa (forest area) and the western adjacent oceanic area;
  - a similar analysis of the anomalies indicates that the first two eigenvalues are of the same order (17% and 13%); the first principal component, related to the ITCZ above the ocean, underlines the more important weight of the years 1985 to 1988, when compared to the rest of the period;
  - the second principal component remains roughly with the same weight throughout the period 1985 - 1992;
  - SST and wind being the main factors of evaporation, SST data provided by the Meteosat TSM data set of Demarcq and Suisse (Orstom) have been processed: the analysis indicates the areas of important variability (already described by Servain et al. 1998) and possible origins of water vapor.

Based mainly on satellite data, the aim of the FLUVAP project is to improve the knowledge of humidity in tropical areas, and to couple these observations to conventional ones in order to provide a regional coverage of the water vapor flux which feeds the west African monsoon.

Taking advantage of the new instrumentation on board NOAA-15 (microwave sensors AMSU A/B) and of an improved version of inversion software (Météo France), a preliminary step of the project will be to provide a data set for validation, and then to process data provided by a network extending from Fortaleza to Dakar - Niamey and Nairobi.

Predicting the error with which a two-band infrared imager can measure sea surface temperature

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The philosophy behind recent government projects for environmental satellite sensors is to make the sensor designers responsible for predicting how accurately their sensors determine the desired geophysical parameters. Although it is relatively easy to develop simple forward models for the radiance generated by a set of environmental parameters, using these forward models to find the largest sensor error which produces acceptably accurate geophysical data is usually a laborious and computer-intensive task when done using standard Monte-Carlo techniques. Fortunately, there are statistical signal-processing techniques which produce closed-form formulas going direct from the measurement noise of the sensor design to the

corresponding error in the geophysical parameters. In this paper we use these techniques to predict the expected error in the sea surface temperature determined by a two-band infrared imaging sensor working in the 10-12 micron atmospheric window and show that the result matches NASA's experience with the accuracy of the sea surface temperature determined by the AVHRR sensor. These formulas can be extremely useful in evaluating the expected performance of satellite sensors from their top-level point designs.

Predicting the error with which an infrared imager can determine the ice-particle size of cirrus clouds

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One hard-to-answer question when using satellite data is the extent to which random errors in radiance measurements combine with modeling errors to produce inaccurate results. In this paper, standard signal-processing statistics are used to predict, using relatively simple closed-form formulas, the expected error when radiance measurements are used to determine the size of ice particles in cirrus clouds. The known errors in the infrared imaging data are combined with the suspected model errors to produce reasonable estimates of the total error in the ice-particle size. The usefulness of these formulas is often overlooked when system analysts try to predict the overall error with which different sensors can determine the values of standard geophysical parameters.

A new cloud-clearing scheme for infrared sounder measurements using the Kriging technique

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A new cloud clearing procedure applied to High-resolution Infrared Radiation Sounder (HIRS/2) radiance measurements is presented.

The techniques for observing the temperature of the atmosphere from satellites are based on measurements of radiation in the infrared and microwave spectral regions. These radiances are affected by the presence of clouds. At infrared wavelengths the problem is acute since most clouds are almost opaque; in the microwave region clouds have a negligible effect on the radiances. Consequently, when retrieving temperature, we must be able to detect clouds which have significant effects on the radiances and, if possible, corrections must be made for these effects. For the infrared this is done by converting the measured radiances to "clear-column" values which would be observed from the same temperature and humidity profile in the absence of clouds. In most retrieval schemes, the inversion process which produces the atmospheric profile operates on clear-column rather than measured radiances and so a preliminary "cloud clearing" step is required.

The new cloud clearing exploits the physical/statistical characteristics of clear field and the synergy with the MSU (Microwave Sounding Unit) instrument and produces a field of cloud cleared values with sufficiently well-defined statistical properties and error structures.

Variational retrievals of humidity using DMSP SSM/T-2 brightness temperatures

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Recently, a number of NWP centers have studied and/or implemented the assimilation of SSM/I retrieved total precipitable water (TPW). The vertical distribution of humidity increments is determined only by the background error statistics. Thus for example, the weight given to the SSM/I retrievals is larger when the humidity background error is larger and vice versa.

It is thus important to also assimilate brightness temperatures from humidity sounders such as the DMSP SSM/T-2 and the NOAA AMSU-B. Both instruments sample water vapor absorption around 183 GHz. With the RTTOV-5 new set of predictors for AMSU-A/B, it turns out that the error using regression equations is larger for the 183 GHz channels than for the remaining ones. A different set of predictors was developed for the 183 GHz channels and the accuracy of the regression equations compared to that of a line-by-line radiative transfer model are now comparable for all AMSU channels.

The 1D variational assimilation code developed by ECMWF is being adapted to handle several sets of predictors at once as well as varying polarization with scan angle, as is needed for the SSM/T-2 and AMSU.

Preliminary results to be presented compare retrievals of humidity for the SSM/T-2, SSM/I and AMSU-A only; correction coefficients for the RFI for

some channels of the AMSU-B are not yet available.

The incorporation of NOAA-15 data and the improved use of radiance data in the NCEP global assimilation system

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Many modifications to the NCEP global analysis/assimilation system have been made which impact the use of TOVS and ATOVS radiances. Many of the changes have been incorporated to facilitate the inclusion of NOAA-15 data (at this time HIRS-3 and AMSU-A data only). These changes include modifications to the surface emissivity model, a quality control step based on the magnitude of the implied error in surface emissivity estimates (to detect precipitation) and a modification to the bias correction scheme. Preliminary results show that the HIRS-3 can be used in a manner similar to earlier instruments and that AMSU-A data can be incorporated in a straightforward manner, providing useful information in the analysis. Results will be presented demonstrating the impact of this data. In addition to the changes in the assimilation system which are directly related to using the new NOAA-15 data, other changes have been made to the system which strongly impact the use of radiance data in the analysis/ assimilation system. The most important of the changes are the incorporation of a new background error covariance matrix and the use of an external iteration to incorporate nonlinearities in the forward model. The background error covariance modification alters the horizontal and vertical distribution of the information in the analysis. The external iteration allows the inclusion of nonlinearities in the forward radiance model for the moisture channels and thus allows additional weight to be given to the data. Results from these changes will also be presented.

ATOVS mapping techniques and validation in AAPP

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The mapping of instrument data to a common grid allows synergistic use of the data to retrieve a single atmospheric profile for use in NWP models and also to aid detection of contamination (for example the comparison of mapped micowave channels and HIRS channels to indicate cloud). With the advent of more powerful computers and more flexible assimilation schemes there is the possibility of direct assimilation of radiances on their own grid. The relative quality of mapped and unmapped radiances will be explored and the merits of assimilating data on a single mapped grid versus the original grid investigated.

The method of mapping data between instrument grids in the ATOVS and AVHRR Processing Package (AAPP) will be illustrated, and examples given. The need for 'empirical corrections' when mapping a high resolution instrument (such as AVHRR) to a low resolution instrument (such as HIRS) will be demonstrated.

Progress of satellite sounding data applications in China

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The Qinghai-Xizang (Tibet) plateau located in the western part of China is the highest in the world. It is the place where weather systems pass over and occur locally. Its existence has an influence on weather and climate not only over the eastern Asia but also over the world. Lack of radiosonde stations makes weather forecasting, numerical prediction and climate study extremely difficult. The activities of the subtropical high in the West Pacific Ocean are greatly related to Meiyu (rainy season), severe rainfall and drought in China. However, it is difficult to determine the position of the subtropical high and then to analyse weather systems over this area.

In recent years, scientists from the Jiang Su provincial meteorological bureau, the Chinese Academy of Meteorological Sciences and the National Satellite Meteorological Center have done some sensitivity studies on satellite sounding data applications in these sparse radiosonde areas. Results show that variational processed retrievals from TOVS data can significantly improve the first guess fields and local severe rainfall prediction in the plateau region. They also assist in monitoring the movement of the subtropical high and even the detection of local heavy rainfall in the high pressure ridge, usually ignored by operational forecasts radiosonde station data only.

A fast generic millimetre-wave surface emissivity model

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The Advanced Microwave Sounding Unit, launched as part of ATOVS on NOAA-15 in May 1998, measures microwave spectral-radiance close to six frequencies (23.8, 31, 50.3, 89.0, 150.0 and 183.31 GHz). At least 11 of the AMSU channels can often see the surface and these channels provide much of the temperature and humidity information in the lowest 5 km of the troposphere. Therefore we need a reliable method of

estimating surface emissivity. In clear air results are not sensitive to errors of just a few percent in the emissivity model, especially for temperature retrievals, but in cloudy areas and more generally for water vapour information an accurate representation of emissivity becomes important. A fast generic emissivity model has been developed which uses tried and tested ideas for the ocean surface but is less mature for other surfaces. The underlying philosophy is that the main purpose of the emissivity model is to constrain the relationship between emissivities at different frequencies. Coefficients have been generated for a range of surfaces. The coefficients can be regarded as background information for which an improved estimate is provided by the retrieval. The details of the model, its validation and the proposed method of its use in ATOVS (and potentially SSM/I too) will be presented.

The impact of cloud and precipitation on AMSU soundings

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Information derived from passive microwave sounders complements that available from infra-red sounders by providing a near all-weather capability. However at sub-millimetre wavelengths cloud and ice strongly attenuate the radiant flux and whilst this attenuation falls in accordance with Rayleigh-Gans theory at longer wavelengths it does not become negligible until the wavelength reaches several centimetres. The Advanced Microwave Sounding Unit (AMSU), launched in May 1998, can therefore provide temperature and humidity information in some cloudy regions but stops short of an all-weather capability. As a result quality control for cloud and precipitation is just as important as for infra-red radiometers. However unlike infra-red radiometers, where the quality-control criterion is simply cloud or no cloud, for microwave radiometry it is a more subtle division between insignificantly cloudy and significantly cloudy, where the definition of significant will depend on the application. In this presentation the cloud and precipitation tests in the ATOVS and AVHRR Processing Package (AAPP) will be evaluated. Initial results show that under 20% of infra-red soundings are clear, whereas over 85% of microwave soundings are insignificantly cloudy. If cloud is correctly handled in the inversion soundings may be possible from many of the remaining 15% of data.

Initial evaluation of ATOVS on NOAA-15 using the UKMO numerical weather forecast model

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For many years, TOVS radiances have been compared with numerical weather prediction (NWP) profiles both in retrieval and radiance space to study the overall quality of the data, regional variations, sensitivity to processing changes (at all stages) and to estimate scan and airmass dependent biases. Such studies have been carried out at a number of NWP centres and this helps to separate changes related to the observations themselves, observation processing and the numerical weather forecast models. This method of evaluation has been applied to ATOVS on NOAA-15. Scan dependent biases are usually small although a residual bias exists near the edges of the AMSU-A scan. Globally, biases are very small for NOAA-15, being less than 0.5K in most channels. Similarly the standard deviations are lower than the equivalent TOVS channels, especially for mid-tropospheric temperature channels where standard deviations are as low as 0.2K (compared to 0.5K for TOVS). Standard deviations in the AMSU window channels are much higher because the effects of errors in the NWP profile are higher: figures of 6-8K are typical. In the AMSU-B humidity channels, standard deviations of 2-4K are found, consistent with the standard deviation of the HIRS water vapour channels in clear air.

The effects of nonlinearity on retrieval errors: implications for the interpretation of advanced Infra-red sounder data

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The error characteristics of an optimal retrieval/analysis are well understood for the linear problem, and linear theory has also been widely used to assess the approximate error characteristics of weakly nonlinear problems. However, in the context of developments for advanced infra-red sounders, it has become apparent that linear theory will lead to an over-optimistic assessment of performance, and particularly of the potential contribution of water vapour channels to temperature sounding performance. The effects of nonlinearities in the radiative transfer on retrieval errors have been studied for the general variational retrieval/assimilation problem. These effects can be treated as an additional source of

"forward model" error, and strategies for quantifying this error source are proposed. This is relevant not only to the assessment of the information content of advanced sounder data but also to the mitigation of nonlinear effects during retrieval or assimilation. Preliminary results will be presented.

New climate applications of TOVS retrievals in polar regions

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As part of the NASA/NOAA Pathfinder Program, we have used the "3I" system to process eighteen years of TOVS radiances for the Arctic region north of 60°N. Retrievals were spatially averaged onto an equal-area polar grid at 100 km resolution and temporally averaged to daily products centered on 12 UTC. The TOVS Pathfinder data set (so-called Path-P) comprises temperature and moisture profiles, and cloud parameters, as well as some quantities of special interest to polar investigators, including boundary-layer stratification, geostrophic drag coefficients, and sea ice extent. [See Schweiger and Francis (this conference) for more detail.]

Several applications of these data are under development. We estimate wind speeds over sea ice at the 10 m level and analyze their spatial and temporal variability. These wind fields also drive a coupled Arctic Ocean/sea ice model. Temperature, moisture, and cloud information are used to compute surface radiation fluxes in high latitudes, where this information is nearly absent. We combine temperature and moisture information with NCEP winds to estimate sensible and latent heat advected into polar regions from lower latitudes and to analyze components of the Arctic moisture budget. Examples of these and other applications will be presented.

Sensitivity of various specified parameters on the assimilation of satellite infrared radiances

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At AES, a fast physical radiative transfer model has been built for the purpose of simulating and assimilating radiances available from weather satellites. The model considers eight gases and non-black surfaces and it operates on any vertical coordinate. Using the adjoint of the model, tests are made in a 1D-var assimilation framework to evaluate the sensitivity of various parameters on the resulting analysis. The most fundamental parameters are the background (B, expressed in T and ln(q) on NWP model levels plus T_s and p_s) and observation (O, radiance) error covariance matrices. Some work is required to ensure an optimum weight of the observations from each channel. The sensitivity to surface emissivity and skin temperature errors is also studied in view of assimilating window channels both over land and sea. Uncertainties in O_3 and CO_2 concentrations (currently ignored) can also be considered since the adjoint model provides the Jacobians associated with these gases. Evaluation within the full 3D-var system will also be presented.

AMSU-A antenna temperature adjustments, limb adjustments and retrievals

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Procedures have been developed to adjust AMSU-A antenna temperatures to brightness temperatures, limb adjust brightness temperatures to compensate for the effects of non-nadir viewing, and generate temperature retrievals from limb-adjusted brightness temperatures. All coefficients for deriving temperature profiles from AMSU are used globally and are never updated. The initial (and only) guess for the temperature retrieval is a global mean. This is possible because of the strong linearity between temperature and Planck radiance, which is not true for infrared observations. The temperature retrieval errors for 1 km layers are generally within 1.5 K above 700 mb. The limb adjustment errors for the temperature sounding channels are within the instrumental noise of AMSU. The methodology is very suitable for climate applications since global fixed linear operators are used in the retrieval procedure (which includes limb adjustment). Daily updated temperature time series for several levels from 700 mb up to 1 mb have been generated since July. For monitoring temperature trends a product based on a single observing system (i.e. satellite), and if possible a linear operator, is advantageous, because any trends can be isolated with much greater confidence and related to the satellite observations as opposed to the algorithm and/or some other ancillary data.

At the conference the entire methodology, which includes characterizing differences between radiative transfer calculations and AMSU observations will be discussed. Retrieval, limb adjustment and forward calculation accuracy will be presented for data

collected from July through December 1998.

Advanced infrared sounder data applications and results

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The next generation of infrared sounders will have much improved spectral resolution and numerous spectral measurements which together will result in significant improvements to the retrieval accuracy of temperature, moisture, and surface properties. Methodologies have been developed to derive retrievals from these sounders. One area of special interest is data compression which can be used to reduce the volume of data to users and to reduce processing time. We have developed and tested several techniques. One is eigenvector decomposition which many have studied using simulated data. It is often reported that 50 or so principal components can represent high spectral resolution spectra consisting of thousands of measurements. In reality, by using high spectral resolution from aircraft we found that many more are needed to account for clouds, solar and surface effects and scan angle. We also developed an approach called channel clustering, which averages channels that are highly correlated with each other. We were able to reduce IASI's 8461 measurements to a few hundred channel clusters without much loss in retrieval accuracy. Another area we studied was the limb adjustment of high spectral resolution data. Because so many measurements are available, errors introduced by limb adjustment are well within the instrumental noise. At the conference we will present the methodology and results on retrieval accuracy, data compression (eigenvector and channel clustering) and limb adjustment. We will also provide an update of NOAA's real-time AIRS processing plan.

Variational TOVS radiance assimilation in the GASP model at BMRC

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As a prelude to the development of a full three-dimension variational data assimilation system known as GenSI (Generalised Statistical Interpolation), a one-dimensional variational radiance assimilation scheme (1DVAR) has been implemented in the GASP global model at BMRC (Bureau of Meteorology Research Centre). The 1DVAR system has been based on the ECMWF 1DVAR scheme; however, many new features have been added which improve upon the original formulation. Firstly, the background error specification has been changed to allow a latitudinally dependent variance, while keeping a global covariance structure. The variances have been specified to agree with the observed minus first guess radiance statistics over all latitude bands. The bias correction now uses a ECMWF type model-dependent air-mass correction with a latitudinally dependent scan correction, and as a result it was found that some of the previous radiance errors needed to be modified. In order to use the retrieved profile in the existing OI (Optimum Interpolation) system in GASP, the 1DVAR retrieval is mapped onto a set of thick layers. However, the pseudo-observation increments and assumed errors must be scaled in order to reduce the dependence of the retrieval on the first guess. The new system uses an exact adjoint technique to calculate both the first-guess and retrieval errors in thick layer space to allow the appropriate scaling factors for both increments and errors to be calculated for each profile. This has the advantage that the retrieval errors and scaling factors will change with both location and and retrieval type. Cloudy soundings, which have fewer useful channels, are automatically given less weight in the analysis, and regions which have higher background errors - such as the southern polar regions - will also have higher pseudo-observation errors. Some experimental results are presented showing an improvement in forecast skill compared to the use of NESDIS retrievals, especially in the Southern Hemisphere.

Total ozone from HIRS

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We used the algorithm proposed by Fernand Karcher of Météo France with AAPP level-1c files to yield the near real-time (+ approx. 90 min) retrievals of total ozone from NOAA HIRS data, running on Silicon Graphics under UNIX. A comparison with the Czech Solar and Ozone Laboratory in Hradec Kralove (lat. 15.833 E, long. 50.183 N) for the last two months shows a good agreement with the computations.

The data are available on the server
www.chmi.cz/meteo/sat/ozon
and they can also be linked from the Karlsruhe University "Topkarten" server of G. Mueller.

The fields computed so far are only for NOAA 14 passes and examples will be shown at ITSC-X. The deviations of ground data from satellite computations can also be partially explained by differences between times of satellite passes and ground observations.

The original algorithm was described by Karcher *et al.* in *J. Geophys. Res.* (1991), 96, *12,983.* It is based on the physical determination of the

transmission (τ) of channel 9 (ozone, 9.6 microns) which can be calculated from the brightness temperatures in channels 9 and 8 (window, 11 microns) and from the mean ozone temperature T_{ozone} (determined by regression from the CO_2 stratospheric sounding channels in an initial step). The calculation of total ozone is performed in a third step using its strong correlation with transmission in the ozone absorption band (Lefèvre at al. 1991).

Direct broadcast reception and processing system for EOS

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The Space Science and Engineering Center at the University of Wisconsin-Madison together with the support of NASA and NOAA are developing a system to directly receive and process EOS AM-1 MODIS (MODerate resolution Imaging Spectroradiometer) data in real time. Data and derived products will be available to the users thirty minutes after receipt. The system will include commercially available antenna hardware, a data receiving front end, ingest software, data reformatting, data calibration, data navigation, image processing, and atmospheric product generation. The MODIS level 1 and level 2 products will be browsed using an interactive and user friendly JAVA based toolkit. An International MODIS Processing Package (IMPP) will be developed for comprehensive processing of MODIS data for weather, climate, nowcasting, NWP, cloud property, and radiation budget studies. Future system capabilities will encompass EOS PM-1 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.

Climate analysis using the TOVS Pathfinder radiance data set

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The data sets produced by operational weather satellites provide the longest record of observations that are used as the backbone for climate and global change studies. These data sets, however, were not originally intended for these purposes and so considerable work must be performed on them in order to make them useful for a variety of climate process studies. 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 easier access at a variety of different user levels of experience, full documentation, and tools that allow users to effectively compare data and models.

The TOVS radiance Pathfinder has a foundation in the very successful International Satellite Cloud Climatology Project; 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 this study 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 sets and (4) to use these data, particularly the water vapor channel data, in studies of climate and global change.

Variational cloud-clearing and assimilation of TOVS and ATOVS data

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Recently, it has been shown that the use of observations from satellite-borne microwave and infrared radiometers in data assimilation systems consistently increases forecast skill. Considerable effort has been expended over the past two decades, particularly with the TIROS Operational Vertical Sounder (TOVS), to achieve this result. The positive impact on forecast skill has resulted from improvements in quality control algorithms, systematic error correction schemes and data assimilation systems. Despite these recent advances, there are still many issues regarding the use of satellite data in data assimilation systems that remain unresolved. For example, the use of data that are affected by cloud in numerical weather prediction (NWP) has remained problematic. As a result, several NWP centers are experimenting with using only data that are not significantly affected by cloud.

Approaches to remove the effect of cloud from cloud-contaminated observations, known as cloud-clearing, have been used for many years. We have developed a method to simultaneously cloud-clear contaminated infrared observations and extract temperature and humidity information from both microwave and infrared data using a one-dimensional variational (1DVAR) approach. Most previous

implementations of cloud-clearing assume the presence of a single cloud formation. We have applied our 1DVAR algorithm to TOVS data, allowing for the possibility of two cloud formations. The temperature and humidity data are currently being evaluated in the Goddard Earth Observing System - Data Assimilation System (GEOS-DAS). Results of the 1DVAR algorithm and 3D assimilation will be shown. We have recently integrated a radiative transfer model from P. Rosenkrantz at MIT for AMSU channels. The algorithm can easily be adapted to use ATOVS (AMSU A) channels. We will soon begin testing the algorithm with ATOVS data.

Results of neural network total ozone retrieval on global NOAA-TOVS data

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The approach of using neural networks for ozone retrieval from TOVS data presented at ITSC-IX has been improved and evaluated by applying it to a long-term global TOVS data set (1990 to 1993). TOVS-Data are classified into day/night and cloud free/cloudy pixels and collocated with ground measurements of total ozone content. The collocated pixels are divided into a learning and test data set, the former being used to train a neural network. For all cases (clear/cloudy, day/night) the absolute mean error of the improved neural network approach for total Ozone Retrieval on the test data set is about 10 Dobson Units compared to globally distributed ground measurement ozone data.

The study shows that it is possible to retrieve the total ozone content of the atmosphere with an accuracy of about 2% for all weather conditions. The advantages of TOVS with respect to other satellite instruments for ozone retrieval (TOMS, SBUV, GOME) using the solar spectrum are that high accuracy ozone retrieval can be maintained during nighttime and that continuous global TOVS data are available for the last 20 years.

Monitoring and bias correction of ATOVS using the ECMWF model

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Simulated radiances from ATOVS instruments AMSU-A, AMSU-B and HIRS have been routinely computed using RTTOV from the ECMWF first guess and compared with the 1B radiances received from NESDIS via the UK Meteorological Office at Bracknell. Generally there is good agreement. The ECMWF bias correction scheme which has been applied is a function of both scan position and airmass. Results will be discussed.

The European AAPP (ATOVS and AVHRR Processing Package) development

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The development of the processing software for locally-received, HRPT-based AVHRR and ATOVS data from the NOAA-K,L,M spacecraft has continued under the co-ordination of the EUMETSAT Secretariat and has achieved its goal: the AAPP package V1.0 is now available for the ingest and pre-processing of TOVS and ATOVS data.

The code available now comprises:

- Ingest code for HRPT, for TOVS and ATOVS instruments;
- Navigation code;
- Calibration code for TOVS and ATOVS instruments;
- Mapping code for the TOVS and ATOVS instruments;
- AVHRR cloud mask processing, including mapping to the HIRS FOV;
- Pre-Processing code for TOVS and ATOVS instruments.

The integration of the code for Ingest and Pre-Processing was completed in 1998 by EUMETSAT with participation from Météo France (CMS, Lannion), the UK Met Office and KNMI. The integrated version 1.0 of the AVHRR and ATOVS Processing Package (AAPP), which performs ingest, navigation, calibration and pre-processing is currently being tested by about 70 parties world wide.

OPTRAN Status Report

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The Optical Path Transmittance (OPTRAN) is a fast transmittance model in which regression is performed on surfaces of constant absorber amount, as opposed to fixed pressure levels. This frees pressure to become a predictor, implicitly includes satellite zenith angle, and permits arbitrary input atmospheric state profiles. Coefficients have been generated for all of the HIRS and AVHRR instruments on TIROS-N through NOAA-15, GOES 8 and 9 imager and sounder, METEOSAT 3 through 7, GMS-5, the MSU, SSM/T and SSM/T-2, AMSU-A and AMSU-B. The code has

been developed as forward model, tangent linear, adjoint and jacobian. This paper will present an update on the code development, and outline improvements to the methodology.

Some anomalies in digital data from satellite radiometers

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and
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The recent launch of NOAA-15 and the accompanying on-orbit verification efforts caused us to take a critical look at the radiometric characteristics of the new Advanced Microwave Sounding Unit (AMSU) instruments. It was discovered that certain instrument count positions are populated preferentially in histograms from scene data. These preferential positions are separated by powers of two. This behavior has been seen in all of the radiometers examined thus far (AMSU- A, AMSU-B, High Resolution InfraRed Sounder (HIRS) on NOAA-9 through 15). The cause of this anomaly is small imperfections in the resistors that make up the analog to digital converter in each instrument. The errors introduced by this are small, on the order of a few hundredths of a degree. Another oddity has been discovered in the level 1B HIRS data. The raw data flowing from the HIRS is signed binary, in which zero can be either positive or negative. Most modern computers are two's complement, in which there is only one form of zero. The net result is both forms of zero in the raw data are folded into the single zero of two's complement. The delta voltage information is lost, with accompanying small errors in the calibration coefficients. The magnitude of these errors are again a few hundredths of a degree. A method will be presented to correct this problem, which has applicability to both central processing sites and direct readout users of HIRS data.

AAPP at NIWA: status report and application to detection of rain

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NOAA-15, first of the 'NOAA-Next' series of satellites, launched on 13 May 1998, is carrying ATOVS, the new set of sounding instruments. Since August 1998 NIWA (National Institute of Water and Atmospheric Research) has been able to process NOAA-15 data in real-time using the new NOAA reception system based in Wellington. Of special interest is data from the Advanced Microwave Sounder Unit, AMSU-A and AMSU-B, first flying on NOAA-15. Being one of the beta-testing sites for the EUMETSAT AAPP software, NIWA has been processing the ATOVS sounder data for validation purposes as part of its operational satellite data processing.

The AMSU-A/B sounder has 20 channels in the frequency range 23 to 190 GHz. The five-channel AMSU-B moisture sounder provides an opportunity (over ocean areas) to identify the phase of cloud water, and ultimately the rain-rate. NIWA is utilising AMSU data together with collocated NOAA AVHRR-data and New Zealand Meteorological Service scanning radar data to determine the relationships between brightness temperatures and rain-rate. AVHRR data together with collocated radar measurements provide a useful data set for validating the rain-rate algorithms based on radiance measurements.

In future the rain-rate estimates together with other derived ATOVS products will be utilised in the Mesoscale Data Assimilation and Weather Prediction Programme. This presentation will outline progress to date.

HAMSR — The first of a new generation of microwave sounders

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The High Altitude MMIC Sounding Radiometer (HAMSR) is the first of a new generation of microwave atmospheric sounders based on emerging Monolithic Microwave Integrated Circuit (MMIC) technology. Funded under NASA's Instrument Incubator Program, HAMSR will be a compact and low cost instrument designed to be reconfigurable to meet mission-specific measurement requirements. The first version will be a temperature sounder operating in the 50-54 GHz and 118 GHz oxygen bands and is planned for initial aircraft flights in the northern summer of 1999.

The second version will also incorporate humidity sounding at 183 GHz and will be flown in the summer of 2000. Both will be self-calibrating crosstrack-scanning systems with measurement accuracies exceeding those of the AMSU-A/B system. Subject to availability, the demonstration flights are planned to take place on one of the solar-powered unmanned aerial vehicles (UAV) currently being developed by NASA's Environmental Research Aircraft and Sensor Technology (ERAST) program, with planned flight altitudes between 60,000 and 80,000 ft. Experimental, light-weight piloted aircraft are also being considered.

NOAA-15 sounding profiles retrieved with the ICI scheme

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The ICI sounding scheme developed at CMS/ Météo France for the processing of HRPT data is interfaced with the 'ATOVS and AVHRR Preprocessing Package' level 1d files and performs retrievals for TOVS and ATOVS channels since last summer.

The AAPP 1d output files are located, calibrated and mapped (to the HIRS grid), observations including information resulting from the AVHRR processing inside the HIRS field-of-view (cloud cover, surface temperature) and AMSU preprocessing (clear/ cloudy/ precipitating flag, surface type).

The ICI package has been updated to take into account the new AMSU channels and the same software is now able to run with NOAA-14 and NOAA-15 data. Several code updates have been included to improve the scheme and will be presented: they mainly concern the micro-wave surface emissivities and the guess selection. The micro-wave surface emissivities are estimated over sea with the FASTEM code by using a forecast of wind speed, and over land from constant values depending upon the surface type. The guess library now includes up- and down-wards radiances and the brightness temperatures and covariance matrix of the library are computed in real time for each situation with the correct surface temperature and surface emissivities. After retrieval, for clear situations (using the AVHRR cloud mask), micro-wave surface emissivities are evaluated for AMSU-A surface channels and are archived with geographical position and scanning angle to create an atlas, input of the retrieval scheme for future runs.

NOAA-15 daily error statistics (retrieval 'in-situ') of the 6 last months of operational runs will be presented for temperature.

In relation to humidity profile retrieval, a routine is just available to correct for the interference aboard the satellite which contaminate the AMSU-B observations and the processing of the water vapor channels will be undertaken in future weeks. First results will be shown.

AVHRR cloud mask for sounding applications

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The CMS/ Météo France has developed an AVHRR cloud mask for sounding purposes. A first version of this cloud mask is now implemented in the 'ATOVS and AVHRR Preprocessing Package' (AAPP).

The routine is based on a threshold technique applied to every AVHRR pixel in the HIRS ellipse and gives two main parameters averaged in the HIRS spot: cloud cover and surface skin temperature computed from clear AVHRR pixels with the split-window method.

Threshold tests are applied to various combinations of channels, which depend on the geographical location of the spot and viewing geometry. The software is interfaced with global and monthly climatological datasets of SST and albedo and reads the forecast of surface air temperature over land. These data are used to compute the thresholds of the tests. They are also defined with empirical functions of viewing angles, pixel brightness temperatures and total water vapor content of a representative mid-latitude atmosphere. In this version, the thresholds are computed for mid-latitude areas.

A study has been undertaken to simulate, in clear conditions, the different combinations of AVHRR channels with the TIGR profiles by using the RTTOV forward model. The results have been tabulated and allow for dynamic adaptation of the threshold values to the given meteorological situation as a function of the forecast surface temperature and the total water vapor content. It is expected - and will be validated in the next weeks - that, in the context of the AAPP + ICI package, the evaluation of the threshold function of the total water vapor content should be part of the monitoring of ICI package.

Some new tests have also been added to better take into account cloud detection over snow or sand. A new version of the mask with these updates will be available in mid 1999 and will allow us to run the mask in other climatological areas.

Evaluation of ITPP-5.12 total ozone amount

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Total ozone amounts determined from atmospheric radiances measured by the TIROS Operational Vertical Sounder (TOVS) have been used in real-time in Korea. The retrieval procedure is done by the International TOVS Processing Package (ITPP-5.12), developed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison. ITPP-5.12 total ozone values are compared with measurements from the local surface-based Dobson spectrophotometers. In this study, results of the evaluation of ITPP-5.12-derived total ozone amounts

are presented.

Recent advances in the application of TOVS, ATOVS, S-VISSR and advanced sounder data in Australia

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Operational Numerical Weather Prediction over the Australian Region is heavily dependent on real-time direct readout data from both polar orbiting and geostationary satellites. Short operational cut-off times, combined with a need to use the radiance data in the local analysis/prognosis environment, make the full resolution and timely direct readout transmissions an ideal data source.

This paper briefly describes the current use of direct readout raw cloudy TOVS radiances in Regional NWP. It discusses the recent development of techniques to use artificial intelligence methods as part of a physical solution of the radiative transfer equation, principally in both improving the forward radiative transfer calculation and in the inversion process. It notes recent moves towards establishing an operational 3-D variational analysis system capable of using clear radiances in the Bureau of Meteorology. Recent work examining the application of ATOVS data, in particular AMSU-A data, in the Australian Region is summarised and some early examples shown. Also described are some recent experiments where asynoptic TOVS observations and GMS-based continuous wind observations have been used with very high resolution (5 km) four dimensional variational assimilation. These experiments show the important role very high resolution continuous assimilation of satellite data can play in the prediction of severe weather events.

High resolution 4-D assimilation of satellite data

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The global 4-D continuous assimilation scheme of Bennett, Chua and Leslie has been extended to run at high resolution over a limited domain. It has been established over domains of 30 deg. square and larger at horizontal resolutions between 15 km and 5 km. It has an extended penalty functional to be minimised which allows extra data sources with much higher spatial and temporal resolution. Its initial application used hourly cloud and water vapour drift winds to compare tropical cyclone (TC) track and intensity forecasts. It also used scatterometer data to ameliorate initial TC position forecast errors.

Recently, the scheme has been further extended to assimilate the primary variables temperature and moisture and the direct assimilation of radiances is under test. This paper describes the basic formulation of the 4-D assimilation scheme in relation to the assimilation of wind, temperature, moisture and radiance observations and also presents a limited number of results.

The International ATOVS Processing Package (IAPP): the algorithm and its application in real data processing

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The International ATOVS Processing Package (IAPP) has been developed to retrieve atmospheric temperature profiles, moisture profiles and other parameters in both clear and cloudy atmospheres from real ATOVS data. This algorithm contains four steps: (1) cloud detection, classification and screening; (2) cloud - removal process for HIRS/3 cloudy radiances; (3) a regression retrieval process; and (4) a non-linear iterative physical retrieval. Nine (3 by 3) adjacent HIRS/3 spot observations together with an AMSU footprint remapped to the HIRS/3 resolution, are used to retrieve the clear HIRS/3 radiances, temperature profile, moisture profile, total atmospheric ozone and microwave surface emissivity, etc. The algorithm is applied to real ATOVS data processing. Retrieval results are evaluated by the root mean square difference between retrieved and radiosonde sounding profiles. The IAPP will be available to world-wide users for processing real-time ATOVS data.

The cloud-removal algorithm for HIRS/3 clear column radiance retrieval using AMSU measurements

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A multichannel cloud-removal method using the principle of the N* method has been developed in cloudy data processing as part of the International ATOVS Processing Package (IAPP). This method uses AMSU brightness temperatures to predict the clear radiances of HIRS/3 channels 5, 6 and 7. These three radiances are used to estimate the N* (the ratio of effective cloud cover over adjacent FOVs) using the adjacent FOVs with the largest cloudy radiance contrast. Finally, the clear column radiances of the remaining HIRS/3 channels are evaluated using N*.

The cloud clearing algorithm is tested by both simulation and real data application. Retrieval results are presented in terms of root mean square (r.m.s.) brightness temperature differences between cloud cleared and true HIRS/3 clear spectra. In general, the average r.m.s. of cloud removed clear radiances is smaller than 0.5K for HIRS/3 channels. The test results illustrate that the proposed cloud-removal method is capable of generating reasonable cloud-removed clear radiances from AMSU data.

Satellite remote sensing of precipitation in the Huaihe River basin area

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Precipitation has been retrieved by the Special Sensor Microwave / Imager (SSM/I) data in the Huaihe River basin area in the Meiyu season of 1991, when heavy rain and floods occurred.

Based on the character of the large changeable microwave emissivity with different kinds of earth surface conditions and the VDISORT model simulation, five categories can be determined by the cluster analysis method, i.e. convective rain, stratus rain, wet soil, dry soil and ocean. The rain area can firstly be discriminated using the Special Sensor Microwave / Imager (SSM/I) data firstly.

Secondly, three algorithms are used here to estimate rain rate:

1. A mixed scattering index is defined on the basis of polarization-corrected temperature and the scattering index, both of which are functionally related to the rain rate. A mixing scattering-based algorithm is presented by integrating the linear and nonlinear relationships between the scattering index and the rain rate.
2. A composite microwave index is defined based on the difference between the land and ocean according to a theoretical calculation. A composite microwave index algorithm is presented with a power fit relationship between rain rate and the composite microwave index.
3. An underlying earth surface index is defined to stand for the ratio of the land in the satellite view field. A composite retrieval algorithm is presented according to relationships between rain rate and other parameters, including the brightness temperature, the polarization-corrected temperature and the scattering index of 85 Ghz channels.

Finally, tests of precipitation retrieval have been carried out in the Huaihe River basin area of China in the Meiyu season of 1991, using SSM/I data with the above cluster analysis and three retrieval algorithms. Results show that the classification and rain rate retrieval algorithms give reasonably good estimates of rain area and rain rate.

Cloud clearing ATOVS and AIRS data

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The AIRS team has been doing extensive simulations of the cloud clearing problem. In the process, the team has developed techniques for handling multiple cloud formations. These techniques have resolved the problems that have resulted from the assumption of a single layer cloud that was made in the original use of the N* cloud clearing technique. This assumption has been the source of difficulties in many of the attempts that were made to use it. These improved techniques come at a time when many TOVS groups are going to single field-of-view approaches to avoid the use of cloud cleared radiances. The main improvement in the technique comes from the use of multiple spots to determine the number of cloud formations in a small area. For example, a single cloud formation requires the use of three channels and at least three spots to determine if more than one cloud formation is present, not just two spots and two channels as in the original version. The new developments have obvious implications for a decision to avoid cloud clearing.

NESDIS has provided a cloud clearing technique that has been adapted by the AIRS team for

the initial cloud clearing step. This approach is being adopted for use with ATOVS data. The revised approach and results based on both ATOVS and AIRS data will be presented. The results will include preliminary results from a comparison of the ATOVS clouds with clouds produced from the AVHRR instrument using the CLAVR technique.

Angle adjustment for TOVS — past, present, and future

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Angle adjustments have been an integral part of data processing with the polar series of satellites since they employ a cross-track scanning pattern. They are used in cloud clearing, where radiances from adjacent spots must be adjusted to a common viewing angle before cloud clearing, and in adjusting radiances to nadir. Historically, angle adjustments were first made with coefficients derived from simulated data. This includes all TOVS processing up to the implementation of RTOVS processing system. Later, for the RTOVS system and NOAA 15, the angle adjustments were made with coefficients generated from measured data. Both have advantages and disadvantages and it is important for users of the TOVS data to understand the differences. Since the implementation of the RTOVS system, some of the effects of using measured radiances have become evident in the form of scan dependent biases in the infrared channels. These biases occur because the cloud cover is a function of the viewing angle. Cloud cover changes with viewing angle because the cloud path varies directly with the secant of the local zenith angle, and because the effective cloud cover increases with viewing angle for clouds with any vertical development. There have also been recent advances in the generation of the simulated coefficients. The item that can be easily missed is that the noise for a particular observation does not depend on the angle at which the observation is made. Thus when noise is applied to the data, the identical noise has to be added to all the angles for each profile. This makes a significant difference to the coefficients and to the accuracy of the results. It is obvious that, near nadir, where the change in angle is extremely small, the error in the angle adjustment is small compared to the instrument noise and must be accurately reflected in the simulation. Using simulated data, the accuracy of the various approaches is evaluated.

Assimilation of TOVS and ATOVS raw radiance data in the ECMWF 4D-Var analysis

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A methodology is described for the direct assimilation of TOVS and ATOVS raw radiance data (that have not undergone any pre-processing such as limb correction or cloud clearing). It will be shown that the non-linear effect of surface emissivity, clouds and precipitation can be dealt with inside the analysis with an appropriate quality control mechanism. A comparison of the performance of the raw radiance scheme with the operational ECMWF analysis (that uses RTOVS pre-processed radiance data) is presented.

Intercomparison of TOVS Path A and NVAP water vapor data sets

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A detailed comparison of global precipitable water (PW) fields, as obtained from TIROS Operational Vertical Sounder (TOVS) Pathfinder Path A and NASA Water Vapor Project (NVAP), is carried out. Total precipitable water above the surface, as well as precipitable water in three atmospheric layers (surface to 700 mb, 700 to 500 mb, 500 to 300 mb) are compared for the years 1989 to 1994. The TOVS Pathfinder Path A retrieval system uses High Resolution Infrared Sounder (HIRS2) and Microwave Sounding Unit (MSU) radiances for PW retrievals. The NVAP provides a blended data product, in which radiosondes and operational TOVS retrievals from the National Environmental Satellite Data and Information Service (NESDIS) are used over land and Special Sensor Microwave Imager (SSM/I)-derived PW estimates are used over occan to obtain total PW.

From daily and monthly mean PW comparisons it is found that the total PW above the surface from the two data sets are within ±10% (± 2 mm) of each other over most of the oceanic regions. There are, however, regions where the two data sets have discrepancies of 10 to 20%. These regions include equatorial and southern Africa, sub-tropical Southern Indian Ocean, South America and off the coast of Peru and India, where TOVS Path A shows 10 to 20% more PW than NVAP. Over the desert regions of the Sahara and the Arabian peninsula, and over Antarctica, NVAP shows 10 to 20% more PW than TOVS Path A. The PW values in the surface to 700 mb, 700 to 500 mb,

and 500 to 300 mb layers as a fraction of total PW from the two data sets are generally within ±2.5% of each other, except over the polar regions, oceanic subtropical high regions and over the Sahara. In the global mean sense, TOVS Path A has more PW in the surface to 700 mb layer compared to NVAP, but has less PW in the 700 to 500 mb and 500 to 300 mb layers than NVAP.

In the presentation we will explain some of the discrepancies seen between the TOVS Path A and NVAP PW data sets. We will also show a comparison of interannual variability of PW as seen from the two data sets. A preliminary comparison of the TOVS Path B PW with TOVS Path A and NVAP PW will also be shown. We will show the impact of the PW differences seen among the data sets on outgoing longwave radiation.

Observing 1997-98 El Niño in the Indian Ocean from the TOVS Pathfinder Path A data set

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In this presentation, we use the TIROS Operational Vertical Sounder (TOVS) Pathfinder Path A retrievals of sea surface temperature (SST) to show the evolution of El Niño in the Indian Ocean during 1997-98. It is found that during this period the Indian Ocean was unusually warm. We will show the phase relationship between the Indian Occan SST and the equatorial Pacific Ocean SST during 1997-98. We will also show how convection (using the Path A outgoing longwave radiation) evolved over the Indian and Pacific Oceans during this period.

Global cirrus clouds and upper tropospheric humidity detected using HIRS

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Global upper tropospheric transmissive cirrus cloud cover has been charted for the past ten years (June 1989 - Dec 1998) using NOAA polar orbiting HIRS multispectral infrared data. The HIRS data have a higher sensitivity to semi-transparent cirrus clouds than visible and infrared window techniques; the threshold for detection appears to be at a visible transmittance greater than 0.1. The global average cloud cover is found to be about 0.75. The effective emissivity of the all semi-transparent clouds (visible transmittance < 6) ranges from 0.2 to 0.6 with an average value of about 0.5. Time trends were re-examined in detail; the ten year record has indications of an increase of high clouds in the northern mid-latitudes (0.5% per year) but little change elsewhere. The seasonal cycle of cloud cover in the southern hemisphere became very noticeable in 1993.

In addition, the upper tropospheric humidity (UTH) is derived from the global HIRS water vapor sensitive radiances for the month of November 1998 and compared with the global cirrus coverage. There is a close similarity in geographical coverage; areas of high UTH in the tropical convection areas have a mean cloud amount above 400 hPa of 25 to 40% and subsidence areas of low UTH are associated with cloud amounts less than 10%. The relationship between clouds, ambient relative humidity fields, and large scale dynamics begins to emerge.

Polar satellite training for the operational weather services

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The National Environmental Satellite and Data Information Service (NESDIS) and National Weather Service (NWS) are working together to develop a computer based learning (CBL) module that will be used to train operational weather forecasters in the use of polar satellite data and products. The training module is being developed in coordination with the Cooperative Program for Operational Meteorology, Education and Training (COMET®) in Boulder, Colorado. This training program is important because the polar satellites offer both unique as well as complementary data to the GOES for the operational forecasting community.

The use of polar satellite data within the operational weather services varies tremendously. Within the NWS, the NOAA polar satellite (POES) imagery and products are used mostly within the Alaska region with some usage by a few other offices. The POES sounder data are used mostly for the initialization of numerical models. For most other areas of the US, NWS forecasters rely mostly on data and products from the imager and sounder of the GOES. Within the Department of Defense, the use of polar satellite data and products (especially from the Defense Meteorological Satellite Program - DMSP) by the operational forecasters is much more extensive. The major reason for this is that their area of responsibility

spans the entire globe and only polar satellites can provide complete coverage for the globe.

To expand the understanding and use of polar satellite data across the weather services, the joint NESDIS/NWS polar satellite training effort at COMET® was established. This program will develop a CBL module that focuses on the data and products available from both the POES and DMSP satellites. The module will review the channels and products available from the POES and DMSP imager and sounder instruments. The module will then move on to the unique capability of the polar satellites: the microwave channels. The microwave instruments described will include the new AMSU-A and -B instruments available on the recently-launched NOAA-15 satellite. The module will include a chapter on the integration of polar satellite data with other datasets (this is a major area of emphasis within the operational weather services especially with the deployment of Advanced Weather Information Processing System in the NWS). The module will conclude with some short case study examples using the polar satellite data.

NESDIS and NWS are working closely with COMET® to provide the polar satellite training module over the World Wide Web. The materials will be located within the meteorological training (meted) site located at **www.meted.ucar.edu** as part of the integrated remote sensing training core. Once the CBL module is complete, it will also be distributed on CDs.

Efficient processing of multi-year global TOVS data using ITPP, 3I and neural networks

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In order to analyse the enormous volume of data delivered by the TOVS sensor during the last 20 years, fast and reliable processing software is required. In our approach, the well-tried ITPP preprocessing package has been combined with airmass type and cloud retrieval algorithms taken from the 3I package developed by LMD, Paris. Data I/0 within the program has been minimized, and some problems with the ITPP MSU interpolation which - according to its programmers - will not be fixed in future releases have been overcome by developing an entirely new interpolation scheme.

Ozone retrieval is achieved by applying a neural network to the output of this preprocessing. However, training of the neural network first demands some of the data to be collocated with corresponding ground and balloon-borne ozone measurements contained in the WOUDC (World Ozone and Ultraviolet Radiation Data Centre) database.

The actual training and classification routines have been implemented using our own neural network simulator which has been developed and tested on various problems over the last eight years.

Our future planning aims towards making available the results in different output formats, implementing SBUV ozone profile retrieval and adapting the code to ingest HIRS/3 and AMSU data.

Assimilation of geostationary water vapour radiance data at ECMWF

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Direct assimilation of radiance data within an NWP system can provide information for the correction of model temperature, humidity and ozone fields. Furthermore, with the implementation of the 4DVAR variational assimilation system at ECMWF, it has become possible to assimilate data at times other than the synoptic times of 00, 06, 12 and 18Z. This is of particular importance for geostationary satellite radiance data where observations are typically available at asynoptic times and, in the case of geostationary radiances, at high temporal resolution. By taking advantage of the high temporal resolution of such data sets there is the possibility to correct not only the model temperature and humidity, but also the wind fields.

This paper describes the impact of assimilation experiments, carried out to assess the importance of the direct assimilation of geostationary water vapour Radiance data, on the ECMWF 4DVAR assimilation system. These impacts are compared to those from the assimilation of the Clear Sky Water Vapour Wind product.

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An assessment of the in-orbit performance of the NOAA-15 AMSU-A instrument

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The NOAA-15 Advanced Microwave Sounding Unit (AMSU) - A radiometer, built by GenCorp Aerojet, was launched in May 1998. This marks the first of a series of AMSU-A instruments to go into space during the next decade. Based on engineering data obtained during the first five months in orbit, the AMSU-A performance shows significant improvements over present space-borne hardware. A look at these improvements in resolution, sensitivity, accuracy, etc. will be addressed. A comparison between the actual performance and the modeled performance will be

shown.

Evaluation of total ozone retrievals from TOVS-ITPP software by comparison with other ozone data sources

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A comparison between total ozone derived from the International TOVS Processing Package (ITPP) and values obtained from other data sources is presented in this work. The comparison is carried out over a particular location sited in the center-north of Spain. The data used in the comparison are TOMS data and also experimental measures obtained with an ozone monitor MICROTOPS II. An application directly related with the availability of ozone values in near-real time is the calculation of the erythemal ultraviolet radiation and first results are presented.

Clouds spatial distribution and satellite sounding contamination: an impact study from AVHRR (1.1 km) up to AVNIR (8 - 16 m) spatial resolution

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An improved knowledge of processes involving clouds' genesis and dynamics and their spatial and temporal distribution, could play a crucial role in order improving our present and future capabilities in satellite remote sensing of the atmosphere. In this paper, spatial distribution of clouds (and, consequently areas suitable for clouds-free satellite sounding) has been investigated at the fine scale by using the first available ADEOS/AVNIR imagery (at 8 - 16 m spatial resolution) and NOAA/AVHRR data. This work represents the natural extension of our previous investigation devoted to characterising the spatial distribution of clouds moving from HIRS (spatial resolution of 18 km at the best with about 40 km of spacing) up to AVHRR (at the best 1.1 km) capabilities.

Using AVNIR sounding, spatial resolutions from a few metres up to a few kilometres have been simulated and the spatial distribution of different cloud-contaminated soundings (up to 25% of the simulated FOV area) investigated. Scaling properties of clouds-free areas and the trade-off between simulated spatial resolutions and observed cloud-contamination have been analysed, in order to assess their implications on design and applications of future satellite sounding systems.

Some results of the identification of multilevel cloudiness on the basis of IR measurements from HIRS/2

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A numerical model of the perturbation of outgoing thermal radiation by multilevel cloudiness in the field of view of an IR satellite radiometer was developed. The cloudiness is described by a variable number of layers with given heights. Every level is characterized by the desired effective cloud amount. For the given cloud model, an estimation of the inverse problem solution from atmospheric remote sensing was considered. The problem solution consists of two modes: 1) identification of cloud presence and estimation of its parameters, and 2) estimation of the temperature-humidity profile under the given values of the cloud model parameters. Applicability of the cloud model was verified using information from the aircraft experiment FIRE-II for modeling the measurement content of the radiometer HIRS/2. Positive results were obtained: Cloudiness was reliably identified and estimates of cloud parameters adequately reproduce a vertical layered structure of the cloudiness which was observed by lidar from the aircraft. The statistical significance of the model's applicability was verified on the large data set of HIRS/2 measurements. Data on the vertical and horizontal distributions of cloud parameter estimates were obtained. Results show that identified multilevel cloud cases constitute a significant percentage of identified cloud cases. Cloud parameter estimates have high spatial coherence and reproduce an internal structure of the cloud field observed. Estimates of cloud parameters from the observed cloudy scene and corresponding images are shown.

Microwave land surface emissivities derived from SSM/I and SSM/T-2: extrapolation to AMSU frequencies and scanning pattern

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Microwave land surface emissivities are estimated from SSM/I and from SSM/T-2 window channels, by removing the atmospheric contributions, clouds and rain using ancillary satellite data. Cloud-free SSM/I and SSM/T-2 observations are first isolated with collocated visible/infrared satellite observations (ISCCP data). Next, the cloud-free atmospheric contribution is calculated from an estimate of the local atmospheric profile (NCEP). Finally, with the surface temperature derived from IR observations, the emissivity is calculated. The emissivities are available for SSM/I channels for a 53° observation angle on a 1/4° grid and for the SSM/T-2 window channels for all scanning angles on a 1/3° grid. AMSU is now flying on the NOAA polar orbiting satellites. It is important to understand and quantify the emissivity of the Earth surface to discriminate between the lower troposphere and the surface contributions and to optimize the AMSU lower atmospheric temperature and moisture retrievals. We examine the feasibility of deriving estimates of AMSU emissivities over the globe from the previously retrieved SSM/I and SSM/T-2 emissivities, considering the different frequencies of observation and the different scanning and polarization mechanisms of the instruments. A simple model is proposed to derive the AMSU surface emissivities from the SSM/I and SSM/T-2 emissivities.

The study of the horizontal structure of the 'Lannion SATEM' data

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During recent years, many investigations have been carried out to study the impact of satellite data on NWP model forecasts. To study the impact of the so-called 'Lannion SATEM' data on the French NWP model ARPEGE, a data assimilation experiment was carried out in 1997 at Météo France (CNRS) in Toulouse.

The impact of the Lannion SATEM data on the 3D-Var assimilation was found to be positive in some cases, negative on others, but neutral in most. Many questions, therefore, arise with respect to the quality of the data used.

The 'Lannion SATEM' data are retrieved using the ICI (Inversion Coupled with Imagery) package developed in Centre de Météorologie Spatiale (CMS), Lannion.

This paper studies the horizontal structure of errors in the Lannion SATEM data, when compared to a 12-h forecast, in order to find an optimal data resolution for the useful data assimilation.

The variance and the correlation between the retrieved data and model forecast were calculated, using the archived data at CMS, Météo France. These data are composed from the orbits in the acquisition area from the ARPEGE model forecast.

The horizontal structure of the error of the Lannion SATEM data was found to be anisotropic.

Scientific status of NESDIS Revised-TOVS (RTOVS) sounding products

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Operational satellite soundings from the TIROS Operational Vertical Sounder (TOVS) onboard National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellites are produced and distributed by the National Environmental Satellite Data and Information Service (NESDIS). Operational products for NOAA-11 and NOAA-14 include derived temperature and moisture soundings based on the High-resolution Infrared Radiation Sounder (HIRS), Microwave Sounding Unit (MSU), Stratospheric Sounding Unit (SSU) instruments, and sounder radiometric measurements.

The following report addresses modifications installed in conjunction with the operational implementation of the Revised-TOVS (RTOVS) sounding products system, which replaced the TOVS system from September 1998. Scientific algorithms and results are presented, including the evaluation of the derived soundings against collocated radiosonde and numerical weather prediction forecast data, and the sounder radiometric measurements.

The RTOVS system was designed to be similar to TOVS, but with some additional scientific and system capability to serve as an appropriate baseline for Advanced-TOVS (planned for NOAA-15). The main scientific changes included a new limb adjustment of radiometric observations, cloud detection using Advanced Very High Resolution Radiometer (AVHRR) data (NOAA-14 only), a more consistent retrieval approach above 50 mb, and a more stable compilation of radiometric and collocated radiosonde observations for product tuning and evaluation. Initial

problem areas identified by users mainly concerned limb adjustment, the cloud mask, and products over anomalous terrain such as extremely hot or cold surfaces, ice, and high terrain. Most of these were resolved; their status and remaining areas targeted for improvement are discussed.

The replacement of TOVS with RTOVS resulted in noticeable improvements related to the global cloud mask, and upper stratospheric soundings. Otherwise, the sounding products are similar to the previous TOVS products but at a 20% increased density. Their value as a source of global weather data and numerical weather forecast information is highlighted.

Scientific status of NESDIS operational sounding products from DMSP polar orbiting satellites

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Operational satellite soundings from the Defense Meteorological Satellite Program (DMSP) polar orbiting satellites are produced and distributed by the National Environmental Satellite Data and Information Service (NESDIS). These products consist of derived temperature soundings from the Special Sensor Microwave/ Temperature (SSM/T1) sounder onboard the F-13 satellite, moisture soundings from the SSM/T2 high resolution moisture sounder onboard the F-14 satellite, and associated radiometric measurements. The following report addresses the current scientific status and products accuracy, including the evaluation against collocated radiosonde and numerical weather prediction forecast data, the sounder radiometric measurements, and NESDIS Revised-TOVS (RTOVS) sounding products.

The primary motivation for upgrading the DMSP sounding systems over the past 18 months has been to achieve better scientific compatibility with their NOAA satellite counterparts. This has resulted in several changes particularly to offline support systems which compile radiometric and collocated radiosonde observation data sets which are used for the tuning and evaluation of the sounding products. In addition, the capability to routinely compare moisture products from the SSM/T2 to those from the SSM/I, namely the total precipitable water (TPW), were developed and results are presented. Problem areas, for example, soundings over high terrain, and the impact of cloud liquid water on derived moisture products are presented. Their status, along with remaining areas targeted for improvement, are discussed.

The DMSP operational sounding products for temperature and moisture provide a reliable source of global weather data and numerical weather forecast information, consistent with the NOAA operational satellite data. The SSM/T2 represents the first capability of measuring global moisture under clear and cloudy weather conditions. Results demonstrating their scientific integrity are presented.

Scientific status of NESDIS Advanced-TOVS (ATOVS) sounding products

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The National Oceanic and Atmospheric Administration (NOAA) successfully deployed the NOAA-15 satellite into polar orbit (ascending, evening) on May 13, 1998. NOAA-15 features the Advanced TIROS Operational Vertical Sounder (ATOVS), which is comprised of the 20-channels High-resolution Infrared Radiation Sounder (HIRS), the 15-channel Advanced Microwave Sounding Unit (AMSU-A), and the 5-channel AMSU-B high resolution moisture sounder. The National Environmental Satellite Data and Information Service (NESDIS) has undertaken intensive scientific checkout of the sounder and operational products generation systems. The following report provides the current status for each sounder, the scientific algorithms, and sounding products. Results include comparisons against collocated radiosonde and numerical weather prediction forecast data, and operational data from NOAA and Defense Meteorological Satellite Program (DMSP) satellites.

Sounding products from NOAA-15 are derived from two separate sounding product generation systems. ATOVS products refer to the temperature and moisture soundings from the combined HIRS and AMSU-A sounders. Advanced Very High Resolution Radiometer (AVHRR) data are also used for cloud detection. AMSU-B products are the high resolution moisture soundings which at full density consist of over 2.5 million soundings daily. At this time, the ATOVS and AMSU-B systems are essentially independent.

The operational implementation process for ATOVS and AMSU-B product systems has proceeded quite smoothly. Initial estimates exceeding 18 months (from launch) for achieving an operational capability have now been reduced to within months. This is despite problem areas, including the radio frequency interference affecting the AMSU-B sounder, higher order limb effects intrinsic of AMSU data, and the reduced vertical extent of AMSU-A relative to the Stratospheric Sounding Unit. Their status, the relatively good performance of the ATOVS and AMSU-B sounding products, and remaining areas targeted for improvement are discussed.

A very real problem area concerning ATOVS and AMSU-B products is the increased volume of data. ATOVS products are available at twice the density (100K soundings daily) of the current Revised-TOVS products. AMSU-B provides an additional 2.5 million

soundings per day at full density. This is likely to cause problems for most users and existing telecommunications systems. A preliminary scheme for subsampling and combining these products for distribution to users is presented.

Impact of ATOVS on NWP forecast accuracy

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The UK Met. Office receives global TOVS and ATOVS data in near real-time from NESDIS. The TOVS data is 120 km resolution NESDIS 'RTOVS' data, with HIRS, MSU and SSU brightness temperatures pre-processed and mapped to the HIRS grid. The ATOVS data are level 1B instrument counts from HIRS, AMSU-A and AMSU-B, which we convert to brightness temperatures, pre-process, and map to the HIRS grid, using the EUMETSAT AAPP software.

TOVS and ATOVS brightness temperatures are processed in a one-dimensional variational analysis (1DVAR) scheme. The brightness temperatures are combined with 6-hour forecasts of temperature and humidity profiles from a NWP model to give statistically optimal profiles. These profiles can be assimilated to initialise our global NWP model.

We currently assimilate only TOVS data, from NOAA-11 and NOAA-14. We present here results from a trial in which NOAA-11 TOVS data was replaced in the assimilation by NOAA-15 ATOVS data. We assess the overall effect of the ATOVS data on forecast skill, verifying against observations and analyses, and we show cases in which the ATOVS data has had an impact upon individual forecasts.

Water vapor profiling with SSM/T-2 data employing a hybrid inversion algorithm

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The feasibility of retrieving water vapor profiles from SSM/T-2 data is demonstrated by use of a hybrid inversion algorithm. The SSM/T-2 downlooking sounder data - consisting of brightness temperature measurements in five microwave bands sensitive to water vapor (frequencies near 90/150/183 GHz) - can be used, together with total water vapor content data, in order to compute water vapor profiles of about 3-5 km vertical resolution.

The radiative transfer equation for this profiling problem yields a nonlinear mapping of state space into measurement space, which is reflected in a significant nonlinearity in the cost functional to be minimized. We employed a Bayesian approach to nonlinear inversion (linearized optimal estimation), complemented by several extensions tailored to further minimize the nonlinear cost functional. We investigated, in particular, problems related to the sensible guess of *a priori* information, the shape of probability density functions involved, and the potential of Monte Carlo and simulated annealing techniques.

The resulting hybrid algorithm combines the strengths of library-furnished minimal-cost *a priori*, Marquardt-Levenberg optimal estimation, simulated annealing, and iterative *a priori* lightweighting. Based on synthetic state vector data, we show the utility and the characteristic features of each of these algorithm components. The hybrid algorithm was found to cope well with the subtleties involved in passive downlooking microwave sounding and to robustly deliver reliable water vapor profiles.

For an initial validation based on genuine data, we compared SSM/T-2 water vapor retrievals to co-located water vapor profiles from ECMWF (European Centre for Medium-Range Weather Forecasts) atmospheric analyses, taking the required auxiliary temperature information from the analyses. A statistical validation indicated an accuracy of about 15 to 20% for retrieved relative humidity profiles.

The developed algorithm can be readily extended to include all sensible sources of additional information, on the state as well as from additional measurements. It is, furthermore, fairly straightforward to adapt it for retrievals of water vapor and temperature from the Advanced Microwave Sounding Unit (AMSU).

Frequency management of EESS (passive)

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Improved stratospheric temperature retrievals for climate reanalysis

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The Data Assimilation Office (DAO) is embarking on plans to generate a twenty year reanalysis data set of climatic atmospheric variables. One of the focus points will be in the evaluation of the dynamics of the

stratosphere. The Stratospheric Sounding Unit (SSU), flown as part of the TIROS Operational Vertical Sounder (TOVS), is one of the primary stratospheric temperature sensors flown consistently throughout the reanalysis period. Seven unique sensors made the measurements over time, with individual instrument characteristics that need to be addressed. The stratospheric temperatures being assimilated across satellite platforms will profoundly impact the reanalysis dynamical fields. To attempt to quantify aspects of instrument and retrieval bias we are carefully collecting and analyzing all available information on the sensors, their instrument anomalies, forward model errors and retrieval biases.

For the retrieval of stratospheric temperatures, we adapted the minimum variance approach of Jazwinski (1970) and Rodgers (1976) and applied it to the SSU soundings. In our algorithm, the state vector contains an initial guess of temperature from a model six hour forecast provided by the Goddard EOS Data Assimilation System (GEOS/DAS). This is combined with an *a priori* covariance matrix, a forward model parameterization, and specifications of instrument noise characteristics. A quasi-Newtonian iteration is used to obtain convergence of the retrieved state to the measurement vector. This algorithm also enables us to analyze and address the systematic errors associated with the unique characteristics of the cell pressures on the individual SSU instruments and the resolving power of the instruments to vertical gradients in the stratosphere.

The preliminary results showing improved retrievals and their assimilation as well as baseline calculations of bias and rms error between the NESDIS operational product and collocated ground measurements will be presented.

Recent developments at ECMWF in the assimilation of TOVS radiances

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There have been a number of significant developments in the use of TOVS radiances at the European Centre for Medium-Range Weather Forecasts (ECMWF) over the past two years. A major change to the variational assimilation system took place on 25 November 1997 when the old 3DVar system was replaced by 4DVar. The transition to RTOVS data, also made in December 1997, enabled the use of HIRS-8 and MSU-1 radiances. In June 1998 the use of the TOVS radiances has been extended to include the use of more channels over land/ice. The observation operator for TOVS (RTTOV) has recently been enhanced and finally a new radiance bias correction scheme was implemented. This paper will outline these changes, except for the bias correction which is described in another paper, and show their impact on the ECMWF model analyses and forecasts.

The TOVS Pathfinder Path-P data set for Arctic climate studies: Data set properties and validation

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The TOVS Path-P data set of temperature and humidity profiles and cloud properties has been generated for the period 1979-1996 for the north polar region (north of 60 degrees). The data set is based on the Improved Initialization Inversion Algorithm (3I; Chedin *et al.* 1985) with modification to improve the performance over the ice-covered surfaces.

In this paper we present the main characteristics of the data set and report our validation results. We discuss remaining problems and investigate errors in the context of potential applications.

Incorporating satellite Microwave Sounder measurements in the Mesoscale Model: MM5

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A regional weather forecast system is established based on a Mesoscale Model and thermodynamic soundings derived from the satellite microwave sounder measurements. The Mesoscale model consists of a UNIX workstation version of the Penn State/ National Center for Atmospheric Research MM5 numerical model. We have been using the SSM/T1 and SSM/T2 sensors of the DMSP satellite series to derive the vertical profiles of atmospheric temperature and humidity. We are currently working on the incorporation of NOAA-15 AMSU measurements. These satellite-derived soundings are applied in the initialization and four-dimensional data assimilation of the regional weather forecasts, in conjunction with the large-scale global model analyses / forecasts which provide boundary conditions for the Mesoscale Model as well as first guess information. All components that make up the forecasting system, including the Mesoscale Model, satellite reception and data processing, global model data ingesting, and Mesoscale

Model output processing and display, are integrated into a complete workstation-based operational system.

Atmospheric moisture flux across the Southern Ocean via satellite analysis

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The mass of the Antarctic ice sheet remains the parameter with largest uncertainty in the global sea level equation. By measuring water vapor convergence, precipitation input to the Antarctic ice sheets may be evaluated. Previous studies have estimated this parameter using output from numerical models or the limited Antarctic radiosonde network. Satellite data from the TOVS Operational Vertical Sounder (TOVS) and the Special Sensor Microwave/ Imager (SSM/I) offer excellent spatial and temporal coverage of both moisture and wind fields. Our research using TOVS and SSM/I data indicates higher poleward moisture transport across 50° South latitude than previously thought. The resulting net precipitation for the 50 - 60° South latitude band is about 50% larger than indicated by contemporary studies using radiosonde and atmospheric analyses. Maximum poleward moisture flux across 60° South occurs in the South Pacific and southeastern Indian Ocean sectors. There is a dramatic moisture flux discontinuity across the Antarctic peninsula and the tip of South America near 45° West with equatorward moisture transport at all latitudes in the Weddell Sea sector. A regional study of precipitation input to the West Antarctic ice sheet surface indicates large poleward moisture flux is accomplished there through the Bellingshausen and Amundsen Seas only.

High spectral resolution sounding: latest results from aircraft and their implications for future satellite systems

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Hampton, VA, USA
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UW-Madison
Madison, WI, USA
D. Cousins, M. Gazarik and D. Mooney
MIT-LL

A new high spectral resolution (0.25 cm^{-1}) and high spatial resolution (2 km) scanning (45 km swath) interferometer sounding system has been built for flight on the NASA high altitude (20 km) ER-2 aircraft. The instrument, called the NPOESS Aircraft Sounding Testbed-Interferometer (NAST-I) has been flown to provide the experimental observations needed to finalize the specifications and to test proposed designs for future satellite instruments, particularly the Crosstrack scanning Infrared Sounder (CrIS) to fly on the National Polar orbiting operational Satellite System (NPOESS). NAST-I has been flown during several field campaigns. The data have been utilized to analyze spectral and spatial resolution requirements for future sounding systems. Also, the NAST-I has provided new and exciting observations of the mesoscale structure of the atmosphere, including the fine scale thermodynamic characteristics of hurricanes. Remote sensing results obtained from the NAST-I aircraft data are presented. Implications for future satellite sounding system designs are discussed.

Intercomparison of NESDIS-retrieved, RAWIN- and HELIPOD-observed, and MRAP-retrieved atmospheric temperature and dewpoint profiles during the PHELIX experiment

B. Stankov, A. Reale*, R. Lataitis, D. Wolfe, T. Wilfong, A. Muschinski, E. Gossard and S. King
NOAA/ETL, Boulder, CO, USA
**NOAA/NESDIS, Washington DC, USA*

The success of the Multi-sensor Retrieval of Atmospheric Parameters (MRAP) method (Stankov 1998) depends on accurate, high frequency, Wind Profiler/RASS measurements of humidity gradients and virtual temperature. In November 1997, NOAA's Environmental Technology Laboratory (ETL) conducted the Profiler/ Helipod Intercomparison Experiment (PHELIX), to test how well the 449 MHz Wind Profiler/RASS system measures atmospheric fine-scale structure. The experiment was conducted at Vandenburg Air Force Base (VAFB), California. In situ, verification measurements were obtained by releasing 30 rawinsondes, and by deploying the University of Hannover's newly developed helicopter-borne turbulence measurement system. In addition, NOAA's National Environmental Satellite, Data and Information Service (NESDIS) collected their operationally-retrieved temperature and dewpoint profiles using NOAA-11, NOAA-12 and NOAA-14 measurements. In the future we will show results of these intercomparisons. In this poster presentation, however, we will only show the experimental setup and one preliminary result.

Preliminary results from analysis of NOAA 15 HIRS/AMSU data

Joel Susskind
Laboratory for Atmospheres
NASA Goddard SFC
Greenbelt, MD, USA

We have begun analyzing NOAA 15 HIRS3/AMSU A/ AMSU B data in a manner basically analogous to that used to produce the TOVS Pathfinder Data Set, with some minor improvements to the processing system. Temperature retrievals using NOAA 15 HIRS3/ AMSU A are found to be similar, but superior to those of nearly collocated NOAA 11 HIRS2/MSU/SSU data. AMSU B has some calibration problems related to RFI from the transmitters on the satellite. We have developed a methodology to account for this interference and have shown that the data are usable giving improved moisture profiling capability over previous satellites.

Monitoring climate variability and trends from the TOVS Pathfinder Path A data set

Joel Susskind
Laboratory for Atmospheres
NASA Goddard SFC
Greenbelt, MD, USA

Surface and atmospheric geophysical parameters derived from infrared and microwave atmospheric sounders provide an important data set for monitoring climate variability on interannual and decadal time scales. Similar TOVS (TIROS Operational Vertical Sounder) instrumentation has flown on the NOAA Operational Polar Orbiting Satellites from November 1979 to the present. We have been analyzing the data using a frozen processing methodology to produce 2-4 times daily global fields of land/ocean surface skin temperature, atmospheric temperature and moisture profile, cloud height and fractional cloud cover, OLR and Clear Sky OLR, and precipitation, on a 1° x 1° latitude - longitude grid. The TOVS Pathfinder Path A data set currently covers the period January 1985 to the present. For most variables, the only significant difference between data obtained from different satellites relates to differences in the time of day they view a given spot. We have developed a methodology to account for this effect in studying interannual variability and trends. Global and regional trends of surface and atmospheric temperature over this time period will be shown and compared to other data sets. Sample results will also be shown comparing the effect of the 1997-98 El Niño on tropical circulation to those of previous El Niño/La Niña episodes in the 1985-1996 time frame. We plan to analyze January 1979-December 1984 in the near future, providing a 20 year data set of consistently analyzed data.

Development activity of JMA on the use of TOVS/ATOVS data

Yoshiaki Takeuchi, Kozo Okamoto and Sang-Won Joo
Numerical Prediction Division, Forecast Dept
Japan Meteorological Agency, Tokyo, Japan

Sounder data from NOAA satellites are used at the Numerical Prediction Division (NPD) and the Meteorological Satellite Center of JMA. The NPD uses global TOVS products from NESDIS and regional products from MSC for numerical weather prediction.

JMA/NPD has developed a 1 dimensional variational (1DVAR) assimilation system for the JMA global numerical weather prediction (NWP) model. The system is based on RTTOV version 3 modified to fit our objective analysis system. The background error data are estimated from the global NWP model (GSM 9603) and radiation biases of RTTOV are calculated each month. Preliminary results from an impact test of TOVS-1DVAR show that a large positive impact is evident in the southern hemisphere.

JMA/MSC has been developing a retrieval system for locally received NOAA-15 data. In the system, AVHRR statistical parameters, HIRS and AMSU data can be interpolated at three kinds of common horizontal resolutions. HIRS resolution data are used to produce vertical temperature/ humidity profiles in clear regions, AMSU-A resolution data are used for vertical temperature/ humidity profiles, and AMSU-B resolution data are used to produce surface and vertically integrated fields. A cloud detection procedure using AVHRR statistical parameters is executed at each resolution.

Detection, by the TOVS, of some cases of influence of the Intertropical Convergence Zone (ITCZ) over the Northeast Region of Brazil in its rainy season

Raul Fritz Bechtel Teixeira
Research and Development Division
Department of Meteorology
Fundacao Cearense de Meteorologia e Recursos Hidricos - FUNCEME
(Foundation of Meteorology and Water Resources of Ceara State)
Fortaleza, Ceara, Brazil

This simple study is concerned with a short outline of the current operational uses of TOVS data received and processed at FUNCEME. It also briefly describes the main research and operational activities related to TOVS already developed at FUNCEME.

Regarding the present operational use of TOVS at FUNCEME, some data derived from the NOAA-14 satellite atmospheric soundings estimated by the ITPP-5.0 (International TOVS Processing Package, version 5.0) software in "regression guess/tigr database" basic mode, and displayed as relative humidity at 1000 mb, total precipitable water vapor and 500 mb lifted index fields, were used to predict (qualitatively) some cases (the first two) of influence, on precipitation, of the ITCZ over the north of the North-east of Brazil, especially Ceara State, in the 1998 rainy season.

The TOVS data (in the form of simple charts of meteorological fields) can be used, with care, as an auxiliary source of meteorological information for the weather forecast over areas in the southern hemisphere and near the equator, such as the North-east Region of Brazil.

SMHI precipitating clouds product from AVHRR and AMSU data

Anke Thoss
Swedish Meteorological and Hydrological Institute
Norrkoeping, Sweden

At SMHI, a precipitating clouds product based on AVHRR and AMSU data is currently being developed. Based on the operational cloud type analysis scheme SCANDIA, optically thick clouds, which might precipitate, are screened out for further investigation. For these clouds the solar reflective part of the 3.7 micron radiance is used to calculate an effective droplet radius near cloud top, which is correlated with the likelihood of precipitation. The retrieval of the effective radius is based on radiative transfer calculations using the adding and doubling method. Making use of the NORDRAD Radar network covering the Baltic Sea area, the correlation between effective radius and precipitation can be accurately specified.

A second input to the scheme over the sea will be an AMSU precipitation retrieval relying mainly on the scattering signature of precipitation-sized ice particles in the 89 GHz and 150 GHz channels. The method is principally the same as the scheme presented by Bennartz and Petty (separate presentation). Over sea, both algorithms will finally be merged, taking into account the areal extent of possibly precipitating clouds within the AMSU footprint to modify the derived precipitation area and intensity.

Temperature and moisture profiles over the Mongolian Region from NOAA/TOVS satellite data

N. Tsengel and Z. Batjargal
Institute of Meteorology and Hydrology
Ulan Bator, Mongolia

Numerical weather prediction models, in addition to wind profiles, need temperature and moisture profiles with radiosonde-type accuracy, but current satellite systems are unable to satisfy this requirement. At the same time, the existing global upper air sounding network cannot provide high temporal and spatial resolution data, particularly over the ocean and over some parts of Asia, like Siberia and the territory of Mongolia. In this regard it is necessary to develop a methodology using an alternative source of information, like TOVS-type data.

The International TOVS Processing Package (ITPP-4) developed by the University of Wisconsin, USA, was used for retrieving temperature and moisture profiles. In the physical retrieval method, as an initial first guess, temperature profiles have been used with the climatological and regression estimates generated from stratospheric level HIRS and MSU channels. This paper discusses the results of temperature and moisture retrievals over Mongolia and neighbouring regions in both the winter and summer seasons. It aims to show an evaluation of the accuracy of TOVS data through a comparative study against two other data sources, namely radiosonde measurements and ECMWF analyses. Basic statistics are presented for clear and cloudy retrievals respectively.

Rapid convolution of LBL transmittances and radiances

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Atmospheric Environment Service (AES)
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Due to the proliferation of new satellites and instruments in recent years, a need has arisen for the relatively rapid calculation of line-by-line quality mean radiances and transmittances for the purpose of creating coefficients for fast forward radiative transfer models and testing purposes. This paper describes a database that is essentially a collection of top-of-the-atmosphere transmittance spectra evaluated in half wavenumber wide bands at various zenith angles for 189 atmospheric states which can be quickly convoluted with an instrument function. The database is also broken down by absorber (H_2O, CO_2, O_3, N_2O, CO, CH_4, O_2 and N_2). The database is applicable to any response function contained within the 600 to 3000 wavenumber region. The database has currently been used to create AES's fast model for the sounding

instruments on NOAA 12, 14 and GOES 8, and the imager on GOES 8 and 10. In addition, the database has been used to examine the error brought about by approximating the radiative transfer equation with a monochromatic equivalent.

AAPP at NIWA: Cloud amount and type: impacts on HIRS, AMSU-A and AMSU-B

Michael Uddstrom and Aarno Korpela
National Inst. of Water and Atmospheric Research
Wellington, New Zealand

NOAA-15, first of the 'NOAA-Next' series of satellites, launched on 13 May 1998, is carrying ATOVS, the new set of sounding instruments. Being one of the beta-testing sites for the EUMETSAT AAPP software, NIWA (National Institute of Water and Atmospheric Research) has been processing NOAA-15 ATOVS data for validation purposes as part of its operational satellite data processing.

The AMSU-A/B sounder has 20 channels in the frequency range 23 to 190 GHz. While HIRS infrared measurements are affected strongly by clouds, at the microwave, low-frequency end the upwelling radiation is not much attenuated. AMSU is therefore expected to improve temperature and humidity retrievals significantly in cloudy conditions. On AMSU higher frequency channels, however, scattering and absorption in thick clouds by ice particles and large water droplets start to limit sounding capability. These channels, on the other hand, can provide useful information about cloud characteristics. NIWA is utilising HIRS and AMSU data together with collocated NOAA AVHRR data and New Zealand Met Service scanning radar data to determine cloud effects on the measured brightness temperatures. Cloud clearing and classification by using AVHRR data, together with collocated radar measurements, provide a useful data set for validating the algorithms for deriving cloud characteristics from radiance measurements.

In future, estimates of cloud liquid water content together with other derived ATOVS products will be utilised in the Mesoscale Data Assimilation Programme. This presentation will outline progress to date.

The prospects for remote sounding of trace gas column amounts and profiles from high spectral resolution IR radiance measurements

Alexander B. Uspensky
SRC Planeta
Moscow, Russia
A.N. Trotsenko, S.V. Romanov *and* **A.N. Rublev**
RRC Kurchatov Institute
Moscow, Russia

The design of space-borne instruments for measurements of IR radiance spectra with high spectral resolution (EOS-AIRS, METOP-IASI missions) promises significant improvements in the remote sounding of atmospheric gas composition. The problem under consideration in this paper is the derivation of column amount (CA) and/or vertical profiles (VP) of some tropospheric trace gases especially nitrous oxide (N_2O), methane (CH_4) and carbon monoxide (CO) from forthcoming IASI data. The approach developed is based upon the relevant inverse problem formulation and solution; the temperature and water vapor profiles are treated as interfering parameters. The entropy reduction (in a Shannon sense) has been used as the measure of information content for the selection of the appropriate subset of channels for retrieval. The paper presents a retrieval error analysis and the sensitivity studies of errors to ancillary data on temperature and water vapor profile uncertainties. The anticipated retrieval accuracy results are demonstrated for different atmosphere models both for CA and VP retrievals.

The improved remote sounding of land skin temperature and emissivity using high spectral resolution IR radiance measurements

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One of the objectives of satellite IR radiance measurements with high spectral resolution (provided by forthcoming EOS-AIRS, METOP-IASI missions) is the derivation of surface skin temperature (Ts) with a target accuracy better than 1.0 K and surface spectral emissivity (SSE). This presentation considers the new method of Ts, SSE retrieval from high resolution radiance measurements in the set of atmospheric microwindow channels selected from two spectral regions: 4.65 - 4.76 and 8.55 - 9.35 micrometers. The

proposed physical retrieval method makes use of data in this set of channels and is based on the following concepts: (1) utilization of the split window type technique for removal of the atmospheric attenuation effect; (2) specification of SSE from measurement or an *a priori* statistical model for diverse types of surfaces. To theoretically validate the proposed method, the r.m.s. errors of Ts and SSE retrievals have been calculated and their sensitivity to various input parameters was investigated. Application of the method to simulated IASI data demonstrates the feasibility of Ts retrievals (attainability of target precision) and closeness of theoretical error analysis results and retrieval simulation statistics.

Validation of NOAA-15 HIRS/3 radiances from high spectral resolution aircraft observations during the Wallops98 field experiment

Paul van Delst
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Madison, WI, USA

During the Wallops98 field experiment, 24 June - 15 July 1998, two clear sky underflights of the NOAA-15 satellite with the ER-2 were performed over the ocean off the US Atlantic coast. The infrared instruments on the ER-2 were the NAST-I, a cross-track scanning interferometer sounder with 9000 channels in the infrared from 3.5 - 17 microns, and the HIS, a nadir viewing interferometer sounder with 3000 channels in the infrared from 3.7 - 16.5 microns. The NOAA-15 channel radiances that fall within these spectral bounds are validated by comparison of the radiance residuals between observations and calculations of the aircraft and satellite radiances (the former after convolution of the high resolution radiances with the HIRS/3 spectral response functions). The sensitivity of this comparison to lack of knowledge of the state of the atmosphere above the aircraft is also investigated.

Tropical cyclone warm core structures as revealed by AMSU-A

Christopher Velden
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University of Wisconsin - CIMSS
Madison, WI, USA

The launch of the first AMSU on NOAA-15 in early 1998 marked a significant step forward in our ability to observe thermal anomalies in tropical cyclones. These anomalies can be related to surface pressure in the storm center through hydrostatic assumptions. Accurate satellite-based techniques to estimate central surface pressure are highly desirable in regions, or at times, when aircraft reconnaissance is unavailable.

The increased footprint resolution and sensor precision of AMSU will greatly improve the resolvability of the peak warming profiles in the tropical cyclone core. Methods to extract this information in profile form will be presented at the workshop. Examples of warm core depictions and profiles, and first attempts to relate these to intensity estimates, will also be given.

The International ATOVS Processing Package (IAPP): the next generation ITPP

W. Wolf, P. van Delst, Jun Li, T. H. Achtor, H. Woolf, F. Nagle, H-L. Huang and Paul Menzel
Coop. Inst. for Meteorological Satellite Studies
Space Science and Engineering Center
University of Wisconsin - Madison
Madison, WI, USA

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has developed the International ATOVS Processing Package (IAPP), the next generation of the International TOVS Processing Package (ITPP). The IAPP is a completely new package with a different design than the ITPP. It has been written in FORTRAN-90 with some FORTRAN-77 subroutines. The code is well documented with an extensive Users Guide.

Currently, the IAPP is written to use the ATOVS and AVHRR Processing Package (AAPP) for signal decommutation, navigation, and calibration. The input NOAA-K data files are in the AAPP level 1D format (HIRS, AMSU-A, AMSU-B, and AVHRR data are all used). All other input and output files are in NetCDF format. This enables a general, widely used data format for the TOVS community. The IAPP outputs include temperature profiles, moisture profiles, ozone profiles, and the microwave surface emissivity.

NOAA-15 HIRS/3 and AMSU transmittance model validation

Hal Woolf and Paul van Delst
CIMSS/SSEC, UW-Madison
Madison, WI, USA

Two regression transmittance models for NOAA-15 HIRS and AMSU are validated - PLOD and OPTRAN. Comparisons are made between the regression and line-by-line transmittances for nadir and a 60° zenith angle for both the dependent and an independent set of atmospheric profiles. The dependent set consists of the 32 atmospheres used in generating RTTOV and the independent set consists of 15 atmospheres from the Météo-France set of 32 atmospheres. For the opaque AMSU channels 9-14 and HIRS channels 1-3, the effect of extending the atmospheric profiles from 0.1

mb to 0.005 mb is presented. Comparisons of co-located sonde and scan bias corrected satellite observations are also presented for both transmittance models.

MSU/TOVS weighting function after limb-adjustment

Zhen-Jia Wu and Bryant McAvaney
Bureau of Meteorology Research Centre, Melbourne, Vic., Australia

In many of the present operational TOVS processing systems, the HIRS, MSU and SSU data undergo a 'limb-adjustment' treatment. This method produces the radiances at the nadir position for a TOVS channel by using a linear combination of the non-nadir radiances of 'associated' channels. There has been a degree of skepticism in the scientific community on this method. Recently, Wu and McAvaney (1998), in a study of climatological MSU data processing methods, found that the weighting functions and properties of MSU were affected by a simple limb-adjustment treatment, which used only one associated channel.

In the present paper, the theoretical weighting functions of the limb-adjusted MSU are derived and calculated according to the linear combination coefficients of Wark (1993) for the viewing angle of 56.6°. It is found that the weighting functions of the limb-adjusted MSU deviate significantly from the originals. The forward calculated original and limb-adjusted MSU data are compared, and significant differences are also found.

Boundary layer water vapor retrieval from AMSU: simulation study and data analysis

Wenjian Zhang[1,*], W. Paul Menzel[3], Jun Li[2], Walter Wolf[2], Allen-Huang[2] Chaohua Dong[1] and Yuanjing Zhu[4]
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Cooperative Institute of Meteorological Satellite Studies, University of Wisconsin, USA[2]
National Environmental Satellite, Data, and Information Service, NOAA, USA[3]
Department of Geophysics, Peking University, Beijing, CHINA[4]

Water vapor is one of the key meteorological variables. Half of the water vapor in the atmosphere is between sea level and 850 hPa, and less then 10% is above 500 hPa. The Infrared sounders, such as HIRS and the GOES-sounder are quite sensitive to high level water vapor variation. However, because of the physical difficulties and instrumental limitations, it is quite difficult to retrieve accurate boundary layer water vapor information from the current operational IR sounders.

Theoretical analysis and sensitivity simulation studies indicate that the response of the channels' brightness temperatures of the Advanced Microwave Sounding Unit (AMSU) onboard the NOAA-15 satellite are very sensitive to boundary layer (below 850 hPa) water vapor variations over oceans with lower emissivity providing a cold background in the microwave radiometric sense. With the optimum channel combination of the HIRS/3 and AMSU, it is possible to retrieve accurately the water vapor vertical distributions. This paper will present firstly the physical principals, theoretical analysis and some simulation results. Then, based upon the AMSU real data analysis, the paper will show the results that fit the physical analysis and simulation results.

* Visiting scholar from the National Satellite Meteorological Center, Beijing, China

Effects of atmospheric correction on retrieving land surface temperature using AVHRR data

Gao-Xiang Zhao and Hong-Qi Wang
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For accurate determination of land surface temperature (LST) from satellite measurements, one severe obstacle is related to the coupling between the surface temperature and emissivity. To deal with this problem, two algorithms have been proposed, in which a set of two or three channel measurement data made at two different times are used. Simulation results show that with these two algorithms, LSTs could be determined rather accurately, if the atmospheric effect could be omitted. In real situations, the atmospheric effect is not negligible; for any retrieval algorithm of practical use, the atmospheric effect must be taken into consideration. In fact, the atmospheric effect constructs another main difficulty in the determination of LSTs. In retrieving LSTs with two or three AVHRR channels, the most practical way to make atmospheric correction is to utilize atmospheric temperature and moisture profiles obtained with collocated TOVS/ATOVS data. With these LST retrieval algorithms and by the use of collocated TOVS/ATOVS data having reasonable retrieval errors to make atmospheric correction, reasonably accurate LSTs could be obtained. The r.m.s. errors in LSTs determined are usually less than 2K.

WEDNESDAY 27 JAN 1999

0800 - 0900 REGISTRATION
0900 - 0955 INTRODUCTORY SESSION
(Chairs: Rochard/ Le Marshall)
- **Welcome**
- **Opening**
- **Presentation and discussion of agenda**

0955 - 1025 BREAK

1025 - 1235 SCIENTIFIC PRESENTATIONS
(Chair: Le Marshall)

SESSION 1a: ATOVS

1a1 Grody
Application of AMSU for obtaining water vapor, cloud liquid water, precipitation and surface measurements.
1a2 Burns
Simulation of ATOVS Temperature Profiling Errors Due to Uncertainty in Microwave Land Surface Emissivity
1a3 English & Jones
The impact of cloud and precipitation on AMSU soundings
1a4 Goldberg
AMSU-A antenna temperature adjustments, limb adjustments and retrievals
1a5 Prigent, Rossow & Wigneron
Microwave land surface emissivities derived from SSM/I and SSM/T-2: extrapolation to AMSU frequencies and scanning pattern
1a6 Reale
Scientific status of NESDIS Advanced-TOVS (ATOVS) sounding products
1a7 Chalfant
A report on AMSU-B (10 min)

1235 - 1350 LUNCH

1350 - 1530 SCIENTIFIC PRESENTATIONS
(Chair: Rochard)

SESSION 1b: ATOVS

1b1 Billing
AMSU surface channels in comparison with infrared data
1b2 Patel, Platt & Burns
An assessment of the in-orbit performance of the NOAA-15 AMSU-A instrument
1b3 Kelly, Harris, Saunders, McNally & Le Marshall
High resolution 1-D Var AMSU-A retrievals using an NWP first-guess and comparison with the TL639 resolution (~30 km) model
1b4 Li, Wolf, Menzel, van Delst, Huang, Achtor, Zhang & Woolf
The International ATOVS Processing Package (IAPP): The algorithm and its application in real data processing
1b5 Velden
Tropical cyclone warm core structures as revealed by AMSU-A

1530 - 1600 BREAK

1600 - 1720 SCIENTIFIC PRESENTATIONS
(Chair: Eyre) .. Sessions 1c and 2a

SESSION 1c: ATOVS

1c1 Zhang, Menzel, Li, Wolf, Huang, Dong & Zhu
Boundary layer water vapor retrieval from AMSU: simulation study and data analysis

SESSION 2a: TOVS/ ATOVS in NWP

2a1 Derber
The incorporation of NOAA-15 data and the improved use of radiance data in the NCEP global assimilation system
2a2 Andersson
A study of TOVS and ATOVS background errors in radiance space in a variational analysis scheme
2a3 Chouinard & Halle
The impact of cloud-cleared TOVS radiances in the CMC 3D variational analysis scheme

1730 - 2100 RECEPTION AT NCAR MESA LAB

THURSDAY 28 JAN 1999

0850 - 1030 SCIENTIFIC PRESENTATIONS (Chair: Chouinard)

SESSION 2b: TOVS/ ATOVS in NWP

2b1 Munro, Kelly & Saunders
Assimilation of geostationary water vapour radiance data at ECMWF
2b2 Saunders, Andersson, Kelly, Munro & Harris
Recent developments at ECMWF in the assimilation of TOVS radiances
2b3 McNally
Assimilation of TOVS and ATOVS raw radiance data in the ECMWF 4D-Var analysis
2b4 Renshaw, English, Smith & Poulsen
Impact of ATOVS on NWP forecast accuracy
2b5 Caille, Cassé, Puech, Rabier &Thépaut
Implementation of the assimilation of TOVS radiances at Météo France

1030 - 1100 BREAK

1100 - 1240 SCIENTIFIC PRESENTATIONS (Chair: Menzel) .. Sessions 2b and 3a

SESSION 2b: TOVS/ ATOVS IN NWP

2b6 Shi
Incorporating Satellite Microwave Sounder Measurements in the Meso-Scale Model MM5
2b7 Harris & Steinle
Variational TOVS radiance assimilation in the GASP model at BMRC

SESSION 3a: TOVS/ ATOVS IN CLIMATE STUDIES

3a1 Bates
Use of TOVS upper tropospheric water vapor channel data in climate and global change research
3a2 Schweiger & Francis
The TOVS Pathfinder Path-P data set for Arctic climate studies: Data set properties and validation
3a3 Susskind
Monitoring climate variability and trends from the TOVS Pathfinder Path A data set

1240 - 1400 LUNCH
1400 - 1540 SCIENTIFIC PRESENTATIONS (Chair: Dong Chaohua) .. Sessions 3b and 4a

SESSION 3b: TOVS/ ATOVS IN CLIMATE STUDIES

3b1 Mehta & Susskind
Intercomparison of TOVS Path A and NVAP Water Vapor data sets
3b2 Francis & Schweiger
New climate applications of TOVS retrievals in polar regions
3b3 Rokke & Joiner
Improved stratospheric temperature retrievals for climate reanalysis

SESSION 4a: PREPARATION FOR ADVANCED SOUNDERS

4a1 Barnet
Simulation studies of advanced infrared and microwave sounders
4a2 Cassé, Brunel, Blaison, Karcher, Labrot, Prunet, Rabier & Thépaut
The IASI program in the framework of Météo-France

1540 - 1610 BREAK

1610 - 1640 WORKING GROUP FORMATION
- **ATOVS/TOVS in Climate Studies**
- **ATOVS/TOVS data in NWP**
- **ATOVS - characteristics, processing software and data use**
- **Advanced Infrared Sounders**
- **International issues and future systems**

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

1730 - 2000 POSTER SESSION
(See list of posters following this agenda)

FRIDAY 29 JAN 1999

0850 - 1030 AGENCY STATUS REPORTS (Chairs: Le Marshall/ Rochard)
Relations with other bodies:
IRC (Smith, 5 min)
CGMS (Menzel, 5 min)
WMO (Hinsman/ Eyre/ Menzel/ Le Marshall, 5 min)

Reports on issues raised at ITSC - IX
Frequency protection (Rochard, 5 min)
Re-analysis at NCEP (Derber, 5 min)
Re-analysis at ECMWF (Kelly, 5 min)
Re-analysis at GSFC (Joiner, 5 min)
TOVS Pathfinder (Goldberg/ Scott/ Susskind/ Bates, 5 min)
Review of actions from ITSC - IX (30 min)
Any other items / discussion
EOS Direct Broadcast Planning Group

1030 - 1100 BREAK

1100 - 1250 SCIENTIFIC PRESENTATIONS (Chair: Kleespies)

SESSION 4b: PREPARATION FOR ADVANCED SOUNDERS

4b1 Smith, Larar, Howell, Sisko, Knuteson, Revercomb, Cousins, Gazanik & Mooney
High spectral resolution sounding: latest results from aircraft and their implications for future satellite systems (30 min)
4b2 Eyre & Collard
The effects of nonlinearity on retrieval errors: implications for the interpretation of Advanced Infra-red sounder data
4b3 Goldberg & McMillin
Advanced infrared sounder data applications and results
4b4 Uspensky, Trotsenko, Romanov & Rublev
The prospects for remote sounding of trace gas column amounts and profiles from high spectral resolution IR radiance measurements
4b5 Huang, Gumley & Menzel
Direct broadcast reception and processing system for EOS

1250 - 1415 LUNCH

1415 - 1530 SCIENTIFIC PRESENTATIONS (Chair: Hinsman)

SESSION 5: FUTURE SYSTEMS

5-1 Menzel / Purdom
NOAA's plans for polar satellites: 1999 and beyond (15 min - invited paper)
5-2 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)

1530 - 1600 BREAK

1600 -1700 SCIENTIFIC PRESENTATIONS (Chair: Kelly)
SESSION 6a: SCIENTIFIC STUDIES AND DEVELOPMENT - USING TOVS/ ATOVS

6a1 Chou
Application of AVHRR data to a one-dimensional variational retrieval scheme for cloudy TOVS data
6a2 Takeuchi, Okamoto & Joo
Development activity of JMA on the use of TOVS/ATOVS data
6a3 Van Delst
Validation of NOAA-15 HIRS/3 radiances from high spectral resolution aircraft observations during the Wallops98 field experiment
6a4 Woolf & van Delst
NOAA-15 HIRS/3 and AMSU transmittance model validation

1700 - 1745 PRESENTATION ON SOFTWARE PACKAGES (Chairs: Rochard/ Le Marshall)

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

Technical sub-groups
AAPP
IAPP
RTATOV
3I/3R

EVENING: WORKING GROUP MEETINGS

SATURDAY 30 JAN 1999
WORKING GROUP MEETINGS

SUNDAY 31 JAN 1999
WORKING GROUP MEETINGS

MONDAY 1 FEB 1999

0900 - 1030 SCIENTIFIC PRESENTATIONS (Chair: Smith)

SESSION 6b: SCIENTIFIC STUDIES AND DEVELOPMENTS - USING NEW INSTRUMENTS

6b1 Garand
Sensitivity of various specified parameters on the assimilation of satellite infrared radiances
6b2 Lambrigtsen
HAMSR - The first of a new generation of microwave sounders
6b3 Ceckowski, Mantica, Predina & Glumb
Preparing for the next generation operational LEO sounder - the NPOESS CrIS
6b4 Pietrapertosa, Cuomo, Kobayashi, Lanorte, Pergola, Romano, Serio & Tramutoli
Clouds spatial distributiuon and satellite sounding contamination: an impact study from AVHRR (1.1 km) up to AVNIR (8-16 m) spatial resolution
6b5 Korpela & Uddstrom
AAPP at NIWA: Status report and application to detection of rain
6b6 McMillin & Crosby
Angle adjustments from TOVS - past, present and future

1030 - 1100 BREAK

1100 - 1230 SCIENTIFIC PRESENTATIONS (Chair: Saunders)

SESSION 6c: SCIENTIFIC STUDIES AND DEVELOPMENTS - SPECIFYING THE ATMOSPHERE

6c1 Menzel & Wylie
Global cirrus clouds and upper tropospheric humidity detected using HIRS
6c2 Amato, Cuomo, Kobayashi, Lanorte, Lubrano, Pergola, Pietrapertosa, Romano & Serio
A cloud detection approach for IASI data
6c3 Cohen
Predicting the error with which an infrared imager can determine the ice-particle size of cirrus clouds
6c4 Dong & Zhang
Progress of satellite sounding data applications in China
6c5 Le Marshall, Kelly, Mills, Leslie, Blank, Choi, Steinle and Seecamp
Recent advances in the application of TOVS, ATOVS, S-VISSR and Advanced Sounder data in Australia
6c6 Kleespies
OPTRAN status report

1230 - 1400 LUNCH

1400 - 1445 SCIENTIFIC PRESENTATIONS (Chair: Bates)

SESSION 6d: SCIENTIFIC STUDIES AND DEVELOPMENTS - SOUNDING

6d1 Wolf, van Delst, Li, Achtor, Woolf, Nagle, Huang & Menzel
The international ATOVS Processing Package (IAPP): the next generation ITPP
6d2 Lavanant, Brunel, Rochard & LabrotNOAA-15 sounding profiles retrieved with the ICI scheme
6d3 Allegrino, Reale, Chalfant & Wark
Application of limb adjustment techniques for polar - orbiting sounding data

1445 - 1515 ATOVS SOFTWARE DEVELOPMENTS - GENERAL DISCUSSIONS (Chairs: Le Marshall / Rochard)

1515 - 1535 BREAK

1535 - 1700 WORKING GROUP MEETINGS

1700 - CONFERENCE DINNER

TUESDAY 2 FEB 1999

0900 - 1030 SCIENTIFIC PRESENTATIONS (Chair: Susskind)

SESSION 6e: SCIENTIFIC STUDIES AND DEVELOPMENTS - SOUNDING

6e1 Joiner and Rokke
Variational cloud-clearing and assimilation of TOVS and ATOVS data

6e2 Plokhenko
Some results of the identification of multilevel cloudiness on the basis of IR measurements from HIRS/2.

6e3 Turner
Rapid convolution of LBL transmittances and radiances

6e4 Deblonde
Variational retrievals of humidity using DMSP SSM/T-2 brightness temperatures

6e5 Kaifel & Müller
Results of neural network total ozone retrieval on global NOAA-TOVS data

6e6 Slonaker & Van Woert
Atmospheric moisture flux across the Southern Ocean via satellite analysis

1030 - 1100 BREAK

1100 - 1230 ITWG PLENARY SESSION
(Chairs: 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 OF ITSC-X

ITSC-X Posters

Achtor, Li, Wolf, Zhang, van Delst, Woolf & Nagle
An evaluation of IAPP retrieval products

Bechtel Teixeira:
Detection, by the TOVS, of some cases of influence of the ITCZ over the NE region of Brazil in its rainy season

Bennartz & Petty
Precipitation identification and retrieval from the Advanced Microwave Sounding Unit (AMSU) at mid- and high-latitudes

Borbás, Szenyán & Randriamampianina
Current status for operational processing of TOVS data at the Hungarian Meteorological Service

Breivik, Schyberg & Tveter
Using TOVS and ATOVS profile information at the Norwegian Meteorological Institute

Brown
NESDIS Products and the Year 2000

Brown
Quality control of the NESDIS sounding products

Chung & Lee
ITPP-5.12 retrievals on MCIDAS system

Citeau & Dagorne
Relationships between the water vapor above the Atlantic and Western Africa and climate in Western Africa (1985-1992): Introduction of FLUVAP project

Cohen
Predicting the error with which a two-band infrared imager can measure sea surface temperature

Cuomo, Lanorte, Pergola, Pietrapertosa, Rizzi, Romano & Serio
A new cloud-clearing scheme for infrared sounder measurements by using Kriging technique

Dibben
ATOVS mapping techniques and validation in AAPP

English
A fast generic millimetre-wave surface emissivity model

English, Smith, Rayer, Renshaw, Dibben & Eyre
Initial evaluation of ATOVS on NOAA-15 using the UKMO numerical weather forecast model

Hlavaty
Total Ozone from HIRS

Jackson & Bates
Climate analysis using the TOVS Pathfinder radiance data set

Kleespies & McMillin
Some anomalies in digital data from satellite radiometers

Lavanant, LeGléau, Derrien, Levasseur, Monnier, Ardouin & Brunel
AVHRR cloud mask for sounding applications

Lee, Chung & Cha
Evaluation of ITPP-5.12 total ozone amount

Leslie & Le Marshall
High resolution 4-D variational assimilation of satellite data

Li, Chen, Zhu & Zhao
Satellite remote sensing of precipitation in Huaihe River basin area

Li, Zhang, Huang & Menzel
The cloud-removal algorithm for HIRS/3 clear column radiance retrieval using AMSU measurements

Mehta & Susskind
Observing 1997-98 El Niño in the Indian Ocean from the TOVS Pathfinder Path A data set

Mostek, Hufford, Taylor, Dills, Wang & Kidder
Polar satellite training for the operational weather services

Müller & Kaifel
Efficient processing of multi-year global TOVS data using ITPP, 3I and neural networks

ITSC-X Posters

Pérez, Calle, Romo & Casanova
Evaluation of total ozone retrievals from TOVS-ITPP software by comparison with other ozone data sources

Randriamampianina, Lavanant & Roquet
The study of the horizontal structure of the 'SATEM Lannion' data

Reale
Scientific status of NESDIS operational sounding products from DMSP polar orbiting satellites

Reale
Scientific status of NESDIS Revised-TOVS (RTOVS) sounding products

Rieder & Kirchengast
Water vapor profiling with SSM/T-2 data employing a hybrid inversion algorithm

Rochard
Frequency management of EESS (passive)

Susskind
Preliminary results from analysis of NOAA 15 HIRS/ AMSU data

Tabor
Distribution and archive of sounding products from NOAA-15

Thoss
SMHI precipitating clouds product from AVHRR and AMSU data

Tsengel & Batjargal
Temperature and moisture profiles over Mongolian Region from NOAA/TOVS satellite data

Uspensky, Trotsenko & Romanov
The improved remote sounding of land skin temperature and emissivity using high spectral resolution IR radiance measurements

Zhao & Wang
Effects of atmospheric correction on retrieving land surface temperature using AVHRR data

ITWG MAILING LIST

Appendix B

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Note : Web references are, in most cases, *not* case sensitive.

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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)
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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/
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