A REPORT ON

THE SEVENTH INTERNATIONAL TOVS STUDY CONFERENCE

Igls, Austria

10-16 February 1993

sponsored by

EUMETSAT

World Meteorological Organisation

European Centre for Medium-range Weather Forecasts

City of Innsbruck

Province of Tyrol

prepared by

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April 1993

FOREWORD

The International TOVS Working Group (ITWG) is convened as a sub-group of the Radiation Commission 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 TOVS data from the NOAA series of polar orbiting satellites have exchanged information on methods for extracting information from TOVS data on the atmospheric temperature/moisture field and on the impact of these data in numerical weather prediction and in climate studies. They have also prepared recommendations to guide the directions of future research and to influence relevant programmes of WMO and other agencies.

Our seventh conference, ITSC-VII, was held in Igls, Austria, from 10-16 February 1993. This "Report on ITSC-VII" summarizes the scientific exchanges and outcomes of the meeting. A companion document entitled "The Technical Proceedings of ITSC-VII" will contain the complete text of the scientific presentations. In addition, the Conference endorsed a report on "ITWG: a Strategy for the 1990s". These documents reflect the conduct of a highly successful meeting in Igls; an active and mature community of TOVS data users now exists, and considerable progress and positive results were reported in a number of areas.

ITSC-VII was sponsored by the Austrian Space Agency, the city of Innsbruck and the province of Tyrol, and by EUMETSAT, WMO and ECMWF. Their support and assistance is gratefully acknowledged. We are indebted to Dr Helmut Rott and his colleagues at the University of Innsbruck and to Ms Silke Trautmann of Eumetsat for the invaluable assistance provided at the conference. In addition we thank the staff of the Kongresszentrum at Igls for their support.

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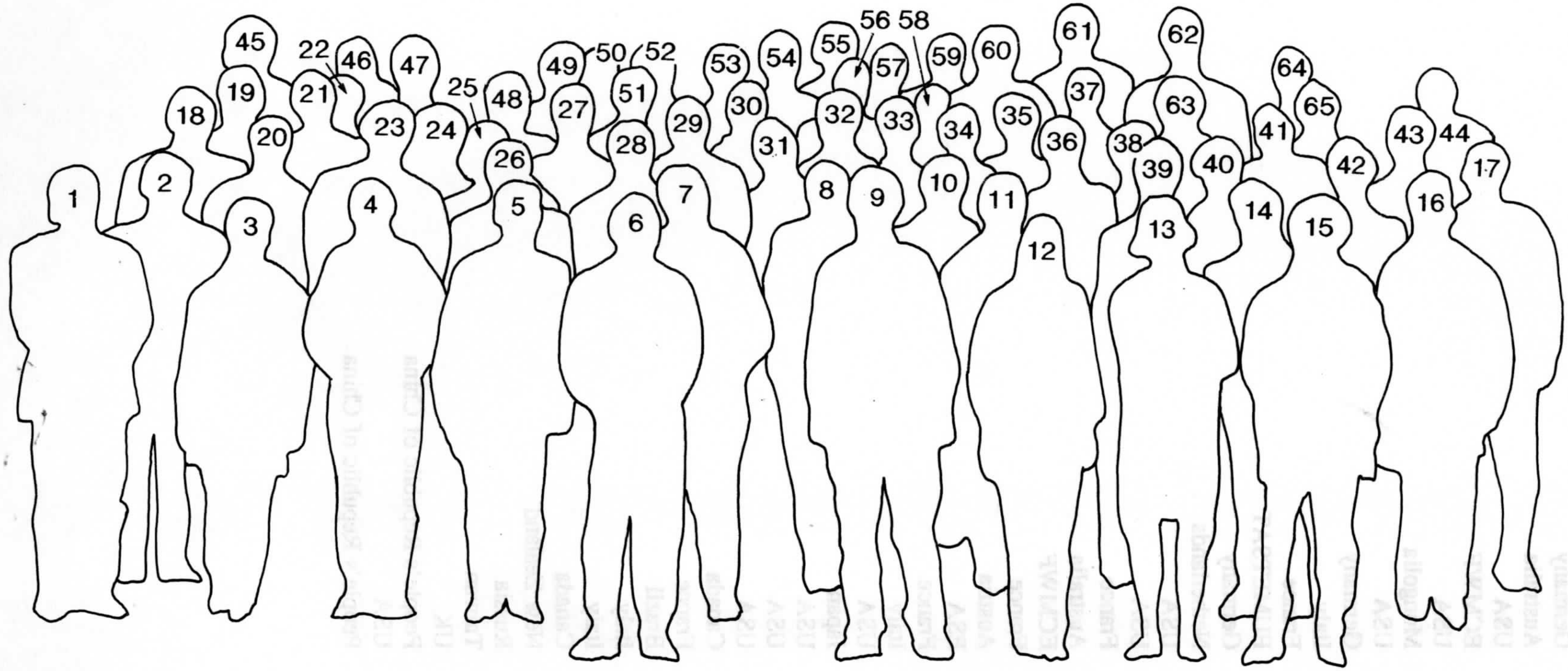

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KONGRESSZENTRUM IGLS

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1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Seventh International TIROS Operational Vertical Sounder (TOVS) Study Conference, ITSC-VII, was held in Igls, Austria, from 10-16 February 1993. 79 participants attended the meeting and provided scientific contributions. 22 countries and 4 international organisations were represented at the meeting: Australia, Austria, Brazil, Canada, People's Republic of China, Republic of China, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Republic of Korea, Mongolia, Netherlands, New Zealand, Norway, Russia, Spain, United Kingdom, United States of America, ECMWF, ESA, EUMETSAT and WMO.

The agenda for ITSC-VII can be found at Appendix A. Most of the meeting was occupied with scientific presentations on the following broad issues: TOVS data in climate studies, TOVS data in numerical weather prediction, preparations for Advanced TOVS (ATOVS) data, future systems, and other scientific studies and developments. These were given either as oral or poster presentations. Section 3 of this report records the abstracts of these scientific contributions. The corresponding papers are published separately in the "Technical Proceedings of the Seventh International TOVS Study Conference" available through the co-chairs of the International TOVS Working Group (ITWG).

During the latter part of the conference, Working Groups were formed to consider four of the main issues identified prior to the conference: TOVS data in climate studies, TOVS data in numerical weather prediction, preparations for Advanced TOVS (ATOVS) data and future systems. The Working Groups reviewed recent progress in these areas, made recommendations on key areas of concern and identified items for action. The reports of these Working Groups are given in Section 2. Earlier in the conference, a session on Status Reports heard reports on relevant meetings and other activities which had taken place since ITSC-VI and reviewed progress on the action items identified by the ITSC-VI Working Groups. Many of these issues formed the basis for further discussion by the Working Groups at ITSC-VII.

During one short session, the conference divided into three Technical Sub-Groups to discuss developments and plans concerning specific software packages in common use among TOVS processing centres. Brief reports on the sub-group meetings are also recorded in Section 2.

1.2 CONCLUSIONS AND RECOMMENDATIONS

As a result of the activities of the Working Groups and their reports to the final session of the conference, the following conclusions and recommendations were adopted as a summary of the main findings of ITWG at ITSC-VII. More details and specific technical recommendations and actions are given in the Working Groups' full reports in Section 2.

1.2.1 TOVS data in climate studies

1.2.1.1 ITWG drew attention to the value of TOVS data in the detection of climate signals. The global, continuous and long record (1978-present) of TOVS data, and their broad spectral coverage render them particularly suitable for investigating inter-annual variability of temperature, humidity and cloud cover. It was noted that a number of institutes have now produced results demonstrating the potential of TOVS data in these areas.

1.2.1.2 Noting the predicted sensitivity of polar regions to climate change, ITWG recommended increased attention to the information contained in TOVS/AVHRR data on air-sea-ice energy exchanges. Promising results are already being obtained, but much work is still required to improve methods of data interpretation and processing in polar (and high plateau) areas.

1.2.1.3 ITWG applauded progress in the NASA/NOAA "TOVS Pathfinder" activities and noted that processing of a benchmark data set (March 1987 - February 1989) had begun. It recommended close involvement of ITWG members in evaluation of the benchmark products. ITWG also drew attention to common aspects in the TOVS Pathfinder activities and the re-analysis projects at NMC and ECMWF, and it encouraged increased dialogue between these projects.

1.2.1.4 With regard to the activities of operational centres, ITWG stressed the importance of maintaining the archive of Level IB data at full resolution for use in climate studies. It also encouraged operational centres to include the generation of climate products from environmental satellite data in their real-time processing.

1.2.1.5 Access to long-period, global TOVS data sets remains a significant impediment to climate studies at many institutes. It was recommended that a policy of open access to data at reasonable cost should be encouraged.

1.2.1.6 ITWG encouraged increased and closer links between ITWG and other groups active in climate research.

1.2.2 <u>TOVS data in numerical weather prediction (NWP)</u>

1.2.2.1 At ITSC-VII, it was reported that TOVS data have shown a positive impact on NWP in both hemispheres. This result was demonstrated both for the use of TOVS radiances directly in NWP data assimilation schemes and through improvements in retrieved products generated by NESDIS. ITWG commended NESDIS for their efforts in improving operational TOVS sounding products.

1.2.2.2 Promising, early results from three- and four-dimensional variational assimilation of radiance data were presented.

1.2.2.3 Results from direct assimilation of radiance data also demonstrated the potential of TOVS water vapour channels for improving humidity analyses in NWP models. However significant improvements are required in model parametrization schemes and assimilation methods before this information can be exploited fully.

1.2.2.4 To improve the utilization of radiance data, more accurate fast radiative transfer models are required. At present their deficiencies limit the information which may be extracted from the measured radiances. It was recommended that this problem be addressed through the generation of high quality collocation data bases of satellite and in situ data, and through the acquisition of high spectral resolution radiances from ground- and aircraft-based platforms. The planned use of the latter by ITRA, in order to validate both line-by-line and fast radiance/transmittance codes was strongly supported.

1.2.2.5 It was recommended that providers of sounding products including (but not limited to) brightness temperatures, and temperature/thickness and water vapour profiles provide users with the expected error characteristics (biases and covariances) of their products.

1.2.2.6 To enable continued operational use of satellite sounder and imager data in local and regional NWP models, real-time direct broadcast data are required. Present plans of NOAA, EUMETSAT and NASA to continue direct broadcast of such data were warmly welcomed.

1.2.2.7 With the anticipated wider use of global satellite radiances at NWP centres, the present limited bandwidth of much of the GTS will prevent their full utilization. It was recommended that WMO should plan for increased bandwidth on the GTS to accommodate these data.

1.2.3 Preparations for ATOVS data

1.2.3.1 It was noted that NESDIS has offered to make available to EUMETSAT their "RTOVS" code, as a basis for development of a processing package for ATOVS data. EUMETSAT plans to develop the code, in collaboration with NESDIS and other centres, in order to provide an international ATOVS processing package. ITWG welcomed these developments and expressed its thanks to NESDIS and EUMETSAT for their assistance in this important area.

1.2.3.2 ITWG stressed the desirability of full international distribution (i.e. beyond EUMETSAT member states and NESDIS) for ATOVS processing code and recommended that the matter be brought to the attention of the Co-ordination Group for Meteorological Satellites (CGMS).

1.2.3.3 ITWG noted that considerable work is still required on the science of ATOVS data pre-processing and retrieval in order to produce algorithms of high quality in time for use at the launch of NOAA-K. It encouraged its members to devote increased activity to this area.

1.2.3.4 In addition to the "RTOVS" code, which applies pre-processing and retrieval algorithms to Level IB data, it was noted that there is also a requirement for standard "Ingest" code to convert locally-received raw ATOVS data to Level IB data. Continuing discussion with NESDIS and EUMETSAT was recommended on these issues to ensure the production and distribution of standard ingest code prior to the launch of NOAA-K.

1.2.3.5 The availability of detailed specifications of the characteristics of ATOVS instruments will be crucial to successful exploitation of their data. It was recommended that, when available, NESDIS draft documentation (i.e. the equivalent of NOAA Tech Rep NESS 107 for TOVS) should be made available to ITWG members for comment. It was also suggested that electronic access (e.g. via Internet) to instrument data would be a very effective method of dissemination to users.

1.2.4 Future systems

1.2.4.1 With regard to future operational sounding and imaging instruments, ITWG drew attention to the desirability of developing common meteorological requirements and compatible instrument specifications and data formats. ITWG would welcome initiatives by CGMS in this area.

1.2.4.2 ITWG re-iterated the urgent need for an operational infra-red sounder of high spectral resolution, along with complementary imaging and microwave sounding instruments.

1.2.4.3 Full exploitation of advanced sounder data will require improvements in atmospheric transmittance models. In this area, ITWG strongly endorsed the development and validation activities of ITRA.

1.2.4.4 To enable wider scientific input in the specification of and preparation for advanced sounding instruments, it was recommended that present and planned synthetic high spectral resolution data sets and associated software be made available to the research community.

1.2.4.5 NASA's plan to install a direct broadcast facility on some of the EOS platforms was warmly welcomed by ITWG.

1.2.4.6 Given the possibility of reducing significantly the HIRS/3 instantaneous field of view (ifov) while retaining the radiometric sensitivity of HIRS/2, ITWG recommended that the specification of the HIRS/3 ifov be changed to reflect this possibility at the earliest possible date.

1.3 FUTURE PLANS

ITSC-VII considered a draft report entitled "ITWG: a Strategy for the 1990s" prepared by the co-chairs. It endorsed the report with some modification. This report reviews the activities and achievements of the first decade of ITWG. It sets out revised aims for the group and proposes specific objectives for the next few years. With regard to the formal status of ITWG and its relationships with and other bodies, ITSC-VII endorsed the following statement, to form part of the "Strategy" document:

- ITWG should retain its present status in relation to the Radiation Commission of IAMAP (i.e. as an ad hoc working group),
- ITWG should seek to establish interactions with CGMS, to provide a more direct channel to/from the operational satellite agencies,
- ITWG should continue to develop appropriate links with WMO.

The next meeting of ITWG is tentatively planned for early 1995 at a venue in the southern hemisphere. ITSC-VIII will attempt to carry forward progress identified at ITSC-VII in the areas of NWP and climate studies, and will address some of the new concerns (identified in the Working Groups' reports) on selected aspects of the science underlying TOVS data processing. It will continue to review international efforts toward future satellite sounding systems. In particular, the timing of ITSC-VIII is likely to make it a key meeting in the international TOVS community's plans to collaborate on developing processing software for data from the ATOVS instruments on NOAA-K.

2. WORKING GROUP REPORTS

2.1 TOVS DATA IN CLIMATE STUDIES

P.Menzel (chair) with J.Bates, A.Chedin, J.Dodge, J.Francis, M.Goldberg, G.Heinemann, A.Kaifel, C.Koepken, F.Loechner, A.Pfister, G.Prangsma, S.Turner, and F.Wu contributing.

2.1.1 Climate signals in TOVS/AVHRR data

The TOVS/AVHRR satellite data represent a unique resource for studying climate signals. The TOVS/AVHRR suite of instruments has provided global coverage over fifteen years (since 1978) without gaps with broad spectral coverage (visible from .5 to .9 and infrared from 4 to 15 microns) and with nearly the same spectral bands. The overlap of the different TOVS/AVHRR spacecraft is particularily important for climate studies in that it assures continuity and provides opportunity for intercalibration. The TOVS/AVHRR measure radiance signals from the atmosphere and surface. Recent works have used these data to investigate interannual climate variability in temperature, moisture, and cloud cover; the magnitude of the anticipated climatic signals and the accuracy of the TOVS-derived products are beginning to emerge. While TOVS/AVHRR data have been used primarily for numerical weather prediction, these data are now recognized as being a very important satellite data set for studying climate variability. In addition, they offer correlative data and supplementary gap-filling data to other climate instruments.

The TOVS climate studies have been affected by stratospheric aerosols produced by large volcanic eruptions. Detection of climatic variability is disrupted by these volcanic events. Volcanic aerosols heat the stratosphere and cool the troposphere directly by intercepting incident solar radiation. They modify the transmittance in longwave infrared TOVS radiances; without appropriate adjustment this leads to differences in observed versus calculated radiances. The effects of stratospheric aerosols must be accounted for explicitly in TOVS processing for climate studies.

The following table indicates those TOVS-derived products of climatic relevance; the Technical Proceedings of the ITSC-VII is a reference. It is an update of a similar table that was presented in the Report on the ITSC-VI (1-6 May 1991). New entries include aerosols, ice cover, and atmospheric mean temperatures derived from linear combinations of radiance measurements (without a priori data).

* The Working Group (WG) noted that aerosol correction to sea surface temperature may be facilitated by several other instruments. These include the ATSR (Along Track Scanning Radiometer) with its multiple views of the same spot and the upcoming MIMR (Multifrequency Imaging Microwave Radiometer) with its 10 GHz channel. An invited talk on these instruments is recommended for ITSC-VIII. **(Action: ITWG co-chairs)**

2.1.2 TOVS/AVHRR data products in polar regions

Climate modelling studies suggest that the polar regions are very sensitive to climate change. However, the representation of high latitudes in global climate models is crude because conventional data are sparse and feedback mechanisms are complex (such as air-ice-ocean energy exchange processes). Polar orbiting satellites represent a most promising tool for alleviating this data need; data coverage has both high temporal and spatial resolution. The promise exists for monitoring polar climate and understanding and parameterizing energy exchange processes. AVHRR has been used for sea ice and snow detection, but only in cloud-free situations. TOVS supplements this with atmospheric and surface information at lower resolution. These data are thought to be useful in filling gaps in the data records of SMMR and SSM/I. In light of recent progress in applying TOVS/AVHRR data in the polar regions, the ITWG has several recommendations.

Parameter	Current Accuracy	Global Resolution	Reference Standard	Interannual Signal	Time Scale	Spatial Scale	Problem Areas
OZONE (T)	20 DU	50 km	Dobson sondes	50 DU	year	synoptic	guess dependent
SST (A)	0.6 C	5 km	ships	1 to 3 K	year ENSO	regional global	bias skin effect volcanic aerosol
CLOUDS (T,A)	?	50 km	sfc obs	5%	year ENSO	all	detection emissivity multilayer
OLR (T)	15 W/m2	50 km	ERBE	10 W/m2	season year ENSO	regional	broad band
VEG IND (A)	unknown	5 km	unknown	regional	season year	regional	no standard
ICE/SNOW (T,M,A)	?	5 km	in situ	10%	year	regional	cloud/snow discrimination
TOT H20 VAPOUR (T,M)	20%	100 km	?	?	month year	all	clear sky only guess dependent
TEMP (T,M)	2 K	100 km	raobs	1 to 5 K	season year	synoptic	volcanic aerosol clouds, rain guess dependent
RAD (T,M,A)	1 rad	100 km	none	?	year	synoptic	calibration
AEROSOL (A)	.1	5 km	none	.1 to .5	season year	regional global	volcanoes

T indicates TOVS, M indicates MSU, and A indicates AVHRR

The WG recognized recent progress to tap the great potential of TOVS/AVHRR for polar climate research and strongly endorses the advancement of several activities. Validation, though difficult, can be sought through field programs.

* Total ozone amounts can be estimated from TOVS even in the absence of daylight, and thus offer useful complementary information to SBUV (Solar Backscatter Ultraviolet) and TOMS (Total Ozone Mapping Sensor). Comparisons between these three ozone estimates and ground measurements should be pursued. In addition TOVS should be exploited to investigate atmospheric dynamics and their relationship to ozone concentration.

* Improved estimates of surface radiation fluxes may be possible by incorporating TOVS retrievals of temperature and cloud information.

* Thickness gradients combined with wind information yield estimates of horizontal heat advection. The same can be said of moisture.

* Retrieval methods should be adapted to high plateau regions such as Antarctica and Greenland, where the attempted retrievals are presently marginally useful.

* Through the combination of TOVS/AVHRR, methods to reduce the ambiguities in cloud detection over snow and ice should continue to be investigated.

2.1.3 TOVS Pathfinder

The WG noted that the NASA/NOAA TOVS Pathfinder activities are beginning to determine the baseline algorithms for deriving climate products. The need for a consistent cloud clearing approach has been addressed and processing of a benchmark data set (March 1987 to February 1989) has begun. It is anticipated that processing of the benchmark data set will require several iterations before optimal climate usage is achieved.

The TOVS Pathfinder is proceeding with three approaches. Both path A (at GSFC) and path B (at LMD) will produce high vertical resolution products drawing heavily on a priori information to linearize and condition the inversion of radiances to geophysical parameters (e.g., temperature and moisture profiles). Path A will use a NWP model to obtain a first guess profile while path B will use a fixed data base that is model independent. The use of a priori information enables products with higher vertical resolution than that inherent in the TOVS radiometric measurements. These path A and B products will be useful to climate modellers to gain insight to atmospheric processes on the scale of conventional data networks. Path C will be independent of a priori information; it will be derived from linear combinations of observed radiances to approximate mean-layer temperatures and moisture. The loss of vertical resolution is offset by the advantage of data set independence. Path C (at NESDIS) will be processed at scales adequate for climate studies and variability in these products can more readily be attributed to true changes in observed radiances rather than changes in the accuracy of the a priori data. The WG was interested in products from all paths, but it recognized the importance of being as independent of a priori information as possible.

* The WG recommended that the ITWG seek invitation of representatives to observe the benchmark data evaluation.

* Since the GOES Pathfinder has adopted the equivalent of path C (independent of a priori information) for their processing, the NESDIS TOVS Pathfinder path C algorithms should be shared with the GOES Pathfinder to enhance commonality from the two platforms.

* The WG encouraged increased interaction between the TOVS Pathfinder and the ECMWF and NMC

reanalysis projects as well as dialogue concerning future analysis of the data.

* The WG recommended that NESDIS adopt the TOVS Pathfinder algorithms for climate products, when they are mature, to assure future continuity of this climate data set with these common algorithms.

2.1.4 Products from operational centres

The WG noted that operational TOVS data processing has been focused almost exclusively on numerical weather prediction applications. Climate applications are now also gaining increasing importance. This implies that operational TOVS data processing must strive to satisfy the requirements of both applications.

* For climate applications, the WG stressed that at a minimum the archive of calibrated raw radiance data at single field-of-view resolution must be continued (without cloud clearing or limb correction).

* Operational centres are encouraged to pursue real time processing of environmental satellite data sets dedicated to climate research. This alleviates extensive processing of historical data sets after the fact. The influence of the TOVS Pathfinder on this activity at NESDIS is discussed above.

* The WG recommended that NESDIS establish ready access to information vital to quantitative use of the TOVS data (e.g., changes in microwave channel gains). Internet access to this information is encouraged. **(Action: Goldberg,** to discuss with NESDIS)

* It was also recommended that future high spectral resolution sensors replacing HIRS enable continuity of spectral coverage through spectral combinations.

2.1.5 Data access and cost

Access to TOVS data remains a significant impediment to climate studies. Data sets delivered upon request are often expensive, incomplete, and slow. Some private data archives are showing considerable success with improved access to large data sets on mass storage devices. It is in the best interests of all that a policy of open exchange of data at reasonable cost be sought by all parties.

* The WG encouraged moves to make Level-1B data from TOVS Pathfinder available through the EOS DAACs.

2.1.6 Linkage with other climate groups

As more of the ITWG energies are being focussed on climate studies we encourage the ITWG to foster closer ties with other Climate Groups.

* Better information exchange with AMIP (Atmospheric Model Intercomparison Program), WCRP (World Climate Research Program), and GCOS (Global Climate Observing System) should be sought **(Action: Chedin)**

* A climate specialist should be invited to speak at the ITSC-VIII. **(Action: ITWG co-chairs)**

2.2 TOVS DATA IN NUMERICAL WEATHER PREDICTION

J.LeMarshall (chair) with E.Andersson, T.Boehm, C.Chouinard, I.Csiszár, P.Dibben, G.Kelly, D.Kim, L.Lavanant, A.McNally, J.Pailleux, G.Prangsma, M.Uddstrom and A.Uspensky contributing.

2.2.1 Introduction

There has been significant progress since the Sixth International TOVS Study Conference (ITSC-VI) in the application of TOVS data to numerical weather prediction (NWP). There has been significant improvement in the quality of NESDIS operational retrievals and an increasing use of interactive retrievals. These factors have allowed positive impact of TOVS data in NWP to be demonstrated in both northern and southern hemispheres, a significant milestone.

Also, since ITSC-VI, variational retrieval schemes of three and four dimensions have been tested and have continued to show improvement. As a result, it is anticipated that they will be used operationally in the near future. The 3D schemes estimate temperature and moisture fields in a way consistent with all observed data (including radiances) and with first guess fields. In addition to this, the 4D versions of these schemes impose a consistent fit to observations over a period of time. This makes it possible (for example) for humidity observations, such as the TOVS water vapour channel radiances, to cause an adjustment in other variables such as wind.

However, improvements in forward radiative transfer (RT) models and in model and data error specification still remain crucial and constitute necessary prerequisites for further significant progress in the use of satellite sounding data in NWP.

In the future, new instrumentation also provides the prospect of enhanced analysis and forecast capability. After 1995, the Advanced Microwave Sounding Unit (AMSU) will provide improved all-weather and enhanced moisture retrieval capability. However there is still an urgent requirement for an advanced infra-red sounder, providing information with an equivalent r.m.s. accuracy of 1K for temperature and 10% for humidity for a vertical resolution of 1 km.

New techniques in TOVS data processing, such as the application of neural networks, also appear promising but require further work to establish their utility for NWP.

2.2.2 Radiative transfer estimations of radiance from atmospheric state

The present practice is to tune the forward model using the radiances or air mass type. The results of recent studies indicate that further development work is urgently required in this area.

2.2.2.1 Sources of error

Errors in the forward models may result from several sources: errors induced by CO_2, O_3, SO_2 and aerosol concentration variation, or the variation of any other atmospheric parameter which affects radiances but is not contained in the forward models. They may result from errors in spectroscopic parameters, the use of 40-level quadrature, the extrapolation of the temperature profile into the stratosphere for the forward calculation or the effect of surface emissivity, particularly over polar regions. Other sources of error include inadequate validation, which may result from the effects of radiosonde errors, inadequate representation of clouds in radiative transfer calculations and the effects of reflection.

2.2.2.2 The way forward

The basic need for an improved forward model remains, including the need for an improved handling of cloud and improved transmittances. The need for careful tuning of the forward model still remains.

Improved data sets are still required for tuning and validation and further investigation of the tuning methodology is required. Again the usefulness of radiance monitoring against NWP/analysis fields was recognised, the obvious advantage being the superior spatial and temporal coverage in such comparisons. However, the WG also agreed that such comparisons should not be pursued in isolation from high quality parallel comparisons with radiosonde data.

In summary improvements in RT models remain crucial for significant progress in the use of satellite sounding data in NWP. As a result, increased efforts to develop improved understanding of the radiative transfer problem are encouraged and validation through airborne experiments, satellite/radiosonde collocations and ground-based measurements are recommended. The activities of the Intercomparison of Transmittance and Radiative Algorithms (ITRA) Working Group, together with those of ITWG and others, should also be encouraged in this regard.

2.2.3 Error estimation required for NWP

Numerical analysis using pre-processed TOVS data requires error covariance matrices describing the error characteristics of the forecast model, the RT model and the error characteristics of the pre-processed radiances. This results in a requirement for constant dialogue between data producers and data users concerning radiance error characteristics. These error characteristics should include the effects of limb adjustment and cloud clearing in the case of clear radiances. The providers of sounding products should also provide the error characteristics of their derived products if they are to be used optimally in NWP. They should also include first guess information and error characteristics where pertinent.

2.2.4 Impact of TOVS data

2.2.4.1 Impact on different scales

Recent studies with global models indicate positive impact at the longer wavelengths in the Northern Hemisphere, while regional studies in the Southern Hemisphere indicate that both long and short wavelengths are being affected. Given the recent significant improvements in retrieval and assimilation systems, it appears to be appropriate that impact studies using global variational assimilation be performed to gauge the effects of TOVS at different spectral intervals (resolutions) and that regional high resolution studies should also be undertaken.

2.2.4.2 Polar areas

There have been significant problems for both RT models and retrieval schemes in polar areas where the assumptions in forward models, retrieval schemes and forecast systems (often used to provide guess fields) are tested in the extreme. There is as a result a clear need for further work to be done in these areas and, to this end, a detailed case study may delineate and help solve these problems.

2.2.4.3 Non-limb-adjusted cloudy radiances

Many interactive retrieval schemes now use raw radiances. In addition, raw radiances are also required to produce homogeneous radiance fields from both local and GTS data. These non-limb-adjusted and sometimes cloudy radiances potentially contain more information than their clear, limb-adjusted counterparts, but further work is required fully to exploit the additional information.

2.2.4.4 Information in the TOVS humidity field

The TOVS instrument provides valuable humidity information particularly in the mid and upper troposphere. At ITSC-VII, studies were presented in which HIRS channels 11 and 12 had been used to detect large deficiencies in NWP humidity analyses, particularly significant regional biases in the tropics.

In an application of 4D assimilation, experiemnts suggest that it is possible to infer information on wind in the tropics from the HIRS water vapour channels, the humidity features being treated as passive tracers. This is an exciting new development where potentially the humidity information of TOVS can be linked to the model physics and so affect the analysis of divergence/convergence and vertical wind.

In traditional assimilation schemes, the method of "physical initialisation" also provides the possibility to use TOVS humidity data and cloud information to improve the analysis of the tropical circulation. Efforts in this area should be encouraged.

2.2.5 Future sounding requirements

2.2.5.1 Use of AVHRR data

There is, at present, a growing desire to improve the quality of TOVS data by using AVHRR data. To facilitate this on global scales, there is a need to indicate to NESDIS the parameters required from AVHRR to allow appropriate use of this data in NWP.

2.2.5.2 Future instruments

The AMSU, now due for launch in 1996, will give better all weather coverage and increased moisture information. A common pre-processing procedure for AMSU data will assist in their proficient use in NWP.

The mooted move of HIRS/3 to a 10 km footprint, with no loss of radiometric resolution, also offers several advantages. It should provide 50% more clear spots, improve the accuracy of soundings, and improve the derived cloud information, all of which would benefit NWP. It would result in some changes to TOVS-based (cloud) climatologies but, on balance, the improved information content of the data outweighs the problems associated with the change.

With the launch of the EOS platforms, later in the decade, there will also be a requirement for selected MODIS channels for NWP.

Most important, however, is the urgent requirement for data from an advanced sounder such as the Infra-red Thermal Sounder (ITS), Atmospheric Infra-Red Sounder (AIRS) or Improved Atmospheric Sounding in the Infra-red (IASI). In addition, future NWP simulation studies indicating the utility of the advanced sounder are required.

2.2.6 Recommendations

2.2.6.1 A crucial and necessary prerequisite for continued progress in the use of satellite sounding data in NWP is improvements in the RT models. It is anticipated that these improvements will result from developments in the basic science, the provision of improved tuning data sets and development of enhanced tuning methodology. These activities should be encouraged.

2.2.6.2 There is a requirement for constant dialogue between data producers and data users concerning radiance error characteristics after preprocessing. These characteristics should include the effect of limb adjustment and cloud clearing in the case of cloud cleared radiances. The providers of sounding products should also provide the error characteristics of their derived products if they are to be used optimally in NWP.

2.2.6.3 Being cognisant of the effect of TOVS data on different scales in recent impact studies, it is recommended that impact studies using global variational assimilation of TOVS at different spectral intervals (resolutions) be performed, and that regional high resolution studies be undertaken.

2.2.6.4 Being mindful of the problems of forward models, retrieval schemes and assimilation systems in polar regions, specific case studies should be undertaken to delineate and help solve problems in these areas.

2.2.6.5 Many interactive retrieval schemes use raw radiances. In addition, they are required to produce homogeneous radiance fields from local and GTS data. As a result these raw radiance data should be available on the GTS.

2.2.6.6 The TOVS instrument provides valuable humidity information particularly in the mid and upper troposphere. However models are relatively insensitive to this information. Improvements are needed both in physical parametrization and in physical initialisation to exploit these data, especially in the tropics. In the light of recent results, the continued development of 4D variational methods should also be encouraged.

2.2.6.7 The WG supported the mooted move of HIRS/3 to a 10 km footprint. It is anticipated to result in a 50% increase in the number of clear radiances and improved cloud retrieval.

2.2.6.8 Given the present state of NWP there is an urgent requirement for an advanced atmospheric sounder (such as ITS, AIRS or IASI) to provide temperature and moisture information at the vertical and horizontal resolutions appropriate for global, regional and climate models.

2.2.6.9 As a result of the short cut-off times associated with operational regional models and the desire to use AVHRR in processing algorithms, there still exists a strong requirement for direct readout. There is also a requirement for data providers to be sensitive to the timeliness and resolution requirements of users.

2.2.7 Actions

2.2.7.1 NWP centres at present require the provision of the error covariance matrices for NESDIS TOVS cloud cleared radiances and products. NESDIS should be requested to assist in this area by providing error characteristics (covariances) for these data. **(Action: McMillin)**

2.2.7.2 As a result of increased interest in using AVHRR data in TOVS processing and because of the increasing potential of NESDIS to provide derived products from these data, it is now timely for the ITWG to provide NESDIS with guidance concerning the requirements for global radiometric parameters from AVHRR pertinent to cloud, TOVS processing and NWP. **(Action: Rochard)**

2.2.7.3 In order to delineate and help solve retrieval, forward and forecast model problems in polar regions it has been decided that Antarctic overpasses should be selected and distributed for a polar case study. **(Action: Le Marshall)**

2.3 PREPARATIONS FOR ATOVS DATA

D.Steenbergen (chair) with P.Brunel, R.Buell, C.Dong, J.Eyre, D.Klaes, J.LeMarshall, L.McMillin, M.Perrone, G.Prangsma, A.Reale, H.Rieu, P.Riley, G.Rochard, N.Scott, P.Watts, and B.Wu contributing.

2.3.1 Background

Following recommendations made at ITSC-V, a small sub-group of the ITOVS Working Group was established to promote and coordinate a collaborative international effort towards development of Advanced TOVS (ATOVS) processing systems. The first meeting of this sub-group at ECMWF in October 1990 was followed by meetings at ITSC-VI in May 1991 and at the Laboratoire de Météorologie Dynamique in Palaiseau, France from 30 March to 1 April 1992.

The WG strategy has been to try to build on, to the greatest extent possible, the major software development effort for ATOVS being undertaken at NESDIS. NESDIS software development is taking place in two stages. In the first stage, a new system known as "RTOVS" will replace the current TOVS software. "RTOVS", which is expected to be completed by mid-1993, will provide the framework for processing ATOVS data. In the second stage, known as "ATOVS", algorithm changes necessary for processing ATOVS data, which cannot be implemented for TOVS, will be made.

At its last meeting, the WG noted that NESDIS policy regarding international access to the NESDIS RTOVS/ATOVS code was the critical issue affecting development of plans by other agencies, and that significant efforts were required before the end of 1992 to resolve this issue. As a result of developments since its last meeting, the WG is now confident that international distribution of the NESDIS code will occur early enough for this code to be used as the basis for development of the software required for operational and research use of ATOVS data by the international community.

2.3.2 ATOVS pre-processing software development

"Pre-processing" refers to everything which is done to the data between the production of level 1-B data and the retrieval or assimilation step, including for example mapping measurements from different instruments into a common projection, detection of and corrections for contaminants such as precipitation, and adjustment of measurements to nadir. The diversity of methods which exist or are under development for inversion or assimilation of TOVS data implies that a similar diversity will exist for ATOVS, leading to differing pre-processing requirements.

At the last meeting the WG concluded that the architecture of the NESDIS RTOVS/ATOVS system would be sufficiently flexible and general to provide an excellent framework to meet the diverse requirements of the international community for pre-processing ATOVS data. It recommended that the architecture of the NESDIS RTOVS/ATOVS system be adopted as a standard for ATOVS pre-processing. Following the meeting, a letter was written to NESDIS to seek an agreement regarding early distribution of the RTOVS code. The ITWG has now received an informal response to this letter from NESDIS which indicates that

> " NESDIS intends to make the RTOVS software available for distribution as soon as possible. This will be after the software is running operationally at NESDIS. The software will be shared by NESDIS with EUMETSAT; where there will be a NOAA/EUMETSAT agreement on a "standard

software" package. The RTOVS/ATOVS software package(s) could be prepared for international distribution through the CGMS. The ITSC would be an ideal group to recommend what the 'standard software' package should be. "

The WG welcomed these developments and expressed its thanks to NESDIS for assistance in this important area.

The WG was informed that during the last year EUMETSAT has begun investigation of the possibility of modifying the NESDIS RTOVS code to meet the ATOVS pre-processing requirements of its member states and other members of the international community. The WG expressed strong support for this activity. (The NESDIS RTOVS code must be used as the basis for development of operational ATOVS pre-processing software by other groups since the NESDIS ATOVS code will not be available far enough ahead of the launch of NOAA-K.)

The WG identified a need to confirm its understanding of the situation regarding access to the RTOVS code and to provide for eventual distribution of the RTOVS code, and code based on RTOVS, to the international community. In the near future, wide distribution of the RTOVS code (i.e. to groups other than EUMETSAT) was not seen as necessary; however, for planning purposes, insight by WG members into the design of the RTOVS system and the proposed EUMETSAT modifications to it is important. The RTOVS documentation provided to members of the WG by NESDIS has been extremely valuable in this regard; distribution of EUMETSAT documentation to WG members as it becomes available is also highly desirable.

Actions were recommended as follows:

* To clarify the status of the agreement between NESDIS and EUMETSAT regarding EUMETSAT access to the RTOVS code. **(Action: Perrone)**

* To include a statement regarding the desirability of international distribution of the NESDIS RTOVS/ATOVS code in the report from ITSC to CGMS. **(Action: Eyre)**

* To distribute the "RTOVS Review Document" and the "Preliminary Development and Implementation Plan" prepared for EUMETSAT to WG members. **(Action: Klaes)**

2.3.3 ATOVS ingest software development

A number of centres are currently using, or are planning to use, direct readout TOVS data for operational purposes. To meet their commitments, these centres must obtain or develop ingest software for ATOVS in time for the launch of NOAA-K. ("Ingest" refers to all operations performed on data in the form received from the satellite to turn it into level 1-B form, in particular decommutation, calibration, and earth location.)

At its last meeting, the WG recommended that NESDIS operational algorithms be used as an international standard for ATOVS ingest, and that NESDIS should be requested to indicate whether it was prepared to make the ATOVS ingest code (and accompanying test data sets) available to the international community before the launch of NOAA-K. This request was made in the letter to NESDIS referred to above. The informal response to the letter from NESDIS does not address this request since it only covers distribution of the NESDIS RTOVS code. (The NESDIS RTOVS/ATOVS systems use level 1-B data as input; the ingest function is performed by a separate system.)

The WG learned that a contract for development of the NESDIS ATOVS ingest software is under way, and that specifications for both algorithms and interfaces (in particular a specification for ATOVS level 1-B data) will be developed under this contract. The members of the WG noted that data at the level 1-B stage will be used by both operational NWP centres and by the research community, and reiterated their interest in providing comments on these specifications. **(Action: Eyre,** to explore how this might be done.)

The WG was informed of EUMETSAT intentions to modify the NESDIS ingest software to provide for ingest of direct readout data. The WG expressed its enthusiastic support for a collaborative initiative between NESDIS and EUMETSAT in this area. It would be highly desirable if interested direct readout station operators could provide comments on the detailed design of these modifications, and if the EUMETSAT modified code could be made available to the international community. If this is to occur, EUMETSAT must obtain the code early enough to provide time to implement the modifications and distribute the modified code to direct readout station operators at least six months before the launch of NOAA-K.
(Action: Perrone, to pursue agreement between EUMETSAT and NESDIS regarding early access to NESDIS ingest software.)
(Action: Klaes, to clarify the technical issues (including time constraints) regarding modification of the NESDIS ingest code for direct readout use.)

2.3.4 Use of AVHRR-GAC data

At its last meeting, the WG noted that plans were under way to use a small number of parameters from AVHRR-GAC data within the HIRS field-of-view in RTOVS/ATOVS retrieval/assimilation, and that the choice of these parameters had not received wide attention. The WG recommended additional consultation between NESDIS and other research groups on this issue. A detailed specification for use of AVHRR-GAC data in the NESDIS RTOVS/ATOVS systems is now expected to be available by mid-1993. Members of the WG expressed interest in providing comments on the document. The WG also noted that simulation of the selected parameters using full resolution AVHRR data could provide useful information on their suitability.

Actions were recommended as follows:

* To request distribution of the NESDIS document to WG members. **(Action: McMillin)**

* To provide consolidated comments from WG members to NESDIS. **(Action: Steenbergen)**

* To simulate the selected parameters using full resolution AVHRR. **(Action: Rochard)**

2.3.5 Instrument data

The WG reiterated its recommendation that detailed instrument data (e.g. measurements of instrument fields-of-view, antenna patterns, alignment characteristics, etc.) be made available as part of the NOAA-KLM equivalent of NESDIS 107. It would be desirable for the numerical information in this document to be available in computer-compatible form. **(Action: Reale,** to pass on recommendation to NESDIS.**)**

2.3.6 Radiance quality control and validation

The WG confirmed its interest in various activities being carried out under the auspices of the NESDIS Calibration Oversight Panel. The chairman of this group should be approached regarding possible distribution of relevant reports to WG members. **(Action: McMillin)**

The WG also noted that new NESDIS calibration procedures for the HIRS instrument use the orbital history of parameters such as the secondary mirror temperature. The WG recommended that NESDIS plan to provide network or electronic bulletin board access to the orbital history data when the new calibration procedures are implemented. **(Action: McMillin,** to pass on recommendation to NESDIS.

2.3.7 Fast radiative transfer models

The WG reiterated its support for ITRA plans to include fast radiative transfer codes in its next radiative transfer model intercomparison. The WG encouraged relevant groups to consider providing access to fast radiative transfer code coefficients over networks such as InterNet. The WG also restated its support for the identification of the ATOVS equivalent of the DSD5 data set as an archived NESDIS product as a means of improving access to collocated radiosonde and ATOVS data for validating and tuning radiative transfer models. It would be desirable for collocated radiosonde/ATOVS data sets to contain data in level 1-B form as well as in later stages of processing, and for parameters derived from AVHRR data to be included if possible. **(Action: Reale,** to determine status of NESDIS plans for collocated radiosonde/ATOVS data sets and pass on WG concerns as appropriate.)

2.3.8 Other actions and recommendations

The WG noted that since its last meeting a bibliography on microwave radiative transfer modelling had been prepared at LMD. It would be desirable for this report to be distributed to WG members. **(Action: Rieu)**

SSM/I/T/T-2 data are a valuable source of information for understanding the scientific problems which will be encountered with ATOVS. These data are not yet available from NESDIS, although this is expected to occur by the end of 1993. The possibility of providing small amounts of SSM-I/T/T-2 data from other sources to interested groups should be explored. **(Action: Shaffer)**

At the last meeting of the WG, copies of the NESDIS draft document "Report to SPOP: Specification for the processing of data from the NOAA-K sounder were distributed to participants, who were invited to send comments to NESDIS. At this meeting, the WG learned that revision of the document is expected within the next year, and that comments from WG members (to H.Drahos) would still be useful. **(Action: Steenbergen,** to encourage WG members to send comments on the document to NESDIS.)

The WG noted that interest in sounding data for climate studies and other research is continuing to increase. The WG reiterated its recommendation that the NESDIS ATOVS coefficient data base be archived to facilitate use of NESDIS ATOVS products at various levels for this purpose. **(Action: Reale,** to pass on recommendation to NESDIS)

The WG reiterated its support for EUMETSAT and NESDIS activities related to distribution of information and satellite instrument data to users via networks and electronic bulletin boards. In particular, the WG recommended to EUMETSAT that it consider establishing an electronic information service in connection with ATOVS software distribution. The WG agreed that a list of information and data items which could usefully be made available in this way should be developed and provided to NESDIS and EUMETSAT. **(Action: Rochard)**

At its previous meeting, the WG noted that availability of a simulated ATOVS data set in level 1-B format was highly desirable. This data set would be used for exercising pre-processing and inversion/assimilation code prior to launch. Identifying a way of making such a data set internationally available prior to the launch of NOAA-K is an outstanding problem.

Regarding working group reports, it was agreed that, in addition to its contribution to the ITSC- VII Report, a combined report on the third and fourth meetings of the WG should be distributed to interested agencies. **(Action: Eyre)**

Regarding follow-on WG activities, it was agreed that it would be desirable to initiate a quarterly newsletter containing information from WG members on activities relevant to ATOVS algorithm development. Contributions will be solicited and the newsletter will be distributed to WG members by electronic mail. **(Action: Steenbergen)**

The WG also agreed that periodic follow-up on action items was desirable and that progress reports on action items should be distributed to WG members through the newsletter. **(Action: Steenbergen)**

2.4 FUTURE SYSTEMS

M Lynch and M Perrone (co-chairs) with D Ceckowski, A Huang, J Jenney, D Klaes, W Knorr, P Menzel, P Pagano, A Reale, H Revercomb, R Rizzi, N Scott, C Serio, W Smith, V Tramutoli, A Uspensky, B Wu and F Zhou contributing.

2.4.1 Existing sensors

Studies have shown that a reduction in the field of view (fov) of HIRS/2 from 20 km to 10 km typically will increase the identification of clear fields of view by up to 50%. Recently, the opportunity has emerged to reduce the fov size on the HIRS to 10 km without making a reduction in radiometric signal-to-noise.

* The WG encouraged NOAA to explore, at the earliest possible opportunity, the implementation of this instrument change including a retrofit on NOAA-KLM series **(Action: Menzel,** to open dialogue with NOAA).

The WG applauded the decision to correct NOAA-K for the systematic drift in equatorial crossing time which in the past has caused much concern for climate studies.

2.4.2 Advanced sounders

The advantages for sounding products of utilizing high spectral resolution sounders has been demonstrated with both simulations and aircraft instruments.

* The WG reiterated the urgent need for satellite agencies to implement their plans for advanced infrared sounders which include recognition of the important synergism which exists with microwave sounders and co-registered imaging instruments **(Action: co-chairs,** to report on this to CGMS).

Concern was expressed that the prospect still exists that different infra-red sounders might be flown on the morning and afternoon operational satellites.

* The WG recommended that EUMETSAT and NOAA/NESDIS establish common operational requirements for advanced sounders to ensure that compatible polar orbiting instrument plans emerge **(Action: Perrone,** to put this concern to Eumetsat and NOAA).

A number a studies have reported on meteorological requirements for future sounders. The ITWG has expertise in instrumentation, sounding and assimilation of soundings and radiances in NWP models.

* The WG recommended that a set of meteorological requirements for future sounders be developed and distributed with appropriate involvement of ITWG expertise **(Action: co-chairs,** to refer the matter to CGMS and to follow up).

2.4.3 Science issues

Sounding instruments presently under development offer the potential to enhance knowledge using multi-sensor approaches to the sounding problem.

* Time should be allocated during ITSC-VIII for presentations on these instruments and related research programs (**Action: co-chairs**, to include selected presentations in ITSC-VIII programme)

The research initiatives currently being undertaken by ITRA with respect to validating transmittance and radiative transfer models were applauded. The continuing efforts of ITRA and the more recent plans of the DOE/ARM program to acquire high spectral resolution data as validation tools were strongly supported. These data should include radiometric data collected for many different atmospheric conditions using both airborne and ground-based sensors (e.g. HIS, SPECTRE) to permit extensive analyses of differences and to identify sources of error. The WG stressed the need for the development of both fast and accurate high spectral resolution transmittance models.

Action should be taken to plan for effective use of data from planned sensors by making available simulated data sets and also measured data sets from comparable non-satellite instruments.

* The WG recommended that satellite agencies investigate mechanisms for making synthetic high spectral resolution radiometric data sets (such as TIGR, Phillips, NMC) and the associated software available to the research community (**Action: co-chairs**, to identify appropriate ITWG members to pursue these matters with relevant agencies).

2.4.4 International concerns

The WG applauded the decision by NASA to provide direct broadcast of EOS satellite data at X-band frequency.

* Agencies should ensure that technical advice on the development of direct broadcast X-band ground stations is widely disseminated among the international community (**Action: co-chairs**, to send ITWG address list to J Dodge).

Concern was expressed at the prospect of significant delays in the dissemination of data from next generation sensors by agency ground station to users.

* The WG recommended that EUMETSAT and NOAA/NESDIS agree on common requirements for timely dissemination of global data sets to users (**Action: co-chairs**, to refer the problem to satellite agencies via CGMS).

3. REPORTS OF TECHNICAL SUB-GROUPS

3.1 TECHNICAL SUB-GROUP ON TOVS PROCESSING SOFTWARE, 3I/3R

Attendance: E.Andersson, J.Francis, G.Heinemann, A.Kaifel, D.Klaes, C.Koepken, A.Pfister, G.Prangsma, G.Rochard, A.Reale, N.Scott, K.-H.Wang and B.Wu

3.1.1 Discussion on current status of installation and distribution of 3I/3R packages

During recent months, several actions took place for the distribution/installation/training (low and high level) of the 3I package through visits (1 week - 3 months) to LMD or on the sites of users. All but one of the groups represented at the sub-group meeting run 3I Version 2 (corresponding to TIGR-2). The 3I system is currently run in these groups on VAX, HP, CRAY-2, IBM compatible systems. The installation and its validation appear to be relatively easy with no systematic problems arising.

3.1.2 Review of various modifications

These were suggested by C.Stubenrauch, J.Francis, C.Koepken, G.Prangsma and others. They arose due to corrections:

- in the INTERP3I step: transition between 180/0 longitude line;
- in the III step: cloud top temperature computation storage of the closest situation in the output file;

... and due to improvements:

- assignment of low clouds;
- re-distribution of the water vapour within the coarse layers of the inversion;
- cloud test in polar regions;
- emissivity in polar regions;
- rain test in polar regions: over sea ice.

3.1.1 Questions and answers

* Are versions other than IBM compatible available? - A VAX local version could be obtained from KNMI (according to the usual 3I LMD/users licence agreement).

* Is it possible to enlarge or modify the input/output files structure? - Obviously yes, but it is the responsibility of the specific user to do so; the nominal structure of the 3I files will presently remain unchanged.

* Do some plans exist to improve the distribution of the 3R software? - This is among LMD/ARA's first priorities. Also a 3R user's guide is in preparation.

* Do some plans exist to include 3R in the 3I system? - Yes, this task will be performed in the coming months. Subsequent distribution of the 3I system will include this modification.

* Is it possible to improve the different versions labelling mode? - Yes, an effort will be made in that direction.

* Do some plans exist to acquire the input coefficients directly from NOAA? - A suggestion was made to refer the question to Ellen Burdsall (NOAA/NESDIS).

3.2 TECHNICAL SUB-GROUP ON TOVS PROCESSING SOFTWARE, ITPP

The technical SG discussed many aspects of present and future uses of ITPP which can be summarized under the following headings.

3.2.1 Documentation

A recurring point during the discussion was that the ITPP package was insufficiently documented. In particular, users were interested in:

- more in-line comments in the code; specifically, subroutine HMTWR was mentioned;
- more information on the structure of ITPP input data files;
- structure of the radiative transfer model coefficients;
- filtering;
- a file included with the delivery of the ITPP5 package containing this documentation.

3.2.2 Proposed improvements in ITPP5

Proposed scientific changes were outlined in the ITSC-VII paper by Smith et al. Most of these comments concerned the use of AVHRR for cloud clearing which has been included in the new ITPP5 package. Specific suggestions included:

- using AVHRR landmark navigation to aide HIRS navigation;
- outputting AVHRR usage information along with the retrieval results;
- the use of upper tropospheric moisture information in the forward calculations.

3.2.3 Further improvements to ITPP5

These suggestions are separate from those already proposed by CIMSS and included in ITPP5. In particular, the user community is interested in:

- retrieval results above the 10 hPa level in the output file;
- availability of the actual first guess in the output file as well as a statement concerning the origin of the guess which is currently stored;
- a new method for evaluating surface pressures at higher altitudes involving the interpolation of the weighting functions to significant levels.

3.2.4 Problems with existing software (ITPP3-4)

These questions concern very specific problems with applying the ITPP software under certain conditions. It was suggested that:

- There is a problem with the long-wave flux computation when no limb correction is employed. CIMSS will correct this problem.
- In HMTWR, the scale factor for conditioning of the matrix to be inverted should be set to equal 1. It is in the resident copy of ITPP4.
- For MSU processing, inconsistencies existed in the past between even/odd satellite numbers and conversions from brightness temperature to radiance. This problem has disappeared for the NOAA11/NOAA12 comparison.
- There is a problem during the ingest of Level-1B data in ITPP3. Small differences in the desired

start time yield large differences in temperature at a given location.

- There are large errors in the HIRS navigation in polar regions, perhaps indicating a problem with the spline fitting in subroutine COORDS. CIMSS will investigate Earth locating every point poleward of 80 degrees.

During the summary presentation of this technical SG it was reported that ITPP5 could be expected to be released within approximately 6-9 months of the Conference.

3.3 TECHNICAL SUB-GROUP ON RADIATIVE TRANSFER MODEL, RTTOV

RTTOV is a fast radiative transfer model for TOVS outlined by Eyre (Tech. Proc. ITSC-VI, 1991) and described fully in ECMWF Tech. Mem. 176. RTTOV constitutes a complete re-coding of the NESDIS/CIMSS TOVS radiative transfer code, available as part of ITPP. The new code can take advantage of vector architecture and has been written with development of future satellite sounding systems in mind. It also contains, in addition to the radiative transfer model itself, the associated tangent linear, adjoint and gradient-matrix models.

RTTOV has been distributed by ECMWF to several other institutions, and this technical sub-group meeting was effectively the first "user group" meeting for this software.

The meeting began with a report on the technical history of the code: the dates on which bugs were fixed, and the dates of versions sent to different institutions. The most recent update, in August 1992, was the creation of Version 2, in which SSU channels were added and some major technical modifications were made.

The interests and applications of the RTTOV users present were summarized and discussed. Groups other than ECMWF already using the code were: AES (Canada), CMS (France), BMRC (Australia), Met. Office (UK), and NESDIS and CIMSS (USA). The software had also been requested by EUMETSAT. Most groups reported that they had made, or intended to make, modifications to the code: to implement more sophisticated physics (cloud radiative properties, solar reflection, diverse surface characteristics), to apply it to instruments other than TOVS (e.g. ATOVS, SEVIRI, high spectral resolution infra-red sounders), or to generate transmittance coefficients using local line-by-line computations.

In the subsequent discussion, a number of problems with the code and errors in the documentation were noted. The problem of calculating and obtaining suitable empirical transmittance correction, "γ", factors was addressed.

The issue of divergence of code, as different groups develop new extensions, was discussed. No easy solution was identified, but it was proposed that a newsletter should be circulated to provide information on developments with RTTOV at different institutions.

Actions:

* **All users**, to report new developments and uses of RTTOV to J.Eyre, at least once per year.
* **Eyre**, to edit annual RTTOV newsletter (target date for first issue: January 1994).

4. ABSTRACTS OF ITSC-VII PRESENTATIONS

INVERTING INTERFEROGRAM SIGNALS TO RETRIEVE ATMOSPHERIC TEMPERATURE PROFILES

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High resolution infra-red sounders for measuring the Earth emission spectrum from satellite are now recognized fundamental for improving accuracy and vertical resolution of the retrieved atmospheric structure. Research is presently under development concerning the use of interferometer spectrometers (e.g. IASI), the related processing of interferogram samples, and algorithms for retrieving temperature and humidity profiles from higher resolution radiance data. Several papers exist covering the above mentioned topics separately. However, much effort still has to be made in developing joint techniques for processing interferometer data and retrieving the structure of the atmosphere.

In the present communication the technique which is under development at our research group is shown. Examples are illustrated by simulating synthetic interferogram signals corresponding to spectra with a spectral resolution of about 0.5 cm^{-1}. Only the spectral range 600-800 cm^{-1} has been considered and only the problem of retrieving temperature profiles has been fully analysed. The radiative transfer equation is convolved according to the lag window (rectangular, Bartlett, GCV) applied to the interferogram signal and linearized on the basis of a first guess temperature profile. Since the number of observations (i.e. infra-red radiances) is much greater than the number of vertical temperatures, techniques based on least squares become practicable and, on the contrary, more specific tools for inverse problems become less effective (e.g. regularization); in addition, the role of the first-guess solution in the inversion algorithm becomes less dominant.

Aim of the present communication is:

a) to develop an inversion algorithm for temperature retrieval;

b) to evaluate the effect of the lag window, in processing interferometer samples, on the final product;

c) to compare the results obtained by simulating high resolution infra-red sounder with the ones corresponding to the TOVS package.

USE OF RADIANCES IN 3D/4D VARIATIONAL DATA ASSIMILATION

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This paper describes the direct use of TOVS radiances in a variational analysis scheme. In its three-dimensional formulation (3DVAR), horizontal as well as vertical consistency is ensured. Mass and wind (and humidity) are analyzed simultaneously under certain balance constraints which control the amount of gravity waves in the analysis. The scheme thus combines retrieval, analysis and initialisation in one step.

In its four-dimensional formulation (4DVAR) time consistency, as given by the evolution of the forecast model and its adjoint, acts as an additional constraint.

The background to the development of a 3D/4D variational analysis scheme from the point of view of radiance data is discussed. The variational method is described and results are presented from the validation of the system when applied to a simplified retrieval/analysis problem with an analytical solution. We present results from a global three-dimensional analysis with radiances and compare with an OI analysis that had used retrieved profiles. Finally we demonstrate that the four-dimensional formulation is able to infer additional information from the dynamics of the forecast.

CLIMATE MONITORING USING TOVS DATA

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Recent work on the use of TOVS data for monitoring long-term variability of tropospheric temperature and moisture will be reviewed. This work has demonstrated the utility of TOVS data over the past 14 years for studies of climate and global change. The TOVS Pathfinder activity, co-sponsored by NASA and NOAA, will expand the usefulness of TOVS data for climate monitoring by creating a calibrated radiance data set and providing retrievals of geophysical variables using three different processing streams. These streams include a model-dependent scheme (Path A), an a-priori data dependent scheme (Path B) and a scheme independent of both models and a-priori data (Path C).

Launch criteria for future NOAA polar-orbiting spacecraft have also been recently updated in recognition of the needs of climate and global change researchers, in addition to the TOVS requirements for numerical weather prediction. These new criteria will be outlined and discussed also.

OPERATIONAL USE OF TOVS DATA AT THE DEUTSCHER WETTERDIENST

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Since several years the ITPP.III has been implemented at the Deutscher Wetterdienst (DWD) in Offenbach. First the profiles have been retrieved with the regression guess.

Since the last year the ITPP was running with the model forecasts of the German "Global Model" (GM) and of the mesoscale "Europe Model" (EM) in parallel. Collocations statistics with radiosonde observations show reduced errors in comparison to profiles which have been processed with regression guess.

At DWD the use of TOVS data will be twofold. At first temperature profiles of good quality are planned to be assimilated into the numerical analysis. For the present, impact studies with TOVS profiles in NWP are being performed. Primarily results are showing now negative impact of the data in the NWP analysis scheme.

The other way using TOVS products at the DWD is their display in the Interactive Graphical System (IGS). Here the TOVS products are not in competition with the conventional data. The forecaster can decide to believe in the data or not. In addition with over data, TOVS products in the IGS shall contribute to diagnosing the state of the atmosphere, to use them for nowcasting purposes in a limited form and to monitor the NWP analysis. Some examples are shown. In addition, activities have been initiated to use the TOVS data in total ozone monitoring.

TRANSMITTANCE COEFFICIENTS GENERATION FOR FAST RADIATIVE TRANSFER MODELS: APPLICATION TO NEW SATELLITE SOUNDING SYSTEMS

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We have generated polynomial transmittance coefficients internal to the RTTOV fast radiative transfer model with atmospheric transmittances calculated by using the FASCOD2 line-by-line model. The FASCOD2 computations are made for a small set of Earth representative profiles, uniformly mixed gases and water vapour molecular species separately and different scanning angles and pressure levels. The accuracy of the process is checked for the NOAA11 TOVS channels. A transmittance storage at a medium frequency resolution is tested. This storage allows afterwards any filter convolution of the transmittances and a quick adaptation of the RTTOV model for any new channels.

TOVS AND SSM/T OPERATIONAL PROCESSING AT NOAA/NESDIS

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NOAA/NESDIS has recently implemented a variety of upgrades and utilities to improve both the TOVS and SSM/T sounding processing systems. Some of these modifications and subsequent results will be discussed. NOAA/NESDIS is also in the midst of replacing the TOVS software, coded in 1978-79, with the Revised TOVS (RTOVS) software system. RTOVS is a modular software system designed to easily transition from the current TOVS instrument suite to the Advanced TOVS (ATOVS) system with a new expanded microwave sounder.

The process to implement the RTOVS code into the operations will be discussed. Current and future data distribution and archive will also be presented.

CLIMATE RESEARCH FROM TOVS THROUGH THE PATHFINDER PROGRAMME

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Several new international projects to study atmospheric and surface processes like:

- Pathfinder, for which official charter, as defined by NASA and NOAA, includes the reprocessing of the whole NOAA/TIROS-N satellite observations over 13 years, starting with the reprocessing of a two year benchmark period,

- GEWEX (Global Energy and Water cycle EXperiment) as defined by the World Climate Research Programme (WCRP), and more particularly GVaP, which, as a part of GEWEX, aims at improving our understanding of the role of atmospheric water vapour and its variability,

- AMIP Atmospheric Model Intercomparison Programme,

heavily rely on satellite observations made by the NOAAs and the DMSPs. The ARA group at LMD has gained a long experience in the processing of both sets of data and in their interpretation in terms of thermodynamic parameters describing the 3D structure of the Earth's system. A NOAA/TOVS dedicated algorithm, the "3I" (Improved Initialization Inversion) system, first published in 1983 was extended to global scale a few years ago, 1991, at ECMWF. A refined version of this algorithm is implemented on a CRAY-2 (CCVR in Palaiseau, France) for application to the processing of long series of observations in connection with the Pathfinder programme. Presently, the two-year benchmark period (1987-1989) is being processed.

RETRIEVAL OF TEMPERATURE AND WATER VAPOUR PROFILES FROM HIGH RESOLUTION DATA IN THE INFRA-RED: METHODOLOGY DEVELOPED AT LMD

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The high spectral resolution infra-red sounders like AIRS/EOS (Atmospheric Infra-red Sounder) or IASI (Improved Atmospheric Sounding in the Infra-red) with about 3000 channels from 3.7 to 15.4 µm, ($\lambda/d\lambda \approx 1200$) should provide great improvement in the retrieval of the atmospheric parameters. The aim is to meet the specifications issued by international agencies: temperature with an average rms error of 1K, humidity with an average rms error of 10%, vertical resolution of 1 km at least in the lower troposphere.

In order to solve the inverse problem, we addressed the following questions:

- forward modelling for analysing high spectral resolution data,
- analysis of the vertical resolution achievable from the next generation of vertical sounder, through the evaluation of the information content of the retrieval compared with that of the a-priori knowledge,
- impact of the initial guess on the quality of the retrievals.

PROGRESS TOWARD ASSIMILATION OF TOVS RADIANCES IN CANADA

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We will report on progress toward assimilation of raw TOVS radiances into the Canadian Meteorological Centre global spectral forecast/analysis system. The radiances are input to a one-dimensional variational analysis within a split (horizontal/vertical) optimal estimation scheme. Our immediate objective is to test the impact of the scheme in the northern hemisphere (in particular the North Pacific Ocean) using data from February 1989.

The presentation will focus on attempted improvements in "radiance tuning" and on assessment of the scheme in passive mode (i.e. without corrections to one analysis affecting the subsequent set of background fields). We are attempting to extend the radiance tuning approach used at ECMWF for assimilation of cloud-cleared radiances to deal with raw radiances. As at ECMWF, tuning is against the model background fields instead of radiosondes. Since cloud top pressure and cloud amount are required to calculate simulated cloudy radiances from the background field and since derivation of these parameters requires use of the forward model, an iterative approach to reducing systematic errors in (observed minus background) radiances is required.

USE OF TOVS DATA IN NUMERICAL WEATHER PREDICTION AT THE HUNGARIAN METEOROLOGICAL SERVICE

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Since July 1991 a Limited Area Model developed at the Swedish Meteorological and Hydrological Institute has been operationally run at the Hungarian Meteorological Service. With the installation of an HRPT receiver it became possible to investigate the applicability of TOVS data in the numerical weather forecasting. Retrieval products of ITPP 4.02 were assimilated into the NWP model. Impact studies were carried out, taking into account the known inaccuracies of the NWP model due to the shortage of appropriate background information. Furthermore, preparations for the direct assimilation of radiances are under way. RAOBHIR and RAOBMSU forward models are used to produce NWP and RAOB brightness temperature field. Statistical analysis of the radiance increments and those of various atmospheric parameters are to be presented. Due to the fact, however, that in the NWP model the initial temperature values are derived from the geopotential height, the emphasis is lain on this parameter.

AN IMPROVED CLOUD CLEARING SCHEME BASED ON RADIAL BASIS FUNCTIONS

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An improved cloud clearing scheme applied to HIRS/2 radiances is presented. The scheme incorporates a cloud-detection algorithm which basically exploits co-location software between the AVHRR and the HIRS/2 instruments. The filtering process consists in obtaining clear radiance at cloudy Fields of View by means of three routes:

a) a regression relation between MSU and HIRS channels;

b) an interpolation scheme;

c) a filtering scheme.

Step a) is based only on the radiances composing the field at hand; it does not involve the use of synthetic radiances therefore avoiding biases introduced by forward models. Interpolation and filtering are then performed using a scheme based on radial basis functions. The whole procedure has been validated using AVHRR data and the results are discussed. Since the cloud filtering involves only endogenous data, that is only data which are pertinent to the satellite pass of interest, the procedure is particularly indicated for climatological studies.

ASSESSING THE IMPACT OF HIGHER SPATIAL RESOLUTION ON CLOUD FILTERING APPLIED TO INFRA-RED RADIANCES

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Cloud filtering plays an important role in the processing of infra-red radiances from satellite for atmospheric applications. Various quantities and parameters can be defined in order to assess the capability of cloud filtering algorithms to produce cloud free radiance fields, e.g. the number of clear spots in a given radiance field, cluster indices such as the minimum average distance between clear and cloudy spots. Such indices, and therefore the ability of cloud filtering schemes, closely depend on the Field of View (FOV) of the infra-red sounder, which in turn determines the spatial resolution of the instrument. In this paper the effect of the spatial resolution on the cloud filtering process and more in general on cloud handling has been analysed. Various spatial resolutions, better than the one presently available with HIRS/2 package, have been simulated and the improvement in the cloud handling process quantified. The analysis has been carried out on the basis of AVHRR data. Six satellite passes have been examined which cover the European area.

USE OF TOVS SOUNDINGS AND METEOSAT IR DATA TO MONITOR CLOUD TOP HEIGHT

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Cloud top height maps using Meteosat IR data are routinely produced at the Italian Meteorological Service. TOVS soundings have been used to improve the spatial consistency of height assignment of cloud tops. The experiment has been carried out by comparing cloud top temperatures obtained from TOVS retrievals with those derived from Meteosat images. The results are shown and the assessment of consistency between the two sets of data are discussed. Three techniques of application of TOVS soundings to establish the cloud height from cloud top temperature obtained by Meteosat IR data shown.

THE EOS DIRECT BROADCAST SYSTEM

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This presentation will provide a summary of NASA's current plans for broadcasting data from its EOS series of satellites. The current observing characteristics of the available sensors will be presented. Of primary value to sounding researchers is the data from the AIRS/MHS, the MODIS, the AMSU and the MIMR.

NASA has conducted a global survey of over 700 potential direct broadcast users and found considerable interest and willingness to participate. This scientific and applications enthusiasm has raised the status of the proposed direct broadcast system to the level where it is a necessary component of the core system and thus has guaranteed functionality and uninterruptability.

NASA will provide information concerning the construction of equipment for reception of the new, higher-bandwidth signal (15 Mbps) and will provide on-site help if required. In addition, all data interpretation algorithms being prepared for product generation within the EOS Data and Information System (EOS DIS) will be available for interpreters of direct broadcast data. The opportunity for advanced, multispectral, high-resolution sounding exists for recipients of the directly broadcast EOS data. Researchers are encouraged to explore new uses of this wealth of data.

TEST OF THE SIMULTANEOUS PHYSICAL RETRIEVAL METHOD FOR CLOUD PARAMETERS AND TOTAL PRECIPITABLE WATER OVER CHINA REGION

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The simultaneous physical retrieval method in the ITPP is modified. The retrieved profiles from the modified scheme are used to compute cloud parameters and precipitable water over the China region with NOAA-10 TOVS data. The cloud parameters are compared with the satellite brightness temperature differences between the shortwave and longwave window channels. The analysis results indicate that the effect of the algorithm is definite.

HIGH RESOLUTION INFRA-RED SOUNDING USING NEURAL NETWORKS

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A new method for retrieving atmospheric thermodynamic variables from satellite vertical sounding observations is presented. This approach relies on a multi-layer perceptron (MLP). As a validation of the method, the neural network approach is used for the inverse (forward) radiative transfer problem on the TOVS instruments and compared to the 3I (3R) algorithms. It should be noticed that a variational approach, like a 1DVAR method, is straightforward from the back-propagation algorithm, which provides the Jacobians of the cost function with respect to the physical parameters. The MLP approach has been applied to the next generation sounders ATOVS and AIRS (or IASI).

PREPARATIONS FOR ATOVS DATA

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The Advanced TOVS (ATOVS) instruments will replace the TOVS system as the operational vertical sounder starting with NOAA-K. At ITSC-V, a working group was established to consider collaborative preparations for reception, processing and exploitation of ATOVS data by the international community. Prior to ITSC-VII, the working group met three times. A report on the discussions and commendations from the third meeting (at LMD, Palaiseau; 30 March - 1 April 1992) will be presented, as an introduction to further discussion of these issues at ITSC-VII.

By the time of the launch of NOAA-K (currently planned for 1996), methods for direct or interactive use of TOVS radiance data will be well established at a number of numerical weather prediction (NWP) centres. The implications of these developments for ATOVS data processing will be discussed. The quality of the ingest and pre-processing routines becomes of primary importance. Not only should pre-processed radiances be as accurate as possible, but their error characteristics should be simple and well-understood. Quality control procedures are required for detecting meteorological conditions under which it is not possible to simulate accurately "forecast radiances" corresponding to the measurements. Preliminary ideas and options will be presented on the pre-processing of ATOVS data prior to NWP data assimilation.

APPLICATIONS OF STATISTICS OF DEPARTURES BETWEEN MEASURED AND FORECAST TOVS BRIGHTNESS TEMPERATURES

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The difference between TOVS clear-column brightness temperatures and equivalent quantities calculated from short-range forecast fields have been accumulated operationally at ECMWF since May 1991 and have been used for several purposes. A bias correction procedure has been developed in the context of the one-dimensional variational analysis scheme used for the operational assimilation of TOVS radiance data. The measured brightness temperatures in a sub-set of channels are used as predictors in a regression scheme which generates a spatially-varying correction for the bias between measured and forecast brightness temperature in each channel. This scheme appears to be successful in compensating for air-mass dependent errors in the radiative transfer model for critical tropospheric temperature sounding channels.

The monthly statistics of brightness temperature departures have been studied. The standard deviations for tropospheric temperature sounding channels are found to be small (less than 1 K) even in data-sparse areas such as the southern oceans. This demonstrates that the errors in the radiative transfer model (after bias correction) must be small. By contrast, errors in humidity channels (HIRS channels 11 and 12) are much larger. In the tropics and sub-tropics the monthly mean brightness temperature departures can be 2-3 K. These values are consistent with mean errors in the forecast model's mid-upper tropospheric specific humidity of up to 20% in these regions. This study has illustrated the potential of TOVS humidity channels for diagnosing problems in the hydrological cycle in numerical weather prediction and climate models.

IMPROVEMENTS TO TOVS RETRIEVALS OVER SEA ICE AND APPLICATIONS TO ESTIMATING ARCTIC ENERGY FLUXES

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One of the most important applications of TOVS-derived products is to the better understanding of atmospheric processes in remote, data-sparse regions of the Earth. The Arctic Ocean is one such region: while snow- and ice-covered areas are believed to play a major role in the global heat engine and in climate modulation, relatively little is known of interactions between sea ice and the atmosphere. The quality of TOVS retrievals in polar regions, however, is often significantly lower than in most other parts of the globe, thus the potential of this valuable tool has not been realized in high latitudes.

The objective of this study is to identify sea-ice related deficiencies in retrievals from the Improved Initialization Inversion ('3I') algorithm, and to investigate methods to remedy them. Comparisons to surface and aircraft observations have revealed systematic errors in estimates of ice surface temperature and microwave emissivity; detection of clouds over snow/ice; and retrievals of low-level temperature inversions, which are nearly ubiquitous in polar regions. Modifications to ameliorate these shortcomings have been incorporated into 3I, and the resulting retrievals are now being applied to studies of the Arctic energy budget. Preliminary work indicates that TOVS-derived products may provide valuable information for calculations of turbulent fluxes in the planetary boundary layer, horizontal advection of sensible heat and moisture into the Arctic Basin from lower latitudes, and surface radiation fluxes.

THE DEVELOPMENT OF AN INTERACTIVE RETRIEVAL/ANALYSIS/FORECAST SYSTEM

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As a joint effort, the National Environmental Satellite, Data and Information Service (NESDIS) Office of Research and Applications (ORA) and the National Meteorological Center (NMC) have developed and tested a TIROS-N Operational Vertical Sounder (TOVS) retrieval/analysis/forecast interactive system which uses the six-hour forecast from NMC's Medium Range Forecast Model for constructing the retrieval algorithm's initial guess. The system is interactive because the satellite-retrieved parameters, in addition to conventional in situ data, are analyzed to produce initial conditions for the subsequent forecast by NMC's Global Data Assimilation System (GDAS), and that forecast is used as the initial condition for the subsequent temperature/moisture retrievals.

Results obtained from a number of real-time interactive impact studies confirmed that:

a) retrieval accuracy is significantly improved, compared to that of the NESDIS operational system, with the use of a 6 hour forecast as the retrieval initial guess, and,

b) 5-day forecasts are significantly improved in the Southern Hemisphere. In the Northern Hemisphere the forecasts are comparable using either interactive or operational retrievals. Operational implementation of the interactive retrieval system as part of NMC's GDAS is expected in 1993. Details of the algorithm, as well as results, will be presented.

THE DEVELOPMENT OF AN ALGORITHM FOR GENERATING HOMOGENEOUS TIME SERIES OF SATELLITE DERIVED LAYER MEAN TEMPERATURES

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Operational satellites are ideal for deriving temperature products for monitoring climate change since they provide global coverage as well as a single instrument for that coverage. However, there are two major conditions that need to be satisfied in order to successfully use satellite derived temperature products for long term climate monitoring. First, the derived temperature products should be independent of any a priori (first guess) information in order to be certain that any observed trends in the data are due to actual climate variability and not to artifacts in the first guess. Second, periodically there is a new generation of sensors with a different ensemble of spectral channels. The temperature products must be derived in such a manner so that characteristics of the product do not change appreciably from sensor to sensor.

An algorithm has been developed that satisfies these two conditions. To satisfy the first condition, the algorithm removes first guess dependency by directly retrieving deep layer mean temperatures (DLMT) in contrast to the more traditional approach of retrieving pointwise temperature profiles and then averaging. To satisfy the second condition, the algorithm has been successful in producing nearly identical DLMTs from two different sensors - the MSU and the future AMSU. In other words, the correct combination of measurements from one sensor can be determined in order to reproduce with exceptional accuracy an averaging kernel derived from a completely different sensor. This is a very important result, because it provides a method for constructing a single continuous time series of satellite derived DLMTs from a succession of present and future sensors.

AN ATTEMPT OF A MOISTURE FIELD ANALYSIS USING METEOSAT AND MICROWAVE DATA

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An improvement of the atmospheric moisture field analysis needs merging of data from different sources. It is shown that the cloud analysis of satellite pictures can be extended to a moisture field analysis above the ocean by means of microwave data. The case study described uses cloud classification of Meteosat and SSM/I microwave data.

TOVS STUDY OF "A MOST BEAUTIFUL" POLAR LOW

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On 26 February 1987 the development of a mesoscale cyclone resembling a tropical hurricane was observed over the western Barents Sea. A synoptic description and a numerical simulation with the LAM of the DNMI (horizontal resolution 25 km) was published by Nordeng and Rasmussen (1992), Tellus 44A. They show that the genesis of this mesocyclone begins near the centre of an occluded synoptic-scale cyclone in the western Barents Sear near 74N/30E at 12 UTC, 26 February 1987. The first signs of a mesoscale circulation with shallow convective cloud spirals is observed at 17 UTC. The mature stage is reached in the first hours of 27 February 1987. Wind speeds up to 20 m/s have been recorded at Norwegian coastal stations.

The investigations with TOVS retrievals (3I-version 2) show a cold air outbreak in the formation stage of the mesocyclone within a few hours, which is not clearly seen in the numerical model results. In agreement with the LAM fields, the development of a warm centre can be detected in the retrievals of the 500/1000 hPa thicknesses.

HIRS INSTRUMENT DESCRIPTION FOR NOAA-K, L, M

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The High resolution Infra-red Radiation Sounder (HIRS/3) is an improved version of the multispectral optical sounding instruments flying on the Advanced TIROS-N (ATN) polar-orbiting meteorological satellites. The HIRS/3 instruments, currently being assembled and tested for NOAA-K, L, M, are compared to the HIRS/2 and HIRS/2I instruments now on orbit. Instrument performance data taken during thermal vacuum testing of the first HIRS/3 instrument, scheduled for NOAA-K, is presented. Instrument upgrades and performance improvements being developed for consideration on NOAA-N and N' are also presented.

A FAST SCHEME FOR LINE-BY-LINE FORWARD MODEL

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A fast scheme for line-by-line forward model has been developed. The keypoint of the scheme is a hybrid of analytical and numerical integration, and it reduces the calculation time approximately by an order of magnitude as compared with that of classical scheme.

The scheme is summarized as follows: (a) divide the whole range of the wavenumber, v, into many intervals with various widths, so that a quadric is obtained as an approximation of the cross section for each interval (making data base of the cross section); the transmittance for a wavenumber interval, T, is the integral of the exponential function of the optical depth, τ, where τ is expressed approximately with a quadric by that approximation, i.e. $\tau = a \times v^2 + b \times v + c$; (b) if $a \geq 0$, calculate the exponential or error function to obtain the integral; (c) if $a < 0$, divide the interval into sub-intervals where the terms of v^2 can be neglected, so that the transmittance for the sub-interval, T_i, is expressed with the exponential function; calculate the weighted mean of T_i, to obtain T.

TOTAL OZONE AMOUNT RETRIEVAL FROM TOVS DATA BY MEANS OF NEURAL NETWORK

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More and more stratospheric ozone depletion not only in the polar regions but even over Europe is discussed during the past years due to climate change impacts. Planet (*J.Clim.Appl.Meteorol., 23, 308-316, 1984*) proposed a retrieval procedure with multivariate linear regression technique using HIRS/2 channels 3, 8 and 9 for determination of total ozone amount. The disadvantage of this technique is that nonlinearities of radiative transfer are not taken into account.

In this paper a new approach by means of neural network technique for determination of total ozone amount is presented. The nonlinear transfer function of a neural network (perceptron) is more suited to such nonlinear problems. Dobson spectrometer measurements are used for training of a neural network with clear column radiances converted to brightness temperatures of relevant TOVS channels (e.g. HIRS channels 3, 8 and 9). Clear pixels of the HIRS data are selected by using the cloud detection algorithm of the "3I"-System.

In a case study NOAA/TOVS satellite data of one month over Europe (April 1992) are processed and the total ozone amount retrievals are compared with Dobson spectrometer measurements in spatial and temporal coincidence of the satellite data. The satellite data retrieved ozone data are in good agreement with the measured data.

The mean error of the total ozone amount retrieved by neural network approach from the TOVS data is 11.5 Dobson Units (DU). This means better than 5% of the total ozone mean value (390.1 DU) of the Dobson spectrometer measurements. Compared to the linear regression approach (mean error 29.1 DU) the accuracy of ozone retrieval by neural networks is much better. This indicates the assumption that a nonlinear approach is more suited for this kind of nonlinear retrieval problem.

ASSESSING THE COMPLETENESS OF THE TIGR DATA BASE FOR ARCTIC RETRIEVALS

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A recently compiled data set of over one million Arctic rawinsonde observations from drifting ice islands and coastal stations has been used to assess the representativeness of the TOVS Initial Guess Retrieval (TIGR) data base for Arctic temperature conditions. This large volume of data has been reduced through principal component and cluster analyses to a set of 2000 cluster means which were then compared to the 416 polar profiles in TIGR. The differences between these temperature profiles and the TIGR data are examined at a variety of tropospheric pressure levels. However, expressing any deficiencies in TIGR as simply temperature differences would not provide any direct information useful for climatological studies. Therefore, we assess the completeness of TIGR in terms of radiation flux retrieval.

To assess the impact of cluster mean temperature and humidity profiles that are not represented in TIGR, they are converted to HIRS and MSU channel radiances with a forward model. These radiances are then input to the Improved Initialization Inversion (3I) retrieval algorithm, using the existing TIGR first guess data base. Shortwave and longwave, upwelling and downwelling fluxes are then computed for the original and retrieved profiles using mean January and June conditions for clouds, aerosols and trace gases. The magnitude of the errors in the estimated fluxes are illustrated in the context of their expected frequency of occurrence, and the implications for energy budget studies are discussed.

APPLICATION OF CLUSTER ANALYSES OF RADIANCE DATA MEASURED BY SATELLITE AND COMPUTED FROM FORECAST PROFILES

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NOAA's Forecast Systems Laboratory (FSL) is running an operational mesoscale numerical model within a 3-hour assimilation called Mesoscale Analysis and Prediction System (MAPS). In order to assimilate TIROS radiance data to NWP model, the specification of error covariance of both measured radiances and computed radiances from 3-hour forecast profile are required. To this end, 455 samples of collocated radiances and temperature/humidity profiles at RAOB sites were obtained over the lower 48 United States during March 1991.

The statistical analyses of these samples involve the clustering procedure, which is based on the closeness of measured-minus-computed radiances among the samples. The means and covariances of the dominant four clusters are applied to a TIROS pass to identify clusters at 0000 UTC on 25 March 1991. Comparisons with the March 1992 data set will be discussed.

EUMETSAT ACTIVITIES FOR THE ATOVS PROCESSING

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With NOAA-K launch scheduled for 1996, there will be a new set of sounding instruments available for the retrieval of the three dimensional thermodynamic structure of the atmosphere from space. The Advanced TOVS (ATOVS) will include a set of microwave instruments giving the capability of retrieval under nearly all meteorological conditions. The planned EUMETSAT contribution in close cooperation with NOAA/NESDIS to provide a standardized processing package for operational users is presented. Planned processing strategies as well as software structure(s) will be demonstrated.

The user requirements have been summarized by EUMETSAT. The planned processing package may include global centralized orbital processing as well as local processing for direct readout users. The User Requirements Document will be presented as a discussion basis for further development.

The RTOVS software currently under development for NOAA/NESDIS to process global TOVS data has been reviewed partially as a common basis for future ATOVS software development.

SYNOPTIC STUDIES WITH TOVS DATA

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This study continues the investigation of two synoptic cloud cluster situations with TOVS data. Comparisons with different model results, with ECMWF analyses as well as a mesoscale model are presented. In addition radiosonde collocations as well as comparisons to other "conventional" data are shown. TOVS derived fields show features which are not covered by "conventional" analyses. Statistics are applied to quantify the comparisons between the different data sets.

The retrieval schemes used are the ITPP-4 and the "3I-2".

ON THE NEAR-REAL TIME OPERATIONAL USE OF TOVS DATA

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In June 1992, a VAX-Version of "3I-2" was implemented into the operational processing scheme of the Satellite Data Processing System SDPS at the German Military Geophysical Office (GMGO), Traben-Trarbach. Thus results of TOVS processing in form of thicknesses 500/1000 hPa were available in nearly real-time for all NOAA-11 passes received directly at GMGO. For a period of one week retrieved fields are shown in comparison with model results. Display on the Interactive Graphics System (IGS) is demonstrated.

This work was performed whilst the author was responsible for satellite data processing at GMGO.

ASSESSMENT OF THE QUALITY OF TOVS RETRIEVALS OBTAINED WITH THE 3I-ALGORITHM FOR ANTARCTIC CONDITIONS

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The performance of the 3I (Improved Initialisation Inversion) algorithm (version 2) developed at the LMD (Laboratoire de Météorologie Dynamique, Paris) has been studied by means of collocations with radiosoundings for two summer periods (January and February 1987 and 1990) in the Weddell Sea (Antarctica). As the corrections of the atmospheric transmission functions of the latest 3I version correspond to end 1989, a recomputation of "deltas" for 1987 was necessary.

A collocation statistic for mean layer temperatures based on 160 cases shows very satisfying results as to the standard deviation with values ranging from 1.5 K (in the middle troposphere and stratosphere) to 1.8 K near the tropopause and 2.1 K in the lowest layer (850/1000 hPa). However, an overall negative bias (-1 to -1.6 K in general) is observed. Considerably lower biases in clear situations suggest that the frequent cloudy situations are one reason. The atmospheric stability index derived from the retrievals corresponds well to the observation.

The layer humidities are calculated with a good absolute accuracy, but errors may be large in terms of percentage of the mean content because of the very dry Antarctic conditions. Comparisons of temperature and humidity retrievals to ECMWF analyses result in larger deviations for 1987 than for 1990 indicating improvements in the analysis scheme in this region and therefore emphasize the value of TOVS retrievals as a source of information. Further comparisons of the total water vapour content to results based on SSM/I measurements show a good agreement between the two different retrieval methods.

INTERACTIVE SOFTWARE FOR TOVS DATA VISUALIZATION

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In the Finnish Meteorological Institute the satellite sounding data is processed operationally on CRAY-XMP using the ITPP software. Most work has been done on a practical level by developing software for graphics workstation, so that a good visual interface to the operational data is available. The same software can be used also for the presentation of surface and radiosonde data, and especially for their comparison against TOVS data.

Main features of the software include:

- Quantities in the ITPP output data can be viewed in colour map presentation over a freely definable geographical area.
- Quick interpolation is done if that option is selected.
- Temperature profile window is presented simultaneously while interactively moving the pointer over the displayed area.
- Comparison against the nearest radiosonde profile is shown at the same time if the radiosonde data is available.
- Animation by using consecutive satellite passes is possible for any quantity. Software supports also video output for animations.

- Retrieval of the archived raw data and ITPP products can be done interactively over the network.

One main use of the software has been the monitoring of total ozone variations. This is also demonstrated further by images in the poster presentation.

UTILISATION OF TOVS DATA AT BMRC

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This paper describes the current, physically-based, real time retrieval system employed at the Bureau of Meteorology. It describes in detail cloud height and ozone determination methods and the radiance tuning technique employed in the system. It details recent numerical experiments designed to investigate the impact of locally processed TOVS data from the system on operational Australian Region numerical weather prediction. These experiments are being done against a background data environment which includes NESDIS low resolution TOVS data and locally generated cloud drift winds. It describes initial work in the implementation of a 1-dimensional variational retrieval scheme in association with the BMRC Global Assimilation and Prognosis Scheme. It also describes the implementation of a PC-based TOVS processing system in a McIDAS environment and its application to research and operations.

TEMPERATURE FIELDS OVER THE ARCTIC FROM TOVS DATA: ADJUSTMENT OF THE ITPP AND INTERCOMPARISON WITH CONVENTIONAL DATA

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In a case study, NOAA 10 data received at Spitzbergen has been processed for eight overpasses. To adjust the ITPP 3.03 appropriately, three problems were studied:

1. the influence of the calibration on the differences $T_b(H10) - T_b(H8)$ over high terrain,

2. a numerical instability of the retrieval algorithm, and

3. the evaluation of δ (MSU 3).

For an intercomparison of retrievals, collocated radiosondes and ECMWF analysis, RMS and biases of their temperature differences were calculated. In the given meteorological situation, neither regression nor climatology used as first guess produced satisfactory results. But RMS $\approx$ 1 K are achieved in the atmosphere with prognosis as first guess.

A NEW CLOUD CLEARING APPROACH FOR NESDIS

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The cloud clearing approach used at NESDIS has remained unchanged for almost a decade. During that time, improvements in the ability to cloud clear measured radiances have been made, and the weaknesses of the current approach have been identified. The operational NESDIS approach is being modified to take advantage of these improvements. The part of the current algorithm that adjusts all the measurements to nadir before cloud clearing is being removed. In the new version, radiances will be corrected first and then cloud cleared. This will result in clear radiances at the observed angles. If angle-adjusted radiances are

required, the clear radiances will be adjusted. This increases the accuracy of the angle adjustment since clouds do not have to be considered in the adjustment. In addition, further changes are being evaluated as part of the joint NOAA/NASA effort to improve operational soundings. This effort includes an evaluation of the effects that the differences between NOAA and NASA algorithms have on accuracy. Changes will be made in the way clear spots are identified and in the way the N* technique is used. Plans for the new procedures and results from the new algorithms will be presented.

EXPERIMENTS USING ONE-DIMENSIONAL VARIATIONAL ANALYSIS OF TOVS DATA AT ECMWF

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As part of a more general plan to assimilate variables as close as possible to observed quantities, a one-dimensional variational analysis of TOVS data has been developed at ECMWF. The scheme known as 1DVAR (within the wider context of the three-dimensional 3DVAR and four-dimensional 4DVAR variational analysis projects currently under development at the Centre) at present analyses clear TOVS radiances to obtain profile estimates of the atmospheric state at the observation location and time.

This paper describes the series of analysis and forecast impact experiments performed prior to the operational implementation of 1DVAR. Results presented (both in terms of subjective synoptic evaluations and more objective skill score verification statistics) demonstrate a clear positive impact of TOVS data on the analysis and the subsequent forecast quality. Some of the other monitoring and diagnostic tools developed to evaluate the performance of the 1DVAR scheme are also described.

Finally the plans for future development and extensions of the 1DVAR scheme will be discussed, in particular regarding the improved specification of forecast and measurement error covariances which are considered crucial to the success of 1DVAR.

NOAA'S SATELLITE PROGRAMMES FOR THE 1990S AND BEYOND

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The primary sensors flown on board the two operational (morning and afternoon) POES and services from this satellite series have changed only slightly over the past fifteen years since the launch of TIROS-N in October 1978. The next significant instrument changes will take place on the NOAA K, L, M, N series starting in 1996. The Advanced Microwave Sounding Unit (AMSU) is replacing the present Microwave Sounding Unit (MSU) and the Stratospheric Sounding Unit (SSU): AMSU-A has 15 channels in the 20 to 90 GHz range that have 45 km resolution and AMSU-B has 5 channels in the 90 to 184 GHz range at 15 km resolution. The Advanced Very High Resolution Radiometer (AVHRR) will time share channel 3 between 3.7 microns at night and 1.6 microns at day (for snow mapping). Even more significant changes are envisioned in the era of the NOAA O, P, Q series of satellites starting about 2004. The Visible Infrared Scanning Radiometer (VIRSR) with 7 channels (.62, .87, 1.6, 3.7, 8.6, 10.8, 12.0 microns) at 12 bit resolution will replace the AVHRR. The Infra-red Temperature Sounder (IRTS) with high spectral resolution will replace the High-resolution Infra-red Radiation Sounder (HIRS). The Solar Backscatter Ultraviolet Radiometer (SBUV) nadir measurements will be supplemented by the Total Ozone Mapping Spectrometer (TOMS) cross-track scans. The Direct Broadcast System (DBS) will be upgraded so that HRPT transmission at the same frequency can handle 3.5 Mbps through two broadcast channels (the I and Q channels); necessary modifications to existing HRPT stations will be minimal. It is the goal of NOAA to provide uninterrupted, global observations from the POES series which will be periodically upgraded in an evolutionary manner.

TRENDS IN GLOBAL CIRRUS INFERRED FROM THREE YEARS OF HIRS DATA

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Trends in global upper tropospheric semi-transparent cirrus cloud cover are beginning to emerge from a three year cloud climatology compiled using NOAA polar orbiting HIRS multispectral infra-red data. Cloud occurrence, height and amount have been determined with the CO_2 slicing technique on the three years of data (June 1989 - May 1992). There continues to be a global preponderance of semi-transparent high clouds, presumed to be cirrus; 40% on the average for the three years covered by June 1989 to May 1992. In the ITCZ a high frequency of cirrus (greater than 50%) is found at all times; a modest seasonal movement tracks the sun. Large seasonal changes in cloud cover occur over the oceans in the storm belts at midlatitudes; the concentrations of these clouds migrate north and south with the seasons following the progressions of the subtropical highs (anticyclones). More cirrus is found in the summer than in the winter in each hemisphere.

The changes in cirrus cloud cover from year 1 to year 2 were insignificant, but the changes from year 2 to year 3 were very noticeable. Opaque cloud cover reduced by 7% globally, while cirrus cloud cover (most of it having effective emissivity less than 0.50) increased by 9%. While 1991 saw the eruption of Mt. Pinatubo and a significant El Niño event in the eastern Pacific, the explanation for this change in global cloud cover is not yet understood.

OPERATIONAL USE OF TOTAL OZONE MAPS RETRIEVED FROM TOVS DATA

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The correlations between total ozone fields as derived from TOVS observations and isentropic potential vorticity and 100 hPa wind fields, jet streams and other meteorological features to be used operationally are underlined. A deep ozone minimum occurring on 14-15 January 1992 over Northern Europe is presented. Extraction of vertical profiles to identify stratospheric air masses intrusions is analyzed.

USE OF TOVS DATA IN NUMERICAL WEATHER PREDICTION

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The use of TOVS data in operational Numerical Weather Prediction (NWP) is reviewed, and its developments in the main NWP centres during the last few years is described. Also the main research activities related to TOVS, performed in data assimilation groups and satellite data groups are reviewed.

Important changes have occurred during the last few years in the algorithmic concepts of data assimilation, with more and more people working on variational analysis schemes. The general tendency has been to try to use more and more directly the TOVS information in the analysis. This can mean radiances (raw or cloud-cleared) used as input of the analysis rather than retrieved profiles.

Examples are also given, showing the potential benefits of using TOVS directly in a 4D assimilation scheme, then exploiting the information contained in the time continuity of the observations. The main lines of the research on use of TOVS data in NWP are highlighted with discussion of some points like:

- Using ATOVS rather than TOVS;

- Analysis of water in the atmosphere (specific humidity, liquid water content).

EUMETSAT FUTURE PLANS FOR SATELLITE SOUNDERS

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The EUMETSAT Polar System (EPS) is the proposed European contribution to the meteorological polar orbiting observing system, aimed at ensuring the timely availability of meteorological data from a series of morning (Europe) and afternoon (USA) polar orbiting spacecraft. The EPS concerns both the space observing system (jointly provided with ESA and NOAA) and the associated ground system. The baseline assumption is the development of the METOP (METeorological OPerational) platform by ESA, with a first launch in the year 2000, which will accommodate the core meteorological payload and a complementary climate payload. The sounders to be flown on METOP-1 will be the High-resolution Infra-red Radiation Sounder/3 (HIRS/3) and the Advanced Microwave Sounding Unit-A (AMSU-A) provided by NOAA, the Microwave Humidity Sounder (MHS) provided by EUMETSAT, and the Infra-red Atmospheric Sounding Interferometer (IASI) provided by ASI/CNES. HIRS/3 and AMSU-A will be copies of the instruments flown on the NOAA-K, -L and -M. MHS is a successor to the Advanced Microwave Sounding Unit-B (AMSU-B) to be flown on NOAA-K, -L and -M and provided by the UK Meteorological Office. MHS will have similar functionality for humidity sounding. The MHS Phase-B studies were completed in June 1992, resulting in detailed instrument specifications, which are being used for Phase C/D planning activities. IASI is a joint Italian/French project currently in Phase B. Also embarked on METOP will be the Advanced Very High Resolution Radiometer (AVHRR), the Space Environment Monitor (SEM), the Search and Rescue (S&R) and the Data Collection System (DCS), all provided by NOAA. In addition, ESA will provide an Advanced SCATterometer (ASCAT) and a Multi-frequency Imaging Microwave Radiometer (MIMR).

Concerning the EPS ground segment activities, a User Requirement Document has been produced, defining the operational meteorological mission objectives and the user requirements, which include software support for HRPT and LRPT stations. A study reviewing the algorithms needed to generate the EPS products was also performed addressing the science, numerical implementation, error assessment and quality control for each of the products requested by the operational community. The results of this study, together with the user requirements, will be the input to the Ground Segment Phase-A studies to be started in 1993.

INFLUENCE OF THE TOPOGRAPHY OF THE EARTH SURFACE ON VERTICAL SOUNDING OF THE TEMPERATURE PROFILE

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The influence of the topography of the Earth's surface on the results is investigated using the 3I-inversion procedure.

To avoid errors when interpreting the measured radiance values from the atmosphere in the radiative transfer calculation assuming a plane surface, a more detailed characterization of the topography of the Earth's surface is required.

Thus the influence of the topography on the calculated temperature profiles, using a new elevation model with a resolution of 500 m and a new topography rejection test, is demonstrated by means of case studies. Variations are mostly found to occur in areas with a highly variable topography, as the procedure is considerably affected by the ground pressure via the initial solution selected. The geographic position of the calculated temperature profile tends to be shifted to areas with a smaller vertical variation in the topography. The mean elevation determined by the new elevation model is more representative for the area observed. Furthermore, the temperature profiles in the proximity to the coast can be improved considerably due to the more precise identification of the surface property "land" or "sea". In individual cases, however, considerable improvements could be achieved in comparison with the mean achieved accuracy of about 2 K.

VERIFICATION OF 3I RETRIEVALS VIS-À-VIS RADIOSONDE OBSERVATIONS

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In cooperation with the Laboratoire de Météorologie Dynamique at Palaiseau, France, a set of TOVS observations from 58 NOAA-11 orbits in the period of 14 September until 3 October 1992 over Europe has been processed with the 3I system. The resulting retrievals have been compared with collocated radiosondes extracted from the operational database at KNMI for the same period. The collocation criteria (less than 3 hours time difference and a maximum distance of 50 km) resulted in a statistical dataset with about 100 or more items in each of the considered sub-cases: clear-cloudy, day-night and their combinations.

Apart from results for the layer mean virtual temperatures, we also obtained statistics for the stability index and for the total water vapour content. These results will be presented along with a number of conclusions and recommendations for further developments.

TOVS PACKAGE UPDATING FOR FIELD DB INPUT

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Most nations still use TOVS products for research purpose. In this study the TOVS package was improved to reduce processing time and to upgrade the quality of outputs for operational applications.

a) To reduce TOVS processing time, data were directly transferred to Field DB without passing through Sounding DB which was resulted in reducing processing time more than on hour.

b) Filtering processing was added to filter out the abnormal data for isopleth chart.

c) The new outputs such as geopotential height analysis, horizontal distribution of ozone amount for certain level and streamline analysis of geostrophic wind were made using modified ITPP-4.

d) The chart of 850 hPa temperature and 500 hPa geopotential heights from TOVS products were serviced 4 times per day for operational purposes.

e) The distribution of total ozone amount over the Korean peninsula on a daily basis and daily and monthly ozone reports of Seoul area were routinely obtained and provided with Applied Meteorology Bureau of Korea Meteorological Administration.

TOVS/DMSP OPERATIONAL STATUS

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The current status of the TIROS Operational Vertical Sounder (TOVS) and Defense Meteorological Satellite Program (DMSP) operational sounding systems is presented. Over the past eighteen months several upgrades of the TOVS and DMSP operational algorithms for sounding products were implemented. The latest upgrade installed during early April 1992 resulted in significant improvements for TOVS cloudy soundings. A summary of these and other upgrades, for example the new cloud, total ozone and SO_2 algorithms and a proposed radiance classification approach to determine the first guess, is presented. The DMSP operational system is currently the focus of much attention as proof-of-concept for Advanced TOVS soundings using the Advanced Microwave Sounding Unit. The status of research to replace the current statistical regression with a physical retrieval algorithm, and to employ the Special Sensor Microwave/Imager (SSM/I) data when generating sounding products, is presented.

DEPARTURES BETWEEN OPERATIONAL SATELLITE SOUNDINGS, RADIOSONDES AND FORECASTS

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An analysis of operational satellite data which has been collocated with numerical weather prediction forecast fields and radiosonde observations is presented. An important tool to compare these voluminous data in the troposphere is the stability departure, although parameters such as temperature and moisture are also compared. The stability departure is defined as the difference in the tropospheric lapse rate of the satellite soundings minus the forecast or radiosonde observations. Global fields of forecast (NMC) based stability departures are shown which indicate that in general, the highest departures collect in areas of maximum satellite radiance gradient. These are typically associated with mid-latitude frontal zones and the jet stream. This conflicts with previous assertions that the satellite soundings typically underestimate the global amplitude of the cold and warm air sectors. A relationship between the sign of the departure and occurrences of either warm or cold advection is discussed. Collocations with radiosonde forecast based stability departures are also presented, and cases of large forecast-based stability departures are isolated. Departures for several such cases are presented and the importance of spatial and temporal differences in the observations is discussed.

ADVANCED SOUNDING SYSTEMS: THE POLAR ORBITING ITS AND THE GROUND-BASED AERI

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A practical instrument design for substantially improving the TOVS sounding system is available, and the soundness of the approach has been proven with ground-based systems. The Interferometer Thermal Sounder (ITS) is a high spectral resolution advanced temperature and water vapour sounder, which is no larger than the current HIRS/3. It was designed for EUMETSAT by the High-resolution Interferometer Sounder (HIS) team (University of Wisconsin, Santa Barbara Research Center, and Bomem, Inc.), with the objective of achieving the simplest possible design for operational sounding. No fundamental technological developments are needed to implement the ITS. In fact, ground-based instrumentation with a similar design concept is being installed for zenith viewing with 24-hour, unattended operational at the Southern Great Plains site for the Atmospheric Radiation Measurement (ARM) programme. An outgrowth of the HIS

program, the Atmospheric Emitted Radiance Interferometer (AERI) has been developed with support from the US DOE and has been used successfully in several field experiments. A future network of ground-based sounding instruments would provide a strong complement to the ITS for significantly advancing capabilities for remotely sensing the state of the atmosphere.

SSM/T FORWARD MODELLING USING NEURAL NETWORKS

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Physical algorithms for retrieving temperature and humidity profiles employ the physics of radiative transfer. Consequently, it is necessary to do the forward problem accurately before attempting the retrieval one.

Apart from "classical" radiative transfer modelling, another method has been developed, the neural network approach.

Back-propagation networks, implemented on a VAX 9000, have been trained on a data set of selected profiles collocated with SSM/T measurements. Then brightness temperatures were produced from unfamiliar real data and compared to the SSM/T measurements and to results from "classical" codes using different architectures of networks. The comparisons seem very promising and a further work is going to be done on this method which can be very powerful to treat data from next generation sounders like AMSU, AIRS or IASI.

OVERVIEW OF AVHRR/TOVS AND ATOVS MATCHING

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Since several years, some studies have been done to combine the use of AVHRR and TOVS. We will present the main results already obtained and the questions which have to be solved in the next future:

- accuracy of co-registration of AVHRR pixels in HIRS field of view
- cloud free HIRS f.o.v. detection and cloudy condition processing
- use of SST, cloud top temperature, cloud emissivity....
- plan to use NDVI and infra-red emissivity atlas (in progress)
- current use of AVHRR/HIRS matching for direct R.T.E.
- plan to use such matching for inverse R.T.E.

Very poor results have been obtained concerning the combined use of AVHRR and MSU due to the raw antenna pattern of MSU. AMSU should give quite better possibilities. We are defining new objectives for this work:

- testing of a combined use AVHRR-SSM/I or METEOSAT-SSM/I
- similar using of SSM/T1 and T2 with AVHRR and METEOSAT
- how to prepare a land microwave emissivity atlas?
- how to get an easy to use, fast and accurate microwave model taking account of surface emissivity, rain, ice etc.?

Such work should be strongly improved by a cooperative action in the framework of ITSC for a local and regional use of HRPT direct readout stations.

UPPER TROPOSPHERIC HUMIDITY OBSERVATIONS FROM METEOSAT AND COMPARISON WITH ECMWF FORECASTS

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The development of a climatology for the upper tropospheric relative humidity (UTH) from Meteosat radiance observations in the water vapour channel (WV: 5.7 - 7.1 μm) is discussed. Since water vapour is the most important greenhouse gas in the Earth's atmosphere and the most variable one, knowledge about the water vapour distribution and its relationship to cloud formation is fundamental to understanding the Earth's greenhouse effect.

Monthly means of the UTH from METEOSAT are compared with ECMWF forecast fields. We find a dry bias in ECMWF field in convective regions and a more severe moist bias in the dry subtropical subsidence regions. The bias persists through all seasons.

The satellite UTH also indicates that large areas in the descending branch of the Hadley circulation have an inverse relationship to the UTH in convective regions, that is the UTH in descending areas of the Hadley circulation is significantly drier in July than in January, April and October. Implications of the observations for the water vapour feedback in the Earth's environment require continuous, consistent and accurate data monitored over long periods of time and over the whole globe. At least the demand for continuity and consistency is well met by operational meteorological satellite programmes. Current data can make already valuable contributions to a global climate monitoring system.

DEVELOPMENT OF A MESOSCALE DATABASE OF ATMOSPHERIC CONDITIONS AND CORRESPONDING TOVS RADIANCE SIGNATURES

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The Midwest Atmospheric Database (MAD) was developed from over 70,000 individual RAOB soundings covering a large portion of the central United States. After a rigorous quality control process, an empirical orthogonal function (EOF) analysis was performed on the data. The orthogonal elements were clustered to reduce the size of MAD while retaining as much atmospheric diversity as possible. Finally, the forward radiance was calculated for each atmospheric condition.

By matching observed TOVS radiances with the radiances in MAD, a statistical estimate as to the atmospheric state can be obtained. The atmospheric estimate can be used itself (as a statistical retrieval) or as a first guess to solve the inversion of the radiative transfer equation. Similar to the TOVS Initial Guess Retrieval (TIGR) data set, MAD offers several advantages for those working within its mesoscale region. By concentrating on a mid-latitude low elevation land mass, MAD can yield high accuracy statistical estimates as to the atmospheric state while minimizing required storage space. These techniques can be used to develop other mesoscale databases throughout the world.

ITPP-5 - THE USE OF AVHRR AND TIGR IN TOVS DATA PROCESSING

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A fifth version of the International TOVS Processing Package (ITPP-5) is to be announced at the seventh meeting of the International TOVS Study Conference (ITSC-VII). The new version includes a number of significant improvements including: (a) the use of AVHRR data for cloud clearing; (b) the use of the LMD "TIGR" statistical data set for the generation of first guess profiles and the provision of statistical covariance used in the maximum likelihood solution; (c) the simultaneous retrieval of cloud phase, infra-red cloud optical depth, microwave surface emissivity and solar reflectivity; (d) improved methods of error detection and channel filtering prior to the profile retrieval process; (e) improved quality control of the end product.

Intercomparison of the results from ITPP-5 and ITPP-4 will be presented to demonstrate the improvement in product quality achieved with these software refinements.

TOWARD OBTAINING A REAL-TIME INTEGRATED TEMPERATURE AND HUMIDITY PROFILES FROM THE GROUND AND SPACE-BASED REMOTE SENSORS USING THE ITPP

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The Wave Propagation Laboratory (WPL) and the Forecast System Laboratory of the National Oceanic and Atmospheric Administration (NOAA) are cooperating on developing methods to integrate ground-based and space-based remote sensor data in real time to provide temperature and humidity profiling throughout the atmosphere in clear and cloudy conditions.

The Radio Acoustic Sounding System (RASS) provides high-resolution vertical profiles of virtual temperature up to 5 km AGL. To extend this coverage to the top of the atmosphere, we used the "physical" retrieval algorithm provided by the International TOVS Processing Package (ITPP). ITPP allows for use of data gathered by polar-orbiting satellites, RASS, and a 2-channel radiometer, as well as the commercial aircraft ACARS data. Regression coefficients computed from a 15-year record of rawinsonde data for Denver, Colorado, together with the RASS, ACARS and 2-channel radiometer data, were used to construct the first guess for the ITPP at the pressure levels required during clear sky conditions. During cloudy conditions, we used the lidar ceilometer cloud-base height measurements and the moist adiabatic estimate of cloud-top height from 2-channel ground-based radiometer measurements in a physical retrieval algorithm that produces a more realistic estimate of the humidity profile first guess.

We show the results of a 26-h period during which the remote sensing and in situ data were collected as part of the FAA-sponsored Winter Icing Storms Experiment (WISP) in 1991 over the Rocky Mountain Front Range.

USE OF TOVS DATA OF THE JOINT TYPHOON WARNING CENTER

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The International Data Systems Office at NASA/GSFC has designed and installed over 30 meteorological ground systems around the world, most notably in Bangladesh, Fiji, Guam and in the near future, Mongolia. These systems include real time ingest, processing and analysis of GMS, GOES, METEOSAT, TIROS (AVHRR and TOVS), and DMSP (OLS, SSMI, SSMT, SSMT2) data. The Joint Typhoon Warning Center, USAF, Guam receives and processes TOVS data in an operational mode to support the identification, classification and forecast of tropical storms. The International TOVS Processing Package, ITPP, was modified to accept the real time file format as input and the analysis display software package, MIDAS, provides a means to view the data. MIDAS is designed for co-registered comparison of all the ingested data. Therefore, processed TOVS data can be displayed over AVHRR imagery or any other imagery ingested in the same time frame. All of the ITPP parameters at any of the standard heights may be displayed and the user can interactively select any sounding for a Skew-T/Log-P display. During an installation in September, 1991 Typhoon Mirielle provided a test case for all of the analysis software. During the late stages of Typhoon Mirielle the eye became sufficiently wide and clear for the ITPP package to process four soundings within the eye-wall as well as numerous soundings around the perimeter. The Typhoon Mirielle case study with emphasis on TOVS is presented.

PROPOSED CORRECTION TO THE TOVS FAST TRANSMITTANCE MODEL TO ACCOUNT FOR VARIABLE CO_2

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The radiative transfer models used in processing TOVS sounder data do not account for changes in CO_2. However, CO_2 mixing ratios have increased by about 30 ppmv during the past 17 years. A simulation has been conducted using a line-by-line radiative transfer model to study the effect of CO_2 on HIRS top of the atmosphere radiances. The results show that brightness temperature differences can be as large as 1 K for a 30 ppmv increase in CO_2 . A simple model to allow the current NESDIS transmittances to be corrected for variable CO_2 is proposed.

THE IMPACT OF TOTAL SYSTEM NOISE ON A TOVS SYSTEM

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TOVS radiance data are not independent, with the result that they are almost always used in combination with first guess or background information. Using a physical approach, the first guess data are transformed into the radiance domain via a radiative transfer equation and the measurement signal is the difference between these values and the satellite measurements. As a result of this approach, which is utilised by both retrieval and direct assimilation methods, the noise appropriate to the "retrieval" process is made up of components arising from radiometer, forward model and radiance contamination noise. In this paper the impact of these noise components will be demonstrated. It is evident that the accuracy of current and future retrieval systems will be severely constrained by radiative transfer equation errors.

TOVS DATA PROCESSING AT THE HYDROMETEOROLOGICAL CENTRE OF RUSSIA

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TOVS data being received by the HRPT station at Moscow are processed operationally using a TOVS Processing Package (HMCTPP). The processing scheme of HMCTPP employs a physical retrieval method and is based on the software originally provided by CIMSS with a number of significant developments. The modifications and refinements of original algorithms and software concern: the procedure of the first guess preparation; the new test for evaluation of quality and consistency of radiance measurements; the adaptive procedure of model correction and data adjustment; the monitoring element for assessment inversion procedure quality and tuning of some parameters. The results of HMCTPP running during 1992 and TOVS retrieval quality evaluation (retrievals against collocated RAOBs) are presented.
The accuracy characteristics of retrievals and first guess (12h numerical weather forecast) are close to each other. Nevertheless the retrievals yield the more detailed spatial structure of meteorological fields and are produced for the impact studies with the analysis scheme of the HMC fine mesh model.

ESTIMATION OF LAND SURFACE TEMPERATURES FROM TOVS/AVHRR IR WINDOW MEASUREMENTS

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The accurate knowledge of Land Surface Temperature (LST) is required for many applications. The LST is one of the key unknown parameters in the interpretation (inversion) of TOVS radiance measurements providing the retrieval of atmospheric temperature/humidity profiles. The main source of information on the LSTs in TOVS measurements is the data in IR window channels of HIRS/2 instrument. The LSTs can also be estimated using measurements of AVHRR instrument in IR split-window channels 10.5-11.5, 11.5-12.5 µm. In both cases the quality of LST retrieval suffers from inaccurate knowledge of land surface spectral emissivities for different IR bands which are generally less than unity.

In this paper the approach for LST and spectral emissivities derivation from satellite IR data is described and evaluated. It employs combined IR radiance measurements in atmospheric window 10.5-12.5 µm (HIRS/2 channel 8) and in split-window bands 10.5-11.5, 11.5-12.5 µm (AVHRR channels 4.5). The method is based on the analysis of temperature invariant spectral indices constructed from the combination of above mentioned data. These indices being practically invariant to temperature variations are sensitive to spectral emissivity variations and therefore can be used for emissivities derivation. The efficiency of described approach is evaluated through the numerical experiments with simulated and real satellite data.

GROUND BASED ATMOSPHERIC PROFILING OF OZONE USING HIGH SPECTRAL RESOLUTION DATA

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A linear least-squares trace gas retrieval scheme using a perturbed form of the radiative transfer equation has been implemented for synthetic ground-based data. Work has been focused on ozone due to its existence in measurable quantities in both the troposphere and stratosphere. The retrieval scheme works well in the troposphere where the atmospheric response for a ozone concentration perturbation is mostly linear. Calculated linear radiance perturbations (ΔR) for a tropospheric ozone perturbation agree closely with FASCOD3P to within noise estimates; set at a nominal level of 0.1 $mW/m^2.ster.cm^{-1}$. Stratospheric ozone retrievals do not perform as well due to the highly nonlinear atmospheric radiative response to changes in stratospheric ozone concentration. In this region the linear ΔR can be 2-3 times that of the nonlinear response calculated using FASCOD3P. Work is proceeding to provide a better estimate of the nonlinear ΔR in the retrieval scheme to allow for input of high resolution spectra from the ground-based HIS instrument.

A CASE STUDY OF HAWAIIAN CONVECTIVE SYSTEMS USING COMPLIMENTARY DMSP AND NOAA SATELLITE-DERIVED METEOROLOGICAL FIELDS

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A case study is presented for convective systems over the Pacific Ocean in the vicinity of the Hawaiian Islands. The study is carried out using Defense Meteorological Satellite Program (DMSP) Operational Line

Scanner (OLS) data plus concurrent Special Sensor Microwave/Imager (SSM/I) data as well as National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data and concurrent TIROS Operational Vertical Sounder (TOVS) data. This example demonstrates some of the advantages and limitations of combining data from multiple satellites and sensors in describing meteorological phenomena in data sparse regions. Specifically, analysis of the DMSP OLS and SSM/I data showed that the cloud fronts precede the moisture front by tens of kilometres and precipitation patterns are located in the centre of the tropical depression where cloud top temperatures are less than -40°C and along the occluded front. The water vapour retrievals from the TOVS sensor are able to detect the extreme meteorological conditions associated with a developing tropical depression but overall differ in both pattern and magnitude from those of the SSM/I.

CLOUD MICROPHYSICAL PARAMETERS FROM TOVS: GEOMETRICAL CONSIDERATIONS

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Retrieval of cloud reflectivity at 3.7 µm from TOVS data is possible using daytime measurements in channel 19 and estimates of cloud cover and height.

Reflectivity can be related to the cloud drop effective radius through scattering calculations given various assumptions. One of these assumptions is that the cloud top is flat and horizontal - then plane parallel scattering calculations can be interpreted given the Sun-sensor geometry.

When the cloud top has vertical and/or horizontal structure then, strictly, the scattering calculations do not apply. However, if the structure is on a large scale we can model the cloud as a collection of facets with different sun-sensor geometries. This method is tested using AVHRR data; channel 4 measurements are used to calculate the cloud top height and hence the sun-sensor geometry of each pixel which is used to interpolate reflectance tables. Comparisons of the calculated and measured (channel 3) reflectances show good agreement for certain cloud types.

One conclusion from this result is that much of the variance seen in AVHRR channel 3 reflectance arises not from the variation in drop size, but from the geometrical effect. Consequently, direct inversion of the reflectance to a drop radius will be very noisy.

However, when reflectances are averaged over an area as large as a HIRS footprint, much of this "geometrical noise" is averaged out.

SOME ASPECTS OF RECENT TOVS WORK IN THE U.K. METEOROLOGICAL OFFICE

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Meteorological Office, Bracknell, U.K.

1. Biases in an interactive retrieval scheme.

Monitoring of the model profile used by a local area interactive retrieval scheme (LASS) has revealed a persistent warm bias in the upper levels when compared to radiosondes. LASS quite correctly reduces this bias but develops smaller biases at lower levels. Investigation has revealed weaknesses in the mapping of model data to the "standard level" data required by LASS, i.e. the origin of the bias is external to the model. Inconsistent mapping from retrieved levels to model data when LASS products are assimilated may be an additional source of bias in the system.

2. Ozone retrieval.

A total column ozone retrieval model (based on a NESDIS model) has been implemented as a pre-processing step in a nonlinear retrieval scheme currently under development. A sequential estimation filter applied to the retrieved ozone field provides ozone values at all HIRS fields of view. The ozone product correlates well with, for example, model tropopause pressure. Ozone values are passed into the inversion step for use by the forward model to assist radiance estimates for those channels sensitive to ozone.

WATER VAPOUR IN THE UPPER TROPOSPHERE AS DERIVED FROM THE TOVS DATA

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[2]NOAA/ERL, Boulder, Colorado, USA

The minute amount of water vapour in the upper troposphere may have important significance in the Earth radiation budget and global warming. Unfortunately the radiosonde network neither covers the globe adequately nor provides measurements of sufficient accuracy at the high altitude. To overcome this gap in observing upper tropospheric water vapour, recently we have compiled a climatology of the HIRS water vapour channel brightness temperatures. Several issues have to be addressed before the data can be used as a substitute for direct observations of water vapour. These issues include: (1) To what extent the change in brightness temperatures represents the fluctuation of atmospheric water vapour, rather than that of atmospheric temperature? (2) How to achieve homogeneity for the data collected over the years by different satellites? How accurate is the data set? (3) How to convert the brightness temperatures into water vapour amount? We will discuss some of these issues during the conference.

PLANS FOR SOUNDING INSTRUMENTS ON CHINESE SATELLITES

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Two experimental polar-orbiting satellites called Feng-Yun 1A and Feng-Yun 1B were launched in 1988 and 1990 respectively by China. The instrument aboard the satellite was a 5-channel radiometer. Though their lifetimes were short, they provided excellent imagery data. The sounding instrument is under development. The first generation of sounder called ASIS (Atmospheric Sounding Infra-red Spectro-radiometer) has 20 channels similar to the present HIRS on board TIROS-N/NOAA satellites. The potential of adding two more infra-red and several visible channels to ASIS can be expected. It is possible to test ASIS on Feng-Yun 1D scheduled for the late 1990s. The more advanced sounder will cover both the infra-red and microwave spectrum with performance close to or better than the current HIRS and MSU. There are 22 infra-red and 7 microwave channels. The satellite to fly the Chinese sounder will be Feng-Yun 3 which is another series of Chinese polar-orbiting satellites to be launched around the year 2000. The data format of the Chinese imager and sounder is very similar to the one adopted by TIROS-N/NOAA satellites, to conform to the current ground receiving and processing systems around the world.

Appendix A.

AGENDA FOR ITSC-VII

SEVENTH INTERNATIONAL TOVS STUDY CONFERENCE
IGLS, AUSTRIA
10-16 FEBRUARY 1993

<u>Wednesday, 10 February 1993</u>

0830-0900	**Registration**	
0900-1030	**INTRODUCTORY SESSION**	(Chair: Uddstrom/Eyre)
	Welcome and opening remarks	
	Presentation and discussion of conference programme	
	Presentation of draft ITWG Strategy Document	
1030-1100	**BREAK**	
1100-1230	**SCIENTIFIC PRESENTATIONS** **I. TOVS data in climate studies**	(Chair: Scott)
J Bates	Climate monitoring using TOVS data	
A Chédin	Climate research from TOVS through the pathfinder programme	
M Goldberg	The development of an algorithm for generating homogeneous time series of satellite derived layer mean temperatures	
P Menzel	Trends in global cirrus inferred from three years of HIRS data	
1230-1400	**BREAK**	
1400-1520	**SCIENTIFIC PRESENTATIONS** **I. TOVS data in climate studies (continued)**	(Chair: Bates)
J Eyre	Applications of statistics of departures between measured and forecast TOVS brightness temperatures	
Xiangqian Wu	Water vapour in the upper troposphere as derived from the TOVS data	
J Schmetz	Upper tropospheric humidity observations from Meteosat and comparison with ECMWF forecasts	
J Francis	Improvements to TOVS retrievals over sea ice and applications to estimating Arctic energy fluxes	

1520-1540 BREAK

1540-1620 **SCIENTIFIC PRESENTATIONS** (Chair: Le Marshall)
I. TOVS data in climate studies (continued)

A Kaifel — Total ozone mapping over Europe using TOVS data by means of a neural network approach

S Turner — Proposed correction to the TOVS fast transmittance model to account for variable CO_2

1620-1730 **SCIENTIFIC PRESENTATIONS** (Chair: Le Marshall)
II. TOVS data in NWP

J Pailleux — Use of TOVS data in NWP

A McNally — Experiments using one-dimensional variational analysis of TOVS data at ECMWF

M Goldberg — The development of an interactive retrieval/analysis/forecast system

1800-1900 **RECEPTION WITH CITY OF INNSBRUCK AND PROVINCE OF TYROL**

Thursday, 11 February 1993

0900-1040 **SCIENTIFIC PRESENTATIONS** (Chair: Pailleux)
II. TOVS data in NWP (continued)

A Uspensky — TOVS data processing at the Hydrometeorological Centre of Russia

C Chouinard — Progress toward assimilation of TOVS radiances in Canada

I Csiszár — Use of TOVS data in the numerical weather prediction at the Hungarian Meteorological Service

E Andersson — Use of radiances in 3D/4D variational data assimilation

J Le Marshall — Utilisation of TOVS data at BMRC

1040-1100 BREAK

1100-1140 **SCIENTIFIC PRESENTATIONS** (Chair: Rochard)
II. TOVS data in NWP (continued)

D Kim — Application of cluster analyses of radiance data measured by satellite and computed from forecast profiles

M Uddstrom The impact of total system noise on a TOVS system

1140-1300 **SCIENTIFIC PRESENTATIONS** (Chair: Rochard)
III. Preparations for ATOVS

J Eyre Preparations for ATOVS processing

A Reale (for E Burdsall Brown)
TOVS and SSM/T operational processing at NOAA/NESDIS

D Klaes Eumetsat activities for the ATOVS processing

L McMillin A new cloud clearing approach for NESDIS

1300-1415 **BREAK**

1415-1700 **ITWG STATUS REPORTS** (Chair: Menzel)

Relations with other bodies
- WMO Rapporteurs (Menzel, Le Marshall)
- ITRA (Chédin, Scott)
- GEWEX (Chédin)
- Radiation Commission (Smith)
- Others

TOVS case study (Uddstrom, Rochard, Kelly)

TOVS processing packages
- ITPP (Smith)
- 3I (Scott)

Review of actions from ITSC-VI

Any other items / discussion

1700-1730 **WORKING GROUP FORMATION** (Chair: Uddstrom)

Friday, 12 February 1993

0900-1040 **SCIENTIFIC PRESENTATIONS** (Chair: Smith)
IV. Future systems

Menzel NOAA future plans for satellite sounders

Perrone EUMETSAT future plans for satellite sounders

Fengxian Zhou Plans for sounding instruments on Chinese satellites

H Revercomb		Advanced sounding systems: the polar orbiting ITS and the ground-based AERI
C Serio		Inverting interferogram signals to retrieve atmospheric temperature profiles
1040-1100	BREAK	
1100-1230	**Technical sub-groups**	
	ITPP (chair: Smith) 3I/3R (chair: Scott) RTTOV (chair: Eyre) Others	
1230-1400	BREAK	
1400-1500	**SCIENTIFIC PRESENTATIONS** (Chair: Chédin) **IV. Future systems** (continued)	
J Dodge		The EOS direct broadcast system
J Escobar		High resolution IR sounding using neural networks
N Scott		Retrieval of temperature and water vapour profiles from high resolution data in the infrared: methodology developed at LMD
1500-1540	**SCIENTIFIC PRESENTATIONS** (Chair: Chédin) **V. Other scientific studies and developments**	
A Reale		TOVS/DMSP operational status
F Loechner		Temperature fields over the Arctic from TOVS data: adjustment of the ITPP and intercomparison with conventional data
1540-1600	BREAK	
1600-1700	**SCIENTIFIC PRESENTATIONS** (Chair: Chédin) **V. Other scientific studies and developments** (continued)	
C Koepken		Assessment of the quality of TOVS retrievals obtained with the 3I-algorithm for Antarctic conditions
A Pfister		Influence of the topography of the Earth's surface on vertical sounding of the temperature profile
B Stankov		Toward obtaining real-time integrated temperature and humidity profiles from the ground and space-based remote sensors using the ITPP

1700-1730 **Introductions to poster presentations** (Chair: Eyre)

1800-1900 **POSTER SESSION**
See attached list

Saturday, 13 February 1993

WORKING GROUP MEETINGS

Sunday, 14 February 1993

WORKING GROUP MEETINGS

Monday, 15 February 1993

0845-0900 **ITWG STATUS REPORTS** (continued) (Chair: Rizzi)

ITWG liaison with WMO (Hinsman)

0900-1040 **SCIENTIFIC PRESENTATIONS** (Chair: Lynch)
V. Other scientific studies and developments (continued)

W Smith	ITPP-5 - the use of AVHRR and TIGR in TOVS data processing
G Rochard	Overview of AVHRR / TOVS and ATOVS matching
A Uspensky	Estimation of land surface temperature from TOVS/AVHRR IR window measurements
V Tramutoli	Assessing the impact of higher spatial resolution on cloud filtering applied to infrared radiances
Dong Chaohua	Computation of cloud cover and precipitation with satellite observations over China region

1040-1100 BREAK

1100-1220 **SCIENTIFIC PRESENTATIONS** (Chair: Rizzi)
V. Other scientific studies and developments (continued)

P Watts	Cloud microphysical parameters from TOVS: geometrical considerations
D Klaes	Synoptic studies with TOVS data
P Pagano	Operational use of total ozone maps retrieved from TOVS data

M Lynch Ground based atmospheric profiling of ozone using high spectral resolution data

1220-1400 BREAK

1400-1730 **WORKING GROUPS MEETINGS**

Tuesday, 16 February 1993

ITWG PLENARY SESSION (Chair: Eyre/Uddstrom)

0900-1030	I.	Working Group Reports
1030-1100	BREAK	
1100-1230	II.	Technical Sub-group Reports
	III.	Executive Summary - major recommendations and actions
1230-1400	BREAK	
1400-1530	IV.	Future plans

- Strategy Document
- Future status of ITWG
- Next meeting
  - issues/ working groups
  - venue

1530 CLOSE

POSTER PRESENTATIONS

T Boehm	Operational use of TOVS data at Deutscher Wetterdienst
P Brunel et al	Transmittances coefficients generation for fast radiative transfer models: application to new satellite sounding systems
P Brunel et al	The ITSC TOVS case study
V Cuomo et al	An improved cloud-clearing scheme based on radial basis functions
L De Leonibus et al	Use of TOVS soundings and Meteosat IR data to monitor cloud top height
P Dibben et al	Monitoring/tuning of a sounding system [change?]
J Gueldner et al	An attempt of a moisture field analysis using Meteosat and microwave data
G Heinemann	TOVS study of "a most beautiful" polar low
J Jenney	HIRS instrument description for NOAA-K, L, M
S Kadokura/A Shimota	A fast scheme for line-by-line forward model
J Key et al	Assessing the completeness of the TIGR data base for Arctic retrievals
D Klaes	On the near real time operational use of TOVS data
A Korpela	Interactive software for TOVS data visualization
G Prangsma	Verification of 3I retrievals vis-à-vis radiosonde observations
C-W Rah/J G Lee	TOVS package updating for field DB input
A Reale	Departures between operational satellite soundings, radiosondes and forecasts
H Rieu et al	SSM/T forward modelling using neural networks
R Slonaker	Development of a mesoscale database of atmospheric conditions and corresponding TOVS radiance signatures
F Stetina et al	Use of TOVS data at the Joint Typhoon Warning Center
M van Woert/D Klaes	A case study of Hawaiian convective systems using complimentary DMSP and NOAA satellite-derived meteorological fields

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