A REPORT ON

THE EIGHTH INTERNATIONAL TOVS STUDY CONFERENCE

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5-11 April 1995

sponsored by

National Institute of Water and Atmospheric Research

EUMETSAT

ITT Aerospace/Communication Division

World Meteorological Organisation

European Centre for Medium-range Weather Forecasts

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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 TIROS Operational Vertical Sounder (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 eighth conference, ITSC-VIII, was held in Queenstown, New Zealand, from 5-11 April 1995. This "Report on ITSC-VIII" summarizes the scientific exchanges and outcomes of the meeting. A companion document entitled "The Technical Proceedings of ITSC-VIII" will contain the complete text of the scientific presentations. These documents reflect the conduct of a highly successful meeting in Queenstown; 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-VIII was sponsored by the New Zealand National Institute of Water and Atmospheric Research (NIWA), by ITT Aerospace/Communications Division, and by EUMETSAT, WMO and ECMWF. Their support and assistance is gratefully acknowledged. We are indebted to Mrs Leona Hermens and the Chief Executive of NIWA for the invaluable assistance provided at the conference. In addition we thank the staff of the Holiday Inn, Queenstown, for their support. We also acknowledge the contribution of the ECMWF staff who assisted with the preparation and publication of this report.

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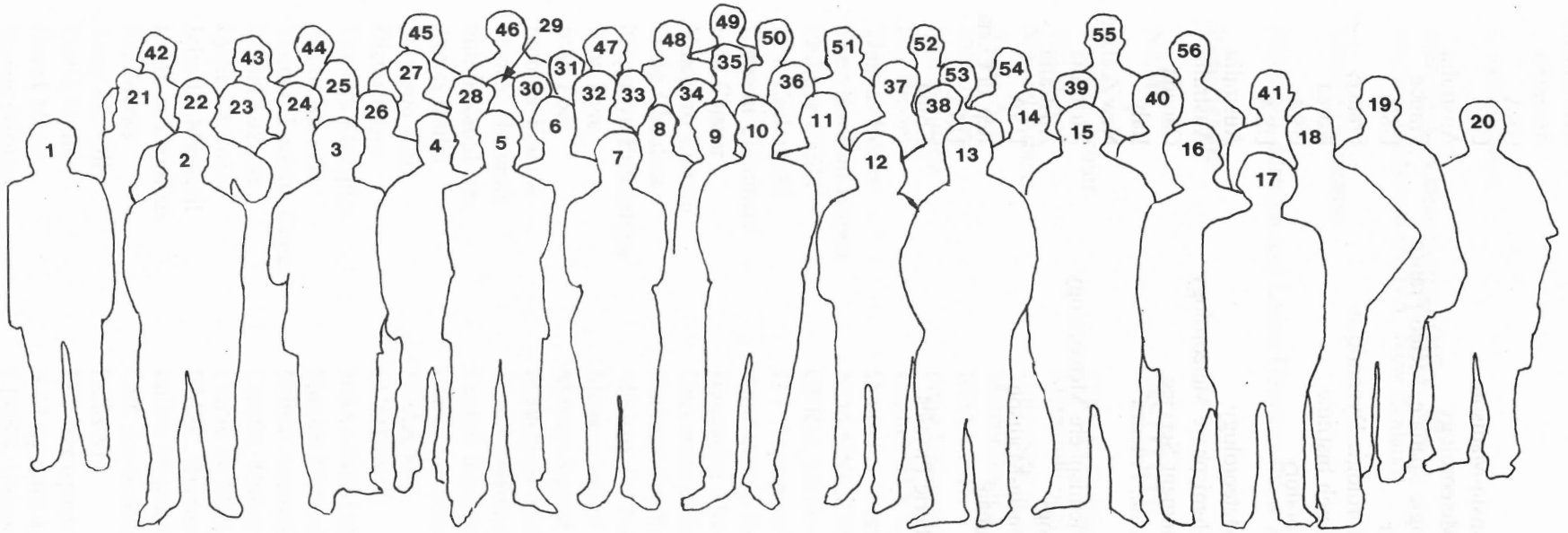

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TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

1.1. INTRODUCTION

The Eighth International TOVS Study Conference, ITSC-VIII, was held in Queenstown, New Zealand, from 5-11 April 1995. 59 participants attended the meeting and provided scientific contributions. 17 countries and 3 international organisations were represented: Australia, Canada, People's Republic of China, Republic of China, Finland, France, Germany, Hungary, Italy, Japan, Republic of Korea, Mongolia, Netherlands, New Zealand, Spain, United Kingdom, United States of America, ECMWF, EUMETSAT and WMO.

The agenda for ITSC-VIII 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, use of AVHRR data in TOVS processing, preparations for advanced TOVS (ATOVS) data, advanced infra-red sounders, international issues and future systems, and other scientific studies and developments. These were given either as oral or poster presentations. Section 4 of this report records the abstracts of these scientific contributions. The corresponding papers are published separately in the "Technical Proceedings of the Eighth 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 five 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, advanced sounder science, and international issues and future systems. The Working Groups reviewed recent progress in these areas, made recommendations on key areas of concern and identified items for action. The reports of these Working Groups are given in Section 2. Earlier in the conference, a session on Status Reports considered inputs on relevant meetings and other activities that had taken place since ITSC-VII and reviewed progress on the action items identified by the ITSC-VII Working Groups. Many of these issues formed the basis for further discussion by the Working Groups at ITSC-VIII.

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 recorded in Section 3.

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 the International TOVS Working Group (ITWG) at ITSC-VIII. 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 noted significant further progress in the application of the TOVS data set (which now covers the period from 1978 to the present) to a range of climate-related problems.

1.2.1.2 The archive of level 1B TOVS data is not readily accessible to the research community as a climate data set. ITWG encourages steps to improve such access,

through the TOVS Pathfinder project or otherwise.

1.2.1.3 The use of TOVS radiances and products in re-analysis projects (at ECMWF, NMC and GSFC) was noted. Increased interaction between these projects and the TOVS Pathfinder project is encouraged.

1.2.1.4 The importance of calibration and validation activities was again stressed. Long-term international calibration sites are required. Also, satellite-to-aircraft and satellite-to-satellite inter-calibration experiments can play an important role.

1.2.1.5 Concerning the interpretation of TOVS data in polar regions, although significant progress has recently been made, substantial problems still remain. To assist the investigation of these problems, ITWG has prepared plans for a TOVS case study over Antarctica, and participation in this study is encouraged.

1.2.1.6 Promising advances were noted in the application of data from the HIRS channel at 8.2μm (now replaced), such as studies of cirrus properties. In the light of this, and on the understanding that technical problems affecting this channel may now be alleviated, ITWG recommended that NOAA considers the re-introduction of this channel on future models of HIRS.

1.2.2 TOVS data in numerical weather prediction (NWP)

1.2.2.1 ITWG noted, and commended NESDIS upon, the improvements in the quality of NESDIS clear radiances and retrieved products reported since the last conference.

1.2.2.2 ITWG noted the present use by NWP centres of both radiances and retrieved products, and the probability that this situation will continue for many years. However it also noted increasing moves towards assimilation of radiance data directly into 3D and 4D variational schemes.

1.2.2.3 The problem of biases between measured radiances and those computed from NWP model fields remains an important obstacle to more effective use of TOVS data. Plans were prepared for exchange of information between NWP centres on biases and bias correction procedures in order to address this issue.

1.2.2.4 Information on the error characteristics of satellite sounding data (whether as radiances or retrieved products) is essential for their successful assimilation. Enhanced collaboration between NWP centres and product generation centres is required to improve the understanding and specification of these errors.

1.2.2.5 The importance within the retrieval/assimilation process of the "first guess" and its error characteristic was again stressed. In particular, increased efforts are required to characterise adequately the covariance of forecast "first guess" error, and its spatial variation, within NWP assimilation systems.

1.2.2.6 It was learnt that notification of some of the operational changes to TOVS processing made by NOAA/NESDIS was not reaching those people in NWP centres involved in the assimilation of these data. It was recommended that all changes with significant meteorological impact be notified and that improved procedures for distributing such

information be considered.

1.2.3 Preparations for Advanced TOVS (ATOVS) data

1.2.3.1 In preparation for the ATOVS system on the NOAA-K satellite, scheduled (at the time of the conference) for launch in May 1996, data processing systems were being developed. In particular, the conference noted the status and plans of NESDIS, of CIMSS and of a consortium of European groups co-ordinated by EUMETSAT.

1.2.3.2 NOAA/NESDIS has made available to EUMETSAT the software of the NESDIS "RTOVS" system. ITWG noted that this had made an important contribution to the planning of the European ATOVS processing package.

1.2.3.3 There was strong support for the plans of CIMSS to collaborate with the EUMETSAT-sponsored project in order to seek a common software framework for ATOVS ingest and pre-processing.

1.2.3.4 ITWG recommended that the ingest and pre-processing software being developed under the EUMETSAT project should be made available to research and operational users during the development phase, in order to facilitate rapid testing and evaluation of the system.

1.2.3.5 The spatial resolution of global ATOVS clear radiances and retrieved products planned at NOAA/NESDIS for international distribution (i.e. 500 km) and the stated WMO requirement (100 km) are not in agreement. ITWG recommended that this matter be brought to the attention of WMO and NOAA through CGMS.

1.2.3.6 ITWG welcomed the plans put forward by representatives of NOAA/NESDIS to provide electronic access to the data that define the characteristics of the ATOVS instruments and are required for successful interpretation of the data from these instruments.

1.2.4 Advanced sounder science

1.2.4.1 ITWG warmly welcomed the news that, from NOAA-N, the HIRS/3 instantaneous field of view would be reduced to 10 km.

1.2.4.2 ITWG emphatically recommended that satellite agencies give their highest priority to the development of advanced infra-red sounders, along with complimentary imaging and microwave sounding instruments.

1.2.4.3 ITWG considers it crucial that WMO goals for operational temperature and water vapour soundings (often summarised as 1 K r.m.s. error with 1 km vertical resolution for temperature, and 10% r.m.s. error with 1 km vertical resolution for water vapour) should not be compromised in operational sounding systems designed for the future joint USA/EUMETSAT polar system.

1.2.4.4 Noting the spatial sample density required to reduce cloud contamination problems, ITWG recommended that the spatial sampling of high resolution infra-red sounding

systems should not be poorer than that of HIRS.

1.2.4.5 Given the scientific requirements for access to satellite sounding data of high spectral resolution at the earliest possible date, ITWG strongly supports the development of HIRS-hybrid as an experimental instrument with immediate operational potential, and acting as a pathfinder for future, more capable high resolution sounders such as AIRS, IASI and ITS.

1.2.4.6 Full exploitation of advanced sounder data will require improved atmospheric transmittance models. ITWG endorsed the work of ITRA and recommended the largest possible participation in such validation activities.

1.2.4.7 In recognising the significant differences in information content contained in data from sounders of low spectral resolution (e.g. TOVS) and high spectral resolution, ITWG strongly supports research on the use of high spectral resolution data, including specification of the error characteristics of measured and calculated radiances and of retrieved products.

1.2.5 International Issues and Future Systems

1.2.5.1 ITWG expressed great concern that absorption features in the 1 to 200 GHz frequency range are not protected for exclusive use by passive sensors on environmental satellites. All satellite operators and ITWG members are encouraged to contact their national representatives to the ITU and register their requirements. ITWG drew up a short-term plan of actions to address this problem (see the working group report for details).

1.2.5.2 In the context of the planned joint USA/EUMETSAT polar system, ITWG encourages EUMETSAT and NOAA/NESDIS to consider a common operational advanced infra-red sounder for flight on both the morning and afternoon satellites.

1.2.5.3 Recognising the key role that direct broadcast of sounder and imager data has had on the exploitation of environmental remote sensing systems, ITWG strongly recommended that all satellite agencies continue to provide or implement, as appropriate, a direct broadcast capability for these data.

1.2.5.4 ITWG encourages EUMETSAT and NOAA/NESDIS to develop an integrated plan for distribution of global data and products to minimise the problems of redundancy and inconsistency. Co-ordination through CGMS is suggested.

1.2.5.5 Acknowledging the utility of targeted implementations of low cost TOVS and AVHRR processing systems, ITWG encourages further development of these systems and invites agencies planning to increase the number of research and operational users of TOVS/ATOVS data to use ITWG's experience and expertise in this area.

1.2.5.6 ITWG acknowledged the great benefit obtained from NOAA/NESDIS participation at ITSC meetings. ITWG is strongly motivated to provide NESDIS with feedback, useful recommendations and ideas. It recommended that NOAA/NESDIS continue its participation and consider an expanded presence to exploit the world-wide source of knowledge found at the meetings of ITWG.

1.2.5.7 ITWG welcomed the offer by the WMO representative to establish a World Wide Web home-page for ITWG and to operate a mail list-server to allow timely exchange of technical data and information between ITWG members.

1.3 FUTURE PLANS

ITWG is keen to retain and improve further its links with CGMS and WMO. Recommendations and guidance on matters relating to satellite sounding will be provided to CGMS through the appointed rapporteur (currently Dr Paul Menzel). ITWG is also prepared to offer specialist advice on utilisation of present sounding data and plans for future operational sounders; requests for assistance can be made through the co-chairs or the rapporteur to CGMS.

The next meeting of ITWG will be at ITSC-IX planned for early 1997. In the interim, ITWG will seek to make progress on many issues identified by the Working Groups at ITSC-VIII; details of the actions items are given in the Working Group reports. Topics of particular importance at ITSC-IX are expected to include evaluation of early data from ATOVS on NOAA-K and continued preparations for advanced infra-red sounding instruments and their data.

2. WORKING GROUP REPORTS

2.1 TOVS DATA IN CLIMATE STUDIES

J Bates (chair) with R Bennartz, H Bloom, M Erdenetuya, J Francis, A Kaifel, T Lachlan-Cope, P Menzel, F Prata, A Schweiger, N Scott, R Slonaker, B Stankov, G Stephens and V Tramutoli contributing.

2.1.1 Introduction

The uses of TOVS data for climate studies have now gone from promise to reality. These uses are the result of several factors including the growing length of the TOVS instrument record, an increasing interest in climate issues, interest by the climate research community in satellite radiances and products, and the ongoing revolution in desk-top computing and mass data storage. Each of these changes has had profound positive impacts on the use of TOVS data by the climate community. The number of researchers who can now process and analyze large quantities of data has significantly increased and TOVS climate products have achieved widespread acceptance in the climate research and diagnostics community. TOVS data are also being used more and more extensively for real-time climate diagnosis including ozone monitoring and monitoring global temperature changes during large volcanic aerosol events. A major consequence of these changes is that convenient, low-cost access to the entire TOVS radiance data set for climate research is even more important than ever.

2.1.2 TOVS data in global and regional climate studies

2.1.2.1 Temperature

The pioneering studies by Spencer and Christy on the use of MSU radiances as a global tropospheric temperature index have now established the MSU as a premier data set for climate and global change studies. The MSU instruments have remained extremely stable over time and their global sampling cannot be matched by any in situ system. This data set has been used to study long-term global tropospheric temperature trends, El Nino/Southern Oscillation events, and volcanic aerosol events such as the eruption of Mt. Pinatubo. The retrieval of higher resolution temperature profile information has started through the NASA/NOAA TOVS Pathfinder programme. Other unique uses of the MSU radiance data continue to be studied including a rain rate index over the oceans, hurricane intensity climatologies, and tropospheric dynamics in mid-latitudes and polar regions.

2.1.2.2 Water vapour

Water vapour is the predominant greenhouse gas and is a crucial component of the global hydrological cycle. Retrieval of water vapour using the HIRS infra-red observations requires clear radiances and highly accurate radiative transfer models. Improvements in each of these areas have led to significant improvements in the analysis, retrieval and assimilation of HIRS moisture data for climate research, but considerable work remains to be done. HIRS channel 12 clear-column radiance data (at 6.7 μm) have been used by several researchers to study upper tropospheric water vapour in the tropics and its role in climate and climate change. These studies have concentrated on the NESDIS operational clear column radiances. Research suggests that all-sky radiances are also useful for radiation studies and climate monitoring of tropical variability.

A particular problem with retrievals of water vapour is the lack of high-quality validation data, either in situ or remotely-sensed. Radiosonde observations have difficulties at low temperatures (below -20°C), and this causes a problem with observations in the upper troposphere and the polar regions. A reference radiosonde would help quantify the errors in measuring water vapour associated with the different radiosondes being used globally. In addition, new ground-based remote sensing techniques, such as ground-based microwave observations or GPS time-delay observations, may by useful for validation of satellite techniques.

2.1.2.3 Ozone

TOVS provides the only long-term satellite measurements of ozone both day and night. Comparisons of these measurements with ground-based, aircraft and other satellite measurements should continue. TOVS ozone observations, along with data from in situ observing networks, are now being used on a routine basis to provide real-time ozone monitoring in high southern latitudes, such as Argentina, New Zealand and Australia, as well as other locations, such as Europe. The WG encourages the continued use and validation of TOVS ozone amounts and fields.

2.1.2.4 Cloud and radiation studies

Uses of TOVS data in cloud studies include improved retrieval of cloud height and discrimination of cloud water/ice phase using multi-channel techniques. Discrimination of cloud water from ice phase is particularly important as demonstrated by recent case studies. Retrieval of cloud fraction remains a problem in all regions of the globe, particularly at night. Top-of-the-atmosphere and surface radiation fluxes are being estimated using HIRS data. Top-of-the-atmosphere fluxes have compared favourably with Earth radiation budget estimates. Estimation of surface radiation fluxes from space remains problematic and, although some research results are promising, this will remain a very difficult quantity to estimate accurately from space. The baseline surface radiation network will provide important process study and satellite validation data sets. However, spatial coverage of surface networks will remain sparse and, given the importance of the surface radiation budget for process and climate studies, the WG recommends that researchers continue to investigate methods for retrieving surface fluxes using satellite data.

Studies have shown that HIRS channel 10 radiances at 8.2 μm have been useful in discriminating cloud water/ice phase changes and studying cirrus properties. The WG is concerned that the wavelength of this channel, originally at 8.2 μm, has been changed to 12.6 μm. Also, the noise characteristics of this channel over time need to be better documented and understood.

2.1.2.5 Polar regions

The polar regions represent a particularly important challenge for TOVS. The complete repeated coverage of the polar regions is in contrast to the almost complete lack of in situ data in both the Arctic and Antarctic. However, the unique climate conditions, including widespread surface inversions, cloud cover during extended darkness and elevated terrain, present unique retrieval problems. Significant improvements in the uses of TOVS data for polar studies are evident from these research data sets.

2.1.2.6 Recommendations

The WG notes the continued and expanded use of TOVS data in climate studies and encourages monitoring and validation of temperature profiles, water vapour profiles, total ozone, clouds and radiation.

The WG encourages continued use of TOVS to address unique sounding problems in the polar regions including cloud detection, dynamical studies and energy budget studies. The WG notes that significant problems remain, particularly the issues of retrieval over high terrain and estimation of surface fluxes. To assist in investigation of these problems, the WG encourages participation in a TOVS case study over Antarctica.

Several researchers have reported positive results using HIRS channel 10, in combination with other channels, to discriminate between cloud water/ice phase. However, the frequency of this channel has been changed (see 2.1.2.4 above) for technical reasons, and these technical problems may now have been alleviated. Because of the unique information provided at 8.2 microns, the WG requests that:

- ITT and NESDIS better document and quantify the changes to HIRS channel 10 over time and the magnitude of the technical problems, and
- if these technical problems no longer exist, consideration should be given to re-introduction of an 8.2 μm channel on future models of HIRS.

(**Action: J Bates with ITT, T Kleespies, D Wark**)

2.1.3 TOVS Pathfinder

A primary goal of the NASA-NOAA TOVS Pathfinder programme includes the recognition that high-volume Level 1 data must be available in a form that facilitates production of higher level, derived geophysical data products. Since the science algorithms and products will continue to evolve, production of higher level products from Level 1 data sets will be performed a number of times. Thus, it is critical that Level 1 data sets be available in a readily accessible form for processing on a suitable working storage medium. With the continuing revolution in desk-top computing and mass storage media, it is now possible for many moderate-sized research groups to process time series of global TOVS data.

Another goal of the TOVS Pathfinder programme is the production of retrieved geophysical parameters from the Level 1 TOVS data. For climate studies, such retrievals should be as free as possible of systematic biases, particularly in the choice of initial guess. Since there is a lack of consensus on which retrieval algorithm performs best both globally and regionally, several different methods, or "paths" are being pursued. The distinctions between these paths lies primarily in the use and choice of initial guess.

The NOAA-NASA Pathfinder programme has completed the production of the TOVS Pathfinder benchmark period (April 1987 - November 1988). Benchmark data sets are available through the EOSDIS DAAC system and other data distribution sites. The WG encourages the use, evaluation and commentary on these products. General information can be obtained:

http://xtreme.gsfc.nasa.gov

The various paths differ most significantly in the way in which they use a priori and/or model data as first guess input and quality control check. Path A is dependent on prior information from a NWP model, path B is model-independent but dependent on other prior information, as is path P, and path C is independent of model and other prior information.

For paths A and B, Phase 1 benchmark data sets have been produced and are available for use and evaluation through the EOSDIS Goddard DAAC. The data producers have performed numerous quality control checks on the data and incorporated many changes to improve their retrievals for the benchmark period.

Path C1 has had several versions of its deep-layer mean temperatures available at the NASA Marshall DAAC for some time. The team are currently reprocessing the data to make better use of additional MSU channels and improved inter-satellite calibration.

For path C2, the Phase 1 benchmark period is processed and available on Internet. The entire period of record for TOVS (1979-1994) is expected to be completed by the end of September 1995. Plans for Phase 2, which will include processing of both the HIRS and MSU, are to be defined by October 1995, and the benchmark period will be completed by December 1995.

For path P, a 20-month data set of surface and atmospheric parameters in the Arctic region has been produced using the 3I algorithm. This product extends from April 1987 to November 1988, covers the area north of 60°N, includes several new polar-specific variables and is gridded on an equal-area 100 km by 100 km grid that is particularly suited for polar applications. Information about the data is available from:

http://psc.apl.washington.edu/Path-P/Path-P.home.html

Recommendations:

The ITSC should help to identify and define specific fields for evaluation of the TOVS Pathfinders.

Producers and users must be aware of different versions of retrievals being used and implications for climate studies. The WG encourages both users and producers to be more pro-active in ensuring they are aware of the most recent versions and the strengths and weaknesses involved in each version.

Increased interaction between TOVS Pathfinders and the ECMWF, NMC and GSFC (GEOS) re-analysis groups is to be encouraged. When Pathfinders have completed a long time series, they should be used in the next cycle of re-analysis.

Given the continuing revolution in desk-top computing and mass storage media, it is likely that many additional uses and improved retrieval methods will continue to be developed from TOVS data. Thus, the WG requests that easy access to the historical TOVS Level 1B data set on convenient, low-cost mass data storage media should be the highest priority for the TOVS Pathfinder. **(Action: J Bates with J Dodge, G Stephens, J Francis, N Scott, A Schweiger)**

2.1.4 Products from operational centres

NOAA/NESDIS currently archives and distributes global climate parameters at the NESDIS retrieval locations. These climate parameters consist of cloud properties (e.g. cloud top temperatures, cloud top pressure, cloud amount), total and layer ozone, and a temperature anomaly parameter which represents the effect on HIRS channel 11 of volcanic eruptions (SO_2). In addition, radiation budget parameters, such as outgoing longwave radiation, downwelling longwave radiation and layer cooling rates, as well as cloud-cleared radiances and cloudy radiances, are produced globally at each HIRS/2 field-of-view in a research mode. These products are expected to become available operationally in September 1995.

Plans for future climate products include improving cloud parameter estimation and adding parameters such as deep layer mean temperatures from the scheme being used for the Pathfinder C2 algorithm. Other climate products can be suggested for implementation into the TOVS operational processing scheme by following established NESDIS procedures for demonstrating a need. These suggestions should be made through the NESDIS sounding implementation branch (currently E Brown).

Currently, access to TOVS data via Internet and the satellite active archive (SAA) is being tested, and a limited set of data can be viewed via the WWW NESDIS home pages. Plans for TOVS at the SAA include provision of rotating, real-time access to TOVS data from the two active polar orbiters. Plans are also under way to put on Internet small amounts of data relevant to TOVS such as: NESDIS 107 Appendix B equivalent information for NOAA-KLM, TBUS information, co-registration instrument specifications and other coefficients. Special case study data sets should also be made available via Internet on a limited basis.

Recommendations:

The WG recommends that other cloud-clearing methods, especially those that incorporate AVHRR and do not use adjacent pixel techniques, should be considered for producing an alternative data set of global cloud-cleared radiances for general use.

The WG encourages the use of both radiances and retrievals for climate studies. Neither has proven more useful than the other and both are needed for more complete understanding.

The WG requests that the NOAA/NESDIS SAA provide low-cost access to the entire global TOVS Level 1B data set for climate researchers. In particular, climate researchers require a system for automated batch extraction for standing orders rather than a browse function with limited data extraction size. **(Action: J Bates with E Brown)**

2.1.5 Long term calibration and validation

Climatological data derived from satellite measurements still need calibration and validation by comparison with accurate, long-term series of in situ measurements performed in places with different surface properties and atmospheric regimes. The most obvious source for validation is routine radiosonde temperature and water vapour profile information. Although, such data have been very useful, the water vapour information remains questionable and other error sources limit the use of these data for long-term climate studies. Other sources of possible calibration and validation data include:

- data sets from process study field experiments such as TOGA COARE,
- data sets to assess the quality of data from new instruments the first time they are flown in space (such as for GOES-8 and SSM/I), and long-term atmospheric monitoring sites (such as the ARM and ozone measuring sites).

Comparisons with all these in situ measurements is critical to establish and continue the long-term calibration of TOVS data for climate studies.

Recommendations:

The WG recommends that a number of complimentary techniques for calibration of satellite data sets be pursued. These techniques include vicarious calibration, long-term in situ calibration sites, and in-orbit satellite-to-satellite and aircraft-to-satellite inter-calibration in a variety of climatic regions.

The WG urges such calibration efforts be identified and the data sets be made easily accessible to the ITSC community for validation studies.

The WG notes that NOAA/NESDIS has identified D Crosby (crosby@nzms.wwb.noaa.gov) as a focal point for long-term calibration of the TOVS instruments and encourages those active and concerned about calibration issues to coordinate with him.

The WG requests that those involved in various programmes obtaining data useful for TOVS satellite calibration share that information with the ITSC community and that an ITSC member will post this information at a world wide web site. (J Bates has agreed to post this information at site www.cdc.noaa.gov.) **(Action: J Bates, with B Stankov, F Prata)**

2.1.6 Other issues

2.1.6.1 Linkage with climate programmes

The WG recognizes that collaboration with ongoing climate research projects, including WCRP, AMIP and GCOS, is very important. However, improved mechanisms for such collaboration must be sought to ensure that communication between these programmes and ITSC occurs.

Recommendation:
Improved collaboration between programmes such as WCRP, AMIP and GCOS should be sought. Such collaboration should include both members of these groups being invited to the next ITSC and ITSC representatives being invited to meetings of WCRP, AMIP and GCOS.

2.1.6.2 The NOAA/DoD converged polar orbiter system

The WG is very concerned that the discussions about the converged NOAA/DoD satellite system are not taking into account input from the broad scientific community, particularly the needs for long-term climate monitoring. Of most concern are the accurate calibration of all instruments on the converged spacecraft and the formats of the archived products. Lack of attention to the calibration may cause a severe degradation of these data for climate studies and make reprocessing of the data much more difficult for climate researchers.

Recommendation
The WG recommends that NOAA/DoD include scientific input from the ITWG in its specifications for instrument design and data archive design.

2.1.6.3 Frequency allocation in the microwave

The WG is concerned that increasing demand for frequency allocation by the telecommunications industry will result in contamination of passive microwave observations. Such contamination could ruin the record of MSU tropospheric temperatures or lead to a systematic increase in MSU brightness temperatures that may be erroneously interpreted as an indication that global warming has occurred.

Recommendation:
The WG recommends that all ITWG members contact their national telecommunications representatives to discuss the issue of frequency protection. (See section 2.5.4 for further details).

2.2 TOVS DATA IN NUMERICAL WEATHER PREDICTION

C Chouinard (chair) with P Caille, D Kim, T McNally, P Riley, P Steinle and C Velden contributing.

2.2.1 Introduction

The impact of satellite data has proved to be greater in the Southern Hemisphere than in the Northern Hemisphere, mostly because of the vastly different radiosonde coverage in each hemisphere. Further, the resolution and the physics of numerical weather prediction (NWP) models are continuously improving and, in some sense, the radiosonde network is becoming too coarse for the models. In this context, the judicious use of high-resolution satellite data, and particularly TOVS, is becoming increasingly important and substantial efforts have to be made to exploit these data to their fullest in day-to-day preparation of analyses at NWP centres.

NESDIS should be commended for providing an excellent set of cloud-cleared radiances and retrieved products at horizontal resolutions that meet today's demands. NESDIS has made significant improvements both in quality and quantity of their data since the last TOVS conference and this has led to very significant improvements as reported at this conference. Both the retrieved products and radiances are complementary and now used extensively by most NWP centres. This will continue for the next decade and probably beyond. It should be recognized that both the retrieved products and the radiances are not competitors but rather complementary data sets as used in the current systems in operation at NWP centres. In the long term, we still believe that the 3D and 4D variational data assimilation systems will probably be formulated solely with radiances even though this is not possible today.

2.2.2 Evaluation and specification of errors of the cloud-cleared radiances

2.2.2.1 Systematic errors

At this conference there has been a number of presentations that have highlighted the problem of large systematic errors associated either with the interpolation and extrapolation of the forecast first guess to the forward model pressure levels or with the forward model itself. There are still no well-established, universal procedures to eliminate these biases and this remains a rather contentious issue.

Action: The members of the WG agreed to exchange information on biases and correction procedures in order to seek an acceptable solution to this problem in the near future. The months of March and August 1994 were selected for the purpose of this comparison. (C Chouinard to co-ordinate)

2.2.2.2 Error estimation required for NWP

Data assimilation using cloud-cleared TOVS data needs specification of the error characteristics associated with these data in order to optimize their impact. To this end the NWP community would like to reiterate its need for an accurate description of the error characteristics of the NESDIS retrieved products and radiances. Furthermore, NWP centres need to be notified of any changes in the nature of the errors in the data, whatever the reasons for and sources of the changes may be.

Action: A representative of the WG (P Steinle) to work with NOAA/NESDIS (E Brown) to establish a list of NWP users of NESDIS products and to recommend procedures for notifying users when changes are to occur in the NESDIS TOVS products. The representative should also establish a link with the NESDIS "Calibration Overview Panel" in order to advise users of any relevant technical changes proposed by that group.

The accurate specification of the error characteristics of the forecast first guess has also been shown to be crucial in order to make best use of NWP fields. There is evidence from preliminary tests with a 3DVAR system that this is a very serious issue and that great care has to be taken in arriving at accurate estimates and their regional variation. There is not yet a unique and unambiguous method to determine these statistics and most centres are still experimenting with different approaches.

The WG recommended that each centre share its results and expertise in a collaborative scientific exchange (but respecting the originality of each other's work) so as to accelerate the implementation of 3D- and 4DVAR systems.

2.2.3 Impact of TOVS data

Presentations reported further evidence of the positive impact of the assimilation of both radiances and NESDIS products, either separately or together as need be, in various systems. To produce a consistent positive impact, however, appropriate error characteristics for the data must be used in their assimilation. In that context, the error characteristics may have to be adjusted depending on whether the data are to be used in a global or a high-resolution regional data assimilation system.

The WG recommended that centres producing TOVS sounding products should specify the error characteristics of their data to enable their correct assimilation and to avoid reports of negative impacts because of improper error specification. Close collaboration with NWP centres will be necessary in order to evaluate these error characteristics.

Much of the work reported using TOVS data in climate studies involves the assimilation of data using NWP systems or could have benefited from such an approach. Such research would benefit from the experience gained by the NWP community and close collaboration is encouraged.

The WG recommended close collaboration between those using TOVS data in climate studies and those with experience in assimilating the data in NWP systems.

2.2.4 Frequency protection issue

NWP is evolving towards more stringent requirements on the accuracy of satellite data. NWP development is clearly demonstrating some catastrophic medium range weather forecast failures originating from very small discrepancies in initial conditions. For those reasons, instruments have to be designed with great accuracy allowing for very little instrument noise and bias. If the frequency bands that are naturally exploited by satellite instruments are to be shared with other applications, the WG considered that the resulting interference levels of the order of 5% randomly and 1% systematically would have devastating impact on data assimilation systems thereby degrading analyses and forecasts severely.

The WG recommended that ITWG should obtain information on the nature of the errors incurred through sharing microwave spectral intervals with other users (see Section 2.5.4), so

that a data assimilation experiment may be undertaken with a state-of-the-art data assimilation system to establish the impact of these errors on NWP analyses and forecasts.

2.2.5 Future collaboration and information exchange

In order to guarantee the future position of ITWG in the NWP community, the WG considered that more presentations should be actively encouraged (invited by the co-chairs) concerning data assimilation issues. A better NWP representation would ensure a valuable and essential exchange between providers and users of sounding data and products. Many institutions still receive little or no guidance on assimilation, resulting in damaging reports of negative TOVS impact in NWP.

A closer liaison between data providers and NWP centres in monitoring the quality of satellite data would improve the standard of data assimilation systems and the quality of the data provided to the centres.

The WG recommended that NWP centres should exchange information on data quality in order to detect common problems. These problems should be discussed with NESDIS.

Action: The compilation of an electronic mailing list of contacts within NWP centres that are willing to exchange satellite data monitoring information. (P Steinle with input from D Hinsman).

2.3 PREPARATIONS FOR ATOVS DATA

D Steenbergen (chair) with T Achtor, R Bennartz, T Böhm, E Brown, Dong Chaohua, J Eyre, J Foot, D Klaes, T Kleespies, L Lavanant, C Marks, D Morel, S Nieman, G Prangsma, G Rochard, M Uddstrom, L Van Burgel, Wang Kuang-Hwa and Zhou FengXian contributing.

2.3.1 Status of processing system development

The two years since ITSC-VII have seen considerable progress in the development of ATOVS processing systems. Invited presentations on this topic by NESDIS, EUMETSAT and CIMSS were given during the plenary sessions. The WG noted the following points in particular:

As is well known, NESDIS software development for ATOVS is taking place in two stages. The first stage, known as "RTOVS", processes the current TOVS data within a framework which is suitable for expansion to ATOVS data; in the second stage, known as "ATOVS", algorithm changes necessary for processing ATOVS data that cannot be implemented for TOVS are being made. The WG noted that the RTOVS processing system was delivered to NESDIS in April 1994, and coding of the modifications to RTOVS to support ATOVS processing is on track for completion in December 1995. Based on trials using a loaned machine, re-hosting of the software to a new RISC processor is expected to take about 2 months.

Since the last meeting, a group was established under the auspices of EUMETSAT to develop ingest and pre-processing software for local readout. This group consists of Météo-France, UK Met Office, KNMI, ECMWF, LMD and DWD. Following delivery of RTOVS to NESDIS, the RTOVS software was provided to EUMETSAT for use in this effort. At this point, a design for the EUMETSAT package has been agreed upon and coding has been started.

The WG took particular note of the value to the EUMETSAT development effort of access to the RTOVS code and documentation. Although, ultimately, RTOVS was not adopted as the framework for the EUMETSAT package, it was invaluable as a source of detailed information on the implementation of the scientific algorithms and on possible design approaches.

The WG recommended that the ingest and pre-processing software being developed under EUMETSAT auspices be made available to research and operational users during the development process for testing and feedback to the developers. The WG does not expect these users to receive any guarantees of software support. In particular, the WG expects that the code and documentation would be provided "as is" and does not expect any commitment from the developers regarding distribution of bug fixes or revisions. WG members from EUMETSAT member states were asked to bring this recommendation to the attention of their national representatives to EUMETSAT. (**Action: WG members**)

At the University of Wisconsin, CIMSS is preparing for ATOVS retrieval processing through evolutionary changes to the ITPP. The so-called "ATPP" will use, where feasible, pre-processing modules based on ITPP designs. CIMSS expressed its commitment to working with the international TOVS community toward the development of an ATOVS pre-processing system, and toward the development, exchange and evaluation of retrieval processing modules with interested members of ITWG. A NOAA-K launch-day ATPP package is planned which will utilize AMSU-A radiances for temperature profiling.

The WG expressed its support for CIMSS intentions to collaborate with the EUMETSAT-sponsored

project in order to seek a common software framework for ATOVS ingest and pre-processing code. The WG also recommended that the outputs of the ATOVS ingest code to be produced by EUMETSAT and/or CIMSS should be compared with the corresponding outputs from the NESDIS global system.

Negotiations between NESDIS and the UK Met Office regarding the "UK products" file are now in an advanced stage. (The UK products file will contain an extensive set of global ATOVS data which will be provided to the UK Met Office over a dedicated link to supplement the products distributed on the GTS.) The data to be transferred under a memorandum of working arrangements between the two organisations comprises five data streams. These are:

- the three Level 1B data sets for HIRS, AMSU-A, and AMSU-B, the format of which is almost completely defined,
- an ATOVS products data set, containing retrievals and clear radiances at every other HIRS field of view,
- an AVHRR cloud products data set containing a small number of parameters derived from the AVHRR GAC data corresponding to each HIRS field of view. The definition of the parameters to be included in this data set is close to being finalized; the main problem has been defining a satisfactory cloud test.

The WG requested that members be informed when final agreement on these parameters is reached. **(Action: J Foot, E Brown)**

2.3.2 Distribution of global data

NESDIS plans for distribution of ATOVS data over the GTS were presented at the conference. The WG noted that these plans call for distribution of ATOVS soundings and clear radiances at a spacing of 500 km. This is inconsistent with the new WMO requirements for satellite sounding data, which indicate that these data are required at a spacing of 100 km. The WG recommended that this issue be brought to the attention of WMO and CGMS. The WG also recommended that operational users who foresee a need for higher resolution ATOVS soundings or clear radiances should write to E Brown at NESDIS.

The WG also noted that considerable progress on assimilation of unadjusted (raw) radiances into NWP models was being achieved. Consequently, the WG foresees an eventual need for unadjusted radiances at the full instrument resolution by an increasing number of users.

2.3.3 Other actions and recommendations

At previous meetings the WG identified a need for rapid access to detailed data on instrument characteristics in electronic form, and made recommendations to both NESDIS and EUMETSAT. The WG was informed that such access could be provided quite easily using systems which were now in place at NESDIS. Accordingly, the WG identified the following actions:

To set up anonymous FTP access to detailed instrument data for NOAA-K. **(Action: T Kleespies, E Brown)**

To provide a detailed list of the data items to which the WG wishes to have access. **(Action: G Rochard)**

At the last meeting, copies of the draft NESDIS document "Report to SPOP: Specifications for

processing of data from the NOAA-K sounder" were distributed to WG participants, who were invited to send comments to NESDIS. The WG noted that some participants had done so, and that a new revision of the document was expected shortly. The WG encouraged participants to provide comments on the new revision to D Wark and H Drahos.

Access to SSM/T-2 data for use as an AMSU pathfinder was a concern at the last meeting. The WG noted that SSM/T-2 Level 1B data (along with both products and 1B data from SSM/I and SSM/T) are now available from the NESDIS archive. The WG concluded, however, that access to a sample of collocated SSM/I, SSM/T and SSM/T-2 data would still be useful. The following action was identified:

To provide access to a small sample of collocated SSM/I, SSM/T and SSM/T-2 data on J Bates' home page. **(Action: J Bates, T Kleespies)**

2.4 ADVANCED SOUNDER SCIENCE

N Scott (chair) with T Aoki, D Ceckowski, V Cuomo, L de Leonibus, S Kadokura, D Klaes, T Kleespies, D LaPorte, J Le Marshall, D Melton, G Prangsma, H Revercomb and M Uddstrom contributing.

2.4.1 Progress on actions from ITSC-VII

Implementation of the 10 km fov into HIRS for NOAA-N and all subsequent units, including those for METOP, is under way. Retrofit of this feature into any of the KLM units was deemed too costly due to their advanced stage of assembly and posed risks to the KLM instrument schedules. The strong support of ITWG was highly influential in the quick decision to make this improvement in future sounding capabilities.

2.4.2 Sounder instrument status

2.4.2.1 Improvements to the current POES systems

Expected improvements from the AMSU/HIRS system or with the high spectral resolution sounders in the infra-red/AMSU system are enhanced accuracy, improved vertical resolution and increased capabilities in deriving new parameters. Scientific communities involved in Earth science - (a) operational meteorology, (b) climate research and monitoring, and (c) atmospheric minor constituents and chemistry - will benefit from such improvements as long as the information content of the spectra and/or products is properly interpreted.

The implementation of advanced sounding systems will provide the potential for major improvements in operational and research areas, including NWP and studies of climate change (i.e. the global hydrology cycle, descriptions of surface-atmosphere processes, etc.).

2.4.2.2 Infra-red sounders of high spectral resolution

The instrument designs which would apply high spectral resolution to improve the sounding data/products now available from the POES system are summarized in Table 2.4.1.

The first three use Fourier transform spectrometers (FTS) for spectral separation, and the AIRS uses a cross-dispersed grating design with several linear detector arrays.

The AIRS is in Phase C/D for the NASA EOS programme PM platform. The AIRS design is finalized and critical subsystems have been breadboarded. The engineering model will be fabricated and ready for testing in 1997.

The IASI is in the design phase B design for EUMETSAT as a joint project of CNES and the Italian Space Agency (ASI).

The ITS was originally designed for EUMETSAT at the Phase A level by the University of Wisconsin and Santa Barbara Research Center; limited sub-system breadboarding is currently being performed for NOAA/NESDIS by Lincoln Laboratories.

Table 2.4.1 Advanced Sounder Options

	HIRS-hybrid	ITS	IASI	AIRS
Approach	FTS+filters	FTS	FTS	grating
Hardware group	ITT/Bomem	95: Lincoln Labs / NOAA 91: UW / SBRC	CNES/ASI/ EUMETSAT	JPL/NASA/ Loral
Spectral range cm^{-1}	LW: 650-1150 + HIRS	LW: 620-1150 MW: 1210-1740 SW: 2150-2720	contiguous 645-2940	LW: 649-1136 MW: 1217-1613 SW: 2169-2674
Spectral resolving power, $\lambda/\delta\lambda$	1000-1800 LW	900-1800	2000-4000	1000-1400
Spatial footprint (824 km altitude)	10 km	10 km	15 km	15 x 30 km
Spatial density (per 50 km square)	2+	9	4	9
Power	24+32 W	73 W	200 W	225 W
Weight	34+13 Kg	40 Kg	160 Kg	140 Kg
Platform (target)	NOAA-N	NOAA/NASA/ DoD C-1	METOP-1	EOS PM and C-1
Launch date	2000	2007	2000	2000
Primary assets	low costs + fits on small spacecraft with HIRS	small + best spatial sampling for cloud clearing	most versatile spectral coverage and resolution	best noise performance, especialy for SW + new technology

A recent new development, the HIRS-hybrid, has been designed as an experiment to serve as a pathfinder for the other advanced sounders which have more complete spectral and spatial coverage. The HIRS-hybrid would add a high spectral resolution long-wave band (650-1150 cm^{-1}) to HIRS, significantly enhancing the vertical resolution of HIRS for temperature sounding without jeopardizing the normal HIRS operations. While clearly not the complete advanced infra-red sounder sought for operations (incomplete spectral coverage at high spectral resolution and insufficient spatial sampling density), a HIRS-hybrid on NOAA-N would help pave the way for the effective use of data from

IASI, AIRS and ITS.

In addition to these instruments, specifically designed as high spectral resolution sounding of temperature and water vapour for weather forecasting applications, there is the Interferometer for Monitoring Greenhouse Gases (IMG), designed exclusively for climate applications. The IMG has been built, tested and delivered to the NASDA ADEOS spacecraft contractor for launch in 1996. The spectral resolution of the IMG is very high, with resolving powers of 7,000 to 30,000 for the spectral range 700 to 3000 cm^{-1}. The spatial coverage of IMG is limited to the satellite sub-track, with samples spaced at intervals of 84 km. The fov of each sample is 8 km (three samples with 12 km separation between fov centres in the cross-track direction are actually used for the total spectral range, with one measuring the long-wave, one the mid-wave and another the short-wave spectral bands). Whilst not suited directly to meteorological sounding, the IMG will be very useful for addressing remaining problems with the forward radiative transfer models used for other advanced sounders.

2.4.3 Future operational sounder system plans

For more than three decades, the main source of meteorological satellite data has been the NOAA polar satellites of the USA. NOAA currently operates two operational satellites in complementary polar orbits, one crossing the equator in descending mode in the morning, and the other in the afternoon. From the year 2000 onwards NOAA is discontinuing the coverage of the morning orbit. At the same time EUMETSAT plans to implement a corresponding system in the morning orbit, with an equator-crossing time of 0900.

The first of three planned METOP (METeorological OPerational) satellites is planned to be launched in 2001. The two first satellites will be the companion satellites of NOAA-N and -N', and they will carry the same payload, except for the advanced sounder. The third METOP spacecraft is not yet finally defined.

2.4.4 Recommendations: advanced sounders

2.4.4.1 The WG emphatically recommends that the satellite agencies give their highest priority to rapid implementation of advanced infra-red sounders, because of the key role anticipated for these sounders (combined with microwave sounders) in improving operational temperature and water vapour soundings, to benefit NWP and global change research.

2.4.4.2 The WG considers it crucial that the WMO goals for operational temperature and water vapour soundings (often summarized as < 1K r.m.s. error in temperature for 1 km vertical resolution and < 10% r.m.s. error in water vapour for 1 km vertical resolution) not be degraded for the coming EUMETSAT / USA(NOAA/NASA/DoD) polar system (NPOES). ITWG offers the extensive scientific experience of its members to assist in the definition and review of requirements for the advanced sounders in NPOES .

2.4.4.3 Consistent with the high priority of advanced sounding, the WG strongly recommends that NOAA/NESDIS proceed to develop the HIRS-hybrid to serve as an experimental pathfinder for the future operational advanced sounders. This instrument provides an opportunity for NOAA to develop an operational high resolution sounder (albeit of limited spectral and range and spatial sampling) prior to the launch of the first USA

component of the NPOES system in 2007. The resulting data should be made available to the operational and research communities.

2.4.4.4 Advanced atmospheric sounding requires both high spectral resolution and coverage (from long-wave to short-wave infra-red), small fields of view and high spatial density. The high spectral resolution is needed to improve the vertical resolution, and high spatial sampling with a small field of view is needed to provide an adequate number of clear soundings in the presence of broken clouds. To achieve an optimal yet practical instrument design, scientific trades-off must be made. In this respect, the WG's consensus is that the horizontal sampling density should be greater than that of HIRS/3, with a fov size no greater than 10 km, in order to satisfy the requirements of NWP. If a performance compromise is necessary, it is preferable to reduce the spectral resolution somewhat, rather than degrade the sample density, provided the above mentioned scientific requirements are fulfilled (i.e. recommendation 2.4.4.2, which requires that signatures of individual CO_2 lines must be separated).

2.4.5 Research needed

Significant contributions are required in the following fields:

- development or extension of new, high-performance suites of forward and inverse algorithms,
- definition and derivation of new products or by-products,
- definition and application of validation plans, of quality control policy and relevant quality flags,
- operational assimilation of advanced sounder data and/or products in NWP.

None of the above mentioned topics may be addressed in isolation. Various scientific contributions towards united actions aiming at providing comprehensive, coherent and pertinent solutions to these problems are needed.

2.4.5.1 Forward modelling

For many years, several "generations" of forward models have been derived ranging from the basic "line-by-line and layer-by-layer" approach to highly parameterized approaches with comparable accuracy but saving impressive amounts of computation time.

Accurate fast and hyper-fast forward models will be used to simulate advanced sounder observations to be used in variational methods for analyses and retrievals, validation processes, etc. In data assimilation for NWP, they will be used to compute the "model-equivalent" of the observation.

Other applications include:

- the definition of the "dynamic range" with respect to spectral and atmospheric variables,
- the selection of the best spectral intervals for observing the atmosphere to retrieve each atmospheric or surface variable (i.e. studies of "information content"),

Some important problems still remain that could hamper the benefit expected from high spectral resolution atmospheric sounding.

Recommendation: The WG strongly endorses the work of ITRA to identify and help solve these problems and to develop validation activities. We strongly recommend the largest possible participation in these validation activities including the

distribution of "ground truth" data sets (e.g. HIS, ARM, SPECTRE, IMG).

2.4.5.2 Validation and error characterization

A key requirement is for studies that lead to a full, quantitative understanding of the error characteristics of the radiance spectra and derived geophysical parameters, over a range of environmental conditions. This is necessary if they are to be used optimally for NWP and other applications.

Within the framework of various working groups (e.g. ITRA, AMIP) validation exercises are performed. These are studying model output products and comparing them with each other or with independent reference data sets (e.g. in situ measurements or data from other satellite-borne or ground-based instruments or output from other models).

Recommendation: The WG recognizes that such studies have been invaluable primary steps towards more complete validation and characterization studies. It recommends that plans for development and extension of algorithms include error characterization and participation in international validation campaigns.

2.4.5.3 Preparatory research and operational development for NWP

Atmospheric forecast models require the complete specification of the initial values of the model variables. Desired information includes temperature, moisture, winds, clouds and surface variables. A current trend is to move towards direct assimilation of radiance data, rather than to use retrieved profiles of temperature and humidity. Due to the huge difference in the number of channels between TOVS and advanced sounders, assimilation of such data is undoubtedly a field for further urgent investigation.

The details of atmospheric absorption and scattering processes affect the choice of observed wavelengths and of those used to retrieve information on different meteorological parameters. Considerable research is required in the selection/combination of sounding channels (according to their information content). This is an important problem as it may affect decisions on the transmission of data to operational centres (i.e. which channels are to be used for which information: temperature, humidity, ozone, clouds, etc.). Research is urgently needed on how to make best use of the information content of the whole spectrum.

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

D Hinsman (chair) with L de Leonibus, J Le Marshall, G Prangsma, A Reale, G Rochard, D Wark and Zhou FengXian contributing.

2.5.1 Background

Following discussions during the first sessions of ITSC-VIII, it was decided to form a new ITSC Working Group entitled "International Issues and Future Systems". The focus of the Working Group would be a review of future systems with regard to programmatic issues that may become of interest to ITSC.

Recommendations of a scientific nature related to future sounding systems were developed by the Working Group on Advanced Sounder Science. The Working Group on International Issues and Future Systems was requested to delineate mechanisms that could impact the decision-making process for the joint system being developed by NOAA, NASA, DoD and EUMETSAT. The Working Group also considered mechanisms for making recommendations to CGMS that would include a path or paths for feedback from CGMS.

The Working Group considered matters under the following topical areas:

- a review of plans for future systems,
- a review of previous ITSC actions,
- frequency protection from 1 to 200 GHz,
- education and training,
- small PC workstations,
- development of an ITSC information system on Internet, and
- relationships between ITWG and NOAA/NESDIS.

2.5.2 Review of plans for future systems

The Working Group considered the information contained in the presentations made by NOAA/NESDIS, EUMETSAT and the People's Republic of China. The Working Group felt that the presentations were comprehensive, covering the present status of operational systems and the plans for future satellites including instrument payloads. The Working Group was pleased to note the continuation of the present suite of operational instruments and the plans to develop and fly pre-operational instruments for advanced sounders with the expectation that these instruments could become the next operational generation. The Working Group agreed that the review of the satellite operators' plans was most valuable and that similar presentations should be made at future meetings of ITSC.

Action: All satellite agencies should be invited to make detailed presentations of the present status of operational systems and future plans for instruments and missions at ITSC-IX. (Co-chairs)

2.5.3 Review of previous ITSC actions

2.5.3.1 Implementation of plans for advanced sounders

The Working Group noted that the satellite agencies had previously been encouraged to implement their plans for "advanced infra-red sounders along with microwave sounders and co-registered imaging instruments". The Working Group agreed that the satellite agencies should still be urged to implement their plans. To avoid ambiguity, the Working Group recommended that co-registration of infra-red and microwave sounders with imaging instruments be accomplished through software with the assumption that the satellite agencies would provide sufficient information to accomplish this.

Recommendation: All satellite agencies are encouraged to implement their plans for advanced infra-red sounders along with microwave sounders and co-registered imaging instruments. (to CGMS)

2.5.3.2 Compatible instrument plans

It had previously been recommended that EUMETSAT and NOAA/NESDIS establish common operational requirements for advanced sounders to ensure compatible polar orbiting instrument plans. The requirement for an advanced infra-red sounder to support NWP before the end of the decade is still an urgent WMO requirement. In this regard, the current plans to develop experimental advanced sounders for flight on both research and operational platforms are commended. However, the Working Group believes that, for operational purposes, a common advanced infra-red sounder is desired for flight on both the morning and afternoon satellites in conjunction with the operational imager and microwave sounder.

Recommendation: EUMETSAT and NOAA/NESDIS are requested to consider a common advanced infra-red sounder for flight on both the morning and afternoon satellites in conjunction with the operational imager and microwave sounder. (to CGMS)

2.5.3.3 ITWG expertise involvement

At ITSC-VII, it was recommended that a set of meteorological requirements for future sounders be developed and distributed with appropriate involvement of ITWG expertise. The Working Group was pleased to learn that three representatives from ITWG were also members of the WMO CBS Working Group on Satellites and brought considerable expertise to WMO. The Working Group noted that WMO was continuing to refine its satellite data requirements including those for sounders and that the three members had already provided useful information to WMO. Furthermore, ITWG would be consulted as the WMO requirements were refined.

However, the Working Group expressed concern that no mechanism existed for involvement of ITWG expertise in assisting in the definition or review of requirements for the "converged" systems now planned by the United States, i.e. the convergence of the NOAA/NESDIS and DMSP satellite systems with participation by DoD, NOAA and NASA. The converged system would include an early morning satellite mission to meet military requirements and an afternoon satellite. The Working Group also noted that EUMETSAT would fly a morning satellite.

In making recommendations with regard to the satellite systems encompassed by the EUMETSAT and "converged" systems, the Working Group agreed that EUMETSAT should be the focal point for the

morning satellite while the new Integrated Program Office (IPO) for the "converged" system should be the focal point for the early morning and afternoon satellites.

Action: ITWG to inform the IPO for the "converged" system and EUMETSAT of its desire to assist in the definition or review of requirements. (Co-chairs and to CGMS)

2.5.3.4 Direct broadcast

The Working Group reconfirmed previous recommendations that direct broadcast of satellite data from both operational meteorological satellites and experimental satellites to be flown under NASA, ESA and NASDA programmes is a mandatory requirement. There is already a large network of ground-stations (for example 200 in the USA) attesting to the importance of this service. The Working Group noted that several countries presently use AVHRR and TOVS data to produce, on a real-time basis, radiances and retrieval profiles for local use and in NWP. Retrieved profiles are also used for monitoring of satellite data, for example in the UK, France and New Zealand. Several countries on an ever increasing basis are using AVHRR and TOVS data for nowcasting, sea surface temperature determination, vegetation index, typhoon monitoring, etc. Activities such as these are occurring in Brazil, the Philippines, China, Kenya, Senegal, etc. Additionally, many institutions and universities also use direct broadcast for research that often produces results useful in improving AVHRR and TOVS products used by the world-wide community.

Recommendation: All satellite agencies are encouraged to continue to provide or implement as appropriate a direct broadcast capability for sounder and related image data. (to CGMS)

2.5.3.5 Timely dissemination

In noting that ITSC-VII had recommended that EUMETSAT and NOAA/NESDIS agree upon common requirements for timely dissemination of global data sets to users, the Working Group reiterated the urgent need that an integrated plan for satellite product generation and distribution be developed by EUMETSAT and NOAA/NESDIS. It expressed concern that such an integrated plan did not yet exist. An integrated plan would minimize the possibility of redundant or inconsistent products being generated while alerting the global user communities as to the type of new products to be expected and their source.

Recommendation: EUMETSAT and NOAA/NESDIS are encouraged to develop an integrated plan for satellite product generation and distribution. (to CGMS)

2.5.3.6 Interaction with CGMS

In searching for the appropriate mechanism to forward recommendations to CGMS, the Working Group was informed of the decision at the last meeting of CGMS to form a working group for radiance and sounding retrievals. CGMS also decided that the meetings of the ITWG would constitute meetings of the working group. To provide guidance and recommendations from the ITWG to the CGMS plenary, a focal point was nominated by the CGMS NOAA/NESDIS delegation, namely Dr Paul Menzel. Therefore it is expected that Dr Menzel will attend CGMS meetings and present ITWG recommendations. He will also report back to ITWG on the results from CGMS meetings. The Working Group recommended that action items for CGMS should be presented by Dr Menzel at the CGMS meetings.

2.5.4 Frequency protection for 1 to 200 GHz

The Working Group unanimously agreed that the protection of the frequencies used or planned to be used by instruments in the 1 to 200 GHz range should be pursued. A detailed work-plan with milestones was developed as follows:

(a) Each participating country should send to Dr Guy Rochard a description of the planned use of microwave frequencies (active and passive) by May 1995 to include:
- frequency bands and applications,
- central frequency and bandwidths,
- existing or planned instruments with accurate details of their central frequencies and bandwidths,
- existing or planned studies concerning possible sharing with active users predominantly commercial telecommunications entities,
- status of registration of HRPT stations and microwave satellite instruments with national telecommunications administrations and the ITU (with a copy to WMO),
- other useful information such as contained in the memorandum from the NOAA/NESDIS Office of Radio Frequency Management.

(b) ITWG members are encouraged to contact their representative to the ITU (particularly ITU Working Group 7C), their representative to the SFCG, and for European Countries, with their representative at CEPT (particularly the SE19 Working Group). (May 1995).

(c) WMO agreed to forward to all ITWG members the names and addresses of the national telecommunications administrations and the SFCG membership as well as a copy of the report from the First Session of the CBS Working Group on Telecommunications Study Group or Radio Frequency Coordination. (April 1995).

(d) The following ITWG members agreed to make contact inside their own country concerning microwave frequency protection as soon as possible (April 1995):

Australia	J Le Marshall
Australia (CSIRO)	F Prata
Canada	D Steenbergen
P R of China	Dong Chaohua
R of China	Wang Kuang-Hwa
ECMWF	R Saunders
EUMETSAT	D Klaes
Finland	A Korpela
France	G Rochard
France (CNRS)	N Scott
Germany	T Böhm
Hungary	I Csiszár
Italy	L de Leonibus
Japan	T Aoki
R of Korea	D-S Shin
Mongolia	M Erdenetuya
Netherlands	G Prangsma
New Zealand	M Uddstrom
Spain	M Arbelo

UK	J Eyre
USA	D Wark
WMO	D Hinsman

(e) WMO agreed to create a list-server for distributing electronic mail via internet automatically. Names for the user's list should be provided to WMO as soon as possible. (April 1995).

G Rochard agreed, upon reception of the above requested material, that he would prepare a consolidated draft document describing the importance of microwave frequencies and its protection requirements for use by both meteorologists and telecommunication personnel (by **July 1995**). Corrections and comments to the draft must be returned to Dr Rochard before **15 September 1995**. A final document will be distributed by the middle of October 1995 to each ITWG participant. Each participant agreed to use the document in contacting his local representatives to ITU, SFCG and CEPT before 1 December 1995.

It was also noted that the Working Groups on NWP and Climate would provide further input on the issue of 5% and 1% interference and their potential impact. Detailed action items were agreed upon by individual participants.

2.5.5 Education and training

The Working Group was pleased to note the latest status of the new Strategy for Education and Training in Satellite Matters at WMO. The Working Group reconfirmed its commitment to provide training expertise in the area of satellite sounding retrievals.

2.5.6 Small PC workstations

The capability of PC systems and more recently UNIX workstations, combined with the maturity of the current TOVS processing software, has allowed the development of inexpensive TOVS processing systems for research and operations. Many of these systems have been deployed and continue to operate successfully providing both extensive and useful data to groups who may not otherwise be members of the sounding community.

Recommendation: ITWG encourages further development of these low cost systems and invites agencies planning to increase the number of research and operational users of TOVS/ATOVS data to use the ITWG's experience and expertise in this area.

2.5.7 Development of an ITWG information system on Internet

The Working Group felt it important that the capabilities available through electronic distribution and mail services on Internet be utilized by ITWG. In this regard, it was pleased that WMO could act as a host for an ITWG home-page and list-server. It agreed that it should form a group to identify the various components to be made available.

Action: ITWG to form a group to identify the various components to be included in the ITWG Information System on Internet. (Co-chairs).

2.5.8 Relationships between ITWG and NOAA/NESDIS

During discussions of the overall progress of ITWG since its early beginnings, the Working Group noted that the primary factor leading to the large success of ITWG was synergism. Participants and organisations equally shared their expertise but gained significantly more due to the combined interactions with their colleagues. This has manifested itself in the fact that ITWG is now recognised as the highest level of focused interactions for TOVS studies anywhere in the world.

The Working Group particularly acknowledged the contributions made by NOAA/NESDIS and the benefits it had received. The Working Group noted that the availability of a multitude of quality sounding products for the international user communities has been due to the high standards established by NOAA/NESDIS and that these products, in an ever increasing manner, were producing positive impacts on NWP.

Since NOAA/NESDIS is a data user as well as a data provider, International TOVS Study Conferences allow NESDIS the unique opportunity to interact with other data users who can provide a highly focused feedback mechanism of independent verification of results and recommendations as to alternate and improved data processing methods.

The Working Group also noted that WMO considers ITWG as the primary source of guidance for matters related to radiance and sounding retrievals. ITWG members have contributed materially to the ATOVS science specifications. Critical areas where NESDIS has benefited from ITWG recommendations include the use of AVHRR in ATOVS processing, and the application of the RTTOV radiative transfer code.

In summary, the Working Group acknowledged that ITWG greatly benefitted from NOAA/NESDIS participation and is strongly motivated to provide NESDIS with feedback, useful recommendations and ideas. It recommended that NOAA/NESDIS continue its participation and consider an expanded presence to exploit the worldwide source of knowledge found at the meetings of ITWG.

3. REPORTS OF TECHNICAL SUB-GROUPS

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

N Scott announced that a new version of the "local" 3I code would be released to users during summer 1995. The new version includes:

- modifications to the cloud retrieval algorithm,
- an improved water vapour retrieval algorithm (surface temperature and water vapour retrievals separated),
- other minor changes introduced to the "global" version,
- organizational and structural modifications to the code (by D Klaes).

The group decided to establish a FTP site at LMD where users can obtain information pertaining to modifications and updates to 3I and 3R code and data files, and where users can send suggestions to LMD. **(Action: N Scott)**

A need for a verification data set was identified by the group. This data set will contain one or more orbits of Level 1B data, Level 2 retrievals (computed using the existing "official" version of 3I) and radiosondes. Users will be able to test code modifications on the data set and compare results to official retrievals to evaluate the impact of the modifications and validate retrievals. G Prangsma believes he has a suitable data set, and he will make it available to all users via the new FTP site.

The 3R forward model is presently undergoing testing on LMD's new computer system and will be available to users in the near future.

Neural network versions of 3I and 3R are under development at LMD. Clear-sky temperature retrievals appear to be more accurate than the current physical/statistical approach.

The incorporation of AVHRR into 3I was discussed. There are no plans at present to mount this effort at LMD, but if significant benefit were demonstrated, it may be considered for future work. Users were encouraged to pursue the task.

3.2 TECHNICAL SUB-GROUP ON TOVS PROCESSING SOFTWARE, ITPP

3.2.1 Documentation

It was reported to the sub-group that ITPP-5.0 does contain much more in-line documentation, especially in the retrieval program, and that was well received. Even so, more external documentation was desired. In particular, the sub-group discussed documentation for:

- all ancillary data files (radiative transfer (RT) coefficients, regression data bases, orbital elements, etc.),
- various supplemental routines (putele, filrew, etc.),
- guidelines for incorporating user-specific regression data bases.

The large amount of software that is used to produce the RT coefficients for these data bases cannot be included with the ITPP. However, a qualitative discussion of what goes into getting such a data base ready for use in the package is certainly possible.

Documentation on how to run these programs appears to be adequate. Better qualitative descriptions about what many of these things do and how they do it was desired.

3.2.2 Climatological applications

Initially, ITPP-5.0 will be released with only the capability to process data from NOAA-11, -12 and -14. Due to the increasing need to use TOVS data for climatological studies, the sub-group agreed that there should be a capability to process data from earlier satellites as well.

3.2.3 Potential problems and questions

3.2.3.1 TIGR

Initial results show possible problems with the application of TIGR within the ITPP. It was suggested that moisture problems in the upper atmosphere could be due to sporadic super-saturations within this specific version of the TIGR data base. [Investigation within CIMSS after ITSC-VIII revealed that there is a check for super-saturation in the code.] Further observation of the results by the sub-group is necessary to characterize better the effects of TIGR.

3.2.3.2 Radiance bias tuning

Due to the absence of H Woolf from ITSC-VIII, there was some confusion within the sub-group as to what is done within the ITPP for radiance bias tuning. Tuning with the ITPP is based on the NESDIS operational satellite/radiosonde match files which are representative of global conditions. The procedure has not changed with the advent of ITPP-5.0.

3.2.3.3 Covariance matrix design

CIMSS reported that improvements in lower levels due to the use of AVHRR are somewhat offset by degradations at higher levels. It was suggested that the design of the error covariance matrix within ITPP-5.0 may contribute to this effect of compensation between levels when added information is introduced.

3.2.4 ITPP-5.0 release

ITPP-5.0 is finished and will be released by CIMSS as soon as a reasonable level of external documentation can be produced and the capability of processing NOAA-14 data is incorporated. NOAA-14 work had been halted while potential problems with the MSU were being diagnosed.

3.3 TECHNICAL SUB-GROUP ON RADIATIVE TRANSFER MODEL, RTTOV

3.3.1 Recent developments

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. Since ITSC-VII, RTTOV version 3 has been created and distributed. It contains the following developments:

- An option to perform calculations for TOVS or for ATOVS. The inclusion of the ATOVS option required modelling of the variation of microwave surface emissivity with frequency and the treatment of emission/absorption by cloud liquid water in the microwave.
- A more flexible user interface with scope for future extensions.

3.3.2 Problems with RTTOV

The sub-group discussed the accuracy of RTTOV in modelling water vapour transmittance. Some users had found problems, and it was not clear whether these were inherent or implementation problems. However it was agreed that the current implementation of RTTOV has limited accuracy for water vapour transmittances (around 2% r.m.s. for some channels, when used over a wide range of profiles) and that the "OPTRAN" approach to this problem was likely to be more accurate (see paper by McMillin et al., this conference).

Some users were not clear how to generate transmittance coefficients for RTTOV for new instruments (e.g. AMSU, SSM/I). Coefficient generation programs were distributed with RTTOV version 1. These programs, with minor modification, can be used to generate transmittance coefficients for RTTOV from line-by-line transmittances appropriate to other instruments.

3.3.3 Line-by-line (LBL) models in use with RTTOV

A survey of current implementations was made. RTTOV was currently in use with LBL transmittances generated by several models including: FASCOD2, GENLN2, HARTCODE and the NESDIS LBL model.

The sub-group was informed that a new LBL code, LBLRTM, is being maintained for the ARM programme by A Clough (AER). The code contains the most up-to-date water vapour continuum, making use of interferometer data. It is planned to incorporate LBLRTM improvements in future versions of FASCODE.

3.3.4 Fast models and climate studies

The sub-group considered concerns that RTTOV and other fast models may introduce unwanted biases in climate studies. The group did not think that the biases inherent in the fast models were the main problem; biases in the underlying LBL models could be more important, as could empirical tuning of the fast models, particularly for water vapour where the question of "ground truth" was still an unresolved problem.

3.3.5 Future developments to RTTOV

Those foreseen were:

- improvements in microwave surface emissivity modelling, including a physical model for the sea-surface, improved parametric models for other surfaces, and a more careful treatment of the reflected radiation,
- improved ozone transmittance (e.g. as already implemented at CMS-Lannion in the RTCMS model),
- improved treatment of the combined transmittance of water vapour and mixed gases (already possible in RTTOV, but requiring appropriate LBL inputs),
- improved transmittance modelling, following the OPTRAN approach,
- improved treatment of cloud in the infra-red, and
- if warranted, a more up-to-date treatment of cloud liquid water absorption.

3.3.6 Actions

To provide information to J Eyre on recent developments in:

- measurements/models of microwave surface emissivity over ice and snow (**Action: A Schweiger**),
- measurements/models of cloud liquid water absorption (**Action: T Kleespies**).

4. ABSTRACTS OF ITSC-VIII PRESENTATIONS

A COMPARISON OF SATELLITE-DERIVED THERMAL GRADIENT WINDS AND RADIOSONDE WINDS AT MANDATORY ATMOSPHERIC LEVELS

T Achtor
CIMSS, University of Wisconsin-Madison, USA

A comparison of atmospheric winds observed with radiosonde and thermal gradient winds generated from NOAA polar orbiting weather satellite vertical temperature sounding information, using the International TOVS Processing Package (ITPP), was conducted for 43 cases from October 1992 through March 1993 over the mid United States. The daily wind information for mandatory atmospheric levels were derived into speed and direction scalar components and statistical comparisons applied. The daily wind comparisons were also concatenated to create one file containing all 43 cases, which produced composite statistics for over 31,000 comparisons. A discussion of the methods applied and the ensuring results will be provided at the ITSC-VIII.

THE REMOTE SOUNDING OF TROPOSPHERIC TRACE GASES BY THE ABSORPTION METHOD

Tadao Aoki, M Fukabori and Teruo Aoki
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A method of remotely sounding tropospheric trace gases by measuring the surface-reflected near infra-red solar radiation is described, involving the characteristics of this method such as the weighting function, vertical resolution and expected accuracy. The advantages of this method are shown in comparison with the method that measures the emission from the atmosphere and surface. An instrument is proposed to measure the reflected solar radiation with high spectral resolution, where the absorption lines of trace gases are selected by a very narrow band pass filter and scanned with a tunable etalon. To demonstrate the feasibility of such remote sounder, a ground-based instrument has been developed to measure the vertical profile of water vapour. Measurements were made with the resolution of about 0.05 cm^{-1} for the absorption line of water vapour at 6541 cm^{-1} and compared with radiosonde observations. The accuracy of column amount of the retrieved water vapour is a few percent, which is much better than those of current satellite observations.

DETERMINATION OF SEA SURFACE TEMPERATURE FROM SYNERGY OF TOVS AND AVHRR DATA

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[1] Dept. of Physics, University of La Laguna, Canary Islands, Spain
[2] Dept. of Thermodynamics, University of Valencia, Spain

An alternative to the current satellite sea surface temperature (SST) algorithms is developed. It uses the information supplied by sensors of TOVS and AVHRR systems on board NOAA satellites. The new SST algorithm is based on the split-window technique, the coefficients A and B being determined as a function of the total column atmospheric water vapour, W, which is determined using TOVS data, and the T_4 and T_5 temperatures are from AVHRR thermal infra-red channels. The proposed method is evaluated by comparison with others algorithms for an image of the Canary Islands region and the

disagreements between them are analyzed. The combination of TOVS and AVHRR data gives us the best results for determining SST in this geographical zone. However, the comparison with in situ measurements will be the next step in our investigation.

INTERPRETING HIRS LEVEL 1B OBSERVATIONS OF CIRRUS USING THE 8μm CHANNEL: MIE OR ADT?

A J Baran[1], D L Mitchell[2] and J S Foot[1]
[1] Meteorological Office, Bracknell, UK
[2]Desert Research Institute, Reno, Nevada, USA

An initial study of the potential of using HIRS data to determine cirrus particle size is presented. The importance of the 8.3μm channel is highlighted through calculations based on various crystal habits using both Mie theory and ADT (Anomalous Diffraction Theory). These calculations are compared with data from mid-latitude frontal cirrus and cirrus associated with a tropical cyclone. Significant differences in the inferred mean sizes arise between Mie theory and ADT.

TOVS OBSERVATIONS OF WATER VAPOUR FOR CLIMATE MONITORING

J J Bates
Climate Diagnostics Center, NOAA/ERL, Boulder, Colorado, USA

A method for the inter-calibration of the TOVS upper tropospheric water vapour band brightness temperature data is developed and applied to NESDIS clear column radiance data from 1981-1994. Particular attention is paid to the inter-calibration of the eight different instruments used over this time period. Analysis of the adjusted anomaly time series show the location and strength of both the large-scale ascending and descending circulations in the tropics as well as water vapour anomalies. Comparison of these TOVS data with outgoing longwave radiation and sea surface temperature anomalies reveals that both convection and increased upper tropospheric moisture occur over anomalously warm water in the deep tropics. The development and movement of deep convection and increased upper tropospheric moisture can clearly be traced during El Nino / Southern Oscillation warm events. These TOVS data are also useful for monitoring upper tropospheric water vapour variability between the tropics and subtropics.

ON THE INFLUENCE OF BEAM FILLING ON THE RESULTS OF MICROWAVE RETRIEVAL ALGORITHMS FOR CLOUD PARAMETERS

R Bennartz, M Schaale, A Thoss, P Bauer and J Fischer
Institute for Space Sciences, Free University of Berlin, Germany

Due to the low resolution of space-borne microwave radiometers (lower than 15 x 15 km) in most cases the measured signal is a combination of signals emitted and reflected from different structures within the instantaneous field of view. To examine the influence of variations in cloud cover, cloud types, and rain-rates within a satellite pixel, a set of radiative transport simulations was carried out using a model based on the matrix operator theory. All simulations were done for the SSM/T2 channels at 183.31 GHz which are identical with the AMSU-B channels. The resulting data set was analyzed using EOFs and neural networks of the Kohonen type which allows us to determine the combinations of parameters having the strongest influence on the measured signal. Based on these

examinations, semi-statistical retrieval algorithms for combined AVHRR/AMSU data sets will be derived using inverse modelling technique for the microwave region combined with statistical information derived from sub-scale AVHRR data.

TOVS OPERATIONAL PROCESSING OF GLOBAL CLIMATE PRODUCTS BASED ON HIRS/2 RADIANCES

H J Bloom[1] and M W Chalfant[2]
[1] Hughes STX Corporation, Lanham, Maryland, USA
[2] NOAA/NESDIS, Washington DC, USA

Satellite derived products are computed operationally using data from the two TOVS on board NOAA polar orbiting satellites. Data are retrieved from real-time radiance measurements made by HIRS/2, MSU and SSU. Currently, temperature and moisture retrievals are distributed globally by NESDIS for primary use in operational numerical weather prediction models. Additional products derived from TOVS radiances are also available for use by numerical models.

The additional derived products include cloud top temperature and pressure, cloud amount, outgoing longwave radiation (OLR), downwelling longwave radiation (DLR), layer cooling rates (LC), sulphur dioxide (SO_2) concentration and total ozone parameters. These products could be important parameters in numerical weather prediction as well as monitoring and scientific study of climate global change. The SO_2 product was recently added to the TOVS operational processing system to aid in monitoring SO_2 concentration from volcanic eruptions. The total ozone and cloud parameters have been recently upgraded in the operational TOVS processing system, and the radiation budget parameters are currently produced as a operational demonstration in the TOVS operation. All products can be distributed worldwide through the GTS.

The paper describes how these products are derived, utilized in TOVS, archived and distributed. Comparison of these products with existing physical features of the atmosphere will be highlighted via data visualization.

ENHANCEMENT OF THE RTOVS SOFTWARE SYSTEM IN PREPARATION FOR IMPLEMENTATION INTO THE NESDIS SOUNDING OPERATION

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The RTOVS system is tentatively scheduled to replace the TOVS system in the spring of 1995 as a bridge to the ATOVS processing system. The RTOVS system has several distinct advantages over the current TOVS such as more dense retrieval coverage, real-time retrieval covariance matrices, a modernized software architecture, and use of the AVHRR in cloud detection. A special emphasis on the use of AVHRR in cloud detection will be presented, including a comparison of the cloud detection process, with and without the use of the AVHRR. These results are compared with those obtained from the current TOVS operation.

The paper will describe past and current activity to improve the accuracy of the RTOVS soundings products relative to the current TOVS system. A summary and description of specific upgrades is provided. RTOVS products are compared with radiosondes and with NMC analysis and forecast data.

The current status and implementation plans of the RTOVS system conclude this report.

ASPECTS OF TOVS ACTIVITIES AT THE DEUTSCHER WETTERDIENST (DWD)

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[1] Deutscher Wetterdienst, Offenbach and Potsdam, Germany
[2] Institute for Ocean Research, University of Kiel, Germany

The use of TOVS data is manifold at the Deutscher Wetterdienst (DWD). The 500 km SATEMs have been used operationally for many years. Recent impact studies using the 120 km retrieved TOVS data in BUFR code in the German Global Model (GM) show no significant change in the forecast performance in comparison to the analyses using the 500 km SATEMS. Products from locally received TOVS data are one component of the Interactive Graphical System (IGS) for diagnosing purposes in the central forecast office.

Total ozone of the atmosphere is being calculated with the algorithm of the ITPP. Comparisons between TOVS ozone, TOMS ozone and ground-based measurements show a good correspondence during the last year. A forecast scheme for the total ozone has been developed and has been running operationally since last summer. The forecast total ozone is one component of the operational UV-B prognosis. The UV-B prognosis provides information about the protection of human beings against sunburn and has been published by the media as recommended maximum solar irradiance exposure hours.

An algorithm for the extraction of humidity profiles over oceans from microwave data has been developed during the last years in cooperation with the University of Kiel. The algorithm is an iterative scheme with a first guess being derived from Empirical Orthogonal Functions (EOFs).

PREPARATIONS AT NOAA/NESDIS FOR THE DISTRIBUTION AND ARCHIVE OF ATOVS DATA

E B Brown
NOAA/NESDIS, Washington DC, USA

The Advanced TOVS (ATOVS) processing system will become operational in 1996, when data from the HIRS, AMSU-A, AMSU-B and AVHRR will be transmitted from the NOAA-K satellite. The ATOVS processing systems require new distribution and archive software to accommodate the new output file structure and increased data volume. This presentation will discuss the various methods NOAA/NESDIS will use to distribute the ATOVS data and what data will be archived. Emphasis will be placed on the international distribution of the data and the archive of the retrieval file.

TOVS DATA PROCESSING AT THE INFORMATION AND COMPUTER CENTRE OF THE MINISTRY FOR NATURE AND ENVIRONMENT

B Bulgin and M Erdenetuya
National Remote Sensing Centre, Ministry for Nature and Environment,
Ulaan Baatar, Mongolia

Information and computer centre of the Ministry for Nature and Environment has a receiving station

based on micro VAX II computer and there is available NOAA TOVS data processing software. We are processing TOVS data and extracting 15 parameters such as geopotential height, temperature and dew points at standard levels (1000-10 hPa); stability; precipitable water vapour; 1000-500, 500-300 and 300-200 hPa thickness; cloud temperature and pressure; surface elevation, temperature and pressure; total ozone and brightness temperature of each HIRS channel. Now we have started to use these parameters for weather forecasting. In first step we have done some methodologies for detection of forest and steppe fire and definition of its parameters. In the future we have a interest to cooperate with other countries' scientists who are working on this field and exchange our experiences.

CURRENT USE OF TOVS DATA AT METEO-FRANCE, TOULOUSE

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CNRM/SCEM, Météo-France, Toulouse, France

The main research activities related to TOVS data ares reported, more particularly the improvement of the algorithm used to calculate the total ozone amount and the processing of polar stratospheric clouds. Use of SATEMs in operational data assimilation system and their monitoring are described; a recent study on the impact of SATEMs is shown. Future plans about TOVS data monitoring and their use in variational assimilation are presented.

HIRS/3 - ITS PREDECESSORS AND PROGENY

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The properties of the HIRS/3 instruments for NOAA-KLM are presented including NEDN performance, ifov sizes and registrations, and radiant cooler performance. Results from the enhanced scope of radiometric calibration data analysis will show residual nonlinearity of first and second order curve fits. Results from a study to implement the 10 km ifov capability will show that radiometric performance within requirement goals is achievable. The first steps towards accommodation of HIRS/3 on to the METOP platforms have shown no fundamental barriers are anticipated. The Hybrid HIRS approach is discussed.

THE "TIGR" DATA SET CONCEPT AND THE NEURAL NETWORK TECHNIQUE: A COORDINATED APPROACH FOR THE FORWARD AND INVERSE ALGORITHMS SUITE AT LMD (TOVS, ATOVS, AIRS, IASI)

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ARA/LMD, Ecole Polytechnique, Palaiseau, France

The coming microwave sounders (AMSU A and B) and high spectral resolution infrared sounders of the 2000s are expected to provide improved measurements of clouds, atmosphere, land and oceans parameters with the accuracy, vertical resolution and coverage required by future advanced weather and climate models. Work is in progress to extend the ARA/LMD forward and inverse algorithms suite (the GEISA spectroscopic data bank, the STRANSAC, 4A, 3R forward models, the TIGR data set, the 3I system) to the processing of the next generations sounders: HIRS and AMSU (ATOVS) for the NOAA K system and the high spectral resolution infrared sounders (AIRS/EOS/NASA, IASI/CNES/ASI). In addition, as already stated during ITSC-VII (1993), we continue developing

"prototype" forward and inverse algorithms combining the current 3I system with the neural network technique. It is very noticeable that such an approach, in all its phases (learning and testing), highly gains from the existence of the "educated" TIGR data set.

The aim of this paper is to describe the work in progress in the framework of ATOVS, IASI or AIRS experiments: e.g. in the case of ATOVS, we are presently applying this approach to key processes as the selection of the initial guess, the cloud detection and the cloud clearing, the inversion procedures, etc. The method, the results and the relative performances will be described and discussed.

THE USE OF AVHRR DATA IN TOVS RETRIEVAL IN TAIWAN AREA

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In this study, a new cloud filtering method was developed by merging AVHRR and HIRS data for solving the problem of inaccurate cloud amount which was encountered in the process of TOVS retrievals. First, a lot of clear and fully cloud fovs (fields of view) of AVHRR and HIRS data are used to derive the relationship between the AVHRR 11 μm (channel 4) radiance and HIRS 11 μm (channel 8) radiance. For partly cloudy HIRS fovs, the equivalent clear and fully cloudy radiances could be derived by the above relationships and the effective cloud amount of the partly cloudy HIRS fov could be also obtained. It was proved that the results obtained by new cloud filtering method are better than that by old method which uses only HIRS data, but the improvement is dependent on the usage of MSU data. Under the situation without using MSU data, the improvement is remarkable: the root mean square difference of temperature compared with collocated soundings was reduced from 4K to 2K. On the other hand the result using MSU data is improved relatively little — about 0.2 K.

ANALYSIS OF THE THERMODYNAMIC AND THE RADIATIVE VERTICAL STRUCTURE OF THE EARTH ATMOSPHERE SYSTEM BASED ON TOVS OBSERVATIONS AND NEURAL NETWORKS TECHNIQUE

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Our goal is to characterize the vertical and the spectral variations of the Earth radiation budget with respect to the thermodynamic variables, in order to identify some of the factors which control the variations of the Earth radiation budget at different time scales. To achieve this goal, we need fast and accurate radiative transfer models. Up to now, the latter requirements appeared to be somewhat contradictory: the accurate computation of the radiative processes requires the use of line-by-line models, for which computing time forbids the use for global, long-term simulations. We have investigated the possibility of elaborating a new generation of radiative transfer models for climate studies based on neural networks technique. We demonstrate that neural networks can be used for accurately deriving the longwave radiative budget from the top of the atmosphere to the surface. The reliable sampling of the Earth atmospheric situations in the TIGR data set developed at LMD allows for an efficient learning of the neural networks. The dramatic saving of computing time based on this technique allows us to use more sophisticated (hence more accurate) radiative schemes for computing the longwave radiative budget either in GCM simulations or from long time series of satellite observations such as those provided by the 16 years of TOVS measurements.

PREPARATIONS FOR THE VARIATIONAL ASSIMILATION OF TOVS RADIANCES IN A 3D DATA ASSIMILATION SYSTEM

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The current operational global data assimilation system at the Canadian Meteorological Centre was recently updated (September 1994). Error statistics were re-calculated based on recent 6-hour global forecasts, including observational error statistics for SATEMS which are now assimilated as 7 thickness layers. This has proven to be very beneficial particularly in the Southern Hemisphere as will be shown with verification statistics against radiosonde reports. The use of satellite data has not proven to be as useful in the Northern Hemisphere mostly because of the availability of good radiosonde coverage. However, the resolution of NWP models is continuously improving and, in some sense, the radiosonde network is becoming too coarse. In this context, the judicious use of high-resolution satellite data, and particularly TOVS, is becoming increasingly important and substantial efforts have to be made to exploit these data at all resolvable scales of motion.

In Canada, a variational data assimilation system has been under development for the last few years in the Data Assimilation and Satellite Meteorology Division. In the context of TOVS data, RTATOV has been interfaced to the variational data assimilation code, and the tuning of the radiative transfer model is well under way in this system. The monitoring and quality control of radiances has been developed and results will be presented. Assimilation tests with 1DVAR TOVS retrievals will be presented and compared with the SATEM-driven global system.

THE EFFECT OF THE HORIZONTAL CLOUD INHOMOGENEITY ON THE HIRS CHANNEL 19 REFLECTIVITY

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HIRS channel 19 measures the 3.7 μm reflectivity that is primarily sensitive to the cloud droplet size and can used in bi- or multi-spectral techniques to retrieve simultaneously the cloud effective radius and the optical depth. These methods are based on the forward modelling of the expected reflectivities or radiances. However, because of the relatively coarse spatial resolution of HIRS, the sub-pixel scale horizontal within-cloud inhomogeneity affects the pixel reflectivity even in the case of stratiform clouds. In the paper reflectivities of opaque plane-parallel water clouds are modeled by Mie scattering and discrete-ordinate radiative transfer calculations for various sun-satellite geometries and for various degrees of the within-cloud variability of the effective radius. The results indicate that a realistic horizontal re-distribution of the droplet population of a uniform cloud causes a bias in its 3.7 μm reflectivity. This effect might have to be accounted for in the retrieval techniques to avoid the potential error in the retrieval of the cloud effective radius by TOVS.

USE OF AVHRR DATA IN HIRS CLOUD-CLEARING FOR SEMITRANSPARENT CLOUDS

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A bi-spectral method based on the nonlinear relationship between the AVHRR channel 4 and 5 radiances was applied to retrieve the mean cloud emissivity, cloud-top temperature, droplet size and fractional cloud cover for HIRS spots covered with semi-transparent single-layered clouds. The cloud emissivities for the HIRS channels were then determined using look-up tables built by a discrete-ordinate radiative transfer model for both water and ice particles and for a series of effective radii and cloud geometrical thicknesses. From the retrieved cloud parameters and atmospheric profiles taken from coincident ECMWF analysis, synthetic cloudy radiances were computed by the ITPP fast forward model and compared with real HIRS measurements. The synthetic radiances proved to be more accurate than those derived from AVHRR cloud parameters retrieved by a dynamic threshold method. Similar improvement could be observed in the quality of the ITPP vertical temperature profiles derived using the two kinds of AVHRR information.

COMBINED SATELLITE AND GROUND BASED ATMOSPHERIC WATER VAPOUR MEASUREMENTS

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Water vapour is an important source of heat driving circulation and acts to modify atmospheric radiative properties through direct absorption of infra-red radiation and by the information of clouds. This problem has been studied theoretically and experimentally using both ground-based systems and satellites. Simultaneous water vapour and temperature measurements from ground-based systems and satellites have been recently performed in Napoli and Potenza. Two lidar systems, developed in a co-operative project between IMAAA, University of Napoli and University in Potenza, provide continuous nighttime water vapour and temperature profile measurements with high vertical resolution (300 m). Water vapour lidar measurements are based on the Raman technique. The retrieval of temperature profiles is based on the Rayleigh-Raman technique. Total water vapour content has been measured during daytime by radiometric techniques using a double split window method. The retrieval of the water vapour content is also obtained using HIRS and AVHRR data. HIRS channels allow us to obtain temperature profiles, too. Measurements of water vapour and temperature profiles were simultaneously performed using radiosondes. Preliminary analysis of the intercomparison results will be presented.

AN ADAPTIVE STRATEGY FOR CLOUD FILTERING IN HIRS/2 CHANNELS

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Measured HIRS/2 infra-red radiances exhibit very different field dynamics as a consequence of spatial variability of atmosphere and earth surface spectral properties related in particular to cloud distribution and land orography. Cloud filtering for HIRS/2 channels requires different approaches depending on what (i.e. high or low) channels are considered and on the involved area (i.e. land or sea). In this paper we propose an adaptive filtering strategy in order to reduce error on clear radiances estimation in cloudy locations. Synthetic brightness temperatures computed from ECMWF operational analyses have been used for HIRS/2 channels 4, 7 and 13. Measured HIRS/2 radiances, together with collocated AVHRR data, have been used to analyze HIRS/2 channel 8. Cloud filtering has been performed with varying interpolation radius, and restored fields compared with the available reference fields for several satellite passes. Completely restored fields with r.m.s. less than 0.3 K have been obtained in channel 4 interpolating at large range. Quite half of the scene has been restored in channels 7 and 13 with r.m.s. still less than 1K. In channel 8, interpolation up to 300 km around each cloudy FOV, produced an r.m.s. smaller than 1K over the sea and not greater than 1.5K over the land. Operational cloud masks obtained by processing real data have been used for HIRS/2 channels 4, 7 and 13. Collocated AVHRR data have been analyzed to determine cloud content inside each HIRS/2 fov for channel 8. Results obtained by cloud contaminated radiances, instead of completely clear, are also discussed.

PROCESSING AND RESEARCH OF TOVS DATA IN NATIONAL SATELLITE METEOROLOGY CENTER OF CHINA METEOROLOGICAL ADMINISTRATION

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The National Satellite Meteorology Centre (NSMC) has been processing TOVS data in real time for operational use since 1983. Now the improved simultaneous physical retrieval method (ISPRM) is running in parallel with the multi-linear statistical regression method (SRM). Comparisons between them and case impact study are made.

Selection of satellite instrument channels for atmospheric soundings is discussed. Simulated numerical computation indicates that we can probably obtain an equivalent channel for which the peak height of its weighting function is higher than that of channel 1 of HIRS/2 and may get more atmospheric information from the upper stratosphere without any additional physical instrument.

Also, the status of the RTTOV model at NSMC is given in this paper.

PLANNING OF ATOVS AT THE UK MET. OFFICE

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The project to exploit ATOVS data is broken down into 3 parts:

- reception of global data from NOAA/NESDIS,
- reception of local data and
- the retrieval system.

All three areas have large elements of international collaboration. The plans and progress will be presented. The retrieval system will be based on extension to the existing Global Sounding System (GLOSS). Its present status and performance will be described together with the staged development of the system to exploit ATOVS data.

TOVS-DERIVED ESTIMATES OF HORIZONTAL ENERGY FLUXES INTO AND WITHIN THE ARCTIC BASIN

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Polar regions play an essential role in the global climate system as they represent the cold extreme of the global heat engine. The energy imbalance between the tropics and high latitudes is continually compensated by the poleward advection of energy by the atmosphere and ocean. Analyses of rawinsonde data from Arctic land stations have quantified this flux across imaginary walls at latitude circles south of 70°N, but little is known of the spatial or temporal variation of the flux or the flux divergence within the basin itself. In this study the lateral advection of sensible heat and water vapour across the entire Arctic is derived from TOVS retrievals and surface pressure analyses. Warm and cold advection associated with synoptic weather systems is clearly apparent in fields of computed fluxes, and longitudinal variations highlight the major conduits of energy flowing into the Arctic basin from lower latitudes. A new parameter called the "advective activity" identifies which regions contribute most to equalizing the imbalance of energy between low and high latitudes. The advectively active regions appear to have large interannual differences and thus may be particularly sensitive to changes in the global circulation. Preliminary results show consistent heating in the East Siberian Sea, while the Barents and Laptev Seas are the most advectively active.

TOVS-DERIVED ESTIMATES OF THE DOWNWELLING LONGWAVE RADIATION FLUX IN THE ARCTIC

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One of the most important and least understood components of the polar surface energy budget is the downwelling flux of longwave radiation (DFL). A new method is presented to estimate DFL from retrievals and brightness temperatures from TOVS. Temperature profiles, humidity estimates and cloud cover are retrieved using the Improved Initialization Inversion ("3I") algorithm. This information is combined with brightness temperature differences from several pairs of infra-red and near infra-red TOVS channels, which are used to estimate cloud phase and base height. Longwave

of CBS. Each meeting made statements, endorsed recommendations and agreed upon matters considered important to the Study Conference. An overview of the statements, recommendations and agreements will be presented to inform ITSC-VIII of these latest developments.

HIRS-HYBRID - A HIGH RESOLUTION SOUNDER FOR THE NEAR TERM

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The accuracy of global weather forecasts is limited by the vertical resolution and accuracy of the HIRS. Higher spectral resolution sounders with 1000-1500 channels are under development but are unlikely to be operational until 2007. A concept has been developed by ITT and the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison that can provide higher resolution sounding much earlier. This concept involves adding a longwave Fourier Transform Spectrometer to the current HIRS/3. This can be done in a low-risk and low-cost way that will provide advanced sounding data without impacting the existing weather system capabilities.

INSTRUMENTS AND DATA ANALYSIS ALGORITHM OF IMG

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Ministry of International Trade and Industry (MITI) has been developing a satellite-borne FTIR: IMG (Interferometric Monitor for Greenhouse Gases). The IMG will be installed on the earth observing satellite ADEOS, which is scheduled to be launched February 1996. The mission objective of the IMG is global mapping of temperature, humidity and density of greenhouse gases: CH_4, N_2O, CO_2, O_3, CO, HNO_3. IMG will take interferograms every 13 seconds with the spectroscopic range and resolution of 700-3000 cm^{-1} and 0.05 cm^{-1} respectively. In this presentation, the features of IMG, the instruments, radiometric capabilities, stabilities and so on are summarized. The retrieval algorithms for IMG data are also described, especially Level 2 data, i.e. processed temperatures and densities.

AN ALGORITHM TO SELECT CHANNEL FOR INDIRECT MEASUREMENTS

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Indirect measurement methods are widely used in geophysical observation, and medical and material inspection. When using "the inverse analysis method" for measurement, an increase in the number of channels results in higher accuracy. However, this increase in accuracy is accompanied by an increase in cost for the computational resources to analyze the data. Therefore, it is important to develop an algorithm which can operate on a minimum number of channels while attaining the required degree of accuracy. An algorithm has been developed that is used for channel selection based on specific quality criteria. This algorithm has been applied to IMG (Interferometric Monitor for Greenhouse Gases), and the analysis of data from IMG has been simulated. The quality of results obtained from the selected channel set are almost equivalent to the results obtained from all the channels.

EVALUATION OF TOTAL OZONE RETRIEVAL FROM NOAA-TOVS DATA BY MEANS OF NEURAL NETWORK TECHNIQUES

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The approach of using neural networks for ozone retrieval from TOVS data presented at ITSC-VII will be evaluated. A case study is carried out for the period of July and August 1993. The data sets cover Europe, North Africa and parts of the Atlantic Ocean. The TOVS data are classified in day/night and cloud free/cloudy pixels and collocated with ground measurements of the total ozone content. The collocated pixels are divided into a training and test data set. The first one is used for training of the neural network and the second one for testing if the retrieval accuracy of the neural network is comparable to the learning data set. The absolute mean error of the test data set is about 10 Dobson Units. For "cloud free day pixels" it is 8.5 Dobson Units and for cloudy pixels it is 10 Dobson Units. For night pixels the absolute mean error is 12 Dobson Unit.

The study shows that it is possible to retrieve the total ozone content of the atmosphere with an accuracy of better than 5% for different weather conditions. The advantage of the TOVS data compared with other satellite instruments for ozone retrieval (TOMS, SBUV, GOME) using the solar spectrum is that good accuracy of the ozone data can also be achieved during night and that long-term TOVS data are available for the last 15 years.

MULTI-LEVEL CLOUD PARAMETER ESTIMATION USING SMOOTHED DENSITY OF AVHRR DATA AND HIRS DATA

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(visiting from Central Weather Bureau, Taiwan, Republic of China)

NOAA's Forecast Systems Laboratory (FSL) has been developing an assimilation method of TOVS raw radiance data to real-time mesoscale numerical weather prediction model. At this stage, we focus on the estimation of multi-level cloud parameters (fractional cloud amount and cloud top heights) by using 3-hour forecast profiles, HIRS channel 7 and 8 radiance data, and AVHRR channel 4 counts collocated on HIRS fields of view. Examples are shown to discuss the validity of method.

PREPARATIONS FOR ATOVS DATA PROCESSING IN EUROPE

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Answering a requirement from the user community, EUMETSAT is coordinating the development of a software package to process locally received ATOVS and AVHRR data from the HRPT data stream of the NOAA-KLM spacecraft. The package is intended to fulfil the INGEST process, i.e. the decommutation, Earth location and calibration of the data, as well as the pre-processing. The latter module is intended to fulfil the analysis of the data for effects which deem them unsuitable for further processing (i.e. contamination by precipitation). A development group of European organisations has been formed and a design has been decided, which is presented in the paper. The development responsibilities and the time schedule are presented. The first frame package is expected to be

finalised at the end of 1995, to be ready for testing.

EUMETSAT FUTURE PLANS

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EUMETSAT plans for future satellite systems are presented. The existing METEOSAT Operational Programme (MOP) and the Meteosat Transition Programme (MTP), to provide geostationary data coverage with the same type of space craft and instrument as METEOSAT-6, are outlined. The characteristics of the METEOSAT Second Generation Programme (MSG) are presented. The EUMETSAT contribution to the Sounding Community will be provided by the EUMETSAT Polar System (EPS). The EPS comprises both the space system and the associated ground system. The assumption is the development of the METOP (METeorological OPerational) platform with a first launch planned in 2001. The core meteorological payload will be the High-resolution Infrared Radiation Sounder (HIRS), the Advanced Microwave Sounding Unit-A (AMSU-A), both provided by NOAA, the Microwave Humidity Sounder (MHS), provided by EUMETSAT, the Advanced Very High Resolution Radiometer (AVHRR), provided by NOAA and the Infra-red Atmospheric Sounding Interferometer (IASI), provided by CNES/ASI. In addition ESA will provide an Advanced Scatterometer (ASCAT), a Multi-frequency Imaging Microwave Radiometer (MIMR) and an Ozone Monitoring Instrument (OMI). Optional payload components are the Scanner for Radiation Budget (ScaRaB), the Space Environment Monitor (SEM) and the Search and Rescue (S&R) system. The ground segment has been studied in Phase A in 1994. The user requirements document is under revision. They define the operational mission requirements and the user requirements.

TOVS PROCESSING IN A PC ENVIRONMENT

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In recent years the processing of satellite data has been proven to represent a significant contribution in the estimation of the three dimensional thermodynamic state of the atmosphere. Processing however has, for performance reasons, always been confined at least to a workstation environment, the constraints being both the processing power as well as the storage. By the progress in technology, treating TOVS data is now in the possibilities of personal computer environments. The paper shows with the example of the "3I" package the use of TOVS data on a PC and shows the validation with VAX and IBM derived results.

MONITORING OF OPERATIONAL TOVS RETRIEVED THICKNESS FIELDS OVER EUROPE

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Satellite-derived data have proven their value in operational meteorology for short-range forecasting and nowcasting. Especially by using direct readout data, information on the three dimensional thermal state of the atmosphere can be obtained a considerable time before the cut-off time of the numerical analyses. Thus valuable information can be obtained complementary to the available "conventional"

synoptic and numerical data.

This study shows the continuous use of "3I-2" derived thickness fields over Europe, which are derived from direct readout HRPT data received at the German Military Geophysical Office (GMGO) at Traben-Trarbach, Germany. The "3I-2" software has been installed for operational use in summer 1992 and since then was used continuously on the data of all received direct readout data. The thicknesses 500/1000 hPa are compared to the results of the nearest numerical analysis. Statistical validation was performed. The results shown are based on several weeks of systematic comparison and extend an earlier-started monitoring. The results show a good agreement in the thickness fields. This encourages the more intense use of these data in operations.

SSM/T-2 DATA ANALYSES

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The ATOVS instrumentation on board the NOAA-KLM satellite series will include a humidity sounder in the microwave spectral region, the Advanced Microwave Sounding Unit part B (AMSU-B). This instrument will provide information on the humidity of the atmosphere at 89 GHz (channel 1), 150 GHz (channel 2) and 183±7 GHz (channel 5), 183±3 GHz (channel 4) and 183±1 GHz (channel 3), all frequencies in the water vapour absorption region of the microwave spectrum. To conduct an appropriate pre-processing of these data their contamination by atmospheric and surface effects must be known. Essential is, for example, the contamination by rain as well as the influence of cloud particles. Furthermore the state of the surface is essential for the surface and near surface channels in the 90 and 150 GHz bands. The dependencies on scan angle and geographic region have to be known.

Since model data alone cannot show all aspects in full detail on one hand, and on the other hand the real ATOVS data are not available before the (projected) launch of NOAA-K in 1996, other similar data have to be taken to give an idea of the processes discussed above. One instrument in orbit, which has channels nearly identical to AMSU-B in terms of frequency, is the Special Sensor Microwave/T-2 on the Defense Meteorological Satellite Program (DMSP) spacecraft F-11, which has been operational since November 1991.

To assess in a qualitative way the information contents of microwave humidity data, the SSM/T-2 data which are available at the Satellite Meteorology Branch of the Geophysics Directorate of the Phillips Laboratory (PL/GPAS) were used to assess their information contents in a qualitative way. These data were gathered during the calibration/validation experiments which were conducted in 1992 at the west coast and east coast of the USA. The purpose of this study was to gain insight into the range of the microwave data for certain situations. There was no intention and possibility to derive algorithms yet.

SIMULATIONS OF THE ATOVS INSTRUMENT CHANNELS BY RADIATIVE TRANSFER MODELING ON SYNOPTIC SITUATIONS OVER EUROPE

K D Klaes
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With the next generation NOAA-K satellite of the polar orbiting NOAA/TIROS-N series, planned to be launched in 1996, the instrument package for sounding will be considerably improved. The current

TOVS instrument package, consisting of the 20-channel infrared HIRS/2, the 4-channel MSU and the 3-channel SSU will be replaced by the Advanced TOVS Instruments. The latter will include the HIRS/3, slightly modified compared to HIRS/2, and the Advanced Microwave Sounding Unit (AMSU), which consists of a 15 channel thermal sounding instrument (AMSU-A) and a 5 channel water vapour sounder (AMSU-B). The AMSU instruments will replace MSU and SSU.

In preparation for the exploitation of these instrument, data radiative transfer studies with the AFGL-developed RADTRAN model were conducted on synoptic data of temperature and humidity over Europe. The synoptic data originate from the European Centre for Medium Range Weather Forecasting (ECMWF). A validation of the radiative transfer results was performed by simulating MSU results and comparing them to actually received satellite data. The simulation study includes clouds and rain contamination of the atmospheric data. The cloud cover was simulated by a relative humidity threshold model. Two synoptic situations in summer will be considered, covering both clear and cloudy parts, including convective clouds. The results of these study are intended to contribute to the development of the pre-processor (i.e. the cloud detection, rain detection etc.) part of a software package to exploit locally received HRPT direct readout data.

PREPARATIONS FOR ATOVS AT NOAA/NESDIS

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The launch of NOAA-K in 1996 brings about the first major changes in TOVS instrumentation since the launch of TIROS-N in 1978. The AMSU-A and AMSU-B will replace the MSU and the SSU. There will be channel changes in the AVHRR and the HIRS instruments. The changes in instrumentation will necessitate changes in ground processing and the retrieval algorithms. This paper will outline these changes that are ongoing and planned at NOAA/NESDIS.

CHARACTERISTICS OF SSM/T-2 ANTENNA TEMPERATURES

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The SSM/T-2 is an instrument with spectral characteristics similar to those of the AMSU-B. The SSM/T-2 has been flying for three years on two DMSP spacecraft. The four leftmost fields of view of the F-11 instrument, which was the first launched, were unusable due to a sunscreen which obscured the Earth view on that side of the spacecraft. This instrument also had scene-dependent biases in the antenna temperatures. These varied with spot number with a maximum change between positions 15 and 16 of about 1K in the 183±3 GHz channel. These beam-dependent biases are not apparent with the recently launched instrument on DMSP F12 which does not have the sunscreen. This paper will present an intercomparison between these two SSM/T-2 instruments.

A STUDY OF THE USE OF AMSU FOR THE DETECTION OF PRECIPITATION OVER ANTARCTICA

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A knowledge of the amount of precipitation over the Antarctic Continent is very important for the study of the mass balance of the Antarctic ice sheets and the effect that climate change may have on the ice sheets. The knowledge of the precipitation over Antarctica has up till now been based largely on measurements made using snow pits or stake arrays but these measure both the precipitation and blowing or drifting snow. AMSU, with its channels for which weighting functions peak in the atmosphere, offers the possibility of retrieving precipitation amounts. This study uses an atmospheric transmission model (Kummerow 1994) coupled with a transmission model for the land ice to investigate the affect of realistic clouds and precipitation on the upwelling microwave radiation.
Reference: Kummerow and Giglio 1994. A passive microwave technique for estimating rainfall and vertical structure information from space. Part I: algorithm description. J Appl Meteorol, **33**, 3034.

TOVS SOUNDING PRODUCTS AT CMS

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We are developing at CMS software having operational specifications for TOVS sounding retrievals. The TOVS observations are collocated with AVHRR measurements. The imager is used to determine the cloud cover, the surface temperature (for partially cloud cover ellipses) and the cloud top temperature. The initial profile selection is made by a search in a library of collocated radiances and radiosondes. Two different data sets are available: the TIGR atmospheric profiles and their corresponding synthetic RTTOV radiances, or a rotating file of TOVS observations matched with radiosonde profiles (selected in the CMS acquisition zone). The retrieval operator is computed by using the RTTOV adjoint. The direct model correcting biases and the background error covariance matrix are periodically generated off-line from statistics of initial profile-radiosonde differences. A validation process has been implemented. Statistics of retrieval-radiosonde are computed on a monthly basis for all the orbits acquired at CMS. We will present our first results.

TYPHOON MONITORING AND TRAJECTORY PREDICTION IN THE PHILIPPINE REGION USING A PC-BASED NOAA DIRECT READOUT SYSTEM AND AN INTEGRATED DATA BASE

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In 1991 a NOAA S-band reception station and integrated data processing system were commissioned at the Philippines Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) in Manila. During 1991, 1992 and 1993, these provided support to weather forecasting operations. In particular, they were used for monitoring the intensity and positions of typhoons during the 1991, 1992 and 1993 typhoon seasons. This paper briefly details the personal computer-based ground station. It also describes the local TOVS sounding, AVHRR sea surface temperature processing and

deep layer mean forecast systems, developed for the National Forecast Centre (NFC) of PAGASA for estimating cyclone intensity and trace. The paper shows that the TOVS data retrieval system, when analyzing cyclone data in the Philippines region, has delineated upper tropospheric temperature anomaly fields which can be related to analyzed storm intensity, central pressure and maximum wind speed. The ground truth data used in this study were, generally, operational estimates of storm intensity but have still allowed useful computation of the coefficients relating temperature anomaly to storm intensity and have resulted in calibration curves that may be used for operational purposes. The deep layer mean forecast system described in the paper is used operationally.

OPERATIONAL ASSIMILATION OF TOVS RADIANCE DATA IN THE AUSTRALIAN BUREAU OF METEOROLOGY

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The physically-based operational TOVS retrieval system currently used to generate meteorological fields from locally received TOVS raw radiances in the Australian region is described in this paper. These meteorological fields are used in the local Regional Assimilation and Prognosis Scheme (RASP) to produce operational forecasts across the Australian region. The paper covers the cloud height and ozone determination techniques employed in the system and new radiance and transmittance tuning methodologies. The impact of these raw TOVS radiances on operational forecasts in the Australian region is discussed, noting that the impacts that have been recorded against background fields which contain low resolution NESDIS TOVS data and local cloud drift winds. The synoptic application of these data, including their use for detecting severe weather and for estimating tropical cyclone intensity is also discussed. In particular, the generation of calibration curves, providing intensity of tropical cyclones versus the upper tropospheric temperature anomaly is reported. In addition, the general characteristics of the new ITPP-5 package are noted and some comparisons of the retrievals from the current operational scheme, which is related to ITPP-4, with retrievals from the new ITPP-5, which incorporates AVHRR data, are also provided. Some examples of the impact of these data from this new system on numerical weather prediction in the Australian region is also noted.

RETRIEVAL OF ATMOSPHERIC PROFILE AND CLOUD PARAMETERS FROM TOVS OBSERVATIONS

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A successive linearized Radiative Transfer Equation (RTE) is used for the retrieval of atmospheric and moisture profiles together with cloud amounts. The atmospheric temperature, water vapour, surface skin temperature and cloud amount component weighting functions are specified analytically, which is more efficient for calculation than a numerical perturbation method. A Newtonian iteration procedure is applied to achieve a nonlinear solution for the atmospheric profile and cloud amounts from TIROS-N Operational Vertical Sounder (TOVS) observations. By use of TOVS Initial Guess Retrieval (TIGR) basis functions, the number of atmospheric variables for retrieval is significantly reduced. Nine (3 by 3) adjacent fov observations are used to retrieve one atmospheric temperature and water vapour profile, as well as the surface skin temperatures and cloud amounts for each fov. Thus, the problem is well-conditioned. This new retrieval procedure has been made part of the

International TOVS Processing Package (ITPP). Results from applying the new method are presented to illustrate its superiority over prior ITPP retrieval schemes.

ARE 1DVAR TOVS RETRIEVALS USEFUL FOR THE SOUTHERN LOWER STRATOSPHERE ?

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This study is concerned with the accuracy of temperature retrievals from the TOVS instruments, with particular emphasis on the high latitude Southern Hemisphere stratosphere. It is split into three parts. The first presents baseline calculations of the biases and r.m.s. errors in NESDIS retrievals and physical (1DVAR) retrievals as currently implemented at the Bureau of Meteorology in Australia. These highlight the inadequacy of the 1DVAR approach for our region of interest. The second part describes two partially successful attempts to improve the 1DVAR retrievals using climatological data and collocated temperature profiles from the Upper Atmosphere Research Satellite (UARS). The third part delves more deeply into the reasons why the 1DVAR approach is so inadequate in this region, using some diagnostics which occur naturally in the variational methodology used in the 1DVAR algorithm. It appears that one reason for the poor performance lies in the existence of error modes in the analysis-retrieval cycle which grow to finite amplitude in data-sparse regions.

CLOUD CLEARING AT NESDIS

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The NESDIS operational and RTOVS cloud clearing approaches have been examined in the past year as part of the preparation for RTOVS and ATOVS. As a result of this examination, several new test have been evaluated. These include use of the AVHRR in cloud clearing and alternatives to the common approach based on passing or failing various global limits. Some tests involve nonlinear combinations of channels. For example, test involving ratios of the difference of selected channels are particularly interesting. For the AVHRR, this test clearly identifies the multiple cloud conditions that can interfere with cloud clearing. Cloud cleared radiances from the new procedures are compared with those produced by current NESDIS procedures. Results are compared with cloud images. In addition, statistics of cleared radiances as a function of local zenith angle, solar zenith angle, and other significant parameters are generated. The new tests will be described and results will be shown. The new tests will be incorporated into the RTOVS and ATOVS processing algorithms.

DEVELOPMENT OF A NEW, HIGHLY ACCURATE FAST TRANSMITTANCE ALGORITHM FOR VARIABLE GASES

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A fast and accurate transmittance calculation procedure, Optical Path TRANsmittance (OPTRAN), is

described. The main difference between this method and other fast transmittance algorithms is that regression takes place on surfaces of equal absorber amount instead of pressure. Angular dependence is implicitly incorporated into the absorber profile. The absorption coefficient is the predictand. Since transmittance is a function of the absorption coefficient and absorber amount, uncertainties due to the pressure dependence are eliminated. This algorithm is demonstrated with channels from the SSM/T-2 instrument.

VARIATIONAL ANALYSIS OF HUMIDITY INFORMATION FROM TOVS RADIANCES AT ECMWF

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An accurate specification of the hydrological cycle is considered extremely important in operational numerical weather prediction (NWP). Through its high temporal and spatial resolution, TOVS data represents a major source of observational information about the tropospheric humidity field, but difficulties have been experienced in successfully exploiting this information in the form of traditional retrieved products. At ECMWF the TOVS radiances are assimilated into the model using a process known as variational analysis. These schemes analyze the TOVS data to produce simultaneous adjustments to the model temperature and humidity field and represent a direct assimilation of the radiance information. Results are presented that demonstrate a significant improvement in the ability of the analysis to represent accurately humidity structure, and the corresponding impact on the short-range forecasting of clouds and precipitation is discussed.

FOUR YEARS OF GLOBAL CIRRUS CLOUD STATISTICS USING HIRS

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Global upper tropospheric transmissive cirrus cloud covers have been charted for the past six years using NOAA polar orbiting HIRS multi-spectral infra-red data. Cloud occurrence, height and effective emissivity are determined with the CO_2 slicing technique on the six years of data (June 1989 - May 1995). There is evidence of a general increase of transmissive high clouds, roughly 1% per year. Comparisons with cloud studies conducted by the International Satellite Cloud Climatology Project reveal similar trends, but the amount of cirrus detected is handicapped by the absence of a semi-transparency correction.

NOAA'S POLAR SATELLITE PROGRAMMES FOR THE 1990S AND BEYOND

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The next significant instrument changes in the POES will occur on the NOAA-KLMN 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 μm at night and 1.6 μm at day (for snow mapping). Even more significant changes are envisioned in the era of a converged NOAA and DoD (Department of Defense) series of afternoon polar satellites starting about 2004. (EUMETSAT is assuming the responsibility for the morning polar satellites in 2000). Plans for an upgraded AVHRR with 7 channels (0.62, 0.87, 1.6, 3.7, 8.6, 10.8 and 12.0 μm) at 12-bit resolution will be reshaped to include DoD desires for more spectral bands (about 15 visible and infra-red). A high spectral resolution sounder (either interferometer or spectrometer) will replace the High-resolution Infra-red Radiation Sounder (HIRS). Technology infusion from the NASA Earth Observing System is expected; MODIS (Moderate resolution Imaging Spectrometer) and AIRS (Atmospheric InfraRed Sounder) instrument options and modifications will be considered. 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.

THE INCORPORATION OF AVHRR DATA WITHIN ITPP5

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The newest version of the International TOVS Processing Package (ITPP5) makes use of the high resolution data available from AVHRR to make better decisions about the possible extent of cloud contamination, and to aid the process of retrieving temperature and moisture profiles in partly cloudy conditions. A pre-processor to the retrieval step collocates AVHRR data to the HIRS footprints using the Aoki method. Versions of this pre-processor exist for both the HRPT (~1 km) and GAC (~5 km) forms of AVHRR. A bi-spectral spatial coherence analysis is done for the AVHRR data associated with each HIRS fov, resulting in statistics for any coherent warm signal, coherent cold signal, and all the data collectively. Statistics are provided for all 5 AVHRR channels, as well as the brightness temperature difference channels 3 and 4. This information is used in the subsequent retrieval step primarily for the purpose of classifying the HIRS fov as clear, cloudy or partly cloudy. Further analysis is done within the pre-processor to provide enough information for the retrieval step to utilize the so-called N* method for clear-correcting the HIRS radiances. Regression between AVHRR channels 3 and 4 is done for each of 8 pairs of HIRS fovs centred around a given HIRS fov, and statistics describing those regressions are made available for the retrieval step so that the feasibility of N* at that location can be addressed.

A COMPREHENSIVE EVALUATION OF ITPP5

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The fifth version of the International TOVS Processing Package incorporates the additional science proposed at ITSC-VII. AVHRR data are now used for cloud-clearing and to produce clear-column radiances. The latest ECMWF fast transmittance algorithms have been incorporated into the radiative transfer calculations. A subset of the TIGR database is now available for use in the package's various regression relationships and, in particular, as a background when a regression estimate of the first

guess is required. Further changes to the retrieval method have occurred in the last year. Temperature and water vapour mixing ratio weighting functions are derived via radiative transfer equation (RTE) linearization. The profiles of temperature and mixing ratio are represented by their empirical orthogonal functions from the TIGR database, and water vapour is now expressed as the logarithm of mixing ratio in those calculations. The least-squares RTE solution has been replaced by a Newtonian iteration method. Finally, the classical clear-correction techniques have been abandoned in favour of a more direct physical retrieval method in which the cloud parameters are obtained simultaneously along with the profiles of atmospheric temperature and humidity.

VARIATIONAL RETRIEVAL OF HUMIDITY, WIND SPEED AND CLOUD LIQUID WATER PATH WITH SSM/I

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SSM/I is a 7-channel microwave radiometer which measures the radiation at the top of the atmosphere at 19.35, 22.235, 37, and 85.5 GHz. Until now, atmospheric parameters have been retrieved from SSM/I data using regression algorithms or using simple physical parametrization of the radiative transfer equation. These methods present several drawbacks for data assimilation into NWP models. The advantages of the variational approach for TOVS data assimilation have been demonstrated at ECMWF. A similar approach has been taken to retrieve the humidity profile, cloud water content and the surface marine wind speed using SSM/I data and ECMWF meteorological fields. The theory and the results are presented in this paper. The implications for preparations for AMSU data processing will be discussed.

IMPACT OF TOVS-3I RETRIEVALS ON A LIMITED-AREA MODEL FORECAST: 2-4 FEBRUARY 1994 DEVELOPMENT OVER THE NORTH ATLANTIC

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Two wave-like disturbances in the North Atlantic polar front have been found in the weather analyses for 2 February 1994, one of which rapidly developed into a deep storm depression, whereas the other virtually disappeared from the analyses in a short period of time. This case has been the subject of an impact study of 3I-retrievals in the KNMI's operational HIRLAM (High Resolution Limited-Area Model) and will be further studied in the framework of a cooperative development project with European Community support. Results of the first HIRLAM impact experiments are presented. From the results conclusions are drawn for further development work on the data assimilation scheme used.

THE AUSTRALIAN CONTINENTAL INTEGRATED GROUND SITE NETWORK - CIGSN

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Global climate models (GCMs) predict an increase in global mean surface temperature of between 2-5°C due to a doubling of CO_2. This increase in temperature is equivalent to an increase in the global net surface radiation budget (SRB) of between 4-10 Wm^2. The net longwave flux at the surface

cannot be inferred from top of the atmosphere values because the downward longwave flux at the surface is largely decoupled from satellite observations. Therefore, there is a need to complement satellite observations with high precision measurements of these fluxes directly at the surface. Currently there are only limited observations of the SRB, and most of these do not have the necessary precision to be able to discern a change in the net flux of 10 Wm^2. A programme of research to retrieve surface radiative fluxes (shortwave and longwave) from satellite observations utilising new or improved models, and complemented by a new set of high quality surface-based observations at several locations has been started.

The continental surface radiation network has the goal of making high quality surface radiation measurements at 4-6 well-chosen sites throughout Australia, over a long-term (several years) period. A station at Hay in New South Wales began operations in August 1992, and the CSIRO and the Australian Bureau of Meteorology are starting a collaborative project to set up instrumentation at a site near Alice Springs. The high quality surface observations from these sites will be used to study important surface processes and will also provide a valuable long-term data set for validating measurements from space-borne instruments. A description of the planned network will be given together with some results illustrating the range of applications and uses of these new data.

DEPARTURES BETWEEN SATELLITE DERIVED SOUNDING PRODUCTS, RADIOSONDES AND WEATHER FORECASTS: PRESENT AND FUTURE

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The precision and accuracy attributed to satellite sounding products are shown to be dependent on the evaluation strategy. For example, accuracy statistics based on ensembles of collocations which are anchored to radiosonde locations do not address performance with respect to prevailing meteorological conditions. Similar arguments apply concerning the use of conventional skill scores to determine the impact on forecast models. A good procedure, and one adopted as an integral part of the routine evaluation of NESDIS sounding products, is the analysis of departure patterns between the satellite soundings and forecast models over global tropospheric layers. These are presented, including performance in cases of cyclogenesis which exhibit tropopause level thermal anomalies. Departure patterns based on two NMC forecasts, one of which is relatively devoid of satellite observations with respect to the other, are compared as a measure of forecast model impact. The departure patterns are shown to be a reliable indicator of thermal advection patterns which are consistent for the current TOVS and DMSP satellite sounding products.

Results demonstrating the correlation between the departure patterns and the sounder resolution are also shown. These are used to support a hypothesis that as the sounder resolution increases, the impact of satellite products on forecast models becomes independent of whether the satellite data is assimilated as radiances, interactive soundings (using a forecast as the first guess), or non-interactive soundings (using forecast independent first guess information). The hypothesis assumes that the radiances are satisfied, that the radiative transfer models and radiance bias corrections applied are the same, and that the first guess is reasonable for all systems. These are realistic constraints that are currently within the specifications of future sounding systems planned by NESDIS and already nearly satisfied by the current systems operating. The hypothesis is pertinent given the advanced, high-resolution sounders (AMSU, ITS, etc.) planned for future operational deployment by NOAA (and EUMETSAT). Closing arguments propose that a critical missing ingredient for realizing optimal accuracy in combined radiosonde, forecast model and satellite product systems, current and future, is a radiosonde network which provides standardized, satellite-coincident observations.

OPERATIONAL STATUS AND OUTLOOK FOR NESDIS POLAR ORBITING SATELLITE SOUNDING SYSTEMS

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Operational satellite soundings from the TIROS Operational Vertical Sounder (TOVS) and the Special Sensor Microwave / Temperature (SSM/T) sounders on board NOAA and DMSP polar orbiting satellites, respectively, are produced and distributed by NOAA/NESDIS. The following report addresses upgrades over the past 18 months and the current status of the scientific algorithms for each system and presents results. Results are based on comparisons of satellite derived products collocated with radiosonde and numerical weather prediction model data. The report concludes with the outlook for NESDIS operational sounding products in the near future. Scientific algorithm development is currently under way in preparation for the Advanced Microwave Sounding Unit (AMSU) A and B modules tentatively scheduled for deployment on NOAA polar orbiting satellites in 1996. Progress concerning the proposed first step in this process, namely the operational implementation of the Revised-TOVS (RTOVS) system, is addressed. Concurrently, algorithm development is under way to generate high resolution moisture products from the SSM/T2 moisture sounder currently on board DMSP satellites. A summary of these improved algorithms and the products planned for distribution and archive by NESDIS is provided.

COMPARISON OF 1DVAR RETRIEVALS FROM LIMB CORRECTED AND NON-LIMB CORRECTED RADIANCES - PRELIMINARY RESULTS

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The 1DVAR package, described by Eyre et al (1993), may be used to perform TOVS retrievals using either limb-corrected or non-limb-corrected soundings. Since the limb-correction procedure is statistical, it may introduce errors that can be avoided by using non-limb-corrected radiances. We have begun a study of the possible improvements to 1DVAR retrievals that may result from taking such a route. So far only a comparison of tuning statistics for the two approaches has been completed. This study suggests that any improvements to retrievals from avoiding the limb correction step are likely to be small.

THE IMPACT OF 1DVAR TOVS RETRIEVALS COMPARED TO NESDIS RETRIEVALS ON 5 DAY GLOBAL FORECASTS

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The Australian Bureau of Meteorology's Global Assimilation and Prediction Model (GASP) is used operationally to provide global numerical weather prognoses up to 7 days ahead. The retrieved TOVS temperature and moisture profiles (250 km resolution) distributed over the GTS by NOAA/NESDIS form part of the observational data base for the model. Experiments have been carried out replacing

the NOAA/NESDIS retrievals with retrievals from global radiance data using the 1DVAR scheme as described in Eyre et al. (1993) to assess the comparative impact of the latter. Difficulties have been encountered in performing retrievals over Antarctica. These may be due to factors including the emissivity correction of the MSU channels and errors in the forward calculation, including extrapolation above the top model level (10 hPa). Five-day prognoses were conducted at daily intervals for three periods of about one month each, running two systems in parallel: one using the NOAA/NESDIS retrievals and the other the 1DVAR retrievals. Forecast intercomparisons show some positive features in the analyses and forecasts using the 1DVAR retrievals in comparison with those using the NESDIS retrievals. Overall, however, the impact of replacing NESDIS with 1DVAR retrievals is small. The improvement from the use of 1DVAR is most significant in the Southern Hemisphere troposphere.

ON THE BEHAVIOUR OF THE ECMWF PROGNOSTIC CLOUD SCHEME WHEN COMPARED TO RAW TOVS RADIANCES

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Clouds exert a strong influence on the distribution of heating and cooling at the Earth's surface and within the atmosphere. This has long been recognized in climate studies and in the development of GCMs, much less in numerical weather prediction until the extension of useful forecast length and the diversification in the products range has given new impulse to the development of more accurate parametrizations of diabatic processes. Since the signature of clouds on upwelling atmospheric radiance is quite marked at visible and infra-red wavelengths, inadequacies in model representations of three-dimensional structure of cloud cover and cloud liquid water are easily identified.

When the new ECMWF prognostic cloud scheme becomes operational, the ECMWF model will acquire some capability to assimilate cloud-related information. Raw TOVS radiances are used as a diagnostic tool to evaluate the ability of sequences of short-range forecasts to simulate some of the features in the measured data. The present exercise is therefore quite different from the diagnostics which employ long-term integrations of a model to test its average properties against some independent data set. The paper presents the results of a comparison between a selected set of raw HIRS/2 radiances and simulations using the required model output fields. Estimates of outgoing longwave flux at the top of the atmosphere (OLR) are also obtained from a subset of HIRS/2 radiances. These are compared with OLR computed from the simulated radiances and with the OLR computed by the flux radiation scheme of the forecast model.

RADNET: A NEURAL NETWORK-BASED ESTIMATION OF THE SURFACE RADIATION BUDGET IN THE ARCTIC FROM TOVS HIRS AND MSU BRIGHTNESS TEMPERATURES

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A new method for calculating components of the surface radiation budget in the Arctic from TOVS HIRS and MSU radiances is presented. This method employs a neural network to bypass

computationally intensive inverse and forward radiative transfer calculations required in traditional retrieval algorithms. Results and comparisons with surface observations from two field experiments during 1988 (CEAREX) and 1992 (LEADEX) are presented. The performance of this method is compared with the results from the retrieval method developed by Francis (1994). Advantages and disadvantages of each method are discussed. The potential of this method to integrate information from other sensors such as AVHRR is investigated.

TOVS PATH-P: A NEW TOVS-BASED DATA SET FOR ARCTIC RESEARCH

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A data set of daily atmospheric temperatures, humidity profiles and cloud information has been created using a modified version of the Improved Initialization Inversion algorithm. Modifications include changes in the cloud detection algorithm to account for Arctic conditions and the addition of several parameters useful for ice-ocean modelling experiments (Francis 1994). This data set presents a unique opportunity for the study of north-polar climate processes. The TOVS Path-P data set covers regions northward of 60°N on a polar projection and is formatted using the popular Hierarchical Data Format (HDF) standard. Currently the TOVS Path-P data set is available for 1987 and 1988. Additional years are currently being processed. Access methods and sample applications are presented.

PROCESSING OF MULTI-YEAR SATELLITE DATA WITH THE 3I SYSTEM WITHIN THE FRAME OF THE NOAA/NASA PATHFINDER PROGRAM

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Several international projects to study atmospheric and surface processes like:

- Pathfinder, for which the official charter, as defined by NOAA and NASA, includes the reprocessing of the whole NOAA/TIROS-N satellite observations over the 1979-1993 period, and
- 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,

heavily rely on satellite observations made by NOAAs and DMSPs.

The Atmospheric Radiation Analysis (ARA) group at LMD has gained a long experience - the "3I" (Improved Initialization Inversion) system, first published in 1983 - in the processing of satellite data and in their interpretation in terms of thermodynamic parameters describing the 3D structure of the Earth's system. Within the framework of the NOAA/NASA Pathfinder Programme, the 3I system is being used to produce a long-term, validated and documented data set of global 3D thermodynamic parameters. A 20-month benchmark period of NOAA-10 HIRS and MSU data from April 1987 to November 1988 has been selected. During this benchmark period, particular attention has been paid to assess critically the quality of the 3I products: radiosondes, analyses, other instruments (SSM/I, AVHRR, ERBE, ISCCP) and other Pathfinder approaches (TOVS, SSM/I) have been used for this

multi-product validation campaign. Some modifications have been brought to the current 3I algorithm; they concern the retrieval of water vapour and of the surface temperature, the cloud detection and the determination of the cloud characteristics, and the definition and formatting of the 3I-output parameters.

The purpose of this paper is to:

- report on the processing of several years of such satellite observations at LMD,
- describe the 3I algorithm modifications,
- assess the quality of the various 3I output products.

STATISTICAL EVALUATION OF GROUND- AND SPACE-BASED RETRIEVALS

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A near real-time integrated temperature and water vapour sounding system was designed in and has operated since June 1993. It combines hourly data from the ground-based Radio Acoustic Sounding System (RASS), a two-channel microwave radiometer, standard surface meteorological instruments, a lidar ceilometer, and the ARINC Communication, Addressing and Reporting System (ACARS) aboard commercial airlines with the space-based data from the TIROS-N Operational Vertical Sounder (TOVS). Neither ground-based nor space-based observing systems are adequate for operational needs if used alone. TOVS soundings lack the vertical resolution needed for many applications, especially in the atmospheric boundary layer, and RASS seldom reaches heights above the 500 hPa level. The physical retrieval algorithm for combining the ground- and space-based temperature and humidity profiles is based on statistical extrapolation of RASS and ACARS data up to 0.1 hPa, and inserting this first-guess profile into the International TOVS Processing Package (ITPP).

Statistical error estimates for the hourly, near real-time ground- and space-based retrieved temperature and humidity profiles based on 119 soundings collected during a two-month long experiment conducted at Platteville, Colorado, during February and March 1994 are presented. The experiment was funded by the Forecast Systems Laboratory (FSL) of NOAA. For comparison CLASS radiosonde data collected during the Winter Icing and Storms Program (WISP), the Environmental Technology Laboratory (ETL) airsonde data from Platteville, and the National Weather Service (NWS) radiosonde data from Denver, Colorado were used. The comparison showed excellent agreement between retrieved and radiosonde soundings. Retrieved temperature profiles show better performance than the retrieved humidity profiles because of the high vertical resolution of the RASS measurements. It is suggested that adding more information from the new individual remote sensors as they develop, through the technique used here, would lead to further profiling improvements.

RECENT PROGRESS OF THE OPERATIONAL TOVS PROCESSING SYSTEM IN MSC

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The Meteorological Satellite Centre (MSC) in Japan recently changed its operational TOVS processing system. A brief description of the new system which retrieve the vertical profile of temperature and water vapour is presented. The new algorithm is characterized by: 1) a strict and dynamic cloud detection with all AVHRR channels by each AVHRR FOV, 2) a fast forward calculation with fewer

model layers, 3) an initial guess produced from prognosis of the Global Spectral Model of JMA and regional MCSST data made at MSC, 4) a minimum variance method with iterations. The new algorithm has been operational since November 1993 except for the strict cloud detection which has been operational since June 1994, and we have monitored the accuracy of products. The system performance estimated by the monitoring are also presented. The computer system in MSC will be renewed in May 1995 in order to cope with an increase in data and new products of GMS-5. The reception facility of NOAA/HRPT data will be also renewed in May 1995.

REMOTE SENSING OF EFFECTIVE DROPLET RADII USING A COMBINATION OF AVHRR AND AMSU DATA

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The effective radius of the droplet distribution has a strong influence on the bulk radiation properties of clouds and therefore on the global energy budget. Using a matrix operator model simulations were carried out for all AVHRR channels for a broad range of effective radii (2-32 μm), for different cloud heights and cloud types. Additionally, the corresponding brightness temperatures in the microwave channels of AMSU have been calculated. This data set is employed to examine the possibility of retrieving the effective radius of cloud droplet distributions. To retrieve the effective radius from multi-spectral satellite measurements inverse modelling technique will be employed. First results will be presented on the conference.

A FAST LINE-BY-LINE RADIATIVE TRANSFER MODEL FOR TOVS RADIANCE/TRANSMITTANCE STUDIES

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A method of evaluating TOVS transmittances and radiances using a fast high-resolution line-by-line radiative transfer model is briefly described. The method depends on pre-computed tabulations of high resolution absorption coefficients and a two-dimensional interpolation scheme. The model has an accuracy comparable to a conventional line-by-line model but is up to two orders of magnitude faster; for example, a set of HIRS-9 transmittances and radiances for an 83-level profile with 6 absorbers requires about 5 minutes on an HP755 workstation. Consequently many simulations can be done in a short time allowing comprehensive studies to be performed relatively quickly. The model's primary purposes are for conducting sensitivity studies and for developing fast transmittance or radiance models. An application to the TOVS water vapour channels is presented.

CLOUD CLASSIFICATION AND RAIN-RATE ESTIMATION THROUGH SPATIAL AND SPECTRAL ANALYSIS

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Twelve months of AVHRR data at full radiometric and spatial resolution were collocated with radar rain-rate data in the New Zealand region, the radar data having been corrected for beam geometry, ground and sea clutter, attenuation and vertical profile of reflectivity effects. Rain-rates were

calculated using the usual $Z=200R^{1.6}$ relationship. An interactive labelling environment was then used to label 11 identifiable "single level" cloud types. To aid the labelling process various diagnostic tools, such as difference and ratio channels, channel 3 reflected and emissive components, histograms, Coakley-Bretherton plots, grey-level difference, and mean and standard deviation statistics were used. Analysis of more than 4000 collocated samples (i.e. 11 cloud classes plus no cloud) demonstrated the separability of nearly all cloud classes when both radiometric and spatial characteristics are used in a Bayesian classifier. Further, within any particular raining cloud class, the rain-rate appears to be related to the spatial and radiometric characteristics of the cloud. This approach, whereby cloud classes are identified then rain-rates estimated as a function of cloud type, would seem to resolve many of the usual problems associated with standard rain-rate analyses of passive satellite data.

THE APPLICATION OF MSU MICROWAVE DATA TO THE STUDY OF AUSTRALIAN REGION TROPICAL CYCLONES

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The Microwave Sounding Unit (MSU) on board the NOAA polar orbiting satellites has been used to determine tropical cyclone intensity by measuring the gradient of the upper warm temperature anomaly. Aircraft measurements and dropsonde data near Northern Hemisphere tropical cyclones indicate that the magnitude of the warm anomaly can reach 16°C. Velden and Smith (1983) correlated the MSU derived temperature anomalies to the intensity of Atlantic tropical cyclones. Similar studies using Australian tropical cyclones have shown a smaller MSU derived anomaly. Anomalies were obtained from MSU raw brightness temperatures adjusted for the effects of increasing slant path and from retrieved temperatures using the TOVS physical retrieval scheme implemented in the Australian Bureau of Meteorology (Le Marshall et al., 1994). Composite temperature profiles obtained from 20 years of radiosonde and cyclone data for the Western Australian region were obtained and synthetic radiances calculated. These were used to determine some of the reasons for the reduced MSU response and to derive adjustments to improve the correlation between the observed anomaly and cyclone intensity. The proposed Advanced Microwave Sounding Unit (AMSU) with greatly improved vertical and horizontal resolution is shown to have potential to give measurements which more closely reflect the magnitude of the upper tropospheric temperature anomaly.

PHYSICAL RETRIEVAL OF TROPICAL CYCLONE STRUCTURE AND INTENSITY FROM POLAR ORBITER MICROWAVE OBSERVATIONS

C Velden and R Merrill
CIMSS, University of Wisconsin-Madison, USA

Electromagnetic radiation in the 50-60 GHz range is emitted by atmospheric O_2 yet is not significantly affected by glaciated cloudiness, and is uniquely suited to remote sensing of upper-tropospheric thermal structures associated with cloudy weather systems. Tropical cyclones occur over data-void regions and are typically characterized by a strong upper-level warm anomaly which is commonly masked by cirrus cloud, making them prime candidates for passive microwave sensing. Knowledge of the warm anomaly strength is of practical value because it can be related to storm intensity through the hydrostatic constraint. Early attempts to measure and correlate the observed warm anomaly with in situ measurements of intensity have met with moderate success. These schemes were purely

statistically based, however, and did not explicitly account for sensor properties (i.e. resolution) which may vary from satellite to satellite, or storm structure (i.e. eye size) which may be uniquely characterized depending on oceanic basin.

This paper describes an algorithm to retrieve physically the upper-tropospheric thermal anomaly of tropical cyclones from passive microwave observations which attempts to account for sensor viewing geometry and storm structure. The effects of antenna resolution and viewing geometry are modelled by convolving the antenna footprint with an analytic function approximation of the warm anomaly. The free parameters of the analytic function, one of which is amplitude, are retrieved from a set of observations using a priori estimates of the means and covariances of the free parameters as a constraint. The technique is ultimately intended for use as a universal (i.e. global) hybrid statistical-physical package for estimating tropical cyclone intensities from satellite microwave observations.

A PRELIMINARY STUDY OF APPLYING SSM/I DATA IN RAINFALL ESTIMATION AROUND TAIWAN AREA

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Microwave remote sensing has more benefits than infra-red and visible sensors in cloudy areas, but there are some difficulties in applying the microwave data. Surface emissivity is so variable over land that most rainfall estimation algorithms are developed over ocean. In a long period global model, rainfall rate estimated by regression method is rapid and easy in contrast to the physical method which is somehow reasonable but the precision is not good enough owing to the scattering problem. In the Taiwan area some regression methods of rainfall estimation are applied and the results compared with surface observed data. From these comparisons the optimal technique will be selected and used in Taiwan area. Besides, using a probability distribution function, a good relationship between SSM/I data and one-hour surface rainfall observations is found. In the future, the use of ground-base microwave radiometers to measure emissivity and combined LANDSAT data to classify surface type will be considered to develop the rainfall estimation model for applying satellite microwave measurements over land.

THE SCIENCE SPECIFICATIONS FOR PROCESSING SOUNDER DATA FROM THE NOAA-K,L,M SATELLITES

D Q Wark
NOAA/NESDIS, Washington DC, USA

The suite of sounder and imaging instruments on the NOAA-K,L,M satellites used for soundings includes the HIRS-3, the AMSU-A, the AMSU-B, and the AVHRR. As a group, data from these must be earth-located, calibrated, limb-adjusted, interpolated, cloud-cleared, and made into single sets of data before they are subjected to the retrieval process. Each of these involves either new algorithms for the AMSU-A, the AMSU-B, and the AVHRR or updated procedures for the HIRS-3. A document describing all the processes has been in preparation for several years, being constantly revised; it will be published after the launch of NOAA-K, but copies of the draft manuscript are available to qualified agencies.

THE SSM/T2 AS A PREVIEW OF THE AMSU-B

D Q Wark
NOAA/NESDIS, Washington DC, USA

Data from the SSM/T2 microwave radiometer carried on the DMSP F-11 and F-12 satellites provide an opportunity to prepare the algorithms for processing the AMSU-B data from the NOAA-KLM satellites. Of particular interest is the potential application of the 183±7 GHz channel to filter precipitation over both land and sea with equal facility. Seasonal variations show expected areas of persistent low humidity, but also show some interesting deviations from anticipated climatological norms.

SATELLITE PLANS IN CHINA

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China is continuing her efforts on meteorological satellite system development. The next satellite to be launched is the spin-stabilized geostationary satellite FY-2b (Feng-Yun 2b) and will be located at 105°E. It has three channels to provide the visible, infra-red and water vapour imagery with 1.25 km, 5 km and 5 km resolution respectively. There are DCP and WEFAX capabilities on FY-2b. The ground system is ready for receiving and processing the data transmitted from satellite. The third one in the polar-orbiting satellite series will be FY-1c. The launch schedule is arranged in the late 1990s. The major improvement of the radiometer is the increase of channel number from 5 to 10, i.e. 4 in visible, 3 in near infra-red, 1 in shortwave window and 2 in longwave window for monitoring the cloud, surface, water vapour and ocean colour. The sounding instrument is still in the research and experimental stage. The sounder with 26 infra-red channels and 7 microwave channels could be expected and might be put up by FY-1d around the year 2000. Since satellite data play a more and more important role in nowcasting, numerical weather prediction, climate research and monitoring of global change, etc., China has benefited a lot from the international satellite programme and would like to place high priority on the implementation of Chinese meteorological satellite programme for her contribution to the world.

Appendix A.

AGENDA FOR ITSC-VIII

EIGHTH INTERNATIONAL TOVS STUDY CONFERENCE
QUEENSTOWN, NEW ZEALAND
5 - 11 APRIL 1995

Wednesday 5 April 1995

0830-0900 REGISTRATION

0900-1000 INTRODUCTORY SESSION (Chair: Uddstrom/Eyre)

Welcome and opening remarks
Presentation and discussion of conference programme

1000-1030 BREAK

1030-1215 SCIENTIFIC PRESENTATIONS (Chair: Uddstrom)

I. TOVS data in climate studies

1030 Stephens G. What can TOVS do for climate research: some examples.

1100 Bates J. TOVS water vapour observations for climate monitoring.

1115 Menzel W.P. Four years of global cirrus cloud statistics using HIRS. (withdrawn)

1130 Scott N.A., A.Chédin, J.P.Chaboureau, F.Cheruy, C.Claud, S.Dardaillon, N.Husson, C.Stubenrauch, B.Bonnet and D.Kasisavanii: Processing of multi year satellite data with the 3I system within the frame of the NOAA / NASA Pathfinder program.

1145 Goldberg M.D. The TOVS Pathfinder Path-C algorithm and results. (Presented by Kleespies)

1200 Bloom H.J. and M.W.Chalfont: TOVS operational processing of global climate products based on HIRS/2 radiances.

1215-1400 LUNCH

1400-1430 SCIENTIFIC PRESENTATIONS (Chair: Bates)

I. TOVS data in climate studies (continued)

1400 Francis J.A. TOVS-derived estimates of horizontal energy fluxes in the Arctic.

1415 Prata F. A continental surface radiation network.

1430-1515 SCIENTIFIC PRESENTATIONS (Chair: Bates)
II. TOVS data in NWP

1430 McNally A.P., J.R.Eyre, G.Kelly, E.Andersson and M.Vesperini: Variational analysis of humidity information from TOVS radiances at ECMWF.

1445 Riley P. P.Steinle, T.Hart and G.Kelly: The impact of 1DVAR TOVS retrievals compared to NESDIS retrievals on 5 day global forecasts.

1500 Chouinard C., J.Halle, P.Gauthier and P.Koclas: Preparations for the variational assimilation of TOVS radiances in a 3D data assimilation system.

1515-1545 BREAK

1545-1615 SCIENTIFIC PRESENTATIONS (Chair: Bates)
II. TOVS data in NWP (continued)

1545 Reale A. Departures between satellite derived sounding products, radiosondes and weather forecasts: Present and future.

1600 Le Marshall J., R.Seecamp, W.L.Smith, S.Nieman and K.Magari: Operational assimilation of TOVS radiance data in the Australian Bureau of Meteorology.

1615-1700 SCIENTIFIC PRESENTATIONS (Chair: Le Marshall)
III. TOVS and AVHRR

1615 Nieman S. The incorporation of AVHRR within ITPP5.

1630 Wann-Jin Chen The use of AVHRR data in TOVS retrieval in Taiwan area. (Presented by Kung-Hwa Wang)

1645 Arbelo M., V.Caselles and F.Herrera: Determination of sea surface temperature from synergy of TOVS with AVHRR data.

1700-1800 SCIENTIFIC PRESENTATIONS (Chair: Steenbergen)
IV. Preparations for ATOVS

1700 Kleespies T. Preparations for ATOVS data at NESDIS

1720 Klaes D. Preparations for ATOVS data in Europe.

1740 Achtor T. Preparations for ATOVS data at CIMSS.

1830-2030 ICE-BREAKER

Thursday 6 April 1995

0900-1030 SCIENTIFIC PRESENTATIONS (Chair: Steenbergen)
IV. Preparations for ATOVS - Continued

0900 Foot J.S. Planning for ATOVS at the UK Met. Office.

0915 Rochard G. A local ATOVS ingest system.

0930 Wark D.Q. The science specifications for processing sounder data from the NOAA-K,L,M satellites.

0945 Bennartz R., A.Thoss and J.Fischer: The influence of beam filling on the results of microwave retrieval algorithms for cloud parameters.

1000 Lachlan-Cope T. A study of the use of AMSU for the detection of precipitation over Antarctica.

1015 Burdsall-Brown E. Distribution and archive of ATOVS data.

1030-1045 BREAK

1045-1130 SCIENTIFIC PRESENTATIONS (Chair: Steenbergen)
IV. Preparations for ATOVS - Continued

1045 Phalippou L. Variational retrieval of humidity profile, cloud water content and marine surface wind speed with SSM/I: implication for ATOVS processing. (Presented by Eyre)

1100 *Open discussion on ATOVS software development and distribution.*

1130-1230 SCIENTIFIC PRESENTATIONS (Chair: Rochard)
V. Advanced infra-red sounders

1130 Revercomb H. Current developments in advanced IR sounders.

1150 Scott N. IASI.

1210 Kadokura S. Instruments and data analysis algorithm of IMG.

1230-1400 LUNCH

1400-1515 SCIENTIFIC PRESENTATIONS (Chair: Rochard)
V. Advanced infra-red sounders (continued)

1400 Melton D.L., J.A.Jenney, L.D.Howell and W.L.Smith: HIRS-Hybrid: a high resolution sounder for the near term.

1415 Amato U., I. De Feis, V.Cuomo, F.Romano, C.Serio and V.Tramutoli: Regularization methods to solve inverse problems: an investigation in the context of Fourier spectroscopy from satellite. (withdrawn)

1430 Chédin A., N.A.Scott, F.Cheruy, H.Rieu, M.Herveou, F.Aires: The "TIGR" data set concept and the neural network technique: a coordinated approach for the forward and inverse algorithms suite at LMD (TOVS, ATOVS, AIRS, IASI). (Presented by Scott).

1445 Kadokura S. An algorithm to select channel for indirect measurements.

1500 Aoki T. The remote sounding of tropospheric trace gases by the absorption method.

1515-1545 BREAK

1545-1730 STATUS REPORTS (Part 1) **(Chair: Eyre)**

Relations with other bodies

ITWG liaison with WMO; Recent WMO developments important to the Eighth International TOVS Study Conference. (Hinsman) (20 min.)

ITRA (Scott) (5 min.)
GEWEX (Scott / Chédin) (5 min.)
IRC (Scott / Chédin) (5 min.)
TOVS Pathfinder (Francis / Dodge) (10 min.)

Review of actions from ITSC-VII (35 actions)

Reports back on issues raised at ITSC-VII

New instruments:

ATSR (Prata) (5 min.)
MIMR (Foot) (5 min.)
AIRS (Revercomb) (5 min.)

TOVS data and climate analysis:

Re-analysis at NMC (Kleespies) (5 min.)
Re-analysis at ECMWF (Eyre) (5 min.)

Frequency protection

AMSU frequency protection in the frame of ITU. (Rochard) (10 min.)

Working group formation **(Chair: Uddstrom/Eyre)**

TOVS data in climate studies
TOVS data in NWP
Preparations for ATOVS data
International issues and future systems
Advanced sounder science

1830 DEPART FOR CONFERENCE DINNER (Walter Peak).

Friday 7 April 1995

0900-0945 STATUS REPORTS (Part 2) (Chair: Eyre)

TOVS processing packages

ITPP (Nieman / Achtor) (5 min.)
3R/4A and 3I (Scott) (5 min.)
RTTOV (Eyre) (5 min.)

TOVS case study (Rochard, LeMarshall) (10 min.)

Any other items / discussion (20 min.)

0945-1025 SCIENTIFIC PRESENTATIONS (Chair: Rochard)
VI. International issues and future systems

0945 Menzel P. NOAA Plans (Presented by Reale)

1005 Klaes D. EUMETSAT Plans

1025-1100 BREAK

1100-1130 SCIENTIFIC PRESENTATIONS (Chair: Rochard)
VI. International issues and future systems (continued)

1100 Fengxian Zhou Satellite plans in China

1115 Dodge J. and F. Stetina: Sounding and imaging capabilities of the EOS Direct Broadcast system (Withdrawn)

1130-1230 SCIENTIFIC PRESENTATIONS (Chair: Le Marshall)
VII. Other scientific studies and developments

processing systems

1130 Caille P., F.Karcher and B.Lacroix : Current use of TOVS data at METEO France, Toulouse.

1145 Bohm T. Aspects of TOVS Activities at the Deutscher Wetterdienst (DWD).

1200 Dong Chaohua, Wu Zhidian, Ran Maonong, Li Guangqing and Zhang Zhaoxian: Processing and research of TOVS data in the Satellite Meteorology Centre of the China Meteorological Administration.

1215 Jun Li, W.L.Smith and H.M.Woolf: Retrieval of atmospheric profile and cloud parameters from TOVS observations (Presented by Achtor).

1230-1400 LUNCH

1400-1515 SCIENTIFIC PRESENTATIONS (Chair: Kleespies)
VII. Other scientific studies and developments (continued)

1400 Nieman S. A comprehensive evaluation of ITPP5.

1415 Bloom H.J. and A.Reale: Enhancement of the RTOVS software system in preparation for implementation into the NESDIS sounding operation. (Presented by Reale)

1430 Erdenetuya M. TOVS data processing at the information and computer centre of the Ministry for Nature and the Environment. (withdrawn)

tropical storms

1445 Gin-Rong Liu Applying NOAA MSU data to estimate typhoon intensity in Taiwan area. (withdrawn)

1500 van Burgel J.L., J.F.LeMarshall, M.J.Lynch and J.Clark: The application of MSU microwave data to the study of Western Australian region tropical cyclones.

1515-1545 BREAK

1545-1700 Technical Sub-Groups

ITPP
3I/3R
RTTOV

1700-1730 POSTER INTRODUCTIONS (Chair: Bates)
(1 minute, 1 viewgraph maximum)

Rizzi R. On the behaviour of the ECMWF prognostic cloud scheme when compared to raw TOVS radiances. (Presented by McNally)

McMillin L.M. Cloud clearing at NESDIS. (Presented by Bloom)

Cuomo V., V.Lanorte, C.Pietrapertosa, C.Serio and V.Tramutoli: An adaptive strategy for cloud filtering in HIRS/2 channels. (Presented by Tramutoli).

Csiszár I. Use of AVHRR data in HIRS cloud-clearing for semitransparent clouds

Francis J.A. TOVS-derived estimates of the downwelling longwave radiation flux in the Arctic.

Schweiger A. and J.Francis: TOVS Path-P: A new TOVS-based data set for Arctic research.

Turner D.S. A fast line-by-line radiative transfer model for TOVS radiance/ transmittance studies. (Presented by Steenbergen)

Velden C.	and R.Merrill: Physical retrieval of tropical cyclone structure and intensity from polar orbiter microwave observations.
LeMarshall J.,	P.D.Nilo, N.T.Servando, B.Rouse and E.A.Adug: Typhoon monitoring and forecasting in the Philippine region using NOAA Direct Readout and an integrated data base.
Lavanant L.	ICI retrieval algorithms.
Riley P.	Comparison of 1DVAR retrievals from limb corrected and non-limb corrected radiances.
Takeuchi Y.	Recent progress of the operational TOVS processing system in MSC. (Presented by Aoki).
Klaes D.	TOVS data processing in a PC-Environment.
Erdenetuya M.	TOVS data processing at the information and computer centre of the Ministry for Nature and the Environment.
Klaes D.	Operational monitoring of TOVS retrieved thickness fields over Europe.
Achtor T.	A comparison of satellite-derived thermal gradient winds and radiosonde winds.
Prangsma G.J.	and S.J.M.Barlag: Impact of TOVS-3I retrievals on a limited-area model forecast: 2-4 February 1994 development over the North Atlantic.
Ceckowski D.H.	and R.P.Galvin: HIRS/3, its predecessors and progeny.
Kleespies T.J.	Characteristics of the SSM/T2 antenna temperatures.
Wark D.Q.	The SSM/T2 as a preview of the AMSU-B.
Klaes D.	SSM/T-2 Data Analysis.
Klaes D.	Simulations of the ATOVS instrument channels by radiative transfer modelling on synoptic situations over Europe.
Thoss A.,	R.Bennartz and J.Fischer: Remote sensing of effective droplet radii using a combination of AVHRR and AMSU data. (Presented by Bennartz)
Kuang-Hwa Wang	A preliminary study of applying SSM/I data in rainfall estimation around Taiwan area.
Uddstrom M.J.	and W.Gray: On the use of AVHRR spectral and spatial measures to estimate surface precipitation.

1830-2030 POSTER SESSION (including refreshments)

Saturday 8 April 1995

WORKING GROUP MEETINGS

Sunday 9 April 1995

WORKING GROUP MEETINGS

Monday 10 April 1995

0900-1030 SCIENTIFIC PRESENTATIONS (Chair: Fengxian Zhou)
VII. Other scientific studies and developments (continued)

temperature

0900 Reale A., H.J.Bloom and D.Donahue: Operational status and outlook for NESDIS polar orbiting satellite sounding systems.

0915 Lavanant L. TOVS sounding products at CMS.

0930 Stankov A.B. Ground and space-based temperature and humidity retrievals: statistical evaluation.

0945 Cheruy F., F.Chevallier, N.A.Scott and A.Chédin: Analysis of the thermodynamic and the radiative vertical structure of the Earth-atmosphere system based on TOVS observations and neural networks technique. (Presented by Scott)

1000 Marks C.J. Are 1DVAR TOVS retrievals useful for the southern lower stratosphere?

water vapour

1015 Cuomo V., V.Berardi, P. Di Girolamo, F.Esposito, G.Pasppalardo, C.Pietrapertosa, F.Romano, C. Serio, N.Spinelli, V. Tramutoli and R.Velotta: Combined satellite and ground based atmospheric water vapour measurements.

1030-1100 BREAK

1100-1200 SCIENTIFIC PRESENTATIONS (Chair: Achtor)

VII. Other scientific studies and developments (continued)

clouds

1100 Baran A.J., D.L.Mitchell and J.S.Foot: Application of global HIRS data to cloud phase and cirrus radiative properties. (Presented by Foot)

1115 Csiszár I. The effect of the horizontal cloud inhomogeneity on the HIRS channel 19 reflectivity.

1130 Dongsoo Kim Retrieval of cloud information by density fitting of AVHRR data.

ozone

1145 Kaifel A. Total ozone retrieval from NOAA-TOVS data by means of neural network techniques - evaluation for different climate regions.

1200-1400 LUNCH

1400-1445 SCIENTIFIC PRESENTATIONS (Chair: Scott)
VII. Other scientific studies and developments (continued)

radiation

1400 Schweiger A. A neural network-based approach to the retrieval of the surface radiation budget of the Arctic from TOVS radiances.

radiative transfer

1415 McMillin L.M., L.J.Crone, M.D.Goldberg and T.J.Kleespies: OPTRAN, a computationally fast and accurate atmospheric transmittance model. (Presented by Kleespies)

1430 Rochard G. RTTOV/RTATOV developments.

1445-1730 WORKING GROUP MEETINGS

Tuesday 11 April 1995

0900-1500 ITWG PLENARY SESSION (Chair: Eyre/Uddstrom)

0900 I Working Group Reports

1030-1100 BREAK

1100 II Technical sub-group reports
III Executive Summary, major recommendations and actions

1230-1400 LUNCH

1400 IV Future Plans
- next meeting
- issues / working groups
- venue

1430 CLOSE

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