A REPORT ON

THE FOURTH INTERNATIONAL TOVS STUDY CONFERENCE

Igls, Austria

16-22 March 1988

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Cooperative Institute for Meteorological Satellite Studies (CIMSS)

Austrian Space Agency (ASA)

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World Meteorological Organization (WMO)

(prepared by M. J. Lynch
and W. P. Menzel)

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May 1988

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June 1988

FOREWORD

Since August 1983, the International TOVS Study Conferences (ITSC) have occurred every eighteen months. As a working group of the International Radiation Commission, TOVS users convene to intercompare results from the application of temperature and moisture retrieval techniques; to discuss recent progress; to coordinate future activities; and to formulate recommendations to the WMO.

The recent ITSC-IV, held during March 1988 in Igls, Austria, focused on improved moisture retrieval techniques, new case studies to study the impact of TOVS in synoptic scale weather forecasting, personal computer advances in acquiring and processing TOVS, participation in the BUAN evaluation, preparing for the Advanced TOVS polar orbiters, and international collaboration on future satellite systems. This report summarizes the presentations and discussions on these and other issues. A companion document entitled the Technical Proceedings of ITSC-IV will contain the complete text of the scientific presentations which are only summarized briefly here.

The first three ITSC were chaired by William Smith and Rolando Rizzi. The present chairmen, Alain Chedin and Paul Menzel, were elected by the ITOVS Working Group at the conclusion of ITSC-III. The efforts of the two former chairmen were gratefully acknowledged by all participants at ITSC-IV.

ITSC-IV was possible only because of the help of many people. We wish to thank a few of them.

Igls, Austria continues to be the favorite meeting place for our group. Three of the four ITSC have been held there. This is largely because of the scenic Alpine setting and the efforts of our gracious Austrian hosts; we thank Helmut Rott and his colleagues, Joseph Aschbacher and Barbara Zsak. They arranged leisure time activities that nicely offset the busy work schedule.

A special thank you goes to Mervyn Lynch, who was drafted on short notice to substitute for one of us (PM) at the conference when a death in the family prevented him from attending. He accomplished the difficult task of understanding hasty instructions and acting upon them. His dynamism and efficiency helped make the conference a productive session.

Participants to ITSC-IV had the opportunity to attend a special session on Geostationary Satellite Plans for the Future, organized by William Smith. It provided a forum for reviewing present status of infrared and microwave sensors and for discussing international collaboration on several exciting instrument platforms.

IBM in Innsbruck, Austria provided personal computer facilities for the PC/TOVS demonstrations. Guy Rochard helped to test the modem communications. The ITSC enthusiasm for the displayed microcomputer capabilities is an expression of our thanks.

On site secretarial support was provided by Laura Beckett, who managed to keep the conference logistics under control and demonstrated remarkable ability in typing the abstracts into readable form. The reproducing and binding of this document was accomplished by Susan Pfefferkorn.

We also gratefully acknowledge that the rental of the conference rooms was sponsored by the Austrian Space Agency and that the publication of this report was sponsored by the NOAA/NESDIS Office of External Relations and the Cooperative Institute for Meteorological Satellite Studies.

Palaiseau, 12 June 1988
Alain Chedin

Madison, 12 June 1988
Paul Menzel

The Fourth International TOVS Study Conference

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P. Menzel (USA)

Organizer
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WMO Representative
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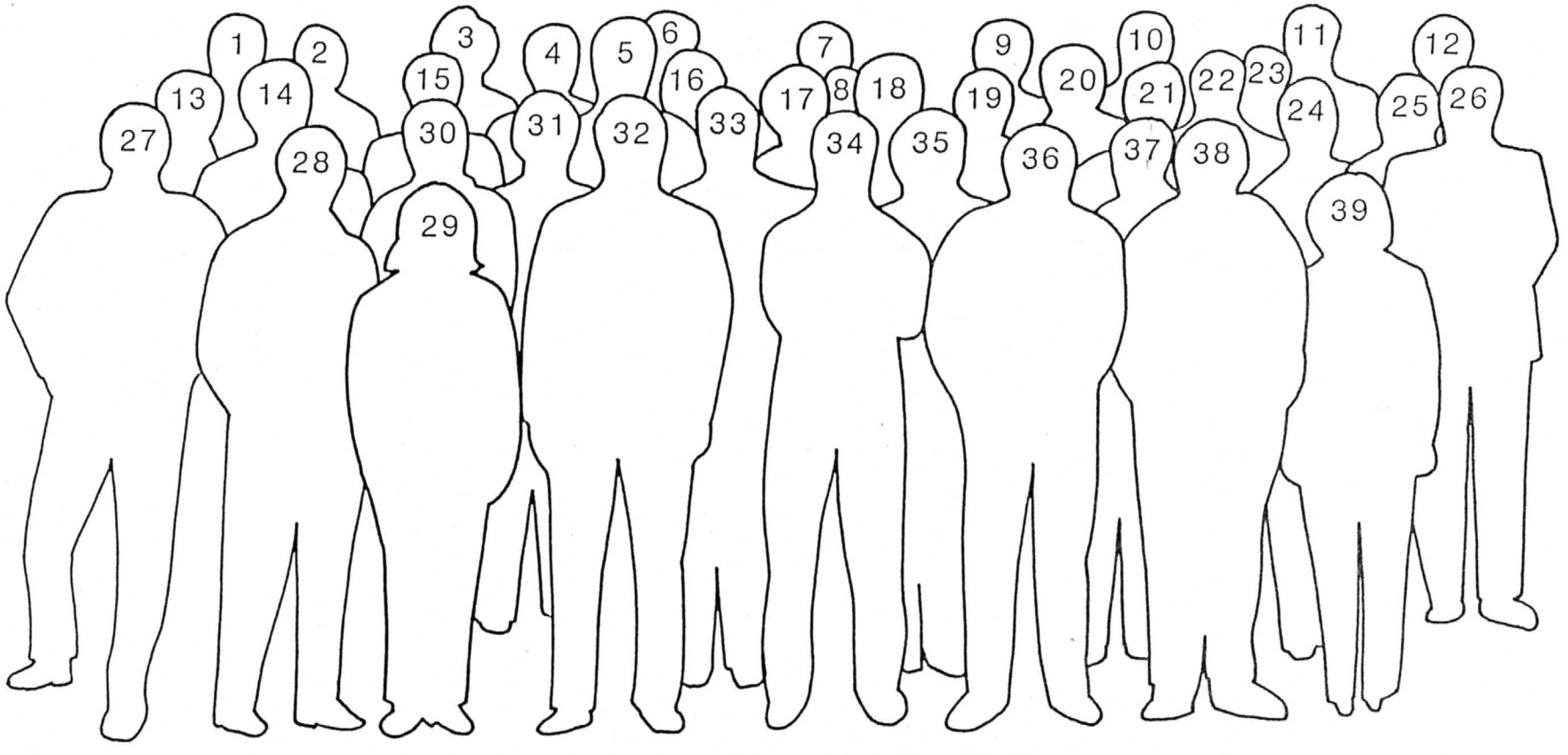

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KONGRESSZENTRUM

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I. EXECUTIVE SUMMARY

A. Introduction

The Fourth International TIROS Operational Vertical Sounder (TOVS) Study Conference (ITSC-IV) was held in Igls, Austria from March 16-22, 1988. Sixty-three delegates attended the meeting and a further seven, not able to attend because of travel restrictions, provided scientific contributions. The twenty countries represented at the meeting included Austria, Australia, Canada, Denmark, Federal Republic of Germany, Finland, France, Hungary, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Peoples Republic of China, Spain, Sweden, Switzerland, United Kingdom, and the United State of America. Participation in the ITSC by national groups continues to increase as does the level of expertise of the participants.

An important function of the conference is that it provides the opportunity for delegates to share through formal and informal exchanges with their colleagues the outcomes of their continuing TOVS activities. The initial phase of the meeting is devoted to presentations by the various national groups, which provide fertile input to the Working Group discussions initiated later in the ITSC meeting. Section II of this Report records the Abstracts of the scientific contributions by delegates. The full papers on which these Abstracts are based are published separately in the Technical Proceedings of the Fourth International TOVS Study Conference.

Successive ITSC have concluded by identifying a range of issues for future action by delegates. Concerns which emerge from ITSC-III were reported upon at ITSC-IV by the designated delegates. The work between meetings, the resolution of problems, and the reporting back to delegates is a significant feature and strength of the ITSC forum. The Status Reports for ITSC-IV are in Section III of this document. They embrace actions which have been taken on documentation of processing software, progress on atmospheric transmittance calculations, satellite sensor calibration, handling clouds in radiance fields, progress on low cost microcomputer-based processing of TOVS data, assimilation and impact of satellite sounding products in numerical weather prediction, developments associated with future instruments, the role of TOVS products in global climate studies, and progress with the WMO Baseline Upper Air Network (BUAN).

This fourth meeting of the ITSC has seen the continuing progress toward the broad goals of improving the quality of satellite-derived atmospheric soundings and studying their applications in the operational meteorological environment. The conference focussed its attention on four areas; the science of atmospheric sounding, the software and associated algorithms for deriving products from satellite data, the application of the products to numerical weather prediction, and international coordination of these activities. Working Groups were established in these four areas to review, debate and make recommendations on the key issues of concern and items for action. The Reports of these Working Groups are detailed in Section IV of this

document. The key recommendations and conclusions deriving from the Working Group Reports are reviewed later in this Executive Summary.

Previous activities by the ITSC have demonstrated the value of case studies as a vehicle for investigating the quality of sounding products and the impact of these satellite products on numerical weather prediction. At the ITSC-IV, two new case studies were proposed. The goals of these new studies, the available ancillary data, and the data distribution and reporting procedures were discussed. The severe storm event which occurred over the north coast of Spain and southwestern region of France on June 7, 1987 was selected for investigation because of the mismatch which was apparent between the forecast and actual weather. A second case study was selected from one of the Australian Meteorological Experiment (AMEX) observation periods. This will be the first tropical region study undertaken by the ITSC. The particular period embraces the formation and development of a tropical storm. Ancillary data from the intense observation network in place for AMEX is available to support the case study. The distribution of data sets for these studies will occur in 1988. Users will process these cases and the results will be synthesized in time for review at the ITSC-V meeting in the autumn of 1989.

The processing of these new case studies will be accomplished with a variety of processing packages. Most of the TOVS community are favoring a combination of physical and statistical retrieval schemes. At the time of ITSC-IV, the dominant algorithms are the ITPP-3, the 3I system, or variants thereof. At the ITSC-I (Igls, Austria, 1983), the International TOVS Processing Package (CIMSS, Madison) was already widely in use. As has been recorded in subsequent meetings of the ITSC, the package has gone through three major upgrades which have improved the quality of the temperature and moisture retrievals. Further, a number of research groups and centers have adapted the ITPP-3 to their local needs using variants to the processing algorithm and locally derived parameters for transmittance tuning. (Appendix D is an updated list of the present users of the ITPP-3.) The 3I system (France) was presented to the TOVS community at the ITSC-I (Igls, Austria, 1983). Together with other packages, it contributed to the intercomparison campaigns of ITSC-I, II, III (see J. LeMarshall in Technical Proceeding of ITSC-II, 1985). The 3I system has been recently made available to the international community (see Appendix D) for impact studies on numerical weather forecasting (global scale or limited area models).

Work on the PC/TOVS version of the ITPP has matured considerably since the ITSC-III meeting. A demonstration of the software and graphics was provided on an IBM/PS2-80 personal computer. Features of the software include a menu driven user interface, improved EGA level graphics, and considerably improved performance of the physical retrieval. A preliminary draft of software documentation was presented. A particular feature of the demonstration was the acquisition of TOVS data through a modem from the CIMSS data base in Madison, Wisconsin and near real time processing and product display.

A specific feature of the ITSC meeting series has been the willingness shown by a number of the participating groups to share processing

softwares and data sets. In parallel with the formal meeting, an informal exchange of various scientific and technical information has occurred. The "sign-up lists" available to ITSC-IV delegates are shown in Appendix C.

The CBS-IX had proposed that the ITSC participants be encouraged to become active in the BUAN evaluation. NESDIS representatives at the ITSC-IV indicated that while some initial problems had arisen, the BUAN data were now being archived routinely. Distribution of a selected subset of the BUAN data to a selected set of processing centers for evaluation purposes was the remaining obstacle. The ITSC agreed that it would undertake action to initiate the evaluation process.

Two rapporteurs from the ITOVS Working Group submitted a preliminary report to the WMO at CBS-IX in January 1988. This report attempted to summarize the findings and recommendations from the previous ITSC and to foreshadow future developments in satellite soundings. The WMO requested that this reporting continue at CBS. (Appendix E contains the CBS-IX report; ITOVS feedback to the rapporteurs is encouraged to help with preparations for their next report.)

Plans for the space agencies to launch new generation geostationary sensors in the 1990s stimulated the ITSC to schedule a half-day forum on "Geostationary Satellite Plans for the Future." NASA, NOAA and commercial sector representatives provided advice on USA's plans while representatives from Europe described prospects for the next generation Meteosat sensors. Ideas for new approaches to remote sensing in the IR and microwave regions were discussed.

In the future, preparations for new satellite systems will begin to increasingly dominate the activities of the ITSC. The phasing out of the TIROS series of satellites in the early 1990s will require that users become familiar with attributes of the new sensors. Assembling and distributing technical information on the new AMSU sensor systems is the first step.

The mid-1990s will see a future change in the range of satellite sensors in space. The Earth Observing System (EOS) involves four polar platforms (two from the USA, one from Europe, and one from Japan) which provide a new array of instruments that will have a direct impact on the meteorological community. Accordingly, the ITSC is concerning itself with the implications of these developments.

B. Recommendations

The full reports of the Working Groups are in Section IV of this document. The key recommendations have been extracted and are summarized below.

1. The Working Group on Sounding Science identified three key problem areas which may affect the quality of the TOVS products - quality of the measurements, quality of the forward model for radiative transfer calculations and inversion constraints - more specifically, the choice of the first guess. The Working Group recommended that:

R1 The identified problems with limb correction procedures and calibration on the NOAA-10 satellite should be reported to NOAA/NESDIS for further investigation.

With respect to transmittances,

R2 ITRA should be requested to initiate the use of the high resolution HIS spectra to improve atmospheric transmittance models, and

R3 The importance of users implementing local tuning of transmittances to achieve higher quality soundings should be stressed. Documentation to implement this tuning should be prepared and distributed.

In that the AMSU instrument launch is scheduled for the early 1990s,

R4 Information on the AMSU pre-launch antenna patterns, a fast forward transmittance model, and a surface emissivity model should be made available to TOVS users, and

R5 Further research efforts should be applied to the modelling of the effects of clouds and precipitation on all AMSU channels.

2. The Working Group on Software considered aspects of implementation and documentation and recommended that:

R6 User feedback and sharing of software improvements should continue to be the mechanism for improving TOVS processing internationally.

R7 Documentation of available software should be developed and/or enhanced to assist installation, maintenance, and utilization.

Further, given the substantial interest in the PC/TOVS software package,

R8 An appropriate infrastructure and funding mechanism should be identified to support the testing and evaluation of the PC/TOVS package.

With the Advanced TOVS (ATOVS) configuration of AMSU and HIRS-3 planned for the NOAA K,L,M on the polar orbiter satellites in the 1990s,

R9 The ITSC should determine if there is the need for an International ATOVS Processing Package (IAPP).

3. The Working Group on Applications, following the earlier successes of the ITSC conducted case studies, recommended that:

R10 Two new ITSC case studies, namely, (i) the June 7, 1987 storm over the northern coast of Spain and southwest France, and (ii) the tropical storm of February 8-13, 1987 over the northern coast of Australia, should be undertaken through the distribution of satellite data and the ECMWF analyses.

With respect to the direct use of radiance data,

R11 Improvements in the quality control of satellite radiances and retrievals should include information on error estimates and the retrieval first guess.

The importance of identifying the impact of TOVS was stressed.

R12 The various meteorological centers should provide results to permit a major review of the impact of TOVS retrieved products on numerical weather prediction.

In connection with the evaluation of the BUAN,

R13 The BUAN data base should include information on the TOVS raw radiances and the collocated sonde profiles. NESDIS should prepare and distribute details of the current BUAN experiment and comprehensive information on the data archive. The major centers and TOVS users should initiate an analyses of the BUAN data to derive retrieval tuning parameters and improvements to the forward radiance models.

4. Using the experience gained by the ITSC, the Working Group on International Activities recommended for future satellite systems that:

R14 Identical operational sounding instruments should be flown in the two polar orbiting platforms and that S-band direct readout should be maintained to permit continued use of existing receiving stations.

R15 Agencies responsible for satellite data processing should coordinate the production of data processing packages by encouraging the formation of appropriate working groups.

The plans to equip geostationary platforms with microwave sensors led to the following recommendations.

R16 Intensive airborne evaluation campaigns should be undertaken to assist in resolving remaining scientific problems with microwave imager/sounders.

R17 Studies should be initiated to assess the probable impact of the proposed microwave sounders in NWP.

R18 Geostationary platforms should include both high vertical resolution IR and microwave sounders.

With respect to education and training,

R19 The prospects for holding workshops or technical symposia on deriving satellite sounding products and their use in forecast systems should be discussed with the WMO.

To facilitate the wider dissemination of knowledge and skills in the use of satellite derived products in the future,

R20 A PC-based demonstration package should be developed to explain the basic principles and demonstrate the utility of satellite sounding products.

R21 A position paper be prepared which would address the issue of implementing a more satisfactory scheme for the exchange of satellite sounding data.

C. Future Plans

The ITSC series continues to contribute to the science and the analysis of the impact of satellite sounding products.

Over the last five years, through the vehicles of group research and selected case studies, the ITSC has learned much on data calibration and navigation, has experimented with algorithm improvements, has identified the need for improvements in transmittances and forward models, and has begun the evaluation of the impact of soundings on numerical weather prediction. The next five years provides a new set of challenges and the ITSC is planning now for the new instrumentation (the NOAA K,L,M series) which will be launched in the early 1990s.

A major change in satellite sounding science will occur onward from 1995 with the advent of the high spectral resolution atmospheric infrared sounder (e.g., AIRS) and coupled infrared and microwave sounders (e.g., MMS) on polar and geostationary platforms, respectively. These instruments will open up new challenges and opportunities in satellite sounding which many of the existing ITSC participants will embrace. While the ITSC group has been concerned primarily with the use of TOVS products in the near real-time application to weather, the application of these same data bases to climate studies was addressed at this meeting. It appears very likely that this aspect of the work will increase in emphasis over the next decade as the International Space Year/Mission to Planet Earth is attempting to focus the application of diverse sets of remotely sensed data to the monitoring of global change. The ITSC group collectively represents a considerable body of skill and knowledge which may be useful to such an emerging application.

The important efforts toward improving the quality of sounding products and assessing their impact in weather prediction will continue. It is clear from the Working Group discussions that the ITSC has many important issues to resolve. In particular, ITSC active contribution to the BUAN program is now just commencing. We would expect by ITSC-V to provide feedback on the value of the BUAN to improving the quality of sounding products.

Considerable progress has been made on the development of the PC-based TOVS capability since ITSC-III. While further effort needs to be applied in refining the software, developing more comprehensive documentation, and testing the performance of the software, it is clear from the demonstration of PC/TOVS at ITSC-IV that a valuable tool has been developed on a relatively low cost system. If the final steps to the PC/TOVS development can be supported financially, there is no doubt that an exceptionally useful vehicle for expanding the TOVS user

community to embrace other national groups, particularly those in the developing world, will be enhanced considerably.

Between the ITSC-IV and ITSC-V meetings, the ITSC community will process and analyze information from the two case studies. These comprehensive data sets provide an excellent vehicle for an evaluation of the performance and impact of TOVS products.

The next meeting of the ITOVS Working Group, ITSC-V, will take place in France in the late summer or early autumn of 1989. The preliminary planning has already commenced.

II. ABSTRACTS OF ITSC-IV PRESENTATIONS

EXPERIENCES WITH THE ITPP AND THE 3I METHOD

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During the Frontal Air-Sea Interaction Experiment (FASINEX) in the northeast Atlantic in winter of 1986, TOVS retrievals were produced from both the ITPP and the 3I packages on the Scripps computer. The aim was to apply the data to the estimation of ocean-atmosphere heat fluxes. This paper presents a comparison of soundings from the ITPP and 3I for February 22.

ACTIVITIES AND PLANS WITH TOVS-DATA AT THE GERMAN WEATHER SERVICE

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The ITPP-III was implemented on a Cyber 860 at the German Weather Service in the last year. The first TOVS and AVHRR data will be received at the end of this year when a new HRPT station will become operational. The old satellite data receiving system computer will be replaced by two new Microvax systems. They will be connected with the main computers: ETA 10 and Cyber 860/850. Data on tape from the DFVLR (Oberpfaffenhofen) were used to test ITPP-III and to learn about it. The first case study results reveal temperature retrievals 2-7K too cold between 300 and 70 hPa in comparison with radiosondes.

Future work includes investigating the sensitivity of the retrieval scheme (first guess, channels, calibration, etc.), collocating TOVS with AVHRR for cloud detection, and extracting clear radiances. Profiles will be retrieved from these radiances and made available to the mesoscale model on an operational basis. There is an urgent need to obtain raw data (3x3) from the western part of the Atlantic which is out of our receiving area; discussions within Europe and with NESDIS are underway to resolve this data access problem.

A REGIONAL TIROS-N SERIES SOUNDING DATA OPERATIONAL PROCESSING SYSTEM

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In 1979, the State Meteorological Administration (SMA), PRC, proposed to establish a ground station system capable of direct readout and processing

of TIROS-N type satellite signals from the High Resolution Picture Transmission (HRPT) in order to improve weather analyses and numerical weather predictions locally. A regional TOVS processing software package, based on the ITPP and the NESDIS TOVS operational processing system, was developed during the period of 1981-82. At present, the initial operational TOVS processing system, interfaced with the data receiving system in Beijing, can process in near real-time the ITPP/HRPT data from NOAA polar-orbiting satellite on an IBM 4361 computer located at the Satellite Meteorology Center (SMC), PRC.

The TOVS processing system is comprised of two subsystems: the operational subsystem for retrieving atmospheric soundings and the support subsystem for generating statistical regression coefficients based upon known instrument characteristics for each spacecraft (obtained from NESDIS, USA). The coefficients for sounding retrievals are updated at weekly intervals to account for short and long period atmospheric variations.

Input to the TOVS processing system are TIP data from the TIROS-N type spacecraft as well as conventional meteorological data from the National Meteorological Center (NMC), SMA. Outputs from the TOVS processing system are temperatures at 40 pressure levels from 1000 to 0.1 hpa, water vapour mixing ratios at 15 pressure levels from 1000 to 300 hpa and total ozone content in a vertical column of the atmosphere. The products are generated roughly every 80 km via the retrieval process.

The soundings from NOAA-10 are compared with the radiosonde data. The temperature root-mean-square (RMS) differences are about 2.5 degrees Centigrade. The largest differences are found near the surface and in the tropopause region. These are caused by vertical temperature lapse rate discontinuities over a scale below the resolving power of the TOVS as well as the poor discrimination of low clouds. The absolute bias (divided by total water vapour mixing ratio for each pressure level) between the retrieved and radiosonde observed water vapour mixing ratio is about 30%. The accuracy of the total ozone amount is about 10% compared to values derived from Dobson measurements.

A THREE-STEP CLOUD-CLEARING PROCEDURE

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There are three physical and statistical features of HIRS radiance data that are mainly associated with the cloud-clearing problem: (1) clear FOVS of tropospheric data exhibit a strong meridional gradient at mid-latitudes; (2) there is low scene variability in the infrared images of the tropospheric channels; and (3) the dynamics are flat in the clear radiance

fields when compared to cloudy fields. From these features, we infer that (1) the main contribution to the complessive field dynamic is carried by the mean dynamic in the quasi-latitudinal direction; (2) the higher the cloud content, the larger the ratio of cloudy versus clear field variance (which is very high anyway), and (3) the power content in the power spectrum of a clear field becomes negligible after just a few of the lowest wavenumbers of a bi-dimensional Fourier development. We founded our "three-step" cloud clearing procedure on this information. It has been tested on HIRS/2 channel 5. The first step consists of restoring the clear sky latitudinal "mean" dynamics using a clear sky estimate based on regression from measured MSU data. The second step reduces the scene variability based on a Kalman filter applied to the Fourier coefficients of each HIRS/2 scan line. The third step increases the homogeneity of the filtered fields by applying a suitable bi-dimensional Gaussian low-pass filter.

INTRODUCTION TO PC/TOVS

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A PC-based TOVS processing and retrieval system has been developed from efforts by personnel at CIMSS of Madison, Wisconsin and at the IAP of Beijing, PRC. While early indications were that it was possible to derive soundings from raw TIP data using a PC system, the lengthy computing time limited prospects for operational retrieval processing. With advances in microcomputer technology and reduction in cost, the potential for using PC/TOVS for other than demonstration processes is being realized. The current version of PC/TOVS (March 1988) has been tested and verified only on a single data set but with satisfactory results. Timing of the retrieval processing shows that a single full physical retrieval takes 4-6 seconds using an IBM PS/2 model 80 (the equivalent process takes nearly one minute on an IBM-AT).

To satisfy the anticipated data requirements of the emerging user community, PC-TOVS has been designed to allow data input compatible with the IBM and VAX versions of the ITPP. Data file formats are consistent, with differences limited to the operating system requirements of the respective ITPP hardware environments. In addition, the PC-TOVS software package allows data input via asynchronous dial-up to the UW McIDAS at CIMSS using a modem.

The PC/TOVS software operates under MS DOS version 3.3 and was developed using Microsoft development languages. Source code is written in FORTRAN, Pascal, Assembler, and C. The software system includes the same preprocessing and retrieval algorithms as other ITPP versions and in addition, includes a number of applications programs for displaying the computed results in graphic and image form. PC/TOVS can be operated via a menu system that makes extensive use of the MS DOS batch capability or via standard DOS key-ins of the executable modules along with their controlling parameters. The following hardware is required for installing PC/TOVS:

- IBM PC-AT (or PS/2) with
  math co-processor (287 or 387)
  2mb RAM (640k minimum)
  20 mb or more hard disk
- Enhanced Graphics Adapter (EGA) with 256k RAM
- Enhanced color display monitor
- Printer
- Modem (for asynchronous dial-up data access)

VARIATIONAL RETRIEVAL OF TEMPERATURE AND HUMIDITY PROFILES FROM OBSERVED RADIANCES

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The use of data which are non-linearly related to the analysis parameter is a crucial problem for operational assimilation schemes. For instance, optimal interpolation used in most operational centres does not permit the simple use of these kinds of data.

In contrast, variational methods offer a powerful way of solving these problems through a simple minimization process. The coding of the adjoint of the associated operator is the major practical difficulty for the implementation of the method.

We shall describe how to deal with observed radiances. The goal is to retrieve a vertical profile of temperature and humidity using a guess profile and a set of observed radiances. The link operator will be the one-dimensional radiative transfer model (RTM) of the International TOVS Processing Package (University of Wisconsin) used in France. This work is part of the French ARPEGE project for numerical prediction.

Let X be the analysis variable (temperature and humidity), Xg the guess-field, Ro the observed radiances, H the RTM model and H the linear tangent model, P the guess-field error covariances matrix and O the observation error covariances matrix. Let J be the cost-function defined as follows:

$$J(X) = {}^{t}(X-X_g)P^{-1}(X-X_g) + (HX-R_o)O^{-1}(HX-R_o)$$

We have to minimize this function using an iterative method which requires the computation of the gradient of J at each iteration:

$$\nabla J_x = 2.{}^{t}(X-X_g)P^{-1} + 2.H^{*t}(HX-R_o)O^{-1}$$

where H* is the adjoint of H.

If the operator H were linear, the theoretical solution of the minimization process would simply be the optimal interpolation:

$$VJ_x = 0 = X = X_g + P^tH(HP^tH+O)^{-1}(R_o-HX_g)$$

The cloudy observed radiances are treated in the same way as in the present operational PERIDOT analysis where AVHRR information is used to determine the cloud classes through the computation of a sum of partial synthetic radiances (in each cloud class) and the corresponding adjoint.

The first experimental results show the feasibility of the method and the convergence of the minimization process, and confirm several of the useful properties of the method, such as (a) better availability of the observation error statistics, and (b) the possibility of inserting constraints (even non-linear) and using ancillary data such as tropopause or surface data.

The physical consistency and quality of the retrieved profiles will be also studied.

A NEW INVERSION METHOD FOR TOVS DATA: NON-LINEAR OPTIMAL ESTIMATION APPLIED TO CLOUDY RADIANCES

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A new method has been developed for inverting "raw", potentially cloud-contaminated, radiances. It could be applied either as an independent retrieval scheme or as a module within the data assimilation scheme of a numerical weather prediction (NWP) system, projecting information in the measured radiances onto the vertical levels of the NWP model. The theory of optimal estimation is applied in the general (i.e. non-linear) case and this leads to an iterative, "physical" inversion scheme in which a forecast profile and its expected error covariance act as constraints. Temperature and humidity profiles, surface temperature and microwave emissivity, and cloud-top pressure and fractional coverage can be retrieved simultaneously when the approach is applied to TOVS data in individual fields of view.

In the presence of cloud, the infrared weighting functions are highly variable, which leads to a very non-linear inversion problem. The convergence and stability problems arising from this are discussed.

The scheme has been explored theoretically through calculation of the expected error covariance of the retrieved profiles and through retrievals using simulated TOVS data. It has been successfully applied to real TOVS data for a small number of cases.

GLOBAL USE OF TOVS RETRIEVALS IN NWP AT ECMWF

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Since December 1986, the 3I code (Chedin et al., 1985) has been implemented, validated and run on a global basis with the data analysis of the ECMWF. The goal of this effort is to run a five day assimilation (30 January to 3 February). The complete processing (from the level 1B raw counts) for two satellites (NOAA-9 and NOAA-10) for a period of six hours requires 23 minutes CPU on the Cray 1 XMP8 used at ECMWF.

The use of 3I at ECMWF involves the replacement of the present operational "Satems" (produced by NOAA-NESDIS in Washington, DC) used in the data assimilation with the corresponding 3I products: relative humidity and thicknesses on the standard layers. The 100 km resolution of the products (compared to the 250 km resolution of the operational Satems received at the ECMWF) has highlighted the need for screening, since we produce 30,000 soundings per analysis cycle (six hour period), whereas the analysis cannot cope with more than 20,000 soundings; therefore a strong quality control is presently being investigated.

The comparison between NESDIS products (80 or 250 km resolution) and 3I products, over three cycles of assimilation with collocated radiosondes, has shown the quality of 3I products to be at least as good as the NESDIS results. However, we need a far deeper investigation (forecasts from assimilated data, impact of the increased resolution) over a longer period (5-15 days), before drawing any definitive conclusion. A five day experiment (assimilation of 3I products) is planned for April 1988.

FUTURE INSTRUMENT REQUIREMENTS

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Remote meteorological measurements are specified by the meteorological and physics communities. They determine what needs to be measured and what spectral channels and bandwidths to select. When this set of information is specified, another set of derived requirements must be developed before a spaceborne instrument can be built and accommodated by a satellite bus. These derived requirements should dictate how the instrument will be used, how often it will be used, and what mix of instruments or channels will be used simultaneously.

In this presentation, the author will identify some of these requirements for geostationary satellites, and some criteria that might be used for specifying the parameters. Too frequently, these derived requirements are omitted and left to procurement processes to develop them. In many cases, it would be more effective if the user community specified these

requirements because they have an impact on the utility of the remotely sensed measurement sets. These derived requirements are used to define the capabilities that will be incorporated into the satellite systems of the future, and to identify the kind of support that can be supplied subsequently to the operational meteorological systems. This is a first step toward providing an infrastructure for commonality.

TOVS PROCESSING AND EVALUATION AT THE NORWEGIAN METEOROLOGICAL INSTITUTE

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HRPT information has been received at DNMI since the late 1970's, and AVHRR pictures are processed operationally. During the last year, the ITPP has been implemented at our local IBM-4341 computer. We are working on methods and software for data evaluation, and will show some preliminary results here. Our plans for the near future include (a) finishing routines for data evaluation, (b) evaluation of TOVS data quality by comparing the calculated parameters with output from our two limited area models with mesh width 50 and 150 km, and with radiosonde data, and (c) assimilation of TOVS data in the limited area models and evaluation of impact.

Our longer range plans are for operational processing and assimilation of TOVS data. DNMI will pay special attention to arctic and subarctic areas, trying to optimize operational TOVS procedures for those areas.

INTERPRETATION OF OBSERVED TOVS IMAGERY FROM SIMULATED RADIANCE FIELDS

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Multispectral infrared (HIRS) and microwave (MSU) satellite radiance data are simulated in order to better understand the relationship between observed image features and the corresponding dynamical processes which cause them. Initial and forcast fields from the Limited Area Mesoscale Prediction System (LAMPS) model are used as input to the ITPP-3 radiative transfer simulation code to generate radiances (brightness temperatures) corresponding to the 24 TOVS channels. The ITPP code has been modified to use atmospheric thermodynamic information provided by the model histories, and to include the effects of clouds, precipitation, and scan angle. The simulated radiances are compared to observed radiance fields and to model dynamic and kinematic parameters to explain the occurrence of prominent features in the multi-channel imagery.

IMPACT STUDIES OF THE PERIDOT FINE MESH SYSTEM ON THE 6 JUNE 1987 CASE

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On the afternoon of 6 June 1987, a severe weather event occurred in the southwestern part of France, causing several deaths and a substantial amount of material damage. While such a squall line is probably out of scope of the Peridot (3.5 km grid mesh) prediction, we have nonetheless performed some impact studies with the Peridot system. The results of these Peridot simulations in different contexts are presented. The best results came from a 12 GMT fine mesh analysis (as compared with a 00 GMT analysis) with all possible ingredients: a fine mesh forecast as first guess and inclusion of radiance data. Some of the predicted fields computed with this simulation have been put in a loop displaying every time step of the model. This demonstrates the use of special diagnostic fields to illustrate the model evolution. In this case, the infrared radiation computed shows high clouds in the Gulf of Biscay, which can be interpreted as an indication of squall line development. Complementary tests will begin in the near future using the 06 GMT analysis, which could have been used for an operational warning.

TRANSMITTANCE TUNING

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A series of retrieval experiments have been carried out at the ECMWF using both the ITPP-3 and the 3I method. Local biases were observed in retrievals using both techniques. Over Europe, the large bias appears to be associated with an unusual stratospheric vortex. Two months of raob matchs were obtained from NESDIS and synthetic radiances were calculated using the ITPP-3 and the 3I model. Both models were in good agreement and showed a large variation in both latitude and longitude which appear to be airmass dependent. Adjustments to the radiances reduced the bias in both retrieval systems.

DATA ASSIMILATION ECMWF

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Some changes have been made to the ECMWF system since the last conference. The satellite data processing has been modified so that only seven layer thicknesses are now used. Also, the error statistics for the analysis has been retuned. In the next six months, it is planned to add a completely revised surface analysis so that two meter temperature, humidity, snow, rain and satellite measured products such as OLR (outgoing longwave radiation) and clouds are included.

Work is also underway to convert the current optimum analysis/six hour forecast assimilation to an adjoint/variational continuous assimilation system. Experiments will begin before 1990, however, a new computer is required for operational use of this method.

DETERMINATION OF PRECIPITABLE WATER WITH THE AVHRR

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The AVHRR has two differentially absorbing channels in the 11 micron region which make up the so called "split-window". The original intent of the split window was to remove the contaminating effects of water vapor in order to achieve a better estimate of the underlying skin temperature, specifically sea surface temperature. In this paper, we extend the split window technique to estimate the transmittances in the split window, and since the primary absorber in this region is water vapor, precipitable water can then be estimated.

CATHIA - A DATA SET FOR CLOUD IDENTIFICATION AND TOVS CLOUD CLEARING

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A method for TOVS cloud clearing is described. The method uses AVHRR data collocated with the HIRS field of view. The AVHRR cloud parameters (cloud cover in the ellipse, emissivity, surface and cloud top temperature) are identified by a series of tests on channel differences. For thick clouds, the cloud top temperature is directly computed from the split window

channel measurements. For the others (cirrus, cumulus of horizontal extension less than the AVHRR resolution) a theoretical curve is fitted on the two dimensional histogram of T4-T5/T5 to obtain the cloud top temperature by extrapolation.

The CATHIA data set is composed of 150 radiosonde profiles collocated with more than 1000 cloudy AVHRR/TOVS measurements. For all the CATHIA situations, the systemtic TOVS clear-sky radiances have been computed by using the 4A radiative transfer model. By using this statistical method, the data set is intended to give the relation between AVHRR and TOVS emissivity necessary in the TOVS cloud clearing scheme.

A PHYSICALLY BASED OPERATIONAL ATMOSPHERIC SOUNDING SYSTEM FOR THE AUSTRALIAN REGION

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The Australian Bureau of Meteorology has recently implemented a physically based real time TOVS processing system. This provides atmospheric temperature and moisture soundings, and surface, ozone and cloud information for the Australian region. The scheme uses either a statistically based, or an operational numerical weather prediction (NWP) model derived, first guess for temperature and moisture fields. Numerically forecast first guess surface temperature and surface moisture fields are also used. Numerical analysis and prognosis fields are used to control the quality of the processing of radiance data into meteorological parameters. This system has been running in real time since late 1987 and results to date indicate the scheme is robust, free from gross errors, and able to produce soundings of good quality. It provides real time data to the National Meteorological Centre and research workers..

AN INTERCOMPARISON OF TEMPERATURES AND MOISTURE FIELDS DERIVED FROM TIROS OPERATIONAL VERTICAL SOUNDER DATA BY DIFFERENT RETRIEVAL TECHNIQUES

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Fields of temperature, thickness, and precipitable water from common sets of TIROS Operational Vertical Sounder (TOVS) radiance data have been previously intercompared at the Second International TOVS Study Conference. This document describes the verification statistics for that intercomparison study associated with cloud-free or clear fields of view (fov). It also provides a comparison of the statistics for these clear soundings with those associated with the clear and cloudy soundings of the previous study. From the small number of cases examined, the results point to a small increase in agreement for clear fovs between the temperatures from satellite soundings and those from the European Centre for Medium Range Weather Forecasts. When compared with raob data, the increase in agreement was not as evident in the RMS statistics, but the correlation

coefficient was generally a little larger. Overall, it would appear a small gain in skill was seen in determining temperatures from cloud-free fovs. However, a detailed intercomparison of statistics for clear and cloudy cases and, in particular, an examination of the characteristics of cloudy retrievals from both statistical and physical retrievals, must await the completion of intercomparisons from the cases cited for study during ITSC-IV.

TOVS OVER POLAR REGIONS

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Because of the lack of radiosonde stations in the polar regions, there is a great need for satellite derived temperature and moisture profiles. The Antarctic continent, which is larger than Europe, has only two radiosonde stations in its interior. Monitoring the polar atmosphere is important for assessing global climate.

Operational temperature and moisture profiles retrieved from the polar orbiting TIROS Operational Vertical Sounder System (TOVS) using statistical regression procedures have been less than satisfactory in polar regions. This is a result of several complications which include the highly variable terrain altitude of the Antarctic and the difficulty of detecting cloud contamination. The physical simultaneous retrieval approach is better suited to deal with these problems since the variables (e.g., cloudiness and terrain altitude) can be handled explicitly. In this paper, improvements are presented for using the simultaneous TOVS retrieval algorithm in polar regions. The operational calibration procedure was changed to remove polar latitude inconsistencies in the radiances observed in the various TOVS channels. The calculated atmospheric transmittance has been tuned, using gamma adjustments, to remove discrepancies between observed and calculated radiances. A special climatological profile is constructed for use as a first guess in the south polar regions (south of 60S). Results obtained from these procedures are compared to radiosonde profiles for several orbits over the southern polar regions (for December 1 and 21, 1987 and February 4, 1988) and for one orbit over northern polar regions (February 4, 1988). The retrieved temperature profiles are generally within two degrees K of the radiosonde measurements.

USE OF NOAA POLAR ORBITING SATELLITES TO PROVIDE REFRACTIVE INDEX PROFILES FOR TROPOSPHERIC DUCTING MODELLING

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In the absence of conventional data, we have been investigating the use of TOVS sounding products for providing atmospheric refractive index profiles over ocean regions. These data are used to study the likely occurrence of the ducting of radio frequency communications. While improved vertical resolution and temporal coverage is desirable, the TOVS instrument presently provides the only data available over remote regions of large geographical extent. Future developments planned for sounding instruments will improve the utility of data.

A TOVS/RAOB DATA SET FOR THE PC

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In the summer and autumn of 1987, a set of radiosonde observations and collocated NOAA-10 TOVS radiances and retrievals was archived on an IBM PC for research purposes. This data set contains roughly 10,000 intercomparisons distributed globally. Radiosonde observations are interpolated between synoptic times to agree with the time of the satellite overpass. The TOVS data is required to be within 3 degrees lat/lon from the raob location. The TOVS radiances are limb corrected. The TOVS retrieval is the NESDIS operational retrieval.

A brief description of the data structures and how to access the data follows. The files listed as TOVS#-##.dat are the data files. They are written as random access integers from BASIC and described in the text file form6000.txt. A program to read the files and plot them is given as an example. It is written in Microsoft Quick BASIC version 4. An executable file is also included. It should be run on a machine with an EGA monitor. When the program starts it will ask for a drive letter for the data files. Type the letter and return. Do not type the colon. It will then list the files and ask for the name of the data file. Type the name only (i.e. TOVS10-4.dat) and hit return. The program will then plot the first file. To see the next file, hit the right arrow. To go back, hit the left arrow. To see file 21, type 21 and return. To see the radiances, type "a". To stop the program, type number 1 to display the first record, then use the

left arrow to go to file 0. This will produce an error and exit the program. In these files, item 157 has been changed from the parameter given in form6000. It is now the retrieval type (clear, partly cloudy, or cloudy).

An ongoing TOVS/raob archive is being maintained with current data by NESDIS. For further information contact Larry McMillin. The 1987 data sets are available upon request from CIMSS. Please provide floppies or diskettes for data transfer.

AN ATMOSPHERIC CORRECTION METHOD FOR AVHRR INFRARED DATA USING HIRS/2 DATA

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Remotely sensed data from the NOAA meteorological satellites can provide very useful and important information in meteorology, oceanography and many other scientific fields, because the observation are instantaneous and periodic over a broad area of the earth. In our laboratory, NOAA satellite data are received, processed, and delivered to other laboratories and institutes all over Japan.

The remotely sensed sea surface temperature (SST) is distorted by the effect of the atmosphere. Therefore the data must be corrected to compensate for the effect of atmosphere by one of two methods. One is the "multichannel correction method", in which the effect of atmosphere is corrected by using the difference of the effect in each channel. As the condition of atmosphere changes dynamically, the correcting equations must be updated regularly. This method requires many in situ SST to update these equations. The other method is the "model correction method", which doesn't intrinsically require any in situ SST and hence the measurement error of the in situ SST is not a consideration. This latter method is good for statistical analysis of SST for wide regions and long term observations. While the atmospheric model must be elaborate, if the atmospheric vertical distribution is known, the model indicates the effect of the atmosphere exactly. In the method proposed in this paper, a standard atmosphere model is used to produce the weighting functions of each atmospheric layer. We assume that pressure and components of each layer are homogeneous (plane-parallel atmosphere). The thickness of each layer depends on the channel used. Weighting functions are used to determine the relation of each channel in each layer, and the relation is used to define the correcting equations.

TOVS PROCESSING IN THE IMK/KFK - PRESENT ACTIVITIES AND FUTURE PLANS

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In 1987, the IMK (Institut fuer Meteorologie und Klimaforschung) began processing of TOVS and AVHRR data. In addition to software developed in the Institute, the ITPP-3 (TOVS retrieval) and the APOLLO (AVHRR cloud detection) software packages are available. The main objective is to derive high quality temperature fields from satellite data for mesoscale models. Therefore, existing methods are used and new ones will be developed. The TOVS sounding techniques will be combined with AVHRR cloud detection schemes and radiosonde data to derive temperature and moisture fields of good quality. Initially, the factors limiting the vertical resolution are being studied with simulated data.

The simulated measurements are generated with the radiative transfer model which is used in the inversion scheme. Thus, the initial guess as well as the result of the retrieval may be compared to the true profile. In this way, the limitations of the vertical resolution in the measurements and the influence of the first guess on the final profile are studied. First results are presented and the relationship between vertical and horizontal resolution is discussed.

PLANS FOR TOVS PROCESSING AND DISTRIBUTION AT THE ITALIAN METEOROLOGICAL SERVICE

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An HRPT receiving station has been operational at the Italian Meteorological Service since January 1988. The ITPP-3 is being implemented for TOVS processing on a dedicated VAX system. Raw and/or processed TOVS data will be available to users in real time through a connection to the facilities in Rome, while historical data will be part of the ESA Earthnet archive. The possibility of disseminating TOVS data by means of the METEOSAT is also suggested.

OPERATIONAL TOVS DATA PROCESSING IN TROMSO

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The TOVS activities in Tromso started in 1985. The original goals were (a) to investigate if atmospheric parameters derived from TOVS were applicable as inputs to atmospheric corrections of surface observations, and (b) to increase the operational product generation from NOAA data at the Tromso Satellite Station (TSS). In 1986, the VAX version of the ITPP-3 was implemented on the VAX 730 computer at TSS. In 1987, a new version of ITPP-3 was received and, during January 1988, this version was implemented operationally. Some modifications and new developments have been incorporated into the new version.

During 1987, direct read-out TOVS data from TSS have been processed and compared to available radiosonde data from the Arctic. Results from the comparisons have been presented. An example of application of radiosonde and TOVS profiles as input for atmospheric corrections of SST data derived from AVHRR has been performed. In cooperation with the University of Oslo, a study of the atmospheric ozone content is currently underway. The satellite derived ozone contents are compared to corresponding ground measurements. For this study, one NOAA data set per day is processed.

TOWARDS OPERATIONAL USE OF TOVS IN THE NETHERLANDS

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An overview is presented of the preparatory work at KNMI to introduce TOVS data into the "Automatic Production Line" (APL) for the operational weather service. The selection of an inversion method for the TOVS radiance data is discussed. The development of the APL is briefly outlined, emphasizing the role of TOVS data in the basic system.

MESOSCALE ANALYSIS AND THE USE OF TOVS - A CASE STUDY USING 3I RESULTS

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Upper air information derived from TOVS is generally fed into a numerical atmospheric model for use in weather forecasting. This is commonly considered to be the most profitable, if not the best way, to apply TOVS data. An entirely different approach, based on theoretical work of

Sutcliffe (1947), is presented here. In this method, meteorological developments are linked to properties of the thickness field of a standard atmospheric layer. It can be applied both in manual synoptic forecast techniques and in numerical models.

For this method to be used, TOVS retrievals should be as evenly spaced as possible. This requires a retrieval method that is insensitive to the presence of clouds. Two case studies are presented in which the results of the 3I-inversion method are used to illustrate the application of Sutcliffe's theory.

TOVS ACTIVITIES IN THE DIVISION OF ATMOSPHERIC RESEARCH

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The Division is studying the use of TOVS data with particular emphasis on cloud studies and derivation of SST from combined TOVS/AVHRR data. As a first step, a version of the TOVS software is being modified for use on the CSIDA system, running under UNIX. Close links with the Bureau of Meteorology and Curtin University will be maintained.

Research into the use of combined polar orbiter data (AVHRR and TOVS) with data from the ERS-1 ATSR/M has also started. The aim is to evaluate the usefulness of combined data (from two or more satellites and two or more instruments) from retrieval of atmospheric parameters to determine satellite SST accurately.

TOVS PHYSICAL RETRIEVAL SOUNDING SYSTEM

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NOAA/NESDIS seeks to replace the current TOVS statistical regression sounding algorithm with a physical retrieval method. The physical retrieval method is based on a minimum variance simultaneous solution to compute temperature, moisture and surface parameters. An important part of the physical retrieval sounding system is the computation of first guess radiance, temperature and moisture profiles. This method uses mean profiles updated weekly for 27 geographic bins and also a first guess adjustment procedure (FGAP) based on a 28-day rotation file of selected radiosonde and sounding match ups which is updated daily. Upon determining the first guess, the retrieval covariance matrix is selected from the candidate geographic bin whose mean temperature profile most closely matches the first guess temperature. Covariance matrices (pre-computed off-line) are appended weekly to each of the 27 geographic bins based on the bin mean temperature profile. The atmospheric weighting function associated with each covariance matrix (for each bin) is also computed each week based on the bin mean temperature profile. Results generated by NESDIS indicate that the physical sounding retrieval better depicts

atmospheric gradients, particularly during active meteorological periods, compared to the regression method. The physical retrieval system is currently in the final phase of the National Meteorological Center (NMC) evaluation which is required prior to operational implementation by NESDIS.

NUMERICAL FINE MESH ANALYSIS AND INCORPORATION OF HIGH RESOLUTION TOVS

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In order to achieve an objective presentation of mesoscale frontal phenomena in a fine mesh analysis on isentropic surfaces, high resolution TOVS were used. The radiances observed by the NOAA satellite are transformed to a numerical grid and the physical retrieval (Smith) is performed. With these data the conventional fine mesh analysis is updated. Although a relapsed effect is noticed, e.g. over areas covered with transparent cirrus, the microwave soundings reveal the ability to update the numerical analysis.

From the German Front Project (the measurement period was October 1987-January 1988), the second "frontal case" of November 12, 1987 will be investigated with use of the HIRS/2 channels and the ITPP-3. We are able to run the ITPP-3 on the newly installed local area network at our institute which contains several microvax-II computers. The DeAnza Graphic Workstations, which have been added quite recently, enable the display of current numerical output. In addition to cloud displacement wind vectors derived from consecutive METEOSAT images, cloud cover statistics and IR cloud top temperature are planned in order to acquire a better knowledge of the mesoscale features (especially the distribution of moisture) in three dimensions.

PLANS FOR TOVS PROCESSING IN THE SPANISH SIVIM SYSTEM

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The Spanish National Institute of Meteorology is developing an Integrated Weather Surveillance System (SIVIM) based on the joint exploitation of satellite, radar, and other conventional data sources. One of the most important parts of the project is the Satellite Data Reception and Processing System (SAIDAS) for Meteosat, GOES-E and TIROS satellites. The processing and data management is based on the well-known McIDAS system which provides a powerful tool for integrating all types of meteorological data.

During this year, a TOVS processing system will be implemented as part of the project. Taking into account the ability of the McIDAS system to access a wide variety of data sets (NWP products, observations, imagery, etc.) and its interactive capabilities, it becomes the ideal framework for

TOVS processing, allowing TOVS retrievals to be produced in an interactive way. These retrievals will provide data for our Limited Area Model in areas with little or no data coverage (Atlantic Ocean, Mediterranean Sea, etc.). Further, they will be available for operational weather forecasting in the Regional Forecast Centers through remote McIDAS workstations. This will allow the forecasters to display and combine with other data sets, temperature and humidity profiles from TOVS, thickness charts and other derived products (stability indexes, total precipitable water, etc.).

OBJECTIVE ANALYSIS OF TEMPERATURE FIELDS OBTAINED FROM CONVENTIONAL AND SATELLITE DATA

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A high resolution objective analysis has been applied to both conventional and satellite retrieved temperature profiles to investigate differences between the two sets of data. The case study selected represents the first stages of a rapid cyclone development in the lee of the ALPS. It is found, both in statistical and qualitative terms, that satellite data are in good agreement with conventional information and that a detailed description of the temperature field at the surface is of primary importance for an accurate retrieval of satellite soundings, particularly for use in mesoscale meteorology. The time lag between the two different data sets is found to explain a consistent portion of the discrepancies and therefore a full quadri-dimensional assimilation scheme appears to be essential to pursue the investigation.

The analysis scheme (ANBO) used in this paper was originally devised for the conventional data from the ALPEX study (Buzzi et al., 1985, and Trevisan et al., 1985). It is characterized by a horizontal resolution of about 50 km, virtual potential temperature as the vertical coordinate, and an extensive use of surface data to describe the intersection of the surfaces with the ground, in particular with the orography. Due to these characteristics, this analysis has been chosen for comparing conventional and satellite upper air data. In particular, the performance of satellite data was compared with Alpex data and the influence of the surface data on the retrieval scheme was tested. The time chosen for the intercomparison is 12 GMT of March 4, 1982. This time is part of an Intensive Observing Period, during which conventional observations were intensified, and two NOAA-7 passes were available at about the same time as the upper air conventional observations.

The software used to process the satellite data shown in this article is a version of the International TOVS Processing Package (Smith et al., 1985). Some changes were made to the inversion algorithm regarding the treatment of conventional surface data and the type of bias corrections applied to calculated radiances to reach a satisfying agreement with the measured ones (Rizzi and Tosi, 1988).

Root mean square differences between satellite and conventional high resolution analysis are smaller than between satellite and ECMWF 1982 operational analysis which lacks small scale features. The two kinds of data seem compatible and it seems possible to use the satellite to fill spatial gaps in the conventional data. In this case study, the time lag between the two different data sets has very important effects which would otherwise be interpreted as an addition of information over ocean areas or errors in derived temperature profiles from satellite data in regions where the raob network is more dense.

MICROWAVE INVESTIGATIONS OF ATMOSPHERIC AND LAND SURFACE PROPERTIES

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Due to a change in the Austrian research priorities related to the European earth observation program, the remote sensing activities at the University of Innsbruck has been shifted to the microwave field. Research emphasis is on the use of active and passive microwave sensors for monitoring hydrological and climatological parameters of the land surface (snow cover, soil humidity conditions, vegetation cover) and for deriving atmospheric properties. Software has been implemented for atmospheric transmittance calculations in the microwave region. In addition to studies of land surface processes, ongoing investigations are concerned with methods for deriving rainfall patterns and cloud transmittances from multispectral microwave data. So far, the Scanning Multichannel Microwave Radiometer (SMMR) of Nimbus-7 has been used for the data base. For algorithm development and testing comparative earth surface and atmospheric data have been available for test regions in Central and Eastern Europe and in the Sahel zone. Research plans are for atmospheric and land surface applications of microwave sensors with improved spectral capabilities such as the SSM/I on board of DMSP and the AMSU.

RECENT ADVANCES IN THE RETRIEVAL OF METEOROLOGICAL PARAMETERS THROUGH THE 3I SYSTEM

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In order to improve the three-dimensional analysis of the atmospheric structure from observations of the operational meteorological satellites of the TIROS-N/NOAA series, the 3I algorithm has been refined since the last meeting of the International TOVS Working Group in the following three main directions. (a) The physics involved in handling a priori information in the pattern recognition approach to initialization of the inversion process has been improved and this has lead to better accuracy of the retrieved products. In particular, the role of the surface, the detection and impact of snow and ice, the role of the clouds in the water vapor inversion, have been studied thoroughly. (b) Through numerous applications to special situations, 3I has progressively been extended and now produces retrievals on a global scale. These applications were conducted either within international programs: MIZEX and ARCTEMIZ for polar latitudes, FASINEX and GALE for west Atlantic at low latitudes, or through cooperation with various meteorological offices: France (CMS, Lannion), Netherlands (KNMI, De Bilt), China (CMS, Beijing), Europe (ECMWF, Reading), etc. (c) The code has been improved and simplified to facilitate transfer to and use in other centers. In particular, the "educated" data set "TIGR" (TOVS Initial Guess Retrieval) has been made unique, regardless of which satellite is to be processed. Its validation, from one satellite to a new one has been greatly simplified and can now be readily accomplished by any center.

DEVELOPMENT OF RETRIEVAL OF ATMOSPHERIC TEMPERATURE PROFILES IN HUNGARY

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In the near future, a new satellite receiving station for TIROS and METEOSAT data will be operational in Hungary. Studies have been renewed to

retrieve atmospheric temperature and moisture profiles. Our first step has been to adapt the International TOVS Processing Package to our computer. Now we are comparing the different methods (statistical, physical) and we will be conducting a detailed statistical investigations. When our station starts to receive TOVS in an operational manner, we intend to process the data routinely and to assimilate the data in the national LAM NWP model. We also plan to install the ITPP software on a stand-alone PC system.

IMPROVEMENTS TO THE SIMULTANEOUS RETRIEVAL ALGORITHM

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In the formulation of the simultaneous retrieval algorithm, a non-linear term involving the product of unknown temperature lapse rate and water vapor distribution is usually neglected. As a result, the solution must be iterated in order to account for this non-linearity. In the ITPP-3 version of the software, an instability in the moisture profile above 700 mb often develops and leads to erroneously low dewpoints.

In this paper, a new formulation for the simultaneous solution for temperature and water vapor profiles is presented. It involves solving for two different temperature profiles simultaneously; one corresponding to the "dry" (i.e., CO_2) component of the weighting function and a second corresponding to the "wet" (i.e., H_2O) component of the weighting function. The water vapor profile is derived from the difference between the "dry" and "wet" profiles. The solution is exact in the sense that the equation to be inverted is linear in this form. Results achieved with the application of this new algorithm to the ALPEX data sets reveal significant improvements in the accuracy, particularly for the water vapor profiles.

SOME EXPERIMENTS WITH NON-LINEAR OPTIMAL ESTIMATION RETRIEVALS FROM RAW TOVS DATA USING CLIMATOLOGICAL CONSTRAINTS

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Experimental retrievals of temperature, relative humidity, cloud top pressure and amount, and microwave emissivity have been made using the framework of non-linear optimal estimation described by Eyre. The background profile and its covariance were calculated from local radiosonde observations. The retrievals were not strictly optimal since a truncated set of eigenvectors was used to represent the vertical covariance of the temperature and moisture profiles.

The performance of the retrieval algorithm in different cloud conditions was investigated using collocator statistics with 551 radiosondes over

eastern North America. The radiosondes and retrievals were matched to within one hour and one HIRS field of view. A comparison was also made between retrievals on the slant path and retrievals using limb-corrected data.

Not surprisingly, a large difference in mean relative humidity was observed between clear and cloudy conditions in the 1984 data. This was linked to a wet bias in clear conditions and a large dry bias in overcast conditions. Tests on 1987 data (using constraints derived from 1984) showed that these biases could be reduced by using relative humidity constraints which depended on cloud amount.

TOVS ACTIVITIES AT THE GEOPHYSICAL INSTITUTE, UNIVERSITY OF COPENHAGEN

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For some years the Arctic cyclone group at the Meteorology Department of the Geophysical Institute has performed case studies of various polar low developments in the Norwegian Sea and the adjacent waters. The conventional data available in these areas is very limited and the horizontal extent of the polar low is only a few hundred kilometers. TOVS data is more or less the only data source that can provide the required high resolution data over the ocean regions for such case studies.

In 1985, a preliminary study using the TOVS data was conducted with retrieval software made available by the British Meteorological Office. The results were very promising. It was therefore decided to process our own direct readout data from the Rudeskov Space Observatory, DMI, with the ITPP software available from CIMSS. The current research is concentrating on the use of the ITPP in the arctic areas, especially in cases involving cold air outflow from the ice pack. The special conditions in these situations require some modifications in the ITPP.

This research is carried out in cooperation with the Danish Meteorological Institute.

PROCESSING OF TOVS DATA AT SMHI

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The TOVS processing system at SMHI is based on ITPP-3. A new physical retrieval method THAP, developed at SMHI, has been included. A satellite receiving and processing station, PROSAT, now provides TOVS data in real-time. TOVS retrievals are automatically processed for selected satellite passages. The selection is dependent on satellite number and time. A number of plot programs are available for the different products. e.g., temperature and humidity, geopotential thickness, and ozone. During the next year the TOVS processing system at SMHI will be used for an evaluation

of the quality of TOVS products and for research projects where real-time data are necessary.

The data assimilation experiment with TOVS data has been carried out within the coordinated Nordic research project called HIRLAM.

THE EFFECT OF COLLOCATION RADIOSONDE ERRORS ON THE ASSESSMENT OF THE PERFORMANCE OF A PHYSICAL RETRIEVAL ESTIMATOR

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A necessary prerequisite to the development of a physical retrieval estimator is the requirement that, for a given atmosphere and observing radiometer, radiative transfer in the atmosphere can be modelled to "sufficient" accuracy.

Results from a collocation experiment indicated that the delta "corrections" for the NESDIS radiative transfer equation (rte) model are a function of air mass type. Further, because the radiosondes making up the collocation data set are, in general, not homogeneous, the resultant delta estimates are rather imprecise. As a consequence of this imprecision, the fidelity of an optimal physical retrieval scheme is compromised, although that of a regression algorithm is not so severely affected.

Proper assessment of the relative merits of both physical and regression retrieval algorithms will only be possible when a quality controlled, large homogeneous sample of radiosonde and satellite collocation data becomes available.

TOVS PROCESSING IN FINLAND AND A CASE STUDY ON TOVS QUALITY IN A DATA ASSIMILATION CYCLE

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Equipment to receive direct readout data from the NOAA polar orbiters has been installed in the Finnish Meteorological Institute. The ITPP-3 is being implemented into the VAX environment. The package will also be integrated with the data assimilation system in order to create possibilities for physical retrievals.

In a case study done in cooperation with the Satellite Branch of the British Meteorological Office, it has been demonstrated that the operational coarse resolution NESDIS retrievals tend to smooth the first guess tropopause structure in the analysis step. The locally derived LASS retrievals, which were not used in the data assimilation, have a small, but broad scale disagreement with the first guess, while small scales are well preserved from the forecast.

LIMB CORRECTIONS OF MICROWAVE SOUNDING CHANNELS

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A scheme has been developed to improve the limb correction of MSU data. The approach uses a five-day global data set from which one degree latitudinal means are produced. Separate means are generated for ocean, land and ice.

Limb correction coefficients are calculated using a multi-channel regression scheme. The results of this approach are reviewed and the implication for other sensors addressed.

RECEPTION AND USE OF TOVS DATA IN THE ANTARCTIC

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Recently data from both the TOVS and the AVHRR are being used for meteorological research at the British Antarctic Survey.

During 1988/89 southern hemisphere summer, we intend to install a VHF radio receiver at our base at Halley (75 degrees south, 27 degrees west) to receive TOVS data broadcast from the operational NOAA satellites. The data acquired with this system will be used to study the occurrence, structure and evolution of mesoscale meteorological systems in the Weddell Sea and to assist local forecasting in support of aircraft and ship operation.

Until this receiver is working, we are conducting individual case studies using data obtained from NESDIS. The TOVS retrievals are performed using a software package obtained from the British Meteorological Office. For the moment, we have ignored the well-known problems associated with performing retrievals at high latitudes, over ice or over high terrain.

One case study is presented. Between 1 January 1986 and 8 January 1986, a small low pressure system developed, matured, and decayed off the Antarctic coast close to Halley. Examination of the surface observations and radiosonde profiles from the base together with the AVHRR imagery and various TOVS products has lead us to a consistent picture of the mechanisms responsible for the system's development. The study also demonstrates that useful information is available from TOVS data, even when the conditions are far from ideal, if attention is restricted to the shape and development of thickness and total moisture fields.

THE SENSITIVITY OF A MINIMUM VARIANCE RETRIEVAL SCHEME TO THE VALUES OF ITS PRINCIPAL PARAMETERS

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The U.K. Meteorological Office has recently implemented a TOVS retrieval scheme which uses a forecast profile as a priori information in a minimum variance retrieval of temperature and humidity. Preliminary results show that the forecast guess and the retrieval are of comparable accuracy, suggesting that the retrieval is providing no additional information. If the problem is modelled correctly the minimum variance solution should be an improvement over the first guess. New estimates are obtained for the three principal parameters of the minimum variance operator: the forecast profile error covariance, the measurement error covariance, and the linearised forward model. The effect on retrieval accuracy of the incorrect specification of these parameters is simulated by using the new estimates and analogous results are obtained with real data.

III. STATUS REPORTS ON ITSC-III ISSUES

ITPP APPLICATION: AUDIT TRAIL AND CLIMATE STUDIES

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(1) Audit Trail. At ITSC-III, we made the general recommendation that central TOVS processing centers consider using a retrieval output format that is similar to that used by NESDIS. In discussing with some users their experience using NESDIS archived data, it has become apparent that just as important as the content of the retrieval output file is the documentation of the format and units of the data and any changes or updates to the file and when they occurred. For example, surface temperature can be computed several different ways and it is important to document which algorithm has been used and when that algorithm may have been updated.

(2) Literature Search. Many libraries now have excellent on-line data based for searching literature titles and abstracts for key words. In the summary of titles and abstracts (a selected list that is by no means all inclusive) that follows, the scientific and technical data base of NASA (the aerospace data base) has been searched using the key words. TOVS, HIRS, HIRS2, and MSU. Also search was the meteorological and geoastrophysical abstracts database, but found mostly duplicates, with the aerospace data base containing more references overall.

The results of the literature search is available at the Conference. Interested delegates are asked to view the document and make additions to the list of references.

(3) It is not surprising to find that the literature reflects an under-utilization of TOVS products in climate studies relative to NIMBUS, the ERBE and the AVHRR. However, it should be noted that the WMO JSC Ad Hoc Working Group Report on Radiative Flux Measurements (WMO, 1987) makes a number of recommendations on the applications of TOVS data in world climate research, including

- heating rate studies related to the surface radiation budget,
- use of the HIRS for ERB estimates (including the proposed channel 20 modification for NOAA-K, L and M) at the top of the atmosphere,
- use of TOVS data in ISCCP and ISLSCP,
- cloud cover and radiation studies.

Worthy of note in the above Report is that HIRS data produces longwave fluxes with an error of order one-third of that using AVHRR channel 5.

(4) The use of TOVS for cloud climatology studies is an area of increasing important. This aspect of addressed elsewhere in this Conference (see Clouds and Climate Report).

TRANSMITTANCES: REPORT ON THE ITRA (INTERCOMPARISON OF TRANSMITTANCE AND RADIANCE ALGORITHMS) WORKING GROUPS

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A. Chedin, Chairman of the Remote Sensing/Direct Problems Working Group of the International Radiation Commission, IAMAP, reported on the successful workshop held in Maryland in March 1986. The report is now almost ready. Three subgroups each produced a separate report:

- nadir sounding,
- limb sounding,
- microwaves.

The main conclusions were that major problems remain in the following areas:

- poor knowledge of half-width and its temperature variation,
- far wing shape,
- continuum,
- scattering,
- specific problems in microwaves.

The ITRA program and, in particular, the nadir sounding working group would benefit highly from HIS (High resolution Interferometer Sounder) data proposed by W. L. Smith. They should be made available at the time of the next International Radiation Symposium in Lille, France (August 1988). The two other ITRA groups have also planned to organize intercomparisons of calculated data with real observations (from satellites or aircrafts).

BASELINE UPPER AIR NETWORK (BUAN): PROGRESS REPORT

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At the ITSC-I (1983), the ITOVS Working Group recommended that an independent baseline sounding capability from radiosondes be established and gave strong support to the concept of a baseline upper air network. The extraordinary session of the Commission for Basic Systems (CBS) in 1983 agreed that there should be an evaluation effort prior to full scale implementation. The USA agreed to formulate the plan and to carry out the studies.

At the ITSC-III a series of recommendations were made regarding the organization and conduct of the BUAN. These recommendations and the action taken are sumarized here.

(1) "The plan should be circulated to an ad-hoc group of ITSC participants." The plan was prepared by the USA and approved by the President of CBS for distribution to WMO members. The plan was distributed to 34 members on 4

September 1987 asking for their participation at 84 radiosonde and 15 rocketsonde stations. The BUAN began operations on 15 January 1988. At present, 46 stations have agreed to participate. At the end of January 1988, 29 stations appeared to be participating.

(2) "Measurements from rocketsondes and lidar should be included and ozone measurements should be made." Rocketsonde stations have been included. Lidar or measurements of ozone have not been included.

(3) "Attention should be given to geographical coverage and climatic variations." This was done.

(4) "A sufficient sample (on the order of 60%) of coincident satellite/radiosonde soundings should be part of BUAN." The present plan is to have at least 20 coincident soundings every three weeks in each latitude zone.

(5) "The evaluation should be conducted for at least one year." The initial phase is scheduled for six months.

(6) "WMO members should be asked to investigate BUAN with respect to both physical and statistical techniques and to investigate the impact of moisture." CBS-IX encouraged the ITOVS to participate in the data analysis phase of the BUAN evaluation. The nature of the participation is yet to be decided by the ITOVS Working Group.

(7) "Participants should be advised of the performance of their systems and that of the sounders." This aspect has yet to be arranged. Centers such as at Bracknell, Paris and ECMWF routinely provide information on the performance of radiosonde systems.

(8) "Close coordination should be maintained between the BUAN evaluations and the OWSE-NA." The WMO is coordinating the flow of information between these two activities. Further steps are to be proposed to the May 1988 meeting of the Implementation Coordination Group for the OWSE-NA.

(9) "Attention should be given to the utility of the BUAN with respect to new satellite instruments." To date there has been no activity on this issue.

(10) "A special BUAN data archive should be established to operate in real time." A BUAN data archive has been established. See the status report of A. Reale on this subject.

A few items should be considered for action at the ITSC-IV. These are:

(11) Sea areas in the latitude band 45-30N need better coverage. Sea and land areas in the latitude band 15-45S also need better coverage.

(12) Procedures for ITSC participation in the BUAN evaluations need to be developed. These procedures should address which centers/organizations will be involved, what evaluations will be carried out, and for which parameters and time periods?

(13) Procedures need to be established for the routine notification of participants on the performance of their systems.

(14) The data archive file needs to be finalized and made available to evaluation participants. Information on the type and performance of the radiosondes used at each station needs to be obtained and circulated to the participants.

RETRIEVALS: USER FEEDBACK PROCEDURES

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Currently at the ECMWF, TOVS data from NESDIS is monitored continuously using the quality controlled raob data and the six hour forecast. Twice weekly, routine reports are sent via FAX to NESDIS. In the event of problems, NESDIS is alerted immediately and kept informed until the normal data quality is restored. Monthly statistics are also calculated comparing TOVS and ECMWF. Six-hour forecast errors and systematic biases can be detected.

STATUS REPORT ON THE NOAA/NESDIS ELECTRONIC BULLETIN BOARD

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The primary purpose of the NOAA/NESDIS Electronic Bulletin Board (EBB) is to provide operationally significant information concerning spacecraft or ground command station anomalies affecting signal reception. Its secondary purpose is to provide news and technical information. News topics include current or future polar and geostationary environmental satellite launch activities, short and long-term operating plans, proposed instrument changes, upcoming conferences, references to reports, search and rescue events, education and training, and electronic mail messages. Technical topics include orbital prediction data. Access to online data bases, including calibration information, will be added later. Most messages pertain to U.S. satellite activities. However, information on environmental satellite activities of other nations is solicited and added when available.

The original implementation of the EBB was a fairly simple minded message posting system which combined all of the above mentioned features. Recently, a more user friendly version of the EBB has come online. The key features of the new system include separate areas for notices and data, personalized login and read status of messages, and extensive online help.

Access to the present EBB is through TELENET. Users in the United States can call into a local TELENET number. At the word 'CONNECT', hit <RETURN> twice. At the word 'TERMINAL' type "D1" and <RETURN> . At the '@' prompt, type "CONNECT 229187" and <RETURN> . To login, type "LOGI NMARK". The password is "GLOBAL". Users outside of the United States should dial (703) 834-9700. All other login procedures are the same, except at the '@' prompt, type "CONNECT 703463". Upon successful login, the user is presented with the main menu which specifies access to EBB-A or EBB-B. EBB-A is for access to notices, mail, news, etc. EBB-B is for the online data repository. The user is asked if he has used this version of the EBB. If not, the user is requested to provide identifying information and a personal password and mailing address. The EBB Display Menu allows the user to browse through the posted message in a variety of ways, or to access the online help as required. Although the menu only offers options numbered from 1-7, there is a hidden option number 99 which allows the user to send a message.

A questionnaire as to the potential data sets to be installed on EBB-B was circulated to the ITOVS community in 1987. Suggested data sets include instrument response functions, orbital elements, synthetic radiances, calibration coefficients, limb correction coefficients, ingest parameters, instrument weighting functions, MSU antenna pattern corrections ,and sea surface temperature retrieval coefficients. As resources become available within NESDIS, many of these data sets will be made available on EBB-B.

Presently, the NESDIS EBB is physically located only in the United States. International access to the EBB can be cumbersome and expensive. Negotiations are in progress to have a copy of the EBB in Scotland as a European node. The ultimate goal is to have EBB nodes also available in South America, Australia and Japan.

VAS DATA DISSEMINATION

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CIMSS and ECMWF are engaged in an evaluation of the VAS soundings and winds. Data were processed by CIMSS for 22-26 June 1987 and forwarded to ECMWF. Daily data sets concentrated on the North Atlantic near 1200 GMT and included roughly 500 soundings and 300 winds, depending on the synoptic situation. The results of this evaluation will be forthcoming in the second quarter of 1988.

ITPP APPLICATION: CLOUDS AND CLIMATE

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Several issues have surfaced during the ISCPP which encourage the utilization of TOVS data in cloud research studies and the development of cloud climatologies. These are summarized below.

(1) The geostationary satellite data exhibits diurnal variability problems.

(2) The polar orbiter data is necessary to fill in areas over the poles and parts of the Indian Ocean, where the geostationary platforms do not provide adequate cover.

(3) Cross calibration of geostationary instruments has not been trouble free. Further, the visible radiometers are typically uncalibrated.

(4) It appears very likely that ISCPP will propose using TOVS data for several of the reasons cited above, but also because TOVS has good cloud investigation capabilities with its onboard IR channels.

The CO_2 slicing or CO_2 absorption technique (Menzel, Smith, and Stewart, 1983) has been applied to the CO_2 channels on the VISSR Atmospheric Sounder (VAS) and a two year cloud climatology has been developed for North America. Statistical data include cloud cover frequency, cloud height, IR attenuation and cloud emissivity (Wylie and Menzel, 1988).

These same procedures can be applied to local or global cloud climatological studies using TOVS radiances. The CO_2 technique is available through D. Wylie to researchers interested in cloud climate studies.

The CO_2 algorithm as implemented on the VAS has had considered success in detection cirrus clouds where other techniques often fail. Uncertainties in identifying accurate cloud heights are about 50 mbar. Cloud emissivities are accurate to within roughly .20. It is recommended that this or a comparable approach be applied to regional and global studies to develop cloud statistics at several national institutes.

MEETING REPORT: FIRST INTERNATIONAL AVHRR WORKSHOP

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The First International AVHRR Workshop was held in Melbourne at the CSIRO, Division of Atmospheric Research on October 27-29, 1986. The attendees were by invitation only and included representatives from many countries (see report for list-attached), and from NOAA/NESDIS. A report of the meeting, compiled by Dr. Garth Paltridge and Dr. Dean Graetz for the International Radiation Commission is available. The report serves as a summary of the discussions. The specific recommendations, items which are reproduced below, are, I believe, also of interest to the TOVS community.

The IRC will sponsor the next workshop, which it is hoped will be hosted by NOAA/NESDIS in Washington. A date has not yet been decided and Mr. Mike Matson (NOAA/NESDIS) has been asked to coordinate this.

(1) It is recommended that NOAA be asked to examine the question of incorporating the satellite orbital element information in the AVHRR data stream. If that is possible, it is important that information on roll, pitch and yaw should also be included.

(2) It is recommended that NOAA be asked to examine the question of updating the satellite clock more frequently - in other words, to greatly improve the current one-second accuracy of the satellite time.

(3) Certain AVHRR receiving stations suffer from interference on the S-band transmission in spite of international agreement on channel allocation. This comes about primarily from lack of knowledge of the existing HRPT transmissions on the part of the governmental authorities concerned with such matters. It is recommended that current and future AVHRR reception stations ensure that the relevant authorities in their area are fully aware of the international agreement which covers channel allocation.

(4) It is recommended that NOAA be asked to examine the possibility of incorporating TIP data in the GAC data archive.

BASELINE UPPER AIR NETWORK (BUAN) STATUS

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BUAN is an international program to augment operational satellite sounding systems with upper air radiosonde data coincident with the satellite overpass. In March 1987, the final version of the BUAN feasibility test plan (F. Zbar, WMO) was distributed. This document is an assimilation of NMC, NESDIS and WMO inputs. About 100 candidate stations (83 land raobs, 11 ships (ASAP) and stationary vessels (OSV), and about 6 rocketsondes) were identified. NESDIS was designated as being responsible for transmitting overpass information, real time processing, and evaluation of BUAN based sounding products. The WMO

responsibility was to coordinate the BUAN launch schedules with the BUAN candidate stations. NMC was given the responsibility to supplement the NESDIS evaluation with collocation studies and perhaps a numerical weather prediction forecast impact study.

The BUAN feasibility test began on January 15, 1988. At this time, the Sounding Implementation Branch (SIB) of NESDIS implemented a "test" system to process NESDIS physical retrieval sounding products using only the identified BUAN stations for tuning. Tuning includes (1) the weekly update of the small sample mean temperature, moisture and radiance profiles per physical retrieval bin (i.e., the 27 geographical categories used in the NESDIS physical retrieval sounding system), (2) selection of the covariance matrix per bin, (3) computation of the weighting function per bin based on the mean temperature and, finally, (4) the daily update of a 28-day rotating file of raob and sounding match-ups used to compute the first guess. The "Control" system for evaluation of the BUAN impact is the NESDIS physical retrieval sounding system using conventional radiosondes for tuning.

USING THE EBB FOR SOUNDING SYSTEM(S) STATUS

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Efforts have begun to use the NOAA Electronic Bulletin Board (EBB) to facilitate international awareness of NESDIS atmospheric sounding processing schemes using satellite data. A separate category has been created on the EBB which will contain descriptions of the present NESDIS sounding systems. Sounding systems from the international community are also invited for entry on the EBB. Details on procedures to use the EBB will be forthcoming.

A proposed format for describing the sounding systems is shown below.

(1) General Information
Provide general information about the satellite sounding system. Include the date of entry and identify key personnel (with address and phone number).

(2) Satellite Data Ingest
Outline procedures to routinely receive and ingest raw satellite data for products processing.

(3) Preprocessing
Outline procedures to generate radiance or brightness temperature (BT) data from raw satellite data, screen the data and other preliminary functions.

(4) Radiance/BT Processing
Describe procedures to cloud clear or otherwise adjust the radiance (or BT) data for the retrieval step.

(5) Radiance/BT Verification
Describe procedures to verify the radiance (or BT) data prior to products generation.

(6) First Guess Procedures
Describe procedures to compute a first guess for the retrieval step.

(7) Retrieval Method and Output
Describe procedures to retrieve sounding products. Indicate the products generated and include the sounding resolution, density, levels (layers), coverage, and types.

(8) Coefficient Data Sets
Identify the key coefficient data sets and their application in the processing of soundings. Indicate whether they are fixed or updated, and reference the atmospheric data bases used for their generation. For updated coefficients, briefly describe the procedures(s) and frequency.

(9) Final Quality Control
Outline procedures to screen sounding products prior to distribution (or use).

(10) Future Plans
Outline future plans and upgrades.

(11) References
List references for methods to produce sounding products.

CALIBRATION, NAVIGATION, AND ARCHIVE FORMATS: STATUS

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In response to the recommendations at the ITSC-III (see the Study Report of ITSC-III, pages 41 and 42), the following actions were taken.

(1) To resolve the calibration problems (see the Technical Proceedings of the ITSC-III, pages 235 to 242), additional information has been solicited and forwarded to NESDIS for inclusion in their revision of the NESS Technical Memorandum 107. Most of the errors and missing information discussed at ITSC-III have been resolved by the NESDIS Calibration Coordination Panel. The new NESDIS Technical Memorandum will be available shortly after the launch of NOAA H. A summary of the calibration issues will be in the Technical Proceedings of ITSC-IV.

(2) A test of navigation during July 1987 involving ARGOS (Toulouse), NESDIS (Washington), CIMSS (Madison), and CMS (Lannion) revealed 5 km accuracy for TBUS IV parameters and 2 km for ARGOS parameters.

(3) Following the recommendation of the first International AVHRR Users Conference held in Perth, Australia in 1986, a questionaire regarding archive formats has been sent to most of the HRPT receiving stations. About 20 responses have been received; more are awaited.

SOFTWARE: STATUS REPORT ON THE 3I

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The Improved Initialization Inversion (3I) System is a physical non-iterative approach developed in 1983 by the Atmospheric Radiance Analysis group at LMD (France). The initial guess is obtained through a pattern recognition approach from the TOVS Initial Guess Retrieval (TIGR) data set. The 3I system has been evaluated by the international TOVS community, at the ITSC-I to III and by the ECMWF, and its capacity to accurately restitute geophysical parameters has been fully demonstrated. The 3I system appears to be a viable baseline system for global operational implementation permitting adjustment to local environments and with tractability for research. The 3I is available to the international community.

Since ITSC-III there have been several upgrades to the 3I system. They are:

(1) extension to global scale for impact studies in NWP (at the ECMWF),
(2) better handling of surface parameters (sea ice, snow) to help in cloud detection,
(3) improved cloud parameters and H2O retrievals,
(4) a more universal TIGR data set (it is no longer specific to one satellite),
(5) easier maintenance through a delta correction procedure (instead of a delta and gamma correction procedure),
(6) a users guide of the 3I system which describes the input/output files and JCL (and includes an extensive bibliography of the scientific background),
(7) validation of the Automized Atmospheric Absorption Atlas (4A) model in the AMSU channels to generate a TIGR data set for AMSU.

Several areas that are presently receiving attention are:

(8) preparing the TIGR and the 3I system for DMSP and NOAA-11,
(9) coverging on a quality control algorithm for objective rejection of bad retrievals to meet the requirements of NWP models.

PC SYSTEMS: NEWSLETTER

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A newsletter to inform users of updates to the PC TOVS system will be initiated after the date of release of the software. The newsletter will be published on a quarterly basis and will incorporate news, updates, and convections suggested by users of the system. The newsletter will be published by UW-CIMSS.

ITPP AND PC/TOVS: FUNDING STATUS

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A non-profit corporation called Weather or Not Consultants (WONC) has been formed to support commercial versions of the ITPP and PC/TOVS software. WONC is handled as a project within the Space Science and Engineering Center (SSEC) at the University of Wisconsin. Monies derived from the software release and overhead from consultant support are to be used to fund updates to the software. Thus far no financial support has been achieved through WONC.

FUTURE INSTRUMENTS: NEW DEVELOPMENTS

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High spectral resolution ($\frac{\nu}{\delta\nu}$ 1000/1) instruments are now being considered for GOES-L and M (1996 and beyond) and the Polar Platform (the Atmospheric Infrared Radiation Sounder (AIRS)). The GOES-L/M instrument would be an interferometer (HIS design) modification of the GOES-I/J/K filter wheel instrument. The AIRS on the Polar Platform will be either an interferometer or a grating array spectrometer; the final design is yet to be determined. The GOES interferometer will enable vertical wind profiling by tracing movements of moisture in narrow vertical layers and will provide high vertical resolution temperature and moisture sounding.

TRANSMITTANCES: HIS DATA

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High resolution Interferometer Spectrometer (HIS) observations from the NASA ER2 aircraft, at a pressure altitude of 55 mb, are useful for validating the spectroscopy and numerical procedures used for atmospheric transmittance

calculations. Intercomparisons of HIS spectra at 0.5 cm^{-1} resolution with calculations using FASCODE have revealed the following:

(1) The differences between calculations and observations are usually less than 1-2% throughout most of the spectrum. Generally this is within the accuracy and representiveness of the radiosonde used to perform the calculations.

(2) The use of CO_2 concentration of 345 ppm (the current level) as opposed to 330 ppm (the default value in FASCODE) reduces discrepancies between observed and calculated radiance by as much as 0.8% in the 15mm CO_2 band region.

(3) Large discrepancies (as much as 10%) are observed in the CO_2 Q-branches due to line coupling. HIS data have been used to validate significant improvement in the handling of line-coupling in the latest version of FASCODE.

(4) There are systematic discrepancies, as large as 1%, in the atmospheric window (800-1000 cm^{-1}). These discrepancies appear to be due to absorption by freons, particularly freon 11 (CFCL3) and freon 12 (CF2CL2). The source of these discrepancies is being investigated by S. A. Clough (AER) and accounted for in FASCODE computations.

(5) There is a discrepancy between observation and calculation of the slope of the radiance spectrum along the 4.18mm band head. This discrepancy is thought to be due to the handling of the N2 continuum. Investigations to alleviate this discrepancy are underway.

A data set including both ocean and land observations with HIS and collocated radiosonde profiles has been established for the ITOVS and ITRA working groups for use in the validation of radiative transfer calculations. The IBM-PC based data set and associated data display and manipulation software is available from the CIMSS - Madison.

CLOUDS: UPDATE ON THE NEW TOVS CLOUD CLEARING SCHEME

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Since ITSC-III, a few minor improvements have been made in the TOVS cloud clearing scheme. (1) Both the visible and IR threshold checks have been made dynamic. This has reduced the number of contaminated fovs. (2) The scheme has been incorporated into the Met Office Local Area Sounding System. (3) Further validation with matched clear radiances and radiosondes at various levels showed that much more data is produced at comparable accuracy in most channels, and improved accuracy in low peaking channels. Temperature retrieval studies have not been as conclusive; retrievals over comparable fovs are marginally more accurate while they are marginally less accurate over all fovs. (3) Impact studies using the Met Office fine mesh model have been made; two showed a slight positive impact with the new scheme and one showed some degradation.

ITPP: SOFTWARE UPGRADES

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The International TOVS Processing Package (ITPP) has recently been upgraded (to version 3.2); while its nominal release date is December 1987 it includes corrections through 18 February 1988. The principal features that distinguish version 3.2 from 3.1 (released in March 1987) are the following:

(1) All software is now compatible with FORTRAN-77 standards, and in fact, must be compiled at that level. As a result, a single version of many routines (see the Software Inventory below) now serves both the IBM and VAX versions.

(2) Each FORTRAN module (main program, subroutine, function, etc.) is now written as a separate card image file on the distribution tape. This will hopefully simplify both installation for new users and ugrading for established users. In addition, the format of the "version date", contained in a comment card near the beginning of each routine, has been altered to conform more closely to international usage. The old form was DDMONYY, where MON was the three letter English abbreviation; the new form is DD.MM.YY where all three quantities are numeric.

(3) The logic associated with the new compact high resolution topography scheme, which initially contained some subtle errors, has been completely debugged and corrected; the scheme is now efficient with respect to computing time as well as disk space.

(4) To assist in dealing with MSU ingest problems such as the decreases in gain that occurred on both NOAA-6 and NOAA-9, two new routines (main programs) have been developed. Under various calibration failure conditions, subroutine INGMSU will issue messages suggesting that "XMSUIP" be used to "examine" one or more ingest parameters (stored reference values), and/or that "UMSUIP" be used to "update" or modify certain parameters.

(5) In addition to the change described in item (1), greater consistency between the IBM and VAX versions has been achieved by providing essentially the same functions in both. Previously, some programs existed in only one or the other.

(6) Logic has been incorporated into subroutines INGHIR, PRECAL, and INGMSU to account for the change of date at midnight. Otherwise, gross navigation (earth location) errors occur after the midnight-crossing.

(7) Software Inventory

IBM-specific:	62 modules,	4531 card images*
VAX-specific:	90 modules,	5620 card images
common:	161 modules,	8268 card images

* Plus four modules and approximately 1400 card images of IBM assembler source code.

IV. WORKING GROUP REPORTS

A. Working Group Report on Science

Co-chairpersons: J. Eyre and J. Svensson, with L. Lavanant, F. Olesen, J. Pedersen, A. Reale, D. Steenbergen, and M. Uddstrom contributing.

The working group identified three key problem areas affecting the quality and utility of TOVS products:

- quality of measurements
- quality of radiative transfer calculations
- inversion constraints

Most inversion schemes take the form:

$$\hat{x} = \bar{x} + W \cdot [y - y(\bar{x})]$$

where $\hat{x}$ is the retrieved (or analyzed) atmospheric profile or field,

$\bar{x}$ is the "first guess" (or "background" or "prior") value of the profile/field (and not necessarily some "mean" value),

y is the vector of measured radiances or brightness temperatures,

$y(\bar{x})$ is the equivalent vector corresponding to $\bar{x}$,

and, W is the inversion operator.

Linear inversion schemes take this form explicitly, whereas non-linear schemes involve this or a similar equation in an iterative sense.

The inversion constraints are imposed by $\bar{x}$ and W and by the form of the algorithm itself (i.e., whether it is iterative, whether it is simultaneous in all variables, etc.), and so they are inherent in all inversion schemes. In physical retrieval schemes, radiative transfer calculations are involved in the calculation of $y(\bar{x})$ and usually also in calculating some components of the operator. In purely statistical schemes, $y(\bar{x})$ and $\bar{x}$ are obtained from collocated profile and radiance measurements, thus bypassing the need for radiative transfer calculations.

The quality of the retrieval/analysis is critically dependent on quality of measurements and radiative transfer calculations, or more precisely (see above equation) on the accuracy of the difference between them. Our ability to control the quality is largely determined by our ability to monitor and validate the accuracy of $\{y - y(x)\}$.

The quality of measurements is determined by a number of factors, including:

- radiometric noise
- calibration accuracy

The quality of the "forward" or radiative transfer calculation (for a given atmospheric profile) is affected by many things, including:

- errors in spectroscopic calculations
- errors in radiative transfer models (effects of ignoring scattering, quadrature errors, etc.)

There are also errors and uncertainties in handling a number of other phenomena. These may appear either as an error in the "measurement" or in the forward calculation depending on how the retrieval is formulated: if the measurements are pre-processed to "correct" for these effects, the uncertainty appears as an error in the pre-processed measurements, whereas if the effects are treated explicitly in the inversion, the uncertainties appear as part of the forward model error. These phenomena include:

- scan angle (limb) effects
- the effects of clouds
- surface effects (emissivity and skin temperature)
- antenna pattern effects
- topography

The validation of measured and calculated radiances (and their differences) is achieved through accumulating sets of measured radiances and collocated independent measurements of profile parameters. In practice, this means radiosondes (although rocketsondes, lidar profiles and other measurements are potentially useful). It was primarily in response to the problem of radiance validation that previous meetings of ITSC stressed the importance of a Baseline Upper Air Network (BUAN). This appears to be the best available means of obtaining sufficient independent measurements with the following characteristics:

- high accuracy and known error characteristics, both in the measurement process itself and in the subsequent processing of the raw radiosonde data,
- low errors of collocation, particularly in time, through launches coincident with satellite overpasses,
- adequate coverage of all climatic regimes.

It was noted that several centres already operate routine systems for collocating radiances (and retrievals) with radiosondes. These are based on "radiosondes of opportunity" obtained via the GTS. In the absence of a BUAN, this is the only means of obtaining the collocation data base essential for either

- tuning the forward model in a physical scheme or
- computing the inversion coefficients for a purely statistical scheme.

However, the utility of such data are limited by their variable quality and lack of knowledge of the radiosonde characteristics. For these reasons, the BUAN should develop towards a system supporting a continuing set of satellite-specific experiments, providing essential operational input to all global and regional TOVS processing centres (as well as providing many additional scientific benefits).

The statistics of measured-minus-calculated radiance obtained from such a system are used to derive empirical corrections to the forward model (usually in the form of the so-called δ or γ-δ corrections). These are essential in any physical retrieval scheme; if these are not applied (and tuned as required), quantitative products of useful accuracy cannot be expected. Moreover, the corrections may be expected to be system dependent, as they depend on a number of factors apart from spectroscopic errors, including:

- radiosonde network accuracy and homogeneity
- TOVS calibration methods
- pre-processing procedures (limb correction, cloud correction, etc.)
- how the stratosphere is extrapolated above the known profile for the forward calculation
- how the surface is treated
- regional and airmass dependent differences in the effects of these sources of error.

For these reasons, operators of TOVS retrievals schemes are encouraged to establish their own systems for monitoring radiance collocation statistics.

In the field of inversion constraints, there has been considerable progress over the last few years, particularly in understanding the role and importance of the "first guess" in the inversion procedure. Two classes of approach are currently favored:

- Stratified climatology: methods in which the measured radiances are used along with a "classification" algorithm to select an appropriate "first guess" (and corresponding inversion constraint) from a large library of historical profiles, or the means of subsets of such profiles stratified or classified in some appropriate manner.

- Forecast: methods in which the constraints are provided by forecast model profiles/fields, either through direct assimilation of radiance data or separate retrieval algorithms in which a forecast profile is used. The diversity of these methods arises largely from different choices of inverse operator: some methods use expected forecast error as a constraint, while others employ minimum information theory or restricted basis functions.

(New users of ITPP should be aware that the software provided includes neither of these options internally although, if available from elsewhere, they may be interfaced to ITPP quite easily.)

Work continues to improve the specification of inversion operators. The working group noted recent progress in the following areas:

- attention to the (non-linear) humidity retrieval problem and its effect on the operator,
- the specification of appropriate "measurement error covariances," particularly the inclusion of forward model errors and the importance of considering error correlation between different radiometric channels.

Nevertheless, the group considered that the performance of retrieval methods was currently limited in practice mainly by errors in the measurements and forward calculations, rather than in the specification of the inversion operator.

Recommendations:

(a) In connection with the problems found with HIRS calibration over Antarctica, the use of the cold blackbody as a calibration target should be investigated further. The reason for HIRS channel 10 being worst affected in this respect should also be studied (H. Woolf, A. Reale).

(b) The limb correction errors experienced by the U.K. Met. Office with HIRS on NOAA-10 (i.e., worse than previous HIRS and worse than MSU) should be reported to NESDIS for investigation (J. Eyre).

(c) ITRA should be requested to initiate the use of HIS spectra to improve transmittance models (A. Chedin).

(d) The TOVS processing community should be advised of the importance of empirical corrections for high quantitative performance. NESDIS should be requested to put their corrections on the EBB (A. Reale, T. Kleespies). However, empirical corrections are often system dependent and should be monitored as part of the TOVS processing system, if possible. A "recipe book" should be written to advise users on how to monitor radiance biases and how to apply the statistics thus generated.

(e) The BUAN offers the potential for the highest quality of radiance validation. For this task, it is important that the BUAN data base include raw and limb corrected radiances, collocated radiosondes profiles, and information on the radiosonde (e.g., type of sonde, processing at station, processing at BUAN center), and that these data be archived. It was recommended that NESDIS/WMO take steps to ensure that this information is assembled and made available. It was noted that confusion existed over the criterion for an acceptable collocation in time. NESDIS/WMO should disseminate to participating countries the revised criterion (A. Reale).

(f) The working group reconsidered the scientific problem areas in relation to the development of retrieval methods and algorithms for AMSU. The following points were noted:

- Pre-launch measurements of antenna pattern should be made available in easily useable form. NESDIS should be requested to inform ITSC of their plans here (A. Reale).

- A fast forward model for AMSU channels should be made available (along with ITPP, if convenient) (H. Woolf).

- The microwave surface emissivity model proposed by Grody should be made available (J. Eyre).

- Accurate modelling of the effects on radiation of clouds and precipitation at all AMSU frequencies represents the major outstanding scientific challenge. More research effort is required in this area.

B. Working Group Report on Software

Co-chairpersons: H. Woolf and N. Scott, with T. Boehm, R. Buell, R. Dedecker, L. DeLeonibus, Z. Fengying, R. Ligi, G. Prangsma, and J. Quere contributing.

1. 3I and ITPP-3

The majority of the TOVS community have adopted, or are moving toward, physical retrieval schemes. The dominant algorithms are 3I and ITPP-3, or variants thereof. Further refinement of these procedures, and implementation by additional users, are welcomed and encouraged.

Recommendations:

(a) Develop and/or enhance documentation of the software, to assist both installation/maintenance and scientific utilization (H. Woolf, N. Scott).

(b) Encourage feedback from users to software designers, as well as information exchange among users. This will aid designers in correcting errors, which tend to become more subtle as systems age, and will also help users avoid attempting to apply procedures to out-of-range situations.

(c) Encourage self-maintenance and/or tuning by users, e.g., the delta-correction in 3I; gammas, deltas, and regression coefficients in ITPP.

(d) Users who develop TOVS product-display software under an international standard such as GKS are encouraged to share such material.

2. PC/TOVS

PC/TOVS is a special case. While it employs the same ingest, preprocessing, and retrieval algorithms as ITPP-3, it includes additional features unique to the PC environment: a menu-driven user interface, an extensive retrieval-product generation, manipulation, and display functions. Implementation of this system has the potential for greater difficulty than the mainframe version, owing to memory and disk-space constraints, the existence of many different versions of compilers and linkers, and possible compatibility problems if using an IBM "clone" or "work-alike." Support for such a system is likely to be more labor-intensive than for the mainframe version.

Recommendations:

(a) Determine if there is likely to be sufficient demand for the PC-TOVS package to warrant creation of the necessary supporting infrastructure (W. Smith).

(b) If answer to (a) is "yes," determine if that demand is accompanied by willingness to provide financial support.

(c) If answers to (a) and (b) are "yes," establish a small number of test sites, i.e., users who are willing to implement the system "as is" and assist in bringing it up to "marketable" standards.

(d) Determine if the number of potential AT users is sufficient to warrant retention of EGA-level graphics (as opposed to upgrading to VGA, which is unique to the PS/2).

(e) If a user community develops, assess data requirements. Possible scenarios include:

- test or case-study data sets, distributed via diskette;
- routine updating of data on McIDAS, for access via dialup;
- description of ingest input-file structure adequate to allow user to construct interface to a real-time data stream, as in ITPP.

3. ATOVS (AMSU + HIRS-3)

It is not too soon to start thinking about, and planning for, the next generation of polar-orbiting sounders. Some of the issues that need to be addressed include decommutation of raw data stream; calibration; navigation; precipitation screening; cloud clearing; cloud water correction; surface effects; parameters to be retrieved and algorithms to be employed; and so on.

Recommendations:

(a) Determine if there is desire and/or need for an International ATOVS Processing Package.

(b) Even if answer to (a) is "no," determine if there are areas where developers of individual systems, e.g., the vertical coordinate (number of levels and associated pressures), data structures, core algorithms such as forward radiative transfer (fast transmittance, in particular), etc.

(c) Attempt a division of labor, to avoid duplication of effort on the one hand, and excessive burden on a few individuals/ institutions on the other.

C. Working Group Report on Applications

Co-chairpersons: G. Kelly and G. J. Prangsma with T. Boehm, J. Eyre, J. Flobert, J. Giraytys, G. Heinemann, M. Homleid, J. LeMarshall, F. Loechner, A. Reale, G. Rochard, M. Steffenson, J. Svensson, M. Uddstrom, and S. Uppala contributing.

1. Case Studies

The ALPEX case study, used in past intercomparisons, has now become an important meteorological situation to test new retrieval methods. Several papers presented new results using this case. Several members of the group requested a new ECMWF analysis of this ALPEX case (based on the current operational code).

As suggested at ITSC-III, two new case studies will be available. The TOVS data will be in a similar format as before and the European case will also include AVHRR data. John LeMarshall has agreed to evaluate the retrieval

quality and will provide an updated file format. It was suggested that layer mean temperatures be compared to radiosonde rather than level temperatures.

The following case studies have been selected for investigation:

- June 7, 1987 - north coast of Spain (from La Coruna to Santander) and southwest France.

This case is of particular interest because of the severe weather that followed. The initial system development occurred over the ocean. It is also hoped that improved TOVS retrievals will have a positive effect of NWP forecasts for these coastal regions.

- February 8-13, 1987 - tropical storm Jason north coast of Australia

This case was chosen during the AMEX experiment which involved a very intensive observation program in the north of Australia. At present, there has been no ITSC comparisons of retrieval method in the low latitudes.

Recommendations:

(a) Details of available dates and data sets to be provided (J. LeMarshall).

(b) Data for the ALPEX case is to be made available by CIMSS (H. Woolf).

(c) Data for the June 7 case is to be made available by Lannion (G. Rochard).

(d) Data from the AMEX case is to be made available by BMRC (J. LeMarshall).

(e) ECMWF will provide the analyses for these cases to CIMSS and BMRC (G. Kelly).

2. Synoptic Use of TOVS Analyses

Some interesting results on the use of TOVS analyses in an (operational) synoptic context have been presented at ITSC-IV. Since this type of approach offers some insight for early warning methods in operational meteorology, it should be pursued.

Recommendation:

(a) Such synoptic use should be further assessed in connection with the proposed case studies, especially the 7 June 1987 case study (G. Prangsma).

3. Numerical Weather Prediction

There have been several new activities following the last ITSC meeting. The first is that there are a number of European NWP groups experimenting with high resolution TOVS (3x3 HIRS pixel) data and they plan to use high resolution TOVS in their operations. A number of NWP centres are studying the direct use of radiances in the context of variational analysis and incorporating the adjoint of the forecast. Finally, an understanding of the

errors of the forward radiance calculation has become an important problem area which requires more work.

It is also becoming evident that as the accuracy of NWP models in the Northern Hemisphere improves, the present vertical resolution of current sounding instruments (HIRS plus MSU, VAS or AMSU) is a limiting factor in demonstrating their impact on NWP. Therefore, new instruments such as HIS and AIRS may only offer the only hope for improved NWP forecasting in much of the Northern Hemisphere.

Several papers reported NWP assimilations using TOVS and it is evident that most numerical analysis methods correctly take into account the satellite retrieval of vertical resolution and horizontally correlated errors. These error properties were discussed and a summary of the statistics, used at ECMWF, will be contained in the proceedings. There was also some concern by the ECMWF about the lack of forecast impact to TOVS data in the Northern Hemisphere. It was considered that the lack of impact may be due in part to poor quality retrievals arising from contamination by rain or cloud. A project is underway to develop new methods of quality control for satellite retrievals. The French, British and HIRLAM NWP groups are either in the process of or have conducted satellite impact experiments. These will be reported in the next meeting.

The French "PERIDOT" system, which has been operational since 1985, uses raw HIRS and MSU observations in its O/I analysis. To further improve the use of radiance data, a new analysis assimilation system is being developed jointly by the French and ECMWF. The analysis will use a variational approach and will be combined with a new forecast model and its adjoint using methods developed by Talagrand, LeDimet, Lorenc, Lewis, and Derber.

A major area of concern to this project is the accuracy of the forward model. At present, empirical adjustments are made using radiosonde data. It was shown, using several studies, that adjustments are required locally and also as a function of time. Hence, it is difficult to apply these corrections in data sparse areas.

Recommendations:

(a) It was recommended that results of NWP impact of TOVS be discussed. Various centres - ECMWF, France, HIRLAM, Norway, UK, U.S. and Australia should provide results (G. Kelly).

(b) At present, there are several versions of the basic NESDIS forward model. It is suggested that version of J. Eyre's be used as the standard together with the associated gradient calculations. Eyre also has produced some useful documentation of the programs (J. Eyre, H. Woolf).

(c) Quality control of satellite radiances and retrievals is becoming extremely important because of numerical analysis systems moving to higher resolution. It is important that the error estimates and first guess information be included and that special effort be made to identify possible sources of errors during preprocessing (A. Reale).

3. Baseline Upper Air Network (BUAN)

The importance of validating the forward radiance models and also the derivation of tuning parameters for these models has been discussed. Unfortunately, these models need to be adjusted in both space and time, otherwise large biases occur in satellite retrievals.

ITSC-III produced a detailed plan for the scientific and technical evaluation of the BUAN project. The USA via NESDIS, following a recommendation of CBS (WMO) have now completed a six month BUAN trial; however, to date little information has been received from NESDIS concerning the format of the data or how the data tapes can be obtained. It is also understood that the radiosonde data used in the BUAN was not quality controlled by either of the Global Assimilation Systems (GAS) at NMC (Washington) or ECMWF.

This project has involved many countries and required extra expenses in launching special radiosondes. It is therefore important that a wide distribution of a selected subset of the BUAN tapes be made in order that the research can be done to improve the quality of TOVS retrievals.

Recommendations:

(a) NESDIS provide details of the current BUAN experiment to major centers together with a file description and an explanation of both the radiosonde and radiance processing (A. Reale, J. LeMarshall).

(b) Several major centres should provide their six hour forecast and the BUAN radiosonde locations in order to enable some independent quality control (G. Kelly).

(c) The data from selected BUAN days should be available to the TOVS users at a low cost (A. Reale, P. Menzel).

(d) The TOVS activity using BUAN should be coordinated with the WMO radiosonde intercomparison program (J. LeMarshall).

D. Working Group Report on International Activities

Co-chairpersons: J. LeMarshall and J. Giraytys with G. Kelly, M. Lynch, J. Morgan, P. Pagano, M. Perrone, R. Rizzi, and W. Smith contributing.

1. Polar Orbiting Satellite/Platform Considerations

Several items concerning the characteristics of the future polar orbiting satellites/platforms are addressed below:

a. Identical operational sounding instruments on the two polar platforms.

The operational use of data from different instruments on the polar orbiters, resulting in differences in areas such as data formats, data types, error characteristics and communication links would result in increased data processing difficulties and would jeopardize present efforts to encourage the use of data by as wide as possible a community. The use of the same sensors on the different polar platforms would allow the data to be processed to

produce geophysical parameters using well documented softwares to facilitate the full use of the data.

b. Direct readout.

Direct readout from polar orbiting satellites has allowed regional meteorological centers to process high resolution image and sounding data directly, and enabled intense use of the data. The need for direct readout is of particular importance for nowcasting purposes, where reducing the delay between satellite pass and data availability is of particular importance. Direct readout is also of importance for synoptic analysis, high resolution numerical weather prediction, and the development of algorithms to generate geophysical parameters.

c. Direct readout transmissions.

The concept of direct readout for satellite data enables the deployment of a network of user receiving stations that can be operated without sophisticated ground infrastructures. This is the case today for HRPT and APT stations. This concept should be maintained for future polar platforms and, in order not to jeopardize the investments already made both in hardware, software, training and education, present user stations with limited alterations or upgrades should be able to continue to receive data from future polar orbiting platforms. In particular for direct readout, the adherence to an S-band down link is required, with a bit rate similar to today's transmission rates.

d. Operational use of important experimental instruments.

Past experience with experimental instruments has shown that particular sensors which could have evolved into operational use have not had the opportunity. This was demonstrated by some of the experimental instruments flown on Seasat and the NIMBUS series satellites. The polar platform concept will allow operational and experimental instruments to be flown side by side. This approach will permit routine comparisons of the performance and products from both these classes of instruments. Following a suitable period of evaluation, this configuration will provide a unique opportunity to allow use of data from suitable experimental sensors by operational groups.

e. Basic processing packages for future operational (and research) instruments available through direct readout.

Sounding data received from today's operational instruments via direct readout are used routinely for synoptic analysis and as input to numerical weather prediction models on both the regional and global scale. The number of users of these data has been increasing primarily due to the availability of software packages such as ITPP and the 3I, which allow production of sounding data without undergoing the full development of the processing software. As experience has shown, the use of satellite data is enhanced if users can operate without the necessity of full development of processing algorithms. Further, it is important that basic software packages to ingest and process raw satellite data are provided to users for future operational instrumentation, and possibly for selected research instruments. This could involve the agencies responsible for satellite data processing in coordinating

the production of software packages by encouraging the formation of appropriate working groups.

Recommendations:

(a) That identical operational sounding instruments, or selected experimental instruments which may be used operationally after a period of evaluation, be flown on the two polar orbiting satellites/platforms.

(b) That direct readout be maintained on the operational meteorological polar orbiting satellite.

(c) That the S-band direct readout be maintained to allow continued use of present groundstations.

(d) That the data from selected experimental instruments shown to be operationally useful should be made available for operational use.

(e) That agencies responsible for satellite data processing should coordinate the production of data processing packages by encouraging the formation of appropriate working groups.

2. Future Geostationary Considerations

At ITSC-III, a recommendation was made that operational satellites should carry both infrared and microwave sounders because of the complementary nature of these instruments. The dramatic benefit offered by the presence of vertical sounders on board geosynchronous platforms has been emphasized as well as the importance of a maximal vertical resolution. It was also recommended that these instruments be of higher vertical resolution than the existing HIRS because of the present and future requirements of NWP. In essence, the ITSC has stated a requirement for both IR and microwave sounders to be flown in geostationary orbit for effective monitoring of severe weather, for use in NWP, and for other applications. Extensive scientific studies for both a high resolution IR sounder and a microwave sounder for geostationary orbit have already been completed and testing and evaluation of experimental IR instruments is already under way. Given the technical difficulty and cost of developing a microwave instrument which will have operational impact, it is important that a data study be undertaken for such an instrument, preferably evaluating it in company with other data such as that from the infrared sounder and AMSU-A and AMSU-B.

Present scientific studies also indicate that, while the design of infrared sounders (interferometers, etalons, spectrometers, etc.) is well advanced, only limited consideration has been given to some instrumental alternatives for microwave sounders. For example, only dish antennae appears to be receiving any real consideration for use from geostationary orbit.

For future operational activities, it is also desirable that several important scientific issues associated with sounding in the microwave areas be further resolved. In particular, the effects of hydrometeors on the high frequency microwave sounding channels currently under consideration for use from geostationary craft could be resolved by aircraft campaigns. As a result of these deliberations, several recommendations have been made.

Recommendations:

(a) That a study be undertaken to evaluate the impact of sounding data (e.g., in 4-D assimilation) from proposed geostationary microwave sounders, particularly when the data is used in conjunction with other data such as that from AMSU-A and AMSU-B, and SSM/T.

(b) That both high vertical resolution IR and microwave sounders be flown together in geostationary orbit as soon as possible for system testing and evaluation.

(c) That intensified airborne campaigns for microwave imagers/sounders be undertaken to assist in solving remaining scientific problems.

3. Improved Access to the Sounding Data Base and Education and Training for Local Readout Processing and Use of Sounding Data

The generation of satellite soundings and related products from radiances is complex, not fully standardized, and not fully documented. The sounding data have been incorporated into the forecasting process in several ways: broadscale NWP, local forecast systems through the use of interactive systems, and now, by the use of PC-based technology.

Several steps are required to increase the availability of sounding data internationally and to provide a better basis for understanding its characteristics. These steps are generally divided into three categories:

- education through workshops and technical conferences,
- standardization of user packages,
- providing better access to data bases.

There has been a rapid increase expansion in the number of users of satellite measured radiance data and in the generation of products from satellite sounding data. As a result of the distribution of both the ITPP packages and more recently the 3I package, centers have been able to tailor the retrieval process to local circumstances. In several instances, the "locally tuned" retrieval schemes are producing results at least as good as the soundings disseminated over the GTS from NESDIS, while producing higher horizontal resolution.

The utility of the sounding data is such that developing countries are becoming increasingly involved with producing and using retrieval data, especially through the use of interactive systems and/or PC-based systems. The spread of the capability to produce soundings has moved ahead of the distribution of information about the characteristics of the physics behind the retrievals. The lack of understanding has led to the misuse of the sounding data, and disappointment in the results. As a result of these considerations, several recommendations can be made.

Recommendations:

(a) That the WMO examine the possibility of holding a workshop or technical symposium on the availability of satellite sounding data, the physical base

for the retrieval process and the impact of sounding data in forecast systems. Such a symposium might be held in conjunction with the meeting of the CBS, particularly in view of the fact that CBS-IX requested a full demonstration of the PC-based retrieval system (J. Giraytys).

(b) In addition, the ITSC recommends that a demonstration package be developed for use on a portable PC system which could be used to explain the basic principles of retrieval techniques and the utility of satellite sounding data (R. Dedecker).

4. Standardization of User Packages

The generation of products based on satellite sounding data can be divided into several modules. They include: data ingestion and preprocessing, earth location and calibration, generation of soundings from radiances, preparation of products and incorporation into NWP.

Each of these modules involves a substantial amount of data processing including the use of ancillary data. There is a requirement to standardize these modules where possible and coordinate the extension and documentation of this basic set of routines. At present, there are various ways to produce soundings from the same basic set of radiances. A first step in making the sounding data more useable would be to identify a minimum set of output products useful to one or more categories of users, and to standardize the procedures for generating these products.

Recommendations:

(a) That this Working Group define the modules involved in producing a minimum set of output products, and provide the extension of the documentation of this basic set of modules.

5. Access to Data Base

Satellite sounding data bases exist at several centers throughout the world. It is possible to provide access to such data bases, e.g., through satellite communications. One example might be through the MDD mission or the use of the AUSSAT and the Australian Bureau of Meteorology's ARM system, i.e., use a commercial telecommunication satellite. Such access would allow developing countries to obtain both soundings and products based on soundings. This could be a basis for introducing the data into a national program.

Recommendation:

(a) That this Working Group prepare a position paper on how satellite sounding data bases might be shared and exchanged.

APPENDIX A. AGENDA FOR THE ITSC-IV

Agenda for the Fourth International TOVS Study Conference
Igls, Austria
16-22 March 1988

Wednesday, 16 March (at Congress Centrum in Igls)

8:00 - 9:00 am	Registration
9:00 - 9:30 am	Welcome (Chedin) History of ITOVS Workling Group (Rizzi) History of Sounding Science (Smith)
9:30 - 9:45 am	Review of Agenda (Chedin)
9:45 - 10:00 am	Summary of ITSC-III (Lynch)
10:00 - 10:30 am	Summary of CBS-IX (Giraytys)
10:30 - 11:00 am	Coffee Break
11:00 - 12:30 pm	Remaining Problems for the ITOVS Working Group (Chedin, Eyre, Giraytys, Smith)
12:30 - 1:30 pm	Lunch
1:30 - 2:30 pm	Brief Presentation of New Case Studies Northern Hemisphere (Chedin) Southern Hemisphere (LeMarshall)
2:30 - 3:00 pm	Update on NOAA KLM and Beyond (Reale)
3:00 - 3:30 pm	Coffee Break
3:30 - 5:00 pm	Demonstration of ITPP on PC (Dedecker)

Thursday, 17 March

9:00 - 12:30 am	Presentation of Participants (chaired by Rizzi) (each speaker has up to 15 minutes)
Coffee Break around 10:30 am	AUSTRALIA (2) AUSTRIA CANADA (1) CHINA-Beijing (2) DENMARK (1) FINLAND FRANCE (4) FRG (2) HUNGARY (1)

12:30 - 1:30 pm Lunch

1:30 - 5:30 pm Presentation of Participants (chaired by Svensson)

ITALY (1)
JAPAN
KOREA (1)
Coffee Break around 3:30 pm
NEW ZEALAND (1)
NORWAY (2)
SPAIN
SWEDEN (1)
UK (4)
USA (4)

Friday, 18 March

9:00 - 12:30 am Status Reports on Action Items (chaired by Lynch)
(each speaker has up to ten minutes)

ITPP
- documentation (Woolf)
- S/W upgrades (Woolf)
- S/W summaries (Reale)
- Q/C procedures documentation (Reale)
- user feedback procedures (Kelly)
- Sounding Research Panel update (Reale)

Coffee Break around 10:30 am

Transmittance
- ITRA (Chedin)
- HIS (Smith)
- Gammas/Deltas (Woolf)

Sensor Calibration
- ITT/JPL/NESDIS feedback (Rochard)
- improved MSU processing (Rochard)
- International AVHRR Conference (Lynch)
- raw and cal comparison tapes for new users (Rochard)
- data storage format (Rochard)
- using EBB (Kleespies)
- TOVS on EBB (Kleespies)

12:30 - 1:30 pm Lunch

1:30 - 5:00 pm Status Reports on Action Items (chaired by Eyre)

Clouds
- single spot techniques
- AVHRR help in TOVS cloud clearing
- cloud classification data sets (Rochard)
- clear only intercomparison (LeMarshall)
- cloud product validation (Phulpin)

PC Systems
- newsletter (Smith)
- processing news on EBB (Reale)
- ITPP and PC/TOVS funding status (Smith)
- TOVS/Raob data for PC (Reale/McMillin)

Coffee Break around 3:30 pm	Future Instruments position paper (Chedin) new developments (Smith) spectral changes for NOAA-KLM (Smith) Soundings in NWP direct assimilation of radiances (Durand) data compression system distribution of global 3x3 (Reale) guess profile indicator (Reale) VAS dissemination (Kelly/Menzel) Climate audit trail (Lynch) cloud climatology (Menzel/Lynch) BUAN ITSC participation in evaluation (Giraytys)
5:00 - 5:30 pm	Working Group Formation (Smith, Chedin)
Saturday, 19 March	Working Group Meetings
Sunday, 20 March	Working Group Meetings
Monday, 21 March	
9:00 - 12:00 am	Geostationary Satellite Plans for the Future (chaired by Smith) Purpose of International Geostationary Experimental Satellite Goals for Working Group (Smith) Planned Future Geostationary Satellite Programs GOES-I/M Sensors (Koczor, Knorr) Second Generation Meteosat Sensors (Chedin) Geoplatform (Wilson) New Science/Technology Opportunities IR Sounding/Imaging (LaPorte, Smith, Goldshlak) Microwave Sounding/Imaging (LeMarshall)
12:30 - 1:30 pm	Lunch
1:30 - 3:00 pm	Working Group Meetings
3:00 - 5:30 pm	Reports of the Working Groups (chaired by Chedin)
Tuesday, 22 March	
9:00 - 10:00 am	Reports of the Working Groups (chaired by Chedin)
10:00 - 10:30 am	Coffee Break
10:30 - 12:00 am	Discussion of Recommendations (chaired by Giraytys)
12:00 - 1:00 pm	Lunch
1:00 - 2:00 pm	Executive Summary (Chedin)

2:00 - 3:00 pm Discussion of Future Plans (chaired by Chedin)

3:00 - Adjournment

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APPENDIX C. SIGN UP LISTS

At the ITSC meetings, a number of the participating groups shared processing software and data sets. The "sign-up lists" for the various scientific and technical information at ITSC-IV included:

- 3I system users guide,
- documentation or recent revisions to the ITPP software (denoted ITPP-3.2),
- an upgraded version (ITPP-4) of the CIMSS TOVS software which will incorporate an improved water vapor retrieval scheme and a cloud height algorithm,
- the Cathia Data Set comprising AVHRR and TOVS data with collocated radiosonde profiles and the associated synthetic radiances,
- personal computer compatible software and data sets comprising global match-up of radiosonde and TOVS radiances,
- a computer code listing of a multispectral (CO_2 slicing) technique for incorporation into the ITPP software for cloud top height determination,
- a limited scope literature review on the application of TOVS data to climate studies,
- report on the ITRA workshop at the University of Maryland, March 1986,
- personal computer compatible software and data set for processing field measurements from the High resolution Interferometer Sounder (HIS).

APPENDIX D.1. ITPP-3 USER LIST

ITPP-3 exists in an IBM and a VAX compatible form. Three upgrades of ITPP-3 (3.0, 3.1, and 3.2) have been distributed in the past two years. The VAX form of ITTP-3.0 has been documented in a CIMSS Report entitled "Documentation of the TOVS Bangladesh Data Processing Software" (Nelson, 1985). To date, ITPP-3 has been sent to 47 users. The list of recipients and country affiliation follows (I stands for IBM and V stands for VAX):

Aoki	I&V	Japan (Tokyo)
Baranski	V	Poland (Krakow)
Bates	V	California (Scripps, San Diego)
Billing	V	West Germany (Berlin)
Boehm	V	West Germany (German Weather Service, Offenbach)
Cannizzaro	V	Italy (Telespazio, Rome)
Diaz	I	Chile (Santiago)
Emery	V	Colorado (CU, Boulder)
Eyre	V	United Kingdom (Hooke Institute, Oxford)
Farrelly	V	Norway (Bergen)
Fedor	V	Colorado (ERL, Boulder)
Hansen	I	Norway (Solheimsviken)
Hillger	V	Colorado (CSU, Fort Collins)
Hoque	V	Bangladesh (SPARRSO, Dhaka)
Huang/Yen	V	R.O.C. (Taipei)
Jedlovec	I	Alabama (MSFC, Huntsville)
Kelly	I	United Kingdom (ECMWF, Reading)
Khanna	V	India (New Dehli)
Kleespies	V	Massachusetts (AFGL, Bedford)
Lai	I	Singapore (Met Service)
LeMarshall	I	Australia (BMRC, Melbourne)
Loechner	I	West Germany (DFVLR, Oberpfaffenhofen)
Lutz	V	West Germany (Cologne)
Lynch	V	Australia (Perth)
Ma	I	P.R.C. (CMB, Beijing)
Murthy	I&V	India (Ahmedabad)
Olesen	V	West Germany (Karlsruhe)
Pagano	I	Italy (Italian Met Service, Rome)
Pedersen	V	Norway (Tromso)
Putsay	V	Hungary (Budapest)
Rochard	I	France (CMS, Lannion)
Riosalido	I	Spain (Madrid)
Rizzi	V	Italy (Bologna)
Sarukhanian	V	Switzerland (WMO, Geneva)
Shin	V	Canada (Univ. of British Columbia, Vancouver)
Steenbergen	I	Canada (AES, Toronto)
Steffensen	V	Denmark (Copenhagen)
Stetina	V	Maryland (GSFC, Greenbelt)
Sunde	I	Norway (Norwegian Met Institute, Oslo)
Svensson	V	Sweden (SMHI, Norrkoping)
Tsui	I	California (NEPRF, Monterey)
Turner	V	United Kingdom (British Antarctic Survey, Cambridge)
Uddstrom	V	New Zealand (New Zealand Met Service, Wellington)
Uppala	V	Finland (Finland Met Institute, Helsinki)
Yamasaki	V	Brazil (INPE, Sao Jose dos Campos)
Young	I	Louisiana (LSU, Baton Rouge)
Zhou	I&V	P.R.C. (IAP, Beijing)

APPENDIX D.2. 3I-SYSTEM USER LIST

To date, the 3I-System has been distributed to 12 institutes; they are:

France:	EERM/CMS (Apr 1987)*
	University of Strasbourg (Jan 1988)
	CRPE/CNET (June 1987)
Netherlands:	KNMI (Jan 1987)
UK:	ECMWF (Dec 1986)
	British Antarctic Survey (Jun 1988)
Japan:	Institute of Industrial Science/Univ. Tokyo (Jun 1988)
FRG:	Inst. fur Meteor. Clim. Res. Karlsruhe (Jun 1988)
	Meteor. Int. Univ. Bonn (Jun 1988)
	German Weather Serv. Offenbach (Jun 1988)
USA:	Scripps Institute (Jul 1987)
PRC:	CMS Beijing (Apr 1988)

*date software made available

APPENDIX E. WMO RAPPORTEUR'S REPORT

Report on TOVS Data Retrieval Methods to CBS

Rapporteurs: J. Le Marshall and P. Menzel

Date: 28 January 1988

Preamble

This report largely summarizes the findings of the International TOVS (TIROS Operational Vertical Sounder) Working Group and foreshadows future developments in the satellite sounding area. It also contains some recommendations for CBS consideration.

1. Introduction

The International TOVS (TIROS Operational Vertical Sounder) Working Group, a committee of the International Radiation Commission, is studying the derivation, quality, and applicability of satellite derived temperature and moisture profiles for operational meteorological purposes. The ITOVS Working Group has met every eighteen months since the autumn of 1983 and has approximately 80 participants representing 20 countries. Each International TOVS Study Conference (ITSC) has produced a Study Report and also a Technical Proceedings which have been distributed to the WMO. These meetings lead to recommendations offered to the WMO members regarding better use of sounding data (and more generally satellite data).

This report to the CBS will attempt to summarize the more relevant ITOVS findings, indicate future developments, and make recommendations for CBS consideration.

2. Data Reduction Techniques

a. The Techniques

Three basic types of data reduction techniques are used at present in research and operations to process TOVS measured radiances into meteorological parameters. The first type are the statistical retrieval techniques which are based on a linearization of the radiative transfer equation to relate TOVS measured brightness temperatures to atmospheric temperature and moisture values, usually with respect to a given mean state. The second type are the physical retrieval techniques which provide a full solution to the radiative transfer equation using a first guess; this offers the simultaneous solution of temperature and moisture profiles along with surface skin temperature and cloud height and amount. Lastly a third type of techniques, recently under development, use the raw or cloud cleared radiances directly in various meteorological analysis schemes to produce meteorological fields. In addition, several reduction techniques similar to these three types have been designed to incorporate Advanced Very High Resolution Radiometer (AVHRR) data to enhance the retrieval process by locating clouds accurately, estimating surface and cloud temperatures, and determining cloud heights and amounts.

b. Comparison of the Techniques

Recent intercomparisons of fields of temperature, geopotential thickness, and precipitable water vapor from statistical and physical

techniques show similar results when compared to radiosonde data or ECMWF (European Center for Medium Range Weather Forecasting) analyses. RMS temperature differences were close to two degrees Kelvin (2K) in the mid troposphere (700-400 mb) with respect to radiosonde measurements, and these differences increase to 3K or 4K near the tropopause. Larger differences were seen at the tropopause and the earth surface, where the TOVS infrared measurements offer little additional information. Near the surface the differences appeared to be strongly dependent on the use of conventional surface data in the retrieval scheme. The differences cited in this study are not solely due to retrieval error, as they also include contributions due to radiosonde error, collocation differences in time and space, and analysis error.

c. Conclusions

This intercomparison study included atmospheric soundings from eleven institutes around the world. Overall, it was evident that a uniformly high standard of retrieval skill has been established on an international level. This suggests that the goal to optimize and standardize TOVS processing procedures, so as to provide accurate and uniformly consistent soundings to the meteorological community, is rapidly being achieved. The ITOVS Working Group will continue its efforts in this direction.

The statistical retrievals require limited computing resources and are capable of providing fast, efficient, and accurate retrievals. They will continue to be useful in both nowcasting and weather analyses. They are especially well suited to the local problem, where statistics can be gathered that are very representative of the local conditions. However, amongst other favorable characteristics, the physical retrievals show indications of increased skill in the retrieval of moisture and, given the importance of moisture distribution for numerical weather prediction, they are thus favored for operational use. The direct use of radiances in numerical analysis schemes shows early promise, but further research is required to prove the value of this approach.

The International TOVS Processing Package (ITPP), developed and distributed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS), has been the main vehicle for testing and developing retrieval techniques by the international community. It serves as the framework for operational implementation and for research improvements at 37 different institutions. The ITPP has been packaged into a modular form to facilitate the addition of recently developed techniques and adjustment to local environments. Contributions to the ITPP are coming from many institutes and it is truly an international package. Other institutes have developed their own processing packages apart from the ITPP, but these are currently not as widely distributed. The ITOVS Working Group considers the ITPP to be a most useful starting point for new users of TOVS soundings.

3. Applications

a. General Applications

TOVS observations measure the key atmospheric variables of temperature, moisture, surface temperature, and cloud parameters and hence

are useful for a large range of applications. In essence, TOVS data may be used for:

(i) subsynoptic scale temperature and moisture analyses for (severe) weather monitoring and prediction;
(ii) subsynoptic scale analysis of surface temperature;
(iii) subsynoptic scale analysis of atmospheric stability;
(iv) subsynoptic scale updating of aviation grid point temperature and wind fields;
(v) estimation of the cloud height and amount;
(vi) estimation of tropical cyclone intensity, maximum wind strength, and central position; and
(vii) estimation of total ozone amount.

A few of these applications are highlighted in the subsequent paragraphs.

b. Use in Numerical Weather Prediction

TOVS data are already used in a range of operational and experimental Numerical Weather Prediction (NWP) models. These include (i) global and hemispheric models with horizontal resolutions of the order of 100-200 km providing short to medium range forecasts of one to ten days, (ii) regional models with horizontal resolutions of about 50-100 km for short range forecasts of one to three days, and (iii) mesoscale models of 10-50 km resolution for very short range forecasting of less than 24 hours. They are run by national meteorological services, international organizations such as ECMWF, and meteorological research centers and university groups.

The significant benefits of TOVS data to global and regional analyses and forecasts are well documented, while their benefit to mesoscale analysis and forecasting are just now being demonstrated. Optimal use of the temperature, moisture and cloud data available from the TOVS instrument in numerical analysis and prediction is still to be achieved. Many data assimilation systems are still designed to use the derived sounding data without accounting for its broad vertical resolution or ensuring that the final analysis is consistent with the satellite measured radiances. Most (operational) modelling applications currently use sounding data in the form of temperature and moisture profiles (or products derived from them such as thickness and precipitable water vapor) in much the same way that radiosonde data are used. However, there is growing interest in direct use of clear or cloudy radiances in data assimilation schemes.

With the advent of the new generation sounders, the ability to sound in cloudy atmospheres will be improved so that data coverage will be more uniform. However, the sounder resolution in the horizontal and, in particular, in the vertical will still be less than is needed by the models anticipated to be in use at the major forecast centers in the early 1990s. This will be ameliorated in part when instruments of higher spectral, and thus better vertical, resolution are flown.

c. Tropical Cyclone Applications

The TOVS has a microwave component, the Microwave Sounding Unit (MSU), which penetrates clouds and helps to delineate the development and

dissipation of tropical cyclones. By tracking the upper tropospheric warm core associated with most tropical cyclones, a relationship has been found that relates the MSU temperature gradients at 250 mb to the storm intensity, as categorized by its surface central pressure and maximum sustained wind speed in the eye wall. Operational evaluation and use of this technique has been underway for several years.

Wind measurements are the most important satellite product for hurricane forecasting. Analysis of the geostationary satellite derived deep layer mean wind field provides information about the steering current of hurricane movement. High and low level cloud drift and mid level water vapor drift winds can be calculated from image loops in the visible, infrared window, and the water vapor sensitive spectral bands. The resulting wind fields have high density and are readily converted to a deep layer mean wind. Early testing of these satellite derived wind analyses for fifty cases in a barotropic model has shown considerable reduction in the hurricane track prediction error of that model.

The water vapor imagery has been shown to be useful in depicting mid to upper tropospheric structure and features in the tropical cyclone environment that are not always apparent in the usual infrared or visible images. Loops of water vapor images available from the geostationary VAS (VISSR Atmospheric Sounder) and METEOSAT are now regularly used to track the synoptic features of hurricane flow.

The AVHRR is capable of producing sea surface temperature (SST) fields with good horizontal coverage and detail which is useful to the hurricane forecaster for preparing large scale analyses and estimating hurricane intensity. For the latter application, an early study indicates that hurricane wind speeds are bounded by the warmth of the underlying SST.

d. Summary

The important applications of TOVS data at several different scales illustrate that they fill important data voids at synoptic scales (for example over the oceans). Furthermore, they provide some definition of meteorological fields at the subsynoptic scales of weather where conventional networks (even over land areas) provide insufficient data density to support detailed subsynoptic scale objective analyses.

Better use of the sounding data in the NWP area relies on improved analysis, availability of data with higher vertical and horizontal resolution, and incorporation of the related information concerning radiance measurements, cloud cover, quality control, and first guess (when relevant). It is also important that direct readout of sounding data continue as accepted international practice to ensure timely availability of TOVS data for nowcasting and mesoscale NWP. Processing software such as the ITPP should also continue to be available to the international user community.

4. Trends

a. Future Systems

In the next decade, significant advances in instrumentation and subsequent products are planned. These include the Advanced TOVS (ATOVS) complement of the new Advanced Microwave Sounding Unit (AMSU) in addition to the existing High resolution Infrared Radiation Sounder (HIRS/2) planned for NOAA-KLM. The ATOVS will considerably improve the sounding performance in cloudy areas and the horizontal resolution of the products. However, the vertical resolution of these instruments is still inadequate to meet the needs of the models expected in the early 1990s. Recent instrument developments in interferometers (such as the High resolution Interferometer Sounder, HIS) and spectrometers offer the hope of significantly improved spectral resolution and hence the attendant vertical resolution. NOAA has embarked on a feasibility study to determine whether the HIS can replace the GOES-L sounder on its operational geostationary satellite. In addition, an experimental lightning mapper, that can identify location and frequency of lightning strikes, is being considered for GOES-M to supplement ground based observations.

The sounding science community continues to stress the need for coordinated infrared and microwave instrumentation on the same platforms to enable all weather sounding. The ITOVS Working Group has tasked its members to stress to their national space agencies that the complementary capabilities of these sensors are superior to either component by itself.

b. Small Processing Systems

Personal computer (PC) technology is starting to facilitate international scientific software exchange and development. The PC activities within the sounding community are rapidly progressing toward nowcasting using TOVS data processed in real time in a stand alone mode. In addition, PCs are used for collaborative research through case study distribution and data analysis and for educational programs. The PC version of the ITPP has been prepared and the ability to process TOVS on a PC data locally with the ITPP has been demonstrated. A common set of components for compatibility of disk operating systems has been suggested by the ITOVS scientists.

The local small computer processing of TOVS data depends upon easy inexpensive access to the data stream. The TIP (TIROS Information Processor) beacon has provided this in the past and NOAA plans to continue it through NOAA-M into the mid 1990s (beyond that NOAA will attempt to accommodate the user community with comparable support). In addition, the prompt and accurate distribution of satellite information to international satellite users is important and this is now possible with the NOAA Electronic Bulletin Board.

5. CBS Considerations

a. Direct Readout Services

Given the present and future importance of satellite data to meteorology and noting the particular importance of real time satellite data in monitoring and predicting sever (local) weather:

- It is recommended that the Commission note the great practical significance of direct readout services from meteorological satellites and urge satellite operators to continue these services.

b. TIP Beacon

Personal computer technology now enables inexpensive processing of TOVS data available in direct readout from the TIP beacon. Maintenance of inexpensive access to the data stream should be continued.

- It is recommended that the Commission note the advantages of the TIP beacon and urge that this facility be maintained on future polar orbiting satellites until a more cost effective system is developed.

c. The Baseline Upper Air Network (BUAN)

The BUAN is viewed as an essential step toward improving global meteorological products by providing a data set from which the relationship between satellite and other data can be better determined. The ITOVS Working Group has suggested that good geographical (land and ocean) and seasonal (winter and summer through twelve months) coverage is important to the achieve a balanced data set. Currently, a suitable candidate set of stations has been approved and the member countries have been asked to participate in data gathering for six months.

- It is recommended that the interested members of the ITOVS community provide information to the WMO secretariat based on their evaluations of the effectiveness of the BUAN, particularly in regard to its impact on statistical and physical retrievals.

d. Sounding Community Expansion

As the interest in satellite soundings increases and the difficulty and cost of obtaining and processing the data diminishes, there is a growing need for coordinated international training programs.

- The ITOVS community is prepared to help, where the WMO deems appropriate, with international training programs.

e. Status of the ITOVS Working Group

The International TOVS Working Group at its last meeting in August 1986 concluded that its efforts should be focussed on the following five activities: (i) improving satellite products via calibration refinements, retrieval method comparisons, verification, and case studies; (ii) expanding the TOVS user community through distribution of processing

software, information exchange, and development of software for low cost processing systems; (iii) investigating the growing number of applications of satellite products in numerical weather prediction and climate studies; (iv) making recommendations to national agencies regarding the development of future satellite sounding instruments for both polar and geostationary platforms; and (v) encouraging an effective level of international cooperation on the above goals for the mutual benefit of the participating countries. The next meeting of the ITOVS Working Group will be in March 1988.

- The ITOVS community plans an active work program at an international level over the next few years in satellite sounding retrievals and utilization of sounding data. The ITOVS Working Group will take steps to inform the Commission of its progress.

APPENDIX F. LIST OF ACRONYMS

AIRS	-	Atmospheric Infra-Red Sounder
ALPEX	-	Alpine Experiment
AMEX	-	Australian Meteorological Experiment
AMSU	-	Advanced Microwave Sounding Unit
ASA	-	Austrian Space Agency
ATOVS	-	Advanced TOVS
AVHRR	-	Advanced Very High Resolution Radiometer
BMRC	-	Bureau of Meteorology Research Center, Melbourne, Australia
BUAN	-	Baseline Upper Air Network
CBS	-	Commission for Basic Systems (WMO)
CIMSS	-	Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison, Wisconsin, USA
CMS	-	Centre de Meteorologie Spatiale, Lannion, France
CNET	-	Centre National d Etudes et de Telecommunications
CRPE	-	Centre de Recherche Physique de l' Environnement
DCS	-	Data Collection System
DFVLR	-	Deutsche Forschungs -und Versuchanstalt fur Luft -und Raumfahrt, Oberpfaffenhofen, Germany
DMSP	-	Defense Meteorological Satellite Program
DSB	-	Direct Sounder Broadcast
EBB	-	Electronic Bulletin Board
ECMWF	-	European Centre for Medium range Weather Forecasting Bracknell, Berkshire, UK
EGA	-	Enhanced Graphics Adaptor
EOS	-	Earth Observing System
ERBE	-	Earth Radiation Budget Experiment
FIRE	-	First ISCCP Regional Experiment
FOV	-	Field of view
GARP	-	Global Atmospheric Research Program
GAS	-	Global Assimilation System
GOES	-	Geostationary Operational Environmental Satellite
GTS	-	Global Telecommunications System
HIRS	-	High resolution Infrared Spectrometer
HIS	-	High resolution Interferometer Sounder
HRPT	-	High Resolution Picture Transmission
IAMAP	-	International Association of Meteorology and Atmospheric Physics
IAPP	-	International ATOVS Processing Package
ICSU	-	International Council of Scientific Unions
3I	-	Improved Initialization Inversion
IRC	-	International Radiation Commission
ISCCP	-	International Satellite Cloud Climatology Project
ISLSCP	-	International Satellite Land Surface Climatology Project
ITSC	-	International TOVS Study Conference
ITRA	-	Intercomparison of Transmittance and Radiance Algorithms Working Group (IRC)
ITPP	-	International TOVS Processing Package
JSC	-	Joint Scientific Committee
LFM	-	Limited Finemesh Model
LMD	-	Laboratoire de Meteorologie Dynamique
MMS	-	Meteosat Microwave Sounder
MSU	-	Microwave Sounding Unit
McIDAS	-	Man-computer Interactive Data Analysis System
NASA	-	National Aeronautics and Space Administration

NESDIS	-	National Environmental Satellite, Data, and Information Service
NMC	-	National Meteorological Center, USA
NOAA	-	National Oceanic and Atmospheric Administration Department of Commerce, USA
NWP	-	Numerical Weather Prediction
OWSE-NA	-	Operational World Weather Watch Systems Evaluation-North Atlantic
PC	-	Personal Computer
PC/TOVS	-	Personal Computer version of the International TOVS Processing Package
RAOB	-	Radiosonde Observation
RTE	-	Radiative Transfer Equation
SCAMS	-	Scanning Microwave Spectrometer
SCC	-	Satellite Calibration Centre, Lannion, France
SMHI	-	Swedish Meteorological and Hydrological Institute, Norrkoping, Sweden
SSEC	-	Space Science and Engineering Center, University of Wisconsin-Madison, Wisconsin, USA
SSMI	-	Special Sensor Microwave Imager
SSU	-	Stratospheric Sounding Unit
TIGR	-	TOVS Initial Guess Retrieval
TIP	-	TIROS Information Processor
TIROS	-	Television Infrared Operational System
TOMS	-	Total Ozone Mapping Spectrometer
TOVS	-	TIROS Operational Vertical Sounder
TSF	-	Typical Shape Functions
VAS	-	VISSR Atmospheric Sounder
VHF	-	Very High Frequency
VISSR	-	Visible Spin Scan Radiometer
WCRP	-	World Climate Research Program
WEFAX	-	Weather Facsimile
WMO	-	World Meteorological Organization
WWW	-	World Weather Watch