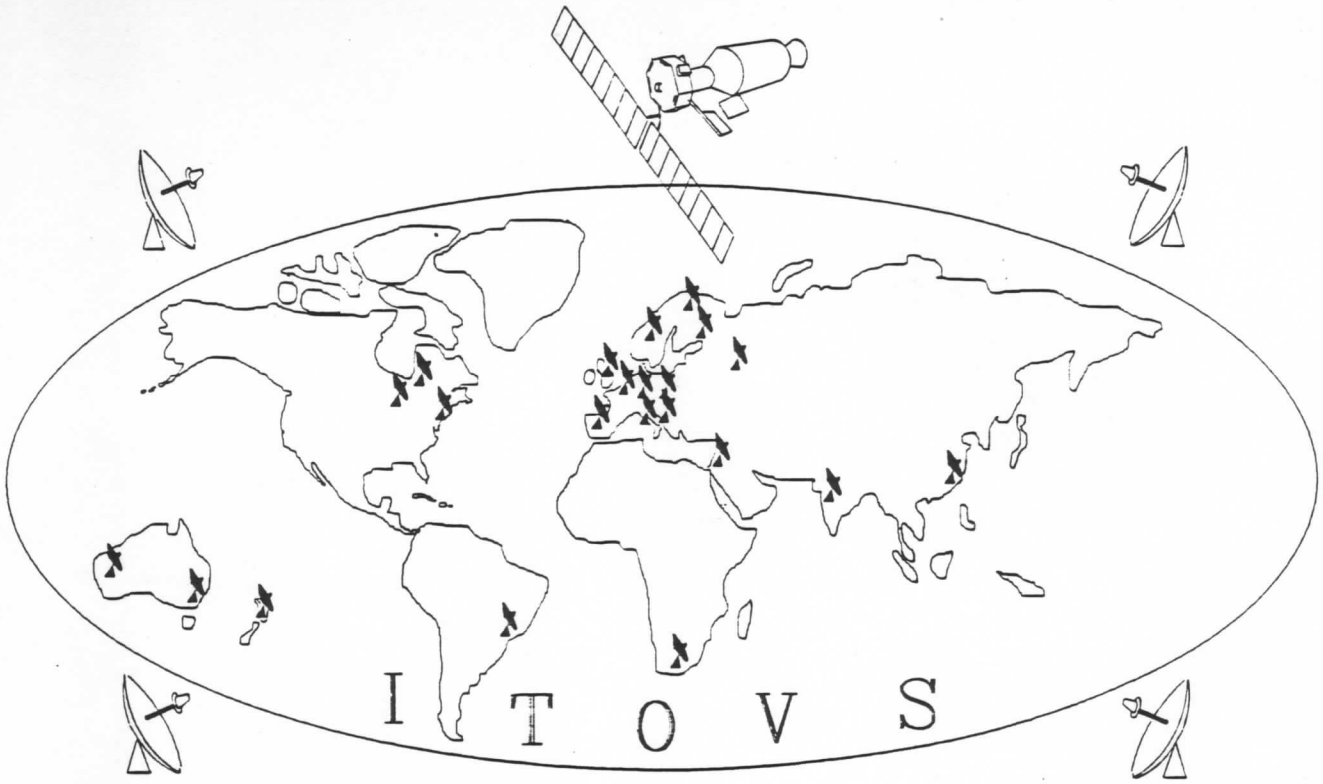
INTERNATIONAL TOVS WORKING GROUP

International Radiation Commission



A REPORT ON

THE SIXTH INTERNATIONAL TOVS STUDY CONFERENCE

Airlie, Virginia, USA

1 - 6 May 1991

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sponsored by

National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite and Data Information Service (NESDIS)
and
National Meteorological Center (NMC)

National Aeronautics and Space Administration (NASA)

World Meteorological Organization (WMO)

prepared by

P. Menzel and M. Lynch

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May 1991

Final Draft
June 1991

FOREWORD

The International TOVS Study Conferences (ITSC) continue to be held at approximately 18 month intervals. Since 1983 this Working Group of the International Radiation Commission has been convening users of the NOAA polar orbiting satellite data to compare performance of schemes for retrieving thermodynamic properties of the atmosphere (such as temperature and moisture), to undertake case studies of the impact of soundings on numerical weather prediction models, to define important directions for further research, and to formulate recommendations to the WMO.

Our sixth meeting, ITSC-VI, was held in Airlie, Virginia, USA during the first week of May, 1991. This "Report on the ITSC-VI" summarizes the scientific exchange and outcomes of that meeting. A companion document entitled "The Technical Proceedings of the ITSC-VI" will contain the complete text of the scientific presentations. The documents are testament to the conduct of a very successful meeting in Airlie. The proximity to Washington ensured participation of a strong contingent of NOAA/NESDIS people from both operations and research.

ITSC-VI was hosted by NOAA/NESDIS and was financially supported by NOAA/NESDIS, NOAA/NMC, and NASA. Their assistance is gratefully acknowledged. Betty Wilson of NOAA/NESDIS provided very capable secretarial support both prior to and at the conference; we thank her for the smooth daily conduct of the meetings. Additionally, thanks go out to the staff of the Airlie Center who provided very professional service support and presented excellent surroundings at the venue.

The conference softball match showed that a priori knowledge is not always a predictor of success; the newly introduced players outscored the veterans. The one casualty of the game was showing good recovery signs as we departed Airlie for home.

P Menzel

Paul Menzel
Madison
May 1991

A. Chédin

Alain Chedin
Palaiseau
May 1991

The Sixth International TOVS Study Conference

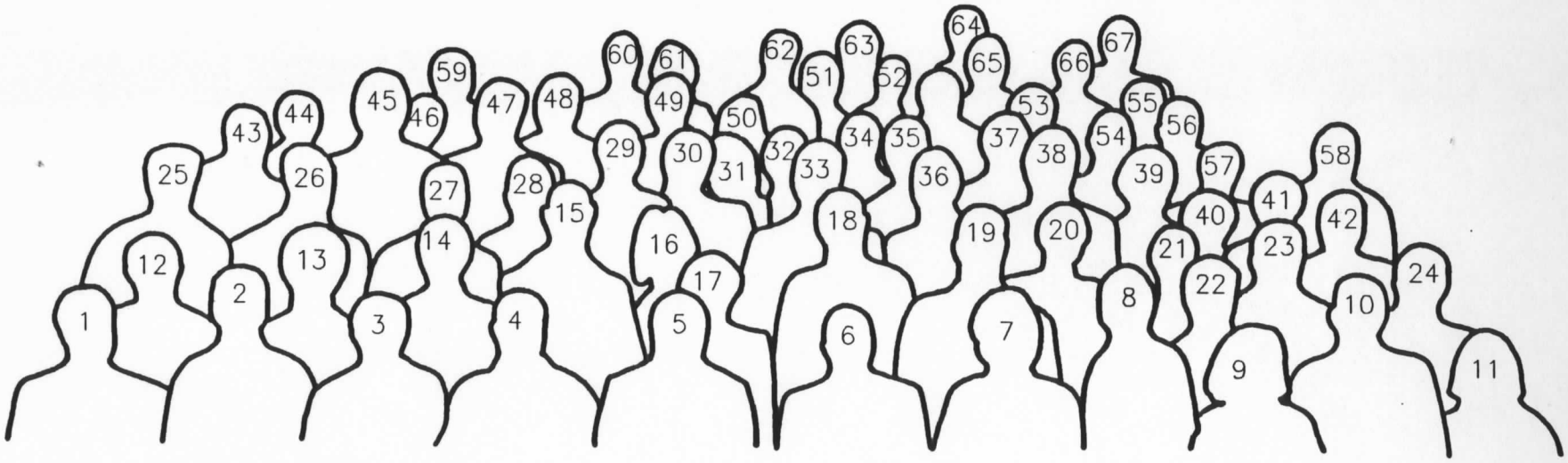
Co-Chairmen
Alain Chedin (France)
Paul Menzel (USA)

Organizer and Host
Paul Menzel (USA)

Participants

1	Achtor, Tom	USA
2	Amato, Umberto	Italy
3	Aoki, Tadao	Japan
4	Baker, Wayman	USA
5	Bates, John	USA
6	Birkenheuer, Dan	USA
7	Bloom, Hal	USA
8	Blondin, Christian	France
9	Boehm, Thomas	Germany
10	Burdsall, Ellen	USA
11	Chedin, Alain	France
12	Chouinard, Clement	France
13	Cox, Karl	USA
14	Daniels, Jamie	USA
15	Dibben, Paul	UK
16	Dong, Chaohua	PRC
17	Drahos, Henry	USA
18	Elkaffas, Saleh Mesbah	Egypt
19	Eyre, John	UK
20	Ferreira, Marlene	Brazil
21	Fleming, Henry	USA
22	Goldberg, Mitch	USA
23	Greaves, Brian	Canada
24	Hayden, Kit	USA
25	Hillger, Don	USA
26	Homleid, Mariken	Norway
27	Hughes, Mary	USA
28	Kadokura, Shinji	Japan
29	Kaifel, Anton	Germany
30	Kakar, Ramesh	USA

31	Khalsa, Siri Jodha	USA
32	Kim, Dongsoo	USA
33	Klaes, Dieter	Germany
34	Kleespies, Tom	USA
35	Koenig, Ed	USA
36	Lachlan-Cope, Thomas	UK
37	LaPorte, Dan	USA
38	Lavanant, Lydie	France
39	Lee, H. Sang	USA
40	LeMarshall, John	Australia
41	Lynch, Merv	Australia
42	Masters, Rob	USA
43	McMillin, Larry	USA
44	McNally, Tony	UK
45	McPherson, Ron	USA
46	Menzel, Paul	USA
47	Metcalf, Kay	USA
48	Miller, Don	USA
49	Moore, Doug	USA
50	Nappi, Andrew	USA
51	Needham, Bruce	USA
52	Olesen, Folke-Soren	Germany
53	Pagano, Paulo	Italy
54	Perrone, Marilena	Italy
55	Pfister, Andreas	Germany
56	Prangsma, Ge	Netherlands
57	Prata, Fred	Australia
58	Quere, Joel	France
59	Rao, P. Krishna	USA
60	Reale, Tony	USA
61	Scott, Noelle	France
62	Schroeder, Judy	USA
63	Serio, Carmine	Italy
64	Sipos, Gyozo	Hungary
65	Slonaker, Richard	USA
66	Stankov, Barbara	USA
67	Steenbergen, David	Canada
68	Suh, Ae Sook	Korea
69	Travaglioni, Fabio	Italy
70	Turner, David	Canada
71	Uddstrom, Michael	New Zealand
72	van Delst, Paul	Australia
73	van Woert, Michael	USA
74	Wark, David	USA
75	Watts, Phil	UK
76	Wilson, Betty	USA
77	Woolf, Hal	USA
78	Zhou, Feng-Xian	PRC
79	Zhou, Sisong	PRC



1. C. Chouinard
2. B. Greaves
3. F. Prata
4. S. Elkaffas
5. R. Kakar
6. A. Chedin
7. B. Wilson
8. M. van Woert
9. A. Suh
10. D. Steenbergen
11. J. Schroeder
12. P. Watts
13. S. Khalsa
14. T. Boehm
15. G. Prangsma
16. M. Ferreira
17. N. Scott
18. D. LaPorte
19. P. van Delst
20. F.-X. Zhou
21. M. Perrone
22. J. Eyre
23. C. Hayden
24. P. Menzel
25. T. McNally
26. G. Sipos
27. F. S. Olesen
28. H. Woolf
29. D. Kim
30. J. Bates
31. E. Burdsall
32. B. Needham
33. H. Drahos
34. F. Travaglioni
35. L. McMillin
36. T. Kleespies
37. P. Pagano
38. E. Koenig
39. M. Hughes
40. B. Stankov
41. C. Dong
42. J. LeMarshall
43. R. Masters
44. M. Lynch
45. A. Pfister
46. M. Homleid
47. D. Klaes
48. A. Kaifel
49. W. Baker
50. R. Slonaker
51. M. Goldberg
52. T. Aoki
53. T. Achtor
54. C. Blondin
55. C. Serio
56. D. Hillger
57. S. Zhou
58. H. Fleming
59. J. Quere
60 D. Birkenheuer
61. L. Lavanant
62. P. Dibben
63. M. Uddstrom
64. T. Lachlan-Cope
65. S. Kadokura
66. U. Amato
67. D. Wark

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I. EXECUTIVE SUMMARY

A. Introduction

The Sixth International TIROS Operational Vertical Sounder (TOVS) Study Conference (ITSC-VI) was held in Airlie, Virginia from 1-6 May 1991. Seventy-nine delegates attended the meeting and provided scientific contributions. Sixteen countries were represented at the meeting; they included Australia, Brazil, Canada, Egypt, Federal Republic of Germany, France, Hungary, Italy, Japan, Republic of Korea, Netherlands, New Zealand, Norway, Peoples Republic of China, United Kingdom, and the United States of America.

The agenda for the ITSC-VI can be found in Appendix A. The first three days were occupied with scientific presentations that fell into the broad categories of retrieval algorithm developments, sounding products and evaluation, instrument studies, and model impact studies. Section III of this Report records the abstracts of the scientific contributions by delegates. The corresponding papers are published separately in the Technical Proceedings of the Sixth International TOVS Study Conference available through the Conference Co-chairpersons.

The afternoon of the second day included presentation of reports concerning previously identified issues/problems and the actions which have been taken toward their resolution. These status reports for ITSC-VI are also presented in Section III of this document.

On the morning of the third day, several invited papers from NESDIS were presented. These addressed NOAA plans for the future, status of the advanced microwave instruments, operational TOVS processing, and the TOVS data archive.

Thereafter, the Conference divided into four Working Groups which considered issues in the following areas; the preparations for the Advanced TOVS (ATOVS) processing, the validation and tuning of retrievals, coordination of international satellite activities, and climate signals in TOVS data. Two additional Subgroup Meetings were convened to discuss operational applications of TOVS data and processing software distribution to users. The Working Groups spent the next days reviewing, debating, and making recommendations on the key issues of concern and items for action. The Reports of these Working Groups are detailed in Section II.

B. Recommendations and Conclusions

A summary of the recommendations and conclusions from the various working groups follows. More details are available in the Working Group Reports of Section II.

* The Working Group on ATOVS Processing indicated the following concerns:

(1) Initial progress on the ATOVS software planning has been slow; increased activity is essential to ensure that adequate preprocessing and retrieval procedures are developed and that a prelaunch synthetic data set is released.

(2) National agencies should be aware that insufficient resources are being directed by the international community toward preparations for utilization of ATOVS data. The level of effort should be increased, recognizing that the Revised TOVS (RTOVS) and Advanced TOVS (ATOVS) software (also referred to as System 90/92) currently being developed by NESDIS provides a useful architecture for software developments.

* The Working Group on Radiance Errors and Validation Studies noted:

(3) Increased efforts should be devoted to (a) developing improved understanding of the radiative transfer problems, and (b) validation through airborne experiments, satellite/radiosonde collocations, and ground-based measurements.

(4) The Intercomparison of Transmittance and Radiance Algorithms (ITRA) is a establishing an essential source of new information regarding improved atmospheric transmittances for use in retrievals. Participation with and collaboration in the ITRA WG is recommended

(5) TOVS data have inherent biases that are likely sources of the sometimes disappointing impact in Numerical Weather Prediction (NWP). Considerable effort is encouraged to achieve local tuning of radiances, monitoring of biases, and access to uncorrected RAOB data in order to improve the impact of sounding data.

(6) Data from the Baseline Upper Air Network (BUAN) will be used to validate forward models and characterize RAOB errors.

(7) Case studies continue to be an important vehicle for algorithm improvement and for end-to-end evaluation of processing schemes. The ITOVS Working Group will be organizing several new case studies in the next year.

* The Working Group on International Collaboration reported:

(8) There is increased advocacy for development of advanced sounders. Achieving a high spectral resolution sounding capability is viewed as a matter of urgency. Commitment to launch an advanced sounder by the year 2000 is strongly encouraged.

(9) There is a need for synergy of US and European programs for advanced sounders. Coordination of efforts through information sharing and exchange of participating scientists should be increased. There should be the goal of common instrumentation on US and European satellites.

* The Working Group on Climate Studies recommended:

(10) TOVS data available from 1978 to the present are a unique data source for climate studies. These TOVS data should become part of a NOAA/NASA Pathfinder data set and this activity should be started by making the operational archive available and easily accessible. Efficient access to long time series of TOVS data will be required to investigate the climate significance of the data.

(11) Because of the significance of clouds in climate, operational centres should retain and archive cloudy field radiances as well as those from clear fields.

(12) Climate researchers using TOVS products should be made aware of the expertise within the ITOVS Working Group (ITWG) regarding adjustments to and use of TOVS data.

* The Subgroup Meeting on the Operational Applications of Satellite Data concluded:

(13) Use of satellite data in NWP is primarily limited by inadequate characterization of the observation errors. Improvements in forward radiative transfer models remain crucial and constitute the necessary prerequisite for any significant progress in the use of satellite data in NWP.

(14) The important ongoing process of maintaining quality control of TOVS products continues to be enhanced by user feedback to the provider of the products. This must continue to be encouraged.

* The Subgroup Meeting on Processing Software Distribution to Users noted:

(15) The prevalent software packages within the TOVS community (Improved Initialization Inversion, 3I, and International TOVS Processing Package, ITPP) are now accompanied with documentation and a benchmark data set to help achieve correct implementation. Providers of these packages were commended for their efforts in this regard.

(16) User support of these packages remains the only means for assuring continued evolution and improvement of the TOVS processing packages. The ITOVS community endorsed this approach unanimously.

* The full assembly of the International TOVS Working Group made several general statements:

(17) The Global Telecommunications System (GTS) resolution of 500 km is no longer appropriate for use in NWP models and less so for local application. Assimilation studies show positive impact of TOVS at a resolution of 250 km or better. Full density data dissemination should be pursued in preparation for utilizing the ATOVS capabilities.

(18) Ozone products derivable from TOVS data are increasingly important. International skill in interpretation of these data is continuing to rise.

C. Future Plans

A report to WMO will be delivered by the ITOVS Working Group rapporteurs in 1992.

The next meeting of the ITOVS Working Group tentatively will be held in Europe in late 1992 or early 1993. ITSC-VII will attempt to consolidate preparations and resolve remaining problems prior to the launch of the next generation polar platforms carrying the Advanced Microwave Sounding Unit (AMSU).

The coordination of international efforts in initiating new satellite programs is a continuing challenge. The ITOVS community will be expending increasing energies to assure some level of international collaboration in instrument development and data sharing.

Incorporating the extensive archive of TOVS data into the Pathfinder on global change and climate studies will become a major focus of the ITOVS members in the coming years.

II. WORKING GROUP REPORTS

A. *Working Group on ATOVS Processing*

Co-chairpersons: J. Eyre and N. Scott, with E. Burdsall, C. Dong, K. Cox, M. Goldberg, L. Lavanant, L. McMillin, D. Steenbergen, D. Wark, and H. Woolf contributing.

1. Background

Following the recommendations at ITSC-V, a small Working Group (WG) was established as a sub-group of the ITOVS Working Group to promote and coordinate a collaborative international effort for developing Advanced TOVS (ATOVS) processing systems. The Working Group held its first meeting at ECMWF (Reading, England) on 15-17 October 1990, and the report of this meeting was presented and circulated at ITSC-VI. The review of this document formed the basis of the work of the ITSC-VI Working Group on ATOVS Processing.

2. Review of Report on First ATOVS Meeting

The WG agreed to refine the objectives of its activities as follows: (a) To review progress and plans on algorithms/software for processing ATOVS data. (b) To identify key scientific aspects requiring urgent research and development. (c) To initiate and promote plans for cooperative development and exchange of ATOVS processing software.

The WG reaffirmed that increased activity must start as soon as possible if a strategy for collaborative software development is to be successful. Access by the WG to the design/code of NESDIS' Revised TOVS (RTOVS) and Advanced TOVS (ATOVS), also referred to as SYSTEM 90/92, documents is the most effective way by which these activities could be initiated.

* The group reviewed the list of RTOVS and ATOVS (SYSTEM 90/92) documents currently available and agreed on a subset which should be distributed immediately to all institutions taking part in the WG's activities. (ACTION: Burdsall)

The WG recognized the importance and potential benefits of sharing ATOVS software as it becomes available. The RTOVS software (SYSTEM 90), which will share a common architecture with and evolve into the ATOVS system (SYSTEM 92), will be available in summer 1992.

* Preparations within NESDIS to ensure the timely distribution of code to WG members should begin immediately. (ACTION: Burdsall)

3. Further Actions and Recommendations

3.1. Data decommutation and calibration/navigation

* Software plans of NESDIS' Satellite Operations Control Center (SOCC) and Ingest Systems Branch (ISB) for, respectively, decommutation and calibration/navigation should be explored and assessed for applicability to the needs of the overall community. (ACTION: Woolf)

The WG supported continued cooperation between NESDIS, CIMSS, and the Centre de Meteorologie Spatiale (CMS) to check and improve TOVS/ATOVS navigation accuracy.

3.2. Preprocessing and retrieval

The WG noted the recent change in NESDIS' plans to use the HIRS grid as the primary processing grid for the inversion stage. It is also recommended, as a general strategy, that (a) corrections with expected errors greater than the design noise level, and (b) data processing steps which reduce subsequent processing options, should be avoided whenever possible.

3.3. Quality control of calibrated radiances

It has been decided to remove the HIRS cool black body facility from NOAA-K onward; its large thermal gradients have made it difficult to use and its data can be replaced by an extra line of earth-view data. The WG noted that its potential use in the quality control (QC) of HIRS calibration (as demonstrated for channel 10 on NOAA-10) can, in principle, be replaced by alternative QC methods. However, concern was expressed over the general lack of QC at the calibrated radiance stage.

* The WG encouraged members to consider how effective QC of calibrated radiances for all ATOVS radiances might be achieved and referred the matter to NESDIS' Sounding Product Oversight Panel (SPOP) for consideration. (ACTION: Hayden, Burdsall)

3.4. Plans for test data sets

The group endorsed the production of test data sets for (a) decommutation/calibration which should come from actual instrument/spacecraft system test (e.g., thermal vacuum), and for (b) processing and retrieval which must be simulated and be as realistic and diverse (land, sea, etc.) as feasible.

* Coordination with instrument/spacecraft groups should be initiated to acquire appropriate ground test data sets (ACTION: Woolf).

* NESDIS' Sounding Implementation Branch (SIB) is already planning simulated data for retrieval investigations; CIMSS ideas should be shared (ACTION: Woolf, Hayden, Drahos, Cox).

3.5 Update on Actions on Scientific Aspects

Considerable effort is already devoted to radiative transfer modelling in the IR and microwave within the framework of the TOVS and AVHRR instrument related studies. Continuing effort is necessary for the IR. It appears also important to obtain complete modelling of the transmittances and radiances in the microwave region of the spectrum, including both gaseous (lines, continua) and "pollutant" effects (water and ice cloud droplets, precipitation, surface emissivity effects...) in order that AMSU-A and AMSU-B data can be exploited fully. Concerning the gaseous contribution, the ITRA working group (IRC/IAMAP) has identified unresolved questions such as: the H2O continuum and

its temperature dependence, the oxygen line mixing and its temperature dependence, the treatment of oxygen zero frequency, line shape in the far wings of the lines, and foreign gas broadening.

Concerning the "pollutants," research must be pursued to achieve reliable modelling of their effects and definition of the processing options for the inverse problem in their presence. Three options are identified: detection and rejection; detection and correction at the pre-processing stage; detection and inclusion in the retrieval problem through appropriate forward and inverse approaches.

The WG recommended that increased efforts should be devoted to: (a) developing improved understanding of the radiative transfer problems, (b) validation through airborne experiments (e.g., MARSS, MMS, AMTS), satellite/radiosonde collocations (SSM/T, SSM/I), and ground-based measurements, for which participation with and collaboration in the ITRA WG is recommended, and (c) studies on the synergistic use of the ATOVS instruments.

* It was agreed that potential contributors of microwave radiative transfer code should be contacted and that a list of such code and the associated bibliography be distributed to WG members (ACTION: Scott)

3.6 Validation archive data sets

The WG noted that systems for obtaining, monitoring, and archiving comprehensive data sets of ATOVS and collocated radiosonde data will be essential for exploiting the sounding data fully, and in particular for validating and tuning radiative transfer models.

The WG recommended that NESDIS and other operational centers be encouraged to establish such systems and to make their archived data available. Prior to ATOVS launch, similar data sets for SSM/T and SSM/I will be valuable for algorithm research and radiative transfer validation.

* It was noted that the current NESDIS operational data set could be improved for this purpose by including additional parameters (eg. surface wind speed). In this regard, the WG recommended that the consistency between the detailed contents of NESDIS' planned data sets and the stated requirements of the ITOVS Working Group should be investigated. (ACTION: Goldberg)

3.7. Action on distribution of first meeting report

* It was agreed that the report of the first Working Group meeting should be distributed to those agencies that supported the meeting. (ACTION: Eyre)

3.8. Continued collaboration on ATOVS

* It was agreed that the WG on ATOVS processing should continue and that it should plan to meet at least once before the next ITSC. (ACTION: Eyre)

B. Working Group on Radiance Errors and Validation Studies

Co-chairpersons: M. Uddstrom and A. Reale, with U. Amato, T. Bohm, P. Dibben, C. Dong, T. Kleespies, J. LeMarshall, A. McNally, C. Serio, and R. Slonaker assisting.

1. Introduction

Unfortunately, atmospheric data derived from TOVS measurements are encumbered by non-zero bias errors and it is this aspect of these data that is the most probable cause of their disappointing impacts in NWP schemes. There are many sources of such errors, but two are of primary importance, since they affect all physical retrieval and direct assimilation algorithms. The first relates to the error characteristics of the "measured" radiances, while the second concerns errors in the forward radiative transfer model, and the associated problem of the specification of the true state of the atmosphere.

The working group identified a formalism for understanding these error sources, and proposed a number of strategies that should help resolve a number of outstanding issues.

2. Characteristics of the Forward Problem

Characterization and analysis of retrieval errors requires careful specification of the errors associated with each step of the retrieval process and the validation procedure. Any physical inverse solution to the radiative transfer equation or direct assimilation, requires accurate forward computation of the outgoing radiance. To this end it is instructive to formally identify the various sources of errors in the forward problem. Let the "true" radiances be symbolically denoted by Y, and "true" atmospheric and surface state and constituency be denoted symbolically by X. Let the measurements of estimates of these quantities be denoted by the modifier "m", and the adjustments to these quantities be denoted by the modifier "a", and computed values be denoted by "c". The measured calibrated radiances produced by the satellite are then given by Y_m, with the radiance error variance and bias given by $\langle Y_m \rangle$ and (Y_m), respectively. If the measured radiances are adjusted in some fashion, such as limb correction, cloud clearing, or resolution remapping, the adjustment of the radiances can be characterized by a generalized operator C, and the adjusted radiances are expressed as $Y_a = CY$. Here the operand is the "true" radiance in order to distinguish between the errors caused by the operator and the errors in the measurements. The radiance adjustment operator errors are given by $\langle C \rangle$ and (C).

The measured state and constituency of the atmosphere and surface are given by X, with the measurement error variance and bias given by $\langle X \rangle$ and (X), respectively. If corrections are made to the measured state, such as radiation corrections to rawinsonde temperatures, or interpolation and extrapolation to missing levels, the correction operator is given by S and the adjusted state is given $X_a = SX$. Again, the correction operator acts on the "true" state in order to separate the measurement errors from the operator errors.

The actual forward radiative transfer operator is given by R. The computed radiance from the operator is $Y_c = RX$, where the "true" measurement is again used as above. The errors of the radiative transfer operator are $\langle R \rangle$ and (R).

In the formal statement of the problem, we have used the "true" values for all of the operators. Unfortunately, this "truth" is fundamentally unknowable, and can only be inferred or estimated in synthetic studies. In actuality the forward problem is characterized by $Y_{ca} = RX_{ma} = RSX_m$ and the satellite radiances are given by $Y_{ma} = CY_m$. The test of the accuracy of the forward problem is whether $Y_{ca} - Y_{ma} = 0$. However, successful equality does not guarantee a correct specification of the forward problem, since the component errors may cancel.

What makes error analysis of the forward problem so challenging is the difficulty in estimating the error variances $\langle X_m \rangle$, $\langle Y_m \rangle$, $\langle C \rangle$, $\langle S \rangle$, $\langle R \rangle$, and their associated biases (X_m), (Y_m), (C), (S), (R). The errors associated with the operators can be estimated by careful simulation studies. The measurement errors are much more difficult to assess for the atmosphere and the satellite radiances. Nevertheless, renewed efforts are required to characterize the composite error terms in the forward radiative transfer problem.

2.1 Sources of Error

There are practical difficulties in estimating the error characteristics of the forward model from input profiles and collocated, observed radiances. There is the problem of the input profiles and the observed radiances not representing the true state of the atmosphere nor the same volume of atmosphere.

Deficiencies in the observed radiances are not necessarily a problem since the error characteristics of the model and the observed radiances can be considered together.

Deficiencies in the input profile and the atmospheric sampling will, however, be detrimental to some degree. Some deficiencies are discussed below together with the possibility of corrective actions.

2.1.1 Intrinsic RAOB Errors

Radiosonde data are used to define the state of the atmosphere. However, it is now clear that these data also suffer from errors that have a non-zero mean. The sources of such errors fall into a number of categories.

- Long and short wave radiation errors, which are a function of the radiosonde sensor's radiative properties, the sounded air mass, the solar zenith angle, and the underlying (or overlying) radiative surfaces.

- Post measurement correction schemes applied at the observing stations, or national processing centers.

- Deletion of valid data by arbitrary national practices (e.g., resetting of dew point depression values).

- Inappropriate data adjustments applied at analysis centers, to data in collocation archives.

The working group strongly recommended that post measurement corrections or adjustments to sonde data should not be applied prior to insertion of the RAOB message on the GTS. Further, in order to enable radiosonde data to be properly adjusted for known bias errors, there is a need to establish and maintain an accurate, global dictionary of upper air measuring systems and processing procedures.

2.1.2 RAOB Usage Errors

In addition to the previously reviewed errors, sources intrinsic to the measurements, the group identified several significant areas of uncertainty relating to how the measurements are subsequently used. Those discussed were:

- non representativeness in point versus field of view (FOV) comparisons

- poor spatial and temporal coincidence of RAOB and satellite

- extrapolation/interpolation of RAOB data by non-standard practices/inappropriate science.

- poor assumptions regarding quantities not measured by the RAOB but vital in radiative transfer calculations (e.g., skin temperature, surface emissivity, cloud).

Attention was drawn to studies which have addressed some of the above problems. The magnitude of errors introduced by the above cannot be considered insignificant.

2.1.3 Forecast Radiance Comparison Errors

The working group recognized the usefulness of radiance monitoring against NWP/analysis fields. The obvious advantage identified being the superior spatial and temporal coverage possible in such comparisons. However, the working group also agreed that such comparisons cannot be pursued in isolation from high quality parallel comparisons with radiosonde data.

2.2. Corrective Strategies

Given the above considerations, the working group concluded that in order to properly specify errors in the forward model, insofar as they relate to errors in radiosonde measurements of atmospheric state, there is a need to specify radiative transfer equation (RTE) model errors as a function of

- air mass,
- presence of clouds,
- the land/sea flag,
- the viewing angle,
- solar zenith angle, and
- radiosonde type.

Collocation window specifications will further perturb the collocation indicative RTE model error characteristics.

The working group believes that there currently exist two promising techniques that should enable a significant component of radiosonde radiation contamination to be removed from the data, namely:

- the new NMC (USA) radiation correction scheme, and

- a NESDIS developed radiation model that may be used to compute the total long and short wave errors in the measurements.

Both these schemes have the capability to reduce radiosonde data to more accurate estimates of the true air temperature. The working group suggested that the Baseline Upper Air Network (BUAN) archive would provide an ideal test data base for experiments with radiation correction schemes.

2.3 Collocation Data Bases

2.3.1 Existing Data Sets

As mentioned in the previous sections, data bases of collocated radiosonde and satellite observations provide one of the basic information sources for research and validation activities regarding the forward model problem. At this time two principal databases containing such collocated observations are available; these are the NESDIS operational data sets on Data Staging Disk 5 (DSD5) and the BUAN archive.

The DSD5 data sets contain the collocated radiosonde and satellite observations required in support of the TOVS operational sounding system. The specific data stored, although valuable, are not the optimal information needed for forward model studies. For example, the significant and mandatory radiosonde data are not preserved but instead are interpolated to the predefined 40 TOVS levels. Also, the TOVS fully processed radiometric temperatures are the only radiometric data stored. The radiosonde data may be time interpolated over the ocean.

Because the DSD5 data sets are not an official NESDIS archive product, data sets over two years old are not available. NESDIS no longer deletes old DSD5 files and most of the collocated observations for NOAA-10 and NOAA-11 are available. Approximately 70,000 "non-redundant" collocated observations are collected per satellite per year.

The BUAN data set contain the collocated radiosonde and satellite observations collected during the BUAN experiment, which was conducted from January 15 to July 15, 1988. The BUAN data set contains 7,019 radiosonde reports and over 30,000 individual collocations for NOAA-10. Using the criteria of the clearest and nearest satellite sounding for redundant collocations, there are:

- 4,546 clear conditions,
- 1,396 partly cloudy conditions, and
- 1,078 cloudy conditions.

The BUAN archive contains three basic collocation types:

- radiosondes and fully processed radiances,
- radiosondes and TOVS "1T" level radiances, and
- radiosondes and TOVS "1B*" level radiances.

2.3.2 Data Base Requirements

The following is a list of recommended criteria for data to be stored in collocation data bases that would be optimal for forward model studies. It is recognized that upgrades of existing data sets to meet these requirements are not plausible. However, it is recommended that these criteria be considered for future data sets.

For the radiosondes, the following information should be included:

- significant levels (all parameters including component winds),

- associated SYNOPs,

- 6-hour forecast and analysis vertical profiles valid at the launch time for the RAOB station location, and

- "all" corrections applied to the data.

It is also recommended that collocated radiosondes should at least reach the 20 hPa level, and that upper air stations strictly adhere to WMO guidelines for radiosonde observations.

Further it is recommended that the following information be included with the radiances:

- raw, cloud cleared and limb corrected radiometric temperatures,

- details regarding the field of view (i.e., elevation),

- field of view (FOV) arrays (e.g., 3x3),

- ozone information, if available, and

- forecast and analysis vectors for the FOV location(s)

It is recommended that a DSD5-like data base containing the above changes be made an official NOAA archive product, perhaps in BUFR format.

3.1 Case Studies

In order to assist in retrieval validation studies and to illustrate the maturity and quality of extant retrieval schemes, an intercomparison of retrieved data derived from common sets of satellite radiance observations should be undertaken, initially for two case studies.

The first study involves a series of NOAA-10 orbits over western Europe on June 6 and 7, 1987, covering the "Whitsunday Storm." The second is a series of NOAA-10 passes crossing the Australian Continent during the Australian Monsoon Experiment (AMEX) special observing period on February 8 and 9, 1987.

The intercomparison (where possible) should involve several fields including calculated radiances derived from a common first guess temperature and moisture field, fields of derived cloud parameters, total ozone amount, temperature and, in particular, moisture.

3.1.1 Data Sources

The data for June 6-7 and the AMEX case will be distributed to interested centers. G. Kelly will provide ECMWF analyses pertinent to the two cases and G. Rochard and J. LeMarshall will provide TOVS and other data pertinent to the Whitsunday and AMEX cases, respectively. Those groups desirous of working on these case studies must communicate directly with the data providers noted here. The common output file structure will be provided by M. Uddstrom (who will be at NESDIS until April 1992).

3.1.2 Intercomparison File Structure

An intercomparison file structure for this intercomparison has been designed and will be distributed with the case study materials. The intercomparisons will be performed by J. LeMarshall at BMRC, Melbourne, Australia.

4. Recommendations

* Users of TOVS data, who also employ a forward radiative transfer model, should be informed of the strict requirement that they "tune" their forward model estimates against measured radiances. (Current indications suggest that such a tuning algorithm should account for errors due to differing air masses, the presence of clouds, viewing angle, over land or sea, radiosonde types, and solar illumination).

* The ITOVS Working Group through the rapporteurs should recommend to the WMO that radiosonde data should not be corrected for perceived measurement errors before insertion on the GTS.

* The WMO should be encouraged to remind all members of the need to conform to WMO guidelines with regard to upper air data collection practices (e.g., especially with regard to the first significant level, and the need to prevent arbitrary modification of dew point depression data).

* The NMC upper air dictionary should be compared with that at ECMWF, with the hope that a unified dictionary can be established and maintained. (ACTION: Baker, Eyre)

* The latest NMC radiosonde radiation correction scheme should be made available to all interested parties. (ACTION: Uddstrom)

* NESDIS should pursue the implementation of its radiosonde radiation error model. (ACTION: McMillin)

* NESDIS should make available the BUAN data archive in scaled integer format, in order to expedite the use of this data base. (ACTION: Reale, Drahos)

* NESDIS should make available the DSD5 collocation data base for forecast model error studies. (ACTION: Reale, Burdsall)

* ITOVS members should conduct experiments with the BUAN archive, in regard to forward model errors, and these results should be reported at the next ITSC meeting in 1992. (ACTION: all members)

* NESDIS should give consideration to the working group's suggestions that the contents of a collocation data base, that would also be optimal for forward model error studies, should be made accessible to users. (ACTION: Uddstrom, Reale)

* The ITOVS Working Group should use the Whitsunday storm and AMEX case studies to intercompare in detail extant TOVS retrieval schemes and to illustrate the quality and maturity of TOVS retrieval science. (ACTION: ITOVS Working Group members)

* Given the meteorological significance and complexity of the Antarctic and the difficulty of sounding in the Qinghai Xigong plateau region, two case studies should be identified and proposed at the next ITSC. (ACTION: J. LeMarshall, C. Dong, T. Lachlan-Cope)

C. Working Group on International Collaboration

Co-chairpersons: M. Perrone and D. Wark, with T. Aoki, A. Chedin, M. Ferreira, S. Kadokoura, P. Menzel, and P. Pagano contributing.

1. Improved Sounding Capability

The group took note of the initiatives regarding the development of IR advanced sounders in the US and in Europe and reiterated the urgent need for such operational instruments. The following issues were noted with some concern.

1.1. Regarding instrument requirements, it was noted that discrepancies exist in the specifications of the IR advanced sounders under development. The group had the following recommendations.

* As a first step, a common set of requirements for the operational IR sounders should be established in order for the European and US efforts to converge to one operational sounder.

* High spatial resolution, no worse than HIRS, should be achieved with the advanced sounder in order to sound through broken clouds. Furthermore, synchronization of the scanning patterns of the AMSU and the IR sensor is very desirable.

1.2. Regarding instrument commonality, the group noted with concern that there is not yet a commitment for an advanced sounder on the operational

satellites by the year 2000. Additionally, the use of two different approaches for observing the same meteorological targets was questioned. Morning and afternoon platforms should converge to the same operational advanced sounder as soon as possible.

* In view of ongoing international sounder developments, NOAA and Eumetsat should seek convergence on such issues as schedules and accommodation for both platforms.

2. Improved Imaging

The group noted that some changes are expected in the spectral bands of the imager for NOAA 2000:

Channel 1	.605	-	.625 microns
Channel 2	.86	-	.88
Channel 3	1.58	-	1.64
Channel 4	3.62	-	3.83
Channel 5	8.4	-	8.7
Channel 6	10.3	-	11.3
Channel 7	11.5	-	12.5

In particular channel 1 has been focussed at .605 to .625 microns (narrower and redder than present .58 to .68 microns) to match the MODIS channel and channel 2 has been moved to .86 to .88 microns (cleaner window in H20 minimum) to enable less noisy vegetation index determinations. While these changes are advantageous for the cited reasons, they do create a discontinuity for established algorithms and users with long data archives.

* As these changes may affect current international use of the data, the rationale for the selection of the spectral bands of the imager should be made available before proceeding to the implementation phase of the instrument.

3. Climate

The group reiterated the importance of continuity of global TOVS data and their availability for climate studies. The group recommended the following.

* The HIRS program should be continued until the sounder is replaced by operational high spectral resolution sounders from which HIRS channels can be synthesized.

* The complete observed spectrum from IR advanced sounders must be archived, as specific data sets for climate needs in the future cannot be predicted at this stage.

* The issue of accurate calibration of TOVS data should be given high priority.

4. Direct Readout

The need for direct read out on the operational polar orbiting satellites was reiterated.

* Direct read out should be maintained for the advanced sounders and should exhibit no degradation of information content of the data. However options might be incorporated to take into account the variety of users and their different ground capabilities.

* Data from the NASA EOS Research Facility instruments (e.g. the Atmospheric Infrared Radiation Sounder, AIRS) should be accessible at full resolution in real time, even if only by a small number of users during the prototype flight on EOS A.

5. Algorithms

The goal of a common operational processing approach for Eumetsat and NOAA was stressed. Research groups should be encouraged to continue their individual efforts to improve the processing algorithms, but cooperation and commonality in the final outputs must be sought as soon as possible. This cooperation has been initiated with regard to the ATOVS preprocessing package.

6. International Cooperation

The group was very encouraged by the increased international collaboration, but noted that more must be done.

* International exchanges of information should be further enhanced. For example, participation in instrument design reviews is a mechanism by which NOAA and Eumetsat can inform each other and the user communities on the status of the development of the operational instrumentation.

* Countries with active space programs are encouraged to participate financially and intellectually in the development of the satellite operational meteorological programs.

* The group noted with pleasure that an international workshop like the ITSC has been established for global winds processing. This cooperation is essential in order to achieve a global data base with sufficient commonality.

* Discussions for the definition of the advanced sounders have involved several members of the International TOVS Working Group (ITWG). As the activities of the ITWG have expanded beyond TOVS, it is appropriate that this group should be used as a forum for work and discussions on future instruments.

* The group also stressed the importance of the geostationary viewing perspective and encouraged progress (as soon as possible) to implement high spectral resolution observations on geosynchronous platforms.

D. Working Group on Climate

Co-Chairpersons: J. Bates and M. Lynch, with C. Blondin, E. Burdsall, A. Chedin, T. Lachlan-Cope, A. Kaifel, S. J. Khalsa, P. Menzel, F. Olsen, A. Pfister, F. Prata, A. Reale, F. Travaglioni, and F.-X. Zhou contributing.

1. Climate Signals in TOVS/AVHRR Data

Satellites provide a unique perspective for observing short and long term climatic signals. The spatial and temporal coverage of satellites is unmatched by any other observing system. Satellite sensors, however, measure atmospheric and surface originating radiances and not the traditional meteorological variables. The advantages and disadvantages of such radiance measurements are discussed in detail in this and other ITSC proceedings.

Particular advantages of the TOVS suite of instruments are their extended length of operation in orbit and the overlap of sequential spacecraft. These are essential elements for climate studies using satellite data as they provide a time continous record and calibration continuity. To date, TOVS data have been used almost exclusively as input to numerical weather prediction models. Only recently has the potential for climate applications become recognised. The monitoring of climate change with satellite data however requires a detailed knowledge the characteristics of satellite sensors and the important instrumental corrections to be applied to the data.

A consensus on how to use the TOVS data for climate studies must be achieved. In that the measurements are not the traditional climate variables it is important initially to establish the sensitivity of TOVS measurements to projected climate change. Further, the distinction between what is natural variability and what is a climate signal in the TOVS radiance data is not yet resolved. The expertise gained by the ITOVS Working Group in working with TOVS data is a crucial element in answering such key questions. Suggested approaches to these issues are addressed below.

* The ITOVS Working Group should be encouraged to research further those TOVS data products of climatic relevance (see the attached Table). In particular, the magnitude of the anticipated climatic signals, the accuracy of the TOVS-derived products, and the relevant spatial and temporal scales need to be addressed. (ACTION: ITOVS WG members)

2. New Products from Operational Centers

If the TOVS data are to be applied to climate research, a review of the list of products currently archived by operational centres is required. Accordingly the following actions are highly desirable.

* There is a need for operational centers to expand the array of archived products appropriate to addressing climate change. In particular, in their climate data bases, centers should (a) incorporate ungrided clear column radiances as radiances for all TOVS channels, (b) save cloud information and cloudy radiances even where operational soundings are not attempted, (c) encourage utilization of archived climate products by establishing easy on-line data access for the research community. (ACTION: Reale)

Parameter	Current Accuracy	Reference Standard	Climate Signal	Time Scale	Spatial Scale	Problem Areas
OZONE (TOVS)	unknown	Dobson sondes	Antrarctic S. Hemisphere N. Hemisphere	annual cycle dominant	highly regional polar	instrument sensitivity validation
SST (AVHRR)	0.6 C	ships	0.3 C global ENSO	annual, decadal	global ENSO/regional	bias validation skin
CLOUDS (TOVS/AVHRR)	ISCCP	ISCCP	amount height emissivity sales/optical depth	annual ENSO decadal	regional hemispheric	can't do microphysic bulk param height
OLR Index	AVHRR Channel 4	ERBE	radiative balance	annual ENSO decadal	global	narrow band orbital height, crossing time.
OLR	TOVS	ERBE	interseasonal	?	regional	orbital
VEGETATION INDEX	poor	unknown relative	regional (land use) (global change) (deserification/ defrostation)	annual seasonal	regional	no calibration standard
SNOW COVER	?	in situ microwave	interannual accumulation areal extent	?	regional	cloud snow discrimination
WATER VAPOR sampling	precipitable H2O intergrated products only	raobs	upward trend? (something better needed) ground-based MW radiometer	annual upper-levels	(all) (climate & global)	diurnal land sampling bias vs raobs no retrieval needed
TEMPERATURE	Z(100-500 hpa) Z(500-200 hpa)	raobs	GCM NWP	interannual predictions	decadal tends	
RADIANCES instrument (MSU Ch. 2&4) (HIRS Ch.7)	(see Spencer)	none	anomalies from long term mean	interannual	regional global	inter- bias interpretation

3. TOVS/AVHRR for Pathfinder Activity

The incorporation of TOVS/AVHRR in a Pathfinder is strongly recommened. The time record is long and the sensors and data are well understood. Because the instruments were not designed to have a climate monitoring role, the user community must now research and document the strengths and limitations of the TOVS/AVHRR data for this new and important task.

* The existing NESDIS TOVS operational clear column radiance products should be identified as a Pathfinder. Reprocessing of the TOVS archive should not occur until the important Pathfinder steps of (a) documentation of the accuracy, sensitivity and long term stability of TOVS radiance measurements, and then (b) undertake an assessment of anticipated value to climate programs of the time series of these operational products. (ACTION: ITOVS WG members, NOAA/NASA Pathfinder committees)

4. Potential of TOVS/AVHRR Data for Climate Research

The ITOVS Working Group (ITWG) has worked with TOVS and AVHRR data sets spanning over 12 years. For some few years the ITWG has recognised that the work it has undertaken with respect to the application of TOVS data to numerical weather prediction embraces many issues important to the proposed use of TOVS/AVHRR for climate research. It is now time for the ITWG to stimulate interest in the use of TOVS as a valuable resource for studies of climate change.

* Brief reports of the activities of the ITWG in researching the use of TOVS/AVHRR for climate studies should be widely disseminated through the literature and to climate research groups. (ACTION: ITWG co-chairpersons)

* To improve the ITWG focus on the role of TOVS/AVHRR for climate research the ITSC VII should assign a session to this topic. (ACTION: ITWG co-chairpersons)

* Specialists in data needs for climate research and modelling should be invited to participate in future Conferences. (ACTION: ITWG co-chairpersons)

E. Subgroup Report on Operational Use of Satellite Data

Co-chairpersons: C. Blondin and G. Prangsma, with C. Chouinard, D. Kim, D. Klaes, J. LeMarshall, P. Watts contributing.

1. Introduction

At ITSC-V, a working group on "TOVS Applications and Impact Studies" was set up. This group extensively reviewed the use of TOVS data, both in the context of NWP and nowcasting and short range forecasting. It was felt that the analysis and the recommendations made at that time are still largely valid and need only minor updates. Recognizing this fact, a small group was set up to carry out the task to review and update the ITSC-V report, to state what has happened in the field of assimilation of satellite data in NWP, and make

suggestions or recommendations for improving the operational use of satellite data.

2. General Remarks

Despite the fact that no major change has occurred since ITSC-V concerning the operational use of satellite data, there has been a fair amount of progress in the understanding and the usefulness of current and future satellite data for NWP, as well as for nowcasting and short range forecasting. Also there is a growing awareness of the limitations of both the data themselves and the methods to exploit them. The primary basic limitation of the use of satellite data is the lack of knowledge of their uncertainties, error bars for example, and more specifically for NWP, of the observation error covariance matrix, either in radiance space or in physical (T, q) space. In this respect, it is still very important to stress that improvements in forward radiative transfer models are crucial, and constitute the necessary prerequisite for any significant progress in the use of satellite data.

The advent of ATOVS has to be translated in an immediate step forward in the operational use of satellite data in order not to shed any doubt about the real profit that the meteorological community will be able to make using the high spectral resolution sounders. Therefore, the group fully endorses the recommendations of the ATOVS WG and encourages any effort preparing the meteorological community for the future use of ATOVS, especially through participation in case studies. Last but not least, continuity and operationality of the sounding mission on polar orbiting satellites remains the main concern of the user community. It is critical that this message goes through to the appropriate agencies.

3. Update to the ITSC-V Report

Relative to the situation described in the ITSC-V report, notable progress has been seen in a number of different areas:

- Studies have been reported in which a considerable increase of the information content of high spectral resolution sounders over the present instruments is demonstrated.

- As extensively discussed in the Validation and Retrieval WG, the meteorological user community is nowadays perfectly aware of the fact that improvements in the utilisation of TOVS data must be accompanied by a thorough understanding of the error characteristics of the TOVS data and the derived products. This applies to both the direct use of raw radiances in variational assimilation schemes and to retrieved products.

- The progress in the state-of-the-art retrieval systems (ITPP and 3I) has resulted in increased data densities. This has opened new ways in nowcasting and short range forecasting, e.g. for mesoscale weather systems.

- Considerable effort has been devoted to the development of quality control/monitoring systems, based on the use of models and model analyses. Success has been reported because such methods guide the retrieval research toward the weak points, e.g. in the cloud clearing algorithms, retrieved tropospheric stability.

The successful of use of TOVS data has been shown in a number of case studies. It should be emphasized that these successes have been obtained in hindcast experiments. Time has come to mould the techniques used in these hindcast experiments into tools that are available for testing in a forecast mode. The emphasis placed on the training aspects at the time of ITSC-V has only increased with the advent of new TOVS derived products for which, again, a proper understanding of their potential (and limitations) is needed if they are to be used advantageously in an operational environment. The meeting greeted with great enthusiasm, and fully supported, the commitments by the relevant agencies to fly high spectral resolution sounders on the next generation of operational satellites in conjunction with improved microwave and imaging instruments. This is all the more valuable since some studies are under way, or will soon be started, to exploit the enhanced synergism of such instrument packages.

4. Assimilation of Satellite Data in NWP

Progress in the use of satellite data in NWP has been made in two areas.

4.1 Improved quality control

Following the pioneering work of ECMWF, a mean tropospheric stability check has been introduced in the data assimilation of some NWP centers to quality control the SATEM retrieved temperatures.

ECMWF has also developed software to monitor satellite data through the comparison of "observed" cloud cleared radiances with either model computed (PRESAT) or collocated RAOB generated (COLLOC) radiances. It has to be recognized that, though these improved quality checks prevent the introduction of erroneous retrieved temperatures in the assimilation cycle, this has not lead to any significant change in the impact of TOVS data in the forecast skill, as already evaluated at ITSC-V. However, this control has helped to identify problems in the cloud clearing procedures and should still be continued.

4.2 Use of raw radiances

Several algorithms have been developed to accommodate the direct use of satellite data in either NWP data assimilation or nowcasting and short range forecasting activities. Some of theses algorithms are currently under intensive tests aiming at future operational implementation. Clearly, an exchange of information between groups carrying out such evaluation is strongly encouraged.

5. Suggestions for Improved Operational Use of Satellite Data

As far as operational use of satellite data is concerned, the first step is often to demonstrate the effective use of the data, since it generally requires staff training, software development and equipment enhancement. The group thus recommends the following.

* Reports on already successful exploitation of satellite data should be made available more systematically, and ITOVS members should disseminate this

information inside their own institute as well as outside as appropriate. The methodology used should be clearly explained in order that similar experiments could be set up within different institutes, results easily compared and more consolidated conclusions drawn.

* The use of common datasets (as the one G. Kelly from ECMWF already provided to various institutes) is strongly encouraged, so that results from different data assimilation systems either in global or limited area models and the impact on the forecasts may be intercompared.

* The potential of TOVS only products should be checked against conventional products. This would generally require establishing a dedicated environment both in terms of staff and equipment. This should lead to evaluation by the forecasters of the quality of TOVS only and TOVS plus conventional output fields against conventional only fields for issuing daily forecasts and products.

* The evaluation of new products derived from satellite data, like cloud parameters (top pressure and amount), and ozone, is strongly encouraged, but requires to be supported by staff training programs and user's guide availability.

* In preparation for ATOVS, research on the use of MSU is strongly recommended (derivation of surface parameters, e.g. ice charts, rain/no rain maps).

* ITSC-VII should dedicate a session to the presentation of results of activity prompted by recommendations from previous ITSC for promoting the operational use of satellite data.

F. Subgroup Report on Processing Software Distribution

1. General Comments

It was noted that the prevalent software packages within the ITOVS user community (3I and ITPP) are now accompanied by documentation and a benchmark data set to assist with implementation. The user community commended the considerable effort on the part of the software distributors that made this possible.

In order to permit support of these packages by the user community, a fee has been suggested that should be paid upon receipt of a given software package. Fees for initial receipt of a given software package will be higher than subsequent fees for package updates. Users are encouraged to assist in this way to assure that the packages continue to evolve and keep pace with instrument changes.

2. Specific Options for Consideration

The following options were identified as desirable additions to the packages. Implementation will be accomplished as possible.

* More detailed output (eg., 40 level temperatures) should be provided. (ACTION: Woolf)

* AVHRR landmark registration should be used to help correct TOVS navigation. (ACTION: Woolf)

* 1-B datasets from INGTOV should be part of the output to facilitate interface to the 3I. (ACTION: Woolf)

* Routines which have general utility outside of TOVS should be indicated. (ACTION: Scott, Woolf)

* List of the changes necessary to permit processing more than 100 HIRS lines should be made available. (ACTION: Woolf)

* The TIGR data base should be incorporated into the ITPP. (ACTION: Bates, Woolf)

III. ABSTRACTS OF ITSC-VI PRESENTATIONS AND STATUS REPORTS

CLOUD CLEARING WITH RADIAL BASIS FUNCTIONS

U. Amato[1], V. Cuomo[2], V. Tramutoli[2], G. Pavese[3], R. Rizzi[4], and C. Serio[5]

[1]Instituto per Applicatizioni della Matematica CNR
Napoli, Italy

[2]Instituto di Fisica, Facolta di Ingegnerin
Universita della Basilicata, Potenza, Italy

[3]IMAAA-CNR
Potenza, Italy

[4]Dipartimento di Fisica
Universita di Bologna, Italy

[5]Dipartimento di Scienze Fisiche
Universita degli Studi di Napoli Frederico II, Napoli, Italy

Cloud-clearing problems very often involve the three canonical tools of prediction, filtering and smoothing. A typical example is offered by cloud-clearing for satellite temperature inversions. Optimal estimation theory, e.g., Wiener filter or Kalman filter, might be used in this case, but their application to such problems is not straightforward, since cloud clearing problems involve at least two-dimensional (2-D) settings. Optimal prediction and filtering are strictly connected to the concept of physical realizability or causality, which, in practice, means that the signal or process of interest must be characterized by an evolution parameter which, in turn, permits to distinguish between past and future realizations of the signal itself. In other words, the presence of an evolution parameter makes it possible to order the measured values of the signal. Typically, such an evolution parameter is the time and, therefore, prediction and filtering are a natural topic in time series analysis.

Furthermore, optimal estimation theory is well developed for cases where the signal and the "noise" are additive and not correlated with each other, whereas the "noise" effects of clouds are not a strictly additive or multiplicative process.

In contrast, objective filters can be fully implemented in 2-D without any mathematical complexity and do not depend critically on the assumptions of additive noise. Thus, in some cases, they can be more suitable than the optimal analogues.

Because of the applications interests, the problem of designing fully 2-D digital objective filters is addressed in this paper. The mathematical background of digital filtering based on radial basis functions is illustrated. Canonical versions of the filtering process are derived for the cases of smooth interpolation and smoothing. Our derivation will point out the immediate extension of such an objective filtering approach to

multidimensional settings (n-D). Applications of the technique are discussed in the context of a new cloud clearing scheme.

OPTIMAL SPECTRAL DECONVOLUTION OF INTERFEROGRAM SAMPLES

U. Amato[1], M. Carfaro[2], F. Esposito[2], V. Cuomo[3], and C. Serio[4]

[1]Instituto per Applicatizioni della Matematica CNR
Napoli, Italy

[2]Instituto per le Metodologie Avanzate di Analisi Ambientale CNR
Tito (Potenza), Italy

[3]Instituto di Fisica, Facolta di Ingegnerin
Universita della Basilicata, Potenza, Italy

[4]Dipartimento di Scienze Fisiche
Universita degli Studi di Napoli Frederico II, Napoli, Italy

It is recognized that interferometers can give radiance estimates in the atmosphere at a much higher spectral resolution than that of current filter radiometers. The consequences can be the improvement of the retrieval of temperature and humidity profiles from radiance data as far as vertical resolution is concerned.

The aim of the present talk is to introduce an optimal mathematical technique for retrieving the spectrum from an interferogram with the following features: a) involve the use of FFT from a computational point of view, so that its speed can allow real-time applications with large quantities of data; b) take account of the experiment error affecting the interferogram, in the sense that the amount of error present is recognized and the right amount of smoothing is applied; c) must generate a final algorithm; this means that any step of the procedure is to be performed by the algorithm, without any external intervention of the researcher, so to give a true objective mathematical technique.

JAPANESE SATELLITE PROGRAMS RELATED TO TROPOSPHERIC VERTICAL SOUNDING

T. Aoki
Meteorological Research Institute
Tsukuba, Ibaraki 305, Japan

A brief summary of the status and plans of Japanese space programs related to tropospheric vertical sounding is presented. Some details are given for the tropospheric sounding sensors proposed for the Japanese Polar Orbiting Platform (JPOP). They are AMSR (Advanced Microwave scanning Radiometer), LIDAR (LIght Detection And Ranging), TERSE (Tunable Etalon Remote Sounder for the Earth), FPITS (Fabry-Perot Inverse Transform Spectrometer) and ISTG (Interferometric Spectrometer for Temperature and Greenhouse gases).

TERSE is an instrument for sounding the tropospheric trace gases such as CO2, CH4, N2O, CO, H2O and HDO by observing reflected solar radiation in the wavelength range between 1.2 - 2.4um. It is shown that in the lower troposphere the error in the simulation study is roughly a few percent.

INFORMATION CENTER OF HIGH SPECTRAL RESOLUTION SOUNDERS

C. Blondin and F. Courtier
Meteo-France
Paris, France

The meteorological community has expressed an urgent need for improved vertical resolution of satellite soundings. Current projects (AIRS, IASI) aim at providing observing systems which will deliver information of the equivalent of thousands of IR channels. It is critical to evaluate in advance (e.g., in a phase A or B) if proposed technical solutions satisfy requirements.

The presentation will show ongoing work at Meteo-France to assess the information content of high spectral resolution sounders, based on a method developed by Thepaut and Moll (QJRMS, 1991). Results indicate the effective gain of information with respect to an a priori knowledge that these new instruments are bringing. Furthermore, the method can be applied to study the quality of the information content under various meteorological conditions, and its dependence upon meteorological parameters like cloudiness.

Work has concentrated on the temperature information. Further studies will be dedicated to evaluate humidity and ozone information content. This work will help to define operational trade-offs which might be envisaged between information volume and accuracy.

TOVS - DATA PROCESSING AT THE DEUTSCHER WETTERDIENST

T. Bohm
Deutscher Wetterdienst
Offenbach, Federal Republic of Germany

TOVS data received daily by the HRPT station are processed operationally at the German Weather Service. The system works automatically without need for any manual interventions. The software is derived from the ITPP-3 with very few modifications. The preprocessing is done on a micro-VAX and the retrieval on a Cyber 990. The whole processing time is no longer than 45 minutes. The results are monitored regularly. Collocation statistics with radiosondes in the global network, ITPP-profiles, and 500 km GTS SATEMS are calculated.

First impact studies with ITPP sounding data in commercial weather prediction are underway. In the future TOVS data of sufficient quality (retrievable with error flags) will be used in the analysis scheme of the German finemesh model and as a diagnostic tool (TOVS-only-fields, for example, of thermal vorticity) in an interactive graphical system.

ASSIMILATION OF RETRIEVALS IN THE CANADIAN METEOROLOGICAL CENTER FORECAST/ANALYSIS SYSTEM AND ITS IMPACT ON THE EASTERN PACIFIC AND WESTERN CANADA

C. Chouinard[1] and B.T. Greaves[2]

[1]Recherche en Prevision Numerique
Environnement Canada, Dorval, Canada

[2]Atmospheric Environment Service/ARMA
Downsview, Canada

A non-linear optimal estimation TOVS system, following the work of J. Eyre, has been implemented in the CMC forecast/analysis system and is being tested on a set of 15-day assimilations to determine its potential usefulness.

The retrieval algorithm has been implemented as an additional 1-D non-linear optimal step of the complete OI analysis steps. At each of the following steps, the error is accounted for by using the analysis error estimate of the previous step.

The analyses and forecasts of the experimental system were compared to a control assimilation based on the current use of SATEM sounding reports. Preliminary results indicate that our current use of SATEMs could be improved, and the proposed scheme appears to correct some of the errors.

ON THE INFORMATION CONTENT OF TOVS RADIANCE FIELDS

D. Devenyi[1], I. Ihasz[1], G. Radnoti[1], and G. Sipos[2]

[1]Central Institute for Weather Forecasting
Budapest, Hungary

[2]Computer Centre of Hungarian Meteorological Service
Budapest, Hungary

In this paper, results are presented which have been obtained from the comparison of nonlinear (mutual information) and linear (correlation) relationships between radiances of different TOVS channels and between TOVS radiance and air temperature. In this examination we used TOVS radiances and radiosonde data derived from the "McMillin data set." The results suggest the existences of nonlinear dependencies. It raises the necessity of elaborating new methods instead of those supporting only linear dependencies.

THE MONITORING OF A LOCAL AREA SOUNDING SYSTEM

P. Dibben and D. Chapman
U.K. Meteorological Office
England

The U.K. Meteorological Office has now been running a Local Area Sounding System (LASS) for some eight years. The current scheme employs a physical, minimum variance method of inverting the satellite radiances. An important component of the total system is the monitoring element which not only assesses retrieval quality but also provides information pertinent to the tuning of the LASS.

If the LASS retrieval is to show a consistent improvement above the first guess and have a consistent positive impact on NWP then careful attention to tuning (and quality control) is essential. It is also of great importance that the "estimate of truth" used in the monitoring should be the best possible. In the future, it is hoped that these objectives can be realized by tuning for only ocean areas (where LASS data is assimilated), identifying the amount of data required for stable tuning parameters, and incorporating the K,C and E matrices into the system.

STUDY OF THE SIMULTANEOUS PHYSICAL RETRIEVAL METHOD FOR METEOROLOGICAL PARAMETERS OVER THE CONTINENT OF CHINA

C. Dong, G. Li, W. Zang, B. Wu, M. Ran, Q. Liu and M. Zhang
Satellite Meteorlogical Center
Beijing 100081, PRC

The simultaneous physical retrieval method (simply called SPRM) developed by Smith et al. is essentially different from usual single parameter retrieval methods. It has many advantages and is a more powerful method. However, if this algorithm is to be adopted in operational practice for processing satellite data from the East-Asia continent, including the Qinghai-Xizang plateau, much work has to be done.

We started with the ill-posed retrieval problem and did some theoretical analysis as well as comparison studies on the important factors causing retrieval errors in the SPRM. Modifications to the SPRM to improve the retrieval accuracy over China's continent have been made. Using 33 overpasses from 11 days of NOAA-10 TOVS data in the winter of 1990, the retrieval results verified by nearby radiosondes show that the modified SPRM is applicable for the continent plateau .

A NEW FAST RADIATIVE TRANSFER MODEL FOR TOVS

J. Eyre
European Centre for Medium-range Weather Forecasts
Reading, UK

Processing systems for exploiting satellite sounding data require fast and accurate radiative transfer schemes. A new scheme has been developed, initially for use with TOVS data but with flexibility for easy extension to other satellite sounding systems. In addition to the radiative transfer model itself, associated tangent linear, adjoint and gradient-matrix models have been developed. This work has been stimulated by the requirements of recent developments in variational data assimilation for numerical weather prediction, and specifically by projects at ECMWF on one-dimensional and three-dimensional schemes for variational analysis of TOVS radiances. The radiative transfer calculation follows the general method used at NESDIS and elsewhere, but the architecture of the new scheme has been redesigned completely to assist efficient implementation on vector hardware. The main scientific change is a new fast transmittance model for water vapor.

The paper discusses the intended applications, design requirements and scientific features of the new model. It then describes the algorithms used in the radiative transfer scheme and also discusses potential developments to the scheme which have been planned in the design but not yet implemented. The roles of the tangent linear, adjoint and gradient-matrix models are described. Finally, examples of execution times and their implications for processing of global data are discussed.

ANALYTICAL APPROXIMATIONS FOR THE SIMULTANEOUS RETRIEVAL OF TEMPERATURE AND MOISTURE

M. Goldberg and H. Fleming
NOAA/NESDIS
Washington, D.C. 20233

In the perturbation form of the radiative transfer equation (RTE) for the one step retrieval algorithm, the term involving the departure of atmospheric transmittance from a mean condition was approximated using a one term Taylor expansion about precipitable water. The approximation of transmittance departure as a function of moisture is necessary so that both moisture and temperature can be derived simultaneously. However, the transmittance departure for a number of HIRS channels is also strongly dependent on temperature departure. A new approximation is derived whereby transmittance departure is now a function of both moisture and temperature departures. In comparison with exact computations of transmittances, the new approximation under many different conditions, was found to be superior to the moisture only approximation. Furthermore, the forward calculation of the perturbation form of the RTE demonstrated that the moisture only approximation was in error by about 1 K for HIRS channels 4 through 7 under certain conditions. The new approximation reduced this error to within 0.2K.

AN EVALUATION OF LEAST SQUARES ALGORITHMS USED IN ATMOSPHERIC RETRIEVALS

L. Gumley, B. White, and M. Lynch
Remote Sensing of Satellite Research Group
Department of Applied Physics
Curtin University of Technology, Perth, Australia

The least squares solution encounted in producing retrievals from satellite radiances is sensitive to ill-conditioning. The normal equation solution scheme attempts to stabilize the process using a Lagrangian multiplier to increase the size of the diagonal elements. We have examined the performance of the normal equation approach and the QR decomposition method. In the latter scheme, the matrix of basis functions is replaced by a product QR, where Q is an orthogonal matrix and R an upper triangular matrix. The two schemes were applied to Hilbert matrices to evaluate their performance in highly ill-conditioned environments, and subsequently to a set of synthetic radiances to examine the accuracy which might be achieved in processing TOVS radiance data in the ITPP-3.

ATOVS PREPARATIONS

C. Hayden
NOAA/NESDIS
Madison, WI

ATOVS is now nine years in the planning and three years from implementation. Lead times of this sort, comprising a third of a scientist's working career, have something of a mesmerizing effect. It is the business of international groups, like the ITOVS Working Group, to guard that interest does not flag, that the best and brightest scientific system be in place to exploit the new instrumentation. In this interest, the ATOVS working group was formed nine months ago. Primary among its objectives is the identification of scientific aspects requiring research and development and the cooperation among ATOVS users in addressing these needs corporately.

If we review the history of the ITSC, it is apparent that the catalyst for a directed and fruitful international exchange was twofold: the availability of TOVS processing systems to reduce the basic development time for new users, and the concentration by all participants on a particular case study. From this precedent, the ATOVS working group at this conference is strongly urged to revisit this approach. To this end, a commitment should be made to make available a package containing a case study of (synthesized) data together with the basic processing algorithms, leaving undefined particular processing details. Examples of the latter include: the collocation of HIRS and AMSU; the correction of AMSU for precipitation and cloud liquid water; the calculation of emissivity; the techniques of quality control. In addition to the package, facilities should be provided at the major centers for those wishing to pursue these problems. Participants might be requested to provide, at the next ITSC, the results of their studies to include both retrievals for comparison with other efforts and software modules unique to their processing.

These products could provide the focus for the conference, and likely show progress on problems which are not well understood at this time

At the time of this Sixth International TOVS Study Conference (ITSC-VI), it seems that some of the vigor of earlier meetings is missing. Perhaps we have become disillusioned by the diminishing return available from an ITOVS system we have studied for twelve years. Fortunately, with the ATOVS, there is opportunity for a fresh beginning. The National Environmental Satellite and Data Information Service, NESDIS, has prepared a "science document" outlining the proposed processing approach. The ATOVS users are urged to review this document. The system is not yet frozen, but the time approaches when it must be, at least for the broader structure. It is not too late for our group to begin an effort which can impact the international processing of the ATOVS. It is also not too early. The scientific answers are not known. We need to work together on them, with focus and enthusiasm.

A PRELIMINARY CASE STUDY ANALYSIS USING TOVS (HIRS/2) FOR THE 28 AUGUST 1990 ILLINOIS TORNADOES

D. Hillger and J. Purdom
NOAA/NESDIS/CIRA
Colorado State University
Fort Collins, CO 80523-0033 USA

This paper presents a preliminary analysis of an interesting case study involving three tornadoes which occurred in northeastern Illinois on 28 August 1990. The special methods employed for the analysis of the TIROS Operational Vertical Sounder (TOVS data have been previously used to analyze VISSR Atmospheric Sounder (VAS) data from the GOES series of satellites. A method to minimize the number of retrievals, while maximizing the differences between retrievals, was applied to this case study and compared to retrievals produced in a normal manner but grouped into two different retrieval densities. The advantage of this particular clustering technique is that the members of a cluster are similar to within the noise levels of the measurements. This acts to reinforce mesoscale features and maintain gradients in the analysis compared to retrievals grouped arbitrarily (blocked).

Significant differences between clustered and non-clustered (blocked) retrievals are solely the result of the way the input data is treated. This case study continues to prove that satellite sounding measurements can produce reasonable retrievals, but it is important that the input data be handled properly. With proper treatment of the input by clustering, the results can be more reflective of the mesoscale air masses surrounding severe storms. Without proper handling, the retrievals can appear like bad data. No wonder satellite retrievals have a bad name. Is it better to produce lots of potentially bad retrievals or to produce a few improved retrievals which involve more effort to obtain?

This work is only the preliminary analysis of this case study. Correctional data (soundings and surface observations) have been fully analyzed. In addition, MSU data was not used actively in the clustering process. These avenues will be explored and results will be presented at the next conference.

COMPARISONS OF NOAA-10 RADIANCES WITH COMPUTED RADIANCES FROM RADISONDE DATA AND A PREDICTION MODEL

D. Kim
NOAA/ERL
Boulder, CO 80303

A pilot study for the direct radiance assimilation into the operational Mesoscale Analysis and Prediction System (MAPS) of the Forecast Systems Laboratory (FSL) has recently started. The study focussed on the generation of error cross-covariances between temperatures and brightness temperatures. Preliminary results from 932 triple paired (measured, RAOB-computed, MAPS-computed) samples collected during February and March 1991 showed that statistics were able to identify known model deficiencies.

FIRST RESULTS OF A COMPARISON BETWEEN THE OLD AND THE NEW "3I"-VERSIONS

D. Klaes*
Geophysics Directorate of the Phillips Laboratory
Hanscom AFB, Massachusetts

*Permanent affiliation:
German Military Geophysical Office (GMGO)
D-5580 Trasur-Troubach, Germany

A. Chedin, N. Scott, N. Husson, B. Bonnet, J. Ecosou and V. Achasd
Laboratorie de Meteorologie Dynamique du CNRS
Ecole Polytechnique, France

The "3I"-algorithm (Improved Initialization Inversion) underwent many improvements in the past. There has been a major change in the "3I"-system recently. This has been the introduction of a completely new derived TIGR (TOVS Initial Guess Retrieval) dataset. It was created out of more than 100,000 radiosonde observations.

The purpose of this paper is to show some aspects of the new "3I"- version from the point of view of applications. It will cover the European orbits of different NOAA/TIROS-N satellites for one day in summer of 1990. The data of this study were received with the German Military Geophysical Office's HRPT reception station.

THE ENVIRONMENT OF MESO-B PHENOMENA WITH TOVS

D. Klaes*
Geophysics Directorate of the Phillips Laboratory
Hanscom AFB, Massachusetts

*Permanent affiliation:
German Military Geophysical Office (GMGO)
D-5580 Trasur-Troubach, Germany

Mesoscale phenomena have already been studied with TOVS data over the Antarctic Region and in mid-latitudes. This study focusses on the environment of mesoscale cloud clusters over mid-latitudes. Preliminary results are described for a situation over Central Europe in summer. Only TOVS data are used. Further studies will be extended to regions where there are not much conventional data available.

The retrieval package used for this study is the "3I" (Improved Initialization Inversion) algorithm, developed and maintained at Laboratoire de Meteorologie Dynamigue, Ecole Polytechnique, Palaisaeu, France.

PRINCIPLE COMPONENT ANALYSIS USED FOR CLOUD DETECTION AND FIRST GUESS SELECTION OVER THE ANTARCTIC

T. Lachlan-Cope
British Antarctic Survey
Cambridge, England

The Principal Component Analysis (PCA) is used on selected TOVS channels to help two problems found with the retrieval of temperature profiles over Antarctica. The first is the detection of cloud over snow and ice. When PCA is used on six days of TOVS passes over Antarctica it was found that cloudy and clear areas could be easily identified in the first two principle component scores. The second problem involved the selection fo a first quess from a library of radiosondes. It was hoped that the eigenvector obtained from the six day set could be applied to radiances obtained from the radiosonde by a tranmittance forward transmittance model. When the principal component vectors were compared the match was found to be very poor.

THE COMPARISON AND CALIBRATION OF THE TOVS DATA IN THE KOREA

J. Lee, H. Cho, and A. Suh
Satellite Meteorology Division
Meteorological Research Institute, Korea

TOVS retrieved outputs produced by ITPP Version 4 at the Korean Meteorological Service for temperature, dewpoint temperature, mixing ratio, precipitable water, and total ozone were compared with radiosonde observations of four aerological stations (Pohang, Cheju, Kwangju, and Osan) to understand those

error ranges for the data of May to September 1990. Special emphasis was placed on analyzing the root mean square error (RMSE) and the bias of TOVS outputs, and the upper air state over Korea.

TOVS temperature RMSE appeared as 2.5 C more or less at the mid-level (700 hPa - 400 hPa), while more than 3.5 C near the surface and tropopause. However, it was shown that the bias error was less than 1 C in general, much smaller than the RMSE. The RMSE was usually smaller for clear days than for cloudy days, and its variability was small.

The comparison of TOVS retrieved dewpoint temperature, mixing ratio, precipitable water, and total ozone with the observations showed that the TOVS outputs were often smaller than the RAOB except for the total ozone.

Monthly mean values of the vertical temperature profile, precipitable water, and total ozone from May to September were obtained by using the TOVS and the RAOB. They are summarized as follows. The temperature at 850 hPa was estimated as 10 C in May, 20 C in July and August, and 15 C in September, while at the 500 hPa level temperatures were -15 C in May, -5 C in July and August, and -10 C in September, and at the 300hPa level temperatures were -35 C in July and August, and below -35 C in September. Monthly mean precipitable water was 20 cm in May, 35 cm in June, 45 cm in July, 48 cm in August, and 35 cm in September. The total ozone was varied from 340 m-atm-cm in May to 270-280 m-Atm-cm in July and August.

It was also shown from the investigation of vertical temperature profiles that the tropopause level was near the 100 hPa height for the period of May through September. The temperatures at the tropopause vary from -70 C at latitudes 30-35 N to -60 C at latitudes 40-45 N.

DETERMINING TOTAL OZONE IN THE AUSTRALIAN REGION USING TOVS DATA FROM NOAA SATELLITES

J. Le Marshall, Z. Wu and G. Mills
Bureau of Meteorology Research Centre
Melbourne, Australia 3001

Total ozone amount and ozone mixing ratio have been determined in real time over the Australian Region using High Resolution Infrared Radiation Sounder (HIRS) radiance measurements from the NOAA series satellites. The method used to calculate ozone amount has been developed from that of Ma et al., (1984). This method uses statistical relationships between HIRS channels 1 to 4 radiances and ozone amount to establish a first guess profile which is refined using the radiative transfer equation. Changes have been made to the Ma et al. algorithm to improve total ozone estimates. Some results from using the method are shown and analysed fields of ozone amount have been used to generate predicted fields using the Regional Assimilation Prognosis system.

PRELIMINARY RESULTS FOR OZONE USING ITPP3

J. Li and M. Lynch
Remote Sensing and Satellite Research Group
Curtin University of Technology, Perth, Australia

For the year 1989 we have processed TOVS data sets using the ITPP3 to produce total column ozone fields. We have undertaken a comparison of the results with measurements from the Perth Dobson station and found good agreement during winter months, but significant discrepancy over the spring, summer and early autumn periods. Subsequent work has included the migration of an alternate cloud routine into the ITPP3 code and incorporation of an adjustment to the ozone transmittance term for water vapour. We report results of limited reprocessing with these adjustments incorporated into the code. This preliminary work is continuing.

RESULTS FROM AN EMPIRICAL CLASSIFICATION RETRIEVAL METHOD

L. McMillin
NOAA/NESDIS
Washington, D. C. 20233

An empirical classification regression approach for retrieving profiles of atmospheric temperature and humidity is described and evaluated. Important features of the approach are the following. The method is entirely empirical in that the classification is done on measured radiances and the retrieval is a regression. These alternatives were selected to avoid the need to calculate radiances that match measured values to the accuracy required to do retrievals. Although a common criticism of empirical approaches is that they need frequent tuning, the method is very stable. Coefficients were generated for a random selection of about 10% of the satellite radiosonde matches obtained during a one-year period, and applied to all the data for a two-year period. In addition, the retrieval consists of one retrieval matrix that was used for all latitudes and all seasons. Finally, the method was applied to radiances that had been adjusted for clouds with an approach that assures that spots used for the N* cloud clearing actually have clouds at the same height. The stability of the retrieval is an important consideration for local retrievals, as well as for climate studies.

The method was evaluated in two ways. It was compared to the operational TOVS result for a two period and it was applied to the French study case on June 7, 1987. In the two-year comparison, the method was more accurate than the TOVS operational results near the surface for the entire year period, even though the operational retrievals are continuously tuned to radiosondes. In the upper atmosphere, the method was more accurate for the first year, but then developed a bias because of some change in the instrument (possibly a change in the characteristics of MSU channel 3) that occurred near the end of the first year. This change affected the operational results when it occurred, but was tuned out over several weeks and could have been tuned out of the classification regression approach also. In the French study case, the approach produced a strong wave pattern in the 1000-500 hPa thickness field with horizontal divergence over the wave in the 500-300 hPa thickness field.

These features were not apparent in the analysis that occurred at that time. If the data produced by the retrieval had been available, they certainly would have alerted forecasters to the intense storm that occurred when the wave moved over France.

RADIANCE ERRORS IN THE ONE DIMENSIONAL ANALYSIS OF TOVS DATA AT ECMWF

Tony McNally
European Centre for Medium-Range Weather Forecasts
Reading, England

ECMWF is currently developing a system to generate retrieved products from TOVS measurements intended for routine assimilation into the operational forecast model. The method of retrieval uses a one dimensional variational analysis (1-D VAR) of (initially) NESDIS cloud cleared radiances and is intended to operate on raw (cloud contaminated) measurements in the near future. The 1-D VAR retrieval scheme is so called within the context of ECMWF's plan to adopt a three and ultimately four dimensional variational analysis of all observations in the operational forecast suite. Though the explicit retrieval step may be regarded as a temporary interface to the current OI analysis, the problems which must be addressed in the 1-D case are directly relevant to the future integration of satellite data within the three and four dimensional systems.

INFLUENCE OF THE TOPOGRAPHY ON TOVS SOUNDINGS

A. Pfister and F. S. Olesen
Institut fur Meteorologie und Klimaforschung
Kernforschungszentrum Karlsruhe/Universitat Karlsruhe
Germany

In 1989, the 3I code was implemented in the Interactive System for Satellite data processing (ISYS) at the Institut fuer Meteorologie und Klimaforschung (IMK). The main goal is to derive high quality temperature and moisture fields from satellite data for use in mesoscale models.

A special aim consists in improving TOVS 3I-processing by a more precise representation of the topography. This means a more accurate determination of the mean elevation and the derivation of topographic roughness parameters of the surface in HIRS spots. HIRS spots with large topographic structure should be identified and rejected in further processing. It is important for the inversion scheme to get a surface elevation, in order to avoid errors and misinterpretation of the radiance contributions originating from the atmosphere or from surfaces inside the HIRS spots. The Digital Terrain Elevation Data model (DTED) with a resolution of 1/6 of a degree presently used in 3I does not allow us to derive such parameters. A new high resolved DTED model, which represents a subset of the Digital Land Mass System (DLMS), was implemented in a modified 3I-version. The resolution was adapted to the resolution of the HIRS radiometer and the AVHRR sensor (15'' x 15'', 450 m). The DLMS DTED-model can be used to derive geomorphometric and

geomorphological parameters for a more accurate description of the topographic surface, as it had been done before.

A method is presented by which roughness parameters and in addition a roughness vector can be determined. In a newly developed topography rejection test, the rough or inhomogeneous HIRS spots can be detected and rejected, before grouping the HIRS spots into the so-called 3I-boxes. Analysis data of the ECMWF are being used to validate the results.

TOWARDS A TOVS COOK BOOK - A GUIDE FOR DAY TO DAY TOVS USERS

G. J. Prangsma
KNMI
DeBilt, Netherlands

Much has been achieved over the past years concerning the implementation of the scientific understanding of TOVS inversions into practical algorithms. With these packages (ITPP as well as 3I) becoming readily available for a wide variety of interested users, time has come to also address the issues involved in routine TOVS processing. A number of these technical aspects are discussed, with the ultimate aim of operational use, and especially data assimilation, in mind. Putting together a "TOVS Cookbook" by building on the various user's guides and experiences is advocated.

DMSP AND TOVS OPERATIONAL STATUS

A. Reale
NOAA/NESDIS
Washington, D.C. 20233

DMSP sounding products based on the Special Sensor Microwave/Temperature (SSM/T) sounder are produced operationally by NESDIS using a statistical regression retrieval approach. Experimental products of cloud liquid water, and of surface wind (over ocean) and snow/ice fields using the Special Sensor Microwave/Imager (SSM/I) mapped data are also produced. Future upgrades to use the SSM/I data to correct the surface channels of the SSM/T, and to install a physical retrieval and classification approach to produce soundings are planned.

TOVS sounding products are produced operationally be NESDIS using a physical retrieval approach with a library search technique to determine the first guess. The guess is based on a carefully selected sample of collocated radiosonde and satellite observations which is updated daily. Upgrades since 1989 were primarily to correct and optimize the use of the collocated data to compute the first guess. A stability departure parameter between the TOVS soundings and corresponding NMC 6-hour forecast data shall be added to the TOVS product suite around June 1991. A classification approach to compute the first guess, and improved usage of available surface air temperature data (particularly for cloudy oceanic soundings), is scheduled for implementation late this year.

BASELINE UPPER AIR NETWORK (BUAN)

Anthony Reale
NOAA/NESDIS
Washington, D.C. 20233

The Baseline Upper Air Network (BUAN) experiment was conducted from January 15 to July 15, 1988. The BUAN consisted of 104 candidate radiosonde (and rocketsonde) observing stations and ships. A final report (NOAA Technical Report 52) has been published. An archive of the collocated radiosonde and satellite observations collected during the BUAN experiment is available from the Satellite Data Services Division (SDSD) of the National Climatic Data Center (NCDC) of NESDIS.

RECENT ADVANCES IN THE 3-D THERMODYNAMIC ANALYSIS OF THE EARTH SYSTEM THROUGH THE "3I" ALGORITHM. EXTENSION TO THE 2ND GENERATION VERTICAL SOUNDERS.

N. A. Scott, A. Chedin, V. Achard, B. Bonnet, F. Cheruy, C. Claud, J. Escobar, N. Husson, H. Rieu, Y. Tahani, and B. Tournier.
Laboratoire de Meteorologique Dynamique
Ecole Polytechnique
Palaiseau Cedex, France

Aiming at the three-dimensional thermodynamic analysis of the Earth's atmosphere structure from observations of the operational meteorological satellites of the TIROS-N/NOAA series, algorithm "3I" (Improved Initialization Inversion), since the last meeting of the International TOVS working group, has been developed and refined following three main directions:

- As a feedback from the extensive series of experiments carried out at ECMWF and numerous other sites aiming at measuring the capabilities of satellite data, processed by the "3I" scheme, to correctly describe the 3D thermodynamic properties of the Earth's system, modifications have been introduced in the first version of the algorithm (3I-1) that do not change neither the mathematical nor the physical concepts which are at its basis but should enhance its performances: modification of the TIGR (TOVS Initial Guess Retrieval) data set; introduction of a new air mass classification scheme; refinements in the moisture retrieval procedure. A few representative examples are shown and discussed.

- Study of mesoscale phenomena over polar regions and, in particular , a cold air outbreak and the observation, from birth to final decay, of polar lows using a multi-sensor approach (TOVS, SSM/I, GEOSAT).

- Developments towards the processing of the second generation vertical sounders: high spectral resolution infrared spectrometers AIRS (Atmospheric Infrared Radiation Sounder) or IASI (Improved Atmospheric Sounding in the Infrared) and the new microwave instrument AMSU (Advanced Microwave Sounding Unit).

INVESTIGATION OF SYSTEMATIC ERRORS IN TOVS FORWARD MODEL CALCULATIONS IN CLOUDY CONDITIONS

D. Turner and J. Steenbergen
Meteorological Services Branch
Atmospheric Environment Service
Canada

We have compared calculated and observed HIRS brightness temperatures for a small number of scenes with uniform overcast clouds selected for the CATHIA database. The collocated AVHRR data and 4A transmittance included in the database were used to estimate the cloud top pressure for the forward calculations. The forward calculations (using the NESDIS fast transmittance model) were modified to include non-unit cloud emissivities and reflectivities based on published scattering calculations, and to include a simple model of solar radiation and downwelling atmospheric radiation reflected from the cloud top.

Inclusion of reflected solar radiation considerably reduced mean differences between observed and calculated brightness temperatures for the most transparent shortwave sounding channels (13 and 14). Smaller mean (observed minus calculated) differences were also obtained for channel 10 (the "dirty window") when non-unit cloud emissivity and reflected downwelling radiation were taken into account.

Particularly large (observed minus calculated) brightness temperature differences were obtained for the water vapor sounding channels (11 and 12), and these differences appeared to increase with increasing cloud top height.

FORWARD MODEL ERRORS

M. Uddstrom
New Zealand Meteorological Service
Wellington, New Zealand

In general, physical retrieval and direct radiance assimilation algorithums assume that satellite radiances may be simulated from atmospheric profiles of temperature and water vapour, with zero bias and little noise. If these conditions are not met, then the information in the satellite radiance data will be improperly utilised, and may produce unexpected observing systems impacts. These conditions are not met for current forward radiative transfer equation (RTE) models. All RTE results must be "adjusted" in some sense in order for synthesised radiances to meet the specified requirements of zero bias and low difference noise. Of these two conditions, the most significant is the requirement for zero bias. If the difference noise is large, that should only result in the satellite data having less influenece on the observing systems.

In this paper, various aspects of the forward model problem are discussed, in so far as they affect both the specification of the state of the atmoshpere, and error in the NESDIS forward (RTE) model. To this end the NESDIS operational collocation data base (the DSD5 data archive) is used to

investigate the forward model errors as a function fo airmass, day and nightime data, and radiosonde type. Results from three different radiance temperature adjustment schemes are presented, and it is shown that forward model data may be adjusted to measured values, and vice versa, with significant skill.

PROGRESS IN THE RECOVERY OF TRACE GAS CONCENTRATION PROFILES FROM HIGH SPECTRAL RESOLUTION DATA

P. van Delst and M. Lynch
Remote Sensing and Satellite Research Group
Curtin University of Technology, Perth, Australia

The trace gas information in the high spectral resolution infrared data acquired by the High-resolution Interferometer Sounder (HIS) at the University of Wisconsin is well above the noise level and offers the potential for recovery of the concentration profiles. Presently, we are computing the expected spectral sensitivity with change in mixing ratio of a species as a function of pressure level. Our intention is to generate synthetic data sets and trial a retrieval scheme on these data. The retrieval approach we are investigating presently is based on the QR least squares method. Subsequent work will apply the retrieval method to data sets acquired during the Ground-based Atmospheric Profiling Experiment (GAPEX), Denver, 1988.

MICROWAVE MEASUREMENT AND THE INFLUENCE OF CLOUDS

D. Q. Wark
NOAA/NESDIS
Washington, DC 20233

There are systematic and random errors introduced into TOVS sounding resulting from improper use of the MSU Channel 2. Because the MSU does not have enough channels to solve the problem, data from the SSM/T on the F9 satellite have been used to illustrate a solution. Using data over oceans only, 64x64 grids of minimum values in the northern and southern hemispheres were generated for the window channel suing data associated only with the minima of Channel 1. Mean differences between observations and the grid values were then found for intervals of cloud liquid water computed from the Grody relation. The results were fitted by least squares to give adjustments needed to correct the measurement for the effects of cloud liquid water. It was shown that the present operation produces errors as great as 2.0 K in the lowest layers of the atmosphere. Their effect on TOVS sounding is to make cloudy soundings incompatiable with those in clear or partly cloudy areas.

LIMB ADJUSTMENTS TO TOVS DATA: A MORE RATIONAL APPROACH

D. Q. Wark
NOAA/NESDIS
Washington, D.C. 20233

Currently the TOVS data are subjected to a limb adjustment in the operational processing. Coefficients for this process are generated from computed radiances using a set of 120 radiosonde-rocketsonde measurements. The procedure has several flaws which lead to small but significant errors. To circumvent these problems, actual observations for a five-day period are averaged in two-degree latitude belts by scan position, channel, and surface type. After smoothing of the data, channels to be used in the limb adjustments are selected on the basis of reduction of variance and minimization of noise amplification, using step-wise regression. Coefficients are then computed by simple least squares. Worst case estimated errors are below the noise level in many channels and noise amplification is well below 2.0 K for all but three of the 27 channels. The heart of the procedure is the generation of a set of about 150 true variations of radiances or radiance temperatures with viewing angle for each channel and beam position.

TWO YEARS OF GLOBAL CIRRUS CLOUD STATISTICS USING HIRS

D. Wylie[1] and P. Menzel[2]

[1]CIMSS
University of Wisconsin

[2]NOAA/NESDIS
Madison, Wisconsin 53706

A climatology of upper tropospheric semi-transparent cirrus clouds has been compiled using HIRS multispectral infrared data sensitive to CO2 absorption from the NOAA polar orbiting satellites. This is a report on the first two years of data analyzed (June 1989 - May 1991). Semi-transparent clouds were found in 35% of the observations. Large seasonal changes occur in areas dominated by the ITCZ, the sub-tropical high pressure systems, and the mid-latitude storm belts. Semi-transparent clouds associated with these features, move latitudinally with the seasons. These clouds also are more frequent in the summer hemisphere than the winter hemisphere. They appear to be linked to convective cloud development and the mid-latitudinal frontal weather systems.

APPLICATIONS OF THE 3I SYSTEM TO NOAA-10/11 OVER CHINA AREA

F.-X. Zhang
Satellite Meteorology Center
State Meteorological Administration
Beijing, China

The paper presents the applications of the 3I system (the 1989 version) to NOAA-10/11 over China. Comparisons have been made between the results from the 3I system and the regression algorithm with the radiosondes. It is shown that the 3I is slightly better than the regression. The standard deviations of the temperature and relative humidity of the 3I retrievals are about 2-3 K and 20-25%, respectively. The thickness and temperature fields of the 3I retrievals have a good agreement with the conventional ones for the large scale system, but the small scale systems are smoothed out. The 3I system and the TIGR data set can be used to process the NOAA satellite data over China, but the accuracy of the retrievals is limited due to the limitations of the samples in the TIGR data set.

The study of combining the simultaneous retrieval algorithm of the ITPP3 with the 3I systems shows that the accuracy of the physical retrieval algorithm is sensitive to the first guess.

SATELLITE SOUNDING APPLICATIONS IN 1990's

F. Zhou
Institute of Atmospheric Physics
Academia Sinica
Beijing, China

With the availability of computer facilities the satellite data have been playing more and more important roles in weather and hydrological services in China. Imagery data from both geostationary and polar orbiting satellites are widely used for monitoring and predicting the tropical cyclone, flash flooding, forest fire, etc., in 1980's and social and economical benefits have been achieved. But the utilization of sounding data still remains in research and experimental stage. In last three years, the computer systems in both national and local meteorological centers were greatly upgraded and different time and space-scale numerical models were developed. Since the TOVS products processed by SMC have not been distributed to local users through the communication line, several HRPT stations were established lately in provinces and regional centers to receive the real-time TOVS data as well as the AVHRR data. Thus the condition is favorable to process TOVS data and do the assimilation locally for improving the numerical forecasting. The scientists in SMC and IAP are facing the task to transfer the TOVS data processing technique to local users and train them. In addition they should also be prepared to deal with the AMSU in the 1990's.

AN IMPROVED CLOUD RETRIEVAL ALGORITHM USING HIRS2/MSU RADIANCE MEASUREMENTS

S. Zhou[1], L. McMillin[2], and S. Yang[3]

[1]National Research Council
Washington, D.C. 20418

[2]NOAA/NESDIS
Washington, D.C. 20233

[3]Research Data System Corporation
Greenbelt, MD 20770

A comparison of TOVS retrievals of cloud top pressure and amount with those produced by NASA Goddard, ESCCP, and the Air Force RTNEPH showed that distribution of cloud amount as a function of cloud top pressure being produced by TOVS differed significantly from the expected pattern.

An improved algorithm has been developed for cloud parameter retrieval using HIRS2/MSU radiance measurements. The principle of the new algorithm is the use of different pairs of HIRS2 15 um CO2 and window channels to retrieve cloud top temperature for corresponding cloud levels. The cloud parameters produced with the new algorithm are in better agreement with NASA Goddard's, ISCCP, and Air Force RTNEP data.

APPENDIX A. AGENDA FOR ITSC-VI

SIXTH INTERNATIONAL TOVS STUDY CONFERENCE
AIRLIE, VIRGINIA
1-6 MAY 1991

Wednesday, 1 May 1991

0830 - 1000 am	Welcome and Opening Remarks
	McPherson NMC Opening Remarks **Kakar** NASA Opening Remarks **Rao** NESDIS Opening Remarks
1000 - 1100 am	Summary of Recent Meetings
	Menzel Extraordinary Session of CBS **Chedin** Report on GEWEX
1100 - 1200 noon	Scientific Presentations (Chair: Menzel) (each speaker has 15-minutes for presentation plus 5-minutes for discussion) Retrieval Algorithm Developments
	Eyre "A new fast radiative transfer model for TOVS" **Fleming** "Forward problem and corrections for AMSU" **Lynch** "An evaluation of least squares algorithms used in atmospheric retrievals"
1200 - 0130 pm	Lunch
0130 - 0530 pm	Scientific Presentations (Chair: LeMarshall) Retrieval Algorithm Developments (continued)
	Uddstrom "Forward model errors" **Turner** "Investigation of systematic errors in TOVS forward model calculations in cloud conditions" **Watts** "Clouds and TOVS radiances" **Serio** "Cloud clearing with radial basis functions" **Zhou, S** "An improved cloud retrieval algorithm using HIRS2/MSU radiance measurements"

Wark
"Microwave measurements and the influences of clouds"
Pfister
"Influence of topography on TOVS soundings"
McMillin
"Results from an empirical classification retrieval method"
Scott
"Impact of the TIGR-2 data set on the 3I system retrievals"
Dong
"Study of retrieval method for meteorological parameters over the continent plateau of China"
Goldberg
"Analytical approximation for simultaneous retrieval of temperature and moisture"

Thursday, 2 May 1991

0830 - 1200 noon — Scientific Presentations (Chair: Lynch)
Products/Evaluation

Travaglioni
"Quality control from Dobson data at the Italian ozonometric network using TOVS/ITPP-3 retrievals"
Bates
"Global atmospheric water vapor content derived from TOVS data"
Lachlan-Cope
"Principle component analysis used for cloud detection and first guess selection over Antarctica"
Menzel
"Global cloud climatology with HIRS"
Prata
"Land surface temperature determination from AVHRR/TOVS"
Dibben
"Monitoring of a local area sounding system"
Zhou, F
"Satellite sounding applications in the 1990's"
Hillger
"A case study analysis of HIRS-2 for 28 August 1990 Illinois Tornadoes"
Pagano
"Operational developments of ITPP-3"
Sipos
"Developments and applications of TOVS retrievals"
Suh
"The comparison and calibration of the TOVS data in Korea"

1230 - 0200 pm — Lunch

0200 - 0530 pm

Status Report on Action Items (Chair: Eyre)
(each speaker has up to ten minutes)

ITPP / Woolf
3I / Scott
BUAN / Reale
SSU documentation / Woolf
Data for case studies / Uddstrom
ERICA case study / Bates
Retrieval file structure / Uddstrom
S/W costs / Smith/Scott
User guides / Smith/Scott
ATOVS / Eyre
Limb adjustments to TOVS data / Wark
Forward calculation for AMSU / Chedin

0800 - 1000 pm

Poster Sessions
(the first thirty minutes will be for brief introduction of new material; all scientific presentations are welcome in poster format for this session)

Aoki
"Future plan for the Japanese Earth Observation Satellites"
Birkenheuer
"Low level moisture field analysis using GOES data"
Bohm
"TOVS data processing at the Deutscher Wetterdienst"
Cuomo
"Optimal mathematical methodology for inverse problems in remote sensing of atmosphere"
Heinemann
"Sensitivity studies with 3I and ITPP"
Kadokura
"Vertical sounding sensor on ADEOS"
Li
"A review of the TOVS ozone products"
Slonaker
"Convective lid analysis using TOVS data"
van Delst
"Investigation of retrievals with high resolution spectral information"
Zhang
"Applications of the 3I method to NOAA series satellites over the China area"

Friday, 3 May 1991

0830 - 1030 am	NOAA Reports (Chair: Uddstrom) (each speaker has 15-minute presentation plus 5-minute discussion period) **Needham** "NOAA polar plans for the 1990s" **Hayden** "AMSU preparations" **Reale** "Operational TOVS processing" **Hughes** "Electronic bulletin board" **Metcalf** "Polar archive" **Masters** "Relationship of ITOVS Working Group and other international groups"
1030 - 1230 pm	Scientific Presentations (Chair: Uddstrom) Instrument Studies **Perrone** "High spectral resolution instruments" **Pagano** "Status of the Improved Atmospheric Sounder in the IR" **Amato** "Optimal spectral deconvolution of interferogram samples" **Blondin** "Information content in high spectral resolution IR spectra" **Chedin** "Simulation studies toward an advanced 3I system for the coming AMSU and high spectral resolution instruments" **Wark** "AIRS status" **Koenig** "Toward more uniform data"
1230 - 0130 pm	Lunch
0130 - 0430 pm	Scientific Presentations (Chair: Chedin) Model Studies **Baker** "Development of an interactive analysis/forecast/retrieval system"

Chouinard
"Assimilation of retrievals in the CMC forecast/ analysis system and its impact on eastern Pacific and western Canada"

Kim
"Comparisons of NOAA-10 radiances with computed radiances from radiosonde data and a prediction model"

Klaes
"The environment of meso-B phenomena with TOVS data"

LeMarshall
"Real time assimilation of TOVS data at the Australian Bureau of Meteorology"

McNally
"Comparison of NESDIS radiances with ECMWF model/radiosonde values"

Prangsma
"Preliminary results of routine 3I retrievals in a limited area model"

0430 - 0530 pm — General Discussions (Chair: Chedin)

Working Group Formation

Saturday, 4 May 1991

0900 am - 0300 pm — Working Group Meetings

Sunday, 5 May 1991

0300 - 0700 pm — Working Group Meetings (as necessary)

Monday, 6 May 1991

0830 - 1200 am — Working Group Presentations
(Co-chair: Chedin and Menzel)

Reports

Discussion of Recommendations

Executive Summary

Future Plans

1230 pm — Adjournment

APPENDIX B. ITOVS WORKING GROUP

Dr. Tadao Aoki
Meteorological Research Institute
Nagamine 1-1, Tsukuba
Ibaraki 305
JAPAN
tel 0298 58 0897
fax 0298 55 6936

Dr. Wayman Baker
NOAA/National Meteorological Center
Development Division, W/NMC21
World Weather Building, Room 204
Washington, DC 20233
USA
tel 301 763 8005
fax 301 423 6241

Dr. Les A. Baranski
Satellite Data Receiving and Processing
Center
Inst. of Met. and Water Management
Piotra Borowego Str. 14
30-215 Krakow
POLAND
fax 48 12 116 798
tel 48 12 113 844

Dr. John J. Bates
NOAA/ERL-R/E/CG2
325 Broadway
Boulder, CO 80303
USA
tel 303 497 6646
fax 303 492 2468

Dr. Heiner Billing
Meteorologisches Institut der
Freien Universitat
Fachbereich 24, WE07
Podbielskialle 62, D-100 Berlin 33
FEDERAL REPUBLIC OF GERMANY

Mr. Thomas Boehm
Duetscher Wetterdienst - Zentralamt
Frankfurter Strasse 135
Postfach 10-04-65
6050 Offenbach AM Main
FEDERAL REPUBLIC OF GERMANY
fax 069 8062673

Mr. Christian Blondin
Meteo France
Service Central d'Exploitation
de la Meteorologie
2, Avenue Rapp
75340 Paris Cedex 07
FRANCE
tel 1 45 56 72 41
fax 1 45 56 72 38

Mr. John-Hon Bong
Meteorological Research Institute
Korea Meteorological Service
1, Songwol-Dong, Chongno-gu
Seoul 110
KOREA
tel 02 733 0565
fax 02 737 0325

Dr. Alain Chedin
Laboratory de Meteorologie Dynamique
Ecole Polytechnique
Route Departementale 36
F-91128 Palaiseau Cedex
FRANCE
tel 33 1 69 334533
fax 33 1 69 333005

Dr. Clement Chouinard
Recherche en Prevision Numerique
2121, voie de Service nord, Suite 508
Route Trans-Canadienne
Dorval, Quebec H9P 1J3
CANADA
tel 514 421 4761
fax 514 421 2106

Mr. Paul C. Dibben
UK Meteorological Office, Met.O.(S)
London Road
Bracknell, Berkshire RG12 2SZ
UNITED KINGDOM
tel 0344 85 4529
fax 0344 85 4442

Dr. Yves Durand
SCEM/PREVI/DEV
2 Avenue Rapp
75007 Paris
FRANCE

Dra. Marlene Elias Ferreira
Rua Antonio Vieira, 17
Apt. 903-LEME
22010 Rio de Janiero RJ
BRAZIL
tel 21 295 3706
fax 123 218743

Mr. Saleh Mesbah Elkaffas
Department of Environmental Studies
Institute of Graduate Studies and Research
University of Alexandria
P.O. Box 832
Alexandria
EGYPT
tel 03 4225007

Dr. John R. Eyre
ECMWF
Shinfield Park
Reading, Berkshire RG2 9AX
UNITED KINGDOM
tel 44 734 499621
fax 44 734 869450
telex 847908 ECMWFG

Mr. Jim Giraytys
World Meteorological Organization
41 Guiseppe-Motta
Case Postale No. 5
CH-1221 Geneva 2
SWITZERLAND

Mr. Brian Greaves
Atmospheric Environment Service/ARMA
4905 Dufferin Street
Downsview, Ontario M3H 5T4
CANADA
tel 416 739 4889
fax 416 739 4221

Dr. Christopher Hayden
NOAA/NESDIS/SDAB
E/RA24
1225 West Dayton Street
Madison, WI 53706
USA
tel 608 264 5325
fax 608 262 5974

Dr. Donald Hinsman
World Meteorological Organization
41 Guiseppe-Motta
Case Postale No. 5
CH-1221 Geneva 2
SWITZERLAND
tel 41 22 730 8285
fax 41 22 734 2326

Ms. Mariken Homleid
Norweigian Meteorological Institute
Box 43, Blindern
N-0313 Oslo 3
NORWAY
tel 47 2 963000
fax 47 2 692515

Mr. F. Jahedi
Iranian Remote Sensing Center
P.O. Box 11365/6713
Tehran
IRAN

Mr. Regis Juvanon du Vachat
EERM/Centre de Recherche en Meteorologie Dynamique
2 Avenue Rapp
75007 Paris
FRANCE

Mr. Graeme Kelly
ECMWF
Shinfield Park
Reading, Berkshire
RG2 9AX
UNITED KINGDOM

Mr. Thomas Kleespies
Geophysics Laboratory
PL/GP/LYS
Hanscom AFB, MA 01731
USA
tel 617 377 4178
fax 617 377 2984

Dr. Thomas Lachlan-Cope
British Antarctic Survey
High Cross, Madingley Road
Cambridge CB3 0ET
UNITED KINGDOM
tel 0223 61188
fax 0223 62616

Ms. Lydie Lavanant
Centre de Meteorologie Spatiale
22300 Lannion
FRANCE

Dr. John LeMarshall
National Meteorological Analysis Center
Bureau of Meteorology
P.O. Box 1289K
Melbourne, Victoria 3001
AUSTRALIA
tel 61 3 669 4420
fax 61 3 669 4660

Professor Jacqueline Lenoble
Universite des Sciences
et Techniques de Lille
Laboratorie d'Optique Atmospherique
59655 Villeneuve d'Ascq Cedex
FRANCE

Dr. Frank Loechner
Deutsche Forschungs-und Versuchsan-
stalt fur Luft-und Raumfahrt
Oberpfaffenhofen
D-8031 Wessling
FEDERAL REPUBLIC OF GERMANY

Dr. Mervyn Lynch
School of Physical Sciences
Curtin University of Technology
GPO Box U1987, Perth W.A.6001
AUSTRALIA
tel 61 9 351 7540 or 7192
fax 61 9 351 2377

Dr. Larry McMillin
NOAA/NESDIS Satellite Experiment
Laboratory
E/RA21
R810 World Weather Building
Washington, DC 20233
USA
tel 301 763 8136
fax 301 763 8108

Mr. Anthony McNally
ECMWF
Shinfield Park
Reading RG2 9AX
UNITED KINGDOM
tel 734 499034

Dr. Paul Menzel
NOAA/NESDIS
1225 West Dayton Street
Madison, WI 53706
USA
tel 608 263 4930
fax 608 262 5974

Mr. Folke - S. Olesen
Inst. for Meteorology and Climate
Research
Kernforschungszentrum Karlsruhe/KfK
Postfach 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY
tel 07247182 2109
fax 07247182 4742

Mr. Paolo Pagano
Italian Meteorological Service
Piazzale degli Archiva, 34
00144 Rome
ITALY
tel 39 6 49864739
fax 39 6 5926964

Ms. Marilena Perrone
EUMETSAT
Am Elfengrund 45
D-6100 Darmstadt-Eberstadt
FEDERAL REPUBLIC OF GERMANY
tel 0049 6151 539242
fax 0049 6151 539225

Dr. Thierry Phulpin
Centre Nationale de Recherches
Meteorologiques, CNRM/ESSI
42 avenue, Gustave Coriolis
31057 Toulouse
FRANCE

Dr. Ge J. Prangsma
KNMI
P.O. Box 201
3730 AE De Bilt
NETHERLANDS
tel 31 30206453
fax 31 30210407

Dr. Fred Prata
CSIRO Division of Atmospheric Research
P.O. Private Bag No. 1
Aspendale, Victoria 3195
AUSTRALIA
fax 61 3 586 7600

Mr. Joel Quere
Centre de Meteorology Spatiale
BP 147
22302 Lannion
FRANCE
tel 33 36056700
fax 33 36056737

Mr. Anthony Reale
NOAA/NESDIS E/RA23
FB-4, Room 3210
Washington, DC 20233
USA
tel 301 763 4380
fax 301 420 0932

Dr. Eberhard Reimer
Freie Universitaet Berlin
Fachbereich Geowissenschaften-WE 07
Dietrich-Schafter-Weg 6-10
1000 Berlin 41
FEDERAL REPUBLIC OF GERMANY

Mr. Ricardo Riosalido
Instituto Nacional de Meteorologia
Apartado de Correos 285
28071 Madrid
SPAIN

Dr. Rolando Rizzi
Dipartimento di Fisica
Via Irnerio 46
I-40126, Bologna
ITALY

Dr. Guy Rochard
Centre de Meteorologie Spatiale
B.P. 147
F-22302 Lannion Cedex
FRANCE
tel 33 36056700
fax 33 36056737

Dr. Helmut Rott
Inst. fur Meteorologie und Geophysik
Universitaet Innsbruck
Innrain 52
A-6020 Innsbruck
AUSTRIA

Dr. Carmine Serio
Universita di Napoli
Dipartimento di Scienze Fisiche
Piazza Tecchio, 80
80125 Napoli
ITALY
tel 39 81 7682424
fax 39 81 611821

Dr. Noelle Scott
Laboratory de Meteorologique Dynamique
Ecole Polytechnique
Route Departementale 36
F-91128 Palaiseau Cedex
FRANCE
tel 33 1 69334532
fax 33 1 69333005

Mr. Gyozo Sipos
Meteorological Service of the
Hungarian Republic
H-1525 Budapest
P.O. Box 38
HUNGARY

Dr. William Smith
CIMSS
1225 West Dayton St.
Madison, WI 53706
USA
tel 608 263 4085
fax 608 262 5974

Dr. Dietrich Spankuch
Meteorologischer dienst der D.D.R.,
Met. Hauptobservat, Telegraphenberg
1561 Potsdam, Albert Einstein Strasse
42-44-46
GERMAN DEMOCRATIC REPUBLIC

Mr. David Steenbergen
Aerospace Meteorology Division
Atmospheric Environment Service/ARMA
4905 Dufferin Street
Downsview, Ontario M3H 5T4
CANADA
tel 416 739 4257
fax 416 739 4221

Mr. Michael Steffensen
University of Copenhagen
Institute for Theoretical Meteorology
Haraldsgade 6, DK-2200
Copenhagen
DENMARK

Mr. Jan Svensson
Swedish Meteorological and
Hydrological Institute
S-60176 Norrkoping
SWEDEN

Mr. Mikio Takagi
Institute of Industrial Science
University of Tokyo
7-22-1, Roppongi
Minato-ku, Tokyo 106
JAPAN

Dr. Michael Uddstrom
New Zealand Meteorological Service
P.O. Box 722
Wellington
NEW ZEALAND

Dr. Sakari Uppala
Finnish Meteorological Institute
Box 503
Vuorikitu 24, 00101 Helsinki
FINLAND

Dr. A. B. Uspenski
Hydometeorological Centre of the USSR
123376 Moscow D376
Bolshevistskaya St., 9-13
USSR

Dr. David Wark
NOAA/NESDIS
E/RA
FB-4, Room 0130
Washington, DC 20233
USA
tel 301 763 4680
fax 301 568 8649

Mr. Phil D. Watts
Hooke Institute for Atmospheric Research
Dept. of Atmospheric, Oceanic and
Planetary Physics
Oxford University
Oxford OX13PU
UNITED KINGDOM

Mr. Harold Woolf
NOAA/NESDIS/SDAB
E/RA24
1225 West Dayton Street
Madison, WI 53706
USA
tel 608 264 5325
fax 608 262 5974

Mr. T.-C. Yen
M.S.G.S., Central Weather Bureau
64, Kung Yan Road
Taipei, Taiwan
REPUBLIC OF CHINA

Mr. P. Zacharov
Institute of Physics of the Atmosphere
Czechoslovakia Academy of Science
Bocni II
141-31 Praha 4
CZECHOSLOVAKIA

Mr. Fred Zbar
NOAA/National Weather Service
W/OM22
8060 13th Street
Silver Spring, MD 20910
USA
tel 301 427 7867
fax 301 427 7598

Dr. Feng Ying Zhang
Satellite Meteorology Center
State Meteorological Administration
Beijing 100081
PEOPLE'S REPUBLIC OF CHINA

Dr. Feng-Xian Zhou
Institute of Atmospheric Physics
Chinese Academy of Sciences
Beijing 100029
PEOPLE'S REPUBLIC OF CHINA
tel 8312277 ext 2215
fax 256 2347

APPENDIX C. ADDITIONAL MAILING LIST

Mr. Thomas Achtor
CIMSS
University of Wisconsin-Madison
1225 West Dayton Street
Madison, WI 53706
USA
tel 608 263 4206
fax 608 262 5974

Dr. Umberto Amato
Institute for Mathematical Applications
via Pietro Castellino, 111
80131 Napoli
ITALY
tel 39 81 546 1101
fax 39 81 770 3288

Ms. Christine Assemat
MS2I
Les Miroirs - B.P. 235
38 Bld. Paul Cezanne
78052 Saint-Quentin en Yvelynes Cedex
FRANCE

Dr. Dan Birkenheuer
NOAA/ERL/FSL
R/E/FS2
325 Broadway
Boulder, CO 80303
USA
tel 303 497 5584
fax 303 497 3096

Dr. H. J. Bolle
Institut fur Meteorologie
WE 07 FB Geowiss, Freie Univ. Berlin
Dietrich-Schafer-Weg 6-8
D-1000 Berlin 41
FEDERAL REPUBLIC OF GERMANY

Mr. Timothy Boyle
CSIR Satellite Applications Centre
P.O. Box 395
Pretoria - 0001
REPUBLIC OF SOUTH AFRICA

Mr. Francois M. Breon
California Space Institute
A-021 UCSD
La Jolla, CA 92093
USA

Mr. Ruediger Buell
Deutsche Forschungsanstalt fuer Luft-und
Raumfahrt (DLR)
Inst. Physics of the Atmosphere
D-8031 Oberpfaffenhofen
FEDERAL REPUBLIC OF GERMANY

Ms. Ellen Burdsall
NOAA/NESDIS
E/RA23
FB-4, Room 3045
Washington, DC 20233
USA
tel 301 763 4310
fax 301 763 1724

Ms. Francesca Carfora
Institute for Mathematical Applications
via P. Castellino, 111
80131 Napoli
ITALY

Dr. Moustafa Chahine
Code 183-301
NASA/Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91103
USA

Dr. A. M. Choudhury
SPARRSO
Agargaon, Sher-E-Banglanagar
Dhaka, GPO Box 529
BANGLADESH

Dr. Karl W. Cox
SM Systems Research Corp.
8401 Corporate Drive
Suite 510
Landover, MD 20785
USA

Mr. Vincent Cuomo
Universita di Napoli
Dipartimento di Scienze Fisiche
Piazza Tecchio, 80
80125 Napoli
ITALY

Mr. Eduardo Diaz
NASA Station Director
U.S. Embassy
APO
Miami, FL 34033

Mr. Luigi de Leonibus
Italian Meteorological Service
Piazzale degli Archiva, 34
00144 Rome
ITALY

Dr. Chaohua Dong
Satellite Meteorology Center
46, Baishiqiaolu
Beijing 100081
PEOPLE'S REPUBLIC OF CHINA
tel 8312277 ext 2617

Mr. Henry Drahos
NOAA/NESDIS
E/RA23
Room 3210A FB4
Washington, D.C. 20233
USA
tel 301 763 4380

Dr. William Emery
University of Colorado
Colorado Center for Astrodynamic Research
Campus Box 431
Boulder, CO 80309
USA

Dr. Brian Farrelly
Geophysical Institute
Department of Oceanography
Univ. of Bergen, Allegt. 70
5000 Bergen
NORWAY

Mr. Henry Fleming
NOAA/NESDIS/SRL
E/RA21
810 World Weather Building
Washington, DC 20233
USA
tel 301 763 8136

Mr. J. F. Flobert
Laboratory de Meteorologie Dynamique
Ecole Polytechnique
Route Departementale 36
F-91128 Palaiseau Cedex
FRANCE

Mr. Mitchell D. Goldberg
NOAA/NESDIS/SRL/Physics Branch
E/RA1
R711 World Weather Building
Washington, DC 20233
USA
tel 301 763 8138
fax 301 763 8108

Mr. Jacques Halle
Canadian Meteorological Centre
2121, North Service Road, Suite 404
Dorval, Quebec H9P 1J3
CANADA

Mr. Gordon Haugen
Martin Marietta Data Systems
c/o Naval Environmental Prediction
Research Facility (NEPRF)
Monterey, CA 93943-5006
USA

Mr. Gunther Heinemann
Meteorologisches Institute
Universitaet Bonn
Auf dem Huegel 20
D-5300 Bonn 1
FEDERAL REPUBLIC OF GERMANY

Dr. Donald Hillger
NOAA/NESDIS/RAMM
Cooperative Institute for Research
in the Atmosphere (CIRA)
Colorado State University
Fort Collins, CO 80523
USA
tel 303 491 8498
fax 303 491 8442

Dr. Karel Hlavaty
Czech Hydrometeorological Institute
Na Sabatce 17
143 06 Praha 4
CZECHOSLOVAKIA

Ms. Mary Hughes
NOAA/NESDIS
Data Collection and
Direct Readout Branch
Washington D.C. 20233
USA
tel 301 763 8447
fax 301 763 8449

Mr. Shinji Kadokura
Kakioka Magnetic Observatory
595 Kakioka, Ibaroki 315-01
JAPAN
tel 0299 43 1151
fax 0299 43 1154

Mr. Anton K. Kaifel
Center for Solar Energy
and Hydrological Research
Hessbruhlstr 61
D-7000 Stuttgart 80
FEDERAL REPUBLIC OF GERMANY
tel 49 711 685 7179
fax 49 711 685 7143

Dr. Ramesh Kakar
Code SEP
NASA Headquarters
600 Independence Avenue, SW
Washington, DC 20546
USA
tel 202 453 1680
fax 202 755 2552

Mr. Fernand Karcher
CNRM
42 Avenue Coriolis
31057 Toulouse Cedex
FRANCE

Siri Jodha Khalsa
CIRES
University of Colorado at Boulder
Campus Box No. 449
Boulder, CO 80309
USA
tel 303 492 1445
fax 303 492 2468

Mr. P. N. Khanna
Satellite Meteorology
Indian Meteorology Department
Mausam Bhavan, Lodi Road
New Delhi 110003
INDIA

Dr. Dongsoo Kim
NOAA/ERL
R/E/FS2
325 Broadway
Boulder, CO 80803
USA
tel 303 497 6725

Mr. Dieter Klaes
PL/GP/LYS
Geophysics Laboratory (AFSC)
Hanscom Air Force Base, MA 01731-5000
USA
tel 617 377 3317
fax 617 377 2984

Mr. Ed Koenig
ITT
Aerospace/Communications Division
P.O. Box 3700
Fort Wayne, IN 46801
USA
tel 219 487 6027

Dr. Pavla Kocikova
Institute of the Physics of the
Atmosphere
Czechoslovakia Academy of Science
Bocni II., 1401
141 31 Praha 4
CZECHOSLOVAKIA

Prof. K. Ya. Kondratyev
Laboratory of Remote Sensing
Academician of the USSR of Sciences
Sevastyano Street, 9
196105, Leningrad
USSR

Dr. W.-S. Lai
Meteorological Service Singapore
P.O. Box 8
Singapore Changi Airport
Singapore 9181
REPUBLIC OF SINGAPORE

Mr. Daniel LaPorte
4432 Meadowlark Lane
Santa Barbara, CA 93105
USA
tel 805 967 8058
fax 805 967 8058

Mr. Dong-Kyou Lee
Department of Atmospheric Sciences
Seoul National University
Seoul 151-742
KOREA

Mr. Hans-Joachim Lutz
Institut fur Geophysik und Meteorologie
Universitat zu Koln
Kerpener St. 13
5000 Koln 41
FEDERAL REPUBLIC OF GERMANY

Mr. Harold Maurer
NASA/GSFC Code 970.1
Greenbelt, MD 20771
USA
tel 301 286 8215

Dr. Ron McPherson
NOAA/NMC
World Weather Building
Washington, D. C. 20233
USA

Dr. Donald Miller
NOAA/NESDIS/SAL E/RA2
601 World Weather Building
Washington, D. C. 20233
USA

Dr. John Morgan
EUMETSAT
Am Elfengrund 45
D-6100 Darmstadt-Eberstadt
FEDERAL REPUBLIC OF GERMANY

Dr. Xia-Lin Ma
CIMSS
University of Wisconsin-Madison
1225 W. Dayton Street
Madison, WI 53706
USA

Mr. K. Paetzold
Deutscher Wetterdienst, Zetralamt
Frankfurter Strasse 135
D-6050 Offenbach/Main
FEDERAL REPUBLIC OF GERMANY

Dr. Jean Pailleux
ECMWF
Shinfield Park
Reading, Berkshire RG2 9AX
UNITED KINGDOM

Mr. Jan-Petter Pedersen
FORUT
Department of Inf. Technology
P.O. Box 2806 Elverhoy
N-9001 Tromso
NORWAY

Mr. Andreas Pfister
Inst. fur Meteorologie und Klimaforschung
(IMK)
Kernforschungszentrum Karlsruh
Postfach 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY
tel 07247 82 3822
fax 07247 82 4742

Dr. P. Krishna Rao
NOAA/NESDIS Office of Research
and Applications, E/RA
810 World Weather Building
Washington, DC 20233
USA

Mr. Kim Richardson
Naval Environmental Prediction
Research Facility
Monterey, CA 93940
USA

Mr. Stan Schneider
NOAA/NESDIS Office of Systems Development
E/OSD
FB-4, Room 0154
Washington, DC 20233
USA

Ms. Judy Schroeder
NOAA/WPL
325 Broadway
Boulder, CO 80303
USA

RnDr. Vladimir Seifert
CHMU
143 06 Praha 4
na Sabatce 17
Prague
CZECHOSLOVAKIA

Mr. Jose M. F. Serdan
Instituto Nacional de Meteorologia
Apartado de Correos 285
28071 Madrid
SPAIN

Mr. Richard Slonaker
NOAA/ERL/FSL
R/E/FS1
325 Broadway
Boulder, CO 80303
USA
tel 303 497 6845

Ms. Boba Stankov
NOAA/ERL/Wave Propagation Laboratory
R/E/WP5
325 Broadway
Boulder, CO 80303
USA

Mrs. Ae-Sook Suh
Korea Meteorological Administration
1 Songwol-dong Chongro-ku
Seoul
KOREA
tel 01 734 7841

Dr. Joel Susskind
NASA/Goddard Space Flight Center
Code 911
Greenbelt, MD 20771
USA

Mr. Paul Tildesley
CSIRO
Remote Sensing Section
GPO Box 1583
Hobart, Tas., 7001
AUSTRALIA

Mr. Fabio Travaglioni
Italian Meteorological Service
Piazzale degli Archiva, 34
00144 Rome
ITALY
tel 39 6 49864739
fax 39 6 5926964

Mr. David S. Turner
Aerospace Meteorlogy Division
Atmospheric Environment Service/AKMA
4905 Dufferin Street
Downsview, Ontario M3H 5T4
CANADA
fax 416 739 4221
tel 416 739 4885

Mr. Paul van Delst
School of Physical Sciences
Curtin University of Technology
GPO Box U1987, Perth W.A. 6001
AUSTRALIA

Mr. Michael van Woert
Seaspace
1537 Green Oak Road
Vista, CA 92083
USA
tel 619 450 9328
fax 619 789 4923

Dr. Ed Westwater
NOAA/ERL Wave Propogation Laboratory
R/E/WP5
325 Broadway
Boulder, CO 80303
USA

Miss Tsoi Yip
Atmospheric Environmental Service
c/o ARMA
4905 Dufferin Street
Downsview, Ontario M3H 5T4
CANADA

Dr. Myron Young
Center for Wetlands Study
Louisiana State University
Baton Rouge, LA 70803
USA

Dr. Francesco Zauli
Italanian Meteorological Service
Piazzale degli Archiva, 34
00144 Rome
ITALY

Mr. Sisong Zhou
NOAA/NESDIS Satellite Experiment
Laboratory
E/RA21
R810 World Weather Building
Washington, DC 20233
USA