CGMS

REPORT OF THE TWENTY-FIRST MEETING OF THE CO-ORDINATION GROUP FOR METEOROLOGICAL SATELLITES

BEIJING, PEOPLES' REPUBLIC OF CHINA

CGMS XXI

19 - 23 APRIL 1993

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FINAL REPORT

A. PRELIMINARIES

The reader should note that a full list of acronyms and abbreviations can be found in Annex I, and that the numbering of chapters in this report corresponds to those used in the Agenda, as shown in Annex II. A full list of Working Papers (WP) submitted to CGMS XXI can be found in Annex III.

A.1 Introduction

CGMS-XXI was convened at 10.00 a.m. on 19 April 1993 by Dr. Xu Jianmin, Director of the Satellite Meteorological Centre, State Meteorological Administration, who welcomed representatives from ESA, EUMETSAT, JAPAN, PRC, USA and WMO to the first meeting of CGMS to be held in the P.R.C. He invited Dr. Li Huang, Deputy Administrator, to address the meeting, on behalf of the Director of the State Meteorological Administration, Dr. Zou Jingmeng.

Mr. Li Huang presented the following address:

"Mr. Chairman,
Ladies and Gentlemen,

First, please allow me, on behalf of the State Meteorological Administration of China, and on behalf of Mr. Zou Jingmeng, Administrator of the State Meteorological Administration of China, to extend our warm welcome to all the participants to the session. Since this is the first meeting of CGMS to be held in China, it is also a great pleasure and special honour for me to express this welcome in the name of the host.

Since its establishment, CGMS has made a great deal of efforts in successfully coordinating meteorological satellite data. These efforts have greatly facilitated the compatibility of geostationary meteorological satellite observation systems and the products of meteorological satellite observation. On the one hand CGMS has organized exchanges of views among the satellite operating countries and organizations, and established a well coordinated global meteorological satellite observation system. On the other hand, it has helped the users to acquire valuable and comparable satellite information. This is of great importance for the development of meteorological satellites as well as for the users. It is expected that the efforts made by CGMS will become increasingly important. We all are aware that environmental issues have become one of the hottest topics under discussion at present in the world. Environment has been considered closely related to the global sustainable development. The UN Conference on Environment and sustainable Development held in 1991 is a very good demonstration of such common understanding. Both the Framework Convention of Climate Change and Agenda 21 approved by the conference have attached great importance to the strengthening of the studies on earth environment and atmosphere. The observations of earth atmosphere from space coordinated by CGMS are indispensable. Therefore the responsibility that CGMS is carrying will have its implications on the future existence of mankind. We are all deeply proud of that.

The Chinese Government has always attached great importance to the environment and development. China has successfully launched two FY-1 polar orbiting meteorological satellites. Next year we shall launch the geostationary meteorological satellite FY-2. Though these satellites are experimental in nature, we believe that we are able to develop and establish our own operational meteorological satellite series and provide valuable satellite information for meteorological operation and scientific research, disaster prevention and environment protection. The orbit parameters of FY-1 were made public by China for the purpose of sharing the information with various countries. In future the data receiving parameters of FY-2 satellite will also be made public in due course after its successful launch.

We all are aware of the paramount importance of the cooperation among various countries in fields of meteorology and environment. Ever since it joined activities of CGMS, the State Meteorological Administration of China has made every effort to develop our own meteorological satellites, and made our due contributions to the development of meteorology of the whole world. On the other hand, we have paid great attention to learn from other countries and organizations concerned, in particular to having international cooperation through CGMS. We have learned useful experience and advanced technology of developing meteorological satellites. We have benefited a great deal. Many of you have been to China, as the experts on meteorological satellites, to give lectures. You have brought us new technology which has played an important part in the development of our meteorological satellites and in the application of satellite information in China. I would like to take this opportunity to express to you our sincere thanks. I also know that it is the first time for some of you in China. Therefore I hope you will take the opportunity to become more aware of the development of meteorological satellites in China and provide us your advice and suggestions. No doubt your advice and suggestions will be highly appreciated by your Chinese counterparts. No matter whether you are our old friends or new friends, I hope that through this meeting we will further deepen the understanding and enhance the friendship and cooperation among us. May I conclude by wishing the meeting every success, and a pleasant stay in China.."

A.2 Election of Chairman

Mr. John Morgan was unanimously elected Chairman of CGMS XXI. Dr. Xu Jianmin was unanimously elected as Vice Chairman.

A.3 Arrangements for the Drafting Committee

A Drafting Committee was appointed and CGMS Members were requested to nominate representatives to provide inputs for the Final Report to this drafting committee.

A.4 Adoption of Agenda and Work Plan of Working Group Sessions

The Agenda (see Annex II) was adopted. CGMS agreed to the work programmes for the Telecommunications and the Satellite Products Working Groups. Mr. L. Heacock was elected Chairman of the Telecommunications Working Group and Dr. D. Hinsman the Chairman of the Satellite Products Working Group. CGMS also agreed that issues of global contingency planning would be addressed by a new CGMS Working Group which would hold its first meeting during the course of CGMS XXI.

A.5 Review of Actions from Previous Meetings

The Secretariat reviewed actions from previous CGMS meetings. A summary is provided below:

i) PERMANENT ACTIONS BY ALL PARTIES

CGMS recalled the following permanent actions:

1. Circulation of satellite Operational Quarterly Reports and Image Photography

2. All satellite operators to provide NOAA/NESDIS with information on unexplained anomalies for study, and NOAA to provide solar event information to the satellite operators on request and a status report on the correlation study at each meeting.

3. USA to issue quarterly to all other admitting authorities the consolidated DCP assignments.

4. All CGMS Members to inform users to register user stations within their area of responsibility.

5. CGMS members generating cloud motion winds to check that monthly statistics are sent and received on a quarterly basis.

6. CGMS Members to consider a way to estimate the number of lost messages, and forward to the WMO, on a quarterly basis, statistics of the loss of DCP messages which are normally distributed on the GTS.

7. Each CGMS operator to monitor the unused IDCS channels for interference according to his own scheme, and prepare a report on results for CGMS. If practical, dates of test and channels to be tested will be coordinated (perhaps via the CGMS EBB) in order to obtain information on possible world-wide phenomena.

It was agreed that any subsequent permanent action would be transferred to the above list.

ii) OUTSTANDING ACTIONS FROM PREVIOUS MEETINGS

ACTION 18.3 The Commonwealth of Independent States (CIS) to provide Meteor-3 temperature sounding data over the GTS as soon as practical.

Continuing. Preliminary sets of soundings have been delivered to ECMWF for evaluation. After evaluation on more complete data sets, the data will be placed on the GTS, if appropriate.

ACTION 18.5 WMO to obtain information on INSAT satellite image transmission schemes.

Continuing.

ACTION 18.11 The People's Republic of China and CIS to inform the Secretariat when IDCS channels will be implemented.

Continuing. PRC informed CGMS XXI of its intention to implement IDCS on FY-II, subject to confirmation of technical suitability.

ACTION 19.3 USA (acting as the IPOMS Secretariat) to inform CGMS Secretariat of any decisions of the IPOMS meeting in September 1991 which might affect the CGMS Charter.

Closed

ACTION 19.8 EUMETSAT to work with NOAA, the Secretariat of IPOMS, on behalf of CGMS in consideration of the roles to be played by the Group in relation to CEOS and IPOMS activities, and report to the next meeting of CGMS.

Continuing. IPOMS intended to finalize its activities in March 1992, possibly through an exchange of letters. The USA to draft a final report on IPOMS activities, and inform CGMS members of final IPOMS developments.

ACTION 19.15 All CGMS members to provide the Secretariat with any corrections or modifications to the IDCS Users' Guide (6th edition) by 1 April 1991.

Closed. Issue 7 distributed in January 1993.

ACTION 20.1 NOAA and EUMETSAT to provide CGMS members with technical details of the ADC extension.

Closed. Details are provided in CGMS XXI WPs

ACTION 20.2 CGMS Secretariat to forward a report of discussions in EC Panel of Experts/CBS Working Group on Satellites to CGMS members.

Closed. Report presented at CGMS XXI.

ACTION 20.3 The Secretariat to include "request for nomination of CGMS representatives at WMO and other meetings" on the Agenda of future CGMS Meetings.

Closed. On the Final Draft Agenda for CGMS XXI.

ACTION 20.4 WMO to be placed on the International DCP allocation notification list.

Closed. WMO is included.

ACTION 20.5 The Secretariat to include an ASDAR admission form, based on the proposal from Japan, as an additional Annex to the IDCS Users Guide.

Closed.

ACTION 20.6 ESA and JMA to complete the necessary programming changes for the processing of AMDAR data as soon as practical and to enter data from within respective areas of responsibility onto the GTS in AMDAR code form.

Closed.

ACTION 20.7 All CGMS Members to note that WMO should be included in the notification list for ASDAR admissions.

Closed.

ACTION 20.9 The Secretariat to distribute a marked up draft text of the next updated issue of the IDCS Users Guide in a few weeks time.

Closed.

ACTION 20.10 CGMS Members to comment on the LRIT proposal by 1 May 1992, and in particular, the acceptance of the three ISO levels so far defined. If Members are unable to meet this deadline, then they should inform the Secretariat by 1 March 1992.

Closed. Discussion of Final Draft at CGMS XXI.

ACTION 20.11 The Secretariat to mail a consolidated CGMS LRIT proposal, together with any further comments, to WMO/CBS by the end of July 1992.

Closed - was distributed in January 1993. - Further consideration to be given by the WG on Telecommunications.

ACTION 20.12 (Directory of Satellite Applications) CGMS members are invited to submit proposals for a similar jointly produced publication focusing upon global applications and the benefits of meteorological satellite data.

Continuing. Second edition of EUMETSAT directory will be distributed shortly.

ACTION 20.13 USA to distribute to CGMS members updated files on solar activity when the compiled data becomes available.

Updated files are usually distributed at CGMS meetings. - to become a permanent action in future (transfer to A.5 i))

ACTION 20.14 CGMS Members to provide WMO with their OMNET names in order that access to the CGMS EBB can be authorised

Closed.

ACTION 20.16 ESA to investigate changes in the SATOB code for winds.

Closed. Will be discussed at CGMS XXI.

ACTION 20.17 WMO to send the INSAT data set to the Secretariat for coordination of circulation.

Closed. Tapes were received and are being reprocessed to cartridge format prior to evaluation of data by USA.

ACTION 20.18 USA to ensure distribution of GOES monthly wind statistics.

Closed.

ACTION 20.19 All CGMS members to provide comments on the "short" list of satellite data requirements listed in EUM-WP-27 to WMO in advance of the March 1992 meeting of the WMO Executive Council Panel of Experts.

Closed. See Final Report prepared by Panel of Experts.

ACTION 20.20 (New products) USA to provide CGMS Members with an information paper on the auto-editing procedure.

Closed. Report was distributed in January 1993.

ACTION 20.21 ESA to provide CGMS Members with additional information on its robot operated archive and retrieval system.

Closed.

ACTION 20.22 CGMS members to provide each other with information on their progress in the further development of archiving and retrieving systems.

Regularly reported upon in WPs . to become a permanent action.

ACTION 20.23 The Secretariat to arrange a planning meeting establishing a Working Group on Global Contingency Planning in the USA during October 1992, and to inform CGMS Members accordingly.

Closed. CGMS XXI, EUM-WP-07 will report on the meeting.

ACTION 20.24 Satellite operators to consider options for long term contingency planning in time for preliminary discussion on this item at the initial meeting of the Working Group on Global contingency Planning, scheduled for October 1992.

Closed. To be discussed further in CGMS XXI.

B. REPORT ON THE STATUS OF CURRENT SATELLITE SYSTEMS

B.1 Polar Orbiting Meteorological Satellite Systems

B.1.1 C.I.S.

No new working papers were presented on this topic.

B.1.2 Peoples Republic of China

No new information was presented on this topic.

B.1.3 USA

The USA reported on the current NOAA polar satellites in its WP-1. NOAA-11 (pm) and NOAA-12 (am) are currently providing the operational functions, while NOAA-9 and NOAA-10 are providing limited specialized data, such as ozone, SBUV, and search and rescue information. The NOAA ground system was designed to support four satellites; therefore with the launch of NOAA-13 scheduled for June 1993, one of the current satellites must be turned off. The USA reported that present plans call for NOAA-10 to be turned off when NOAA-13 is operational.

The PRC asked the USA to provide calibration data for the NOAA satellites. The USA agreed to provide this information to the PRC and to other interested CGMS members.

ACTION 21.01 USA to provide NOAA image calibration data to PRC and other interested members of CGMS.

B.2 Geostationary Meteorological Satellite Systems

B.2.1 Status of the Meteosat Operational Programme

EUM-WP-2 presented a status report on the Meteosat Operational Programme (MOP) satellites and missions. The meeting noted that Meteosat-3 had been moved to the X-ADC location at 75° West in January 1993. Meteosat-4 remained the operational European satellite and Meteosat-5 the in orbit standby. MOP-3 (Meteosat-6) would be ready for launch in November 1993.

ESA reported on anomalies which had affected the three in-orbit spacecraft during the last year (ESA-WP-01). Meteosat-3 still experienced known anomalies due to the environment which usually resulted in the loss of two images on each occasion. Some new anomalies on Meteosat-4 and 5 had both been overcome by the introduction of new processing software on ground and the switching to redundant hardware on-board the satellite. All three satellites retain their operational capability to support the main Meteosat mission.

PRC requested further information on anomalies affecting the Meteosat geostationary satellites.

ACTION 21.02 ESA to provide PRC with details of anomalies affecting Meteosat Satellites and means used to cope with them.

In its WP-02 on the implementation of the XADC mission, ESA provided details on the technical approach which had allowed Meteosat-3 to be operated at 75° West. The required ground system was installed within 14 months after the initial agreement between ESA, EUMETSAT and NOAA. This allowed the spacecraft to be moved towards its new location at 75° West in late January and commence operations there approximately four weeks later.

WMO expressed its deepest appreciation to ESA, EUMETSAT and the USA for their outstanding and well co-ordinated efforts to place into operations Meteosat-3 at 75° West under the Extended Atlantic Data Coverage Programme (X-ADC). It was noted that the Meteosat-3 was providing valuable services to WMO members throughout WMO regions III and IV. Most important to WMO was the demonstration by ESA, EUMETSAT and the USA of their dedication to providing continuous data and services in supporting the space-based sub-system of the GOS.

This effort was an excellent example for implementing a global contingency plan under the auspices of CGMS.

B.2.2 India

No working papers were presented on this topic.

B.2.3 Japan

Japan, in its WPs 2 and 3, described the status of its current geostationary satellites. GMS-3 is kept at 120° East as the back-up satellite, without orbit inclination control in order to save fuel. GMS-4 is the current operational satellite. It has been kept at 140° East since December 4, 1989 and has been operating nominally. The new normalization procedure of visible channels was put into operation on July 3, 1992.

B.2.4 USA

In WP-2, the USA reported on the status of its GOES-2, -3, -6, and -7 satellites. GOES-7 is fully operational and is the only satellite providing imagery data. The fuel remaining on GOES-7 does not allow for any further north/south inclination adjustments, but is sufficient for east/west stationkeeping for several more years. GOES-7 will attain an inclination of 2 degrees in September 1994. The USA also reported that, although in a drifting mode, GOES-6 will be utilized (on a scheduled basis) to transpond the GOES Variable Format (GVAR) simulated data for use by ground stations in preparing for GOES-I.

EUMETSAT requested the USA to provide a schedule of these broadcasts.

ACTION 21.03 USA to provide EUMETSAT with details of the GOES-6 GVAR dissemination schedules.

C. REPORT ON FUTURE SATELLITE SYSTEMS

C.1 Future Polar Orbiting Meteorological Satellite Systems

C.1.1 C.I.S.

No working papers were presented on this topic.

C.1.2 EUMETSAT - Status of the EUMETSAT Polar System

EUM-WP-3 summarised current and planned activities leading to the development of a EUMETSAT Polar System (EPS). The meeting noted the new proposal from ESA, offering a dedicated platform for the meteorology payload, METOP-1, which would complement the ESA ENVISAT platform, supporting an experimental climate orientated mission. The paper also described progress with the development of the Meteorological Communication Package (MCP), the Microwave Humidity Sounder (MHS), the common instrument (EUMETSAT/NOAA) interface studies, and the preliminary consideration of the necessary ground segment.

C.1.3 India

No working papers were presented on this topic.

C.1.4 Peoples Republic of China

PRC Working Paper 1 described future plans for the continuation of the FY-1 series of polar orbiting meteorological satellites. The future satellites, FY-1C and FY-1D, are planned for launch in the second half of the 1990's. These satellites, in addition to reliability enhancements, would carry a multi-channel visible and infrared radiometer (MVIS). The data flow from the new satellites will once again be made freely available. The FY-1C and FY-1D will utilize a Chinese High Resolution Picture Transmission (CHRPT) communications format which is not yet fully defined. HRPT stations which receive data from NOAA satellites may also be able to receive and process CHRPT data with some modifications. PRC added that it would try to make the format as similar as possible to the NOAA HRPT. Full adoption of the standard would be possible after phase C-D activities.

C.1.5 USA

The USA-WP-3 was complementary to EUM-WP-3 and laid out US plans until the early portion of the twenty-first century. The currently contracted series runs through NOAA-I, to be launched in June 1993 and J in 1995, with no essential change in instrumentation plus NOAA-K, L, and M with the addition of the AMSU instruments provided by the USA and Europe. To this will be added NOAA-N and -N' which will bridge the gap to the future system in collaboration with Europe providing the morning satellite while the United States continues to provide the afternoon satellite through the projected NOAA-O, P and Q.

C.2 Future Geostationary Meteorological Satellite Systems

C.2.1 C.I.S.

No working papers were presented on this topic.

C.2.2 EUMETSAT

The Meteosat Transition Programme

In its WP-4, EUMETSAT reviewed current and future activities relating to the development of the Meteosat Transition Programme (MTP) space and ground segments. Planning for the ground station was well advanced, and hardware would be integrated later in 1994, ready for full operations by mid-1995. The meeting recalled that this satellite system is designed to bridge the gap between the end of MOP satellite operations in 1995 and the beginning of the Meteosat Second Generation Programme in 2000.

The Meteosat Second Generation (MSG) Programme

EUM-WP-5 provided an update on current and future activities leading to the development of a series of Meteosat Second Generation (MSG) satellites, which would come into operation around the year 2000.

Further details of the MSG main payload (SEVIRI) channel characteristics were presented. An MSG meteorological product study programme would commence during 1993.

C.2.3 India

No working papers were presented on this topic.

C.2.4 Japan

Japan presented in WP-04 its plan for the future of the GMS-project, indicating that it expected to launch GMS-5 on an H-II rocket in early 1995. The successor of GMS-5 was considered for launch by the end of the decade (see Annex IX for details).

C.2.5 The People's Republic of China

PRC-WP-2 described the PRC's progress in the development of its FY-2 geostationary meteorological satellite and its associated ground system. The PRC plans to launch FY-2 in 1994.

In response to a question from PRC relating to the launch of FY-2 close to the equinox, representatives of ESA, EUMETSAT, JMA, NASDA, and NOAA recommended to SMA that any launch date which would result in satellite commissioning (check-out) during the eclipse period should be avoided.

C.2.6 USA

The USA presented in its WP-4, the status of the GOES-I-M series (Annex XV). The GOES-I development and testing is on schedule for a launch on an Atlas I vehicle in April 1994, and GOES-J is expected to be launched in May 1995. The meeting noted that previous details on the GOES-I programme had not changed and are summarized in USA WP-4. It was also noted by the USA that while it is too early to define in detail the follow-on system to GOES I-M, efforts are already underway to plan for continuity beyond GOES M, as a strategy, and for the definition of the major characteristics of the follow-on systems. For assuring the continuity of the geostationary mission following GOES I-M, perhaps two or three additional satellites, are under consideration. These would be similar systems to GOES I-M but with modest improvements based upon the early GOES I-M operational experience. In consideration for the follow-on systems, two major characteristics stand out: Providing for "independent" imaging both for local and global scales and examining opportunities to make further improvements to the sounder.

D. OPERATIONAL CONTINUITY AND RELIABILITY

D.1 Woods Hole Meeting - Secretariat Report

The Secretariat presented the report of the first meeting of the Working Group for Global Contingency Planning, which had taken place in Woods Hole, USA, on 12-14 October 1992. The meeting had been attended by experts from Japan, the USA, EUMETSAT and the WMO and had made substantial progress in defining a contingency concept for the global meteorological geostationary satellite system.

The report concluded that no single satellite operator could be expected to guarantee satellite availability in all circumstances and that the establishment of joint contingency plans was essential in order to achieve a reliable global system at a realistic cost. The meeting had established a proposal for a contingency concept which could meet global needs.

This concept, based on a philosophy of assisting neighbouring satellite operators, extended by the "bent-pipe" technique already developed for the Europe-USA Extended Atlantic Data Coverage project (X-ADC), could prove to be a cost effective method of improving global satellite availability. The WMO, through its participation in the meeting, had provided a useful list of key products and services which should be supported by a system operating in a reduced configuration as defined by a Contingency Plan.

The Working Group had established a number of interim conclusions and had initiated a number of actions, including the follow-up technical meeting in Tokyo, reported under item D3 below. The meeting believed that the working group should continue its work and had attached draft terms of reference to its report.

The CGMS thanked the Working Group for its report and agreed that the recommendations would be discussed further after a further session of the Working Group.

D.2 Inter-Regional Planning

Update on Atlantic Data Coverage

The meeting took note of the transition of the Meteosat-3 ADC mission, located at 50° West, to the Meteosat X-ADC mission located at 75° West, and described in EUM-WP-6. It was noted that sufficient power margin would be supplied by the solar parameters until the end of 1994, however, station keeping fuel would be consumed by mid 1994, after which the inclination of the satellite would slowly increase. The working paper also presented details of WEFAX image formats and a revised dissemination schedule which would be agreed with NWS in the coming weeks.

As part of its agreement with NOAA, selected GMS WEFAX imagery would be acquired from the GOES-Tap system in Washington DC and disseminated via Meteosat-4 by the end of May 1993.

USA WP-5 described the recent history and current status of contingency planning arrangements among satellite operators. Particular reference was made to the ongoing

NOAA/EUMETSAT/ESA Extended Atlantic Data Coverage (XADC) Mission, and to the draft EUMETSAT/NOAA Long Term Mutual Back Up Agreement. NOAA said that copies of this draft document were available and could be provided to interested CGMS members. If current programmatic planning and expectations are fulfilled, NOAA and EUMETSAT will be able to provide emergency back up to each other on a relatively equal footing by 1997. Attachments to the working paper provided charts on the XADC Mission, and on associated NOAA one-GOES, two-GOES, and no-GOES scenarios.

Update on Pacific Data Coverage

Japan presented in WP-5 the interim support capacity provided by GMS-4 for data collection of regional DCP for GOES DCS in channel I-16 since September 1992.

Japan recalled that according to a CGMS agreement each satellite operator supports the collection of data from International Data Collection Platforms (IDCP) within its area of responsibility. However the USA is currently not in a position to achieve data collection over the mid-Pacific due to the deficiency of the GOES satellite system. JMA furthermore indicated its readiness to support temporarily the full data collection between 140° and 180° West, as of September 1993, if required on an interim basis. The USA thanked Japan for its offer and requested that this facility be implemented as soon as feasible.

Concluding this discussion item, ESA thanked NOAA for its excellent support received from the Wallops station personnel during the X-ADC implementation and validation phases, resulting in a start of this mission ahead of schedule. In return, USA expressed its most sincere gratitude to both ESA and EUMETSAT for their X-ADC contingency support, and also to JMA for its ongoing contingency data collection support over the Pacific using GMS-4. USA further noted that the NOAA-EUMETSAT long term back-up Agreement, once signed, will be a major step towards providing for the continuity of meteorological satellite data. This long term back-up Agreement is possibly the first of other similar agreements to be established between satellite operators to ensure further data continuity in the future.

Finally, WMO congratulated all three agencies for these examples of contingency support, and welcomed the further proposal for Japan to extend its IDCS Coverage.

D.3 Global Planning, including Orbital Positions

CGMS noted that the WMO Forty-Fourth Executive Council had endorsed a statement of WMO requirements for continuity of the space based portion of the GOS while stressing its importance for all WMO Members. The Executive Council felt it important that contingency plans, including long-term plans for 10 years or more, should be developed by the satellite operators.

CGMS was informed that space segment contingency planning was the primary focus of the statement of WMO requirements for continuity. Furthermore, it was anticipated that CGMS will continue its role of standardization such that ground receiving equipment would be able to receive and process services from any contingency satellite provided by another operator, eg. standardized data formats.

The statement of WMO requirements for continuity was presented at the recent CGMS Working Group Meeting on Global Contingency Planning where EUMETSAT, NOAA/NESDIS and Japan agreed to consider and study contingency planning that could provide continuity of data necessary to WMO Programmes. At the CGMS Working Group Meeting on Global Contingency Planning, it was agreed to forward the statement of WMO requirements for continuity to CGMS-XXI for endorsement. CGMS agreed that the WMO requirements as stated form the basis for CGMS global contingency planning. However, it recognized that work on WMO's part was necessary to further articulate and define contingency requirements with regard to satellite services.

ACTION 21.04 WMO to further define its contingency requirements as regards satellite services.

WMO stressed the need to continue the excellent progress that had been accomplished by the CGMS Working Group Meetings on Global Contingency Planning. WMO highlighted the existing need for full global coverage in view of the data void over the Indian Ocean. It cited the need to develop and implement contingency plans by CGMS for this important area of the world (Annex XIX refers).

ACTION 21.05 CGMS Members to consider mechanisms to provide coverage over the Indian Ocean and report progress to CGMS XXII.

2nd Meeting on Global Contingency Planning

In its WP-3, EUMETSAT presented the report on the "2nd meeting on global contingency planning" which took place on 17 and 18 February 1993 at the JMA Headquarters, Tokyo (Japan).

The main objective of the meeting was to discuss action items 3, 4 and 5 from the "Woods Hole" meeting concerning the technical feasibility of developing global contingency plans by establishing a 3 way contingency agreement between EUMETSAT, NOAA and Japan, referring to the existing draft agreement between NOAA and EUMETSAT. The results are referred to the working group on global contingency planning held during CGMS XXI.

E. METEOROLOGICAL SATELLITES AS PART OF WMO PROGRAMMES

E.1. World Weather Watch

CGMS was informed that the present constellation of geosynchronous meteorological satellites (GMS-4, METEOSAT 3 and 4 and GOES-7) provided valuable data and almost full coverage for the detection and monitoring of tropical cyclone regions in support of the WWW Tropical Cyclone Programme (WMO WP-1 refers). One difficulty remains in the Indian Ocean, which is one of the few areas on earth not covered by an <u>operational</u> geostationary meteorological satellite.

The data from INSAT-1, located at 83°E and covering the Indian Ocean, is not available to WMO Members and in particular to the Regional Specialized Meteorological Centre (RSMC) at La Reunion with responsibility for the South-West Indian Ocean. This lack of full meteorological satellite data over the Indian Ocean is a deficiency that needs to be resolved very urgently for support of the Tropical Cyclone Programme of the WMO.

CGMS agreed to stress to the Government of India the importance of INSAT data to the entire Indian Ocean region and to the Global Observing System (GOS), and to urge the Government of India to make the data available to WMO Members by integrating the satellite system into the GOS. CGMS also agreed to draw to the attention of the Russian Federation the continuing deficiencies in the Indian Ocean and to stress the importance of its planned launch of GOMS.

ACTION 21.06 WMO notify the Government of India and the Russian Federation about the impact of the lack of coverage over the Indian Ocean.

In WMO-WP-6, CGMS was informed that CBS had formed a new CBS Working Group on Satellites effective 19 June 1993 when it is anticipated that EC-XLV will not re-establish an Executive Committee Panel of Experts on Satellites but let CBS assume full responsibility for satellite matters. CGMS will continue to be invited as observers to meetings of the new CBS Working Group.

CGMS noted in WMO-WP-08 that the WMO EC supported the conclusion that the Workshop on Wind Extraction from Operational Meteorological Satellite Data was effective in providing a forum to help improve wind quality and assist wind users in their effective application and that further activities of this type should be encouraged.

CGMS also noted the new WMO list of satellite service requirements as follows:

Polar orbit

Full resolution imagery - HRPT
Low resolution imagery - LRPT
Direct Sounding Broadcast - DSB
Data Collection System - DCS

Geostationary orbit

Full resolution imagery - S-VISSR
Low resolution imagery - LRIT
Direct Sounding Broadcast - DSB
Telecommunications - MDD (for example)
Data Collection System - DCS

CGMS also noted that direct readout services from meteorological satellites are essential and should be continued.

WMO briefed CGMS Members on the latest WMO Satellite Data Requirements (see Annex XXI). It was noted that the requirements had been first developed by the EC Panel of Experts/CBS Working Group on Satellites and then refined through an iterative process with satellite operators and the various users within the WMO Technical Commissions. CGMS was informed that the latest version would be reviewed by the June 1993 session of the WMO EC and most probably approved. However, it was noted that the requirements should be reviewed by satellite operators as their future plans became more clearly defined.

CGMS Members welcomed the development of such a list of satellite data requirements, noting the value to their own planning process. EUMETSAT noted that the WMO Satellite Data Requirements would be used as a reference in the Mission Objectives of their METEOSAT Second Generation Programme (MSG). CGMS agreed that further review and refinement of the requirements were necessary by both satellite operators and WMO.

ACTION 21.07 **CGMS satellite operators to review the WMO Satellite Data Requirements as to their achievability within currently planned systems, accuracy and mission schedule and the anticipated time frame Members could wholly or partially satisfy the requirements. The results of this review should be received at the CGMS Secretariat by July, 1993.**

ACTION 21.08 **WMO to further refine the Satellite Data Requirements based on inputs from CGMS satellite operators.**

In its WP-11, WMO briefed CGMS on the Operational WWW Systems Evaluation for Africa (OWSE-Africa) in noting that it was conducted in two phases. The first phase was an evaluation of the improvement to data collection through the use of the METEOSAT Data Collection System and the second phase was an evaluation of the improvement to data distribution of GTS data and products through the METEOROLOGICAL Data Distribution (MDD) System.

Phase I had already completed and dramatically demonstrated the ability to improve data collection in areas that previously provided little or no data. Phase II was nearing completion and preliminary results also indicate a positive impact to distributing data and products to African Centres. It was noted that many lessons had been learned during the evaluation that would be of great benefit to the next step in the process, that of an implementation programme.

CGMS welcomed the results of OWSE-Africa and encouraged WMO to identify more detailed service requirements based on such (e.g. data collection and data relay services). Since CGMS had previously been informed of the WMO Satellite Service Requirements, it felt it most appropriate that WMO could undertake this task.

ACTION 21.09 WMO to develop detailed satellite service requirements based on experiences learned during the OWSE-Africa Phases I and II.

In WP-14, WMO briefed CGMS on the draft Final Report from the EC Panel of Experts on Satellites which would be reviewed in June 1993 by EC for approval. Two important components of the report were a Consolidated Report and a Strategy for Education and Training for Satellite Matters.

The Consolidated Report contained important recommendations from the ten sessions of the Panel and would provide an important heritage for the new CBS Working Group on Satellites. CGMS noted the outstanding issues identified by the Consolidated Report including the need to further refine definitions found in the report, the need to identify and further develop data management requirements for satellite data, the need to continue the dialogue leading to global contingency planning and the need to identify satellite product requirements.

With regard to the Strategy for Education and Training, WMO explained that a new concept of training the trainers at Regional Meteorological Training Centres (RMTCs) would be submitted for approval at the next WMO EC in June. The present strategy contained in the Final Report had three major objectives to implement the concept. The objectives including building on the existing infrastructure, focusing on the developing countries and anticipating future trends in satellite data applications. Of great interest to CGMS was the proposal to establish six specialised satellite training centres at Regional Meteorological Training Centres (RMTCs). WMO further proposed that each satellite operator adopt at least one of the six centres.

PRC informed CGMS of its own experience and requirements concerning training on satellite meteorology, and stressed the need for a parallel and harmonized effort on training and on operational equipment. PRC identified three key elements for the success of such an effort:

- availability of written training support material (e.g. handbooks)
- an operational environment enabling acquired knowledge to be put into practice
- sufficient support staff trained to maintain the operational equipment

JMA indicated a willingness to cooperate with such a strategy and encouraged WMO to further study implementation mechanisms. NOAA noted the need to accommodate regional training requirements.

CGMS agreed in principle with the strategy and also to a willingness to further discuss the proposal with WMO. It also indicated that WMO should further identify specific needs to aid potential CGMS supporters in evaluating resource requirements for such sponsorship, together with a proposed implementation dates.

ACTION 21.10 WMO to finalize its proposal for a Training strategy involving sponsorship of specialised RMTC by satellite operators as soon as practicable, and to identify corresponding needs before CGMS XXII.

CGMS noted, in WMO-WP-15, the WMO presentation of a recent survey of satellite ground receiving equipment of WMO National Meteorological and Hydrological Services in WMO regions. The results were in a draft report containing sections on the sources of data used in the analysis, geographic distributions, statistical information and changes since the 1990 survey for each WMO region. The report also noted an overall increase (674 to 697) in the total number of satellite receiving equipment. Although formal goals for the implementation of satellite receiving equipment have yet to be established, proposed goals of 100% of WMO Members equipped with polar orbiting receivers and 100% for geostationary receivers show that WMO presently has achieved 80% implementation.

CGMS expressed its appreciation for the development of such a database which will provide valuable information. It stressed the need to highlight that the draft report contained information from WMO National Meteorological and Hydrological services which was not inclusive of all receiving equipment (i.e. commercial, private, educational establishment systems, etc.)

ACTION 21.11 Satellite operators to comment on content and format of the present draft report on satellite ground receiving stations and make recommendations to WMO for future issues of the report by 30 September 1993.

CGMS was briefed (WMO-WP-3 refers) on the latest status in the development of the Global Climate Observing System (Annex XVIII refers) and noted that GCOS will liaise with CGMS through WMO.

E.2 Other Programmes

The meeting noted that Japan had been continuously contributing to ISCCP and GPCP data production and distribution based on GMS data and were congratulated for their 100% performance.

WMO briefed CGMS in WP-2 on results from the most recent Commission for Hydrology meeting where one acute need was the guaranteed free access to data collection systems for all WMO Programmes. Many CGMS Members noted that this was already the case. Therefore CGMS agreed, in principle, all WMO Programmes should have free access to data collection systems recognising that this must also be subject to individual regulations and policies.

In WP-16, WMO informed CGMS on a preliminary draft project plan to develop low cost low resolution satellite data receivers. Several CGMS Members felt that such a plan was appropriate and encouraged WMO to further develop the concept. CGMS stressed that the plan should consider the global cost, which includes not only the initial capital costs but also installation, maintenance and training (i.e. overall life cycle management). Standardization was also considered as an important element of any low-cost approach.

CGMS was informed (WMO-WP-2 refers) that the WMO's Commission for Basic Systems (CBS) at its tenth session (CBS-X, Geneva, November 1992) underscored the need for improved standardization of WMO Technical Co-operation computer projects, in particular as regards the exchange of data between computer systems or sub-systems (including meteorological computer workstations and satellite workstations). CGMS noted that the Commission had adopted specific guidelines and it agreed to follow the guidelines where practical and appropriate. It also agreed to inform other organizations and commercial enterprises with whom it interacts with regard to the guidelines. The guidelines can be found in Annex XX.

F. CO-ORDINATION OF INTERNATIONAL DATA COLLECTION & DISTRIBUTION

F.1 Status and Problems of the IDCS

F.1.1 EUMETSAT

CGMS noted the current utilisation of Meteosat IDCS channels as presented in EUM-WP-8. 7 international channels were regularly in use, with one additional channel, I17, held in reserve for additional ASDAR units and ASAP testing.

CGMS were pleased to note that earlier interferences to channel I16 in the Meteosat field of view had largely disappeared. The meeting also took note of the consolidated list of IDCS allocations presented in the document.

ACTION 21.12 All CGMS members to check the consolidated IDCS allocations list and report any discrepancies to the Secretariat by 31st May 1993.

2nd Data Collection System User Conference

In EUM-WP-9, the meeting was informed about the first announcement of the Second Data Collection System User Conference to be held in Athens, Greece, from 14 to 17 September 1993. Although many of the topics for discussions would concern Meteosat DCP applications and experiences, there will be a session dealing with other satellite DCP system. CGMS members were cordially invited to attend or present papers at the Conference.

F.1.2 Japan

In WP-7 CGMS noted that JMA had implemented a full International Data Collection System (IDCS) service. The messages from IDCPs, relayed by GMS-4, were entered onto the Global Telecommunication System (GTS) through the JMA communication networks. Six international channels (I6, I7, I12, I14, I15 and I18) of GMS-4 DCP transponder had been operationally used to relay messages.

Since September 1, 1992, I16 of GMS-4 had been offered to relay the messages from 60 GOES regional DCPs temporarily until the new GOES Satellite resumes operations in the Pacific region. CGMS thanks Japan for its kind offer to assist with Pacific data relay and remarked that this was a fine example of one agency supporting another.

Interference Monitoring of IDCS Channels

CGMS were informed in Japan-WP-8 that JMA had developed a system for monitoring interference on IDCS channels in 1991. The system comprised a personal computer and a spectrum analyzer. The spectrums of down link signals of all IDCP channels could be automatically monitored. CGMS recalled that details of this system were presented at the 20th CGMS conference.

CGMS noted that JMA monitored interference on GMS channels at three-hourly intervals throughout a day for periods of ten days. Results of monitoring from January to December 1992 were presented.

JMA had not observed any serious interferences on the all IDCS channels in the GMS coverage in 1992. But weak interferences were observed on channels 2, 3, 7, 28, 29 and 30. The weak interferences on channels 3 and 29 were observed as of March 1993.

F.1.4 P.R.C

PRC WP-5 described the data collection system of the FY-2 satellite, through information on the satellite, transmission frequencies, DCP type, time slot, data coding, and platform. There are 133 DCP channels in the FY-2 system, of which 100 channels are regional and 33 channels are international. Two outstanding issues with FY-2 DCP system need coordination: harmonization of the DCP signal with the IDCS, and the allocation of an IDCP address code for the PRC. These issues were referred to the Telecommunications Working Group for further consideration.

F.1.5 USA

USA WP-6 was presented and discussed in further detail the DCS support provided by Japan via International Channel 16 (I16). Not all DCPs affected by the loss of GOES-6 could be switched to I6. To compensate, GOES-2 was positioned to 135 degrees West. This repositioning was partially successful in that GOES-2 has an inclination of 10 degrees and the DCPs cannot report continuously through the satellite. Use of I16 on GMS is still part of the USA planning until a new GOES-West satellite is operational.

The USA then presented WP-7 on interference checks on IDCS Channels. It was noted that monitoring of any channel is possible by the USA for short periods, but continuous monitoring was not performed. No significant interference was observed during the monitoring.

USA also reported that it intended to study possibilities for sub-dividing the IDCS channel frequency range from 3 kHz to 1.5 kHz.

ACTION 21.13 USA to report the results of a study to sub-divide the IDCS Channel frequency range at CGMS XXII.

F.2 Ships, including those in the Automated Shipboard Aerological Programme (ASAP)

F.2.1 Japan

In JAPAN-WP-9, CGMS were informed that JMA relays the messages from IDCPs and put them onto the Global Telecommunication System (GTS) in cooperation with other satellite operators. 119 ship IDCPs (170 addresses) including several ASAP were registered to the GMS IDCS as of 31 December 1992.

The current status of channel and time slot assignment for ship IDCPs was presented in the paper.

F.2.2 USA

The USA presented WP-8 as information on current ship and ASAP allocations.

F.2.3 WMO

In its WP-10, CGMS was briefed on the status of the ASDAR and ASAP programmes from a WMO perspective. CGMS agreed that the Operating Consortium of ASDAR Participants (OCAP) would act as the single focal point of contact for ASDAR matter with CGMS through WMO.

ACTION 21.14 WMO to notify OCAP about any possible need for update of its Terms of Reference resulting from the decision that it reports to CGMS via WMO.

F.3 ASDAR

F.3.1 Japan

JMA recalled that it had been requested by EUMETSAT to register two operational ASDAR to GMS DCS on 5 November 1991. In response to the request, JMA also modified its software for dissemination of operational ASDAR messages transmitted in the new AMDAR code format. The dissemination of AMDAR coded data started on 25 March 1992.

Furthermore, and in response to a request from the CGMS Secretariat to use the USA proposed look-up table for aircraft identifiers in AMDAR bulletins, JMA had made further modifications to the processing software and started to disseminate fully modified AMDAR bulletins on 30 October 1992. The dissemination statistics showed that around one third of all received ASDAR messages were normally disseminated from MSC. Other messages were not disseminated mainly because they were outside the area of responsibility of JMA.

The Chairman expressed the gratitude of CGMS for the way Japan had been able to quickly respond to this request.

F.3.2 USA

The USA WP-9 on ASDAR was presented, and it was noted that a GTS address for the KLM aircraft required a change to KLO12UMZ. All members acknowledged being notified of this requirement.

F.4 Dissemination of DCP Messages (GTS or other means)

F.4.1 Japan

In Japan WP-11, CGMS noted that the Meteorological Satellite Center (MSC) received messages from 270 DCPs via 7 international and 23 regional DCP channels via the GMS-4 transponder as of December 1992. Received messages were processed at MSC and disseminated to the headquarters of Japan Meteorological Agency for further distribution on the GTS.

F.4.2 USA

Various methods (current and planned) of GOES DCP data dissemination were presented in USA in WP-10. Telephone dial-in dissemination is used by 53% of the users, while the number of DOMSAT receiving stations has increased to 25. The USA also noted that testing is being planned for the utilization of the Internet network for some data dissemination.

G. CO-ORDINATION OF DATA DISSEMINATION

G.1 Dissemination via Satellite

G.1.1 Digital HR Dissemination

EUMETSAT

EUM-WP-10 provided outline planning for the encryption of HR image data. The chosen scheme would be similar to that used for MDD. Implementation of the uplink hardware would take place during 1993, with tests of encrypted image broadcasts starting in 1994. A black box decryption unit for PDUS would be developed in parallel. More regular encryption of the image data would occur from 1995. HR image data from the MTP satellite system would also be encrypted.

Additionally, a new LXI format containing Visible data had been introduced into the Meteosat-Nominal schedule.

USA informed CGMS that they were not planning any encryption of polar or geostationary meteorological satellite data.

Japan

In the S-VISSR dissemination service of GMS-5, all image data will be disseminated to MDUS users (Annex X). The additional data will be put into unused blocks in current GMS-4 dissemination formats. This will not affect current MDUS users as long as they receive only the visible and infrared images.

The details of GMS-5 S-VISSR formats will be announced to users in July 1993.

PRC

SMA presented PRC WP-3, which provided detailed specifications of the transmission characteristics of its FY-2 Stretched VISSR data (Annex XII). Since, apart from their frequency, the signal characteristics and data format of FY-2 S-VISSR data will be the same as GMS S-VISSR data, user stations now receiving GMS data may also receive FY-2 S-VISSR data by changing antenna direction and oscillator frequency.

PRC WP-4 (Annex XIII) described the transmission characteristics of the FY-2 S-FAX system for PRC's domestic users. In the case of NOAA HRPT interference with FY-2 S-FAX, SMA will reschedule the S-FAX broadcast time. It was agreed that this potential interference would be discussed further in the Telecommunications Working Group.

USA

USA WP-11 summarized the new GOES Variable (GVAR) format, which will be utilized on GOES I-M (see Annex XVI for details). Several items were highlighted, including the reduced EIRP, new frequency of the GVAR signal, the current scanning scenarios and possible modification to these scenarios and the extensive testing planned for ground processing options. EUMETSAT requested that information on the testing plans be provided and the latest version of the GVAR simulator software be forwarded.

ACTION 21.15 **USA to provide CGMS Secretariat with details of GVAR test plans together with the latest version of the GVAR simulator software.**

The USA confirmed that as it supported full and unrestricted distribution of all environmental data, it had no intention of encrypting any image data transmissions and did not require users to enter into restrictive data agreements.

G.1.2 Analogue Low Resolution WEFAX Dissemination

EUMETSAT

In EUM-WP-10, the meeting noted that during 1992 some minor modifications were made to the dissemination of Meteosat-ADC High Resolution and WEFAX images and a modification to the digital WEFAX header had been implemented.

Japan

In Japan WP-13, CGMS were informed about planned GMS-5 WEFAX dissemination as follows:

a) Four-sectorized water vapour images, observed at 00 and 12 UTC, will be disseminated in addition to the current dissemination,

b) Four-sectorized images will be made from a rectified (mapped) disk image in place of a non-rectified (observed) disk image. The rectified disk image is equivalent to the disk image observed from a nominal geostationary position, 140° E above the equator with a nominal attitude, i.e. the spin axis exactly vertical to the orbital plane.

CGMS also noted that as a result of the introduction of a rectified image WEFAX service, SDUS users will be able to make animation of four-sectorized images without geographical fluctuations caused by temporal variations of the position and attitude of the spacecraft.

USA

NOAA presented USA WP-12, which updated CGMS members on the status of the United States' WEFAX system. The paper reported on a standby no-GOES WEFAX schedule, the development of a WEFAX product catalog, and the ongoing status of the NOAA.SAT electronic bulletin board, which provides scheduling information on NOAA satellites and services.

G.1.3 Future Formats, LRIT, LRPT

The meeting recalled that version 2.2 of the LRIT Format-Global Specification (EUM-WP-11 refers) was mailed to CGMS members in January 1993. This document contains all format details to be applied by all satellite operators. Additional documents will contain satellite related specifications. These documents will be edited and issued by individual satellite operators.

The meeting commented positively to the LRIT Format-Global Specifications and at the request of the Chairman, all participants were invited to confirm their agreement of the standard as soon as possible.

ACTION 21.16 CGMS Members to confirm their agreement to the LRIT-Format by July 1993.

ACTION 21.17 All CGMS Members are requested to indicate planned introduction dates of LRIT

The USA presented WP-13, which summarized current planning for the definition of the new LRPT data format in the NOAA O,P,Q period. NOAA has rescheduled the issuance of the LRPT specifications due to the extension of NOAA's upcoming spacecraft series (K,L,M,N,N'). However, the existing draft specifications have not changed, and the final specifications are expected to be essentially similar to the LRIT format.

ACTION 21.18 **NOAA to provide CGMS members with a draft global LRPT specification within the next 6 months.**

Issues highlighted were the frequency adjustments required to avoid interference from mobile telephone systems, antenna type and performance, and data stream content.

The PRC questioned whether procedures were established to decide on the spectral channel selection for LRPT image data. The USA said that the design to allow any 3 of the 7 channels to be selected for broadcast will provide flexibility, but that criteria for selection have not been developed.

WMO expressed some concern on the reported antenna type/performance characteristics. WMO noted that a hemi-isotropic antenna (currently used by most APT stations) will give a 10^{-6} bit error rate for orbits 25 degrees above the horizon (thus limiting reception coverage area) and to achieve similar performance for all orbits a tracking antenna will be required (thus adding significant cost to an LRPT station).

ACTION 21.19 **USA to make further assessment of the impact of using an LRPT omnidirectional antenna, and report the results to CGMS Members**

CGMS also took note of EUM-WP-15 which presented proposals for the coordination of data formats from future polar orbiting satellite systems.

G.1.4 Other Product Dissemination

EUMETSAT

CGMS noted that since 1990 there had been regular broadcasts of Meteosat MDD data. Graphical products uplinked from Bracknell (UK) and alphanumeric (GTS) bulletins from Rome (Italy). From 1 March 1993, both channels had been fully encrypted except for test and administrative messages. At the time of writing 41 MDD user stations had been equipped with decryption key units. Additionally, around 65 requests for access to MDD data had been received.

The meeting also noted that EUMETSAT was now considering the introduction of a third MDD uplink station, in France, to provide additional system capacity, redundancy, and to focus specifically on the provision of special products generated within and for use by African meteorological services.

USA

USA WP-14 reported on the status of the NOAAPORT Broadcast System. It was noted that this service is primarily for providing satellite data to the US National Weather Service and will have a limited coverage area (continental U.S., Alaska, and Hawaii).

USA-WP-15 reported on the status of a pilot Satellite Active Archive. The archive will provide an interactive browse and ordering system for near real time NOAA satellite data.

G.2 Dissemination via GTS or other Means

In its WP-16, USA described how soundings and multi-channel sea surface temperature data processed from the NOAA Polar Satellites were distributed over the GTS. The meeting noted that the data volume of TOVS data was such that the dissemination would be carried out using WMO approved BUFR code.

The USA presented WP-16 as information on the TIROS Operational Vertical Sounder (TOVS) and Sea Surface Temperature (SST) data processing and distribution.

H. OTHER ITEMS OF MORE GENERAL INTEREST

H.1 Report on International Space Year Activities (ISY)

CGMS were pleased to note the many activities conducted in Europe (EUM-WP-19) and in Japan (JAPAN-WP-17) during the International Space Year and considered that the now established Space Agency Forum would provide an ideal organisation for the continuation of these activities.

H.2 Special Applications of Meteorological Satellite Data in the Fields of Earth Environment Monitoring

EUMETSAT presented in WP-17 the status of its Directory of Meteorological Applications whose second edition was about to be issued shortly and reminded CGMS about the proposal of a joint publication covering global applications. CGMS members congratulated EUMETSAT for the directory and expressed again their interest in contributing to a similar CGMS publication on global applications. To this end NOAA and WMO requested EUMETSAT to provide some cost indications.

ACTION 21.20 **EUMETSAT to inform NOAA and WMO about costs and any other related issues involved with the setting up of a CGMS directory of meteorological satellite applications.**

USA WP-17 reported on the status of the NOAA/NASA Pathfinder Program and Pathfinder instrument characteristics. The Pathfinder Program, a continuing program of NOAA and NASA, will generate research-quality, long-term data sets of atmospheric, oceanic and land variables from operational satellite observations. These data sets will be made available to the global change research community. CGMS took note with appreciation of the constant effort made to maintain up-to-date the archiving system.

USA WP-19 described the application of vegetation index for vegetation condition diagnoses and for drought detection. The working paper listed several examples of the recent application of vegetation indices for the detection and tracking of droughts. CGMS welcomed the developments of primary importance with regard to global environment. EUMETSAT further noted that it would be considered with special attention in the light of both the EPS and MSG programmes.

CGMS recalled that USA-WP-18 and PRC-WP-7 had been discussed by Working Group II.

H.3 Search and Rescue (S & R)

USA WP-20 provided a copy of the most recent COSPAS-SARSAT System Data Report, to inform the CGMS membership of the COSPAS-SARSAT Program's current status. The report, which is published by the COSPAS-SARSAT Secretariat, lists the number of search and rescue events assisted by COSPAS-SARSAT, describes the system's space and ground segments, and lists the Program's participating countries and organizations. CGMS noted the considerably useful service provided by COSPAS-SARSAT.

USA WP-21 described the utility of a geostationary satellite component to the U.S. search and rescue satellite-aided tracking program. The paper described current North American and international efforts, and reported on the status of the COSPAS-SARSAT Geostationary Satellite Working Group (GWG).

CGMS noted that prospects for the development of a worldwide geostationary S & R capability for COSPAS-SARSAT were still being investigated.

H.4 Anomalies from Solar and Other Events

USA WP-22 provided CGMS members with an update and compiled data on solar activity for environmental satellites. The working paper was provided as part of a continuing CGMS action assigned to the United States. The paper concluded with a tentative prediction that the next sunspot maximum will be a very high one, with significant impact on the operation of meteorological satellites.

USA WP-23 described the history and increasing priority of NOAA's requirements for measurements of the solar wind and interplanetary magnetic field for geomagnetic storm alerts, and NOAA's plans to acquire these measurements.

CGMS took note of this information which was provided in response to CGMS action 20.13.

H.5 Other Items of Interest

CGMS took note of the updated list of EUMETSAT publications.

I. REPORT FROM WORKING GROUP I - TELECOMMUNICATIONS

Introduction

Mr. Larry Heacock (NOAA) was elected as Chairman of Working Group 1, and Mr. Timothy Stryker (NOAA) as Rapporteur.

I/1 Co-ordination of frequency allocations

EUMETSAT WP-21 described the potential reallocation of the bands of meteorological satellite service near 7.5 GHz and 8.2 GHz, an action proposed by the Space Frequency Coordination Group (SFCG). The Working Group recommended that the CGMS Plenary endorse this proposed reallocation, as an initial step toward obtaining usable frequency bands from frequency management authorities to provide future expansion capability for the Meteorological Satellite Service.

In Japan WP-14, NASDA informed CGMS that JMA and NASDA have explained to the Japanese radio administrative authority the necessity of protecting the 400 Mhz, 1.6 GHz, and 2 GHz bands. JMA and NASDA requested from their authorities that these three bands not be allocated to other services without assuring the protection of space operation, meteorological satellite and meteorological aids services.

USA WP-24 informed the Working Group on the results of the 1992 World Administrative Radio Conference (WARC), and its implications for frequencies used by meteorological satellites of the USA. The WARC meeting resulted in a considerably larger amount of frequency sharing than had been expected. The working group participants agreed that future developments must be closely monitored, to ensure protection of frequencies vital to meteorological satellite operations.

The Working Group revisited those PRC Working Papers with special relevance to the Group. The first paper reviewed was PRC WP-3, which describes the transmission characteristics of FY-2 Stretched Visible Infrared Spin Scan Radiometer (S-VISSR). The USA noted that, due to the planned 15 degree separation between FY-2 and GMS, there should be no interference between the two satellites.

Working Group participants also reviewed PRC WP-4, which describes the transmission characteristics of the FY-2 S-FAX, low resolution image dissemination. Earlier discussion in the Plenary session had focused upon the possible interference of this transmission with that of the HRPT signal of NOAA polar orbiting satellites.

The PRC representative stated that interference was unlikely, due to the FY-2 S-FAX transmission's narrow bandwidth, and its separation by 1.5 Mhz from that of the center frequency of NOAA HRPT. PRC distributed a spectrum analysis and spectrum diagram to support this assertion. The PRC further stated that if any interference were observed, then the PRC would reschedule its broadcasts to avoid the times of NOAA satellite passes.

The USA reminded members of the Working Group that, under ITU regulations, if any user of the FY-2 S-FAX transmissions complained to the ITU about interference from NOAA HRPT, the USA would have no choice but to shut off NOAA HRPT during potential interference periods.

The Working Group members agreed that any interference was unlikely. However, they also agreed that more detailed studies of this issue are required, and that the results of these studies would be reported to CGMS within the next three months.

ACTION 21.21 **CGMS Members to study the possible interference of the FY-2 S-FAX downlink with that of the NOAA HRPT, and report the results of these studies to the CGMS Secretariat by 1 August 1993.**

The Working Group then considered PRC Working Paper 5, which described the FY-2 Data Collection System. During the Plenary session, the PRC noted that two outstanding issues needed coordination through CGMS: harmonization of the FY-2 IDCP time-slot allocation, and the allocation of an IDCP address code for the PRC on the IDCS. The Working Group welcomed the PRC's interest in participating in the IDCS, and recognized that this issue was an appropriate area for CGMS action. At the request of the Working Group, the PRC agreed to change its IDCP time slot from 2 minutes to 1.5 minutes — at least for IDCS channels, bringing it into conformity with established IDCS time slot allocation.

ACTION 21.22 **PRC to reallocate IDCP time slots on a 1.5 minute basis.**

Attention then shifted to the question of address codes. When agency assignments of DCP address codes had been made in the 1970s, the addition of satellites operators other than the then-members of CGMS (Europe, Japan, Russia, and USA) had not been foreseen. Hence, no provision had been made for additional agency address codes. However, the possibility that certain users might be admitted through the WMO had not been realized. Thus the address codes originally allocated to WMO were still not utilized. Both short-term and long-term actions are required. First, since it was now possible that preliminary, short-term assignments must be made for IDCPs reporting through FY-2, provisional reallocation to the PRC of the WMO 1110 (hex "E") IDCS prefix. This action will be investigated by the WMO and confirmed within the next three months.

ACTION 21.23 **The WMO to provisionally agree to the reallocation to the PRC of its 1110 IDCS prefix, and to confirm its decision to the CGMS Secretariat and PRC by 1 August 1993.**

As a second, longer term action, the Group noted that the inclusion in the IDCS of new operators would necessitate a major review of the system. After twenty years, it is probable that other adjustments may be necessary. This matter would need comprehensive consideration and coordination through CGMS.

ACTION 21.24 **CGMS Members to consider the possible technical measures for the reorganization of the IDCS to include the PRC and any other changes necessary to meet currently foreseen uses of the IDCS.**

It was recognized by the Working Group that the CGMS Plenary would need to approve these actions, as well as the procedural method for adding FY-2 to the operational IDCS. The Working Group referred the issue to the Plenary, with the recommendation that the necessary steps be taken to include the PRC in the IDCS as soon as possible.

Before leaving this agenda item, the Working Group discussed PRC WP-9, which presented the transmission frequencies for HRPT on future satellites in the FY-1 (polar orbiting) series. It was recalled that direct broadcast from this series for FY-1A and FY-1B at 1695.5 MHz had caused interference with METEOSAT dissemination channels. PRC representatives announced in WP-9 that the direct broadcast frequency for future FY-1 satellites would be on a frequency of 1708 MHz, in time sharing mode with NOAA HRPT and the future METOP of EUMETSAT, thus utilizing the portion of the band agreed upon by CGMS for polar satellites. The 1695.5 MHz downlink would only be used for Delayed Picture Transmission (DPT) internally within China. While accepting that this appeared to resolve the problem of interference with METEOSAT, WG members reminded PRC of the necessity to insure that the turn-off command for this transmitter is reliably sent and accomplished.

WMO WP-13 provided information on frequency coordination matters, including the decisions of WARC-92 regarding frequency bands for meteorological activities, recent CBS decisions, and frequency coordination activities of the WMO Secretariat. The Working Paper included as an appendix an understanding between the WMO and the International Frequency Registration Board (IFRB) regarding coordination and notification of stations in the Meteorological Satellite Service.

I/2 Results of SFCG

EUMETSAT WP-13 reported on the 12th Meeting of the Space Frequency Coordination Group (SFCG). CGMS was represented at the meeting by Mr. Robert Wolf of EUMETSAT. Much of the SFCG's work focused on the reallocation of frequencies for mobile satellite services, such as those of Motorola and Inmarsat. The Group noted the particular importance of protecting meteorological satellite frequencies from further encroachment of commercial services. The SFCG also heard a report from NASDA on the Phase A study of ADEOS II. The SFCG also reviewed the status of the future LRIT format. NASDA then updated the Working Group on the status of ADEOS-II. The Phase A study of ADEOS-II was almost finished. Data transmission in 1.7 GHz was studied as one option, but NASDA has not decided whether or not it will use this band. This option will be examined in a Phase B study, which will carried out in FY 1993, commencing in April 93. After the Phase B study is complete, NASDA will provide the SFCG and CGMS with more detailed information.

I/3 Electronic bulletin boards

WMO WP-13 reported on the creation of two Omnet electronic bulletin boards for CGMS members, **CGMS.PLENARY.WMO** and **CGMS.WINDS.WMO**.

CGMS members were encouraged to use these bulletin boards to better facilitate information and exchange. They may be accessed via the Omnet account of Dr. Hinsman.

PRC WP-8 informed the Working Group of the establishment of an Omnet account, **J.XU**, for SMA. CGMS members were encouraged to use this account as they deemed appropriate. The Working Group also noted that the Russian Committee for Hydrometeorology now has an established Omnet account through Dr. Aleksandr Karpov, **A.KARPOV.HYDROMET**.

In concluding this item, the Chairman was pleased to note that with the exception of India, all Members of CGMS could now communicate through the CGMS bulletin board.

II. REPORT FROM WORKING GROUP II - SATELLITE PRODUCTS

Introduction

Dr. D. Hinsman (WMO) and Dr Xu Jianmin were elected as Co-Chairmen of Working Group II, and Mr. Carl Staton (USA) as rapporteur.

The group noted 3 general items for this session, baseline support for Product Quality, the significance of Global Monitoring of various events and parameters, and the need to continue Product Improvements and new Product Development.

The significance of Product Quality was emphasized throughout the session by all participants and in a variety of papers.

Satellite data calibration continued as an important aspect of product quality and several papers were presented on this subject as well as various quality control procedures for specific products. The group encouraged all members to continue providing information through CGMS on all such efforts.

Discussion on global monitoring of events (e.g. volcanos) and parameters (e.g. ozone) was extensive. The group noted CGMS' unique position to foster and support global event monitoring programmes. With a chartered interest in both geostationary and polar orbiting satellites, CGMS should continue to be a leading forum for coordinating such programmes. As an example actions were assigned regarding volcano ash cloud monitoring (see section summary below for details).

In order to assist CGMS members in their long-term planning for meteorological satellites and instrumentation, the group noted the continuing need to be appraised of new products that are being developed. Included during discussions were satellite derived cloud heights and amounts as well as improvements to wind vector calculations.

II/1 Co-ordination of satellite instrument performance

ESA WP-3 described a transputer augmented workstation which has been constructed initially in order to implement an improved resampling technique in the image rectification process. The workstation is presently being developed to produce and automatically quality control water vapour winds produced on a half-hourly basis. The speed of the processing is paramount in the hardware design.

II/2 Satellite data calibration

Radiometric calibration of Meteosat-3 is performed at ESOC using an inter-calibration technique in the area of overlap with Meteosat-4. The method is described in ESA-WP-5 where possible improvements are also discussed.

GOES-I calibration was discussed in USA-WP-25. It was noted that the scanning times have been increased due to the requirement to "scan to space" in order to obtain frequent space views to maintain calibration of the longwave IR channels. It was noted that GOES-I will require 26.5 minutes to scan the full earth image.

USA-WP-6 on AVHRR pathfinder calibration was submitted for members' information.

PRC requested information on the various methods of calibration. The chair assigned EUMETSAT and USA an action to forward relative information.

ACTION 21.25 EUMETSAT and USA to provide PRC with technical information on calibration methods/procedures.

II/3 Meteorological and other parameter extraction

The Chairmen requested that papers in this section be presented in subject related groups as follows ; volcano/flood monitoring, cloud radiances and ozone, winds and announcements and conferences.

Volcano/flood monitoring

The effects of dust from volcanic eruption on rectified image quality are described in ESA-WP-4. The observed errors were reduced by the temporary modification of software parameters.

USA-WP-18, was recalled from agenda item H.2 by the Chair for inclusion in this discussion. The paper discussed current procedures and resources utilized to detect, evaluate and track ash clouds in support of aviation warnings (Annex XVII).

PRC also reported on their extensive flood monitoring programme, noting significant benefits in disaster relief coordination during recent flooding. Through AVHRR image analysis flooding estimates were made for individual countries.

Japan-WP-15 reported on studies of volcanic ash cloud monitoring. Using current GMS data of visible and infrared, almost all ash clouds with the altitude of 10 km or higher caused by large eruptions can be detected, and the temporal variation is well observed. An example using the Pinatubo eruption was presented. Furthermore, the split window infrared data, to be incorporated on GMS-5, and NOAA AVHRR data, will be very useful for discriminating between ash and "normal" clouds. Japan added that it intended to continue investigating ash cloud monitoring, and is considering the implementation of an ash cloud monitoring programme in a few years.

Dr. Zbar (USA/CBS) noted that CBS continues to support global volcanic ash monitoring in support of ICAO requests by all possible resources and encouraged Japan to begin its operational monitoring programme as soon as practical. To emphasize this important programme the chair assigned an action to CBS.

ACTION 21.26 WMO(CBS) to confirm its request to CGMS members that they examine the feasibility of extending satellite based volcano ash monitoring and warning services to all parts of the globe.

EUMETSAT activities for ATOVS processing

The Working Group were informed that EUMETSAT is presently conducting a project for the development of an ATOVS software package (Annex VII). The objective of the project is to provide the user community with a core processing system before the launch of NOAA-K. The processing package addressing direct readout of ATOVS data shall also be applicable to global processing requirements and consistent with the ATOVS system developed and implemented by NOAA. The architecture and the structure of the package will be designed on the basis of the NOAA/NESDIS RTOVS platform.

Work will be carried out mostly at EUMETSAT HQ in close collaboration with international users and organisations in particular NOAA/NESDIS and ECMWF.
The project will be conducted in four phases: Definition, Development, Implementation, and Demonstration.

Coordination with the international user community is currently planned through the ATOVS working group which should provide a system with the most flexible architectural approach (e.g. multiple user defined algorithms) (Annex VI refers).

After extensive discussion of the EUMETSAT proposal the Working group agreed to a mechanism for the ATOVS working group (ITWG) to keep CGMS informed of TOVS applications development.

The Working Group therefore recommends to the CGMS plenary that, during agenda item J.3 discussions, CGMS nominate a Member to identify a representative to the next ITWG meeting. The Member of CGMS so designated will report at CGMS XXII on pertinent issues.

Satellite winds/comparisons

ESA presented two working papers on cloud motion wind processing. In WP-6 (see Annex IV) the major algorithm changes and improvements affecting the derivation of infrared winds since 1987 were documented. WP-7 (Annex V) provided information on the current status of the automatic production of water vapour and visible winds. It was noted that the water vapour winds are now closely approaching the quality of the infrared winds.

Japan reported that most of the effort to improve the quality of CMVs had been directed towards the assignment of better heights to the winds. The height assignment procedures had changed many times over recent years and, as a consequence, the quality of CMV had improved significantly.

USA-WP-27 presented a new statistical method for validating satellite derived wind vectors. It is proving useful in assessing changes to wind processing. It showed e.g. an improvement in the RMS when the automatic winds editing processing was installed.

The Working Group took note of the extensive work carried out by satellite operators in providing statistical analysis on the quality of CMV (by comparison with radiosondes) and noted the existence of different presentation formats. The Working Group therefore recommended that the issue of presentation of results be addressed at the forthcoming

Winds Workshop meeting being held in Tokyo in December 1993 with a view to more uniform presentation approach.

Additionally, the Working Group recommended that consideration be given to the introduction of other observing systems (e.g. ASDAR) in future comparisons for quality assessment.

II/4 New products and their use in NWP

USA-WP-31 presented the new NOAA satellite-derived cloud height and amount programme which will provide cloud height and amount information above 12,000 feet, in real-time, to National Weather Service field sites, U.S. National Centers, and for climatological purposes at National Archive Centers. The document described the algorithm and provided a general description and uses of the new product.

II/5 Co-ordination of code forms for satellite data

As a result of recommendations presented in ESA-WP-10, the CBS sub-group on codes had recommended changes to the SATOB code for winds which were subsequently accepted by CBS-X. The Working Group noted that subject to approval by WMO E.C. in June 1993, they will be introduced on 3 November 1993.

II/6 Co-ordination of data formats for the archive and retrieval of satellite data

ESA-WP-11 reported on the introduction of the ESOC cartridge-based archiving system. The latest development, data compression and the doubling of the number of tracks, has increased the capacity of one cartridge from about 200 Mbyte to 1.2 Gbyte.

ESA distributed an additional working paper on its Meteorological Archive in the form of a CD. The CD contains some 2300 images and a full catalogue which provides comprehensive information on all data contained in the ESA archive. All software required to display the images is included together with some image data handling tools. Furthermore, the CD contains all relevant documentation.

In its WP-16, Japan presented the status of archiving of GMS image data and the planning for its new data archiving system which will be implemented when GMS-5 starts its operations in 1995 (Annex XI refers). The archiving of FY-1 data by PRC is detailed in Annex XIV).

The Working Group took note of the above presentations and during the course of ensuing discussions the Group addressed the issue of common data formats, access and distribution (Annex VIII). The Group agreed that although the concept of common data formats, access and distribution was vital, it was not necessary for CGMS to develop another format but rather to use already available methods. In this respect the Group recommended that CGMS Members should review the detailed data formats specified by CEOS and CCSDS. CGMS should consider the use of one of these standards for future archives. CGMS Members should also study the CEOS catalogue system and to consider supporting the CEOS International Directory Network (IDN) and to consider conducting and maintaining Directory Interchange Formats (DIF) for inclusion in the CEOS IDN.

ACTION 21.27 **CGMS Members to consider CEOS and CCSDS data formats and the CEOS catalogue system as a candidate for future archive and retrieval systems and report their findings to CGMS XXII.**

III REPORT FROM WORKING GROUP III - Global Contingency Planning

The first meeting of Working Group III - Global Contingency Planning elected Mr J. Morgan (EUMETSAT) as Chairman and Mr J Lafeuille (EUMETSAT) as Rapporteur. The Group agreed the following Agenda:

III/1 To review the draft terms of reference provided in the report of the Woods Hole meeting.

III/2 To review the Action list established at the Woods Hole planning meeting.

III/3 To discuss the results of Woods Hole Action 3, concerning the possibility of bent-pipe operations by GOES, Meteosat or GMS

III/4 To review the conclusions and recommendations of the Woods Hole meeting.

III/5 To prepare a report for the plenary session.

III/1 Draft Terms of Reference

The Group reviewed the draft Terms of Reference (TOR) provided in the report of the Woods Hole meeting, and suggested minor modifications, also adding the provision that the Group should normally conduct its business on the occasion of full meetings of CGMS, supplemented by correspondence and essential ad-hoc meetings as necessary.

III/2 Review of Action from the Woods Hole meeting

The Working Group reviewed the action list established by the Woods Hole meeting, with the following conclusions:

Action WH1: WMO to provide a list of global satellite data requirements.
Status: **Completed**

Action WH2: Satellite Operators and WMO to provide lists of products needed on national, regional and global scales as a check list for consideration during implementation of contingency actions (for example to help determine possible providers of such products during contingency situations).
Status: **Continuing, to be adopted as a CGMS action.**

Action WH3: The USA, EUMETSAT and Japan to explore technical and cost requirements for bent-pipe operations of GOES, Meteosat and GMS respectively.
Status: **This action is discussed under agenda 3 below and is closed.**

Action WH4:	The USA, EUMETSAT and Japan to analyse and respond to the reports provided under Action WH3.
Status:	**Continuing, discussed under agenda item 3 below and to be adopted as a CGMS action.**
Action WH5:	Japan to provide budgetary estimates of the cost involved in simultaneous operation of two GMS satellites.
Status:	**Closed. Japan provided this information to the planning meeting in Tokyo and this is recorded in the report of that meeting in EUM-WP-7 presented to CGMS XXI.**
Action WH6:	Japan to propose a date for a technical planning meeting.
Status:	**Closed. The Technical Planning Meeting took place in Tokyo on 17-18 February 1993.**
Action WH7:	WMO and EUMETSAT to provide coverage diagrams from the existing CDA stations.
Status:	**Closed.**

III/3 Bent-Pipe operations with GMS, GOES or Meteosat

The Group discussed the possibility of bent-pipe operations with GMS, GOES or Meteosat satellite systems. In the case of GOES and Meteosat this had been documented by the report of the meeting in Tokyo on 17-18 February 1993, while the GMS situation had been documented in Japan paper CGMS/Contingency WG:WP-01. The Group concluded that in each case there is a technical possibility although costs had not been established in detail and that the processing elements (including meteorological products and Data Collection) need further clarification. The Group wished to recommend that this concept be studied further as a basis for a global contingency plan for meteorological satellite operations.

It was stressed that the establishment of joint contingency plans requires a definition of the baseline plans of each operator. This would help to ensure that all participants in an agreement could potentially contribute as well as benefit from the arrangements made. In this context, PRC made the point that its systems were still in an experimental stage and that participation in contingency arrangements would only be considered when their satellites had achieved a high reliability. The Group agreed that this was coherent with the concept of contingency planning for operational systems.

It was agreed that the next steps would be to produce a draft global contingency concept plan taking into account all technical inputs which had been received and for the satellite operators to consider that draft from political and financial perspectives. This should be established by appropriate actions formulated by the plenary session of the CGMS.

III/4 Conclusions and Recommendations of the Woods Hole meeting.

The Group reviewed the conclusions and recommendations of the Woods Hole meeting. It endorsed all of the items and identified a number of points, additional to those discussed above, which needed further discussion at future meetings of the Group and during the CGMS plenary. These are:

* The need for continuing efforts to establish a global contingency plan.

* The absence of essential data coverage over the Indian Ocean. This had already been discussed by CGMS-XXI, resulting in an Action which should be followed-up as necessary.

* The need for improved compatibility between satellites so as to ease contingency plans.

III/5 Preparation of the report for the plenary session

The WG reviewed and agreed the contents of this report to the CGMS plenary.

Proposed CGMS XXI Action Items from WG III were:

ACTION 21.28 **The CGMS Secretariat to ensure that a session of the Working Group on Contingency Planning is included in the Agenda of future meetings of CGMS.**

ACTION 21.29 **The CGMS Secretariat to circulate the provisional terms of reference of the Working Group on Global Contingency Planning for comments before the next meeting of the CGMS.**

ACTION 21.30 **EUMETSAT to prepare and distribute a document on a global Contingency Plan based on the "Woods Hole Concept" before the end of July 1993.**

ACTION 21.31 **All Satellite Operators to consider the above document, together with the Working Group reports from Woods Hole, Tokyo and Beijing meetings, and to prepare their position on this subject prior to the next meeting of the CGMS.**

ACTION 21.32 **All Satellite Operators and WMO to establish lists of products and services needed on national, regional and global scales to serve as a check list when establishing contingency arrangements and to distribute them to other members before the next meeting of CGMS.**

J. SENIOR OFFICIALS MEETING

The CGMS XX Senior Officials (Heads of Delegations) meeting convened at 15h45 on 22 April 1993. Dr Xu Jianmin (PRC) was elected Chairman.

J.1 Approval on Draft Final Report

The plenary session with all present Senior Officials reviewed the draft Final Report of the meeting. Noting a few modifications and corrections and the draft list of Actions, the Senior Officials approved the report. The Secretariat agreed to include all the amendments into a revised draft which would be distributed to CGMS Members for final comment prior to publication.

J.2 Reports from the Working Groups

The reports of Working Group I - Telecommunications and Working Group II - Satellite Products were presented by Mr L Heacock (USA) and Dr D Hinsman (WMO) respectively. The report of Working Group III - Global Contingency Planning was presented by Mr J Morgan (EUMETSAT).

The Senior Officials took note of the reports and the Chairman thanked participants for their active and fruitful discussions. Many important actions had been generated during the sessions and the new CGMS Working Group III had taken very important steps towards establishing global contingency plans. He added that the continuation of all three Working Groups was assured and their recommendations would be long valued by CGMS.

J.3 Nomination of CGMS Representatives at WMO and Other Meetings

The Senior Officials proposed that Mr L Heacock (USA) will represent CGMS at the next meeting of the ITWG, and Mr J Morgan and Mr J Lafeuille (EUMETSAT) would represent CGMS at the WMO EC in June 1993. Mr R Wolf (EUMETSAT) will represent CGMS interests with the SFCG. Dr D Hinsman (WMO) announced that the next meeting of WMO´s CBS Working Group on Satellites would take place in the Spring of 1994.

J.4 Any Other Business.

Mr Heacock (USA) on behalf of all CGMS participants, recalled that this meeting would be the last attended by Mr Brian Mason (ESA) as he would be leaving ESA at the end of 1993. He thanked Brian for his many years of patient, constructive and helpful service to CGMS and its missions. Brian's warmth and congeniality had always been welcomed and would be greatly missed by all of his colleagues.

In response, Mr Mason thanked CGMS for their kind words, adding that he had always enjoyed working with such an international distinguished group of experts, the constructive debates on so many subjects of great technical importance and was pleased to have been able to contribute towards a successful cooperation between so many satellite operators. He wished the participants and CGMS every success in the future.

J.5 Date and Place of next Meeting

CGMS was pleased to accept an offer by the USA, to host CGMS XXII, in Anapolis, near Washington DC, in the Spring of 1994.

An offer to host CGMS XXIII in EUMETSAT, in the first half of 1995, was noted and provisionally accepted by the meeting .

K. SUMMARY LIST OF ACTIONS FROM CGMS XXI

ACTION 21.01 **USA to provide NOAA image calibration data to P.R.C. and other interested members of CGMS.**

ACTION 21.02 **ESA to provide P.R.C. with details of anomalies affecting Meteosat Satellites and means used to cope with them.**

ACTION 21.03 **USA to provide EUMETSAT with details of the GOES-6 GVAR dissemination schedules.**

ACTION 21.04 **WMO to further define its contingency requirements as regards satellite services.**

ACTION 21.05 **CGMS Members to consider mechanisms to provide coverage over the Indian Ocean before CGMS XXII.**

ACTION 21.06 **WMO notify the Government of India and the Russian Federation about the impact of the lack of coverage over the Indian Ocean.**

ACTION 21.07 **CGMS satellite operators to review the WMO Satellite Data Requirements as to their achievability within currently planned systems, accuracy and mission schedules and within which anticipated time frame Members could wholly or partially satisfy the requirements. The results of this review should be received at the CGMS Secretariat by July, 1993.**

ACTION 21.08 **WMO to further refine the Satellite Data Requirements based on inputs from CGMS satellite operators.**

ACTION 21.09 **WMO to develop detailed satellite service requirements based on experiences learned during the OWSE-Africa Phases I and II.**

ACTION 21.10 WMO to finalize its proposal for a Training strategy involving sponsorship of specialised RMTC by satellite operators, and to identify corresponding needs before CGMS XXII.

ACTION 21.11 Satellite operators to comment on content and format of the present draft report on satellite ground receiving stations and make recommendations to WMO for future issues of the report by 30 September 1993.

ACTION 21.12 All CGMS members to check the consolidated IDCS allocations list and report any discrepancies to the Secretariat by 31st May 1993.

ACTION 21.13 USA to report the results of a study to sub-divide the IDCS Channel frequency range at CGMS XXII.

ACTION 21.14 WMO to notify OCAP about any relevant modification of its Terms of Reference resulting upon its agreed reporting channel to CGMS via WMO.

ACTION 21.15 USA to provide CGMS Secretariat with details of GVAR test plans together with the latest version of the GVAR simulator software.

ACTION 21.16 CGMS Members to confirm their agreement to the LRIT-Format by July 1993.

ACTION 21.17 All CGMS Members are requested to indicate planned introduction dates of LRIT

ACTION 21.18 NOAA to provide CGMS members with a draft global LRPT specification within the next 6 months.

ACTION 21.19 USA to make further assessment of the impact of using an LRPT omnidirectional antenna, and report the results to CGMS Members

ACTION 21.20 EUMETSAT to inform NOAA and WMO about costs and any other related issues involved with the setting up of a CGMS directory of meteorological satellite applications.

ACTION 21.21 CGMS Members to study the possible interference of the FY-2 S-Fax downlink with that of the NOAA HRPT, and report the results of these studies to the CGMS Secretariat by 1 August 1993.

ACTION 21.22 PRC to reallocate IDCP time slots on a 1.5 minute basis.

ACTION 21.23 The WMO to provisionally agree to the reallocation to the PRC of its 1110 IDCS prefix, and to confirm its decision to the CGMS Secretariat and PRC by 1 August 1993.

ACTION 21.24 CGMS Members to consider the possible technical measures for the reorganization of the IDCS to include the PRC and any other changes necessary to meet currently foreseen uses of the IDCS.

ACTION 21.25	**EUMETSAT and USA to provide PRC with technical information on calibration methods/procedures.**
ACTION 21.26	**WMO(CBS) to confirm its request to CGMS members that they examine the feasibility of extending satellite based volcano ash monitoring and warning services to all parts of the globe.**
ACTION 21.27	**CGMS Members to consider CEOS and CCSDS data formats and the CEOS catalogue system as a candidate for future archive and retrieval systems and report their findings to CGMS XXII.**
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ANNEXES TO THE FINAL REPORT OF CGMS XX

LIST OF ABBREVIATIONS AND ACRONYMS

ACARS	Automated Communications Addressing and Reporting System
ACC	ASAP Coordinating Committee
ADC	Atlantic Data Coverage
AMDAR	Aircraft Meteorological Data Relay
AMS	American Meteorological Society
AMSU	Advanced Microwave Sounding Unit
APT	Automatic Picture Transmission
ARGOS	Data Collection and Location System
ASAP	Automated Shipboard Aerological Programme
ASCII	American Standard Code for Information Interchange
ASDAR	Aircraft to Satellite Data Relay
ATOVS	Advanced TOVS
AVHRR	Advanced Very High Resolution Radiometer
BBC	Black Body Calibration (METEOSAT)
BUFR	Binary Universal Form for data Representation
CBS	Commission for Basic Systems
CCIR	Consultative Committee on International Radio
CCSDS	Consultative Committee on Space Data Systems
CD	Compact Disk
CEOS	Committee on Earth Observations Satellites
CEPT	Conference European des Postes et Telecommunications
CGMS	Coordination of Group for Meteorological Satellites
CHRPT	Chinese HRPT (FY-1C and D)
CIS	Commonwealth of Independent States
CIIS	Common Instrument Interface Studies
CLS	Collecte Localisation Satellites (Toulouse)
CMS	Centre de Meteorologie Spatiale (Lannion)
CMV	Cloud Motion Vector
CMW	Cloud Motion Wind
COSPAR	Committee on Space Research
DAPS	DCS Automated Processing System (USA)
DCP	Data Collection Platform
DCS	Data Collection System
DIF	Directory Interchange Format
DOMSAT	Domestic telecommunications relay Satellite (USA)
DPT	Delayed Picture Transmission
DRS	DCP Retransmission System (Meteosat)
DRT	Data Relay Transponder (INSAT)
DSB	Direct Soundings Broadcast
DUS	Data Utilisation Station (USA) (Japan)
DWS	Disaster Warning System (India)

EBB	Electronic Bulletin Board
EC	Executive Council (WMO)
ECMWF	European Centre for Medium range Weather forecasts
ENVISAT	ESA proposed future polar satellite for environment monitoring
EO	Earth Observation
EOS	Earth Observation System
EPS	EUMETSAT Polar System
ERBE	Earth Radiation Budget Experiment
ESA	European Space Agency
ESJWG	Earth Sciences Joint Working Group
ESOC	European Space Operations Centre (ESA)
EUMETSAT	European Meteorological Satellite Organisation
EVIRI	Enhanced VIS and IR imager (MSG)
FAA	Federal Aviation Authority (USA)
FAO	Food and Agriculture Organisation (UN)
FAX	Facsimile
FXTS	Facsimile Transmission System (USA)
FY-1	Polar Orbiting Meteorological Satellite (PRC)
FY-2	Future Geostationary Meteorological Satellite (PRC)
GCOS	Global Climate Observing System
GIMTACS	GOES I-M Telemetry and Command System
GMR	GOES-Meteosat Relay
GMS	Geostationary Meteorological Satellite (Japan)
GOES	Geostationary Operational Environmental Satellite (USA)
GOMS	Geostationary Operational Meteorological Satellite (CIS)
GOS	Global Observing System
GSLMP	Global Sea Level Monitoring Programme
GPCP	Global Precipitation Climatology Project
GTS	Global Telecommunications System
GVAR	GOES Variable (data format) (USA)
HR	High Resolution
HRPT	High Resolution Picture Transmission
HIRS	High Resolution Infra-red Sounder
HSRS	High Spectral Resolution Sounder (MSG)
ICWG	International Coordination Working Group (EO)
IDCP	International DCP
IDCS	International Data Collection System
IDN	International Directory Network (CEOS)
IFRB	International Frequency Registration Board
INSAT	Indian geostationary satellite
IPOMS	International Polar Orbiting Meteorological Satellite Group
IR	Infrared
IRTS	Infrared Temperature Sounder (EPS)
ISCCP	International Satellite Cloud Climatology project
ISY	International Space Year

ITT	Invitation to Tender
ITU	International Telecommunications Union
ITWG	International TOVS Working Group
JMA	Japanese Meteorological Agency
LR	Low Resolution
LRIT	Low Rate Information Transmission
LRPT	Low Rate Picture Transmission
LST	Local Solar Time
MCP	Meteorological Communications Package
MDD	Meteorological Data Distribution (Meteosat)
MDUS	Medium-scale Data Utilization Station (for GMS S-VISSR)
METOP	Future European meteorological polar orbiting satellite
METEOR	Polar orbiting meteorological satellite (CIS)
METEOSAT	Geostationary meteorological satellite (EUMETSAT)
MHS	Microwave Humidity Sounder (EPS)
MIEC	Meteorological Information Extraction Centre (ESOC)
MOCC	Meteosat Operational Control Centre (ESOC)
MOP	Meteosat Operational Programme
MPEF	Meteorological Product Extraction Facility (EUMETSAT)
MSC	Meteorological Satellite Centre (Japan)
MSG	Meteosat Second Generation
MSU	Microwave Sounding Unit
MTP	METEOSAT Transition Programme
MTS	Microwave Temperature Sounder (EPS)
MVIS	Multi-channel VIS and IR Radiometer (FY-1C and D of PRC)
NASA	National Aeronautics and Space Agency
NASDA	Japanese National Space Agency
NEDT	Noise Equivalent Delta Temperature
NESDIS	National Environmental Satellite Data and Information Service
NGDC	National Geophysical Data Centre (USA)
NMC	National Meteorological Centre
NOAA	National Oceanographic and Atmospheric Administration
NOS	National Ocean Service (USA)
NTIA	National Telecommunications and Information Agency (USA)
NWP	Numerical Weather Prediction
NWS	National weather service (USA)
OCAP	Operational Consortium of ASDAR Participants
OWSE-AF	Operational WWW Systems Evaluation for Africa
PC	Personal Computer
POEM	Polar Orbiting Earth observation Mission (ESA)
POES	Polar orbiting Operational Environmental Satellite (USA)
PRC	Peoples Republic of China
PTT	Post Telegraph and Telecommunications authority

RDCP	Regional DCP (Japan)
RMS	Root Mean Square
RMTC	Regional Meteorological Training Centre (WMO)
RSMC	Regional Specialised Meteorological Centre
S&R	Search and Rescue mission
SAM	Satellite Anomaly Manager
SAFISY	Space Agency Forum on the ISY
SARSAT	Search And Rescue, Satellite supported facility
SATOB	WMO code for Satellite Observation
SBUV	Solar Backscattered Ultra-Violet (ozone)
SEAS	Shipboard Environmental (data) Acquisition System
SEM	Space Environment Monitor
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager
S-FAX	S-band facsimile broadcast of FY-2 (PRC)
SFCG	Space Frequency Coordination Group
SMA	State Meteorological Administration (PRC)
SSP	Sub Satellite Point
SST	Sea Surface Temperature
SSU	Stratospheric Sounding Unit
S-VISSR	Stretched VISSR
TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Sounder
UHF	Ultra High Frequency
UK	United Kingdom
UN	United Nations
USA	United States of America
UTC	Universal Time Coordinated
VAS	VISSR Atmospheric Sounder
VHF	Very High Frequency
VIRSR	Visible and Infra-Red Scanning Radiometer (EPS)
VIS	Visible channel
VISSR	Visible and Infra-red Spin Scan Radiometer
VLSI	Very Large Scale Integrated circuit
WARC	World Administrative Radio Conference
WCRP	World Climate Research Programme
WEFAX	Weather facsimile
WG	Working Group
WMO	World Meteorological Organization
WP	Working Paper
WV	Water Vapour
WWW	World Weather Watch
X-ADC	Extended Atlantic Data Coverage

DRAFT AGENDA FOR CGMS XXI, BEIJING, PRC, 19-24 APRIL 1993

A. PRELIMINARIES

A.1 Introduction
A.2 Election of Chairman
A.3 Arrangements for the Drafting Committee
A.4 Adoption of Agenda and Work plan of W/G Sessions
A.5 Review of Action Items from Previous CGMS Meetings

B. REPORT ON THE STATUS OF CURRENT SATELLITE SYSTEMS

B.1 Polar Orbiting Meteorological Satellite Systems
B.2 Geostationary Meteorological Satellite Systems

C. REPORT ON FUTURE SATELLITE SYSTEMS

C.1 Future Polar Orbiting Meteorological Satellite Systems
C.2 Future Geostationary Meteorological Satellite Systems

D. OPERATIONAL CONTINUITY AND RELIABILITY

D.1 Woods Hole Meeting - Secretariat Report
D.2 Inter-regional planning
D.3 Global planning, including orbital positions

E. METEOROLOGICAL SATELLITES AS PART OF WMO PROGRAMS

E.1 World Weather Watch
E.2 Other Programs

F. COORDINATION OF INTERNATIONAL DATA COLLECTION & DISTRIBUTION

F.1 Status and Problems of IDCS
F.2 Ships, including ASAP
F.3 ASDAR
F.4 Dissemination of DCP messages (GTS or other means)

G. COORDINATION OF DATA DISSEMINATION

G.1 Dissemination via Satellite

G.2 Dissemination via GTS or other means

H. OTHER ITEMS OF MORE GENERAL INTEREST

H.1 Report on International Space Year Activities
H.2 Special Applications of Meteorological Satellite Data in the Fields of Earth Environment Monitoring
H.3 Search and Rescue (S&R)

H.4 Anomalies from Solar and Other Events
H.5 Other items of interest

J. SENIOR OFFICIALS MEETING

J.1 Approval of Draft Final Report
J.2 Reports from the Working Groups
J.3 Nomination of CGMS Representatives at WMO and other meetings
J.4 Any Other Business
J.5 Date and Place of Next Meetings

K. SUMMARY LIST OF ACTIONS FROM CGMS XXI

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I/1 Coordination of Frequency Allocations
I/2 Results of SFCG - Secretariat Report
I/3 Electronic Bulletin Boards (EBB)
I/4 Preparation of WG Report

WORKING GROUP II - SATELLITE PRODUCTS

II/1 Coordination of satellite instrument performance
II/2 Satellite Data Calibration
II/3 Meteorological & Other Parameter Extraction
II/4 New Products & Their Use in Numerical Weather Prediction
II/5 Coordination of Code forms for satellite Data
II/6 Coordination of Data Formats for the Archive and Retrieval of Satellite Data
II/7 Preparation of WG Report

WORKING GROUP III - GLOBAL CONTINGENCY PLANNING

III/1 Draft Terms of Reference
III/2 Review of Actions from the Woods Hole Meeting
III/3 Bent Pipe Operations with GMS, GOES or Meteosat
III/4 Conclusions and Recommendations of the Woods Hole Meeting
III/5 Preparation of WG Report

WORKING PAPERS SUBMITTED TO CGMS XXI

(Summary titles - agenda item in brackets)

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ESA-WP- 1	METEOSAT spacecraft anomalies (B.2)
ESA-WP- 2	The implementation of the X-ADC system (B.2)
ESA-WP- 3	Transputer augmented workstation for fast Meteosat image processing and product extraction (II.1)
ESA-WP- 4	Impact of the Pinatubo eruption on Meteosat images (II.3)
ESA-WP- 5	The radiometric calibration of Meteosat-3 (II.2)
ESA-WP- 6	Operational cloud motion winds from Meteosat IR images (II.3)
ESA-WP- 7	Cloud motion wind processing (WV and VIS) at ESOC (II.3)
ESA-WP- 8	Neural networks for cloud recognition and classification (II.3)
ESA-WP- 9	Radiation budget parameters from Meteosat (II.3)
ESA-WP-10	The SATOB code for satellite winds (II.5)
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EUMETSAT

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EUM-WP- 2	Status of the Meteosat Operational Programme (B.2)
EUM-WP- 3	Status of the EUMETSAT Polar System (C.1)
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EUM-WP- 5	Status of Meteosat Second Generation Programme (C.2)

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EUM-WP- 6	Update on Atlantic Data Coverage (X-ADC), (D.2)
EUM-WP- 7	Report of 2nd Meeting on Global Contingency Planning, (D.3)
EUM-WP- 8	Status and problems of the IDCS (F.1)
EUM-WP- 9	Data Collection System Users Conference (F.1)
EUM-WP-10	Status of Meteosat HR and WEFAX Disseminations (G.1.1/2)
EUM-WP-11	Definition of a Low Rate Image Transmission Format (G.1.3)
EUM-WP-12	Status of the METEOSAT MDD mission (G.1.4)
EUM-WP-13	Report of the 12th Meeting of SFCG (I/2)
EUM-WP-14	Verification of Cloud Motion winds (II/2)
EUM-WP-15	Coordination of data from Polar Satellites (G.1.3 & II.5)
EUM-WP-16	Meteosat Scientific Users Meeting (II/3)
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EUM-WP-19	Review of ISY (Europe) 1992 (H.1)
EUM-WP-20	Announcement of the 2nd International Wind Workshop (II/3)
EUM-WP-21	Potential Reallocation of MSS Frequency Bands (I/1)
EUM-WP-22	Report & Recommendations from the ITWG (II/3)
EUM-WP-23	EUMETSAT activities for ATOVS processing (II.3)
EUM-WP-24	6th AVHRR Data Users Conference (II.3)
EUM-WP-25	Geo Sats Data Archiving & Retrieval Centres - an approach to common data formats, access and Distribution (II.6)

JAPAN

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JAPAN-WP- 2	Status of GMS-4 (B.2)
JAPAN-WP- 3	Report on status of satellite systems - GMS (B.2)
JAPAN-WP- 4	GMS-5 and beyond (C.2)
JAPAN-WP- 5	Temporary and interim DCP data collection via GMS-4 in the western Pacific (D.2)
JAPAN-WP- 6	Support to WCRP (E.2)
JAPAN-WP- 7	Status and problems of IDCS (F.1)
JAPAN-WP- 8	Interference monitoring of IDCS channels (F.1)
JAPAN-WP- 9	Status of ship IDCPs including ASAP (F.2)
JAPAN-WP-10	Status of the ASDAR (F.3)
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JAPAN-WP-12	Stretched VISSR of GMS-5 (G.1)
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USA-WP- 2	Status of Geostationary Operational Environmental Satellites (GOES) (B.2)
USA-WP- 3	NOAA Polar Orbiting Meteorological Satellite System (C.1)
USA-WP- 4	The GOES I-M Satellite Program (C.2)
USA-WP- 5	Regional Contingency Arrangements (D.2)
USA-WP- 6	Status and Problems of IDCS (F.1)
USA-WP- 7	Interference Checks on IDCS Channels (F.1)
USA-WP- 8	Ships including ASAP (F.2)
USA-WP- 9	ASDAR Update (F.3)
USA-WP-10	Dissemination of DCP Messages (GTS or other means) (F.4)
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USA-WP-15	NOAA Satellite Active Archive (G.1.4)
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USA-WP-20	System Data on COSPAS-SARSAT (H.3)
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USA-WP-22	Solar activity update (H.4)
USA-WP-23	Geostorms (H.4)
USA-WP-24	Impact of the 1992 world radio administrative conference on meteorological satellite frequencies (I/1)
USA-WP-25	Preparations for in-orbit calibration of the infrared Channels of the GOES-I imager and sounder (II/2)
USA-WP-26	AVHRR Pathfinder Calibration Activity (II/2)
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USA-WP-30	Recent developments related to observations of radiation and clouds from operational satellite measurements (II/3)
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WMO

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WMO-WP- 6	Recent WMO decisions of importance to CGMS (E.1)
WMO-WP- 7	WMO contingency planning requirements (D.3)
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WMO-WP-14	Draft final report of the WMO EC Panel of Experts on Satellites (II/3)
WMO-WP-15	Draft Status Report of Satellite Ground Receiving Equipment in WMO Regions (E.1)
WMO-WP-16	Draft Project Plan for Low Cost, Low Resolution Satellite Data Receivers (E.1)

CGMS-XXI ESA WP-06
Prepared by ESA
Agenda Item: WGII

Operational Cloud Motion Winds from Meteosat Infrared Images

During the last year there have been no significant changes to the manner in which infrared images are processed for the extraction of cloud motion winds. Members of the CGMS will find attached a draft copy of a paper documenting the algorithm changes and improvements which have been made to the operational cloud motion wind processing from 1987 onwards. The paper has been accepted for a future issue of the Journal of Applied Meteorology.

ANNEX IV

Operational Cloud Motion Winds from METEOSAT Infrared Images

JOHANNES SCHMETZ, KENNETH HOLMLUND

European Space Agency (ESA), European Space Operations Centre (ESOC),
Robert Bosch-Str. 5, D-6100 Darmstadt, FR Germany

JOEL HOFFMAN

METEO France, ENM, 42 av. G. Coriolis, F-31057 Toulouse, France

BERNARD STRAUSS

European Centre for Medium-Range Weather Forecasts, Shinfield Park,
Reading, Berks. RG2 9AX, United Kingdom

BRIAN MASON, VOLKER GAERTNER, ARNO KOCH, and LEO VAN DE BERG

European Space Agency (ESA), European Space Operations Centre (ESOC),
Robert Bosch-Str. 5, D-6100 Darmstadt, FR Germany

NOVEMBER 1992 (REVISED)

Accepted for the Journal of Applied Meteorology

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Abstract

The displacements of clouds in successive satellite images reflects the atmospheric circulation at various scales. The main application of the satellite derived cloud motion vectors, is their use as winds in the data analysis for numerical weather prediction. In particular at low latitudes they constitute an indispensible data source for numerical weather prediction.

This paper describes the operational method of deriving cloud motion winds (CMW) from the IR images (infrared: 10.5 - 12.5 μm) of the European geostationary METEOSAT satellites. The method is automatic, that is, the cloud tracking uses cross-correlation and the height assignment is based on satellite observed brightness temperature and a forecast temperature profile. Semi-transparent clouds undergo a height correction based on radiative forward calculations and simultaneous radiance observations in both the IR and WV (water vapor $5.7 - 7.1 \mu m$) channel. CMWs are subject to various quality checks that include manual quality control as the last step. Typically about 3000 wind vectors are produced per day over four production cycles.

This paper documents algorithm changes and improvements to the operational CMWs that have been made over the last five years. The improvements are shown by long-term comparisons with both collocated radiosondes and the first guess of the forecast model of the European Centre for Medium Range Weather Forecast (ECMWF). In particular the height assignment of a wind vector and radiance filtering techniques preceding the cloud tracking have ameliorated the errors in METEOSAT winds. The slow speed bias of high level CMWs ($<$ 400 hPa) in comparison to radiosonde winds has been reduced from about 4 m/s to 1.3 m/s for a mean wind speed of 24 m/s. Correspondingly the RMS vector error of METEOSAT high level CMWs decreased from about 7.8 m/s to about 5 m/s. Medium and low level CMWs were also significantly improved.

1. Introduction

Global observations of atmospheric wind fields are potentially the most important data in the analysis for numerical weather prediction (NWP) (e.g. Baker, 1991; Kalnay et al., 1985). Direct wind observations are indispensible at low latitudes where winds cannot be inferred from the mass field. Wind observations from satellites also constitute the sole source of wind data over wide regions of the Southern hemisphere.

The global network of geostationary satellites provides the basis for the derivation of cloud motion winds (CMW) from successive and carefully aligned satellite images. The operational derivation of CMWs from satellite images started in the second half of the seventies (for a review see Smith, 1985). Initial impact studies of this new data source on weather forecasts revealed a positive impact (Kallberg et al., 1982; Pailleux, 1987).

The last decade has seen a substantial progress in data assimilation and numerical weather prediction, whereas development work on CMWs was idle for the first half of that decade. Logically the sequel studies on the impact of CMWs on the forecast quality have been less convincing (Kelly and Pailleux, 1989). The lack of improvements to the operationally produced CMWs led to a situation where the use of CMWs for NWP became more restrictive. However, the impact always remained positive at low latitudes and in the Southern Hemisphere, while adverse effects on the forecast were occasionally observed in the Northern Hemisphere. The primary criticism of CMWs arose from the underestimation of wind speed especially in and near jet streams. It is encouraging that more recent impact studies at the European Centre for Medium-Range Weather Forecasts (ECMWF) (Thoss ,1992) with the upgraded CMWs and with an improved quality control also indicate a positive impact in the Northern Hemisphere extra-tropics.

To date CMWs are the only satellite-based direct wind retrievals in operational use for numerical weather prediction, although they will be complemented soon by surface wind estimates from passive and active microwave instruments aboard polar orbiting satellites. It is important to realize that CMWs are not a direct measurement of the wind field and, therefore, may possess properties that compromise their use as single level observations of the wind field. Firstly, clouds are are not always passive tracers. Secondly, the location of cloud occurrence may be in areas that are not representative for the wind field. Cloud motion may also represent a layer-mean flow rather than a wind vector at a specific level. In spite of those reservations, it has to be accepted for the foreseeable future, that CMWs will be used as a single level vector in NWP. Consequently improvements should principally enhance the usefulness of CMWs as single level wind data.

Recently operational data centres other than ESOC have commenced similar efforts to improve the quality of CMWs. Merrill et al. (1991) demonstrated upgrades to the CMWs from the U.S. GOES. Hayden (1992) reports on new ways to improve the quality control of GOES winds with an automatic editing that is based on an objective analysis method (Hayden and Purser, 1988). Improved altitude assignment has considerably improved the winds from the Japanese Himawari satellite (Uchida, 1992). Noteworthy is also the potential of cloud motion winds for climatological studies (e.g. Gruber et al., 1971; Cadet and Desbois, 1980; Desbois et al., 1984).

This paper provides a description of the operational method for extracting CMWs from METEOSAT images at the European Space Operations Centre (ESOC). The method is fully automatic except for a manual quality check as a last step before dissemination. There are no plans to extend the manual interaction by meteorologists at any level of the processing. Therefore it is beyond the scope of this paper to discuss the advantages of manual tracking, although it is realized that this can improve the product (e.g. Shenk, 1991; Fujita, 1992). The paper is structured as follows: Section 2 describes the present system that evolved over a period of about 5 years of continuous research and lead to the situation that METEOSAT CMWs are widely accepted as a valuable data source for NWP (Radford, 1989; Eriksson, 1990; Thoss, 1992). Section 3 is a short account of CMW comparisons with radiosondes for the purpose of quality monitoring. In section 4 the improvements to the present CMW algorithm are discussed chronologically and quantified by comparison with collocated radiosonde winds. Section 5 discusses and concludes the paper. Four important technical aspects of the CMW algorithm, namely the multispectral image analysis, the image filtering, the cloud tracking and the height correction of semi-transparent clouds, are described in the Appendices.

2. Cloud motion winds from METEOSAT images

The geostationary METEOSAT satellites observe the Earth with an imaging radiometer in three channels: in the solar spectrum (VIS) between 0.4 and 1.1 μm , in the infrared window region (IR) between 10.5 and 12.5 μm, and in the water vapour (WV) absorption band between 5.7 and 7.1 μm . Images are taken at half hourly intervals and the spatial sampling at the subsatellite point corresponds to 2.5 km x 2.5 km for the VIS, and 5 km x 5 km in the IR and WV channels. The operational derivation of CMWs uses IR images for the cloud tracking; the WV channel is used in a bi-spectral algorithm for the height attribution of wind vectors from semi-transparent clouds.

CMWs are derived four times per day from a triplet of successive IR images. Table 1 provides the nominal schedule of images used for cloud tracking. During the process of CMW derivation forecast data from ECMWF on temperature, humidity and wind fields are used as ancillary data for the purpose of radiative forward calculations, guiding of the cloud tracking and quality control. The validity of the forecasts ranges from 12 h for the 2300 UT wind run to 30 h for the 1700 UT wind run. The use of a 30h forecast is especially in tropical regions not always useful, however no alternative exists due to operational data link constraints. While the use of a first guess (6h forecast) would be an improvement, it appears even more sensible to turn away from the use of forecast fields at least in tropical regions.

The processing is confined to the 55 ° arc around the sub-satellite point, since image distortion becomes too large toward the horizon. Basically the generation of a CMW from a sequence of registered satellite images requires two steps: in our algorithm a pressure altitude is first assigned to a cloud tracer, then a displacement vector is computed that estimates the wind speed.

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Figure 1 shows an example of the CMW product as obtained with one production run for 26 January 1992 at 1100 UT. A total of 698 CMWs was disseminated consisting of 306 high, 146 medium and 246 low level winds. All three wind levels are plotted in one figure to exemplify the total yield. Figure 2 is the corresponding IR image used as the central image and helps to associate the wind field with an altitude level.

The specific example in Figure 1 shows that over the marine stratocumulus regions the low level flow is clearly depicted. High wind speed areas at high altitudes, such as over the North and South Atlantic and the sub-tropical jet over the Sahara stand out as vectors with an increased number of barbs.

In what follows we detail the individual steps of the present algorithm for deriving CMWs from METEOSAT IR images.

a. Tracer selection and image filtering

The first step in the processing is a multispectral image analysis (Tomassini, 1981), that extracts the dominating scenes in an image segment corresponding to an area of 32x 32 IR pixels or about 160 km x 160 km at the sub-satellite point. The scenes can be sea, various types of land, and clouds at different altitudes. For the CMW algorithm no more than 4 scenes per target area or segment and only one surface scene are allowed, otherwise the number is reduced by merging scenes in close proximity. A brief description of the multispectral histogram analysis for the extraction of clusters is provided in Appendix A.

Typically about 1900 - 2300 out of about 3500 possible segments per image are found with cloud tracers and only those segments are considered for the automatic cloud tracking.

The mean scene properties $\overline{C}$ of a target area are used in the image filtering that precedes the cloud tracking. The purpose of the image filtering is to enhance the highest cloud layer, that usually is the easiest to track since it is not partially obscured.

The image filtering (Hoffman, 1990) employs the spatial coherence technique (Coakley and Bretherton ,1982). The mathematical details of this radiance slicing or filtering are described in Appendix B.

An example of the image filtering for a segment area containing sea, medium level and high level clouds is shown in Figure 3. Figure 3a shows the original IR image with the target area indicated by a frame. The chosen example presents a rather complex segment area as substantiated by the IR histogram in Figure 3b, where no pronounced peak is discernable. Figure 3c provides the spatial coherence plot where the local standard deviations of 3x3 pixels are plotted versus the local mean. The feet of the arches are apriori known as the mean scene radiances $\bar{C}$ from the multispectral image analysis (Appendix A). The upper cloud layer in any target area is the tracer of interest. The objective of the radiance filtering is to enhance the upper level cloud such that relevant information in the contaminated pixels is also kept. Since the form of the arches can be parameterized, as described in Appendix B, it is possible to apply the concept of the spatial coherence analysis, that is, each pixel can be assigned to either an uncontaminated or a certain contaminated scene. This way of segregating an image enables discrimination of fully covered and partially covered high level cloud pixels, the latter of which still carry useful information on the upper cloud layer. The result of this image filtering is shown in Figure 3d, and clearly the upper level cloud is enhanced. The filtered image is then used for the tracking.

At the stage of the image filtering a rejection of tracers may take place for two reasons:

i) a tracer is rejected if there is the maximum of four scenes in a target area and each scene comprises more than 150 pixels.

ii) a tracer is rejected, if the two highest clouds both undergo an altitude correction (see Appendix C) and, as a result, the cloud with the warmer brightness temperature is assigned to a higher altitude.

Typically about 6 - 8 % of the medium or high level clouds are rejected due to either reason (see Table 2).

b. Height assignment

The height assignment of opaque clouds is based on the IR cloud brightness temperature. ECMWF forecast temperature profiles are used as ancillary data. The pressure level of a CMW is determined as the level where the brightness temperature fits the forecast temperature; that is, a vector is assigned to the cloud top altitude. Although this procedure generally yields satisfactory results, it can be improved as it is known that, for instance, low level cumulus clouds rather travel with the wind speed at cloud base. Hasler et al. (1979) found from aircraft measurements that the vector difference between cloud motion and the cloud-base wind ranged from 0.9 - 1.7 m/s for cumuli-form clouds in the trade and subtropical regions.

The effects of atmospheric absorption above the cloud top on the IR brightness temperature are neglected. The absorption in the IR window region is primarily due to the water vapor continuum and is most pronounced in moist tropical atmospheres. Radiative transfer calculations (Schmetz, 1986) show that the deficit in brightness temperature for nadir viewing does not exceed about 2 K for a cloud with tops at 2 km embedded in a tropical atmosphere and the effect decreases rapidly with increasing cloud top.

Large errors in the height assignment occur for semi-transparent or sub-pixel clouds, since the satellite observed IR radiance contains contributions from below the cloud; a CMW then would be assigned to too low a level. Corrections for the semi-transparency are possible with multichannel observations. Smith and Platt (1979) developed a radiance ratioing method (also referred to as 'CO_2 slicing') that has been successfully applied to the height attribution of CMWs from the U.S. GOES satellite (Menzel et al., 1983; Merrill et al., 1991). Further applications have been presented by Smith and Frey (1990) and Liou et al. (1990).

With METEOSAT imagery it is possible to use a conceptually similar technique based on simultaneous IR and WV images (Cayla and Tomassini, 1978; Szejwach, 1982; Pollinger and Wendling, 1984; Bowen and Saunders, 1984). The method operationally in use for the height attribution of METEOSAT wind vectors is referred to as 'semi-transparency correction' and it is detailed in Appendix C. It should be noted that the so-called semi-transparency correction is conceptually correct only for sub-pixel opaque clouds but not for a horizontally extended clouds with varying optical depth, as it is explained in the Appendix C (Figure C2).

Principally the operational method for the height assignment of semi-transparent clouds requires a clear sky and a cloudy sky radiance pair in both the IR and WV channel. In addition the relationship between the IR and WV radiances for opaque clouds at different levels in a given atmosphere is computed with radiative forward calculations using the ECMWF temperature and humidity forecast. The radiation model calculations are conducted in real time for both the IR and WV channel (Schmetz, 1986; Schmetz and Turpeinen, 1988) and provide the theoretical relationship between the satellite observed radiances in both channels for opaque clouds at different levels.

The combined use of radiance calculations and satellite observations necessitates an accurate calibration for linking the observed radiances (in counts) and calculated radiances. Thus the height attribution of semi-transparent clouds crucially depends on calibration, as exemplified by a related improvement discussed in section 4.

c. Cloud tracking

The automatic cloud tracking employs cross-correlation and three successive IR images are used to determine a displacement vector. A segment of 32x32 IR pixels of an image at the time h forms the target area that is correlated at times $h + 30$ min and $h - 30$ min with areas equivalent to the size of a segment. The search area consists of 3x3 segments which yields 65x65 possible displacements to be correlated. For the different positions n, m of the target window within the search area, the standard pattern correlation coefficient (PCC) is calculated as described in Appendix D. In order to save computer run-time the search starts at the cloud displacement suggested by a wind forecast, yet the pattern correlation extends over a region large enough so that the dependence on the forecast is minimized.

Due to the limited search it is possible that a pattern matching is obtained on the boundary of the correlation surface. The correponding failure rate for pattern matching is between 5% for low level cloud tracers and some 10% for high level (referred to as bad peaks in Table 2).

The use of three successive images enables a symmetry check of the two corresponding vectors for quality control, where the two vectors have to agree within certain limits with respect to speed and direction (Schmetz and Nuret, 1987). Typically about 10 % of the low-level and 20 % of the high-level vector pairs fail to pass the symmetry check (c.f. Table 2). CMWs slower than 5 m/s are suppressed, which effectively eliminates directionally inconsistent wind fields due to the image registration error that amounts to about 1.5 - 2 m/s. About 4 % (high-level) to 21 % (medium-level) of the vectors fall in this class. The final displacement velocity is computed as the mean norm of the vector pair and the direction is computed from the vector sum.

The CMWs are produced four times per day and the range of the forecast used for deriving the wind varies between 12 hours and 30 hours (see Table 1). It is noted that the use of forecasts for periods beyond 6 hours is less than optimal, especially in the tropical region.

d. Quality control

There is still a considerable number of poor cloud motion winds produced by the automatic scheme. Most often errors can be traced to difficulties in allocating the appropriate altitude to a tracer. Furthermore, clouds may be correctly tracked and assigned to the right altitude but their motion is not representative of the air flow at the assigned altitude. An example for the latter are stationary wave clouds. Obviously such situations are not captured by the symmetry check. Therefore an extended quality control is required that goes beyond the symmetry check of the two corresponding displacements vectors.

At present the extended quality control is done in two steps. Firstly, the cloud motion winds are subject to an automatic quality control and secondly, CMWs are manually checked by an experienced meteorologist. The automatic quality control consists of a rough check against the ECMWF forecast winds. CMWs are assigned a 'poor quality flag' when the norm of the vector difference between CMW and forecast wind exceeds 55% of the norm of the forecast vector. In order to limit the rejections at low forecast wind speeds, CMWs are not flagged when the speed difference between forecast and vector difference is less than 5 m/s.

The final step before dissemination is a manual quality control where CMWs are displayed and scrutinized by an experienced meteorologist. The meteorologist has the possibility to delete any CMW and to reinstate CMWs previously flagged by the automatic quality control. It turns out that, in particular in the tropical regions, reinstatement of CMWs frequently occurs due to incorrect forecast fields. This suggests that in future developments one should only use short-term forecasts (up to 12 h at maximum) in tropical regions or discount the forecasts.

Table 2 shows that roughly 20% of all winds are flagged by the check against the forecast. During the manual control about 4% get reinstated and a further 9% are deleted. In total about 35 % of all potential tracers identified by the multispectral image analysis provide valid CMWs that are disseminated to the users via the Global Telecommunication System (GTS) of the World Meteorological Organization (WMO). Typically CMW dissemination occurs two hours after completion of the scanning of three successive images.

3. Monitoring the quality of CMWs

The quality of CMWs is monitored routinely by comparisons with collocated radiosondes where the collocation area extends over 2°x2° and is within a time interval of one hour. Poleward of 20 ° the longitude interval of a collocation box is increased to 3 °. The comparison is conducted on a daily basis with the sonde data received through the Global Telecommunication System. Monthly mean statistics are routinely computed. It is the purpose of this section to, firstly, describe how the CMWs are monitored at ESOC and, secondly, how the accuracy of a CMW can be estimated. The methods discussed will be used in Section 4 for quantifying the improvements to the CMWs due to various changes over recent years. Two quantities are directly derived from a comparison with radiosondes (RS). The average speed difference is defined as:

$$BIAS = <|\vec{v}_{CMW}|> - <|\vec{v}_{RS}|> \qquad [1]$$

where $< . >$ denotes a monthly mean and $| . |$ is the norm of a wind vector. The second quantity considered for quality monitoring is the monthly mean of RMS vector difference:

$$\sigma_{CMW,RS} = <[(\Delta u)^2 + (\Delta v)^2]>^{1/2} \qquad [2]$$

where:

$$(\Delta u)^2 = \sum_{i=1}^{N}(u_i^{CMW} - u_i^{RS})^2 \qquad [3]$$

$$(\Delta v)^2 = \sum_{i=1}^{N}(v_i^{CMW} - v_i^{RS})^2 \qquad [4]$$

N is the number of collocations in a month, u and v are the zonal and meridional wind components of a wind vector.

Assuming that a radiosonde provides an unbiased measure of wind velocity, Equation 1 defines the mean velocity bias inherent in CMWs. $\sigma_{CMW,RS}$ in Equation 2 is only a relative measure of the CMW error, because it encompasses the error of the radiosonde measurement and the differences due to separation in both time and space. The representativeness error due to the different nature of both wind measurements, i.e. CMWs rather being a volume average, will be considered as part of the CMW error. This appears justified since CMWs are simply used as single level wind for NWP, although it is recognized that the representativeness error in some cases may dominate the total CMW error.

It should be noted that radiosondes are not scrutinized for quality, hence the quality of the radiosonde data used for comparison may vary considerably. In order to reject gross errors in the radiosonde data a collocation is not considered for statistics if the vector difference exceeds 30 m/s or the directional difference exceeds 60 °. The directional threshold could be chosen even more stringent since independent monitoring at NWP centres shows that the CMWs do not exhibit large directional errors (Kelly, 1992). This also confirms our own monitoring results based on radiosondes that show mean directional differences of only about 1 °.

Following the work of Morgan (1985) and Kitchen (1989) one can estimate the RMS error σ_{CMW} of CMWs from:

$$\sigma_{CMW}^2 = \sigma_{CMW,RS}^2 - \sigma_t^2 - \sigma_d^2 \qquad [5]$$

where $\sigma_{CMW,RS}$ is the RMS vector difference between radiosonde and CMW, σ_t and σ_d are the vector differences associated with the separation in both horizontal space and time, respectively. While $\sigma_{CMW,RS}$ is available to us through our comparisons with radiosondes, the two quantities σ_t and σ_d need to be estimated. For that purpose we use the analysis of Kitchen (1989) who studied the spatial and temporal variation of the atmosphere from a large set of radiosonde soundings over the United Kingdom. Table 3 summarizes the values that we will adopt for estimating the CMW error. For details the reader is referred to the original paper by Kitchen (1989). The basis for extracting the values in Table 3 from Kitchen (1989) are as follows: First, the radiosonde versus CMW comparison is separated by about one hour since the CMWs are derived from an image triplet centered around 1100 UT and 2300 UT. This implies an RMS difference of 4 m/s for the high level clouds (see Table 3). Second, the mean separation distance of about 100 km is assumed in accordance with the size of the collocation area for a radiosonde - CMW comparison. Thus, the RMS difference due to spatial separation is taken as 6 - 7 m/s for the high level clouds.

The CMW error σ_{CMW} still contains the vertical separation between sonde and satellite wind vector; i.e. it is considered as a height assignment problem of the CMW. This is justified since the altitude error of radiosonde measurements constitutes only a small fraction of the total radiosonde wind RMS vector errors.

Kitchen quotes a total radiosonde error between about 0.9 m/s at 900 hPa to about 2.1 m/s at 100 hPa. It is certainly true that these radiosonde errors are on the low side since Kitchen used a radiosonde network of good quality. Our METEOSAT CMW monitoring takes all radiosonde data and rejects only gross outliers, although some stations may have wind vector errors exceeding 10 m/s occasionally (Hall, 1991, personal communication). Thus the estimated errors of CMWs provided in the following section may well be too high. Further comparisons with high-quality observations are needed to more accurately estimate CMW errors.

4. Improvements to the CMW retrieval

a. Chronicle of changes

The early cloud tracking method used at ESOC has been described by Morgan (1979) and Bowen et al. (1979). The outstanding feature of that wind processing scheme was its fully automatic performance using cross-correlation (Leese et al., 1971), that is, the tracking was always automatic not only for low-level but also for high-level clouds. At that time the cloud tracking used the navigated IR images without any radiance slicing of the image data and height assignment followed the tracking. An important feature of the system was and still is the use of a sequence of three images. That enables the computation of two complementary displacement vectors, which enables a check for consistency in time. This 'symmetry check' of a vector pair turned out to be the most important internal quality check (Schmetz and Nuret, 1987). Other internal quality tests, including the test for the magnitude of the pattern correlation, were abandonded since they did not show a significant correlation with the quality of CMWs. Man-machine interaction was and still is confined to a final quality control, where a meteorologist has the options to delete a CMW or to reinstate winds that were previously flagged by an automatic quality control.

The original CMW retrieval as described by Morgan (1979) and Bowen et al. (1979) has been completely revised between 1987 and 1990. Since March 1990 no conceptual change has been made, although fine-tuning of the algorithm continued. The changes brought about considerable improvements in quality, in particular success was achieved in reducing the slow bias of high speed winds. This underestimation of the true wind speed increases with wind speed and consequently it is most pronounced for high level winds.

The revisions of the CMW derivation consisted of four major software deliveries. The significance of the changes can be described as follows:

■ March1987: The radiance slicing or windowing technique for high level clouds was introduced in order to alleviate the problem of tracking a mixture of clouds and background (Schmetz and Nuret, 1987). Tracking unsliced images potentially introduces a slow bias since lower clouds/backgrounds move at a slower speed or not at all. The radiance slicing simply used the warm end of the high level cloud cluster, as obtained from the multispectral image analysis, as the cut-off for masking the background pixels.

■ September 1987: A new method of calibrating the Meteosat water vapour channel based on radiative transfer calculations was introduced (Schmetz, 1989). The new calibration method has a physically sound concept: radiances are calculated from radiosonde soundings for clear-sky segment areas and the radiances are related to the measured clear- sky count. The inherent flaw of the method is the quality of high-level humidity measurements with radiosondes. The previous calibration was more qualitative since the upper tropospheric humidity product from METEOSAT was forced to agree with radiosonde-observed relative humidity (Campbell, 1982). The new method brought about an increase in calibration coefficients of about 8%. This has lead to a better height assignment of cloud motion vectors derived from semi-transparent clouds (Schmetz et al., 1988). The impact of the WV calibration on the semi-transparency correction is due to the combined use of radiative forward calculations and satellite measured raw counts in the correction process (c.f. Appendix C).

■ March 1989: The cloud tracking was modified such that the cross-correlation is calculated for an area of 35 x 35 pixels around a displacement suggested by a wind forecast (Nuret and Schmetz, 1988; Nuret, 1990). This guided tracking replaced a search 'strategy' which started at 'zero'-displacement and stopped at the first peak found in the correlation surface (Bowen et al., 1979). Since correlation surfaces are generally multi-peaked (Schmetz and Nuret, 1987) there was a tendency for a slow bias in the old search method that was overcome by the use of a forecast wind. One should also note that the radiance slicing introduced in March 1987 had the unwanted effect of increasing the noise in the correlation surface, thus increasing the probability of tracking false peaks. The use of a forecast also reduces that problem. As noted in section 2c and the Appendix D, the dependence on the forecast wind is diminished due to the large search area around the displacement suggested by the forecast.

- March 1990: The simple radiance slicing was replaced by an image filtering which uses a spatial coherence method (Hoffman, 1990) to extract pixels belonging to the highest cloud layer. Its main advantage over the previous slicing is the better enhancement of the high level cloud layer to be tracked through a gradual screening of warmer pixel values (c.f. Appendix B).

b. Impact of changes

A thorough assessment of the impact of changes summarized above requires some processing of the monthly mean speed bias and RMS vector difference between CMWs and radiosondes, since both the speed bias and the RMS vector difference increase with wind speed (see Figures 4 and 5). Therefore a normalization has been computed in the following way: Linear regression is calculated for the speed bias and the RMS vector difference versus the monthly mean radiosonde speed for the time periods between changes. This method has been used previously (Schmetz et al., 1988) and was extended by Woick (1990) for monitoring the quality of CMWs. Figures 4 and 5 show the speed bias and the RMS vector differences for high level CMWs versus radiosonde wind speed for the five periods embracing the four algorithm changes listed above. The observed shifts of the regression lines indicate the changes in product quality.

Taking a monthly mean radiosonde speed of 24 m/s as reference the decrease of the speed bias and RMS vector difference can be computed from the regression lines. The results are plotted in Figure 6. Notably the bias at the reference wind speed decreased from 4 m/s to about 1.3 m/s over the period from August 1987 through March 1990. Simultaneously the RMS vector difference decreased from about 10.9 m/s to 9.2 m/s.

With Equation 5 and Table 3 we can also estimate the actual error of the high level CMWs; the result is that the vector error of high level METEOSAT CMWs decreased from about 7.8 m/s before August 1987 to about 5 m/s after March 1990.

An analogous analysis has been conducted for medium and low level CMWs. Results are presented in Figures 7 and 8, respectively. Medium level winds were most significantly improved by the initial radiance slicing and the advanced image filtering using the spatial coherence method. This points at the particular sensitivity of medium level cloud winds to tracer selection and enhancement. The error of medium level CMWs was reduced from about 6.0 m/s to 3.6 m/s at a reference wind speed of 15 m/s.

Interestingly low level CMWs experienced a noticable improvement only through the initial radiance slicing whereas the three following changes to the algorithm did not produce any further improvement. The radiance slicing had a positive impact on low level CMWs because the tracking of unsliced images had the potential of tracking some upper level cloud remnants while using the low level cloud radiance for the height allocation. The error improved from 4.1 m/s to about 2.7 m/s at a reference wind speed of 10 m/s.

c. Quality monitoring at ECMWF

The quality of observational data is monitored at ECMWF by monthly statistics of differences between the observations and their 6-hour forecast (first-guess). It has long been recognised that, on average, the quality of the first-guess is of the same order as the quality of a normal observing system (Hollingsworth et al., 1986; Hall, 1991). Therefore, a systematic discrepancy between first-guess and observations usually tends to point out a problem with the quality of the observations. This technique is an established tool for spotting problems at individual observing sites.

However, care should be taken to also consider possible first-guess errors. Indeed available statistics show significant variations of the quality of the first-guess, depending mainly on the density and quality of data available to the preceding analyses. This problem is particularly severe in the tropics and the mid-latitude southern hemisphere. The problem is aggravated when monitoring a data type, the impact of which ranges from large to small, as is the case for satellite data. That is to say, in areas where satellite data are the only source of information the first guess monitoring may overestimate the data quality. Likewise one can expect that a disproportionately large weight to conventional data will make satellite data look worse than they are. Nevertheless the first-guess comparison is a very valuable tool for monitoring the quality of a data observing system because of the consistent objective treatment of all data.

An application to the assessment of cloud motion wind data is shown in Figure 9. It concerns METEOSAT high level CMWs (above 400 hPa) since 1988, and gives the 12-month moving average of the monthly mean departures of the observed wind speed from the first guess (6 hour forecast). Figure 9 is has three panels corresponding to the three latitude bands North of 20°N, the tropical belt from 20°S - 20°N and the area South of 20°S.. In each panel the bias is plotted for different classes of forecast speed. The well known problem of the underestimation of the high wind speed can be seen, although one should realize that the reference to the forecast speeds always yields a bias, which is positive for slow wind speeds and negative for higher wind speeds. The important point is that the ECMWF monitoring shows a significant reduction of the slow bias of high wind speeds over recent years, thus confirming the results obtained in the comparison with radiosondes.

5. Discussion and conclusions

Winds estimated from the tracking of clouds in successive satellite images have been used for the global analysis of numerical weather prediction (NWP) models for more than a decade. The recent research and development of the CMW product has reversed a trend where the CMWs had been found less beneficial for Northern hemisphere forecasts (Thoss, 1992). In particular the operational winds from METEOSAT are considered as a very useful data source at all latitudes. An important general conclusion is that research and development work on satellite products should be a continuous effort in order to keep abreast with the advances on the user side. The need to do so has been realized at the EUMETSAT/NOAA/WMO Workshop on Wind Extraction from Operational Meteorological Satellites (EUMETSAT, 1992).

This paper has summarized the advances of the operational CMW retrieval from METEOSAT IR images at ESOC. Between August 1987 and March 1990 the speed bias of high level CMWs (< 400 hPa) versus radiosondes within a 2 ° by 2 ° collocation box has been diminished from about 4 m/s to 1.3 m/s for a mean radiosonde speed of 24 m/s. At the same time the vector error decreased from 7.8 m/s to about 5 m/s. Improvements for the medium level CMW vector error were from 6.0 m/s to 3.6 m/s at a wind speed of 15 m/s. Low level CMW errors decreased from 4.1 m/s to 2.7 m/s at a reference speed of 10 m/s.

The improvements have been achieved through different changes to the CMW algorithm. Specifically, two changes improved screening the highest cloud level for the tracking which in turn improved the height allocation of the cloud tracer. The use of a forecast for the tracking by automatic cross-correlation reduced the slow speed bias of CMWs, since the previous tracking invariably stopped at the first local correlation maximum obtained in a strategy search that started at zero-displacement. A new calibration of the METEOSAT 6.3 μm channel also improved the height assignment of displacement vectors through the altitude correction for semi-transparent and broken clouds.

The work on CMWs was particularly successful in improving the height assignment either directly through the semi-transparency/ broken cloud correction or indirectly through a better definition of the height range of a tracer. Consequently future work will also focus on an improved concept for height assignment.

Current research work at ESOC also addresses the definition of quality flags for individual cloud motion vectors and better quality control (Holmlund, 1992). The use of quality flags would enhance the information content of the product for NWP analyses as lower error characteristics could be given to the high quality CMWs, thus increasing their impact in the analyses.

The problem of height assignment becomes formidable when there is a strong wind shear across the cloud. Unfortunately there generally exists a substantial vertical shear in both speed and direction through a cirrus cloud (e.g. Quante, 1989, Reuss, 1967). Dedicated aicraft campaigns will be a useful means for further investigations and may lead to a better understanding of the significance of CMWs obtained from optically thin cirrus (Shenk, 1991).

The dependence of the displacement on the size of the target area needs to be considered. Lunnon and Lowe (1992) have shown that a target area of 16x16 pixels is superior to the presently used 32x32 pixels for METEOSAT, since it better represents the local wind field.

Previous studies (e.g. Shenk, 1991 and references therein; Uchida et al., 1991) have demonstrated the value of high temporal resolution for correctly identifying cloud tracers Cumulus clouds may require repeat cycles for the images as low as a few minutes, which is is substantially different from the typical 30 min repeat cycle of scanning at most operational centers. The number of useful tracers could be enhanced through shorter scanning intervals.

Acknowledgment. The constructive comments of the three anonymous reviewers helped to improve this paper.

APPENDIX A

Multispectral Image Analysis and Cluster Extraction

The operational analysis of METEOSAT images and the extraction of clusters or scenes has been described by Tomassini (1981). A similar method, namely the asymmetric Gaussian histogram analysis of Simmer et al. (1982), has been employed in a comparison of algorithms for the International Cloud Climatology Project (ISCCP) as reported by Rossow et al. (1985). Here it should suffice to recall the essentials of the image analysis in order to make this paper self-contained. The procedure of image analysis and cluster extraction works as follows:

i) A METEOSAT image is segregated into 80x80 segment areas each comprising 32x32 IR or WV pixels, thus representing an area of 160 km x 160 km at nadir. Since the resolution of the VIS channel is 2.5 km x 2.5 km, full resolution VIS images are reduced by sampling every other line and averaging over two pixels.

ii) Bidimensional histograms for IR/WV and IR/VIS, if available, and the one-dimensional histograms are created for segment areas within the 55° circle arc around nadir.

iii) In the one-dimensional IR histogram the principal maxima are found which are defined as the absolute maximum between two stable minima, where stable is defined as being a minimum in a sequence of relative minima. It is assumed that the frequency distribution of such a cluster of pixels can be described by two half-Gaussians which are defined by the standard deviation σ_{cl}. The standard deviation is defined as the count difference between the principal maximum and the point in the histogram where the frequency attains the value of the Gaussian at one standard deviation (i.e. 0.607). Note that σ_{cl} differs for the two sides of the cluster.

iv) Pixel values within one σ_{cl} fully contribute to a cluster whereas pixel values outside the 3 σ_{cl} range do not contribute at all. Pixels with count values in the intervall $\{\sigma_{cl},\ 3\sigma_{cl}\}$ obtain a weight of according to the Gaussian if the histogram exceeds the Gaussian curve; otherwise they are assigned a value of 1.

v) the original two-dimensional IR/VIS histogram is reduced to a new IR/VIS intermedidate histogram by multiplying the IR and the VIS frequency distribution with the above defined weights for the IR clusters. In that way a reduced one-dimensional VIS histogram is constructed which only contains pixels that belong to the previously extracted IR cluster.

vi) the one-dimensional VIS histogram is now analysed in the same way as the IR one-dimensional histogram (steps iii to v) leading to a two dimensional IR/VIS cluster histogram.

vii) steps iii) through vi) are repeated until all pixels are assigned to clusters. A cluster has a minimum of 60 pixels.

vii) finally the WV characteristics (mean and standard deviation) of each cluster are determined by constructing, with the aid of the IR weights, a two-dimensional IR/WV

cluster histogram and a one-dimensional WV cluster histogram. When the VIS channel is not available a two-dimensional IR/WV analysis is performed.
After the cluster analysis has been performed, all clusters have to be attributed to a specific scene (e.g. surface, clouds). The classification is aided by radiative transfer model calculations for clear scenes and clouds at specified altitudes, respectively, and, more importantly, the result of the previous classification from one hour before is used.

APPENDIX B

Image Filtering for Extracting the Highest Cloud Tracer

The aim of the image filtering or slicing is to enhance the highest cloud tracer that is suitable for tracking in a target area of 32x32 IR pixels. Hoffman (1990) has studied in detail the relationship between local mean count (3x3 pixels) and the local standard deviation for clouds with varying transparency over a homogeneous background. He found a simple parabolic function most suitable to fit the arch-like relationship between local standard deviation σ and local mean count C. For instance the arch between the cold scene $\overline{C}_1$ and a warmer scene $\overline{C}_2$ (see Figure A1) is described by the function:

$$\sigma_{12}(C) = \frac{-4\,\sigma_{top}\,(C - \overline{C}_1)\,(C - \overline{C}_2)}{(\overline{C}_2 - \overline{C}_1)^2} \qquad [B1]$$

where C is the satellite observed local mean radiance (in terms of raw count), $\overline{C}_1$ and $\overline{C}_2$ correspond to the cold and warm scene, repectively, and σ_{top} is the maximum standard deviation corresponding to the top of the arch. $\overline{C}_1$ and $\overline{C}_2$ are provided by the multispectral image analysis. σ_{top} is parameterized as a piecewise linear function of the brightness temperature difference ΔT between $\overline{C}_1$ and $\overline{C}_2$:

$$\sigma_{top} = a\,\Delta T + b \qquad [B2]$$

a and b are regression coefficients that take in the present scheme the values: $a = 1.97$ (counts per Kelvin) and $b = -50$ (counts) for $\Delta T > 50$ K; and $a = 0.66$ and $b = 9$ for $\Delta T < 50$ K. ΔT is computed using the actual IR calibration coefficient.

The image filtering distinguishes four different cases with clouds. In the trivial case where only one cloud is identified in a segment, the image remains unfiltered. When the multispectral image analysis has identified two scenes within a segment, the pixel values warmer than the mean value $\overline{C}_2$ are set equal to $\overline{C}_2$. If four significantly large scenes, each comprising more than 150 pixels, are detected, the target area is not considered for tracking. Otherwise the smallest scene will be neglected and the problem is reduced to the case of three scenes.

The spatial coherence filtering is applied in cases with three scene types (that is at least two cloud layers) in a segment. The multispectral image analysis provides the mean counts for the scenes $\overline{C}_1, \overline{C}_2$ and $\overline{C}_3$. These values are used in three equations like Equation B1, segregating the histogram of local mean versus local standard deviation into several domains as exemplified in Figure B1.

Principally the image filtering projects all counts into a basic radiometric range, defined as the range between $\overline{C}_1$ and $\overline{C}_3$. The counts belonging to the six domains are treated in the following manner:

- Uncontaminated pixels belonging to the coldest scene (highest cloud) remain unchanged (area 1)

- Uncontaminated pixels from the warmest scene (area 6) are set to a constant value $\overline{C}_3$.

- Pixels that are a mixture of the two warmer scenes (area 5) are also set to $\overline{C}_3$.

- Pixels that are a mixture of the coldest and the warmest scene (area 2) remain unchanged since they already extend over the basic radiometric range between $\overline{C}_1$ and $\overline{C}_3$.

- Pixels that are a mixture of the two coldest scenes $\overline{C}_1$ and $\overline{C}_2$ (area 4), are re-scaled such that they stretch over the basic radiometric range. A new count C_{new} is computed from:

$$C_{new} = \overline{C}_1 N_{12} + (1 - N_{12})\, \overline{C}_3 \qquad [B3]$$

where N_{12} is a sub-pixel fractional cloud amount defined as:

$$N_{12} = \frac{\overline{C}_2 - C}{\overline{C}_2 - \overline{C}_1} \qquad [B4]$$

with the constraint $0 < N_{12} < 1$.

It follows:

$$C_{new} = \frac{\overline{C}_3 - \overline{C}_1}{\overline{C}_2 - \overline{C}_1}(C - \overline{C}_1) + \overline{C}_1 \qquad [B5]$$

That is, the rescaling is a linear shift towards the warm scene $\overline{C}_3$, which increases the contrast between $\overline{C}_1$ and $\overline{C}_2$.

- Pixels from area 3 are within the basic radiometric range between $\overline{C}_1$ and $\overline{C}_3$ and are assumed to contain information from all three scenes. Area 3 is defined by the condition $\sigma_{12}(C) \leq \sigma(C) \leq \sigma_{13}(C)$. Here, in addition to a scaling with fractional cloud amount, a scaling with local standard deviations is required:

$$C_{new} = \frac{\sigma_{13}(C) - \sigma(C)}{\sigma_{13}(C) - \sigma'}\left[\frac{\overline{C}_3 - \overline{C}_1}{\overline{C}_2 - \overline{C}_1}(C' - \overline{C}_1) + \overline{C}_1\right] + \frac{\sigma(C) - \sigma'}{\sigma_{13}(C) - \sigma'}\, C \qquad [B6]$$

where $\sigma(C)$ is the local standard deviation as computed for 3x3 pixels, and σ', C' take the following values:

i) if $C \leq \overline{C}_2$, then $\sigma' = \sigma_{12}(C)$, $C' = C$

ii) if $C > \overline{C}_2$, then $\sigma' = \sigma_{23}(C)$, $C' = \overline{C}_2$

$\sigma_{12}(C)$, $\sigma_{13}(C)$ are defined by Equation B1, except that for $\sigma_{13}(C)$ the scene $\overline{C}_3$ replaces $\overline{C}_2$.

APPENDIX C

Altitude Correction for Semi-transparent and Broken Clouds

For a horizontally stratified non-scattering atmosphere with a cloud between pressure levels p_{bot} and p_{top}, the monochromatic radiance L_λ observed at the top of the atmosphere is:

$$L_\lambda = L_\lambda^{sfc}(p_{sfc}) \; \tau_\lambda(p_{sfc}, p_{bot}) \; \tau_\lambda(p_{bot}, p_{top}) \; \tau_\lambda(p_{top}, 0) \; + \int_{p_{sfc}}^{p_{bot}} B_\lambda(p) \frac{\partial \tau_\lambda}{\partial p} \, dp \; + \int_{p_{bot}}^{p_{top}} B_\lambda(p) \frac{\partial \tau_\lambda}{\partial p} \, dp \; + \int_{p_{top}}^{0} B_\lambda(p) \frac{\partial \tau_\lambda}{\partial p} \, dp \qquad [C1]$$

where B_λ is the spectral Planck function, τ_λ the spectral transmittance and p_{sfc} denotes surface pressure.

Evaluating the integrals and assuming that the cloud is represented by an effective transmittance τ^{cld} and a mean Planck function B^{cld}, one can write for the satellite observed radiance L_{sat}:

$$L_{sat} = L^0 \, \tau^{cld} \, \tau^A \; + \; B^{cld} \, (1 - \tau^{cld}) \, \tau^A \; + \; L^A \qquad [C2]$$

where L^0 is the upwelling radiance at cloud bottom, τ^A and L^A are the transmittance and the emitted radiance, respectively, of the atmospheric layer above cloud top. Equation C2 also assumes that the monochromatic equation can be extended to a finite spectral interval as observed by the satellite, hence the subscript λ will be omitted.

Previous methods for inferring the cloud top pressure of semi-transparent clouds from simultaneous measurements in the IR and WV channel (e.g. Szejwach, 1982; Pollinger and Wendling, 1984) have used two cloudy radiance measurements in each channel. The operational Meteosat correction method employs two simultaneous radiance observations in both the WV and IR channels where one pair of radiances is from the semi-transparent cloud (L_{ir}, L_{wv}) and a second pair from an adjacent cloud-free area (L_{ir}^{clr}, L_{wv}^{clr}). This cloud-free pair may actually be cloud-contaminated without violating the validity of the approach, as long as the contamination is due to the cloud to be corrected. The approach follows the work of Cayla and Tomassini

(1978) and its operational implementation has been described by Bowen and Saunders (1984). It should also be noted that the present method considers the water vapor absorption above cloud top.

Following Equation C2 the cloudy radiances observed by Meteosat in the IR and WV channel can be written as:

$$L_{ir} = [(L_{ir}^{0} - B_{ir}^{cld})\,\tau_{ir}^{cld} + B_{ir}^{cld}]\,\tau_{ir}^{A} + L_{ir}^{A} \qquad [C3]$$

$$L_{wv} = [(L_{wv}^{0} - B_{wv}^{cld})\,\tau_{wv}^{cld} + B_{wv}^{cld}]\,\tau_{wv}^{A} + L_{wv}^{A} \qquad [C4]$$

For the clear-sky radiances one obtains:

$$L_{ir}^{clr} = L_{ir}^{0}\,\tau_{ir}^{A} + L_{ir}^{A} \qquad [C5]$$

$$L_{wv}^{clr} = L_{wv}^{0}\,\tau_{wv}^{A} + L_{wv}^{A} \qquad [C6]$$

Assuming furthermore that the ratio of the effective cloud emissivities in the two channels $(1 - \tau_{ir}^{cld}) / (1 - \tau_{wv}^{cld}) = \zeta$, where ζ is a constant, Equations C3 - C6 can be combined to give a linear relationship between the observed radiances L_{ir} and L_{wv}:

$$L_{wv} = \zeta\, L_{ir}\, \frac{L_{wv}^{clr} - L_{WV}^{opaq}}{L_{ir}^{clr} - B_{ir}^{cld}} + \frac{\zeta\, L_{ir}^{clr}\, L_{WV}^{opaq} + (1 - \zeta)\, L_{ir}^{clr}\, L_{wv}^{clr} - L_{wv}^{clr}\, B_{ir}^{cld}}{L_{ir}^{clr} - B_{ir}^{cld}} \qquad [C7]$$

where:

$$L_{WV}^{opaq} = B_{wv}^{cld}\,\tau_{wv}^{A} + L_{wv}^{A} \qquad [C8]$$

Equation C7 shows that all radiance pairs L_{ir}, L_{wv} from one cloud layer with variable transparency and located at a specific altitude, lie on a straight line between the clear-sky radiances L_{ir}^{clr}, L_{wv}^{clr} and the theoretical radiances B_{ir}^{cld}, L_{WV}^{opaq} for the opaque cloud (see Figure C1). B_{ir}^{cld} or B_{wv}^{cld} are sought since they determine the corrected cloud top height. It should be noted that for METEOSAT the relationship between radiance and count is linear.

It is worthwhile to note that, with the assumption $\zeta = 1$ and after some rearrangement, Equation C7 can be written as in Bowen and Saunders (1984):

$$B_{wv}^{cld}\,\tau_{wv}^{A} + L_{wv}^{A} = L_{wv}^{clr} + \frac{L_{ir}^{clr} - B_{ir}^{cld}}{L_{ir}^{clr} - L_{ir}}\,(L_{wv} - L_{wv}^{clr}) \qquad [C9]$$

where the left side and B_{ir}^{cld} are the unknowns, that correspond to the radiances that the satellite would observe for an opaque cloud in the WV and IR channel, respectively.

As a second equation for solving the problem a theoretical relationship between the satellite observed WV and IR radiances for opaque clouds at different levels is used:

$$B_{wv}^{cld}\,\tau_{wv}^{A} + L_{wv}^{A} = f(B_{ir}^{cld}) \qquad [C10]$$

Equation C10 is shown in Figure C1 as solid curve. This relationship is computed with a radiative forward model for the IR channel (Schmetz, 1986) and WV channel (Schmetz and Turpeinen, 1988) using the ECMWF temperature and humidity forecast. The operational algorithm for finding the correct height then simply seeks for the intercept between Equation C7 and C10.

The above procedure for correcting the altitude of semi-transparent and/or sub-pixel clouds needs some comment:

In an ideal situation the measured clear-sky radiance pair (cross in Figure C1) should lie on the precalculated solid curve (Equation C10). Generally that is not the case, mainly due to differences between actual and forecast upper tropospheric moisture. In the present algorithm the observed clear-sky radiance must not deviate by more than 10 % from Equation C10. An alternative approach would be to adjust the computed curve C10 to the actually measured radiance pair by a vertical shift.

It is also important to realize that the above approach is strictly speaking a height correction for sub-pixel broken clouds, where the broken cloud elements are opaque and cloud cover varies (Schmetz, 1991). The development of a semi-transparent plane-parallel cloud from clear-sky to an opaque cloud is rather described by the dashed line in Figure C2. The dashed line has been computed with a radiation model by increasing first the ambient humidity at cloud level and then optical depth of the cloud particles. The shape of the curve is understood from the fact that the initial moisture increase is noticable only in the WV channel. After the formation of a sufficient number of cloud particles the IR radiance will also be affected. Preliminary analyses indicate that this effect is observable in the satellite data and may lead to systematic errors in altitude correction.

Thus the present semi-transparency correction is conceptually correct only for a semi-transparent cloud scene with sub-pixel opaque clouds. Further work is warranted to improve the concept for semi-transparent cloud height corrections.

APPENDIX D

Cross-Correlation for Cloud Tracking

For the cloud tracking the standard pattern correlation coefficient (PCC) is calculated:

$$PCC = \frac{\sigma_{ST}(n,m)}{\sigma_T \; \sigma_S(n,m)} \qquad [D1]$$

where n and m are the row and column indices of the correlation surface and can range from 1 to 65. σ_T is the standard deviation of the counts $C_T(i,j)$ within the target area at the time h,

$$\sigma_T = \left[\frac{1}{1024} \sum_{i=1}^{32} \sum_{j=1}^{32} \left[C_T(i,j) - \overline{C}_T \right]^2 \right]^{1/2} \qquad [D2]$$

where i and j denote row and column within a target area and $\overline{C}_T$ is the mean count.

$\sigma_S(n,m)$ is the standard deviation of counts C_S the target-equivalent area within the search area in the images at at h-30 minutes and h + 30 minutes, respectively:

$$\sigma_S(n,m) = \left[\frac{1}{1024} \sum_{i=1}^{32} \sum_{j=1}^{32} \left[C_S(n+i, m+j) - \overline{C}_S(n,m) \right]^2 \right]^{1/2} \qquad [D3]$$

The covariance $\sigma_{ST}(n,m)$ is:

$$\sigma_{ST}(n,m) = \frac{1}{1024} \sum_{i=1}^{32} \sum_{j=1}^{32} [\, C_S(n+i, m+j) - \bar{C}_S(n,m)] \, [C_T(i,j) - \bar{C}_T] \qquad [D4]$$

In the operational environment at ESOC computer time is prohibitive to compute full correlation surfaces. Therefore the search in the correlation surface for a peak commences in the displacement positions *nfc* and *mfc* as suggested by a wind forecast (Nuret and Schmetz, 1988; Nuret, 1990). The search around the forecast wind speed is within a range of $n = nfc - nh, \ldots\ldots nfc + nh$ and $m = mfc - mh, \ldots\ldots, mfc + mh$; where $nh = mh = 17$, that is an area of 35x35 pixels.

This area of 35 by 35 pixels is large enough to limit the dependence of the result on the forecast since a displacement of 35 pixels in 30 minutes corresponds to a speed of about 100 m/s. Inside the 35x35 matrix only every other correlation is computed initially and a full search is performed around the peak value. A final sub-pixel accuracy of the peak location is obtained with a parabolic interpolation.

The first search for a best pattern match is followed by a second correlation between the target area and the search area at the time $h + 30$ min. The second search starts in the symmetry point of the first displacement and extends over a search area of 19x19 pixels. Pattern matchings where the peak value is obtained on the boundary of the correlation surface are rejected.

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Images used for CMW derivation	Range of forecast used for: • Radiative forward calculations • Start of the cloud tracking • Automatic quality control
0430, 0500, 0530 UT	18 h
1030, 1100, 1130 UT	24 h
1630, 1700, 1730 UT	30 h
2230, 2300, 2330 UT	12 h

Table 1: CMWs are derived from three consecutive METEOSAT IR images four times a day. The CMW derivation is aided by correlative forecast data from ECMWF. The forecast temperature/humidity profiles are used for height assignment and radiation calculations for the semi-transparency correction. The search for a pattern matching starts in the cloud displacement suggested by a forecast wind, and the product is grossly checked by comparison with the forecast winds.

ANNEX IV

CMW level	Number of tracers	Rejected by image filtering	Bad peaks in correlation surface	Speed < 5 m/s	Rejected by symmetry check	Rejected by automatic quality control	Rejected by manual quality control	Total rejections	Reinstated by manual quality control	Disseminated
High (< 400 hpa)	958	7.3%	9.7%	3.8%	18.2%	21.4%	9.0%	69.4%	5.7%	36.3%
Medium	562	6.0%	8.7%	21.2%	14.6%	19.1%	12.0%	81.6%	0.8%	19.2%
Low (> 700 hPa)	739	0.0%	4.6%	17.9%	11.2%	17.1%	7.2%	58.0%	2.9%	44.9%
Total	2259	4.6%	7.8%	12.7%	15.0%	19.4%	9.2%	68.7%	3.6%	34.9%

Table 2: Typical results for a production run of cloud motion winds. The number of tracers is the number of cloud features that are actually used for tracking. Note, that the algorithm selects the highest cloud in a target area of 32x 32 IR pixels as a tracer. Percentages refer to the number of tracers as given in the first column.

Cloud level	RMS difference due to distance separation	RMS difference due to time separation
High	6 - 7 m/s	4 m/s
Medium	5 m/s	3 m/s
Low	4 m/s	2 m/s

Table 3: Root mean square differences between measurements of vector wind separated by about 100 km distance and 1 hour time interval, respectively (estimated from Kitchen, 1989). The values are used for estimating the RMS error of the CMWs from the RMS differences versus collocated radiosondes (see Figures 6 - 8).

ANNEX IV

FIGURE CAPTIONS

Figure 1: Cloud motion winds from METEOSAT IR images for 26 January at 1100 UT.

Figure 2: IR image corresponding to the wind field in Figure 8. The image is the center of the triplet of images used for the tracking of clouds.

Figure 3: Illustration of the image filtering using the spatial coherence technique. Figure 3a shows the original IR image where the target area is indicated with a frame. Figure 3b depicts the IR histogram and Figure 3c the spatial coherence plot, where the local standard deviation over 3x3 IR pixels is plotted versus the local mean. Figure 3d finally presents the filtered target area where the highest cloud layer is more clearly separated from the background.

Figure 4: Monthly mean speed bias (CMW minus radiosonde) for high level winds (< 400 hPa) versus the average radiosonde wind speed for five time periods separated by the major changes to the CMW algorithm as decribed in section 4a.

The regression for the most recent analysis (current performance) reads: $Bias = -0.14 |\vec{v}_{RS}| + 2.1$ (m/s).

Figure 5: Monthly mean RMS vector difference for high level winds ($<$ 400 hPa) versus the average radiosonde wind speed for five time periods separated by the major changes to the CMW algorithm as decribed in section 4a.

The regression for the most recent analysis (current performance) reads:

$\sigma_{CMW,RS} = 0.208 |\vec{v}_{RS}| + 4.1$ (m/s).

Figure 6: Evolution of the monthly mean RMS vector difference, the speed bias and the estimated RMS error of high-level ($<$ 400 hPa) CMWs over the period from November 1984 to March 1991. Time periods are defined by the changes to the CMW algorithm as described in section 4, that is:

1 = period before any change

2 = radiance slicing for high level clouds

3 = new calibration of the water vapor channel

4 = use of forecast winds to start cloud tracking

5 = image filtering before start of cloud tracking

The values in the figure correspond to a mean radiosonde wind speed of 24 m/s.

Figure 7: As Figure 6 except for medium-level cloud (700 $<$ p $<$ 400 hPa).

The values in the figure correspond to a mean radiosonde wind speed of 15 m/s.

Figure 8: As Figure 6 except for low-level cloud ($>$ 700 hPa).

The values in the figure correspond to a mean radiosonde wind speed of 10 m/s.

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Figure 9: Twelve-months running mean of the bias between METEOSAT high-level CMWs and the ECMWF first-guess for the period of January 1988 through September 1991. Results are broken down into four different speed classes of the first guess (10 - 20 m/s, 20 - 30 m/s, 30 - 40 m/s and 40 - 50 m/s). The different panels correspond to Northern hemisphere (North of 20°N), tropical belt, and the Southern hemisphere (South of 20°S).

Figure B1: Schematic showing the different domains of pixel contamination for a target area (segment) containing three different scene types, namely sea surface and two levels of cloud (for details see text).

Figure C1: Schematic of the bi-spectral altitude correction for semi-transparent clouds operationally in use at ESOC. The solid curve refers to model calculations for opaque clouds. Squares along the curve correspond to clear sky and clouds at 1.6, 3.2, 6, 8, 9.6, 11, 12 and 14 km altitude, respectively, embedded into tropical standard atmosphere and nadir viewing.

The straight line pertains to a broken cloud layer with sub-pixel opaque cloud elements at an altitude of 9.6 km. The intersection of this line with the solid curve provides the corrected estimate of cloud height as described above. The straight line is defined by a background (clear-sky) radiance pair (cross) and a cloudy radiance pair (diamond).

The vertical axis on the right side provides an approximate scale for the equivalent blackbody brightness temperature (EBBT) in the water vapor channel.

Figure C2: As Figure C1 except that the dashed line corresponds to the trace that a plane-parallel semi-transparent cloud at 9.6 km altitude leaves in the IR/WV count domain when the cloud forms and optical depth increases from zero to that for an opaque cloud.

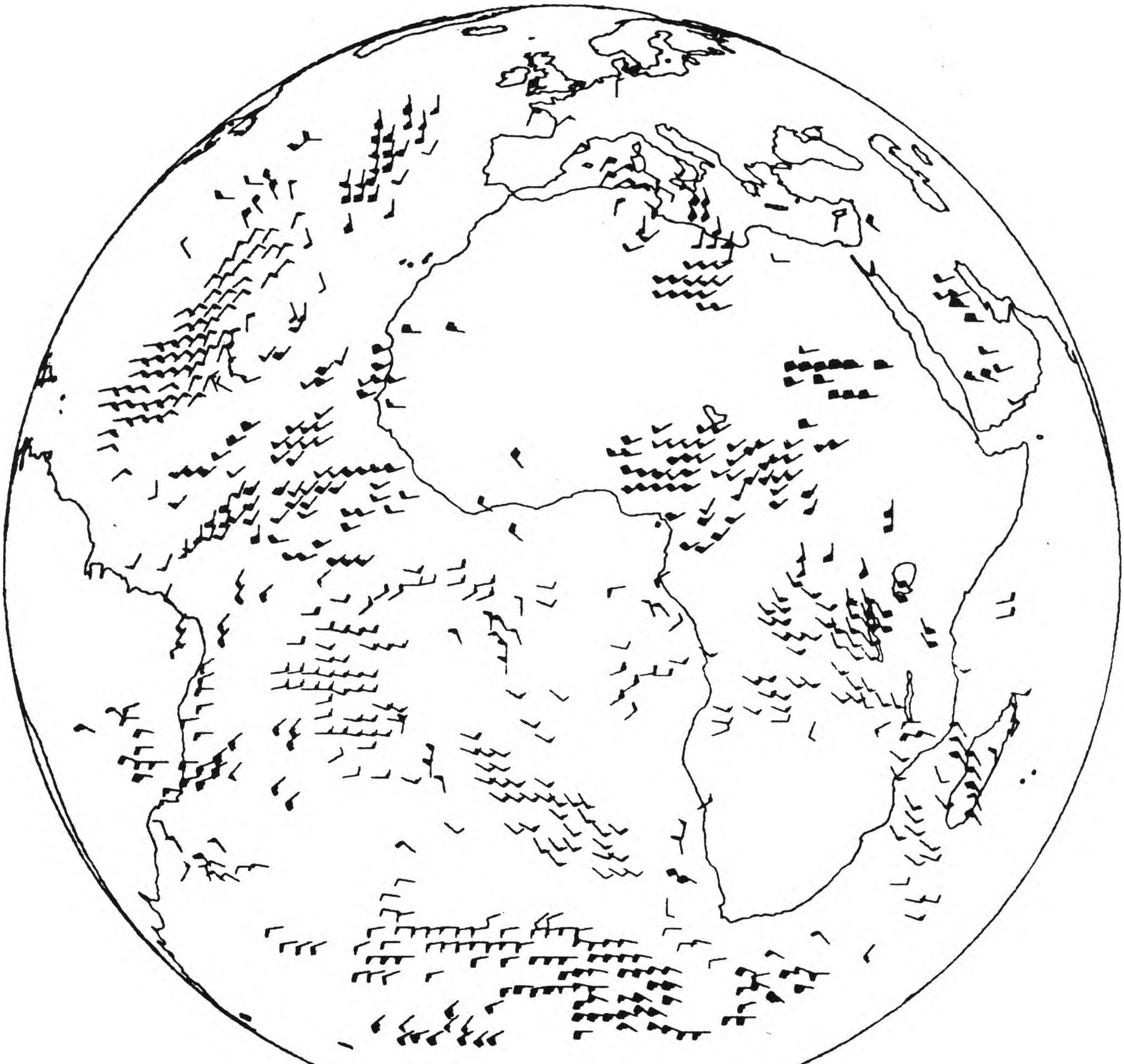


Figure 1

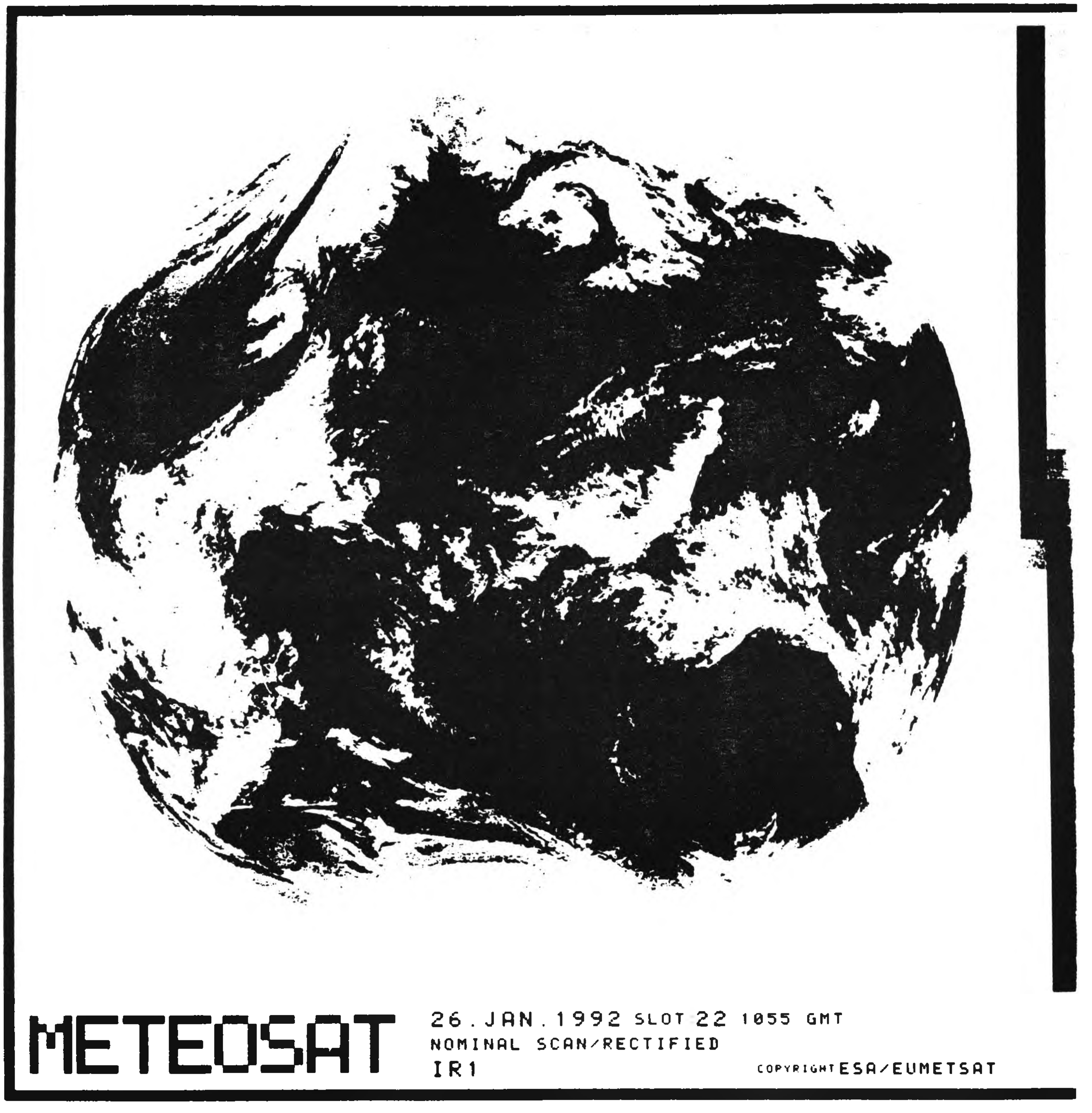

METEOSAT
26.JAN.1992 SLOT 22 1055 GMT
NOMINAL SCAN/RECTIFIED
IR1
COPYRIGHT ESA/EUMETSAT

Figure 2

ANNEX IV

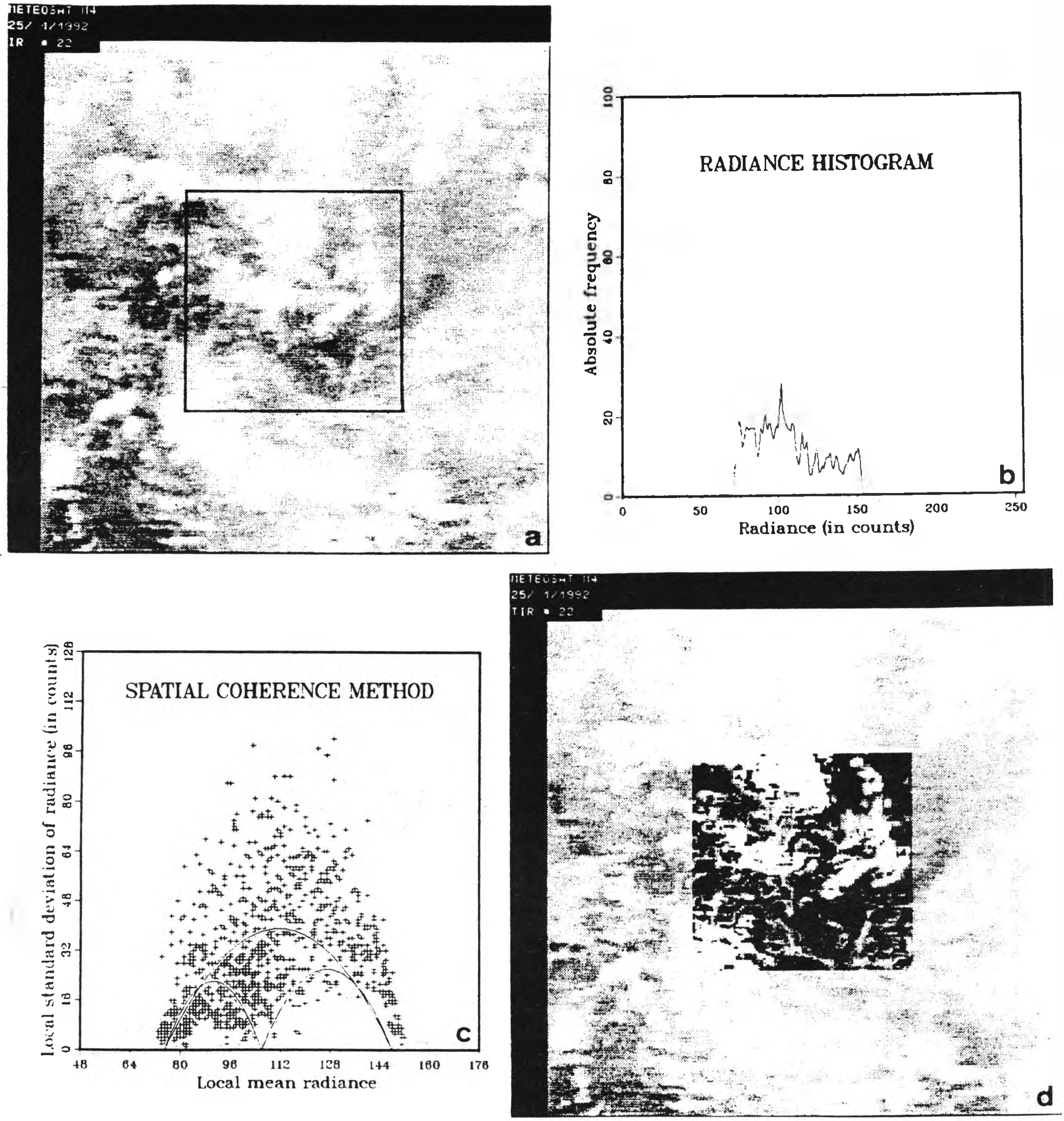


Figure 3

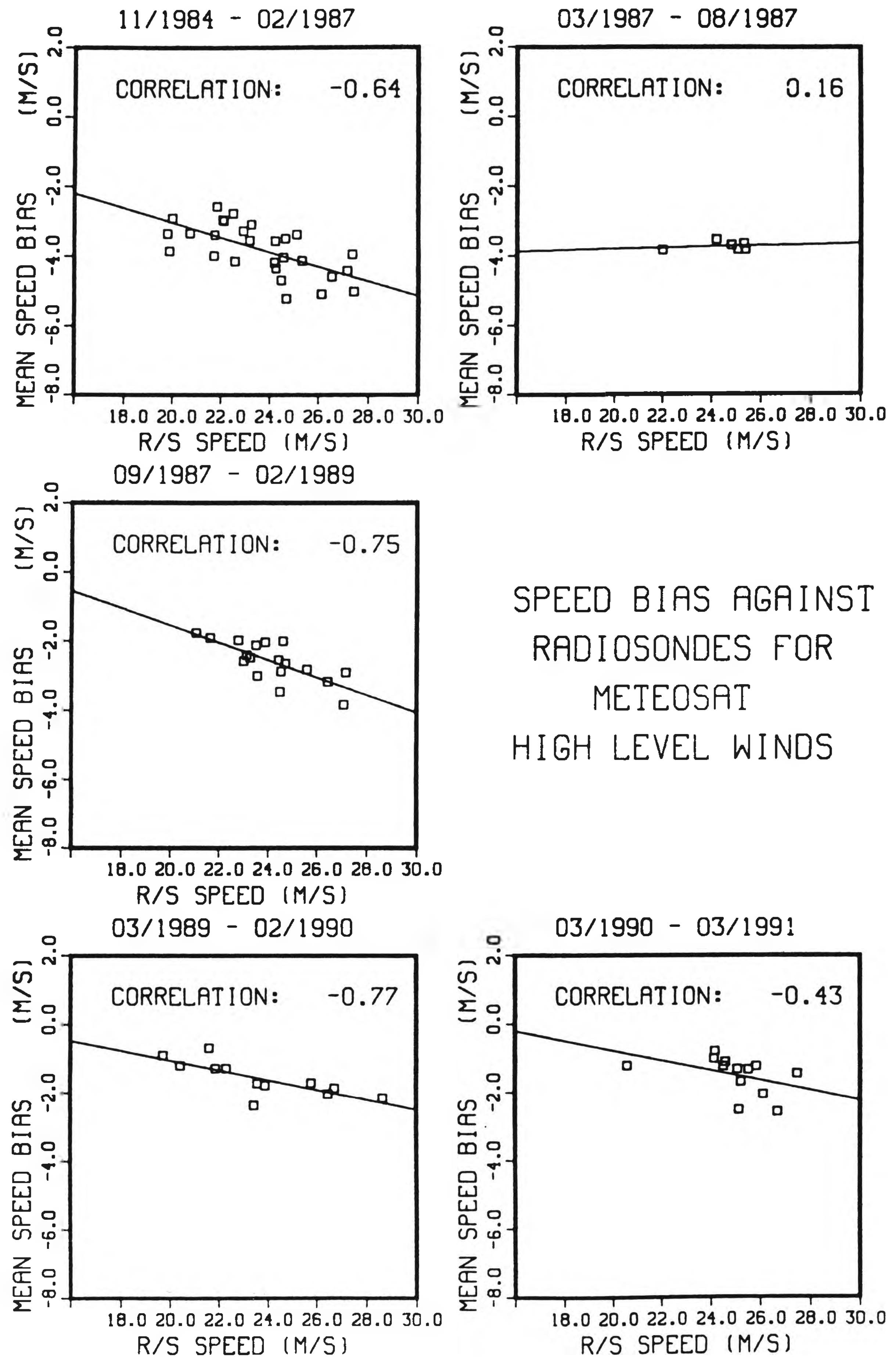

11/1984 - 02/1987
CORRELATION: -0.64
03/1987 - 08/1987
CORRELATION: 0.16
09/1987 - 02/1989
CORRELATION: -0.75
SPEED BIAS AGAINST
RADIOSONDES FOR
METEOSAT
HIGH LEVEL WINDS
03/1989 - 02/1990
CORRELATION: -0.77
03/1990 - 03/1991
CORRELATION: -0.43
MEAN SPEED BIAS (M/S)
-8.0 -6.0 -4.0 -2.0 0.0 2.0
R/S SPEED (M/S)
18.0 20.0 22.0 24.0 26.0 28.0 30.0

Figure 4

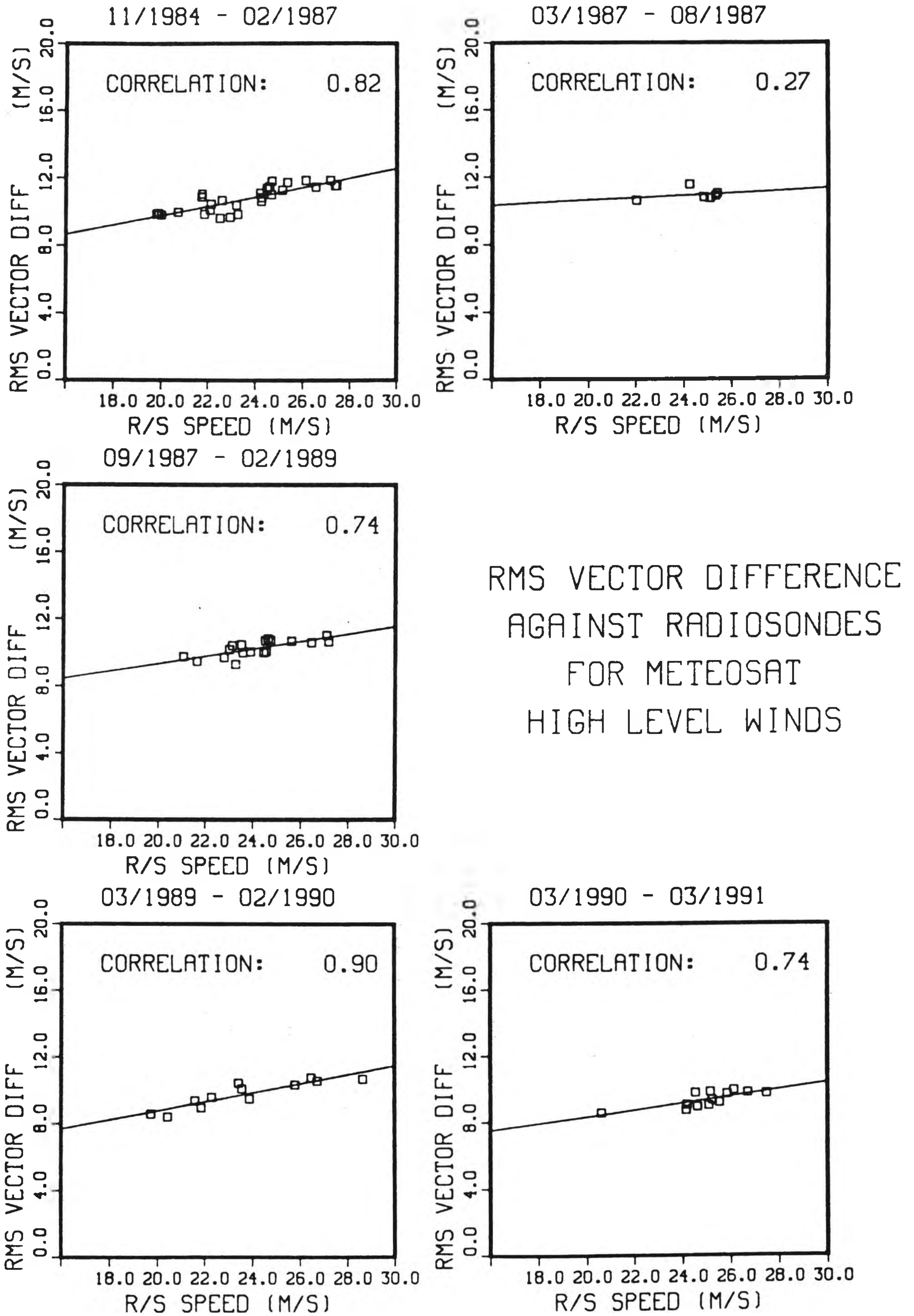

11/1984 - 02/1987
CORRELATION: 0.82
03/1987 - 08/1987
CORRELATION: 0.27
09/1987 - 02/1989
CORRELATION: 0.74
RMS VECTOR DIFFERENCE
AGAINST RADIOSONDES
FOR METEOSAT
HIGH LEVEL WINDS
03/1989 - 02/1990
CORRELATION: 0.90
03/1990 - 03/1991
CORRELATION: 0.74
RMS VECTOR DIFF (M/S)
R/S SPEED (M/S)
0.0
4.0
8.0
12.0
16.0
20.0
18.0 20.0 22.0 24.0 26.0 28.0 30.0

Figure 5

High Level Cloud Motion Winds

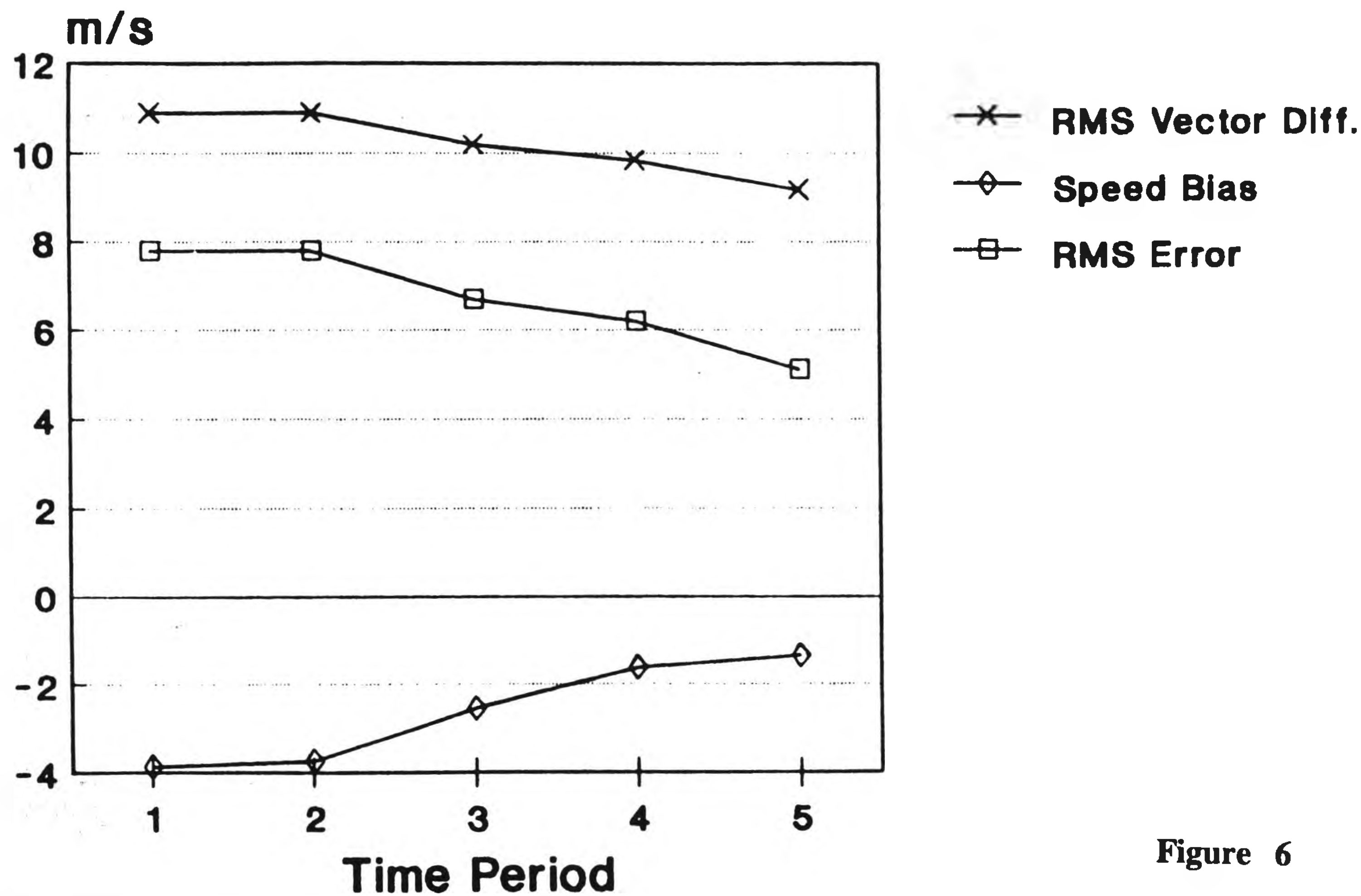


Figure 6

Medium Level Cloud Motion Winds

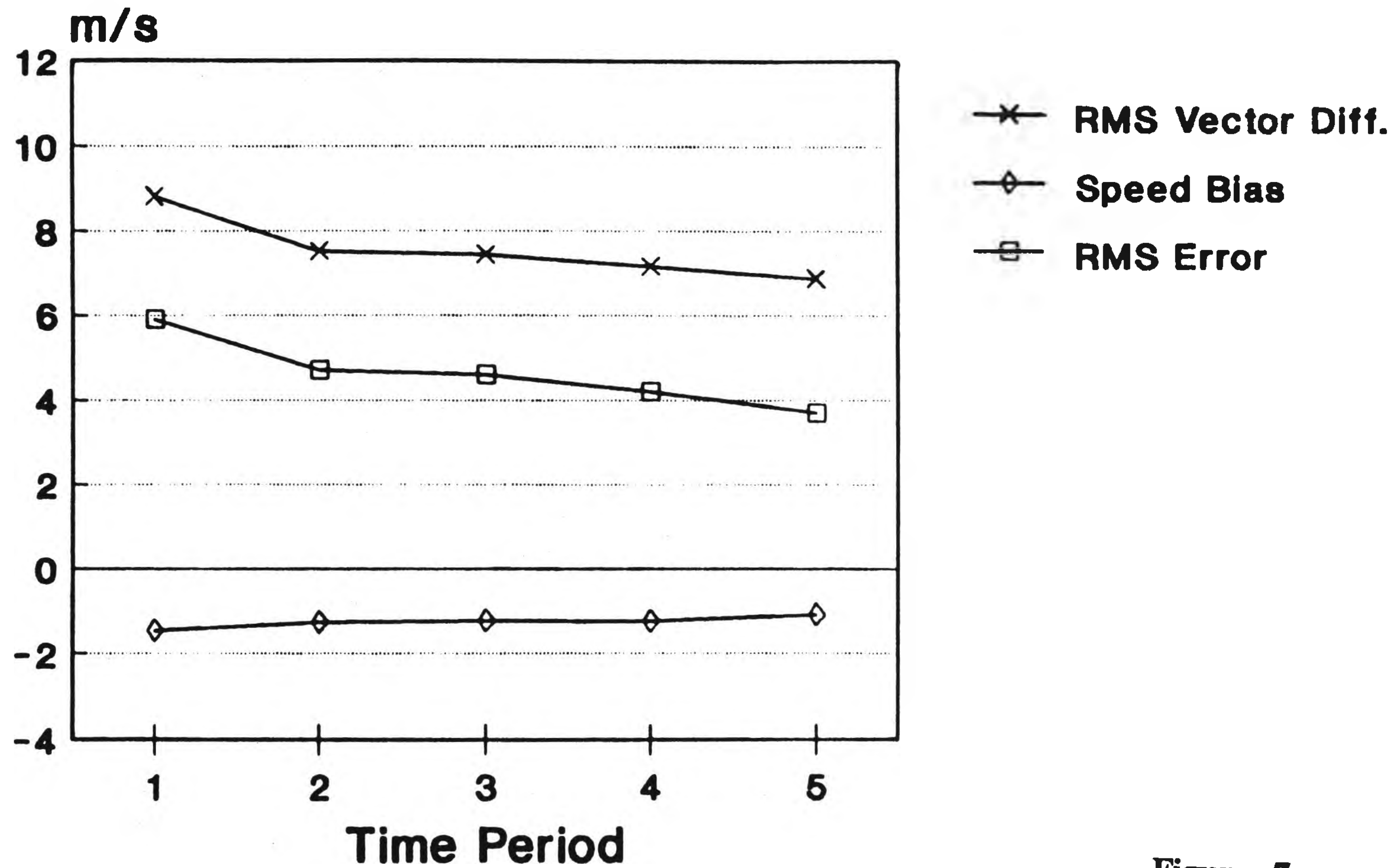


Figure 7

Low Level Cloud Motion Winds

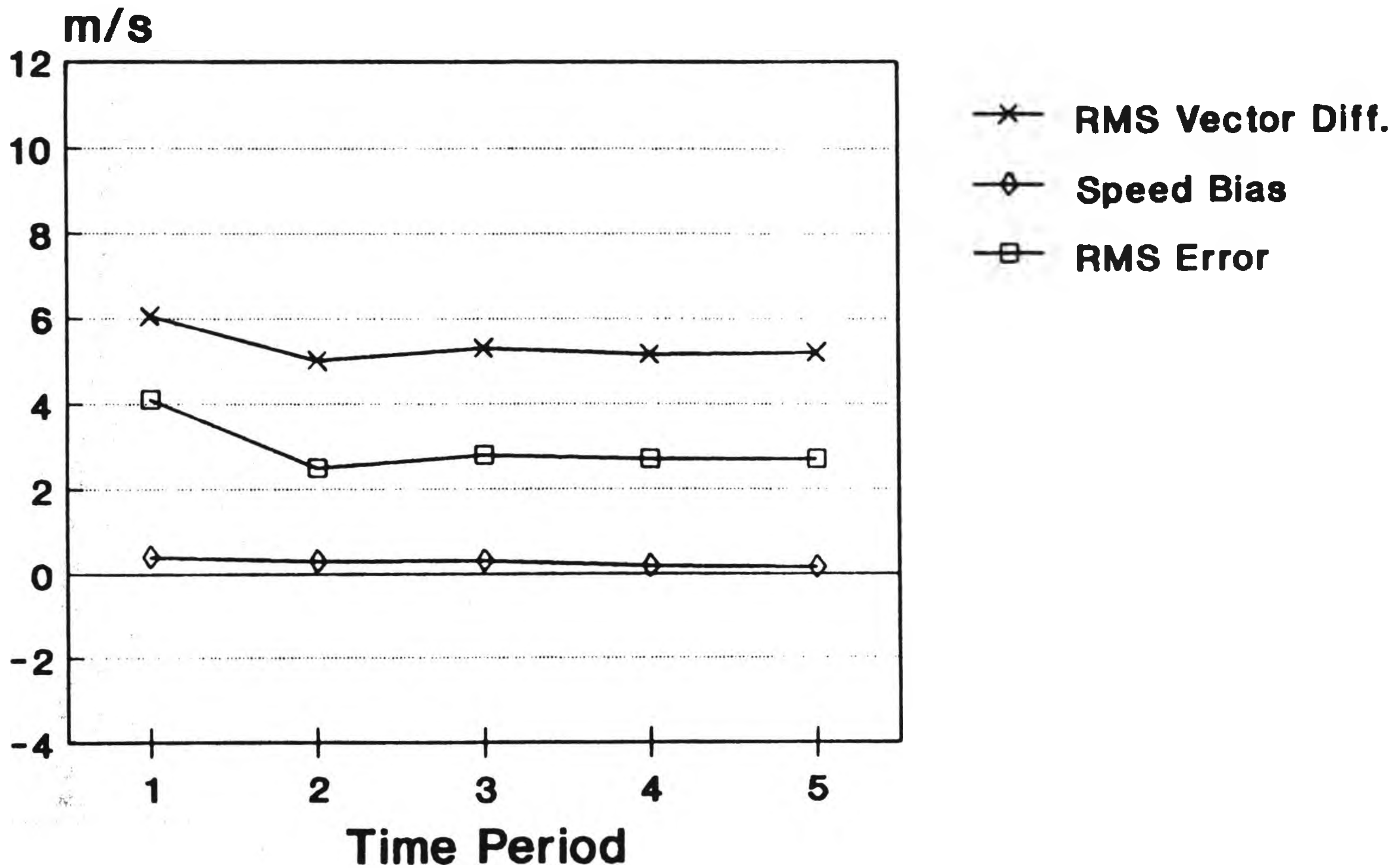
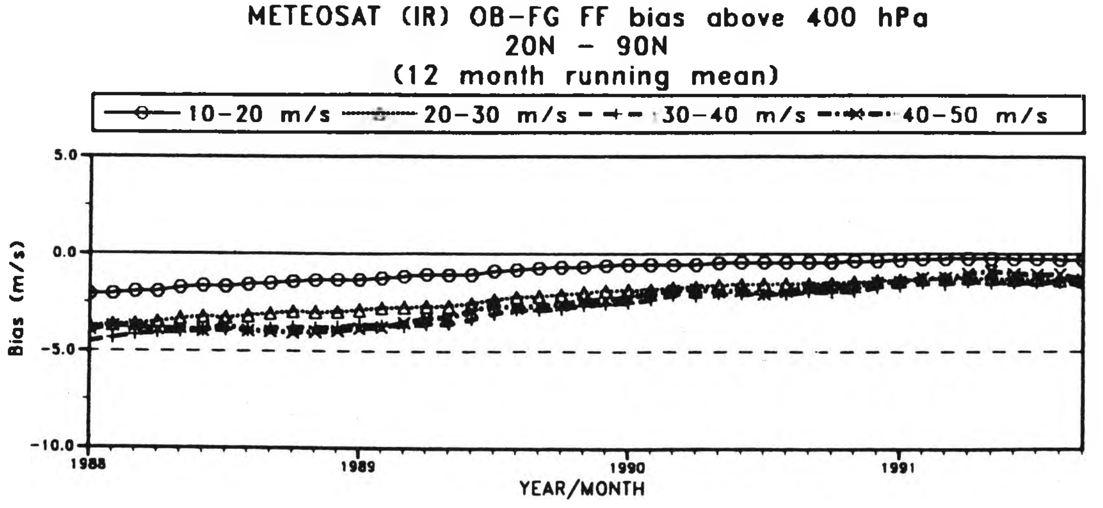
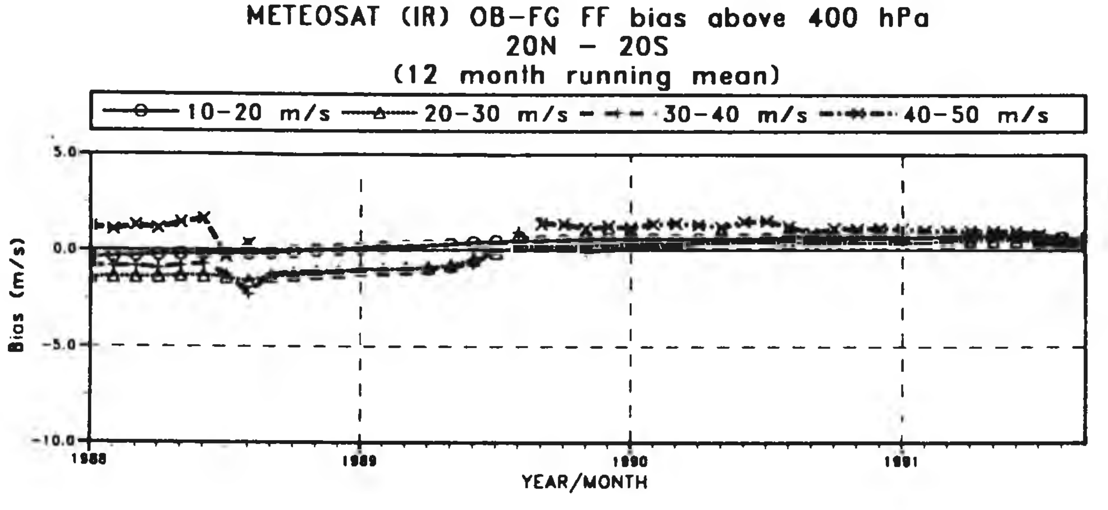


Figure 8

ANNEX IV





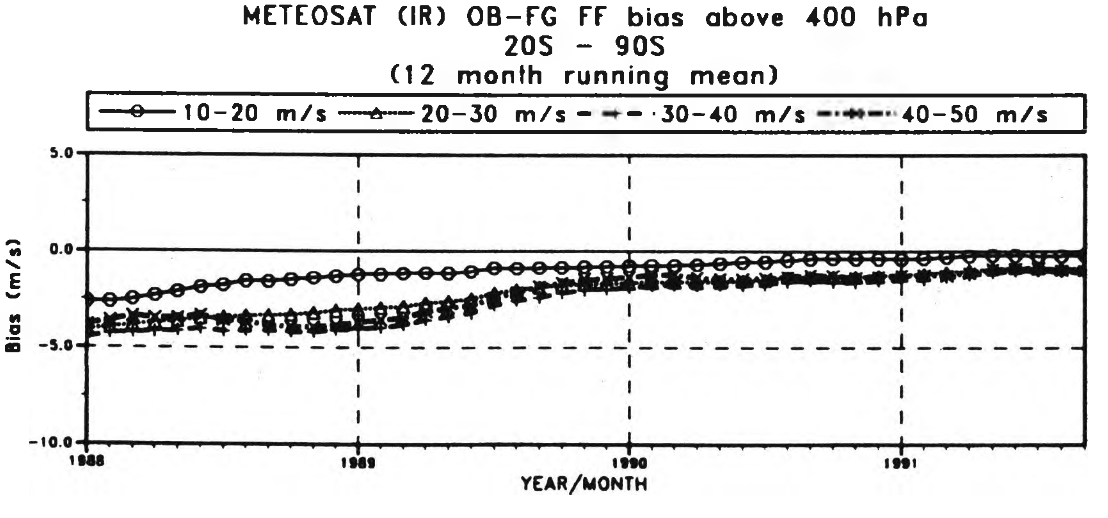
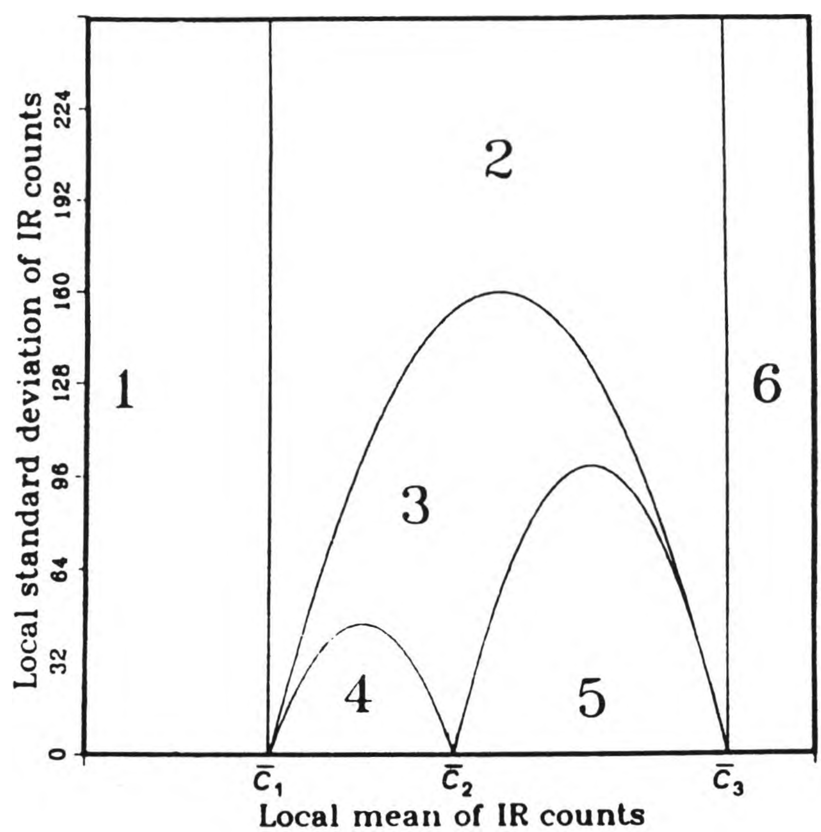


Figure 9



Local standard deviation of IR counts
0
32
64
96
128
160
192
224
1
2
3
4
5
6
$\bar{C}_1$
$\bar{C}_2$
$\bar{C}_3$
Local mean of IR counts

Figure B1

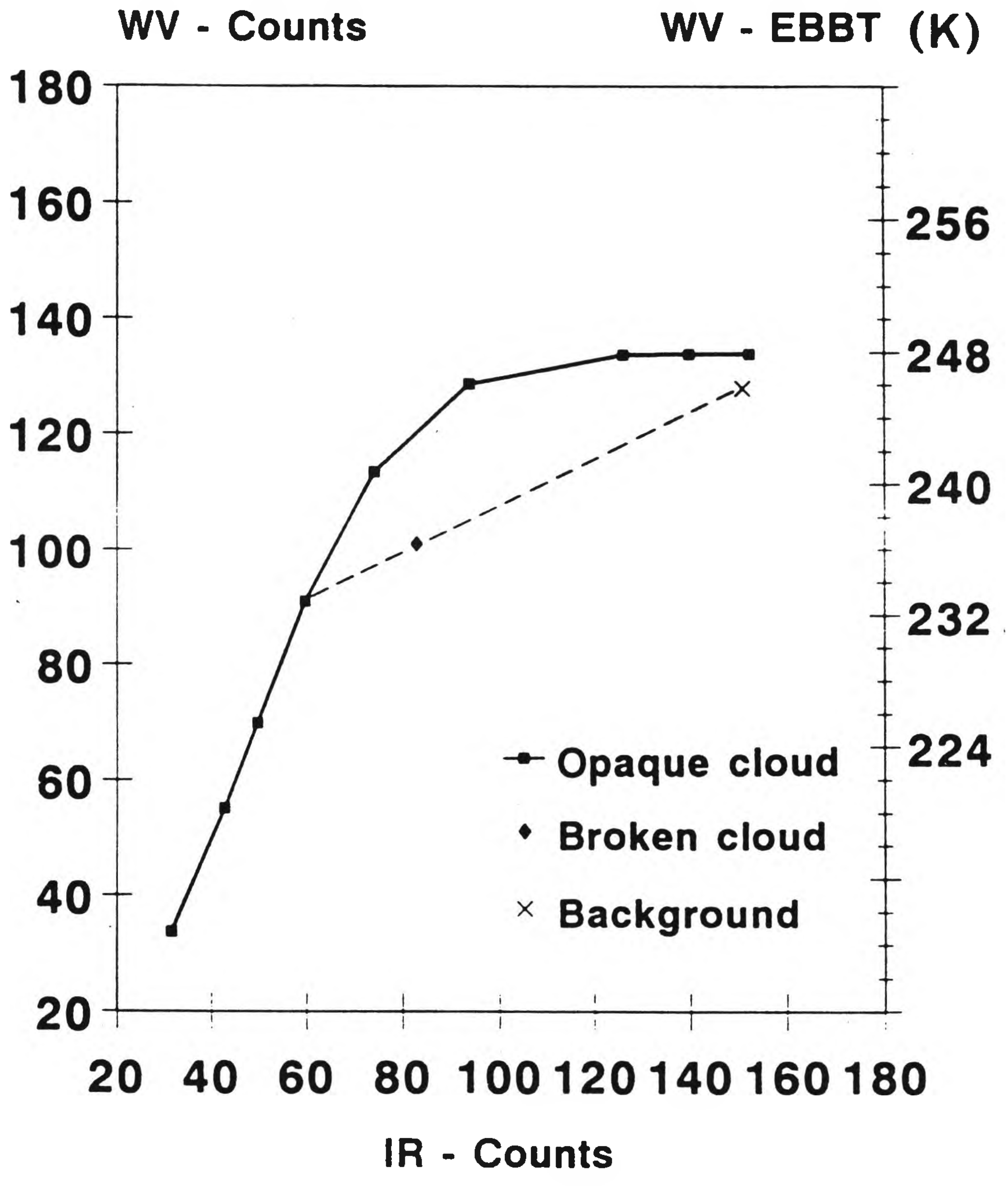

WV - Counts
WV - EBBT (K)
180
160
140
120
100
80
60
40
20
256
248
240
232
224
Opaque cloud
Broken cloud
Background
20 40 60 80 100 120 140 160 180
IR - Counts

Figure C1

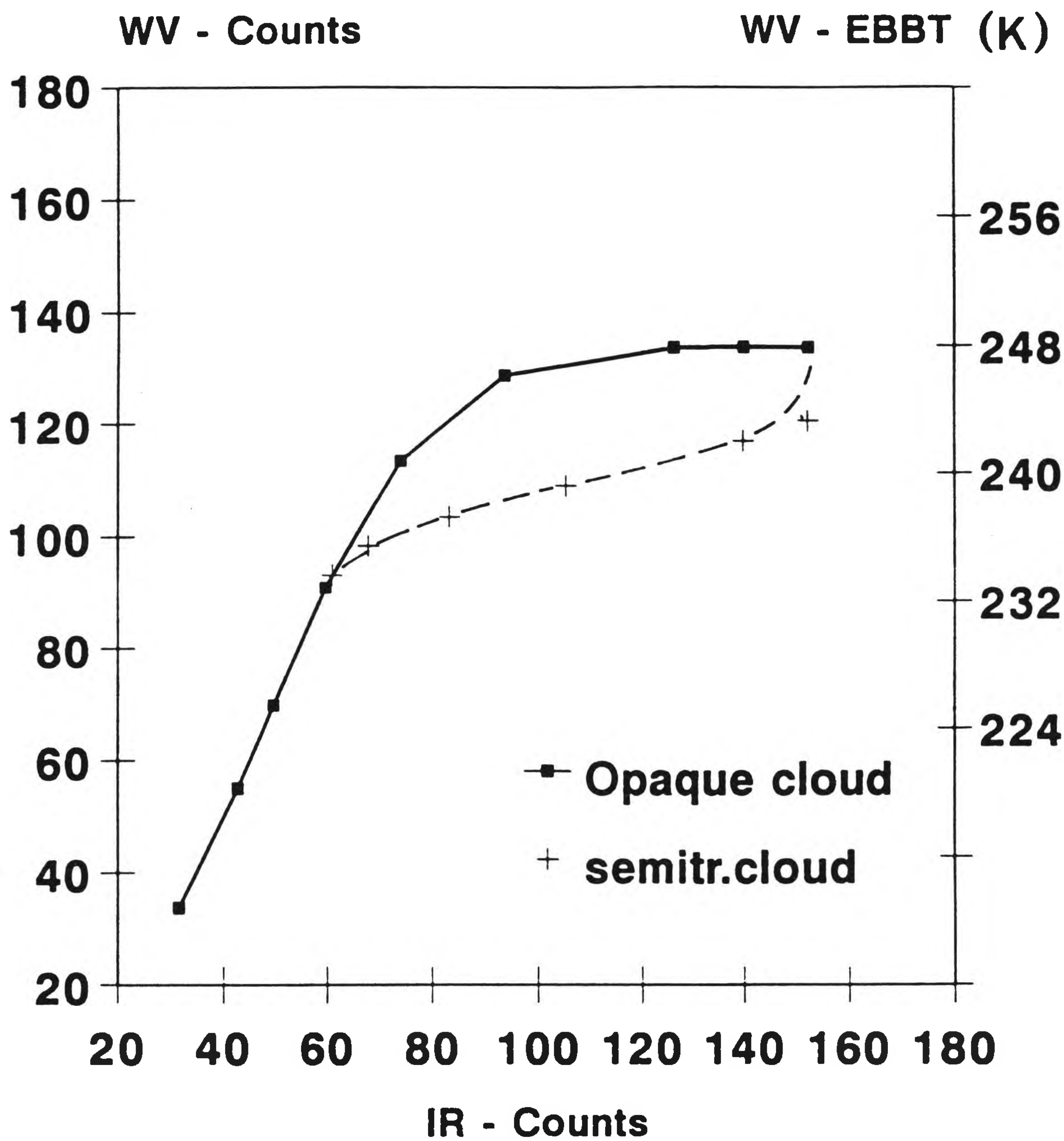

WV - Counts
WV - EBBT (K)
180
160
140
120
100
80
60
40
20
256
248
240
232
224
Opaque cloud
semitr.cloud
20
40
60
80
100
120
140
160
180
IR - Counts

Figure C2

CGMS-XXI ESA WP-07
Prepared by ESA
Agenda Item: WGII

Cloud Motion Wind Processing (WV and VIS) at ESOC

WV Winds

The WV wind processing scheme has continued to run on a quasi-operational basis twice per day for the nominal times of 00 and 12 UTC. The derived data are disseminated in SATOB coded form via RTH Offenbach to ECMWF.

Since CGMS-XX a number of changes have been incorporated in the derivation of the product. Manpower has never been available to quality control this product manually therefore a concerted effort has been made to introduce automatic quality control (AQC) techniques to improve the product quality. In many respects WV winds can also be seen as a test bed for AQC techniques which could also be applied to IR winds and eventually VIS winds

The techniques which have been introduced are relatively simple and consist mainly of nearest neighbour consistency checks for height, wind speed and wind direction. The system currently in operation will accept a wind if all of these parameters agree, within predefined limits, with at least one other wind in one of the eight neighbouring METEOSAT segments (a segment is an area of 32 x 32 WV pixels in which a wind can be derived). At the same time the software has been redesigned so that all quality control features of the processing are performed after the calculation of all possible winds. Thus the symmetry check on two consecutive half-hourly winds now forms part of the AQC processing. The application of these AQC techniques resulted in a noticeable improvement of the overall quality of the WV winds such that it started to approach that of the METEOSAT IR winds.

Nonetheless there was still a significant number of rogue winds present in the dataset; these were often associated with the tracking of water vapour features in the image, rather than clouds. Therefore, it was decided to try an alternative approach whereby only high level clouds, as determined from the analysis of the IR image, would be tracked in the water vapour images. At the same time height assignment became based on radiances determined from the IR image, in particular since no really solid method had been determined using only water vapour radiances. The results of tests were rather convincing and, despite this approach deviating from the original intention of being able to track water vapour features, the new scheme was introduced operationally during December 1992. It is noteworthy that the number of high level winds produced by this new scheme considerably exceeds those produced by the IR wind extraction scheme (80% more winds in the first month of operation). The attached tables provide a comparison of WV and IR winds derived during the first weeks of operation of the new scheme.

VIS Winds

Work has continued on the extraction of winds from visible channel only data. The major problem is of course height assignment and although the only logical solution is to use heights determined from the infrared channel, one can never be sure that the feature tracked in the visible image is the same for which a height was assigned in the infrared channel. The overall result is that the wind field produced from visible images is closely aligned to that produced from IR images. Although more winds are produced it is often difficult to assign a height to some of the additional winds.

Since visible images from METEOSAT have twice the geometric resolution of those of the IR and WV channels the next change to be introduced will be the derivation of winds from segments consisting of 32 x 32 visible pixels. The improved geometric resolution should enable a more precise derivation of wind speed and direction and also an increase in the number of winds extracted. When performing automatic quality control the availability of more winds, e.g. for nearest neighbour consistency checks, should result in a greater confidence of those winds which actually pass the test. Generally, the availability of winds derived from all radiometric channels should benefit AQC techniques.

Parameter	IR	WV	IRALL	WVALL
Vec diff	7.6	7.7	8.2	8.3
Vec RMS	9.4	9.4	9.6	9.8
Spd diff	0.3	0.9	-0.9	0.6
Spd RMS	6.9	6.9	7.4	7.8
Dir diff	-0.2	-0.5	-0.9	0.2
Dir RMS	19.4	20.7	14.8	16.9
CMW spd	29.0	29.4	29.5	27.7
R/S spd	28.7	28.6	30.4	27.1
Number	386	386	749	774

Table 1. Comparison of WV and IR High Level Winds: Slot 22, 23 December 1992 - Slot 22, 24 January 1993. The statistics for 'IR and 'WV' relate only to segments where both an IR and WV wind was produced and a radiosonde comparison was possible. The 'IRALL' and 'WVALL' show the statistics for all possible comparisons.

REPORT FROM THE INTERNATIONAL TOVS WORKING GROUP

by J R Eyre and M J Uddstrom
Co-chairs, ITWG

February 1993

1. INTRODUCTION

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

Most of the meeting was occupied with scientific presentations on a broad range of issues. During the latter part of the conference, working groups were formed to consider four of the main issues: TOVS data in climate studies, TOVS data in numerical weather prediction, preparations for Advanced TOVS (ATOVS) data and future systems. The working groups reviewed recent progress in these areas, made recommendations on key areas of concern and identified items for action. During one short session, the conference divided into three technical sub-group to discuss developments and plans concerning specific software packages in common use among TOVS processing centres.

A "Report on the Seventh International TOVS Study Conference" is being prepared. It will include an executive summary, the reports of the working groups and technical sub-groups, and the abstracts of the scientific contributions. Below, we have extracted from the draft of this report those items which we would like to bring to the early attention of CGMS.

The full text of the scientific papers will be published separately in the "Technical Proceedings of the Seventh International TOVS Study Conference".

In addition, ITSC-VII endorsed a report "ITWG: a Strategy for the 1990s" which includes a discussion of the present and desired relationships between ITWG and other bodies, including CGMS.

2. CONCLUSIONS AND RECOMMENDATIONS FROM ITSC-VII

2.1 Future systems

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

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

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

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

2.2 Preparations for ATOVS data

2.2.1 The following statement from NESDIS was noted:

> " NESDIS intends to make the "RTOVS" software available for distribution as soon as possible. This will be after the software is running operationally at NESDIS. The software will be shared by NESDIS with EUMETSAT, where there will be a NOAA/EUMETSAT agreement on a standard software package.
> The "RTOVS/ATOVS" software package(s) will be prepared for international distribution through the CGMS.
> The ITSC would be an ideal group to recommend what the 'standard software' package should be. "

ITWG welcomed these developments and expressed its appreciation to NESDIS and EUMETSAT for their assistance in this important area.

2.2.2 ITWG stressed the desirability of full international distribution (i.e. beyond EUMETSAT member states and NESDIS) for code to process ATOVS data and recommended that this matter be brought to the attention of CGMS.

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

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

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

2.3 TOVS data in numerical weather prediction (NWP)

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

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

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

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

2.3.5 To improve the utilization of radiance data, more accurate fast radiative transfer models are required. At present their deficiencies limit the information which may be extracted from the measured radiances.

2.4 TOVS data in climate studies

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

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

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

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

European Centre for Medium-Range Weather Forecasts

Centre européen pour les prévisions météorologiques à moyen terme

Europees Centrum voor weervoorspellingen op middellange termijn

Europäisches Zentrum für mittelfristige Wettervorhersage

Centro europeo per le previsioni meteorologiche a medio termine

R57.6.2/JE/78

Direct line: 499621

2 February 1993

Mr J Morgan
Director
Eumetsat
Am Elfengrund 45
D-6100 Darmstadt-Eberstadt

Dear John

Relationships between CGMS and the International TOVS Working Group (ITWG)

On behalf of my fellow ITWG co-chair, Dr Michael Uddstrom, and myself, I am writing to follow up our previous discussions concerning the relationship between CGMS and ITWG. At the recent Seventh International TOVS Study Conference (ITSC-VII), members of ITWG had a very full and lively discussion of this and related issues, and they endorsed the following statement:

"At ITSC-VII, members of ITWG discussed the formal status of the group and its relationships with other bodies. It was recommended that:

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

We should be very grateful if you could bring this matter to the attention of CGMS and ask them to consider what might be the most appropriate form for the proposed interactions in the future. We have in mind some mechanism which allows ITWG to put its recommendations and concerns for consideration by CGMS, and which allows CGMS to put appropriate technical questions to ITWG.

Attached are copies of the two documents you requested we prepare in advance of the next meeting of CGMS:

- A revised version of the document "ITWG: a Strategy for the 1990s", which has now been endorsed by ITWG. It contains in section 3.2.3 a revised proposal for relations with CGMS as outlined above.

.../2

Please address all correspondence to THE DIRECTOR: DAVID BURRIDGE

Shinfield Park, Reading, Berkshire RG2 9AX, England. Telephone: U.K. (0734) 499000. International (+44 734) 499000. Telex 847908 ECMWF G, Fax (0734) 869450.

- A brief report on those conclusions and recommendations of ITSC-VII which we should like to bring to the attention of CGMS. We should be interested to hear of CGMS's reactions to these matters and of any plans to address them.

The "Report on ITSC-VII" and the "Technical Proceedings of ITSC-VII" will become available later this year. Please could you advise us whether these documents will be of interest to CGMS members and to whom they should be distributed.

ITSC-VII was a very lively and successful meeting, and we are very grateful for the EUMETSAT support which helped to make it so. Marilena Perrone and Dieter Klaes made excellent contributions. Silke Trautmann's hard work, efficiency and cheerfulness with diverse aspects of the local organisation were greatly appreciated by all, especially the co-chairs. Please pass on our thanks to them. Regarding your generous financial support for the meeting, I shall provide an account of our expenditure as soon as possible.

Best regards

J R Eyre
Co-chair, ITWG

Enc

Copies: Dr M J Uddstrom, Co-chair ITWG, NIWAR, New Zealand
Mr G Bridge, EUMETSAT
Dr D Hinsman, WMO

Version dated 22 February 1993

INTERNATIONAL TOVS WORKING GROUP: A STRATEGY FOR THE 1990s

by

J R Eyre and M J Uddstrom
co-chairs, ITWG

CONTENTS

1. INTRODUCTION

The International TOVS Working Group (ITWG) was formed in 1981 under the auspices of the International Radiation Commission (IRC) in order to promote international collaboration in research and development on data from the TOVS (TIROS Operational Vertical Sounder) instruments on the NOAA series of polar-orbiting satellites. Over the last decade, ITWG has undertaken a range of activities based around the International TOVS Study Conferences (ITSCs), of which there have been six.

As a result of the considerable efforts of its previous co-chairs (1981-86: Dr W L Smith and Dr R Rizzi, 1986-91: Dr W P Menzel and Dr A Chedin) and the enthusiastic support of its members, ITWG has been effective in promoting a great expansion in the TOVS data user community and in raising the level of skill with which the data are processed and applied. Recognizing that international activities on TOVS data processing have developed considerably in the decade since the inception of ITWG, it now seems an appropriate time to review its achievements and to consider its aims and objectives for the next decade.

In this document, we

- review briefly the past activities and achievements of ITWG/ITSC,
- review the aims of ITWG,
- consider the new challenges to be faced, and
- propose specific objectives for the next few years.

Its purpose is to serve as a focus for discussion on these issues within ITWG and as an aid to communication with other bodies (e.g. IRC, WMO, satellite agencies).

2. REVIEW OF ITWG ACTIVITIES

2.1 Background

ITWG was formed as a working group (WG) of the IRC in 1981, and IRC recommended that a Study Conference should be organised to consider the results of activities to improve TOVS retrieval algorithms. Following 3 meetings of a small group of European scientists in Innsbruck, Berlin and Bologna during 1981-2, the full international group met for the first time at the First International TOVS Study Conference (ITSC-I) in 1983, and 6 more conferences have followed at 18-24 month intervals:

ITSC-I	Igls, Austria	29 August - 2 September 1983
ITSC-II	Igls, Austria	18-22 February 1985
ITSC-III	Madison, Wisconsin, USA	13-19 August 1986
ITSC-IV	Igls, Austria	16-22 March 1988
ITSC-V	Toulouse, France	24-28 July 1989
ITSC-VI	Airlie, Virginia, USA	1-6 May 1991
ITSC-VII	Igls, Austria	10-16 February 1993

Each meeting has served both as a scientific conference at which the latest scientific and technical developments on TOVS data have been presented and discussed, and also as a working group in which common problems have been identified and their solutions pursued, either internally within the ITWG community or in collaboration with other bodies.

Each conference has been documented as a Report (including an executive summary, working group reports, abstracts of presentations and a mailing list of participants) and Technical Proceedings containing papers presented. Participation at the conferences has ranged from 50 to 80 scientists, and about 30 countries are represented in the current membership.

Apart from the activities of the conferences themselves, ITWG activities have continued between conferences in several ways, including:

- development, maintenance and distribution of TOVS software packages to research institutes and national meteorological centres,

- reports on tasks listed as actions at the preceding conference, and identification of new problems requiring attention,

- conduct of several TOVS data case studies, involving distribution of common data sets, processing by participating members at their home institutions using a variety of techniques, and collation and evaluation of results,

- meetings of sub-groups on particular problems, e.g. preparation for processing Advanced TOVS (ATOVS) data,

- reports to CBS of WMO by designated rapporteurs (Dr J LeMarshall and Dr W P Menzel).

2.2 Aims and emphasis of activities

ITWG was created by IRC specifically to organise a study conference (ITSC-I) to compare the results from different TOVS processing algorithms. Its continuing activities and broadened scope have been largely self-motivated.

Initially ITWG was concerned almost exclusively with the problem of retrieving from TOVS data information on the temperature and humidity structure of the atmosphere in the context of weather analysis and forecasting. This is still the primary concern of most ITWG members, but there has been a growing interest in other potential applications of TOVS data, including the analysis of cloud, ozone and surface temperature. Also, the potential uses of the TOVS data archive (now exceeding 12 years continuous global coverage) in climate analysis has received increasing attention.

ITWG has given some consideration to a number of other areas, including:

- AVHRR data, particularly their use in combination with TOVS data,

- data from sounders on geostationary satellites, i.e. VAS, where scientific problems in common with TOVS arise,

- data from the instruments SSM/T and SSM/I on the USA's DMSP satellites,

- plans for future satellite sounders, particularly Advanced TOVS and infra-red sounders of high spectral resolution,

- related ground-based and aircraft measurements.

Because of its focus on tropospheric analysis for weather forecasting and despite the presence of stratospheric temperature sounding channels as part of TOVS, ITWG has paid little attention to the retrieval of information on stratospheric temperature (except in so far as it improves the interpretation of tropospheric information) and has had relatively little contact with the scientific community concerned with the middle atmosphere.

2.3 Summary of achievements

The main achievements of ITWG have derived from activities internal to the TOVS data community itself:

- Exchange of information on developments in the science of satellite sounding and retrieval algorithms.

- Exchange of technical information on satellite/instrument parameters, etc.

- Distribution of TOVS data processing packages and exchange of information to improve them.

- Assistance and training to new users of TOVS data. This has included provision of lecturers at training workshops supported by WMO.

- As a catalyst for collaborative research experiments.

It is chiefly as a result of these activities that there has been such a growth in the number of organisations which receive and process TOVS data and an increase in the level of skill with which they do so.

Another area of achievement has been:

- Evaluation of the accuracy, impact and utility of TOVS products.

This has been achieved mainly through a number of case studies. Evaluation of their results has demonstrated and confirmed the level of skill in TOVS processing which has now been obtained. More importantly, it has highlighted areas of weakness and focused the attention of the TOVS community on important areas of activity (e.g. radiative transfer modelling and tuning, treatment of cloud).

Important progress has been made in the use of TOVS data in numerical weather prediction (NWP) as a result of:

- Feedback between the generators of TOVS products (chiefly NESDIS) and the community of users.

- Improving the interface between TOVS data and NWP systems.

One of the most encouraging recent developments has been the increased dialogue between the satellite sounding and NWP communities, in which ITWG has played a significant part. The fruits of this dialogue are now beginning to appear in more effective use of TOVS data within NWP systems.

Significant achievements have also been made in the following areas involving collaboration with other bodies and scientific communities:

- Alerting the TOVS user community and other bodies (e.g. satellite agencies, WMO) to scientific and technical issues requiring action or research.

- Promoting and exchanging information on related activities (e.g. the IRC Working Group on Intercomparison of Radiance and Transmittance Algorithms, ITRA) and supporting measurement campaigns.

- Demonstrating new processing technologies (e.g. TOVS processing and display on low-cost PCs).

- Providing input to decisions on future satellite systems (e.g. maintenance of direct read-out facilities, promotion of sounders of high spectral resolution).

2.4 Problem areas

It may be useful at this point to list some areas in which activities of ITWG have been less successful than anticipated or where the achievement has been significantly different from the expectation.

- Common processing software. An original objective stated for ITWG was to seek a standard set of algorithms incorporating the "best method" for processing TOVS data. This has not been achieved. Indeed, ITWG has increasingly come to the view that it is not even desirable, since the best method depends on the user's application and on the computer resources available. However, there is agreement that it is desirable to achieve common methods and algorithms for certain steps of the processing. This has been achieved to a large extent for TOVS through common software packages, and it is a stated intention of the community for future sounding systems. Also, despite the diversity of retrieval methods which still exist, there has been a considerable convergence of approach where the application is common (e.g. NWP).

- Baseline Upper Air Network (BUAN). The idea of BUAN was strongly promoted by ITWG as a means of providing a high-quality radiosonde data set to tune the radiative transfer models required in the interpretation of TOVS data. Under the auspices of WMO, an experimental trial of BUAN was planned and conducted in 1988. This exercise was useful as a pilot study; it revealed some logistical problems and yielded information for improving any future project. However, mainly due to lack of availability of the data to the ITWG community, the original purpose of the BUAN (as conceived by ITWG) has not yet been tested.

- Preparation for ATOVS. As early as ITSC-II (1985), ITWG identified a need for the TOVS community to prepare for ATOVS data. Despite considerable discussion and a dedicated sub-group within ITWG, it has had limited success in persuading other bodies (apart from NESDIS) to make significant provision of resources in planning for ATOVS data processing. However, developments at ITSC-VII promise significant progress in the near future.

- External contacts. ITWG contains a unique blend of international expertise on satellite sounding, and it is well placed to offer advice and make proposals regarding present and future satellite systems. This has occurred already, with a degree of success in some areas. However there is a strong feeling within ITWG that it could play a more useful role in this respect if it had more effective interfaces to other organisations. Until now, the relations between ITWG and other bodies have been rather informal, and this has impeded the use of ITWG's significant pool of expertise in a more systematic and effective manner.

2.5 Strengths and weaknesses

ITWG represents a small international group of committed scientists active in the fields of research and development on TOVS data and their operational exploitation. The day-to-day proximity of its members to the scientific and technical problems involved leads to a very high level of internal debate on these issues and to a body uniquely positioned to consider some of the problems posed in relation to future sounding instruments.

The focus of attention within ITWG on a single set of operational instruments (rather than atmospheric sounders or satellite instruments in general, or some broader scientific theme) has had considerable advantages. It has kept the number of participants reasonably small and hence the WG's activities manageable. It has also allowed technical issues and practical problems posed by TOVS to be addressed in the detail required, without dilution through the need to consider broader issues.

These, then, are the strengths of ITWG; however, its weaknesses stem also from its nature as a rather ad hoc gathering. Apart from its status as a WG of IRC and its reports to WMO, it has no formal status in relation to other bodies. This is the main cause of its limited influence on future system planning as reported above (section 2.4). In addition ITWG has no resources (other than those obtained to stage individual conferences) and no secretariat. This limits the kind of activities which it can effectively pursue and, whilst there are many useful things which can be achieved under these conditions, it is important to recognise what they are. A review of the recommendations and action items from past ITSC and the success rate for their fulfilment shows that there are certain categories of activities which are not effectively pursued given ITWG's present structure and resourcing.

3. FUTURE STRATEGY AND PLANS

3.1 Revised aims

Taking into account the evolution in the TOVS data community and its level of expertise, and the planned changes in satellite sounding instrumentation, it is proposed to revise the aims of ITWG into three general areas:

- to promote improvements in the processing and application of TOVS data,
- to promote effective preparation for and subsequent exploitation of sounding data from new operational satellite systems,
- to liaise with relevant agencies on the planning and implementation of satellite sounding systems and their ground segments.

3.2 Continuing activities and new challenges

3.2.1 **Improving the exploitation of TOVS data**

Successful activities should be continued in order to maintain and enhance the exploitation of TOVS data by the international community:

- Exchange of information on: sounding science, technical aspects, software packages, supporting measurement campaigns.
- Assistance to new users.
- Evaluation of accuracy and utility of products.
- Promotion of improved applications in NWP and synoptic analysis.

Initiatives are required to address new challenges including:

- Extending and improving the use of TOVS data in climate analysis.
- Extending the understanding of TOVS data and its processing through appropriate training initiatives.

3.2.2 **Preparing for new sounding data**

In preparation for ATOVS, increased efforts are required on:

- Improving understanding of the relevant radiative transfer problems.
- Developing processing algorithms for ATOVS data.
- Preparing for operational transitions from TOVS to ATOVS processing.

As design and implementation plans mature for infra-red sounders of high spectral resolution, a line of development activities comparable with those listed for ATOVS will be required.

3.2.3 Liaison with other agencies

Continued efforts are required in:

- Maintaining and improving contacts with satellite agencies.
- Maintaining and improving contacts with other bodies (e.g. IRC, WMO, CGMS) and relevant scientific programmes (e.g. GEWEX, GCOS).
- Giving effective input to the planning of new satellite programmes.
- Identifying research and development required in support of future systems.

ITWG can play a valuable role by relaying scientific and technical recommendations to other agencies. However, this will be most effective if its relationships with other bodies are clear and if they are aware of what ITWG is trying to do and of ITWG's potential contributions to their activities.

At ITSC-VII, members of ITWG discussed the formal status of the group and its relationships with other bodies. It was recommended that:

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

3.3 Specific objectives

ITWG will promote activities in support of the following objectives. In the field of NWP:

- to achieve consistent positive impact of TOVS data in both hemispheres in global-scale models,
- to achieve positive impacts in regional-scale models,

- to achieve increased use of the humidity information in TOVS data.

In the field of climate studies:

- to define and promote TOVS products suitable for climate monitoring and research,
- to achieve high-quality and consistent data sets of TOVS radiances and products, suitable for climate research, through re-processing of the complete TOVS data archive,
- to quantify the error characteristics of these data.

In the field of education and training:

- to increase the number of users skilled in the processing and application of TOVS data,
- to promote workshops on the processing and application of operational satellite sounding data.

Concerning ATOVS data:

- to achieve a common framework of software for processing ATOVS data,
- to achieve a smooth operational transition from TOVS to ATOVS without reduction in skill, for global data and for locally-received data,
- to exploit those new features of ATOVS which should lead to improved impact compared with TOVS.

Concerning infra-red sounders of high-spectral resolution:

- to secure the provision of high-resolution sounders on operational polar satellites as soon as possible,
- to develop algorithms for processing and applying their data.

Concerning liaison with other agencies:

- to conduct systematic reviews of the plans of NOAA and Eumetsat concerning present and future sounding systems and to provide useful feedback.

4. RESOURCES

The chief resources of ITWG have been the efforts and enthusiasm of its members and the support of their home institutions. However, in addition, the financial resources required to support ITWG activities have not been insignificant. They can be divided into 3 main categories:

- Support for the staging of conferences. An ITSC costs around $30 K, which includes the costs of the conference centre, travel support, publication costs and correspondence with members. ITWG has received valuable support, particularly towards travel support, from a number of sponsoring agencies. Most other costs have been borne by the host institute or have been absorbed by one or two of the members' institutions. For each conference the funding has been assembled in an ad hoc manner; there is no guaranteed or long-term support.

- Support for activities between meetings (e.g. sub-group meetings, case study activities). Valuable support has been obtained from sponsoring agencies for some travel expenses. Apart from this, all activities have been supported by members' home institutions.

- Support for software packages. There are two TOVS processing packages which are readily portable and widely distributed. These are the ITPP package developed at CIMSS and the 3I package from LMD. Development costs have been borne almost entirely by these two institutes, with a little help in terms of feedback of ideas and code from other ITWG members. Until recently, maintenance and distribution costs were also borne by the developers, but in future it is planned that these will be supported through software licence agreements. It is not yet clear how these aspects will develop on the timescale of ATOVS.

Regarding the funding of these activities, it should be possible to continue with the ad hoc means of support which have been used so far. However, these impose limitations, particularly on the scale of activities which can be supported between conferences and hence on the types of activities which ITWG can effectively pursue. These limitations must at least be recognised when planning activities. Higher levels of activities would require a higher level of support and one which is more assured.

5. CONCLUSIONS

ITWG has recorded a number of significant achievements over the last decade and has been an important factor in the growth and improvement in the exploitation of TOVS data around the world during this period.

During the next decade we can see a continuing role for ITWG, although with its aim and objectives modified to take account of recent developments and the new challenges of the 1990s.

EUMETSAT ACTIVITIES FOR THE ATOVS PROCESSING

K. Dieter Klaes and Marilena Perrone
EUMETSAT
Am Elfengrund 45
D-6100 Darmstadt
Germany

1 INTRODUCTION

By 1996 the polar orbiting satellites of the NOAA/TIROS-N series will undergo a considerable improvement in their instrumentation. There will be a new set of sounding instruments for the retrieval of the three dimensional thermodynamic structure of the atmosphere from space. The current TIROS Operational Vertical Sounder (TOVS) will be replaced by a set of advanced instruments, including a set of microwave instruments. This Advanced TOVS (ATOVS) will include the HIRS/3 20 channel infrared sounder as well as the microwave sounders Advanced Microwave Sounding Unit A (AMSU-A, 15 channels) for temperature sounding and the Advanced Microwave Sounding Unit B (AMSU-B, 5 channels) for humidity sounding.

In view of the need for increased European activity in the area of soundings, EUMETSAT is conducting a project for the development of an ATOVS software package. The objective of the project is to provide the user community with a core processing system before the launch of NOAA-K, currently scheduled for January 1996, for processing direct readout ATOVS data received locally in real time. The processing package shall also be applicable to global processing requirements and coherent with the ATOVS system developed and implemented by NOAA.

This project is of interest to EUMETSAT in view of the future *EUMETSAT* EPS responsibilities and activities. For these global ATOVS processing will be an important component.

2 PROJECT ORGANIZATION

To carry out the project *EUMETSAT* has set up a long term consultancy for the development of the software. The setup of the software will strongly rely on contributions of the international user community, i.e. from the ATOVS Working Group etc.

2.1 General

One of the potential starting items for the development is the NOAA/NESDIS RTOVS system, currently being under development and undergoing its final implementation phase. The architecture and the structure of the processing package will be designed on the basis of this platform.

The project work will be carried out at EUMETSAT HQ at Darmstadt. Nevertheless in course of collaboration with international users and organizations work will be done at NOAA/NESDIS Suitland, in close connection to the group who develops the ATOVS system. Work will also be carried out at ECMWF to ensure meeting the requirements for global processing and the integration into a global numerical weather prediction scheme.

Work at Research Institute will assure to meet the requirements of the research community and to allow for the integration of scientific issues.

2.2 Working Phases

In the project four working phases may be identified. The first phase is the **Definition Phase.** The user requirements are analyzed and summarized to provide a guideline for the development and initialize the exchange with the international user community. In this phase the review of the NOAA/NESDIS RTOVS software is also been performed as well as the identification of pending scientific problems and the proposal of their solution. This work, which requires close cooperation with the international community, has already been started within the frame of the ATOVS Working Group.

The second phase of the project is the **Development Phase.** This phase will include the definition of specific software requirements and the design of the system architecture. One decisive part of this phase is the proper definition of interfaces to guarantee the most possible flexibility and modularity and thus the highest degree of maintainability. Furthermore the detailed design of particular software modules and the essential coding of the modules will be carried out. This phase will also include necessary scientific studies with EUMETSAT financial support. Simulated data as well will be made available. It is planned at this stage that the Software Documentation and maintenance will be provided by *EUMETSAT*. The conditions and requirements for the distribution to the users will also be defined.

The third phase is the **Implementation Phase.** This means the implementation of the software system at sites to be decided before the launch of the NOAA-K satellite.

Testing of the system will be done using simulated data, but may include a TOVS version of the new system

The final phase is the **Demonstration phase** which will start with launch of NOAA-K. In this phase the system will be evaluated and the necessary adjustments will be done. The distribution to interested users will we prepared and done within 6 months after the launch of NOAA-K. Further planning will be done for the preparation of the EPS global processing.

2.3 International Collaboration

A collaboration with NOAA/NESDIS has been set up by a visit of the consultant in October 1992 to Suitland. The objective of this collaboration is to achieve the greatest commonality in the design of the system with the RTOVS/ATOVS architecture of the NOAA/NESDIS development. Common scientific approaches are envisaged AS WELL AS EUMETSAT/NESDIS formal agreement on software exchanges.

Coordination with the international user community is at this stage planned through the ATOVS Working Group which should guarantee the system with the most flexible architectural approach (e.g. multiple user defined algorithms).

3 STATUS

3.1 User Requirements

The work has been started with the employment of the consultant (D. Klaes) by EUMETSAT the 1 September 1992. The project is in the definition phase and is following the initial plan. The User Requirements Document (Klaes, 1992) is available in its first draft issue and will be reviewed by the user community. This document tries to give an overview on the user requirements of a wider user community for ATOVS data and products. The requirements of the essential software modules and their performance, i.e. what they are meant to do and what operations the modules have to perform, will be addressed by a document later in the Definition Phase, the Development and Implementation Plan.
The feedback from the TOVS conference on the document will go into this document.

The delivery of the NOAA/NESDIS RTOVS system has not been cleared yet and discussion is ongoing between EUMETSAT and NESDIS.

Visits to ECMWF, the UK Met Office, CMS Lannion, LMD and Deutscher Wetterdienst have been made for preliminary assess of the possible contribution(s) of these institutions to the software design.

3.2 RTOVS review

In October 1992 the consultant visited NOAA/NESDIS and could look at parts of the RTOVS processing system currently being in its final production state and just before parallel testing.

There are five major subsystems for RTOVS. The SPGS Soundings Product Generation Subsystem takes the level 1B data and generates the soundings output, conducting the inversion procedure after preparing the data (calibration, cloud clearing and/or limb correction). This was the part of RTOVS which was primarily reviewed. The radiosonde match subsystem (RMS) creates collocation controls with radiosondes and contributes to the creation of coefficients. It should be run only with operational data. It is run off line (that means not in real time mode). The data collection subsystem (DCS) collects the match data and composes them with the product data to update the coefficients with the coefficient update subsystem (CUS). This subsystem is as well run off line. The evaluation and testing subsystem (E&T) performs the same tasks as the whole system for development purposes and is run off line.

The system is set up in a very modular way. Generally each sequence of modules is called by a driver. The specific routines have their error handling, invoking special error routines which report to a log-file.

More details of the RTOVS review are summarized in a Review Document, which is available as a draft version.

3.3 Open Scientific Issues

Several items may be identified to be treated/resolved in the course of the ongoing project. They arise mainly from the results of the last ATOVS Working Group meeting within the framework of the ITWG at Palaiseau, France.

There may be three groups of issues be identified: Scientific problems, Processing and Data and Software related items. The Items are summarized in table 2. One of the expectations of the outcome of this conference is the feedback on this items and proposals for their resolution. Feedback is expected to give ideas on both how issues can be addressed/solved and who and where contributions can be made in which time frame.

For the project the first priority is on the software and the processing side at this time.

4 PLANS

The activities described in the previous paragraphs complete the definition phase. An ATOVS Development and Implementation Plan will be available in a draft form at the time of this conference. It will cover the time and resources needed to carry out the project as well as the breakup of the project into packages.

Using latest information and based on the User Requirements a preliminary design for the software will be compiled, accompanied by the detailed definition of the data interfaces. An assessment of all the ancillary data sets which are required to guarantee the processing will be also provided.

The work is proceeding according to the WORK SCHEDULE (see table 1) defined at the beginning of the consultant contract.

5 REFERENCES

Klaes, K. Dieter, 1992:
ATOVS processing Software: User Requirements Document. EUMETSAT, Darmstadt, issue 1.0, 38 + VII pp.

Klaes, K. Dieter, 1992:
ATOVS processing software: NOAA/NESDIS RTOVS Software Review Document. EUMETSAT, Darmstadt, issue 1.0, 67 + IX pp.

Table 1: Work schedule for the EUMETSAT ATOVS processing software.

YEAR	MONTH	WORK SCHEDULED
1992	09	Project starts, recruitment of consultant USER REQUIREMENTS DOCUMENT
	10	Visit of the consultant at NOAA/NESDIS, Suitland, Maryland, USA, to review the available documentation and the RTOVS code
	11	NOAA/NESDIS RTOVS SOFTWARE REVIEW DOCUMENT available.
1992	12	Visit to ATOVS Working Group member institutions ECMWF, UK Met Office, CMS/Lannion and LMD/Palaiseau. Preparation of the implementation and development plan.
1993	01	Preliminary design, Development and Implementation Plan Visit to Deutscher Wetterdienst
	02	ITSC VII, User feedback.
1993	03	Preliminary software design
	04	
	05	Preliminary software design available

YEAR	MONTH	WORK SCHEDULED
1993	06 07 08	Start detailed design Definition of data interfaces
1993	09 10 11	Start coding
1993 1994	12 01 02	Coding Preliminary Version of code up to the interface to the retrieval system(s)

ANNEX VII

PROCESSING/DATA

- reception	new ingest and decommutation software produce a level Ib data set
- instrument synchronization	get a standard for this (RTOVS approach ??)
- earth location(navigation)	standard, what about BROLYD ? (usable ?)
- test data	-create a simulated data set -cover different meteorological situations in different regions of the world -get satellite data from the assembled instruments on the satellite platform -get "similar" instrument data (SSM/I, SSM/T, MARSS) for validation
-instrument configuration	define valid instrument configurations
-ancillary data	what -surface elevation -surface type -microwave surface emissivity -surface albedos -standard surface temperatures resolution and cover where to get
- mapping	one standard procedure ? (like map a to b)
- transparency	data should always be able to be reduced to their original state

SOFTWARE

- modules	- maximum size - separation by processing or by scientific task or
both	
	- architecture standardized ---> different methods
usable	
	- well defined standardized interfaces necessary
- data sets	- make standard data sets with header, contents and standard file structure (one defined record length e.g, waste of space) - transparent ? - how big is the allowed overhead
- languages	- only standard, FORTRAN77 at present - no operating system dependent parts
- tools	- only for development, not for management

- libraries	- use of standards allowed (like IMSL, NAG etc.) - work arounds required (or vice versa)
- software distribution	- core system on floppy - JCL NOT provided (to remain independent)
- data set exchange tools	- to use different standards (IEEE, VAX, IBM) - transparent for users

ANNEX VIII

CGMS-XXI EUM-WP-25
Prepared by EUMETSAT
Agenda Item: II.6

Geostationary Meteorological Satellite Data Archiving and Retrieval Centres

An approach to common data formats, access and distribution

1 INTRODUCTION

The issues of common data formats, access and distribution are becoming of greater importance as the amount of archived data grows ever greater and the capacity for data production by new instruments increases. The recognition of the importance of these issues and the potential for applying standard approaches to their solution has led to a number of recommendations being made by various agencies and bodies.

Up to now there have been two main organisations involved in producing standards for space data handling: the Committee on Earth Observations Satellites (CEOS) and the Consultative Committee for Space Data Systems (CCSDS).

It is, of course, not mandatory for any new or existing archive system to adopt these recommendations, however, not to adopt them may mean lost opportunities for an effective global data exchange between institutions and organisations involved in satellite data handling. This applies, of course, as well to centres processing and archiving data from meteorological satellites.

This working paper provides an introduction to the subject in order to initiate discussions within CGMS members, on the establishment of standards for data from meteorological satellites. Although the charter of CGMS is broader, this paper concentrates only on geostationary meteorological satellites. It is proposed to coordinate the work with the organisations already involved in producing standards, i.e. CEOS and CCSDS.

An operational archive and retrieval facility for data from meteorological satellites must store satellite data and derived products, must allow users to search through these data and must provide users with copies of data requested.

The following sections of this document examine the issues related to the format in which data is stored in the archive, the format in which information on the archived data is presented and the format and media in which product data should be distributed to the users.

2 BENEFITS OF STANDARDISATION

The early Earth Observation projects used project specific methods for archive data handling and distribution. These projects had only limited requirements for interoperability with other projects.

It is expected that current and future Earth Observation programmes will span many decades and produce very large amounts of data. If this data is not handled correctly there will inevitably be inaccessibility problems. Therefore, with advancing in technology, the utilisation and application of standards and a layered approach to data handling is becoming even more important.

3 DATA FORMATS AND CATALOGUE SYSTEMS

This section reviews the standards that CGMS should consider as recommended standards for future meteorological satellite data archives. These standards originate mainly from CEOS and CCSDS, to which most of the CGMS members are affiliated or about to become affiliated. In addition, the WMO has established a number of code standards which are also applicable for satellite data archives.

3.1 Archive Data Formats

The CEOS is an international coordination group created in 1984 and maintains a family of data formats. Encouraged by the work on Landsat imagery formats standardisation CEOS have re-defined the initial formats to allow a more flexible approach to data formats and to remove the dependency of the format on the physical media. This has resulted in the **CEOS Superstructure** which enables data to be encapsulated within a standard framework.

The CEOS Superstructure has four basic components:

- Volume directory which globally defines the configuration of the tape or tape set
- File descriptors which describe in more detail the configuration of the files
- Logical volume, or a logical grouping of files on one or more physical volume
- Physical volume, i.e. a unit of physical medium (e.g. one CCT, one CD-ROM, etc.)

The overhead associated with the CEOS Superstructure can be calculated. Estimates for Meteosat data using all three spectral channels in full spatial resolution results in an overhead of about 5% of the total user data.

The CCSDS evolved, in the early eighties, from a NASA/ESA working group and is now organised as a number of panels, each looking at different aspects of space data handling. Panel 2 of the CCSDS is concerned with data interchange and archiving, and has investigated the problems associated with long term data storage and interchange of data between different agencies. This approach has resulted in the **Standard Formatted Data Unit (SFDU)** concept.

The SFDU concept is based on a single structure called the Label Value Object (LVO). This structure comprises two fields, the LABEL and a VALUE. LVO can be nested so that a compound LVO is built from a number of other LVO´s.

The percentage overhead associated with the CCSDS SFDU concept in the case of Meteosat data, with all spectral channels in full spatial resolution, is only 0.000079%. This extremely low overhead is achieved through the use of unique levels to identify elements of the SFDU.

The WMO (World Meteorological Organisation) is maintaining a number of international codes for meteorological data and other geophysical data related to meteorology. The binary codes BUFR (Binary Universal Form for the Representation of meteorological data) and GRIB (Processed data in the form of grid-point values expressed in binary form) could both be suitable formats for the archiving of satellite products and related data.

Within an archive and retrieval facility the archive data formats are only internally used presentations of data and a standardisation is not as important as for the distribution data format.

3.2 Distribution Data Formats

The distribution is concerned with the delivery of the archived data from the archive to the user. There are two main issues in distribution: the media used to transport the data; and the format in which the data is presented to the user.

Transportation media can be of many types, including for example magnetic tapes, optical discs, photographic paper or electronic network service. The choice of media type is influenced by the cost and quantity of the data required, cost of physical media, availability of media drives, method of transportation, etc.

Both CEOS and CCSDS use the same concepts for data storage and distribution, i.e. the CEOS Superstructure and SFDU concepts respectively.

The CEOS formats ease the problems of distribution of data to users through the adoption of a fixed formats on sequential access media. Consequently common software can be used to access the formats. Because the number of formats that a user can interpret is limited more flexible approaches using the Superstructure concept to encapsulate multiple data formats are being studied including the use of data description languages.

The CCSDS SFDU concept requires that all data is completely self describing. This means that all data must be accompanied by a data description, either in complete form with the data or by using a reference to a registered description.

The WMO binary codes are used for data distribution on the WMO GTS (Global Telecommunication System) and could, of course, be used for data distribution from a meteorological satellite data archive.

3.3 Catalogue Systems

Modern archive systems do not exist as closed systems serving a known group of users. The description of the archive contents given by different catalogues must be easily understood by a large number of international users with experiences in different disciplines. The catalogue itself should be accessible by outside systems, at least to the extent that a user can make a decision as to whether the archive contents may be of interest. This open, interoperable approach requires common standards across all cooperating archives for catalogue formats.

CEOS has defined different levels of interoperability. The directories of the participating catalogue systems in the International Directory Network (IDN) achieve interoperability by use of a standard file format for directory records, known as the Directory Interchange Format (DIF). This enables an International Master Directory to be created which holds information about each catalogue and, amongst other details, describes how to link to the catalogue system.

The catalog systems defines the first level of interoperability. The further levels will include standardisation in the area of inventory, guides and browse.

CCSDS does not currently offer an alternative to the CEOS catalogue formats.

4 ARCHIVING TECHNOLOGY

Archiving technology now ranges from conventional magnetic disk to optical disk solutions to both magnetic and optical tape systems. Two different applications have to be distinguished, long-term archiving and distribution. The following concentrates on media used for data distribution.

The Computer Compatible Tape (CCT) remains the most common medium worldwide for mass storage and data distribution. It is extremely well established and widely available with a very high degree of hardware compatibility. However, its dominance is being eroded by the physical size of tapes and drives and by the storage capacity (50 - 170 MBytes) which compare poorly with newer technologies.

It will be necessary in the framework of international projects in which meteorological satellite data are exchanged (e.g. the WMO International Satellite Cloud Climatology Project, ISCCP and the WMO Global Precipitation Climatology Project, GPCP) to agree which archive media are used in future for data exchange. For instance, the ISCCP has started to use cartridges instead of magnetic tapes for the distribution of one data set.

5 ELECTRONIC ACCESS AND DISTRIBUTION

Currently there are no electronic access services offered by meteorological archive centres. But there are a number of options available in providing remote access services to users. This could include the provision of network access to the catalogue information, the provision of online product ordering, the access to browse data products over the network and finally the dissemination of image data and products to end users over the network.

6 Recommendations and Conclusions

In this paper the existing standards in the key areas of satellite data archiving and retrieval, i.e. data and catalogue formats, archiving technology and remote access services have been reviewed.

A need for closer cooperation in satellite data management issues between CGMS members and other organisations involved in producing standards for space data handling is identified.

The CGMS is invited to comment on the following recommendations:

a) That consideration shall be given by CGMS towards adopted standard data formats for data exchange.

b) That CGMS members should review the detailed data formats specified by CEOS and CCSDS and discuss the adoption, for the future, of a common data standard amongst CGMS members for data exchange.

c) That CGMS members should consider the use of one of these standards for future archives.

d) That CGMS members study the CEOS catalog system and to consider to support the CEOS International Directory Network (IDN) and to consider to construct and maintain Directory Interchange Formats (DIF) for inclusion in the CEOS IDN.

e) That CGMS members be requested to provide information on plans concerning the introduction of new archive and distribution media.

f) That CGMS should regularly discuss developments in this field through further consideration of information about CEOS and CCSDS work.

7 REFERENCE DOCUMENTATION

1. CEOS, Consolidated Report 1991

2. CCSDS, Draft Recommendation for Space Data System Standards: Standard Formatted Data Units - Structure and Construction Rules, CCSDS 620.0-R-1.1, Red Book, Issue 1.1, June 1991

3. WMO, Manual on Codes, Volume 1, Annex II to WMO Technical Regulations, WMO - No. 306, 1988 and attachments

CGMS-XXI WP-04
Prepared by Japan
Agenda Item: C.2

GMS-5 and Beyond

1. GMS-5

GMS-5 is now under development and fabrication as the successor to the current operational satellite GMS-4. The launch of GMS-5 was postponed by 1 year until early 1995 due to delay of development of launching vehicle. GMS-5 will be additionally equipped with water vapor sensor and infrared split window sensors; current thermal infrared channel sensor will be divided into two. Space Environmental Monitor (SEM) will not be aboard GMS-5. The other functions of the GMS-5 are identical to those of the GMS-4. The following table shows the channels of sensors of the GMS-4 and GMS-5.

BANDS	GMS-4	GMS-5
Visible	0.5 to 0.75 μm	0.55 to 0.90 μm
Thermal Infrared	10.5 to 12.5 μm	10.5 to 11.5 μm 11.5 to 12.5 μm
Water Vapor	-	6.5 to 7.0 μm

Furthermore, GMS-5 will have a search and rescue equipment to relay signals of distress on an experimental basis.

2. Post GMS-5

The successor to the GMS-5 is expected to be put into geostationary orbit before the end of GMS-5's life time. Details have not been determined as yet, but at least the same functions as GMS-5's will be furnished.

ANNEX X

CGMS-XXI WP-12
Prepared by Japan
Agenda Item: G.1

Stretched VISSR of GMS-5

Dissemination of Stretched VISSR (S-VISSR) data which is the direct broadcasting service of GMS high resolution image data to Medium-scale Data Utilization Station (MDUS) was started on March 1, 1988. Since then all VISSR data observed by a visible sensor and a thermal infrared sensor have been disseminated as stretched VISSR data in digital form.

GMS-5 will be additionally equipped with a water vapor sensor and infrared split window sensors; i.e. current thermal infrared channel will be divided into two.

In the S-VISSR dissemination service of GMS-5, all VISSR data will be also disseminated to MDUS users. The additional data, such as image data of infrared channel 2 (one of the split window channels) and infrared channel 3 (the water vapor channel) will be put into spare blocks in the current dissemination format.

These modifications of dissemination format will not affect the MDUS users as long as they continue to utilize the current image data of the visible channel and infrared channel 1 (one of the split window channels).

ANNEX XI

CGMS-XXI WP-16
Prepared by Japan
Agenda Item: II/6

Archiving of GMS image data

1.Status of GMS image data archiving

Since April 1978, Geostationary Meteorological Satellites, GMS to GMS-4, have been operated to take the earth images with visible and infrared spectral bands. The GMS images have been archived in digital and analogue formats at Meteorological Satellite Center (MSC).

In the previous data processing system installed at MSC from April 1978 through February 1987, open-reel magnetic tape had been used as digital data archiving. And HR-FAX film (508mm x 610mm), 35mm film and 16mm movie film had been used as analogue data archiving.

In the present system operated since March 1987, cartridge magnetic tapes (double-reel cartridge) that are incompatible with IBM format, are used for digital data archiving, and HR-FAX film (508mm x 610mm), 35mm film and video tapes have been used for analogue data archiving. The 16mm movie films which had been produced in the previous system were replaced by video tape.

Status of GMS image data archiving is shown in Table 1.

2. GMS image data archiving in the next computer system

It is planned that the next data processing system will be operated from May 1995 when GMS-5 takes over the missions of GMS-4. The plan of GMS image data archiving in the new system is as follows,

(1) Archiving of digital image data

New cartridge magnetic tapes (single-reel cartridge) that are compatible with IBM format will be introduced in place of current double-reel cartridge. A dimension of single-reel cartridge is two thirds of the current type and its capacity is comparable to that of current type by using the data compression technique which reduces the data volume of GMS image to about 50% of its original volume with decompressible format. Image data archiving on the new cartridge tapes will be operated by using an automated library subsystem that handles as many as 658 cartridge tapes.

In order to access the digital data archived in the old and the current systems, I/O devices for open-reel and cartridge magnetic tapes will be also provided in the new system. The specifications of the three types of magnetic tapes are shown in Table 2.

(2) Archiving of VTR image data

A digital type VTR will be introduced in the next system in place of the current analogue recording type. GMS images in digital form will be recorded to each frame with 640 pixels x 480 lines.

(3) Archiving of film data

In the current system, HR-FAX film (508mm x 610mm) is produced with the analogue recording type film recorder, and 35mm film is made by reprinting of the HR-FAX film.

In the new system, digital type film recorders will be installed. By using the new film recorder, not only 8inch x 10inch film replacing HR-FAX film but also 35mm film can be directly produced from digital image data with 256 gray levels.

Furthermore, image printers will be newly introduced as a quick-look of GMS images. The printing process is performed by combination with laser exposure and thermal development/transfer. Its resolution is 15.7 dots/mm of recording density with 256 gray levels for each color of cyan, magenta and yellow.

Table 1 Status of GMS image data archiving

Satel-lite	Observation Period	Frequen-cy	Digital data (Magnetic Tape)	VTR	Film
GMS	78. 4-81. 11	3 hours	VS/IR(78. 12-79. 11) IR(79. 12-81. 2) VS/IR(81. 3-81. 11)	IR(78. 4-81. 11)	VS/IR(78. 4-81. 11)
GMS-2	81. 11-84. 1	3 hours	VS/IR(81. 11-84. 1)	IR(81. 11-84. 1)	VS/IR(81. 11-84. 1)
GMS	84. 1-84. 6	3 hours	VS/IR(84. 1-84. 6)	IR(84. 1-84. 6)	VS/IR(84. 1-84. 6)
GMS-2	84. 7-84. 9	6 hours	VS/IR(84. 7-84. 9)	IR(84. 7-84. 9)	VS/IR(84. 7-84. 9)
GMS-3	84. 9-87. 2 87. 3-89. 12	3 hour 1 hour	VS/IR(84. 9-87. 2) VS/IR(87. 3-89. 12)	IR(84. 9-87. 2) IR(87. 3-89. 12)	VS/IR(84. 9-87. 2) VS/IR(87. 3-89. 12)
GMS-4	89. 12-	1 hour	VS/IR(89. 12-)	IR(89. 12-)	VS/IR(89. 12-)

Table 2 Magnetic Tape Specification

Type	Open-reel	Double-reel cartridge (IBM incompatible)	Single-reel cartridge (IBM compatible)
Tape width	0. 5 inch	0. 5 inch	0. 5 inch
Tape length	2400 feet	800 feet	540 feet
Recording density	6250 bpi	32000 bpi	37871 bpi
No. of tracks	9	18	18
Storage capacity	120 MB (block length 10KB)	280 MB (block length 32KB)	200 MB (block length 24KB)
Interblock gap		0. 08 inch	2 mm
Data compression	None	None	EDRC
Library system	None	None	658 cartridges (131. 6GB)
Adoption in GMS data processing system	The previous system (1978. 4～1987. 2) The present system (1987. 3～) The next system (1995. 5:planned)	The present system (1987. 3～) The next system (1995. 5:planned)	The next system (1995. 5:planned)

CGMS XXI P. R. C WP—3
Prepared by P. R. C
Agenda Item: G. 1

The Transmission Characteristics of FY—2 S—VISSR Data

FY — 2 satellite will be located at 105°E. The S — VISSR data will be transmitted to users.

1. Signal characteristics.

The signal characteristics of FY—2 S—VISSR data are as follows:

. Frequency:	1687.5 MHz
. Modulation:	PCM/BPSK NRZ—M
. Bit rate:	660 Kb/s(fixed)
. EIRP:	57.5±1 dBm
. Polarization:	linear
. Bandwidth:	2 MHz
. Data Volume:	329,872 bits/line(including SYNC code)
. Data coding:	Byte complimenting and PN scrambling

Since the signal characteristics of FY—2 S—VISSR data are as same as GMS S—VISSR data except frequency, the user stations now receiving GMS S—VISSR data can receive FY — 2 S — VISSR data by changing the antenna pointing and frequency of receiver local oscillator.

2. Data format

The S — VISSR data consists of synchronous code, information sector and dummy data. The format of the S—VISSR data is shown in Fig. 1.

2. 1 Synchronous code

The synchronous (SYNC) code is transmitted to allow bit and frame synchronization by demodulators at user stations. The code consists of 20000 bits of PN code of Maximal Length Sequence generated by a 15 digit serial shift register. The PN Sequence begins with 010001001100001 at a timing of every satellite spin, and the last 15 bits a.e fixed—logic ones.

2.2 Documentation sector

This sector contains eight data blocks, which consist of 2293 eight—bit words, as following.

(1)Sector ID:

This block, containing 2 words (16 bits) of all logic zeros, is used to identify the documentation sector.

(2)Satellite and CDAS data block:

This block contains 126 words(1008 bits)and the information is provided to process S—VISSR image data.

(3)Constant parameters for simplified mapping:

This block consists of 64 words (512 bits)and contains parameters to be used for simplified mapping together with the data in the simplified mapping block for geographical location.

(4)Sub—Commutation ID block:

In order to make a difference between transmission number and repetition time for simplified mapping, orbit and attitude data, operational schedule, Sub — Commutation ID block is set.

This block consists of four words (32 bits)and contains the repeat counter indicating the Sub—Commutation ID.

(5)Parameters for simplified mapping:

The block consists of 2500 words(25 sets, 100words/set)and contains mapping information(longitude range 45°E—165°E, latitude range 60°N—60°S), line and pixel number for each 5°longitude x 5°latitude.

(6)Orbit and attitude data block:

This block contains the information of the orbit and attitude parameters of the satellite. It consists of 3200 words (25sets, 128 words/set).

(7)Satellite operational schedule block:

This information is provided to notify users of the FY—2 operational schedule. This block consists of 10200 words.

(8)Spare block:

This block contains 1461 words filled with some meteorological products data.

2.3 Sensor data

(1)Infrared image data sector:

The infrared data sector consists of two words(16bits)of sector ID code.2291 words of infrared image data,16 bits of CRC code and 2048 bits of filler.

Infrared image data ID word: 00010001, 00010001.

(2)Water vapor image data sector:

Water vapor image data sector is similar to the infrared data sector. It consists of two words of sector ID code.2291 words of water vapor image data,16 bits of CRC code and 2048 bits of filler.

Water vapor image data ID words: 00100010.00100010.

(3)Reservation sector:

The rest are reserved for future use and filled with logic zeros.reservation sector is similar to the infrared. It consists of two words of sector ID code.2291 words of reservation information,16 bits of CRC code and 2048 bits of filler.

Reservation sector ID words: 01000100.01000100

(4)Visible image data sectors:

Each visible image data sector consists of two words (12 bits)of sector ID code, 9146 words of visible image data,16 bits of CRC code and 2048 bits of filler.

The four visible sectors contain the observed image data of the four visible detectors(visible 1,2,3,4)from one VISSR scan.

Visible image data ID word:

Visible 1 011011, 011011

2 101101, 101101

3 110110,110110

4 111111,111111

(5)CRC Code

The CRC code contains 16 bits. Its operational polynomial equation is

$$G(X)=x^{16}+x^{12}+x^{5}+1$$

(6)Filler

The filler containing 2048 bits is a series of dummy bits filled with logic zeros. It works to provide a buffering time of approximately three milliseconds for data processing in computer.

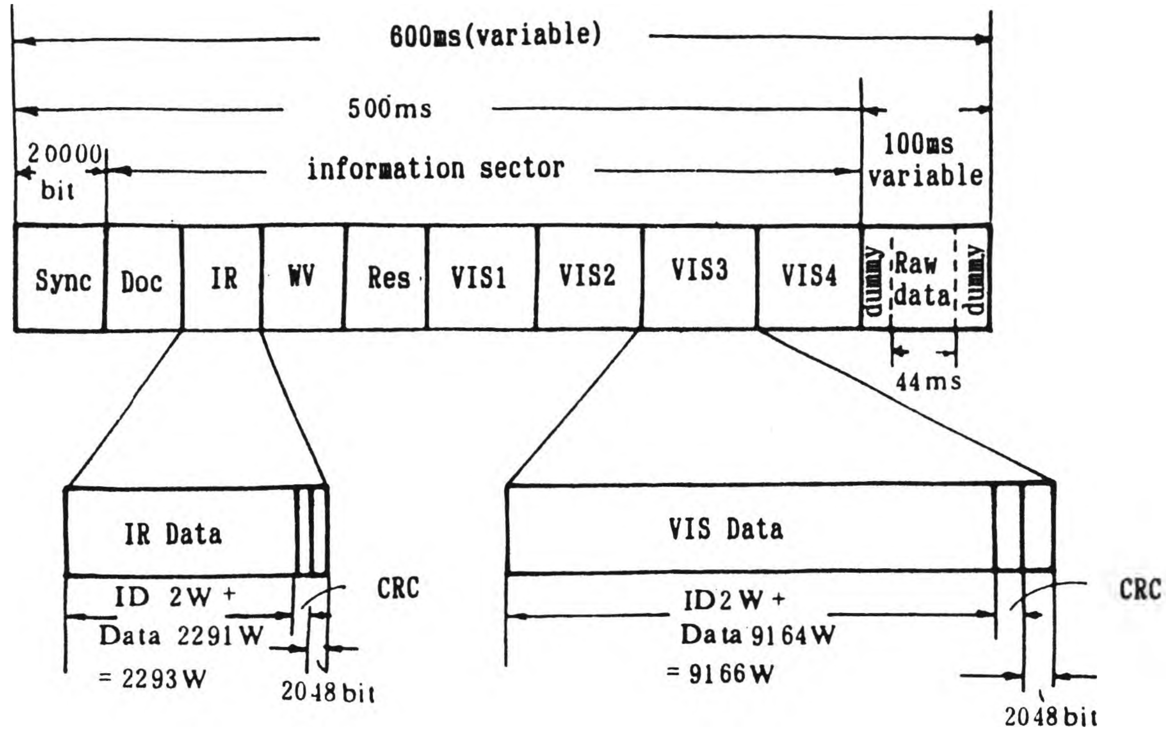


Fig 1. Data Format of FY—2.

CGMS—XXI P.R.C WP—4
Prepared by P. R. China
Agenda Item: G. 1

The Transmission Characteristics of FY—2 S—band WEFAX/Cloud Image

FY — 2 satellite will transmit WEFAX/Cloud Image through S — band to domestic users of China. The transmission characteristics are as follows.

. Frequency: 1699.5 MHz
. EIRP: 46 dBm
. Polarization: linear (vertical)
. Modulation: PM—AM/FM
. Carrier frequency deviation (FM): 9 KHz
. Bandwidth of carrier (FM): 26 KHz
. Sub—Carrier frequency: 1.7/1.8 KHz
. Bandwidth of sub—carrier (PM—AM): 300—3400 Hz
. Modulation of sub—carrier: G3 FAX
. Coding: CCITT T.4
. Transmission protocal CCITT T.30
. Bit rate: 300bps, CCITT V.21
  2400/4800 bps CCITT V.27 ter
  7200/9600 bps CCITT V.29
. Scan line density: 3.85/7.7 lines/mm
. Horizantal resolution: 8 pixels/mm
. Transmission duration: 1—3 minutes for WEFAX
  3—10 minutes for Cloud image
. Format:

pre—message procedure	message	post—message procedure
300bps (6 seconds)	2400—9600bps (1—10minutes)	300 bps (6 seconds)

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Prepared by P. R. China
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The SMC/SMA Satellite Data Archiving System

SMC/SMA has established satellite data archiving system and provided CCT tape and cassete tape as following to users.

Data	Tape	Period	Content
NOAA/1.B	CCT 6252 BPI	1986.5—1989.6	8—10 full passes/day (Single station)
NOAA/1.B& FY—1/1.B	3480 1/2" Cassete Tape	1989.6—Now	14 full passes/day (Three stations)
GMS S—VISSR	3480 1/2" Cassete Tape	1989.6—Now	1 disk image /hours 8 disk images/day

Now the optical disk archiving system is constructing for test. Since optical disk is expensive and the number of optical disks is very limited, the optical disk archiving system is only for experiment and is not for operation.

CGMS-XXI USA WP-4
Prepared by USA
Agenda Item: C.2

THE GOES I-M SATELLITE PROGRAM

Summary and Purpose of Document

This document presents a brief description of the GOES I-M satellites, their instrumentation, and the products which will be produced using these new spacecraft. The status of the GOES-I spacecraft is given. An oral update will be given by the USA delegation at CGMS XXI.

Action Proposed

CGMS members are invited to take note of the information presented.

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Prepared by USA
Agenda Item: C.2

INTRODUCTION

The GOES program is a key element of the National Weather Service (NWS) operation. GOES weather imagery and quantitative sounding data are a continuous and reliable stream of environmental information used in support of weather forecasting and related services. Spacecraft and ground-based systems work together to accomplish the GOES mission. Evolutionary improvements in the geostationary satellite system since 1974 (i.e., since the first Synchronous Meteorological Satellite, SMS-1) have been responsible for making the current GOES system the basic element of the U.S. weather monitoring and forecast operation.

The advanced GOES I-M spacecraft three-axis, body-stabilized design enables the sensors to "stare" at the earth and thus more frequently image clouds, monitor the earth's surface temperature and water vapor fields, and sound the earth's atmosphere for its vertical thermal and vapor structures. Thus the evolution of atmospheric phenomena can be followed, ensuring real-time coverage of short-lived, dynamic events, especially severe local storms and tropical cyclones — two meteorological events that directly affect public safety; protection of property; and, ultimately, economic health and development.

The GOES I-M series of spacecraft are the prime observational platforms for covering dynamic weather events and the near-earth space environment for the 1990's and into the 21st century. These advanced spacecraft enhance the capability of the GOES system to continuously observe and measure meteorological phenomena in real time, providing the meteorological community and atmospheric scientist of the western hemisphere with greatly improved observational and measurement data. These enhanced operational services improve support for short-term weather forecasting and space environment monitoring as well as atmospheric sciences research and development into numerical weather prediction models, meteorological phenomena, and environmental sensor design and development.

SYSTEM OVERVIEW

The GOES I-M system will provide the following functions:

- Acquisition, processing, and dissemination of imaging data
- Acquisition, processing, and dissemination of sounding data
- Acquisition and dissemination of Space Environment Monitor (SEM) data

- Reception and relay of data from ground-based Data Collection Platforms (DCP) to the NOAA Command and Data Acquisition (CDA) station
- Continuous relay of WEFAX and other data to small users, independent of all other functions
- Relay of distress signals from aircraft or marine vessels to the search and rescue ground stations of the Search and Rescue Satellite-Aided Tracking (SARSAT) system

As with the present system, the GOES I-M system will provide these services over a region covering the central and eastern Pacific Ocean, the contiguous 48 states, and the central and western Atlantic ocean (see Figure 1). Pacific coverage includes both Hawaii and the Gulf of Alaska. This is accomplished by two satellites, GOES West located at 135° West and GOES East at 75° West. A common ground station, the CDA station located at Wallops Island, Virginia, services both satellites. The satellites will be station-kept to ±0.5° in longitude and ±0.5° in inclination. Figure 2 illustrates the key features of the overall system.

The GOES I-M system employs a three-axis, stabilized satellite, separate Imager and Sounder instruments, and a full complement of four Space Environment Monitor (SEM) sensors. The basic system approach involves ground processing of the raw instrument data for radiometric calibration and earth location information, and retransmission to the satellite for relay to the users. The processed data are received primarily at the NOAA Science Center, through the Satellite Operations Control Center (SOCC) in Suitland, Maryland, and disseminated to the various Field Service Stations. The processed data is also received by the National Severe Storm Forecast Center, the U.S. Air Force Global Weather Center, and other users.

SPACECRAFT DESCRIPTION

GOES I-M is a three-axis-stabilized satellite that enables continuous pointing of the optical line-of-sight of the imaging and sounding radiometers to the earth. Figures 3 and 4 show the satellite in the deployed orbital configuration. It consists of a central body containing all the propulsion and electronic equipment and provides the platform on which the payload instruments are mounted. A single-wing, two-panel solar array, on the south side of the satellite, continuously rotates about the satellite pitch axis to track the sun during orbital motion generating a minimum 1057 W at summer solstice, at the end of five years. An unobstructed view of the instrument detector passive radiation coolers to space on the north side of the satellite is required to maintain the temperature of the infrared detectors at near 100°K. An asymmetric (single-wing) solar array configuration that avoids solar input into the passive coolers was selected to fulfill this requirement. A conical shaped solar sail on top of the 16 meter boom on the north side of the satellite is used to balance the torque caused by solar radiation pressure. A trim tab panel at the tip of the solar array is used to fine-balance the solar radiation pressure torque on the satellite by adjusting the tilt angle of the tab to daily account for varying sun declination effects.

The satellite attitude control uses a momentum bias concept with two skewed momentum wheels that provide pitch and roll control. The earth sensor provides pitch and roll information that is used to maintain earth pointing. Two magnetic torquers are used to absorb gradual buildup of roll and yaw momentum from the solar radiation pressure torques, minimizing the need to unload the wheels by firing thrusters.

The telemetry and command antenna is mounted on a fixed 2 meter boom on the east end of the satellite to provide near omni-directional coverage. Redundant magnetometers are mounted on a deployable 3 meter boom to minimize interference from the spacecraft magnetic field. All communication antennas, except telemetry and command, are hard-mounted to the earth facing panel for unobstructed earth coverage and maximum alignment stability.

THE IMAGER

The imager is a multispectral earth scanning instrument capable of sweeping simultaneously one visible and four infrared channels in a north-to-south scan across an east-west path, and providing full earth imagery, sector imagery containing edges of earth's disk, and area scans of local regions. Besides simultaneous imaging, it features higher infrared spatial (4 kilometers) and spectral resolution in the surface and cloud detection channels, and increased sensitivity, all of which enhance quantitative estimates of surface temperature and low-level moisture and monitoring of convective intensity. Imaging over five channels significantly improves cloud and water vapor measurements and produces visual and infrared images of the earth's surface, oceans, cloud cover, and severe storm developments. Cloud imagery is available to users in mapped format (available for each channel) as well as the familiar GOES projection sectors. Two composite images, visible-infrared and infrared-water vapor, are also produced. The key features of the imager are summarized

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in Table 1, and the performance requirements are summarized in Table 2.

THE SOUNDER

The GOES I-M Sounder features more spectral channels, higher spatial resolution (8 kilometers), and increased sensitivity for high quality soundings. It is capable of sweeping 1 visible and 18 infrared channels in a north-to-south scan across an east-west path. The Sounder provides full earth imagery, sector imagery containing the edges of the earth's disk, and area scans of local regions. Nineteen spectral bands (seven long-wave, five mid-wave, six shortwave, and one visible wavelengths) yield the prime sounding products of vertical temperature profiles, vertical moisture profiles, layer mean temperature, layer mean moisture, total precipitable water, and the lifted index (a measure of stability). These products are used to augment data from the Imager to provide information on atmospheric temperature and moisture profiles, surface and cloud top temperatures, and the distribution of atmospheric ozone. The key features of the sounder are summarized in Table 1, and the sounder sensing performance requirements are summarized in Table 3.

FLEXIBLE SCAN CONTROL

Both Imager and Sounder employ a servo-driven, two-axis gimballed mirror system in conjunction with a 31-centimeter Cassegrain telescope. As separate sensors, they allow simultaneous and independent surface imaging and atmospheric sounding. Each has flexible scan control, enabling coverage of small areas (1500 by 1500 kilometers) as well as hemispheric (North and South America) and global scenes (earth's full disk), and close-up, continuous observations of severe storms and dynamic, short-lived weather phenomena. A priority scan feature allows higher spatial and temporal resolution data to be generated that improve short range forecasts and storm warnings. Image priority large area scans of 3000 by 3000 kilometers are accomplished in three minutes and image priority small area scans of 1000 by 1000 kilometers can be made in 41 seconds. A 3000- by 3000-kilometer area can be sounded in 42 minutes.

SPACE ENVIRONMENT MONITORING

The SEM instruments survey the sun, measuring *in-situ* its effect on the near-earth solar-terrestrial electromagnetic environment.

Changes in this "space weather" can affect operational reliability of ionospheric radio, over-the-horizon radar, electric power transmission, and – most importantly – human crews of high altitude aircraft, Space Shuttle, or Space Station. The X-Ray Sensor (XRS) monitors the sun's total X-ray activity.

The Energetic Particle Sensor (EPS) and High Energy Proton and Alpha Detector (HEPAD) detect the most energetic electron and proton radiation trapped by the earth's magnetic field as well as direct solar protons and alpha particles. The magnetometer measures three components of earth's magnetic filed in the vicinity of the spacecraft and variations caused by ionospheric and magnetospheric current flows.

DATA BROADCAST

GOES also enhances services for receiving meteorological data from earth-based data collection platforms and relaying the data to end-users. A continuous, dedicated search and rescue transponder on the satellite provides for immediate detection of distress signals from downed aircraft or marine vessels in distress, and relays them to ground terminals to speed help to people in need. Increased communications capacity permits transmission of processed weather data and weather facsimile for small local user terminals in the western hemisphere.

GEOGRAPHIC COVERAGE

The GOES spacecraft, on-station 35,770 kilometers (19,312 nautical miles) above the equator and stationary relative to the earth's surface, can view the contiguous 48 states and major portions of the central and eastern Pacific Ocean and the central and western Atlantic Ocean areas. Pacific coverage includes Hawaii and the Gulf of Alaska, the latter known to weather forecasters as "the birthplace of North American weather systems." Because the Atlantic and Pacific basins strongly influence the weather affecting the United States, coverage is provided by two GOES spacecraft, one at 75° west longitude, GOES East, and the other at 135° west longitude, GOES West.

The combined footprint (radiometric coverage and communications range) of the two spacecraft encompasses earth's full disk about the meridian approximately in the center of the continental United States. Circles of observational limits centered at a spacecraft's suborbital point extend about 60 geocentric degrees.

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The Command and Data Acquisition (CDA) Station is in line-of-sight communications with both spacecraft so that it can uplink commands and receive down-linked data from each simultaneously. Data collection platforms within the coverage area of a spacecraft can transmit their surface-based sensed data to the CDA Station via the on-board data collection subsystem. Similarly, ground terminals can receive processed environmental data and WEFAX transmissions.

GOES SPACECRAFT STATUS SUMMARY

Indicated below is the activity that is planned for between early April and the launch of the GOES-I satellite in mid-April 1994.

- Comprehensive post storage functional test
- Thermal vacuum test
- Acoustic test
- Stray magnetic test
- Installation of deployables
- Mass Properties
- Final alignment
- Launch operations

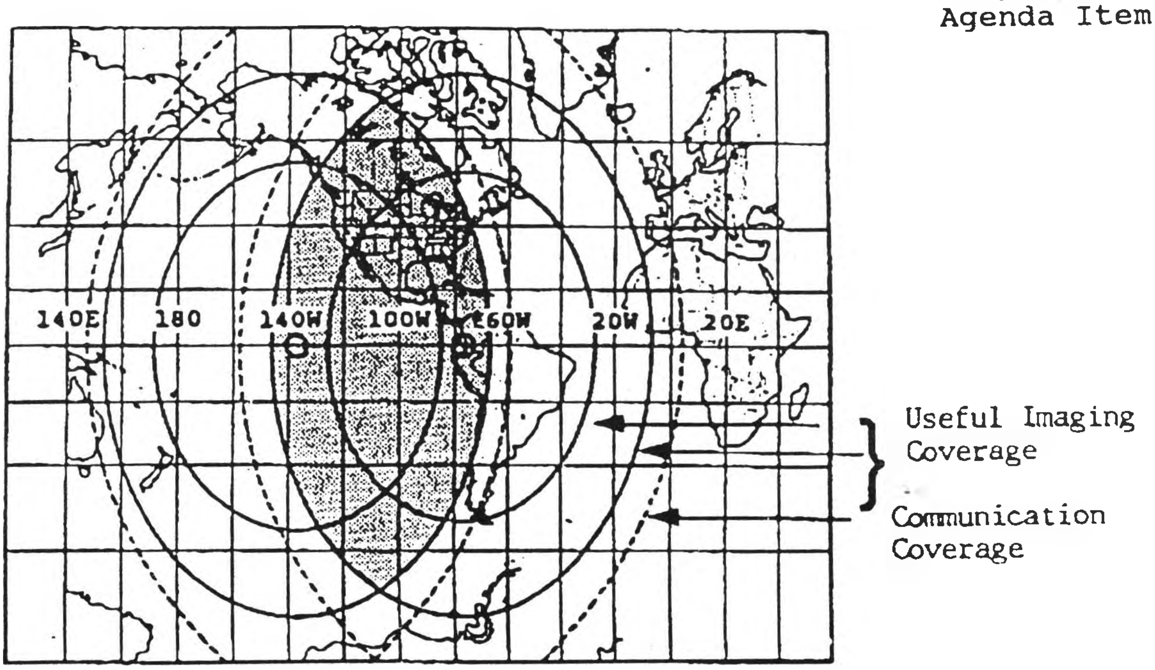
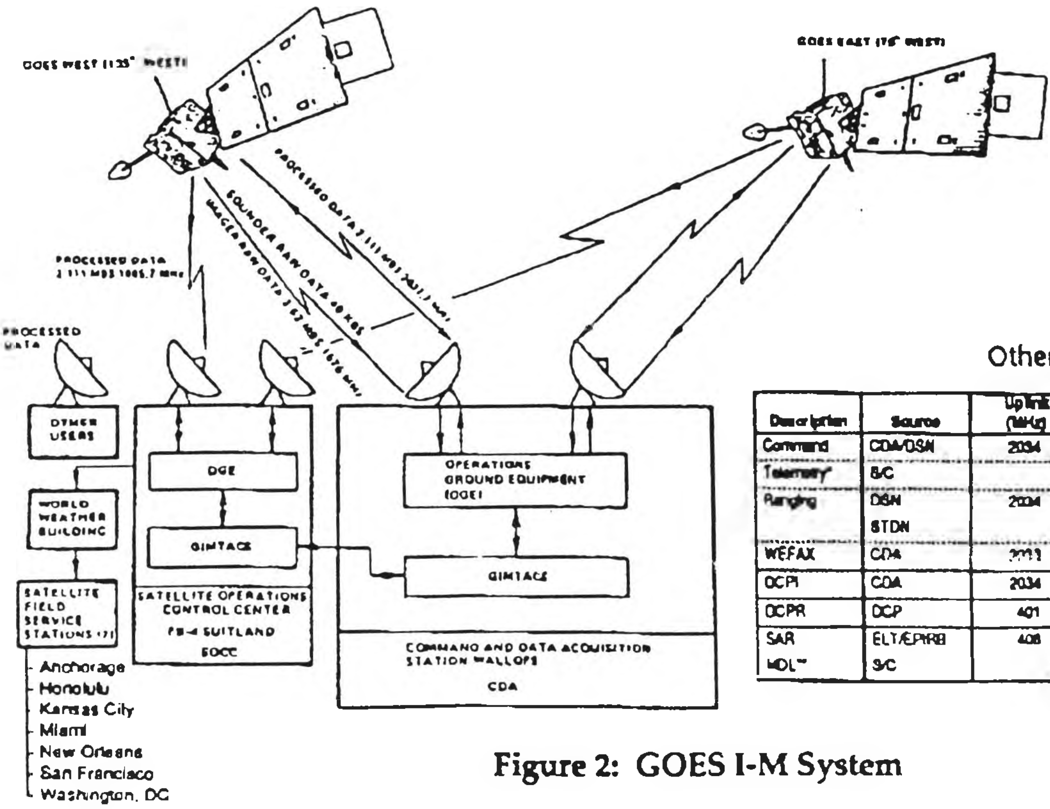


Figure 1: GOES East and GOES West Geographic Coverage



Other Links

Description	Source	Uplink (MHz)	Downlink (MHz)	Destination
Command	CDA/DSN	2034		S/C
Telemetry*	S/C		1694	CDA, ERL-Boulder, DSN
Ranging	DSN STDN	2034	2209	S/C, DSN
WEFAX	CDA	2033	1691	Users/APT
DCPI	CDA	2034	468	DCP
DCPR	DCP	401	1694	CDA/Users
SAR	ELT/EPIRB	406	1544	SAR Ground Station
MDL**	S/C		1681.5	SOCC/ERL Boulder

* Including SEM data.
** Diagnostic data.

Figure 2: GOES I-M System

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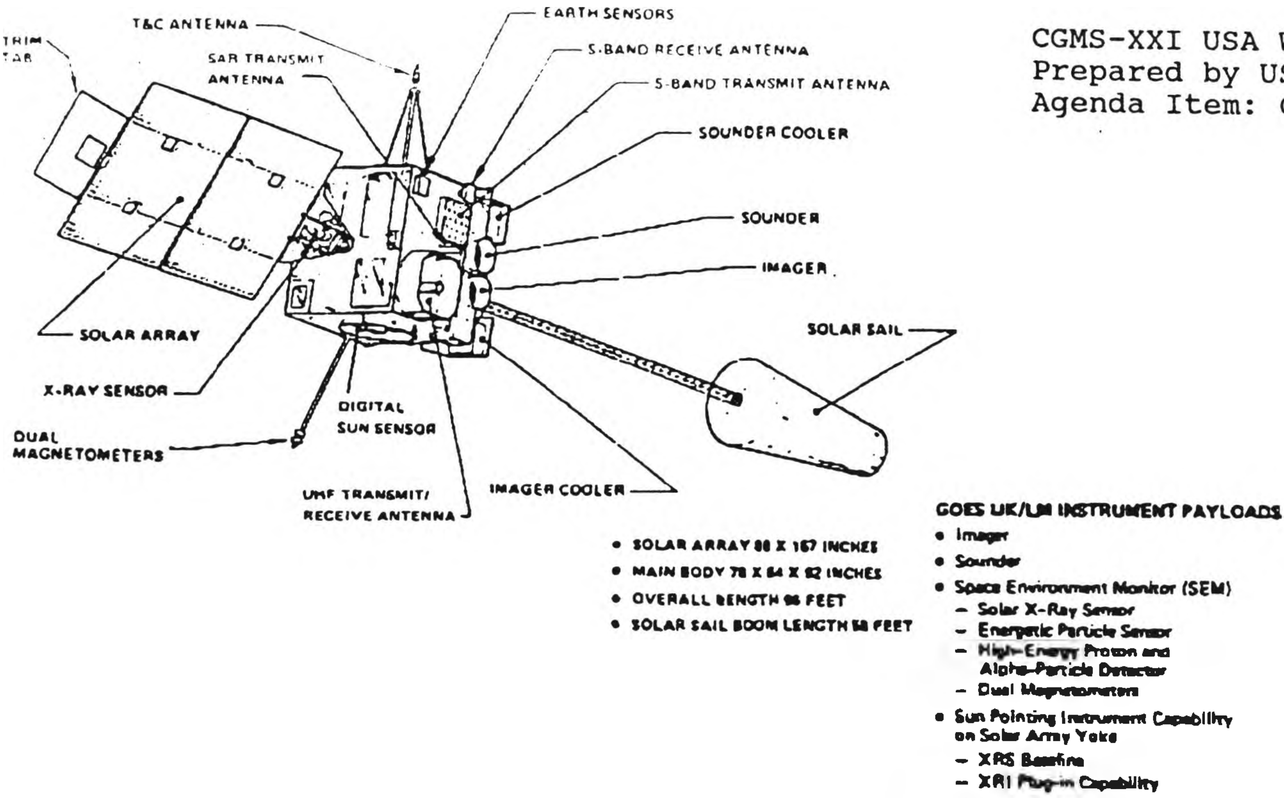

Figure 3: Spacecraft On-Orbit Configuration

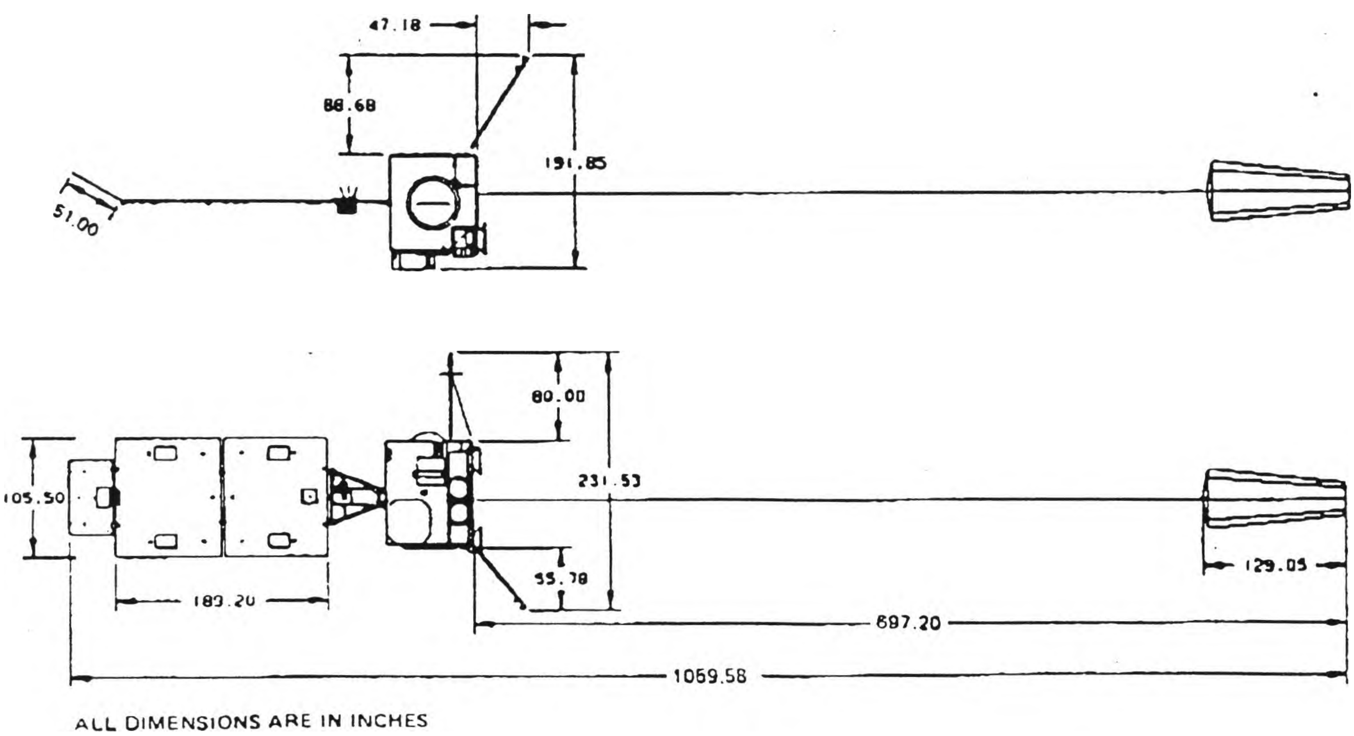

Figure 4: Deployed Spacecraft Outline/Dimensions

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TABLE 1: KEY FEATURES OF THE IMAGER AND SOUNDER

Feature	Imager	Sounder
Optical Aperture	31.1 cm (12.25 in.)	31.1 cm (12.25 in.)
Total Step & Sample Time	N/A	0.1 sec. (0.2 sec. 0.4 sec. optional)
Methods of Scan	2-axis, linear E-W, line step N-S	2-axis, step & dwell E/W 280 μrad steps N/S 1120 μrad steps (optional 2240 μrad steps, 0.2 sec. dwell)
Scan Rate	20°/sec. optical	40 soundings/sec.
Slew Rate	10°/sec. mechanical	10°/sec. mechanical
Spatial Resolution (μrad)	Channel VIS: 28 2.4 & 5: 112 3: 224	All Channels 242 μrad (diameter)
Sampling	1.75/IGFOV VIS, Ch. 2, Ch. 4 & Ch. 5 3.5/IGFOV channel 3	4 IGFOVs sampled simultaneously
Sampling Rate	183.3 μs/pixel (IR) 45.8 μs/pixel (VIS)	0.1 sec.
Channel Coregistration	±28 μrad	Within 22 μrad of Ch. 8
Star Sensing	Uses visible array SNR 6 for 4th mag stars (400 samples)	Separate visible array SNR 6 for 4th mag stars (each sample)
Data Output	10 bit quantization	13 bit quantization
Data Rate	2.6208 Mb/s	40 kb/s
Data Format	NRZ-S. PN code	NRZ-S. PN code
Patch Temperature	Regulated at 94K 101K or 104K	Regulated at 94K 101K or 104K
Time Between Space Looks	2.2 sec. large frame 9.2 or 36.6 sec. smaller frame	2 min.
Time Between Black Body Calibrations (Nominal)	10 to 30 min. (can override or inhibit)	20 min. (can override or inhibit)
Priority Frame Select	1 level normal 2 levels priority 1 level star sense	1 level normal 2 levels priority 1 level star sense

TABLE 2: IMAGER PERFORMANCE REQUIREMENTS SUMMARY

Spectral Channels	1	2	3	4	5
Purpose	Cloud Cover	Nighttime Clouds	Water Vapor	Surface Temp.	Sea Surface Temp. & Water Vapor
Wavelength (mm)	0.55 to 0.75	3.80 to 4.00	6.50 to 7.00	10.20 to 11.20	11.50 to 12.50
S/N or NEDT Spec	150:1	1.4K at 300K	1.0K at 230K	0.35K at 300K	0.35K at 300K
Detector Type	Silicon	InSb	HgCdTe	HgCdTe	HgCdTe
Spatial Resolution (µrad)	28 + 0% - 10%	112 + 0% - 10%	224 + 0% - 25%	112 + 0% - 25%	112 +0% - 25%
Star Sense	4th mag stars SNR 6	-	-	-	-

TABLE 3: SOUNDER SENSING PERFORMANCE REQUIREMENTS

Detector Channel (Band)		Central Wavelength [um (cm^{-1})]	NE (Delta) N (mW/m^2/sr/cm^{-1}) Spec	Purpose
HgCdTe (LW)	1	14.71 (680)	0.66	Temperature Sounding
	2	14.37 (696)	0.58	"
	3	14.06 (711)	0.54	"
	4	13.96 (733)	0.45	"
	5	13.37 (748)	0.44	"
	6	12.66 (790)	0.25	"
	7	12.02 (832)	0.16	Surface Temperature
HgCdTe (MW)	8	11.03 (907)	0.16	Surface Temperature
	9	9.71 (1030)	0.33	Total Ozone
	10	7.43 (1345)	0.16	Water Vapor Sounding
	11	7.02 (1425)	0.12	"
	12	6.51 (1535)	0.15	"
InSb (SW)	13	4.57 (2188)	0.013	Temperature Sounding
	14	4.52 (2210	0.013	"
	15	4.45 (2245)	0.013	"
	16	4.13 (2420)	0.008	"
	17	3.98 (2513)	0.0082	Surface Temperature
	18	3.74 (2671)	0.0036	"
Silicon (Visible)	19	0.70 (14367)	0.10% Albedo	Cloud
Silicon (Star Sense)		0.65 (15384)	6:1 SNR	4th mag stars

DIRECT READOUT (GVAR) USER SYSTEMS: THE TRANSITION TO GVAR FROM MODE AAA

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Prepared by USA
Agenda Item: G.1.1

1.0 INTRODUCTION

GOES-I is the first of a new series of five GOES being built by Space Systems/Loral (SS/L). It is projected to be launched April 15, 1994, and to become operational in the fall of 1994. The GVAR format is the retransmission format for the GOES spacecraft's Imager & Sounder instruments.

2.0 BACKGROUND

The GOES I spacecraft is a 3-axis stabilized spacecraft, not a spinner like all the previous GOES spacecraft. This makes the instrument operation analogous to that of the polar (NOAA/TIROS) spacecraft. Sector scanning will be the standard mode of operation with the scanning of almost any sector area technically possible. NOAA has defined a Day-1 scenario for both Imager and Sounder instruments containing a standard set of large sectors scheduled at fixed times during the day. Future scenarios are likely to take advantage of the more advanced features of the Imager and Sounder instruments.

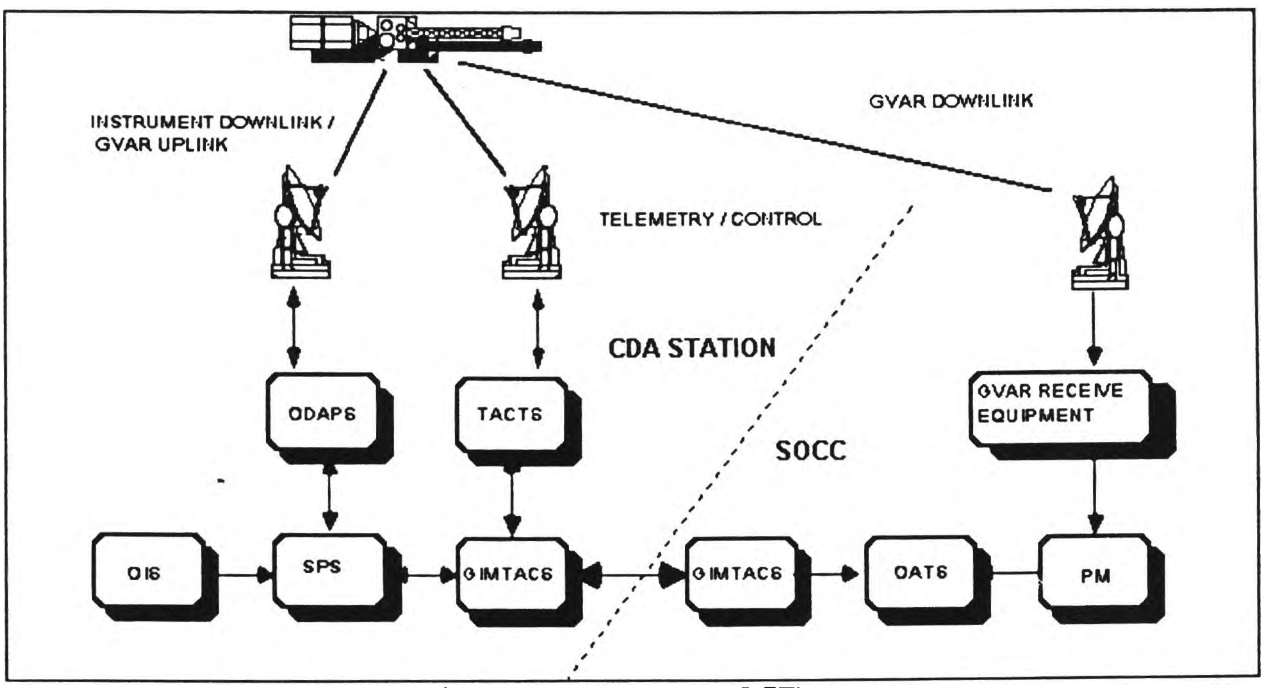

Figure 1 - GOES I-M Operational Ground Equipment (OGE)

GVAR

The GVAR (GOES Variable) format will be the retransmission format for the GOES I-M era. The RF for GVAR has changed from Mode AAA. The **RF for GVAR will be 1685.7 Mhz** against 1687.1 Mhz. for Mode AAA. The data rate for GVAR will remain the same as for Mode AAA at 2.111360 Mbps.

The CRC structure of the format will be maintained with CRC codes appearing at the end of each redundant header and at the end of each information Block. The basic header structure will remain unchanged. The same header words will be used, although spare header words may be redefined in the future. The number of header words will not change.

No squelch period (earth view period) is required in GVAR, the earth view Block will be replaced with a documentation Block analogous to the common documentation Block in Mode AAA.

The size of IR and Visible Blocks will depend upon the east-west width of the Imager sector being scanned. As a result, the 'frame rate' (delineated by a Block 0 transmission) will not be fixed to 0.6 seconds as in Mode AAA. Visible video word sizes will be increased from 6 to 10 bits. IR data will remain the same at 10 bits. Raw Sounder data will be 16 bits (13 bit accuracy).

The Auxiliary Block of Mode AAA will be replaced with a Sounder / Auxiliary Data Block (SAD) or "Block 11". This Block will carry all Sounder data, and Imager and Sounder ancillary data. TEXT message Blocks will also be sent by way of SAD Blocks.

The Operational Ground Equipment (OGE)

Figure 1 shows the data flow through the Operational Ground Equipment (OGE).

The SPS generates the GVAR format for broadcast. It receives the raw Imager and Sounder downlink streams from the satellite and reorders each line in a west to east sequence. It calibrates the IR and normalizes the visible data. Imager visible and IR are coregistered. Grid points are computed for the Imager data, and earth location points are computed for the Sounder data before each scan is formatted as individual GVAR data Blocks. Blocks are then put into an output queue for broadcast according to a fixed priority scheme.

The Orbit and Attitude data contained in the GVAR transmission is computed by the Orbit and Attitude Tracking System (OATS) before being passed on to the SPS. Orbit and Attitude (O&A) data is used by the SPS in its computing of grid and earth location points. The OATS relies on landmark data supplied by the PM (Product Monitor), and Star Sense and range data provided by the SPS to computer the O&A sets. The PM provides quality monitoring to the whole OGE system. As well as providing landmarks to the OATS, the PM also generates Normalization Look-Up (NLUT) tables for the SPS.

The OGE Input Simulator (OIS) will be used prior to launch to simulate the instrument downlink streams as a test input to the SPS (see Figure 1). The resulting GVAR data stream will then be uplinked to users for prelaunch GVAR compatibility testing. This subsystem will be discussed in greater detail in a later paragraph.

The GIMTACS acts as the control system for both the satellite and the other components of the ground system. It sends commands to the satellite based upon operator generated command schedules, monitors telemetry, configures the ground equipment for proper operation, and generates text messages for transmission in the GVAR data stream.

Table I - EIRP in dBm for GOES Series

	East Horizon	Satellite Subpoint	West Horizon	Spec
GOES-6				
Side 1	57.5		57.4	54.4
Side 2	57.0		57.2	54.4
GOES-7				
Side 1	56.3	58.0	54.4	
Side 2	57.0			54.4
GOES I-M	54.4	55.2	54.4	54.4

3.0 THE TRANSITION TO THE NEW FORMAT

User Receiving Hardware[1]

The Effective Isotropic Radiated Power (EIRP) from GOES-I is not expected to be as great as from GOES-7. Table I[2] compares previous Hughes spacecraft to what can be expected from GOES-I. Additionally, **the RF for GVAR is changing from 1687.1 Mhz to 1685.7 Mhz.** Users will have to make changes in their receive systems to compensate for these changes.

Test Broadcasts of GVAR Data

Test broadcasts of GVAR data are currently being supported[3], and plans are to continue this support up to the launch of GOES-I. **Initial broadcasts have been at the current Mode AAA frequency of 1687.1 Mhz.** Future broadcasts will be at the new RF of 1685.7 Mhz.

Schedules of broadcasts will be made available to users over the OMNET Electronic Bulletin Board.

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[1] Users should consult NESDIS Technical Memorandum 33 for information on calculating the performance of their receive system for GVAR data. Section 7 of this document, "Downlink Parameters" was the source document for Table 1.

[2] The EIRP figures for GOES-6 and GOES-7 are measured values. The EIRP for GOES I-M represent anticipated values. Actual post-launch measurements may differ.

[3] Test broadcasts are currently being supported through GOES-6 on a non-priority basis, with GOES-2 as the backup satellite. GOES-6 has a 4.5 degree inclination as of this writing (2/18/93), and is out of fuel. It is drifting at the rate of 0.5 degree east-west.

The GVAR Simulator

The GVAR simulator[4] was developed by Integral Systems Inc. (ISI) of Lanham, Maryland. The simulator has one GOES-BUS output, and an NRZ-S data output and clock. Rear panel mounting connectors for the NRZ-S output are SMAs. Levels are TTL.

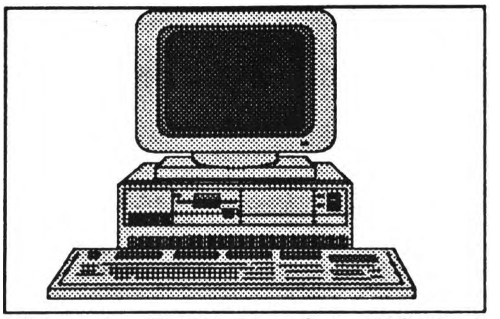

Figure 2 - GVAR Simulator PC Host

The simulator is built around a standard NEC 386 AT compatible running at 16 Mhz with 10 Meg of RAM and a 66 Meg hard disk (See figure 2). An amber monitor is contained in a separate rack mount assembly. The simulator is Microport UNIX based with the majority of the code written in "C". The simulator supports a user programmable command set, allowing the user considerable control over the simulation. The simulator supports either interactive or batch mode operation. Batch files can be edited using a UNIX text editor and loaded in or scheduled for loading prior to being executed.

The simulator supports both static and dynamic parameters. Static parameters can be set in one of three ways. Start up parameters for the simulator are contained in 12 reference files created by a UNIX text editor. The files contain all the static parameters for the 12 initial GVAR Blocks. The GRID and O&A fields are treated uniquely. Separate GRID or O&A files may be referenced by the operator during simulator setup. TEXT Block 11s can be referenced in the same fashion. Other files contain initial values for both Imager and Sounder video.

The GVAR simulator is being used to support most current GVAR test broadcasts.

The OIS Simulator

The OIS simulates the raw downlink from the GOES-I satellite. The Imager and Sounder instruments generate independent downlink data streams carried on the same QPSK RF carrier and separated in the CDA station receive equipment.

The OIS serves as a source of test data at the Wallops CDA station for the SPS during ground system testing. **With the SPS taking its input from the OIS (see Figure 1), the SPS can be used to uplink a more realistic simulation of GOES GVAR data.** It is the OIS broadcast that will be supported in the months just preceding the GOES-I launch.

[4] Users desiring to purchase simulators should contact Integral Systems, Inc. (ISI) of Lanham, Maryland. Scenario definition files, static files, and detector definition files created by the government and its agents are available upon request.

The OIS' strength is in its variety of video patterns, and realistic O&A and calibration data. While the OIS supports the standard bar and checkerboard patterns of the GVAR simulator, it also supports the more sophisticated earth model mode.

The earth model mode projects predefined radiance patterns onto a model of the earth. Over this are laid (embedded) geopolitical grid points in agreement with the current simulated O&A set. This model should aid users in checking out their own earth location and IR scaling.

Users doing their own true image navigation and/or calibration will also find this mode useful.

The GVAR Archive Unit

NOAA has funded the development of GVAR "Bulk" tape archive units through a contract with the University of Wisconsin's Space Science and Engineering Center (SSEC). These units allow the recording of up to 6 hours of GVAR data on one 3/4" U-MATIC tape cassette. GVAR recorders take GOES-BUS inputs from a GVAR frame sync, while the playback units provide a modified GOES-BUS output on playback.

Archive units are particularly useful when testing has gone beyond the stage where the PC based GVAR simulator is sufficient for further testing. In this case, OIS broadcasts of specific operational scenarios can be recorded and played back at the users convenience.

The archive units have an additional advantage over the GVAR simulator in that they are relatively simple to operate. The disadvantage of these units is that the user is slave to recording and playing back GVAR test broadcasts, and so must have receive equipment available to capture the initial recording.

Currently Defined Operational Scenarios[5]

Both the GVAR and OIS simulators have Day-1 scenarios defined for them. These scenarios are regularly run as part of the GVAR test broadcast operation. The basic East[6] Day-1 scenarios currently defined for GOES I Imager operation appear below. **There are three basic modes defined: Normal, Alert, and Warning**. Each of the three basic modes are divided into 6 data periods of 30 minutes each, in which Day-1 sectors are output.

The following table shows the Day-1 sector definitions:

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[5] Users desiring detail and up-to-date information on GOES I-M Day-1 Operational scenarios should contact the NESDIS Office of Systems Development. The Day-1 scenarios as originally proposed are under revision by NESDIS and the National Weather Service (NWS). Information will be made available to users as documented revisions become available.

[6] Descriptions of Day-1 West scenarios are available upon request.

GOES I East Sector Definitions[7]

Sector Name	North Boundary	South Boundary	West Boundary	East Boundary	Time To Image
Full Disk					26.56 min
Northern Hemisphere	75N	0	110W	20W	11.55 min
East CONUS	62N	14N	112W	63W	6.44 min
Sub-CONUS A	52N	23N	105W	75W	2.77 min
Sub-CONUS B	40N	19N	100W	67W	2.6 min
Sub-CONUS C	55N	26N	90W	60W	2.75 min
Sub-CONUS D	57N	27N	112W	82W	2.66 min

For Imager Normal Mode operation, the Imager outputs full disk Images at 30 minute centers. The following table shows the Imager scenario for the Normal Mode operation:

Imager Normal Mode Scenario

Time Start	Activity
00:00	Full Disk 1
00:30	Full Disk 2
01:00	Full Disk 3
01:30	Full Disk 4
02:00	Full Disk 5
02:30	Full Disk 6

The Imager Alert Mode scenario for the Imager is shown in the following table. This mode starts off with a full disk imager, and follows with Hemispheric sectors on 15 minute centers:

[7] Time to image figures computed using GVAR storage requirements program written by Ray Komajda of the MITRE Corporation, as updated in February 1993.

Imager Alert Mode Scenario

Time Start	Activity
00:00	Full Disk
00:30	North Hemisphere 1
00:45	North Hemisphere 2
01:00	North Hemisphere 3
01:15	North Hemisphere 4
01:30	North Hemisphere 5
01:45	North Hemisphere 6
02:00	North Hemisphere 7
02:15	North Hemisphere 8
02:30	North Hemisphere 9
02:45	North Hemisphere 10

The Imager Warning Mode scenario is more complex than the Normal or Alert mode scenarios, and includes Sub-CONUS sectors. The first half hour is a full disk image, with the second half hour as illustrated. The second half hour is repeated four more times to fill out the 3 hour schedule period.

The following table illustrates the proposed Imager Warning mode scenario for the east GOES satellite:

Imager Warning Mode Scenario

Time Start	Activity
00:00	Full Disk
00:30	Northern Hemisphere
00:42	Sub-CONUS x
00:45	Conus
00:52	Sub-CONUS x
00:55	Sub-CONUS x

The current Day-1 sectors and scenarios are under review by NESDIS and the NWS, and are likely to change. Both the GVAR and OIS simulator scenarios will be redefined to track any changes to the official Day-1 scenario descriptions. Scenarios have also been defined for the Sounder instrument, but are not presented here. Users desiring information on these scenarios should contact the NESDIS Office of Systems Development.

4.0 NESDIS Operational Readiness

NESDIS has developed new systems and host applications specifically for GOES I-M operations. In addition, NESDIS has a host of disparate operational Mode AAA systems that must be converted to GVAR operations. Current Mode AAA systems will likely support concurrent Mode AAA and GVAR operations.

NESDIS is adopting a multi-phased approach in determining its operational readiness for GVAR operations. Those prelaunch phases include: subsystem level testing, system level testing, and end-to-end testing. Subsystem level testing is conducted by system contractors at government direction, and is designed to fully test the functionality of each system/application. Both the system level and end-to-end test phases are part of the overall Ground Segment System Test (GSST), and are designed to test the full operability of NESDIS GVAR systems/applications.

The GSST tests are specifically developed to minimize impact upon existing Mode AAA/METEOSAT operations, and are patterned after actual operational procedures. Additional procedures are added to ensure peak system loads and contingencies (failover/recovery) are tested. Testing is also planned using (likely) future operational scenarios, such as Imager and Sounder priority modes[8].

NESDIS has used the GVAR simulator almost exclusively for all subsystem level testing. The simulator's portability and flexibility with regard to scenarios make it useful for 90% of subsystem level testing. The OIS/SPS broadcast will be used for most GSST testing, because the GVAR simulator does not support the earth model mode.

NESDIS does not plan to use the SSEC archive unit in any formal system testing. The archive units are available to NESDIS as a backup to the GOES-6 link currently being used to broadcast OIS/SPS GVAR.

GVAR Quality Monitoring

Quantitative and qualitative monitoring of the GVAR link will be done continually during GSST execution. **Quantitative monitoring of the link Bit Error Rate (BER) is done through an automated BER monitoring system.** This system provides a continual display of the instantaneous BER, the average BER over a half-hour data period, and displays the standard deviation for the

[8] Specifically, N-S priority frame, and S-N (reverse scan) priority frame scenarios have been created for the OIS, but are not modeled after planned operational modes. Also, GVAR simulator scenarios have been generated to model (some) likely data anomalies. These scenarios are no substitute for post-launch GVAR data.

product period. Plots of the BER for each product period can be generated for up to a week's worth of statistics. Specific instantaneous BER samples are archived so histories can be traced when investigating specific product system anomalies.

Qualitative monitoring of the link will be performed by NESDIS Satellite Operation Control Center (SOCC) personnel using GVAR Product Monitor (PM) systems. PM systems allow page displays of GVAR parameters to be built allowing analysis of specific GVAR subfields. In addition, GVAR Imager and Sounder sensor data can be displayed, and telemetry fields plotted.

In this way, GVAR will be continuously monitored throughout the testing period. Any observed anomalies will be recorded on Test Incident Reports (TIRs).

Tracking System Anomalies

The Anomaly Tracking System (ATS) is a database that is used by NESDIS to track system anomalies by system, date, time, etc. All NESDIS and NASA generated TIRs will be transferred to the ATS, and reported in ATS weekly reports[9]. These reports are in turn made available through a NESDIS electronic mail system to test engineers and technicians investigating observed anomalies in GVAR processing systems/applications. In addition, the ATS is available to LAN users with accounts on the NESDIS Office of Systems Development.

These reports may become available to external users at a later date through the OMNET Electronic Bulletin Board (EBB).

5.0 USER INTERFACING

NESDIS will fully support the user transition to GVAR. One of the main tools for communicating with users will be the **OMNET Electronic Bulletin Board**.

Schedules for simulated GVAR broadcasts will be announced in advance over the electronic bulletin board. NESDIS will keep users abreast of equipment outages and anomalies as well.

A database of direct readout users of GOES data is kept by the NESDIS Office of Systems Development. Users are encouraged to contact this office to have their names and addresses placed on this database so that they can receive periodic updates of GOES related documentation, especially of the GVAR format specification.

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[9] Weekly reports will be generated up to the launch of GOES-I. From launch to launch plus four months, the reports will be updated daily.

Available NESDIS Documentation on GOES I-M

Designation	Title	Author	Rev.
NESDIS Tech Report 33	An Introduction to the Imager & Sounder Instruments And The GVAR Retransmission Format (Original Pub.)	MITRE Corp.	10/87
NESDIS Tech Report 40	The GOES I-M System Functional Description	Various Authors	11/88
NESDIS Tech Memo 21	The GVAR Users Compendium	Various Authors	5/88
DRL 504-02 (Sect. 3)	The GVAR Format Description	Loral Aerospace	12/92
NASA	Geostationary Operational Environmental Satellite GOES I-M System Description	NASA	12/92
DRL 504-11	Earth Location Users Guide For The GOES I-M Spacecrafts (ELUG).	Integral Systems, Inc.	5/90

Available Documentation

Numerous documents have been written by NESDIS to document the new spacecraft, instruments, and ground system. The table above provides a partial list of that documentation. Users needing background in GOES I-M are encouraged to read **NESDIS 33, "An Introduction to the Imager & Sounder Instruments and the GVAR Retransmission Format"**. Also, **NESDIS 40, "The GOES I-M System Functional Description"** includes additional detailed information on the NESDIS spacecraft support ground system, and product processing systems.

Additionally, some **software** has been developed in support of the GOES I-M development effort that is available for use by future GVAR users. Fortran 77 software that performs navigation transforms (see the ELUG) is available. BASIC software that computes approximate storage requirements for GOES I-M Imager and Sounder subsectors is also available. Listings and IBM compatible diskettes can be mailed to users upon request to the NESDIS Office of Systems Development.

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Prepared by USA
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MONITORING GLOBAL AND REGIONAL VOLCANO AND FIRE ACTIVITY WITH ENVIRONMENTAL SATELLITE DATA

INTRODUCTION

Environmental satellite data from geostationary and polar orbiting platforms are useful for monitoring a number of land surface phenomena. This paper addresses their use in detecting, monitoring and issuing timely warnings of volcanic eruptions and fire activity.

The National Environmental Satellite, Data, and Information Service (NESDIS) of the U. S. National Oceanic and Atmospheric Administration (NOAA) operates a Geostationary Operational Environmental Satellite (GOES) system and a Polar Orbiting Environmental Satellite (POES) system. In addition, other countries operate geostationary systems: METEOSAT (Europe), GMS (Japan) and INSAT (India) which may also be used for environmental monitoring if data is available.

GEOSTATIONARY SATELLITES

The GOES system nominally consists of two geostationary satellites stationed over the equator near the East and West coasts of the continent, although at present, only one satellite (GOES-7) is in operation, positioned near the middle of the continent. GOES-7 senses data at 4 km resolution in the visible spectrum and 8 km in the infrared spectrum, obtaining a full disk view twice every hour. It is useful for monitoring volcanos and fires in North, Central, and South America in the mid-latitudes.

POLAR ORBITING SATELLITES

The POES system, designated the NOAA-N series, consists of two satellites in circular, Sun synchronous, near polar orbits. Each satellite provides coverage of the entire Earth's surface twice a day, so that any location will be observed at least four times each day. One satellite (the 'morning' satellite) has nominal local equatorial crossing times of 07:30 hrs. and 19:30 hrs., the other (the 'afternoon' satellite), has nominal equatorial crossing times of 13:30 hrs. and 01:30 hrs. Presently, the morning and afternoon satellites are NOAA-12 and NOAA-11.

One of the primary sensors onboard the NOAA-N satellites is the Advanced Very High Resolution Radiometer (AVHRR). This scanning instrument acquires data in five spectral channels; one in the visible range (channel 1: 0.55-0.68 μm), one in the near infrared range (channel 2: 0.725-1.1 μm), and three in the thermal infrared range (channel 3: 3.53-3.93 μm, channel 4: 10.3-11.3 μm, and channel 5: 11.5-12.5 um). Data are sensed by all channels simultaneously at 1.1 km spacial resolution. Data acquired by the instrument are resampled on board the satellite to 4 km spatial resolution and recorded for later transmission to one of two NOAA Command Data Acquisition (CDA) stations, at Gilmore Creek, Alaska and Wallops Island, Virginia. This is known as the Global Area Coverage (GAC) mode of transmission. In addition, the full spatial resolution 1.1 km data can be recorded for previously scheduled areas of the world, in the Local Area Coverage (LAC) mode, or can be received directly from the satellites by suitably equipped receiving stations, in the High Resolution Picture Transmission (HRPT) mode.

VOLCANO DETECTION AND MONITORING

Volcanoes pose serious hazards to human populations in many parts of the world. In addition to destruction caused by ashfall, mudslides, and lahars in the immediate vicinity of an erupting volcano, ash plumes injected into the atmosphere pose dangers to aircraft flying through them. Chemicals and particulates from large eruptions may cause climatic changes in ways which are at present poorly understood.

Meteorological satellite data offer a means of detecting volcanic eruptions in order to issue timely warnings, and can be used to study atmospheric effects.

Volcanic ash plumes may be detected by either visible of infrared sensors during daylight hours, and by infrared sensors at night. Infrared data yield information on plume temperatures, which when correlated with radiosonde information, may be used to estimate plume altitude. Infrared data have also been shown to be able to detect "hot spots" at the eruption site.

Figure 1 is a visible and infrared composite image processed from 1 km AVHRR data over Mt. Spurr, Alaska, taken about 4 hours after the initiation of an explosive eruption. The light area over Cook Inlet and Anchorage is the ash plume, and the dark area just northeast of the plume is the shadow cast by the ash. Here, the altitude of the plume may be determined trigonometrically from the solar zenith angle. The infrared image of the eruption yielded temperatures of the ash plume of -60° C., which corresponded to an altitude of about 45,000 feet.

In single band visible or infrared images, it is often difficult to discriminate ash from meteorological clouds or underlying ground. It has been demonstrated (Holasek and Rose 1991) that mathematically combining two bands often will enhance the ash plume, while attenuating other features. Figure 2. is an image of the Mt. Spurr ash plume produced by dividing channel 5 by channel 4. The underlying reasons for the accentuation of the ash are not well understood, but may involve differential emissivities of silicate dust in the 11 μm (channel 4) versus the 12 μm (channel 5) regions of the spectrum.

NOAA/FAA VOLCANO HAZARDS ALERT PLAN

In response to several situations where jet aircraft flew into the ash cloud of an erupting volcano and experienced severe engine and avionics damage and windscreen abrasion, NOAA and the U.S. Federal Aviation Administration (FAA) have implemented the Volcano Hazards Alert Plan. This is a cooperative, operational system to coordinate information on ongoing eruptions and issue warnings of the presence of airborne ash to aviation interests. The plan is activated whenever an eruption occurs which may endanger aircraft within U.S. Flight Information Regions (FIR), which include the continental United States, Alaska, and adjacent areas of the Atlantic Ocean, and much of the Central Pacific Ocean. In addition, it may be formally activated for areas outside the FIRs at the request of appropriate authority (e.g., the Department of Defense requested activation during the eruption of Mt. Pinatubo in 1991), or information may be transmitted on an advisory basis.

NESDIS' Synoptic Analysis Branch (SAB) is responsible for the satellite support and overall coordination required for the plan. Upon learning from any source (including cooperating agencies, news reports, or examination of satellite imagery) of the occurrence of an explosive eruption, SAB determines, according to prescribed criteria, if it is a significant eruption within a U.S. FIR. These criteria include confirmation from a National Weather Service (NWS) Meteorological Watch Office (MWO) or the indication of a significant eruption on satellite imagery. Upon confirmation, SAB contacts the NWS Central Flow Weather Service Unit, the NWS National Aviation Weather Advisory Unit, the affected MWO, the NWS National Meteorological Center (NMC) (which runs a trajectory model to predict ash movement), and the Smithsonian Institution's Global Volcanism Network, and provides information based on satellite data on the location and time of the eruption, estimated height and horizontal distribution of the ash cloud, estimated direction of movement, pilot reports, ARL trajectory model guidance, and time of the next update. SAB then issues updates at 3 to 12 hour intervals as long as the ash cloud is visible on satellite imagery. The National Aviation Weather Advisory Unit issues Significant Meteorological Event reports (SIGMETs) and forecasts for domestic FIR's, Meteorological Watch Offices issue international SIGMETs, and the Central Flow Weather Service Unit transmits information to affected FAA Air Route Traffic Control Centers and Center Weather Service Units for dissemination to pilots.

Currently under development at NESDIS is a procedure to provide timely access by SAB to high resolution AVHRR imagery, using modern communication links and workstation technology.

ATMOSPHERIC EFFECTS OF VOLCANIC ERUPTIONS

Large volcanic eruptions may affect long term climate conditions by the injection of aerosols (mainly sulfur and particulates) into the atmosphere, especially the stratosphere. Meteorological satellite data have been used to monitor the dispersal of aerosols after large eruptions, notably El Chichon in 1982 (Matson 1984) and Mt. Pinatubo in 1991 (Lynch et al. 1992). Using visible band data from both geostationary and polar orbiting satellites, the aerosol clouds from both eruptions could be tracked as they circumnavigated the Earth in about two weeks. In addition, the subsequent behavior of the aerosols from Mt. Pinatubo has been continuously monitored by the NESDIS Office of Research and Applications using the operational Aerosol Optical Thickness Product, derived from AVHRR channels 1 and 2 (Stowe et al. 1992).

RESEARCH ON VOLCANIC ERUPTIONS

In addition to its utility in operational settings, meteorological satellite data are of interest to scientific researchers. Satellite data have been used to estimate volumes of material injected into the atmosphere by volcanos (Holasek and Rose 1991), for calibrating models of volcanic plume dynamics (Woods and Self 1992), and estimating chemical compositions of volcanic emissions (Prata 1989).

FIRE DETECTION AND MONITORING

Knowledge of regional and global fire activity is needed for atmospheric, climatic, and deforestation studies. Biomass burning contributes significant amounts of chemicals and particulates to the atmosphere, affecting long term climate, and concern for the fate of the world's forests is becoming acute. Meteorological satellites, especially polar orbiters with their frequent, complete areal coverage, afford timely monitoring of fire activity anywhere on the globe.

Matson and Dozier (1981) and Matson et al. (1987) demonstrated that the use of AVHRR channel 3 provides the capability to detect high temperature sources. Figure 3. shows that with increasing temperature the maximum blackbody radiance of a heated object shifts away from the channel 4 region of the spectrum toward the channel 3 region, thus producing a correspondingly greater increase in response for channel 3 than for channel 4 for a given increase in temperature. On a channel 3 image, a high temperature target will appear much brighter than its surroundings, and in fact if hot enough, will saturate the sensor. Even targets much smaller than the 1 km resolution of the AVHRR will produce a large response if sufficiently hot. Using an algorithm developed by Matson and Dozier (1981), it is possible to use the different temperatures sensed by channel 3 and channel 4 to estimate the size and temperature of a target.

During the Persian Gulf War, Kuwait and surrounding areas were monitored continuously by NESDIS investigators (Stephens and Matson 1993). Figure 4. is a channel 3 image showing the large fires set in the oil fields of Kuwait. Note that even though the hot areas are seen as being hundreds of square kilometers in extent, the response is caused by many smaller, hot fires causing the sensor to saturate.

Figure 5. is a false color composite of AVHRR channel 1 expressed as blue, channel 2 as green, and channel 3 as red of forest fires in Sumatra. Environmental satellite data is vital in monitoring the depletion of the world's forests, particularly in tropical areas (Justice 1992).

The examples above were processed from 1 km resolution AVHRR data. Fires may also be detected in the 4 km resolution GAC data (Malingreau et al. 1985). Since GAC data is available daily for all areas of the globe, and is routinely resampled and mapped by NESDIS to become the basis for various operational environmental products, it may be possible to use these data to produce an operational, global fire detection product. NESDIS investigators are currently developing such a product using the remapped channel 3 and 4 data, composited over one week and displayed at approximately 25 km resolution.

CONCLUSIONS

With their frequent, world wide multispectral data acquisition capabilities, environmental satellites have been demonstrated to be useful in detecting, monitoring, and providing research data on volcanic eruptions and fire activity around the globe.

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GCOS STATUS AND REQUIREMENTS

(Submitted by the WMO Secretariat)

DISCUSSION

1. The Global Climate Observing System was recently established by a Memorandum of Understanding by WMO, IOC, ICSU and UNEP. Its principal objective is to meet the data requirements for climate. The Annex details these objectives and discusses the potential role of satellite observations in GCOS.

2. Although still in its early planning, it is anticipated that GCOS will work closely with both the research and operational satellite communities to develop the observational capabilities that will be required for the atmosphere, ocean and land.

3. Planning and oversight for GCOS are provided by a Joint Scientific and Technical Committee (JSTC). It is anticipated that while the JSTC will make specific recommendations for collaboration with CEOS, with regard to CGMS, it may be more appropriate to continue liaison via the WMO.

Global Climate Observing System

The Contribution of Satellite Observations to GCOS

Presented by

Sir John Houghton

Chairman, GCOS Joint Scientific & Technical Committee

CEOS Meeting, London,
9-11 December, 1992

GCOS

The Contribution of Satellite Observations to GCOS

1. Introduction

The Global Climate Observing System (GCOS) arose out of the 1990 Second World Climate Conference (SWCC), and is sponsored by the World Meteorological Organisation (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the International Council of Scientific Unions (ICSU), and the United Nations Environment Programme (UNEP). In recognising the urgent need for better understanding of climate change, the Ministers at the SWCC recommended that " the further development and implementation of the GCOS should be pursued with urgency".

The principal objective of the GCOS programme is to ensure the acquisition of the diverse observations required to meet the needs of :

- Climate system monitoring, climate change detection, and response monitoring, especially in terrestrial ecosystems
- Data for application to national economic development
- Research towards improved understanding, modelling and prediction of the climate system

The GCOS strategy for achieving this has three components :

(a) in the light of current knowledge and expertise to define and specify an operational climate observation system to be realised early next century

(b) to identify current key deficiencies in the observing system , to look urgently for means to overcome them, and to add them into the operational system in (a) as early as possible

(c) in consort with relevant international research programmes to stimulate a Research and Development programme for new directions for climate research and prediction studies, which will lead to future enhancements of the operational system.

In developing this strategy GCOS will rely to a large extent on the plans of related global programmes, namely the World Climate Programme (WCP), the World Climate Research Programme (WCRP), and the climate parts of the International Geosphere-Biosphere Programme (IGBP) and the Global Ocean Observing System (GOOS) , together with the ongoing and proposed satellite missions of the various space agencies. For its implementation GCOS will be looking to national and international agencies to provide appropriate components of the overall system. GCOS will operate in a systematic fashion, including the use of assimilative global models which depend on both space- and ground-based data. The aims of GCOS are described more fully in a booklet prepared under the auspices of the GCOS Joint Scientific & Technical Committee (JSTC), and published by the WMO in 1992.

Space observations constitute one major tool at the disposal of GCOS towards achieving its objectives. The principal space agencies currently have in place an extensive system of operational meteorological satellites, together with continuing programmes of developing advanced instruments directed towards climate-related problems. These programmes are backed up by associated programmes for research into developing new techniques and technologies for climate-related space observations, and for the ground processing, analysis and interpretation of the data aimed at longer term enhancement of information available for climate study.

The present programmes were mostly initiated before GCOS came into existence, and provide an extensive body of data which GCOS can combine with data from other sources. Although both parts make significant contributions on their own they complement and supplement each other. On the one hand space measurements are a valuable means of interpolating between widely spaced ground stations, especially over oceanic regions, and on the other ground-stations can provide valuable calibration data for the space instruments. GCOS is concerned to consolidate, co-ordinate and extend these activities in so far as they contribute to our knowledge of world climate problems.

The Committee on Earth Observations Satellites (CEOS) has recently published a detailed dossier summarising most of these programmes, together with other Earth-oriented programmes, according to the parameter to be measured and covering a time-frame extending from now until about 2007. The document constitutes a valuable source of initial data for use in drawing up the space element of the detailed GCOS plan, but GCOS must now address its objectives with a more detailed and focused approach.

GCOS has established small Task Groups to address particular elements of the climate system (Atmospheric Composition, Atmospheric Processes, Ocean Processes, and Land Surface Processes) with the aim of preparing a draft plan for GCOS to be presented to a meeting of the GCOS JSTC in January 1993. These Task Forces are taking an initial look at the overall rationale for observational requirements, current capabilities, specification of parameters to be measured, prioritisation, cost-effectiveness, and data requirements and strategies. They are required to make specific recommendations for both actions to be taken immediately, and for the systematic and orderly development of a programme of future observations.

This current report concentrates on future programmes, though recognises the contribution that past and existing missions have, and are currently, making to the general problems of environmental change. It seeks to draw attention to areas where further work is needed and where co-operation between CEOS and GCOS is essential in developing a greatly enhanced system for investigating the broader aspects of climate change.

2. Operational Requirements for Climate

2.1 The Current Position

Climate interests over the next few years are covered in large part by:

- Operational meteorological satellites (e.g. the NOAA and planned EUMETSAT polar orbiting series, and various geostationary platforms)

- The various major polar orbiting platform programmes planned for the end of the decade and early next century (e.g. ESA's ERS and ENVISAT series, the ESA-EUMETSAT METOP, NASA's EOS series, and NASDA's ADEOS series)

Among the key areas that have substantial coverage under these programmes, either through current fully operational instruments and their derivatives, or through instruments based on designs whose operational potential has already been demonstrated, are:

- Temperature profiles in the troposphere and stratosphere (HIRS , AMSU-A, SAGE)
- Precipitation measurements (e.g. SSM/I, AMSU-A, MIMR)
- Cloud track winds from geostationary satellites
- Radiation budget measurements (a continuation of ERBE or equivalent instruments such as CERES, SCARAB)
- High accuracy sea surface temperature measurements (ATSR, and its successors such as ATSR-2, AATSR)
- Ocean wind speed / velocity / wind stress (e.g. AMI, ALT, NSCATT etc)
- Ocean colour instruments for measuring ocean biology elements that impact, or are impacted on by, climate change (SeaWIFS, MODIS-N etc)
- Ocean surface topography (currents, gyres etc) measurements (advanced Radar Altimeters, but with ultimately improved geoid required)
- Land surface characteristics such as vegetative cover, global vegetation index, albedo, surface temperature etc (AVHRR, ATSR, MODIS-N and their derivatives)
- Cryosphere characteristics such as sea-ice distribution, snow cover, polar land ice, glacier monitoring etc (AVHRR, Radar Altimeters, AMI, MIMR, etc)
- Continuous measurement of profiles and column densities of key tropospheric (H_2O) and lower stratospheric (O_3) gases and aerosols (HIRS, AMSU-B, TOMS etc)

All these can be regarded as contributing to GCOS objectives. A subset is required for continuous long-term climate monitoring. In some respects climate studies do not place the same stringent demands with respect to response time, or in some areas the need for absolute continuity, that are required for Operational Meteorology. However, use in assimilation schemes may impose time restraints similar to those for Operational Meteorology and the demands of long-term climate monitoring imply the need for detailed instrument intercomparisons involving temporal overlap of instruments in orbit.

Additionally several instruments dedicated to measuring a wide range of stratospheric species relevant to the ozone layer problem are included in the planned programmes (i.e. Eos MLS, GOME, HIRDLS, ILAS, MIPAS, SAGE-III, SCIAMACHY etc)

2.2 The need for Analysis, Appraisal, and Specification of Operational Requirements

Although the above areas are strongly represented in the current and planned space programmes there are some general points which need particularly continued careful attention in relation to climate, i.e.

- Assurance of continuous operational meteorological a.m. and p.m. polar platforms
- The need to fill the geostationary data gap over the Indian Ocean
- Synergy of missions between different agencies (especially the avoidance of duplicating instruments where unjustified by scientific requirements)
- Synergy of payloads, including operational meteorology instruments (and especially avoiding time-sharing between instruments)
- The need for continuous operation and improved spatial coverage for some key instruments (e.g. scatterometers for ocean surface winds)
- The need for improved calibration and validation (including mission overlaps to allow in-orbit instrument intercalibrations)
- The need to consider in detail the extent to which continuous measurements are necessary in specific areas, as opposed to periodic measurements coupled with intense ground-based campaigns (e.g. with respect to studies of the ozone problem)

The overall measurement programme of climate variation and its effects, and of the behaviour of the ozone layer, require a detailed analysis and appraisal of current and planned observational systems. GCOS will be setting up machinery to make recommendations on :

- Improving accuracy and resolution where essential
- Expanding the range of measurements in the operational programmes, including extending geographical coverage where necessary

Detailed specifications of the additional operational requirements needed to effect long-term climate studies will then be drawn up. To avoid potential gaps particular emphasis needs to be placed on defining the climate aspects of instruments/missions not yet finalised, and to ensure a smooth transition from current to planned programmes. GCOS plans to develop proposals in concert with space agencies with the needs of long-term environmental issues in mind.

3. Specific Current Deficiencies

Some specific parameters where improvements are urgently required for climate studies and which could come in part as developments from existing and planned operational programmes include :

- Temperature profile accuracy and vertical resolution - CEOS 2.1.1
- Water-vapour profile accuracy and vertical resolution - CEOS 2.1.2

- Improved precipitation data over ocean, see also Section 4 -CEOS 2.1.3
- Surface wind velocity accuracy and calibration, and improved spatial/time coverage - CEOS 2.5.2

The above have been picked out as specific examples, but measurements of several other parameters which currently have substantial coverage would benefit from improved accuracy and/or spatial coverage. They will be covered in the studies proposed in Section 2.2 above.

There are other deficiencies which require substantial programmes of research and development before reliable space instruments, some of which will be of novel types in relation to today's instruments, can be produced. These are considered in the following section.

4. The Need for Research and Development

Other specific key needs cannot be met by current or imminent programmes. Techniques are available for addressing them and urgent action regarding them is required. Further research and development in these areas could lead to significant advances on a realistic timescale. Examples include :

- Tropospheric wind profiles (e.g. through Doppler lidars) - CEOS 2.1.4
- Improved detail on tropospheric aerosols, i.e. especially optical depth, turbidity, condensation nucleii concentration, light scattering and absorption coefficients etc (e.g. through space lidars) - CEOS 2.2.1
- Global precipitation (c.f. GEWEX programme) - 2.1.3
- Improved , and 3-dimensional, cloud data , i.e. top and base heights, droplet size and distribution etc (c.f. the GEWEX programme) - CEOS 2.1.6,7,8
- Soil moisture (e.g. through large real or synthetic aperture microwave radiometers) - CEOS 2.3.4
- Ocean salinity (as for soil moisture) - Not specifically mentioned in CEOS dossier
- Height distribution and density of tropospheric species (e.g. through developments from stratospheric instruments etc) - CEOS 2.2.2 to 2.2.5
- The measurement, or improved measurement, of additional important lower stratospheric species (e.g. OH) - CEOS 2.2.7 to 2.2.12

Some activities in these areas are already being carried out to varying degrees by agencies represented by CEOS. GCOS will work with other programmes (WRCP / IGCP / GOOS etc) on methodologies to tackle these and other problems, with space as one of the potential major tools. Resulting from this work, GCOS will be making proposals for the continuation and extension of some or all of these areas, and with respect to the space elements. GCOS would welcome joint studies with CEOS, with the objective of carrying at least some of them through to the stage of becoming new research instruments, and in some cases to becoming operational ones.

5. Data Needs

A major problem for GCOS is how to deal with the vast amount of data which is, and will be, produced by a long-term climate observing system. This data will come from a wide range of scientific disciplines, and from both ground- and space-based sources, with a corresponding divergence of time-scales, geographic coverage, distribution of data points, etc. Such data will generally not match the data grids used in current models.

The problem of acquiring, processing, disseminating and merging this data, bearing in mind the need to combine space data with ground-based data, is a formidable one which has consistently been underfunded in the past. However, GCOS notes the focus which space agencies are putting on the data systems for currently planned programmes (i.e. NASA's EOS-DIS, ESA's POEM Data Segment etc), though these tend to be centred on data from specific space missions. The value of the space data will be considerably enhanced by co-ordination with users such as GCOS in defining means by which space-based climate data and ground-based climate data can most effectively be merged into a combined Global Climate Database, and to investigate ways in which space instrument data acquisition modes and/or models could be modified so as to optimise their assimilation into climate models. The definition will need to take account of existing and planned systems, and to consider the balance between a few large data-centres and a large number of smaller distributed ones. Such co-operation with users is essential if the vast investment in the space programme is to provide a cost-effective return.

As part of the overall plan existing climate data management programmes will need to be expanded, followed by the development of new higher level (assimilated) data set capabilities based on existing centres of expertise. These will need to address quality control, assimilation techniques, data handling and distribution, and integration into a comprehensive and readily accessible climate data system. At the same time work on non-assimilated data will be required, including archiving, in order to maintain accurate and consistent long-term records both in series and parallel with improved assimilation schemes.

Additionally, it must not be overlooked that much can be gained by reworking some existing satellite data, especially sea-surface temperature and cloud data.

Finally, whatever system is put in place must be readily accessible and readily usable for a large number of users worldwide.

6. Concluding Remarks

The Joint Scientific and Technical Committee (JSTC) of GCOS will be meeting in January 1993 in Washington DC to produce a draft GCOS plan to go before the Inter-Government Meeting on the World Climate Programme and related activities being arranged for April 1993. This draft plan will be refined during 1993 through Working Groups which GCOS will set up to consider in detail the various components of the observing system and to consider the matters raised in the earlier sections.

In conclusion:

- GCOS would benefit from the support of CEOS in developing the space-based element of climate observations
- CEOS would benefit from the support of GCOS in fully exploiting the climate data output resulting from the enormous investment in the space programmes

Consequently, GCOS:

- Requests the co-operation of CEOS in defining and establishing the space segment of GCOS, including the associated data system, in order to maximise the effectiveness of satellite climate data

and specifically:

- Invites CEOS to participate in the GCOS Working Groups

List of Abbreviations / Acronyms etc

AATSR	Advanced Along Track Scanning Radiometer
ADEOS	Advanced Earth Observing System
ALT	Altimeter
AMI	Active Microwave Instrument
AMSU-A	Advanced Microwave Sounding Instrument - A
ATSR	Along track Scanning Radiometer
AVHRR	Advanced High Resolution Radiometer
CEOS	Committee for Earth Observation Satellites
CERES	Clouds and Earth Radiant Energy System
ENVISAT	Environmental Satellite Platform of ESA's POEM Programme
EOS	Earth Observing System
EOS-DIS	Earth Observation System Data Information System
ERBE	Earth Radiation Budget Experiment
ERS	European Remote Sensing Satellite
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GCOS	Global Climate Observing System
GDF	Geophysical Data Facility
GEWEX	Global Energy and Water Cycle Experiment
GOME	Global Ozone Monitoring Experiment
GOOS	Global Ocean Observing System
HIRDLS	High resolution Dynamics Limb Sounder
HIRS	High resolution Infrared Sounder
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
ILAS	Improved Limb Atmospheric Sounder
IOC	Intergovernmental Oceanographic Commission
JSTC	Joint Scientific and Technical Committee of GCOS
METOP	Operational Meteorology Platform of ESA's POEM Programme
MIMR	Multi-frequency Imaging Microwave Radiometer
MIPAS	Michelson Interferometric Passive Atmospheric Sounder
MLS	Microwave Limb Sounder
MODIS-N	Moderate Resolution Imaging Spectrometer - Nadir
NASA	National Aeronautics and Space Administration (USA)
NASDA	National Space Development Agency (Japan)
NOAA	National Oceanic and Atmospheric Administration (USA)
NSCATT	NASA Scatterometer
POEM	Polar Orbit Earth Observation Mission
SAGE	Stratospheric Aerosol and Gas Experiment
SCARAB	Scanner for Earth's Radiation Budget
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmos. Cartography
SeaWIFS	Sea Viewing Wide-Field Sensor
SSM/I	Special Sensor Microwave Imager
SWCC	Second World Climate Conference
TM	Thematic Mapper
TOMS	Total Ozone Mapping Spectrometer
UNEP	United Nations Environment Programme

UNESCO	United Nations Educational, Scientific and Cultural Organisation
WCP	World Climate Programme
WCRP	World Climate Research Programme
WMO	World Meteorological Organisation

ANNEX XIX

CGMS-XXI, WMO WP-7
Prepared by WMO
Agenda Item: D.3

WMO Contingency Planning Requirements

(Submitted by the WMO Secretariat)

Summary and purpose of document

This document discusses the latest contingency planning requirements of the WMO. This document was presented to the CGMS Working Group on Contingency Planning. It has been updated to include discussions that occurred at CBS-X.

ACTION PROPOSED

The CGMS is invited to:

1. note the WMO Contingency Planning Requirements when discussing short and long range planning.

Appendix I

WMO REQUIREMENTS FOR CONTINUITY OF THE SPACE BASED PORTION OF THE GOS

DISCUSSION

1. The WMO EC Panel of Experts/CBS Working Group on Satellites met in Geneva 16-20 March 1992. The Panel/WG discussed as an agenda item WMO Contingency Planning for Use by Satellite Operators. The Panel/WG developed a draft statement of WMO requirements for continuity of the space based portion of the GOS.

2. The Forty-Fourth Executive Council reviewed the draft statement of WMO requirements for continuity of the space based portion of the GOS and stressed the importance of continuity of satellite data for all WMO Members.

3. The Executive Council noted that the satellite operators would develop detailed specifications for contingency planning and thus it was appropriate for WMO to articulate its requirement for continuity of the space-based portion of the GOS. The Executive Council felt it important that contingency plans, including long-term (10 years), should be developed by the satellite operators.

4. The Executive Council endorsed the statement of requirements which is given in the Appendix I.

5. It should be understood that the primary focus of the statement in Appendix I is towards space segment contingency planning. Furthermore, it is anticipated that CGMS will continue its role of standardization such that ground receiving equipment would be able to receive and process services from any contingency satellite provided by another operator, eg. standardized data formats.

6. The Tenth session of the Commission for Basic Systems agreed with the importance of a statement of WMO requirements for continuity of the space-based portion of the GOS endorsed by EC-XLIV (See Appendix I). It was pleased to learn of the recent CGMS Working Group Meeting on Global Contingency Planning where EUMETSAT, NOAA/NESDIS and Japan had agreed to consider and study contingency planning that could provide continuity of data necessary to WMO Programmes.

WMO REQUIREMENTS FOR CONTINUITY OF THE SPACE BASED PORTION OF THE GOS

I. Introduction

1. The purpose of this statement is to provide guidance to the satellite operators who support the space-based sub-system of the GOS in the preparation of their contingency plans.

2. WMO's Eleventh Congress "urged Members concerned to maintain the polar-orbiting and geostationary satellite systems to ensure the continuity of operation, and the data dissemination and distribution services of those satellite systems ...".

3. Ensuring continuity in this context refers to minimizing any interruption in WMO required environmental satellite missions services due to a failure in the space-based portion of the GOS. The GOS space segment operators have developed internal contingency plans to provide substitute products and services in the event of a service outage. Many of these internal plans draw upon the data and products of other space segment operators. In addition, the satellite operators of the space-based portion of the GOS have through a policy of "help your neighbour" worked together to help each other in the event of such a failure. The most recent example of this being the willingness of EUMETSAT to make available a METEOSAT spacecraft for coverage over the Atlantic. This event highlights the importance of co-operation contingency planning amongst the operators.

4. CGMS has long served as a forum for addressing the WMO Executive Council Panel of Experts concern regarding ensuring continuity of the meteorological satellite services and will continue to be the focus for continuity planning.

II. Satellite mission service requirements

5. The WMO general requirements for the space-based su'-system of the Global Observing System were endorsed at EC-XLIII which requested that its content be used by WMO when stating overall WMO satellite requirements (see report of the EC Panel of Experts on Satellites, ninth session) All of the current operational mission requirements of WMO should be addressed in the contingency plans of the satellite operators. The most urgent attention of the operators should be directed to the key missions listed below:

(a) For geostationary satellites:

- The imagery mission;
- The capability to produce winds;
- The capability to broadcast data to local users;
- The capability to collect and relay in situ data;

(b) For polar satellites:

- The sounding mission;
- The imagery mission;

explore a wide range of contingency strategies involving for example spacecraft, ground systems, alternative products, etc. The satellite operators should also explore measures to improve the compatibility of their various systems.

13. Section II outlined the mission requirements that are considered critical by WMO. The contingency plans of satellite operators should ensure coverage of those regions of the world where severe weather conditions (eg. cyclones, tornadoes, etc.) develop. The importance of direct broadcast services such as APT, WEFAX, HRPT continuity should also be considered. To ensure the continued availability of high resolution data, standardization of transmission links and formats should be considered.

14. Contingency planning of this nature must be a continuing dialogue between the satellite operators and their user representatives in order to develop practical cost effective contingency alternatives which respond to the needs of the user communities.

CGMS-XXI, WMO WP-7, Appendix I, 9

ANNEX

GUIDELINES FOR TECHNICAL CO-OPERATION PROJECTS PROVIDING COMPUTER-BASED SYSTEMS FOR THE IMPLEMENTATION OF WWW COMPONENTS AND FACILITIES

Computer-based systems or sub-systems which are planned to be installed in developing countries for the implementation of WWW components and facilities through Technical Co-operation Projects, should be designed in compliance with the following guidelines regarding the data exchange and training support:

(a) The computer systems interfaces should comply with ISO/CCITT standards;

(b) GTS bulletins should be the standard format for the data exchange between computer systems or sub-systems for telecommunication, data handling and data-processing functions;

(c) The software should be written in a modular way with a view to simplifying the software maintenance to be carried out in the field;

(d) The data handling should comprise functions for WMO binary representation forms, or should be designed in such a way that the software modules necessary for this purpose can be easily incorporated at a later date when required;

(e) Computer-based systems should include appropriate user manuals and guides which may be accompanied by computer-based training packages (tutorials) with a view to assisting the user in operating and applying the system;

(f) Training courses should be organized at centres equipped with the appropriate systems for users of computer systems installed under Technical Co-operation Projects. In this context, the role of the RMTCs for conducting refresher courses for computer users should be strengthened.

CGMS-XXI WMO WP-2
Prepared by WMO
Agenda Item: E.1

GUIDELINES FOR THE TECHNICAL CO-OPERATION COMPUTER PROJECTS

(Submitted by the WMO Secretariat)

Summary and purpose of document

The Commission for Basic Systems at its tenth session (CBS-X, Geneva, November 1992) underscored the need for improved standardization of WMO Technical Co-operation computer projects, in particular as regards the exchange of data between computer systems or sub-systems (including meteorological computer workstations and satellite workstations), and discussed possibilities for improving the training support provided along with computer implementations and/or maintenance measures in developing countries. To this end, the Commission adopted specific guidelines and tasked its Working Groups on Data Management, on Telecommunications and on Satellites to consider these aspects further and to develop conceptual proposals. This document summarizes the deliberations of the Commission and presents the guidelines.

ACTION PROPOSED

The CGMS is invited to note the guidelines adopted by CBS and the related tasking issued for the pertinent CBS Working Groups. The meeting may further wish to comment on aspects concerning meteorological computer workstations for processing satellite imagery.

Appendix: Guidelines for Technical Co-operation Projects Providing Computer-based Systems for the Implementation of WWW Components and Facilities

DISCUSSION

1. The objective of the WWW Systems Support Activities (SSA) is to ensure that all Members, particularly developing countries, have at least the minimum necessary equipment and technical know-how to meet national needs and to allow them to fulfill their agreed responsibilities within the WWW system. The WWW/SSA include computer projects for automating key WWW facilities which are carried out in close co-operation with the Technical Co-operation Programme.

2. It has been difficult to carry out such projects through a comprehensive systems management approach which would provide to each recipient country modular, compatible computer systems or sub-systems, because the various sub-systems have different development histories and are very seldom, if ever, donated together or from a single source. This has lead to compatibility problems between the various sub-systems with respect to the exchange of meteorological data which results in an overall loss of performance, great difficulties in maintaining the systems and a possible lack of confidence in the Technical Co-operation Computer Projects.

3. CBS-X (Geneva, November 1992) recognized that a standard interface for the exchange of meteorological data between systems and sub-systems would improve the effectiveness of the Technical Co-operation Computer Projects implemented under various operational conditions and would facilitate the maintenance support required. The Commission, therefore, agreed that it is reasonable and practical to adopt the GTS bulletin format which is, in fact, the backbone of the WWW data exchange, as the appropriate standard format for the exchange of data between the computer systems and sub-systems for telecommunication, data handling and data-processing involved in Technical Co-operation Projects.

4. The Commission also recognized that more sophisticated data structures may have to be developed in the future with a view to meeting requirements for a more efficient data transfer (e.g. file transfer) between advanced telecommunication, data handling and data-processing systems, including workstations for the handling of satellite imagery and related products. It requested the Working Group on Data Management, in concert with its Working Groups on Telecommunications and on Satellites, to consider this aspect further and to develop conceptual proposals.

5. So far, WMO has provided training support for Technical Co-operation Computer Projects individually for each project through experts seconded by a donor country or contracted by the WMO Secretariat which has not satisfied the need for repetitious training, and has thus not achieved the lasting effect required for the longer-term operation of the received computer system. The Commission felt that an improvement in this area can be expected from the use of computer-based training tools which may be provided in addition to the instructor-based training. These tools could also cover a wider range of related subjects, such as basic computer training, use of operating systems, and specific meteorological subjects related to the computer applications, such as use and interpretation techniques of numerical

products, forecasting techniques, etc. Donor Members were invited to foster the development of computer based tutorials together with the development of applications software.

6. In this context, the Commission recommended that some RMTCs should provide refresher courses for the use of computer systems fielded through Technical Co-operation Projects and apply computer-based training tools and video-taped material, as appropriate. To this end, some RMTCs should be equipped, through Technical Co-operation Projects as required, with the appropriate computer systems and the necessary computer-based tutorials. The delegate from India mentioned the possibility of providing VCP fellowships with respect to general computer applications and management of computer systems at the RMTC in India.

7. The Commission adopted the guidelines for Technical Co-operation Projects providing computer-based systems for the implementation of WWW components and facilities as given in the Appendix. The Commission recommended that the Secretary-General and donor countries take these guidelines into account, as appropriate, in the development of relevant Technical Co-operation Projects. The Working Groups on Data Management, Telecommunications and Data Processing were requested to consider the inclusion of these guidelines in the respective WWW Guides. The Working Group on Data Management was further requested to develop practical guidelines on planning and management for meteorological computer systems. The guidelines will also be circulated to manufacturers that deal with such and related computerized products.

Appendix: 1

GUIDELINES FOR TECHNICAL CO-OPERATION PROJECTS PROVIDING COMPUTER-BASED SYSTEMS FOR THE IMPLEMENTATION OF WWW COMPONENTS AND FACILITIES

Computer-based systems or sub-systems which are planned to be installed in developing countries for the implementation of WWW components and facilities through Technical Co-operation Projects, should be designed in compliance with the following guidelines regarding the data exchange and training support:

(a) The computer systems interfaces should comply with ISO/CCITT standards;

(b) GTS bulletins should be the standard format for the data exchange between computer systems or sub-systems for telecommunication, data handling and data-processing functions;

(c) The software should be written in a modular way with a view to simplifying the software maintenance to be carried out in the field;

(d) The data handling should comprise functions for WMO binary representation forms, or should be designed in such a way that the software modules necessary for this purpose can be easily incorporated at a later date when required;

(e) Computer-based systems should include appropriate user manuals and guides which may be accompanied by computer-based training packages (tutorials) with a view to assisting the user in operating and applying the system;

(f) Training courses should be organized at centres equipped with the appropriate systems for users of computer systems installed under Technical Co-operation Projects. In this context, the role of the RMTCs for conducting refresher courses for computer users should be strengthened.

CGMS-XXI WMO WP-8
Prepared by WMO
Agenda Item: E.1

WMO Satellite Data Requirements

(Submitted by the WMO Secretariat)

Summary and purpose of document

This working paper presents the latest set of WMO satellite data requirements.

ACTION PROPOSED

The CGMS is invited to:

1. note the short list of satellite data requirements and to comment as appropriate.

Appendix I

Short list of WMO Satellite Data Requirements

DISCUSSION

1. At the tenth session of the WMO EC Panel of Experts/CBS Working Group on Satellites, the Panel/WG discussed the WMO satellite data requirements. The following information refers to their discussions, recommendations and actions that have subsequently occurred.

2. The original consolidated list of satellite data requirements stated by all WMO Programmes was very lengthy, comprehensive and in many cases duplicative. The Panel/WG condensed this into what is named a "short list of WMO satellite data requirements". The Panel/WG proposed that the short list of satellite data requirements provided a useful summary that could guide satellite operators or instrument scientists/engineers. The Panel/WG also suggested that there was a need for continued iteration with the Technical Commissions and other bodies implementing WMO Programmes for which CGMS is most important.

3. To begin this iterative process, the Panel/WG recommended that the various user communities should be categorized and that priority order should be given to the satellite data requirements to reflect the importance of the data, the ability to use observations from space, and the status of space observing techniques. The main WMO Programme user categories (drivers) were regarded by the Panel/WG as being:

A) Operational meteorology;
B) Climate and Environment monitoring and change;
C) Hydrology/Hydrometeorology/Agrometeorology.

4. The Panel/WG recommended that each user should be asked to consider those data needed for its applications or research activities. To standardize the responses, the users should be advised of the accuracies and resolutions that are:

a) Currently available or will be available from instruments now under development for flight or agreed missions (e.g., NOAA K to O, POEM-1, EOS, ERS-2, etc.);

b) Currently foreseen as achievable but not yet under active development for operational or research flight purposes.

5. The Panel/WG felt that users should be asked to review their requirements for data obtained from space in the light of (a) and (b) above. They should also be asked to put priorities on their data needs. This review action was accomplished through correspondence between the WMO Secretariat and the Presidents of Technical Commissions. The Panel/WG believed that the results of such iteration would help refine the "short list" and also help to guide the satellite and instrument scientists/engineers. The responses received from the Technical Commissions have been incorporated into the revised short list of satellite data requirements.

6. To start the provider/user dialogue, the Panel/WG agreed that CEOS, working in conjunction with CGMS, should be given the short list

to advise on current and expected instrument and observation capabilities. The short list is in priority order and the main user categories for each measurement are shown. The forwarding of the requirements to the satellite operators would be for the purpose of validating the detailed specifications attributed to the programmes and systems of the satellite operators. The short list was presented to CEOS at their April 1992 Plenary in London and again at their December 1992 Plenary in London. The second presentation benefitted from feedback from CEOS concerning specific details. This was anticipated and welcomed as part of the iteration process. After the list has been reviewed by CEOS, working with CGMS, and by the Technical Commissions, it will be integrated into the Consolidated Report for the Panel/WG and subsequently for the WMO Executive Council to review and approve at its Forty-fifth session in June 1993.

7. The Panel/WG agreed that the short list should also be forwarded to the meeting of the Joint Scientific and Technical Committee (JSTC) for GCOS (13-15 April 1992) in order that JSTC could be aware of the progress being made in the development of WMO satellite data requirements. In view of the fact that the president of CBS was also a JSTC member, he was asked to present the results of the Panel's deliberations to the JSTC. The Panel was of the opinion that this action would insure that WMO satellite data requirements would be considered during the initial stages of the development of the GCOS.

8. The forty-fourth session of the WMO Executive Council (June 1992) welcomed the development of the short list which would provide useful guidance to satellite operators.

9. The latest short list is attached as Appendix I. It is presented in two formats. The first format lists the satellite data parameter, type of instrument that could measure that parameter, candidate sensors and missions. The second format lists more detailed specification for each parameter in terms of horizontal, vertical, temporal and spatial resolutions.

10. It should be noted that the format (not the requirements) in Appendix I is now being utilized by other organizations, for example the World Climate Research Programme and the Intergovernmental Oceanographic Commission, when stating their satellite data requirements. It is felt that this should provide for a more uniform manner for the various user communities to articulate their needs and facilitate combining the various lists. It should also present the satellite operators with an overall picture of usage of their satellite data.

Measurement	Instrument type	Candidate sensor	Mission
Wind profile	(undetermined)	(undetermined)	
Temperature profile	Sounder (IR & microwave)	HIRS,AIRS,IASI,MSU	EPS, NOAA, EOS,
Humidity profile	Sounder (IR & microwave)	HIRS,AIRS,IASI,MSU,AMSU	NOAA, EPS
Precipitation rate	Microwave imager	SSMI, TMI, MIMR	EOS, TRMM
Liquid water, total	Microwave imager	SSMI, TMI, MIMR	EOS, TRMM
Cloud top height (1)			
Cloud top temperature	Imaging radiometer, sounder (IR)	AVHRR,HIRS, AIRS, IASI	NOAA, EOS, EPS
Cloud type and amount	Imaging radiometer	AVHRR, SEVIRI, VISSR, MVIRI	NOAA, EPS
Height of tropopause (1)			
Ozone total and profile	Mapping spectrometers	GOME, GOMOS, TOMS,	ERS, NOAA, POEM
Radiation, net	Wide-band scanning radiometer	CERES, ScaRaB	NOAA, POEM, TRMM
Aerosol	Imaging radiometer	AVHRR	NOAA
Multi-purpose imagery	Imaging radiometer	AVHRR,SEVIRI,MODIS, MERIS	NOAA, MSG
Pressure, sea surface	(undetermined)	(undetermined)	
Temperature, sea surface	Imaging radiometer, sounder	AVHRR,ATSR,AIRS, IASI,OCTS	NOAA, ADEOS
Temperature, surface	Imaging radiometer	AVHRR, ATSR	NOAA, ERS
Sea surface wind	Microwave scatterometer	AMI, NSCATT, STIKSCAT	ERS, ADEOS, EOS
Soil moisture	(undetermined)	(undetermined)	
Albedo, visible	Imaging radiometer	MODIS-N, MERIS	EOS, POEM
Albedo, near IR	Imaging radiometer	MODIS-N, MERIS	EOS, POEM
Ocean wave height	Radar altimeters	ALT, RA	EOS, ERS, POEM
Wave spectrum	Microwave scatterometer	AMI	ERS
Ice coverage	IR/microwave imaging radiometer	AVHRR,SSMI, MIMR	NOAA, EOS, POEM
Ice edge	IR/microwave imaging radiometer	AVHRR, SSMI, MIMR	NOAA, EOS, POEM
Ice thickness	(undetermined)	(undetermined)	
Snow coverage	Vis & IR imaging radiometer	AVHRR	NOAA
Snow edge	Vis & IR imaging radiometer	AVHRR	NOAA
Snow depth	(undetermined)	(undetermined)	
Snow water equivalent	(undetermined)	(undetermined)	

Footnote: (1) Diagnostic

Short List of WMO Satellite Data Requirements - Upper Air

with estimates of operational products/capability for the 1990s and of operational and prototype operational products/capabiliity for 2000 and beyond

Individual requirements are highlighted in large, bold print. Some requirements are further specified by underlining for "Limited Area" and/or "Global". "Global" and "Limited Area" refer to spatial coverage. The User Categories are as noted below and also contain the name(s) of the WMO Technical Commission(s) which provided input in the formulation of the requirement.

User Category codes
A = operational meteorology
B = climate and environmental monitoring and change
C = hydrology/hydrometeorology/agrometeorology

CAgM (Commission for Agricultural Meteorology)
CAS (Commission for Atmospheric Science)
CCl (Commission for Climatology)
CMM (Commission for Marine Meteorology)
CAeM (Commission for Aeronautical Meteorology)
CBS (Commission for Basic Systems)
CHy (Commission for Hydrology)
WCRP (World Climate Research Programme)
ISCCP (International Satellite Cloud Climatology Project)
ISLSCP (International Satellite Land Surface Climatology Project)

Abbreviations:

Ly = layers, min = minute, hr = hourly
d = day, wk = weekly, mon = monthly

	Horizontal resolution	Vertical resolution	Frequency	Accuracy	User Categories
Wind profile					
Limited Area Rqmt	25km	50Ly	6hr	1m/s	A [CAS, CCl]
Global Rqmt	100km	15Ly	12hr	1m/s	A [CAeM, CBS, CCl, WCRP]

ANNEX XXI

5

Temperature profile

	Horizontal resolution	Vertical resolution	Frequency
Limited Area Rqmt	25km	50Ly	6hr
Global Rqmt	25km	15Ly	6hr

Humidity profile

	Horizontal resolution	Vertical resolution	Frequency
Limited Area Rqmt	25km	10Ly	6hr
Global Rqmt	50km	10Ly	6hr

Precipitation rate

	Horizontal resolution	Vertical resolution	Frequency
Limited Area Rqmt	5km		30min
Global Rqmt	25km		6hr

Liquid water, total

	Horizontal resolution	Vertical resolution	Frequency
Global Rqmt	25km	5Ly	6hr

ANNEX XXI

Accuracy	User Categories
1.0K	A [CAgM, CAS]
1.0K	A,B [CAeM, CMM, CAS, CBS, CCl, WCRP]
5%	A [CAS, CHy]
5%	A,B [CAeM, CMM, CAS, CBS, CCl]
1mm/d	A,B,C [CAgM, CHy, CAS, CCl]
3mm/d	A,B,C [CAS, CCl, CMM, ISLSCP, WCRP]
0.1 (<100nm) 2 (>100nm)	A,B [CCl, CAS]

	Horizontal resolution	Vertical resolution	Frequency
Cloud top height			
Limited Area Rqmt	5km		1hr
Global Rqmt	10km		3hr
Cloud top temperature			
Limited Area Rqmt	5km		1hr
Global Rqmt	5km		3hr
Cloud type and amount			
Limited Area Rqmt	5km	10Ly	1hr
Global Rqmt	5km	10Ly	6hr
Height of tropopause			
Limited Area Rqmt	25km		6hr

Accuracy	User Categories
.2km	A [CAS, CCl]
.2km	A [CCl, ISCCP, WCRP]
1K	A [CAS]
1K	A [CCl, ISCCP WCRP]
10%	A,B [CAS, CCl, CMM]
10%	A,B [CCl, CMM ISCCP, WCRP]
1km	A [CAS]

	Horizontal resolution	Vertical resolution	Frequency
Ozone total and profile			
Global Rqmt	50km		6hr
Radiation, net			
Limited Area Rqmt	10km		12hr
Global Rqmt	50km		12hr
Aerosol			
Global Rqmt	.5km	1km	6hr

Accuracy	User Categories
5%	B [CCl, CAS]
$5 w/m^2$	A,B,C [CAgM, CCl WCRP]
$2.5 w/m^2$	A,B,C [CAS, CCl, ISLSCP, WCRP]
10%	B [CAeM, CCl]

with estimates of operational products/capability for the 1990s
and of operational and prototype operational products/capabiliity for 2000 and beyond

Individual requirements are highlighted in large, bold print. Some requirements are further specified by underlining for "Limited Area" and/or "Global". "Global" and "Limited Area" refer to spatial coverage. The User Categories are as noted below and also contain the name(s) of the WMO Technical Commission(s) which provided input in the formulation of the requirement.

User Category codes
A = operational meteorology
B = climate and environmental monitoring and change
C = hydrology/hydrometeorology/agrometeorology

CAgM (Commission for Agricultural Meteorology)
CAS (Commission for Atmospheric Science)
CCl (Commission for Climatology)
CMM (Commission for Marine Meteorology)
CAeM (Commission for Aeronautical Meteorology)
CBS (Commission for Basic Systems)
CHy (Commission for Hydrology)
WCRP (World Climate Research Programme)
ISCCP (International Satellite Cloud Climatology Project)
ISLSCP (International Satellite Land Surface Climatology Project)

Abbreviations:

Ly = layers, min = minute, hr = hourly
d = day, wk = weekly, mon = monthly

	Horizontal resolution	Frequency	Accuracy	User Categories

Multi-purpose imagery

	Horizontal resolution	Frequency	Accuracy	User Categories
Limited Area Rqmt	10m	12hr		A,B,C [CAgM, CBS, CCl,CHy]
Global Rqmt	.4km	6hr		A,B,C [CAS, CCl, ISLSCP, IOC]

ANNEX XXI

	Horizontal resolution	Frequence
Pressure, sea surface		
Limited Area Rqmt	20km	1hr
Global Rqmt	25km	6hr
Temperature, sea surface		
Limited Area Rqmt	1km	6hr
Global Rqmt	1km	6hr
Temperature, surface		
Limited Area Rqmt	.5km	12hr
Global Rqmt	1km	12hr
Sea surface wind		
Limited Area Rqmt	10km	6hr
Global Rqmt	25km	6hr

ANNEX XXI

Accuracy	User Categories
.5mb	A [CAS]
.5mb	A [CAS, CBS, WCRP]
.1K	A [CCl, CMM, CBS]
.1K	A,B [CBS, CCl, CMM, WCRP, IOC]
.1K	A,B,C [CAS, CAgM, CCl, CHy]
.5K	A,B,C [CCl, CBS, ISLSCP]
3kts 10deg	A [CAS, CCl, CAeM, CMM]
2kts 10deg	A [CAeM, CAS, CBS, CCl, CMM]

	Horizontal resolution	Frequency

Soil moisture

<u>Limited Area Rqmt</u>	20km	24hr
<u>Global Rqmt</u>	25km	24hr

Albedo, visible

<u>Limited Area Rqmt</u>	1km	6hr
<u>Global Rqmt</u>	5km	24hr

Albedo, near IR

<u>Global Rqmt</u>	2x2deg	1month

Ocean wave height

<u>Global Rqmt</u>	10km	1hr

Wave spectrum

<u>Global Rqmt</u>	10km	1hr

Accuracy	User Categories
6mm	A,B,C [CCl, CHy]
6mm	A,B,C [ISLSCP]
1%	B,C [CAgM, CAS, CCl, CHy]
1%	B,C [CCl, ISLSCP]
3%	B,C [WCRP]
.3m	A [CCl, CMM, IOC]
10deg (dir) .5s (period)	A [CCl, CMM, IOC]

ANNEX XXI

	Horizontal resolution	Frequency	Accuracy
Ice coverage			
Limited Area Rqmt	10km	1d	2%
Ice edge			
Limited Area Rqmt	10km	1d	2%
Ice thickness			
Limited Area Rqmt	25km	1d	10%
Snow coverage			
Limited Area Rqmt	1km	1d	2%
Global Rqmt	1km	1d	10%

User
Categories

ANNEX XXI

A,B,C [CHy, CCl,
CMM, CAS]

A,B [CHy]

B,C [CCl]

A,B,C [CAS, CCl,
CAgM, CHy]

A,B,C [CAS, CCl,
ISCCP, WCRP]

	Horizontal resolution	Frequency	Accuracy
Snow edge			
Limited Area Rqmt	1km	1d	
Snow depth			
Limited Area Rqmt	1km	1d	5mm
Global Rqmt	1km	12hr	5mm
Snow water equivalent			
Limited Area Rqmt	1km	12hr	2mm

User
Categories

A,B,C [CHy]

A,B,C [CAgM, CCl]

A,B,C [ISLSCP]

C [CHy, CCl]

ADDRESSES FOR PROCURING ARCHIVE DATA

ESA (specific requests for Meteosat imagery and data tapes)

METEOSAT EXPLOITATION PROJECT - Data Service
ESOC
Robert Bosch Str. 5
64276 Darmstadt
Germany

EUMETSAT (general requests for Meteosat archived material)

The Director
EUMETSAT
Am Elfengrund 45
64242 Darmstadt-Eberstadt
Germany

INDIA

India Meteorological Department
Attention: Director (Satellite Service)
Lodi Road
New Delhi
110003 India

JAPAN

Japan Meteorological Association,
Department of Data Service
1-3-4, Otemachi
Chiyoda-ku
Tokyo
Japan

ANNEX XXII

PRC

Mr. Xu Jianmin
Director
Satellite Meteorology Center
State Meteorological Administration
46 Baishiqiaolu
Beijing, 100081
People's Republic of China

USA

Satellite Data Services Division (E/CC6)
Room 100, World Weather Building
NOAA/NESDIS
Washington DC 20233
U.S.A.

ANNEX XXIII

CONTACT LIST FOR OPERATIONAL ENGINEERING MATTERS

CIS

Mr. V. Kharitonov	State Committee for Hydrometeorology Pavlika Morozova Str. 12 D-376 Moscow, Russia, CIS Telex: 411117 Telephone: +7 095 252 08 08

ESA

Mr. A. Massart	METEOSAT Exploitation Project ESOC Robert-Bosch-Strasse 5 64276 Darmstadt, Germany Telex: 419453 Telephone: +49 6151 902602

EUMETSAT

Dr. G. Szejwach	EUMETSAT Am Elfengrund 45 64242 Darmstadt, Germany Telex: 4197335 Telephone: +49 6151 950 212

INDIA

Dr. R. R. Kelkar	Directorate of Satellite Meteorology India Meteorological Department Lodi Road New Delhi 110003, India Telex: 3166412 Telephone: +91 11611710

ANNEX XXIII

JAPAN

Mr. T. Kitamura	Satellite Operational Technology Lab. Nat'l Space Development Agency of Japan 2-1-1 Sengen, Sakura-Mora, Niihari-gun Ibaraki-ken, Japan 305 NASCOM: GTSC Telex: 3652420 Telephone: +81 298-51-2271, Ext. 287

JAPAN

Mr. T. Hamada	Head/Meteorological Satellite Planning Meteorological Satellite Center 3-235 Nakakiyoto, Kiyose Tokyo, Japan 204 Telex: 2222163 Telephone: +81 3 32114966

PRC

Mr. Xu Jianmin	Director Satellite Meteorology Center State Meteorology Administration 46 Baishiqiaolu Beijing, 100081 People's Republic of China Telex: 22094 Telephone: +86-1-8312277 , Ext. 2367

USA

Mr. G. Davis	Manager, Satellite Operations Control Center NOAA/NESDIS, (E/S01) Room 0226, Mail Stop B Washington DC 20233, USA NASCOM: GTOS Telex: RCA 248376 Telephone: +1 301 763 1610

ADDRESS LIST FOR THE DISTRIBUTION OF CGMS DOCUMENTS

CIS

Mr. V. Kharitonov
State Committee for Hydrometeorology
Pavlika Morozova Str. 12
D-376 Moscow, Russia
Tel: ++7 095 252 08 08
Telex: 411117

CIS

Mr. A.B. Uspensky
Deputy Director
Hydrometeorological Centre of Russia
B. Predtechensky 9-13
123242 Moscow, Russia
Tel: ++7 095 253 9484
Telex: 411117

ESA

Mr. J de Waard,
Manager/MEP
ESA / ESOC
Robert-Bosch-Straße 5,
64276 Darmstadt, Germany
Tel: ++49 6151 902660
Fax: ++49 6151 903082
Telex: 419453

ESA

Mr. B. D. Mason
Head of Meteorology/MEP
ESA / ESOC
Robert-Bosch-Straße 5
64276 Darmstadt, Germany
Tel: ++49 6151 902601
Fax: ++49 6151 903082
Telex: 419453

ANNEX XXIV

EUMETSAT

Mr. J. Morgan
Director, EUMETSAT
Am Elfengrund 45
64242 Darmstadt, Germany
Tel: ++49 6151 9500
Fax: ++49 6151 950125
Telex: 4197335

EUMETSAT

Dr. G. Szejwach
Head of Technical Department
EUMETSAT
Am Elfengrund 45
64242 Darmstadt, Germany
Tel: ++49 6151 950212
Fax: ++49 6151 950225
Telex: 4197335

EUMETSAT

Mr. J. Lafeuille
International Affairs Officer
EUMETSAT
Am Elfengrund 45
64242 Darmstadt, Germany
Tel: ++49 6151 950180
Fax: ++49 6151 950125
Telex: 4197335

EUMETSAT

Mr. R. Wolf
Head/Ground Segment Support Division
EUMETSAT
Am Elfengrund 45
64242 Darmstadt, Germany
Tel: ++49 6151 950226
Fax: ++49 6151 950225
Telex: 4197335

EUMETSAT

Mr. G. C. Bridge
CGMS Secretariat
EUMETSAT
Am Elfengrund 45
64242 Darmstadt, Germany
Tel: ++49 6151 950116
Fax: ++49 6151 950125
Telex: 4197335

INDIA

Dr. R. R. Kelkar
Deputy Director General of Meteorology
(Satellite Meteorology)
India Meteorological Department
Lodi Road,
New Delhi 110003, India
Tel: ++91 11 611710
Fax: ++91 11 699216
Telex: 3166494

JAPAN

Mr H. Kishida
Director, Earth Observation Satellite Group
NASDA
World Trade Center Building
2-4-1 Hamamatsu-Cho, Minato-Ku
Tokyo 105, Japan
Tel: ++81 3 54704372
Fax: ++81 3 34323969
Telex: 28424

JAPAN

Mr. Y. Sano
Director-General
Meteorological Satellite Center
3-235, Nakakiyoto, Kiyose-shi
Tokyo 204, Japan
Tel: ++81 424931111
Fax: ++81 424914701
Telex: 2222163

ANNEX XXIV

JAPAN

Mr. T. Hamada
Head/Office of Met. Sat. Pllaning
Administration Department
Japan Meteorological Agency
1-3-4, Otemachi, Chiyoda-ku
Tokyo 100, Japan
Tel: +81 3 3211 4966
Fax: +81 3 3211 2032
Telex: 2222163

PRC

Mr. Xu Jianmin
Director,
Satellite Meteorology Center
State Meteorological Administration
46 Baishiqiaolu
Beijing 100081, People's Republic of China
Tel: ++86 1 8312277 ext. 2367
Fax: ++86 1 8321135 or 8311191
Telex: 22094

PRC

Mr. Huang Hanwen
Senior Engineer
Shanghai Inst. of Satellite Engineering
251 Hua-Yin Road,
Minhang, 200240 Shanghai, People's Republic of China
Tel: ++886 4301091 ext. 30
Fax: ++886 83782373
Telex: 22473

WMO

Dr D. Hinsman, Senior Scientific Officer
WMO Satellite Activities
World Meteorological Organisation
41 Ave Giuseppe-Motta
P.O. Box 2300
1211 Geneva 2, Switzerland
Tel: ++41 22 730 8285
Fax: ++41 22 734 2326
Telex: 23260

WMO/CBS

Dr. T. Mohr, Vice President CBS,
Deutscher Wetterdienst, Zentralamt
Frankfurter Str. 135
63004 Offenbach/Main, Germany
Tel: ++49 69 8062 2200
Fax: ++49 69 8062 2484
Telex: 4152871

USA

Mr. E. L. Heacock
Director, Satellite Operations
NOAA/NESDIS
Room 0135, FB4
Washington DC 20233, USA
Tel: ++1 301 763 1610
Fax: ++1 301 763 7083
Telex: 7401071

USA

Mr. J. W. Hussey
Director, Office of Systems Development
NOAA/NESDIS
Room 3301, FB4
Washington, DC 20233, USA
Tel: ++1 301 763 5877
Fax: ++1 301 420 0932

USA

Mr. T. Stryker,
International Relations Specialist,
NOAA/NESDIS
Room 0110, FB4, Suitland (E/IA1)
Washington DC 20233, USA
Tel: ++1 301 763 4586
Fax: ++1 301 736 5828
Telex: 7407641

ANNEX XXIV

USA

Mr. C. P. Staton
Deputy Chief, Information Processing Division
NOAA/NESDIS E/SP21
Room 0301, FB4
Suitland, MD 20233, USA
Tel: ++1 301 763 5687
Fax: ++1 301 763 1724
Telex: 7400359

USA

Mr. J. E. Wydick
Chief, Data Collection &
Direct Broadcast Branch
NOAA/NESDIS
Room 806, World Weather Building
5200 Auth Road
Camp Springs, Maryland 20233, USA
Tel: ++1 301 763 8062
Fax: ++1 301 763 8449
Telex: 7400359

USA

Mr. F. S. Zbar
Chief, Systems Rqts. Branch
National Weather Service
Office of Meteorology /OM22
1325 East Weat Highway/SSMC #2
Silver Spring, Maryland 20910,USA
Tel: ++1 301 713 1867
Fax: ++1 301 589 1321

CO-ORDINATION GROUP FOR METEOROLOGICAL SATELLITES (CGMS)

XXI Meeting held in Beijing, PRC
19 - 23 April 1993

LIST OF PARTICIPANTS

CIS

Not represented.

ESA

Mr. Johannes **de WAARD**
Project Manager, Meteosat Exploitation Project, ESA/ESOC

Mr. Brian D. **MASON**
Head of Meteorology, Meteosat Exploitation Project, ESA/ESOC

EUMETSAT

Mr. Gordon **BRIDGE**
CGMS Secretariat
Meteosat Operational Programme Manager

Mr. Jerome **LAFEUILLE**
International Affairs Officer

Mr. John **MORGAN**
Director

Mrs. Angela **NICHOLAS**
Personal Assistant to the Director

Dr. Gerard **SZEJWACH**
Head of Technical Department

Ms. Silke **TRAUTMANN**
Secretary

Mr. Robert **WOLF**
Head of Ground Segment Division

INDIA

Not represented.

JAPAN

Mr. Tadaaki **HAMADA**
Head, Office of Meteorological Satellite Planning
Japan Meteorological Agency

Mr. Hideo **SAKABE**
Associate Senior Engineer
National Space Development Agency of Japan (NASDA)

PEOPLES REPUBLIC OF CHINA

Mr. Han-wen **HUANG**
Senior Engineer, Shanghai Institute of Satellite Engineering
Chinese Academy of Space Technology

Mr. Kangmu **QIU**
Director, Satellite Meteorology Research Institute, Satellite Meteorological Center,
State Meteorological Administration

Ms. Yunzhu **SUN**
Shanghai Institute of Satellite Engineering
Chinese Academy of Space Technology

Ms. Shou Hui **WANG**
Senior Engineer, Satellite Meteorological Center
State Meteorological Administration

Mr. Jianmin **XU**
Director, Satellite Meteorological Center,
State Meteorological Administration

Mr. Jianping **XU**
Senior Engineer, Satellite Meteorological Center
State Meteorological Administration

Mr. Xi **XU**
Director, System Technology Division, Satellite Meteorological Center,
State Meteorological Administration

USA

Mr. E. Larry **HEACOCK**
Director, Satellite Operations, NOAA/NESDIS

Mr. W. John **HUSSEY**
Acting Deputy Assistant Administrator for Satellite and Information Services, NOAA/NESDIS

Mr. Carl P. **STATON**
Deputy Chief, Information Processing Division, NOAA/NESDIS

Mr. Timothy S. **STRYKER**
International Relations Specialist, NOAA/NESDIS

Mr. Frederick S. **ZBAR**
Chief, Systems Requirements Branch, NOAA/NWS
(Chair, CBS Working Group on Observations)

WMO

Dr. Donald **HINSMAN**
Senior Scientific Officer, WMO Satellite Activities

Dr. Tillmann **MOHR**
Director of German Weather Service
Chairman EC Panel of Experts on Satellites

MEMBERS OF WORKING GROUP I

TELECOMMUNICATIONS

Mr.	L. Heacock (Chairman)	NOAA/NESDIS, USA
Mr.	T. Stryker (Secretary)	NOAA/NESDIS, USA
Mr.	J. de Waard	ESA, Germany
Mr.	R. Wolf	EUMETSAT, Germany
Mr.	H. Sakabe	NASDA, Japan
Mr.	H. Huang	SMA/SMC, PRC
Ms.	Y. Sun	SMA/SMC, PRC
Ms.	S. Wang	SMA/SMC, PRC
Mr.	J. Xu	SMA/SMC, PRC
Mr.	X. Xu	SMA/SMC, PRC
Mr.	L. Heacock	NOAA/NESDIS, USA
Mr.	T. Stryker	NOAA/NESDIS, USA
Mr.	D. Hinsman (part-time)	WMO, Switzerland
Dr.	T. Mohr	WMO,EC Panel Experts Satellites

MEMBERS OF WORKING GROUP II

SATELLITE PRODUCTS

Mr.	D. Hinsman (Chairman)	WMO, Switzerland
Mr.	C. Staton (Secretary)	NOAA/NESDIS,USA
Mr.	B. Mason	ESA, Germany
Dr.	G. Szejwach	EUMETSAT, Germany
Mr.	T. Hamada	JMA, Japan
Mr.	K. Qiu	SMA/SMC, PRC
Mr.	J. Xu	SMA/SMC, PRC
Mr.	C. Staton	NOAA/NESDIS, USA
Mr.	F. Zbar	NOAA/NESDIS, USA
Mr.	D. Hinsman	WMO, Switzerland

MEMBERS OF THE WORKING GROUP III

CONTINGENCY PLANNING

Mr.	J. Morgan (Chairman)	EUMETSAT, Germany
Mr.	J. Lafeuille (Secretary)	EUMETSAT, Germany
Mr.	J. de Waard	ESA, Germany
Mr.	R. Wolf	EUMETSAT, Germany
Mr.	T. Hamada	JMA, Japan
Mr.	L. Heacock	NOAA/NESDIS, USA
Mr.	T. Stryker	NOAA/NESDIS, USA
Mr.	Jianmin Xu	SMA/SMC, PRC
Mr.	D. Hinsman	WMO, Switzerland
Dr.	T. Mohr	WMO/EC Panel of Experts Satellites