W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

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COMMISSION FOR BASIC SYSTEMS

OPEN PROGRAMME AREA GROUP ON INTEGRATED OBSERVING SYSTEMS

EXPERT TEAM ON SATELLITE SYSTEMS

FIRST SESSION

GENEVA, SWITZERLAND

5 –9 DECEMBER 2005

FINAL REPORT

Regulation 42

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 43

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation of behalf of the constituent body when the matter is, in his opinion, urgent and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

EXECUTIVE SUMMARY

The first session of the Expert Team on Satellite System met in Geneva, Switzerland, 5–9 December 2005. Primary objectives for the meeting were to: review operational and R&D environmental satellites present and planned capabilities and evaluate recommendations related to the transition of relevant R&D instruments to operational environmental satellites (discussion starts in Chapter 4); review requirements related to satellite system capabilities for WMO programmes other than WWW (discussion starts in Chapter 6); THORPEX (discussion starts in Chapter 10); review Rolling Review of Requirements process for evolution of the Global Observing and evolution of the space-based sub-system of the GOS(discussion starts in Chapter 8).

Two significant outcomes were a description of the progress in the implementation of the space-based sub-system of the GOS (see Appendix VII) as well as the process involved in the transition of R&D satellite capabilities to operational environmental satellites (see Appendix IV).

First row from left to right: Mr Tatsuya Kimura, Mr AS Kiran Kumar, Dr Jian Liu, Dr E. Oriole-Pibernat, Mr Lorenzo Sarlo, Dr Wenjian Zhang (Chairman)
Second row from left to right: Mr James Gurka, Mr Jérôme Lafeuille, , Dr Michael King, Dr James Purdom, Dr Donald Hinsman,

1. ORGANIZATION OF THE SESSION (*agenda item 1)*

1.1 Opening of the session (*agenda item 1.1*)

The first session of the Expert Team on Satellite Systems was held at the Headquarters of the World Meteorological Organization (WMO) in Geneva, Switzerland, from 5 to 9 December 2005.

The session was opened at 09h30 on Monday, 5 December 2005 by Dr Donald Hinsman, Director of the WMO Space Programme on behalf of the WMO Secretary-General. In his opening remarks, he informed the session of the decision by the Fourteenth WMO Congress in May 2003 to establish a new major cross cutting Programme, the WMO Space Programme. The Fourteenth Congress had also assigned lead responsibility for the WMO Space Programme to the Commission for Basic Systems. He noted that the establishment of a new major WMO Programme was a reflection of the great importance placed on the exploitation of satellite data, product and services by WMO Members.

He also informed the session that in January 2004 the fourth session of the WMO Consultative Meetings on High-level Policy on Satellite Matters had recommended that CBS establish a new OPAG IOS Expert Team on Satellite Systems (ET-SAT) while retaining the Expert Team on Satellite Utilization and Products (ET-SUP). ET-SAT was identified as important in order to provide advice on satellite system level capabilities in view of the needs for WMO Programmes in response to the new WMO Space Programme. ET-SUP will focus on improving satellite system utilization and products. Both Expert Teams will work within the CBS Open Programme Area Group on Integrated Observing Systems thus ensuring close coordination across WMO programmes.

He also highlighted a recommendation by the fourth session of the WMO Consultative Meetings to move towards a single integrated WMO global observing system and subsequently approved by the WMO Executive Council. The Executive Council agreed that the space component of the integrated WMO global observing system would serve the needs of three Earth-system domains and two cross cutting areas. Furthermore, the fifty-sixth session agreed that the WMO Space Programme was well placed to serve as one of the core components of the new and emerging Global Earth Observation System of Systems (GEOSS). He noted that ET-SAT has the mandate to advise and guide all the WMO and supported programmes on how to best exploit satellite systems.

In his concluding remarks, he thanked the participants for their advice and dedication to the goals and objectives guiding WMO into this next decade and millennium.

1.2 Adoption of the agenda *(agenda item 1.2)*

The agenda for the session was adopted and is reproduced in Appendix II. Appendix I contains a list of participants for the session.

1.3 Working arrangements for the session

The working arrangements for the session were agreed upon. It was also agreed that the work of the session would be conducted mainly in Plenary and Working Groups as appropriate.

2. CHAIRMAN'S REPORT (*agenda item 2*)

Dr Wenjian Zhang, the Chairman of the CBS OPAG IOS Expert Team on Satellite Systems (ET SAT) noted that this was the first session of Expert Team established by CBS-XIII, which had met in St Petersburg in February 2005. The Chairman noted his intention to focus the team's attention on satellite systems, i.e., to analyze the capabilities of operational and R&D

environmental satellite systems, and analyze requirements related to satellite system capabilities for WMO Programmes. He informed the session that CBS had explicitly tasked ET-SAT to ensure that the space-based sub-system of the GOS contributed towards an integrated WMO global observing system that would encompass all present WMO and supported Programme observing systems.

The Chairman also indicated that the session would address all the items listed in the work programme prescribed by the CBS, although not necessarily with the same emphasis at this first session. In particular, he anticipated the following:

- A review of operational and R&D environmental satellites, present and planned capabilities;
- A review of the Rolling Review of Requirements (RRR) Process;
- An evaluation of recommendations related to the transition of relevant R&D instruments to operational environmental satellites;
- A review of requirements related to satellite system capabilities for WMO Programmes other than the World Weather Watch (WWW); and
- Monitoring the implementation for the evolution of space-based sub-system of the GOS related to satellite systems provided by space agencies;

The Chairman noted that discussions should also be initiated, at least at a preliminary stage, on new issues related to R&D satellite systems, and to the GCOS Implementation Plan.

2.1 OPAG IOS Chairman's Report *(agenda item 2)*

Dr James F.W. Purdom, Chairman of the Open Programme Area Group on Integrated Observing Systems (OPAG IOS), reviewed OPAG IOS activities relevant to ET-SAT including the Implementation and Coordination Team (ICT) meeting, WMO training event for Latin American countries, and the Coordination Group for Meteorological Satellites (CGMS). Dr Purdom also recalled the CBS-XIII meeting and provided additional background information to ET-SAT.

He also thanked them in advance for their efforts at this first session as well as their respective agencies for providing the time and financial resources to allow their participation.

3. REVIEW ACTIVITIES RELATED TO THE ESTABLISHMENT OF ET-SAT *(agenda item 3)*

3.1 The session noted that the Fourteenth WMO Congress (Cg-XIV), held in Geneva, Switzerland, May 2003, had agreed to establish a new major cross cutting Programme, the WMO Space Programme, and had also supported the WMO Space Programme Long-term Strategy.

3.2 The session noted that CBS-XIII, held in St Petersburg, Russian Federation from 23 February to 3 March 2005 had agreed to establish under OPAG IOS the new Expert Team on Satellite Systems (ET-SAT). It also noted that membership of the ET-SAT should comprise representatives from space agencies and satellite operators participating in the WMO Consultative Meetings on High-level Policy on Satellite Matters (CM) and contributing, or with the potential to contribute, to the space-based sub-system of the GOS. Participation in the work of ET-SAT would be at no cost to WMO.

3.3 The session also noted that the present Open Programme Area Group on Integrated Observing Systems (OPAG-IOS) Expert Team on Satellite Systems Utilization and Products was

renamed the Expert Team on Satellite Utilization and Products (ET-SUP) and maintained its present Terms of Reference.

3.4 The session noted that CBS XIII had agreed to establish the new OPAG IOS Expert Team on Satellite Systems (ET-SAT) that would provide the necessary satellite expertise (both for operational and Research and Development satellites) to ensure an integrated WMO global observing system that would encompass all present WMO and supported Programme observing systems. The Expert Team would be comprised solely of representatives from space agencies contributing to the space-based sub-system of the GOS. The Chairman of the new Expert Team would ensure that a member/expert would be designated to represent the Expert Team to each of the various other WMO Programme expert groups, as appropriate. Representatives from the Expert Team could also serve as regional rapporteurs for the various Implementation and Coordination Teams thus ensuring regional influence reflecting WMO needs as well as those of the space agency. While working within the CBS structure, the new Expert Team would support all WMO Programmes, as well as providing for direct feedback through the CBS President to the WMO Consultative Meetings providing overall guidance to the WMO Space Programme. The WMO Space Programme Office would serve as the WMO Secretariat for the new Expert Team as it already did for the present Expert Team on Satellite Systems Utilization and Products. Such a structure would provide the nucleus of satellite expertise towards the integration of the space components described above into a single integrated WMO global observing system.

3.5 The session also noted activities within the process established at the Third Earth Observation Summit (EOS-III) including those by the new intergovernmental Group on Earth Observations (GEO) to implement a Global Earth Observation System of Systems (GEOSS).

3.6 The session reviewed the tasks and work plan of the Expert Team on Satellite Systems (ET-SAT) for 2005-2006 as agreed by CBS XIII and the CBS Management Group (Tasks and Terms of Reference are also contained in Appendix III):

(a) Review both operational and R&D environmental satellites present capabilities and plans and provide input to relevant OPAG IOS and OPAG Information Systems and Services (ISS) Expert Teams and Implementation Coordination Team (ICT) meetings to assist in the integration of WMO-coordinated observing systems;

(b) Review CM-5 and CM-6 recommendations and guidance for relevance and provide input to OPAG IOS ET and ICT work programmes;

(c) Review Statements of Guidance (SOGs) and plans for the global observing system (GOS) evolution and provide input to Expert Team on the Evolution of the Global Observing System (ET-EGOS) towards improvements of system capabilities, particularly with respect to developing countries;

(d) Evaluate regional workshop recommendations with respect to the transition of relevant R&D instruments to operational environmental satellites and advise CBS;

(e) Provide input to other WMO sponsored expert groups' meetings, e.g., GCOS discipline panels, JCOMM, GCOS, WCRP and GAW with regard to satellite system capabilities and their requirements;

(f) Initiate actions, monitor and assure progress on the "Implementation Plan for Evolution of Surface and Space-based Components of the GOS" and coordinate this activity with the ET-EGOS.

3.7 The session was informed that the first meeting of the CBS/OPAG-IOS Expert Team on Satellite Utilization and Products (ET-SUP-1) was held in Geneva, Switzerland, 17-21 October 2005. The main outcomes resulting from the first meeting of the ET-SUP were:

- affirmation of the summary analysis on the status of the availability and use of satellite data and products by WMO Members that will be included in a new WMO

Space Programme Technical Document "*Status of the Availability and Use of Satellite Data and Products by WMO Members, 2005*" (WMO/TD No. 1296 (SP-2)) as well as a revised structure for future versions of the questionnaire;

- a refinement of the concept for a WMO Integrated Global Data Dissemination Service (IGDDS) through the integration of regional Advanced Dissemination Methods (ADM);
- advancement of the Virtual Laboratory for Education and Training in Satellite Meteorology through a high profile training event;
- review of an offer from Argentina and a preliminary offer from Brazil to host Centres of Excellence;
- preliminary review of the potential of R&D Satellites for operational use;
- discussion on harmonization of RGB composites of multi-spectral imagery;
- recommendations for the transition to new operational products.

3.8 The session was informed of the 2nd Global RARS Workshop held in Geneva on 1-2 December 2005, where steps were taken towards establishing a new RARS in the Asia-Pacific in 2006, and in South America in 2007.

4. REVIEW OPERATIONAL AND R&D ENVIRONMENTAL SATELLITES PRESENT AND PLANNED CAPABILITIES *(agenda item 4)*

The session reviewed the current status of operational meteorological geostationary and polar-orbiting satellites and relevant R&D missions as discussed at CGMS-XXXIII (the list of R&D satellites is contained in Appendix IV). As part of its inter-sessional work programme, the session agreed to review and update the information contained in ET SAT-1 Document 5. The session also reviewed the implementation plan for the evolution of the space-based sub-system of the GOS under agenda item 8 and additional relevant details on the status of the space-based sub-system of the GOS can be found in the section of this report for agenda item 8 below.

The session noted that there were six satellites regularly spaced in the geostationary orbit now fulfilling the WMO requirement. The session noted that Elektro-L and INSAT-3D, were planned for launch in 2007 and INSAT-3D would be placed at the current position of INSAT-2E (83°E).

The session reviewed the future development of geostationary satellites as recommended in the "*Implementation Plan for Evolution of Space and Surface-based Sub-systems of the GOS*" developed by the CBS Open Programme Area Group on the Integrated Observing Systems (OPAG-IOS) (WMO/TD No. 1267 dated April 2005). In particular, the session noted that the Implementation Plan stated:

- GEO Imagers - Imagers of future geostationary satellites should have improved spatial and temporal resolution (appropriate to the phenomena being observed), in particular for those spectral bands relevant for depiction of rapidly developing small-scale events and retrieval of wind information;
- GEO Sounders - All meteorological geostationary satellites should be equipped with hyper-spectral infrared sensors for frequent temperature/humidity sounding as well as tracer wind profiling with adequately high resolution (horizontal, vertical and time);
- GEO Sub-mm - An early demonstration mission on the applicability of sub-mm radiometry for precipitation estimation and cloud property definition from *geostationary orbit should be provided, with a view to possible operational follow-on*.

The session then reviewed the status of operational polar orbiting satellites. The session noted that there were four satellites in sun-synchronous orbit in December 2005.

Concerning future polar satellites, the session reviewed the "*Implementation Plan for Evolution of Space and Surface-based Sub-systems of the GOS*" developed by the CBS Open Programme Area Group on the Integrated Observing Systems (OPAG-IOS) (WMO/TD No. 1267 dated April 2005). In particular, the session noted the Implementation Plan stated:

- LEO Sea Surface Wind - Sea-surface wind data from R&D satellites should continue to be made available for operational use; 6-hourly coverage is required. In the NPOESS and Metop era, sea surface wind should be observed in a fully operational framework. Therefore, it is also urgent to assess whether the multi-polarisation passive MW radiometry is competitive with scatterometry;
- LEO Altimeter - Missions for ocean topography should become an integral part of the operational system;
- LEO Earth Radiation Budget - Continuity of ERB-type global measurements for climate records requires immediate planning to maintain broad-band radiometers on at least one LEO satellite.

The session noted that three major polar-orbiting satellites were expected to be launched in 2006 and 2007 (Metop-A, Meteor-3M-N2, and FY-3A).

The session also reviewed R&D programmes either contributing or with the potential to contribute to the space-based sub-system of the GOS. Some R&D missions & instruments are also indicated in Appendix IV.

5. REVIEW ROLLING REVIEW OF REQUIREMENTS PROCESS FOR EVOLUTION OF THE GOS *(agenda item 5)*

The session noted the concept and background for the Rolling Review of Requirements (RRR) including the end result of the RRR process, Statements of Guidance (SOG). The session reviewed the latest SOGs for Global NWP, Regional NWP, Synoptic Meteorology, Nowcasting and Very Short Range Forecasting and Aeronautical Meteorology and made specific comments and suggestions (as contained in Appendix V) that should be utilized by ET EGOS and the associated application expert in future updates to the SOGs. Many SOGs have reference dates more than four years ago. Since the particular SOG's reference date, many satellite missions have been launched, or recently placed in an operational status, or anticipated satellite programmes have been cancelled, or new planned missions have been approved. The comments and suggestions seek to highlight those events with the expectation that the application expert responsible for the SOG will review it. ET-SAT, as part of its work programme, will update expected performances to reflect the comments and thus allow the expert responsible for the SOG to utilize the latest Critical Review charts.

The session also reviewed the latest expected performance for satellites systems presently contributing to the space-based global observing system and agreed to update the performances as appropriate as part of its inter-sessional work plan (See agenda item 12, Future Work Programme)

6. EVALUATE RECOMMENDATIONS RELATED TO THE TRANSITION OF RELEVANT R&D INSTRUMENTS TO OPERATIONAL ENVIRONMENTAL SATELLITES *(agenda item 6)*

The session reviewed the capabilities of R&D satellites within the evolution of the space-based sub-system of the GOS as described in the GOS Implementation Plan. The session

developed the following recommendations for the transition from relevant R&D instruments to operational status.

In noting the guidance from the WMO Executive Council in June 2003, the session confirmed the potential benefit of an active interaction between R&D space agencies and prospective operational users. The early involvement of users would be essential as part of a learning process for the use of future systems. It should also help identifying the impact on operations within NMHS and enable collecting feedback from the NMHS operational community.

The session also noted that a number of recommendations of the Implementation Plan for the Evolution of the Global Observing System were related to the development of demonstration missions, to the availability of data from such missions and to their operational follow-on. It welcomed the interest of operational users for early use of R&D instrument data in an operational context, while bearing in mind the technical conditions and data policies for data access. It further noted the expectation of the operational user community that, once an instrument is successfully demonstrated, continuity is ensured by an operational follow-on without any gap if possible.

The session stressed however the need for a careful planning of the transition between demonstration missions and operational ones and recommended the following approach:

- Since an operational mission is only confirmed, normally, after the successful outcome of a demonstration phase, and taking into account the lead time for mission approval and implementation, there may be a significant gap between availability of demonstration data and operational data, unless a transition phase can be implemented;

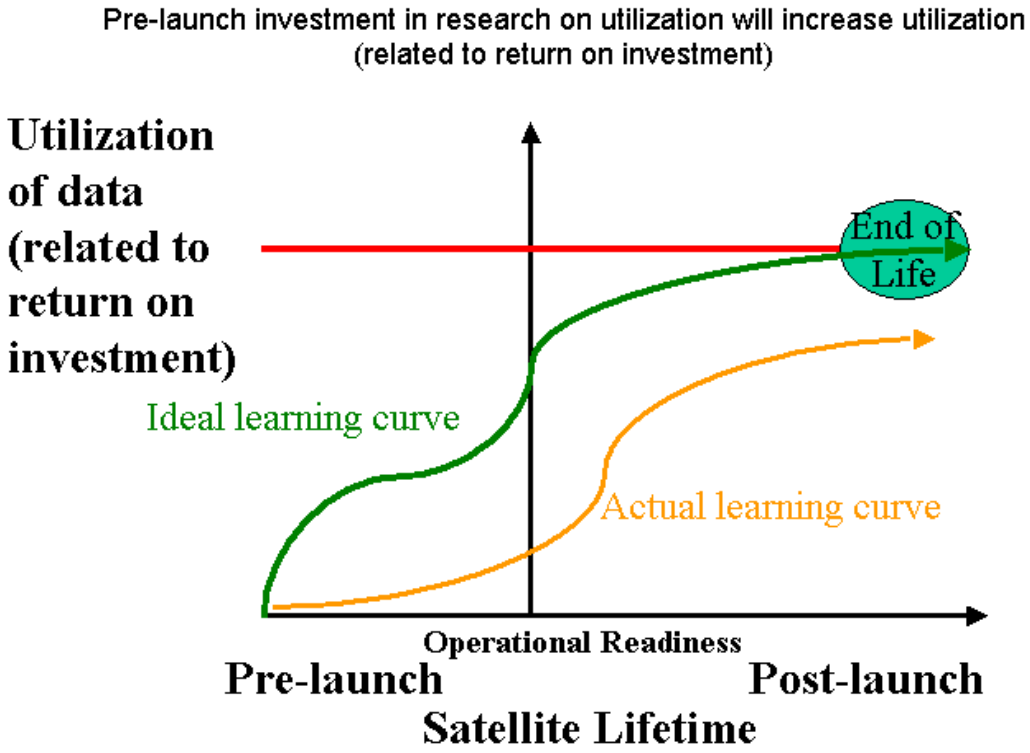
- Distinction should thus be made between purely *R&D demonstration missions*, aiming at a proof of concept from a science and technology point of view, and *transition (or preparatory) missions*, aiming at initiating and evaluating potential applications of proven instrument concepts;

- Transition missions may be implemented for selected relevant instruments after successful proof of concept. They require appropriate mechanisms ensuring quasi-operational data availability and strong user involvement in data and products validation activities;

- There are different possible frameworks to implement transition missions. It can be through dedicated missions (such as the NPP risk-reduction mission as a precursor for NPOESS) or e.g., through the decision to extend the operations of a demonstration mission if the spacecraft remains functional beyond its planned lifetime, and provided that sufficient financial resources are available. Transition missions offer a particular scope for cooperative projects, namely through the provision of flight opportunities for pre-operational instruments. To this end, it is recommended that plans/requirements for new operational satellite systems include spare capabilities to accommodate such instruments;

- The concepts of demonstration and transition missions should be taken into account in future updates of the Statement of Guidance and of the Implementation Plan of the Evolution of the GOS. Advantage shall be taken of dedicated R&D to Operations Transition Workshops to express specific needs and priorities for transition missions;

- When planning for new operational satellite systems, operational agencies shall timely prepare utilization plans involving users from preparatory activities onwards. This would help reducing the gap between the optimal users learning curve and their actual readiness to make full use of the new data.



7. REVIEW REQUIREMENTS RELATED TO SATELLITE SYSTEM CAPABILITIES FOR OTHER WMO PROGRAMMES OTHER THAN WWW *(agenda item 7)*

The session also reviewed the latest requirements and associated SOGs for other WMO Programmes other than WWW, i.e., Tropical Cyclone, Atmospheric Chemistry, JCOMM, and Agricultural Meteorology and made specific comments and suggestions that should be utilized by ET EGOS and the associated application expert in future updates to the SOGs. Since the particular SOG's reference date, some satellite missions have been launched, or recently placed in an operational status, or anticipated satellite programmes have been cancelled, or new planned missions have been approved. The comments and suggestions seek to highlight those events with the expectation that the application expert responsible for the SOG will review it. ET-SAT, as part of its work programme, will update expected performances to reflect the comments and thus allow the expert responsible for the SOG to utilize the latest Critical Review charts. Comments and suggestions are contained in Appendix VI. The session also agreed to review the latest Statement of Guidance for Hydrology as part of its inter-sessional work programme as described in Appendix IX.

8. MONITOR IMPLEMENTATION FOR EVOLUTION OF THE SPACE-BASED SUB-SYSTEM OF THE GOS *(agenda item 8)*

The session reviewed the progress and actions related to the evolution of the space-based sub-system of the GOS. The session noted that China, EUMETSAT, India, Japan, Russian Federation, USA and the Republic of Korea have substantial plans for future operational geostationary satellites.

The session was informed that EUMETSAT had recently initiated planning for the post-EPS era (i.e., from ~2019) through a thorough assessment of the user requirements that may be useful for all observations from low Earth orbit. Future development of the USA-EUMETSAT's

Joint Polar System, and other partnerships, could be substantially extended towards inclusion of the full range of user requirements for observations as well as serve as a major contribution towards the goals of GEOSS.

The session was informed that NOAA was conducting studies relevant to the characteristics of medium Earth orbits (MEO), at altitude 10,400 km, as an observation venue possibly replacing the traditional GEO and LEO orbits. The studies were investigating if MEO performance capabilities would be comparable for VIS/IR imagers and IR sounders. Also under investigation was the possibility that global coverage from 8 MEOs would be capable of capturing the attributes of 3 LEO and 6 GEO satellites. The session discussed the possible ramifications to the GOS from such a MEO system.

In particular a joint session between ET-SAT and ET-EGOS discussed the potential future role of mid-Earth orbit (MEO) satellites. Both Expert Teams expressed concern that such satellites could not feasibly fulfil some of the missions undertaken by current operational polar satellites (e.g., microwave sounding and imaging) and so did not appear to offer the potential cost savings that prompted their study. The meeting also noted potential gaps in the Implementation Plan (IP) concerning atmospheric chemistry and perhaps other applications that had not yet been fully analyzed by ET-EGOS.

The session also reviewed the recommendations for the evolution of the space-based sub-system of the GOS. Appendix VII contains a consolidated set of recommendations and status in the progress for the implementation for the space-based sub-system of the GOS.

The session also reviewed the outcome of CGMS XXXIII discussions on two particular items: in particular the Global Space-based Inter-calibration System (GSICS) and the International Geostationary Laboratory concept (IGeoLab).

9. GCOS IMPLEMENTATION PLAN *(agenda item 9)*

The session made a preliminary review of the status of the Global Climate Observing System (GCOS) Implementation Plan. The session noted that the *Implementation Plan* called for some 131 actions needed over the next 5 to 10 years to address the critical issues related to global observing systems for climate, namely: improving key satellite and *in situ* networks for atmospheric, oceanic and terrestrial observations; generating integrated global climate analysis products; enhancing the participation of least-developed countries and small island developing states; improving access to high-quality global data for essential climate variables; and strengthening national and international infrastructure.

The session made specific suggestions concerning Key Actions of the GCOS Implementation Plan as contained in Appendix VIII. The session also agreed to review the GCOS Implementation Plan in-depth and provide comments to be available for the GCOS Experts' meeting planned for 9-11 January 2006 as part of its inter-sessional work programme. The session also agreed that an in-depth review of the GCOS Implementation Plan will be addressed as an agenda item during its next session.

10. RECENT DEVELOPMENT WITH RESPECT TO THORPEX *(agenda item 7)*

The session was informed of the background of THORPEX Programme, recent activities within the THORPEX Programme and the relationship between OPAG-IOS Expert Teams and THORPEX. The session noted that THORPEX had submitted a cluster of related projects involving some 18 institutions and 16 countries as a significant contribution to the International Polar Year (IPY.) The session also noted that THORPEX had invited CGMS to join the THORPEX ICSC as an observer and at CGMS XXXIII, Dr James Purdom, Chair, CBS OPAG-IOS, had been appointed Rapporteur to THORPEX.

The session was of the opinion that many activities within the four Expert Teams within OPAG-IOS were relevant to THORPEX. Matters concerning satellite operations and requirements to support THORPEX would be coordinated with the appropriate space-based system operator (R&D or operational) through ET-SAT. Matters that relate to products would be coordinated through the ET-SUP and/or ET-SAT. Matters that related to the evolution of the GOS would be coordinated through the ET-EGOS, as well as ET-SAT as appropriate. All satellite related activities and matters with respect to THORPEX should be coordinated through the CBS OPAG-IOS who would act in conjunction with the WMO Space Programme.

The OPAG IOS Chairman recalled the Terms of Reference for the THORPEX Observing System Working Group and requested that ET SAT provide comments if appropriate by the end of February 2006 to the Chairman OPAG IOS.

11. FUTURE WORK PLAN *(agenda item 10)*

The session agreed to the inter-sessional work plan as contained in Appendix IX. In doing so, it noted that it was anticipated that the inter-sessional work would be completed prior to its next session in mid-2006, at a possible joint session with the Expert Team on Satellite Utilization and Products.

12. ANY OTHER BUSINESS *(agenda item 11)*

13. CLOSURE OF THE SESSION *(agenda item 12)*

The Chairman thanked the Expert Team members and session participants for their excellent preparation, cooperation and dedication. The Chairman closed the session at 12h30 on Friday, 9 December 2005.

APPENDIX I

LIST OF PARTICIPANTS

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APPENDIX II

AGENDA

1. ORGANIZATION OF THE SESSION
   - 1.1 Opening of the session
   - 1.2 Adoption of the agenda
   - 1.3 Working arrangements for the session

2. CHAIRMAN'S REPORT

3. REVIEW ACTIVITIES RELATED TO THE ESTABLISHMENT OF ET-SAT

4. REVIEW OPERATIONAL AND R&D ENVIRONMENTAL SATELLITES PRESENT AND PLANNED CAPABILITIES

5. REVIEW ROLLING REVIEW OF REQUIREMENTS PROCESS FOR EVOLUTION OF THE GOS

6. EVALUATE RECOMMENDATIONS RELATED TO THE TRANSITION OF RELEVANT R&D INSTRUMENTS TO OPERATIONAL ENVIRONMENTAL SATELLITES

7. REVIEW REQUIREMENTS RELATED TO SATELLITE SYSTEM CAPABILITIES FOR OTHER WMO PROGRAMMES OTHER THAN WWW

8. MONITOR IMPLEMENTATION FOR EVOLUTION OF THE SPACE-BASED SUB-SYSTEM THE GOS

9. GCOS IMPLEMENTATION PLAN

10. FUTURE WORK PROGRAMME

11. ANY OTHER BUSINESS

12. CLOSURE OF THE SESSION

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APPENDIX III

OPAG IOS EXPERT TEAM TASKS AGREED UPON AT CBS-XIII

Expert Team on Satellite Systems (ET-SAT)

(a) To provide technical advice with respect to both operational and R&D environmental satellites to assist in the integration of WMO-coordinated observing systems;

(b) To advise through ICT-IOS CBS on matters requiring feedback to the WMO Consultative Meetings on High-level Policy on Satellite Matters;

(c) To assess the observation, collection, and analysis systems relating to the use of operational and R&D environmental satellites contributing, or with the potential to contribute, to the space-based sub-system of the GOS, and to suggest improvements of system capabilities, particularly with respect to developing countries;

(d) To assist CBS in assessing the status of implementation of the space-based sub-system of the GOS and the adequacy of plans for implementation for meeting established requirements for satellite data and products;

(e) To make recommendations with respect to the transition of relevant R&D instruments to operational environmental satellites;

(f) To coordinate with other relevant Teams of CBS with a view to making recommendations on matters, such as the exchange, management, and archiving of satellite data and products, radio frequency utilization, as well as education an training and other appropriate capacity building measures related to satellite meteorology;

(g) To identify and assess opportunities and/or problem areas concerning satellite technology and plans of relevant satellite operators, and inform through ICT-IOS CBS timely and comprehensively.

WORK PROGRAMME AND DELIVERABLES FOR 2005-2006

Expert Team on Satellite Systems (ET-SAT)

(1) Review both operational and R&D environmental satellites present capabilities and plans and provide input to relevant OPAG IOS and OPAG ISS ET and ICT meetings to assist in the integration of WMO-coordinated observing systems;

(2) Review CM-5 and CM-6 recommendations and guidance for relevance and provide input to OPAG IOS ET and ICT work programmes;

(3) Review SOGs and plans for GOS evolution and provide input to ET EGOS towards improvements of system capabilities, particularly with respect to developing countries;

(4) Evaluate regional workshop recommendations with respect to the transition of relevant R&D instruments to operational environmental satellites and advise CBS;

(5) Provide input to other WMO sponsored expert groups' meetings, e.g., GCOS discipline panels, JCOMM, GCOS, WCRP and GAW with regard to satellite system capabilities and their requirements.

(6) Initiate actions, monitor and assure progress on the Implementation Plan for Evolution of Space- and Surface-based sub-systems of the GOS and coordinate this activity with the ET-EGOS.

APPENDIX IV
CURRENT R&D SATELLITES DISCUSSED AT ET-SAT-1
(sorted in alphabetical space agency order)

Satellites	Space Agency	Equator Crossing Time *A=Northw* *D=Southw* Altitude	Launch date	Instruments	Status, application and other information
PARASOL	CNES	13 :32 (A) 705 km	18/12/04	POLDER	Characterization of clouds and aerosols microphysical and radiative properties. Data can be accessed for level 1 at <http://parasol-polder.cnes.fr/> and for level 2 and more at <http://www-icare.univ-lille1.fr/>
SPOT-5	CNES	10:30 (D) 832 km	05/2002	DORIS, HRG, HRS, VEGETATION	Cartography, land surface, agriculture and forestry, civil planning and mapping, digital terrain models, environmental monitoring
ERS-2	ESA	10:30 (D) 785 km	04/95	Altimeter, SAR, SAR-wave, ATSR, Scatterometer, GOME	Due to OB recorder problems in 06/03, the LBR mission is ensured over ESA agreed acquisition stations Operations extended till 2008.
ENVISAT	ESA	10:00 (D) 800 km	03/2002	ASAR, RA-2 AATSR, MERIS GOMOS, MIPAS MWR, SCHIAMACHY	Since January 2005: ▪ MIPAS is operated in discontinuous scenario. ▪ GOMOS data measurements are resumed since 29 august 2005.Operations extended 3 years (till 2010)
PROBA	ESA	10: 30 (D) 615 km	10/2001	CHRIS	Drifting orbit. Technology experiment. AO Science mission since 2003.
EP-TOMS	NASA	sun-synchronous 740 km	02/07/96	Total Ozone Mapping Spectrometer	(Total Ozone Mapping Spectrometer - Earth Probe) measures total column ozone and its variation on a daily basis
TRMM	JAXA/ NASA	non-sun-synchronous (35° incl) 402 km	28/11/97	PR (Precipitation Radar) TMI (TRMM Microwave Imager) CERES, VIRS LIS (Lightning Imaging Sensor)	Measures tropical rainfall/precipitation and radiation energy Precipitation Radar (PR) provided by JAXA Satellite bus and other instruments provided by NASA CERES no longer functional

Satellites	Space Agency	Equator Crossing Time *A=Northw* *D=Southw* Altitude	Launch date	Instruments	Status, application and other information
TOPEX/ POSEIDON	NASA/ CNES	Non sun-synchronous (66° incl) 1336 km	10/08/92	- Microwave radiometer - GPS receiver - Laser retroreflector array - Dual freq. NASA radar altimeter - Single freq. CNES radar altimeter - DORIS receiver	Measures ocean surface topography and monitors global ocean circulation for global climate predictions DORIS : Doppler Orbitography and Radio positioning Integrated by Satellite
Landsat 7	NASA	10:05 (D) 705 km	15/04/99	ETM+ (Enhanced Thematic Mapper Plus)	well-calibrated, multispectral, moderate resolution, substantially cloud-free, sunlit digital images of the Earth's continental and coastal areas
QuikSCAT (Quick Scatterometer)	NASA	06:00 (A) 803 km	19/06/99	SeaWinds	Sea surface wind speed and direction data for global climate research and operational weather forecasting and storm warning
Terra	NASA	10 :30 (D) 720 km	18/12/99	CERES, MISR, MODIS, MOPITT, ASTER	Measurement of Earth' climate system, atmosphere, land, oceans and interactions with solar radiation
ACRIMSAT	NASA	10 :50 (D) 720 km	20/12/99	ACRIM 3	Active Cavity Radiometer Irradiance Monitor Satellite measures total solar irradiance
NMP EO-1 (New Millennium Program Earth Observing-1)	NASA	10 :01 (D) 705 km	21/11/00	Advanced Land Imager Hyperion LAC(atmospheric corrector)	demonstrates and validates advanced technology instruments (multi and hyperspectral), spacecraft systems, and mission concepts in flight
Jason-1	NASA/ CNES	non-sun-synchronous (66° incl) 1336 km	07/12/01	LRA (Laser retroreflector array) Poseidon-2 solid state radar altimeter DORIS receiver Jason Microwave Radiometer BlackJack GPS Receiver	Ocean surface topography follow-on mission to TOPEX/Poseidon. Monitors global ocean circulation for global climate prediction
SAGE III (Stratosperic Aerosol & Gas Experiment)	NASA/ FSA	(See Meteor 3M) 09:15 (A) 1020 km	10/12/01	SAGE III	One of nine experiments on Russian Meteor-3M spacecraft measures ozone and aerosols in high latitudes

Satellites	Space Agency	Equator Crossing Time *A=Northw* *D=Southw* Altitude	Launch date	Instruments	Status, application and other information
GRACE (Gravity Recovery and Climate Experiment)	NASA/ DRL	non-sun-synchronous (89°incl) 485 km	17/03/02	- Star Camera Assembly - GPS BlackJack Receiver - Instruments Processing Unit - Laser Retro-Reflector Assembly - K-Band Ranging Instruments - SuperSTAR Accelerometers	accurate global and high-resolution determination of static and time-variable components of Earth's gravity field measurement of: - Gravitational field - GPS atmospheric and ionospheric limb sounding
Aqua	NASA	13:30 (A) 705 km	04/05/02	AMSR-E, AIRS, HSB , AMSU-A, CERES, MODIS	collects data on Earth's water cycle, precise atmospheric, land and oceanic measurements, and interaction with solar radiation AMSR-E provided by JAXA. HSB provided by INPE (no longer functional)
ICESat (Ice, Cloud, and Land Elevation Satellite)	NASA	Circular non sun-synchronous (94° incl) 600 km	12/01/03	GLAS (Geo-science Laser Altimeter System) GPS BlackJack receiver	measures ice sheet topography, ice sheet elevation changes, cloud and aerosol heights, land topography and vegetation characteristics.
SORCE (Solar Radiation and Climate Experiment)	NASA	non-sun-synchronous (40° incl) 640 km	25/01/03	- XPS (Extreme Ultraviolet (XUV) Photometer System) - TIM (Total Irradiance Monitor) - SIM (Spectral Irradiance Monitor A&B) - SOLSTICE (Solar Stellar Irradiance Comparison Experiment A&B)	Will provide total irradiance measurements and full spectral irradiance measurements. Continuation of ACRIMSAT total solar irradiance measurements.
Aura	NASASC	13:45 (A) 705 km	15/07/04	HIRDLS MLS (Microwave Limb Sounder) OMI (Ozone Monitoring Instrument) TES	Comprehensive measurements of atmospheric chemistry and trace gasses : HIRDLS = High Resolution Dynamic Limb Sounder (IR) TES = Tropospheric Emission Spectrometer
Monitor-E	Russia	10:30 550 km	08/2005	Land Observing Satellite	

FUTURE R&D SATELLITES DISCUSSED AT ET SAT-1
(sorted by planned launch dates)

Satellites	Space Agency	Equator Crossing Time A=Northw D=Southw Altitude	Launch date	Status, application and other information
Kompas-2	Russia	400-550 km 79° incl	11/2005	Monitoring of anomaly phenomena in the Earth ionosphere
ALOS	JAXA	10:30 700km	12/2005	Advanced Land Observing Satellite (mapping, precise land coverage observation, disaster monitoring, resource surveying)
CALIPSO	NASA/ CNES	705 km sun-synchronous 14:10 – 12:50	02/2006	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations for climate predictions CALIOP, WFC, IIR
ESSP/ CloudSAT	NASA/ CSA	13:30 705 km	02/2006	global cloud properties (applications: air quality, aviation safety, disaster management, energy and water management)
GOCE	ESA	250 km (dawn-dusk)	11/2006	Gravity mission
Baumanets	Russia	(11:30) 490-500 km	2006	Land observing satellite
Resurs-DK	Russia	350 km	2006	Land Observing Satellite
SMOS	ESA	(6:00 A) 755 km	09/2007	Salinity & Soil moisture
GOSAT	JAXA & Japan's Ministry of Environment	13:00 666km	08/2008	Greenhouse Gases Observing Satellite monitoring the distribution of the density of carbon dioxide
ADM-Aeolus	ESA	405 km (18:00 A)	09/2008	Wind profile
ESSP/ OCO	NASA	13 :15 705 km	09/2008	Orbiting Carbon Observatory (observations of atmospheric carbon dioxide) 3 grating spectrometers

Satellites	Space Agency	Equator Crossing Time A=Northw D=Southw Altitude	Launch date	Status, application and other information
Glory	NASA	13:30 824 km	12/2008	in framework of Climate Change Research Initiative (CCRI) global distribution of natural and anthropogenic aerosols Airborne Polarimeter Sensor (APS) Total Irradiance Monitor (TIM)
ESSP/ Aquarius	NASA/ CONAE	6:00 657 km	03/2009	Global sea surface salinity (SSS) L-band Radiometer (LBR) and Scatterometer (LBS)
Megha-Tropiques	ISRO (+CNES)	Non sun-synchronous (20° incl) 870 km	2009	Monitoring convective systems, water cycle and energy budget in tropical atmosphere MADRAS (microwave imager), SAPHIR (humidity microwave sounder) 183 GHz, SCARAB (outgoing radiative flux at TOA)
CRYOSAT-2	ESA	717 km	2009	Polar ice monitoring (replacing CRYOSAT-1 lost on launch failure in October 2005)
LDCM Landsat Data Continuity Mission	NASA/US Geological Survey	828 km (at equator) sun-synchronous	07/2010	Extension of Landsat record of multispectral 30m resolution
ESSP/ HYDROS	NASA	6:00 670 km	9/2010	Hydrosphere State Mission (L-band active and passive systems) Earth's changing soil moisture and land surface freeze/thaw conditions
GPM (core-satellite)	NASA/ JAXA	407 km Non sun-synchronous (65° incl)	2010	Global Precipitation Measurement, follow-on and expanded mission of the current TRMM
GMES-1	ESA	TBD	2010-2011	Gap-filler between ENVISAT and Sentinel-1, -2, -3
EarthCare	ESA-JAXA	10:30 (D) 450 km	2012	ATLID, BBR, CPR, MSI . Cloud, radiation and aerosol interaction processes
DSCOVR (Deep Space Climate Observatory)	NASA offices of Earth and SpaceScience	L1	TBD	Measure how solar radiation affects climate by using Sun-Earth libration point L1 from which it will observe Earth

LIST OF R&D ENVIRONMENTAL MISSIONS AND INSTRUMENTS WITH POTENTIAL OPERATIONAL USE

Parameter/Area	Instruments	Missions	Products	Additional information
Precipitation	PR	TRMM	Rainfall rate	TRMM operations extended to September 2009
	TMI	TRMM	Microwave imagery	http://www.eorc.jaxa.jp/TRMM/index_e.htm
	AMSR-E	Aqua	Rainfall - Level 2, 12km resol	http://aqua.nasa.gov/about/instrument_amsr.php
	GMI	*GPM-core*	*Products TBD*	*http://gpm.gsfc.nasa.gov/index.html*
		GPM-core	*Products TBD*	*Launch planned 2010/2011*
Cloud microphysics, aerosols and trace gases	MODIS	Aqua	Aerosol concentration	http://aqua.nasa.gov/about/instrument_modis.php
		Terra	Cloud properties	http://terra.nasa.gov/
	AIRS	Aqua	Trace constituents	http://aqua.nasa.gov/about/instrument_airs.php
	AMSU-A		Cloud properties	
	MISR	Terra	Aerosol concentration	
	TES	Aura		http://www.nasa.gov/mission_pages/aura/main/index.html
	POLDER	Parasol		http://parasol-polder.cnes.fr/ http://www-icare.univ-lille1.fr/
	CALIOP	CALIPSO		http://smsc.cnes.fr/CALIPSO/ http://www-icare.univ-lille1.fr/ http://www.nasa.gov/mission_pages/calipso/main/index.html http://www-calipso.larc.nasa.gov
	CPR	CLOUDSAT		http://www.nasa.gov/mission_pages/cloudsat/main/index.html
	GGOS	GOSAT		*Planned by JAXA for 2007/2008*
	APS	*GLORY*		*Planned by NASA Dec 2008*
	ALADIN	*ADM-Aeolus*	*Aerosol properties*	*Planned 2008 by ESA*
	ATLID, CPR BBR, MSI	*EarthCare*		*http://www.esa.int/esaLP/LPearthcare.html (ESA,JAXA, planned 2012)*

Parameter/Area	Instruments	Missions	Products	Additional information
Ocean Surface wind	SeaWinds	Quikscat	Level 2B Ocean Wind Vectors in 25 Km Grid	http://winds.jpl.nasa.gov/missions/quikscat/index.cfm http://www.ifremer.fr/cersat/fr/data/overview/swath/l2b.htm
	AMI/Wind	ERS-2		http://www.esa.int/esaEO/SEMGWH2VQUD_index_0_m.html
	RA	ERS-2		http://earth.esa.int/services/pg/index.html#ERS.WSC
	RA-2	ENVISAT		http://envisat.esa.int
Wind				
	MODIS	Aqua	Water vapour polar winds	http://aqua.nasa.gov/
	MODIS	Terra	Water vapour polar winds	http://terra.nasa.gov/
				http://terra.nasa.gov/About/MODIS/index.php
	ALADIN	*ADM(Aeolus)*	*Lev. 2 wind comp.profiles*	*ESA plans launch in 09/2008* *http://www.esa.int/esaLP/LPadmaeolus.html*
Soil moisture	ASAR	ENVISAT		
	MWR	ENVISAT		
	AMSR-E	AQUA	Surface soil moisture 56 km resol	http://aqua.nasa.gov/about/instrument_amsr.php
	MIRAS	SMOS	Soil moisture	L band Microwave Imaging Radiometer
				Global coverage every 3 days
				http://www.esa.int/esaLP/LPsmos.html

Parameter/Area	Instruments	Missions	Products	Additional information
Ocean surface SST, colour, salinity	AATSR	ENVISAT	Grid/average surf temp	Near Real time "meteo product " , resol 1/6 degr lat
	MERIS	ENVISAT	Reduced or Full resol, level 1 or 2	Global coverage every 3 days http://envisat.esa.int
	MODIS	Aqua / Terra	Gridded average	http://oceancolor.gsfc.nasa.gov
			ocean surface	
			temperature	
			and colour	
	MIRAS	SMOS	Salinity	http://www.esa.int/esaLP/LPsmos.html planned for 2007
	LBR-LBS	*Aquarius*	*Salinity*	*http://aquarius.gsfc.nasa.gov/overview.html planned for 2009*
Disaster monitoring				International Charter « Space and Major disasters » initiated by ESA, CNES and CSA in 2000 http://www.disasterscharter.org
	ETM+	Landsat	Visible and infrared	http://landsat.gsfc.nasa.gov/
	HRS	Spot	Stereoscopic imagery	
	ASAR	ENVISAT	SAR imagery	http://envisat.esa.int
	SAR	RadarSat	SAR imagery	
	..	CBERS	Imagery	http://www.cbers.inpe.br/en/programas/cbers1-2.htm
	MERIS	ENVISAT		http://envisat.esa.int
	CCD camera	IRS	VIS/IR imagery	
		Vulkan-Kompas2		
		DMC		Disaster Monitoring Constellation (multi-national)
	MODIS	Aqua/Terra	Fire, dust	http://rapidfire.sci.gsfc.nasa.gov

NB : Cells are shaded for missions to be launched beyond 2007

APPENDIX V

REVIEW OF EXISTING STATEMENT OF GUIDANCE FOR WWW

Appendix V contains comments and suggestions on existing Statement of Guidance (SOGs) for consideration by ET-EGOS for Global NWP, Regional NWP, Synoptic Meteorology, Nowcasting and Very Short Range Forecasting and Aeronautical Meteorology that should be utilized by ET EGOS and the associated application expert in future updates to the SOGs. Many SOGs have reference dates more than four years ago. Since the particular SOG's reference date, many satellite missions have been launched, or recently placed in an operational status, or anticipated satellite programmes have been cancelled, or new planned missions have been approved. The comments and suggestions seek to highlight those events with the expectation that the application expert responsible for the SOG will review it. ET-SAT, as part of its work programme, will update expected performances to reflect the below comments and thus allow the expert responsible for the SOG to utilize the latest Critical Review charts. Only the relevant sections of the SOGs are commented on below. For a complete SOG, it will be necessary to utilize the original latest version.

Global Numerical Weather Prediction

3D wind field (horizontal component)

Progress: There is recently available satellite observations of cloud and humidity motion vectors over high-latitude and polar regions from the MODIS instruments on Terra and Aqua satellites. In the lower stratosphere, only radiosondes provide information. Accuracy is good/acceptable for in situ systems and acceptable/marginal for satellite winds, with the ingest of polar wind observations recently showing positive forecast impact in many numerical meteorological centres, especially valuable to avert forecast busts.

In the GOES-R era, the quality of satellite cloud drift and moisture drift winds will be significantly improved due to better definition of the representative wind height. The improved spatial, and temporal resolution will also allow for better definition of targets for wind derivation. Improved image navigation will further improve the quality of satellite derived winds.

Surface Pressure And Surface Wind

Progress*:* WINDSAT/CORIOLIS data are being evaluated as a potential new source of ocean surface wind using a passive microwave instrument.

3-D temperature field

Polar satellites provide information on temperature with global coverage, good horizontal resolution and acceptable accuracy. However, vertical resolution is now achieving 1 km with the recently availability of high-resolution infrared sounders on EOS-Aqua, which is sufficiently accurate resolution to be of value to the models. Until recently, performance in cloudy areas was poor, but the new microwave measurements from AMSU have provided substantial improvements here, and strong positive impact has been demonstrated by several NWP centres. Geostationary infrared soundings (GOES) are also helping to expand coverage in some regions by making measurements hourly and thus creating more opportunities for finding cloud-free areas. Vertical resolution will be maintained at the EOS-Aqua level of accuracy in cloud-free areas with the future launch of high-resolution infra-red sounders on METOP, NPP, and NPOESS. Satellite sounding data are currently under-utilised over land, but progress in this area is anticipated in the near future. Radio-occultation measurements for planned satellites will complement other

systems through high accuracy and vertical resolution in the stratosphere and upper troposphere (thus helping to improve analyses around the tropopause).

Progress: In the GOES-R era, improved spatial, spectral and temporal resolution of the Hyperspectral Environmental Suite (HES) will improve the value of GOES soundings in NWP models. The improved spectral resolution and radiometric accuracy will provide temperature and moisture profiles in clear air with near radiosonde quality. Also, the inherent flexibility of the HES will lend itself to providing targeted observations.

3-D humidity field

Polar satellites provide information on tropospheric humidity with global coverage, good horizontal resolution and acceptable accuracy. However, vertical resolution has been marginal until the recent availability of high resolution infrared sounders on EOS-Aqua (~2 km). Until recently, performance in cloudy areas was poor, but the new microwave measurements from AMSU offer substantial improvements as well as EUMETSAT's new Microwave Humidity Sensor (MHS) operational on NOAA-18. Geostationary infrared soundings (GOES) are also helping to expand coverage in some regions by making measurements hourly and thus creating more opportunities for finding cloud-free areas. Over ocean, coverage is currently supplemented by information on total column water vapour from microwave imagers.

Vertical resolution will be maintained at the EOS-Aqua level of accuracy in cloud-free areas with the future launch of high-resolution infra-red sounders on METOP, NPP, and NPOESS. Satellite sounding data are currently under-utilised over land, but progress in this area is anticipated in the near future. Radio-occultation measurements from planned satellites will complement other systems by providing information on the humidity profile in the lower troposphere. Over populated land areas, growth is expected in the availability of total column water vapour data from ground-based GPS measurements. Total column water vapour data are currently available at up to 1 km horizontal resolution over land (and 5 km over ocean) from the Terra and Aqua satellites. These high-resolution observations from MODIS lack the vertical resolution of AIRS on Aqua but provide very substantial improvements in horizontal resolution. Very few aircraft currently provide humidity measurements, and these data are not generally available, but technical advances in this area are anticipated in the next decade.

Progress: In the GOES-R era, improved spatial, spectral and temporal resolution of the Hyperspectral Environmental Suite (HES) will improve the value of GOES soundings in NWP models. The improved spectral resolution and radiometric accuracy will provide temperature and moisture profiles in clear air with near radiosonde quality. Also, the inherent flexibility of the HES will lend itself to providing targeted observations.

Sea surface temperature

Passive microwave instruments provide valuable sea surface temperature information under all sky conditions except near the coasts but at reduced spatial resolution to those provided by infrared imagers.

Progress: Improved spatial and temporal resolution of the Advanced Baseline Imager (ABI) in the GOES-R series, together with the capability of improved atmospheric correction will result in improved sea surface temperatures with high temporal refresh rate.

Sea-ice

Progress: This capability has recently been demonstrated using GLAS observations from the ICESat satellite, where the elevation of the sea ice is observed from high-accuracy

lidar observations, and the free-board thickness is computed, thus yielding maps of sea ice thickness. These research observations are intermittently available, and are not presently appropriate as a reliable NWP data source. CRYOSAT-2 (a replacement for the anticipated CRYOSAT that experienced an unsuccessful launch in 2005) is planned for launch in 2009 will provide useful information about sea ice thickness and mass.

Snow

Comments: Microwave imagery offers the potential of more information on snow water equivalence (at lower but still good horizontal resolution) but data interpretation is difficult. Microwave imagery is sensitive to surface wetness in sparsely vegetated areas, e.g. AMSR-E on Aqua and CMIS, but no present or planned operational missions meet minimum requirements for measurement of soil moisture (i.e. below the surface). Research missions such as Aqua and, in the future, SMOS and Hydros, offer some progress here. Some land surface stations report soil moisture routinely with marginal accuracy, but most do not report. ERS-2's Scatterometer provides some information on soil moisture as does AMSR-E on Aqua.

Land and sea-ice surface skin temperature

Progress: Recent Terra and Aqua research satellites and planned imaging instruments offer data of good resolution and frequency.

Vegetation type and cover

Progress: With channels at 0.865 (1 km resolution) and 2.25 microns (1 km resolution) together with improved atmospheric correction, the ABI on the GOES-R series will be able to provide improved vegetative indices. MERIS on board ENVISAT provides" Extracted vegetation Indices" product intended for NRT land monitoring.

Clouds

Comments: Microwave imagers and sounders offer information on cloud liquid water of good horizontal resolution and acceptable temporal resolution, with an accuracy that is probably acceptable (though validation is difficult), but only over ocean. The well-calibrated visible and near-infrared MODIS imagers on Terra and Aqua provide valuable estimates of cloud optical thickness and effective particle radius of both liquid water and ice clouds globally (though again validation is difficult).

Progress: GOES-R series ABI channels at 1.61 (1 km resolution) and 8.5 microns (2 km resolution) will help provide improved information on cloud top phase with high temporal refresh rate. The ABI channel at 2.25 microns (1 km resolution) will provide improve information on cloud top particle size. The ABI, together with HES on GOES-R will provide improved information on cloud top height.

Precipitation

Progress: Indirect quantitative estimates of precipitation rate (QPE) from geostationary IR imagery, such as NOAA's autoestimator and hydroestimator will be improved due to better spatial, and temporal resolution and additional channels on the ABI. The geostationary lightning mapper on the GOES-R series will help distinguish active convection from dead anvil cirrus, and thus further improve QPE. Studies have also shown some correlation between change in total lightning flash rate and rainfall rate.

Ozone

Comments**:** GOES-R will provide total column ozone measurements as does MSG with its ozone channel. Additionally, GOME-2 on Metop, SCHIAMACHY, MIPA and GOMOS on ENVISAT and OMI on Aura are in operations.

Progress: The HES instrument on GOES-R will help improve detection of total column ozone.

3-D aerosol

Progress: Advanced imagers such as MODIS and MISR are providing improved accuracy for total column amounts and providing information on aerosol particle size both over ocean and land areas of the globe. The EARTHCARE mission for clouds and aerosols, a joint ESA/JAXA mission is planned in 2012. The ABI on the GOES-R series and MSG will provide improved detection of aerosols at high temporal and spatial resolution.

3-D Wind Vertical Component

Progress: No present or planned direct observational capability. Research required on indirect observation via sequences of geostationary infra-red imagery and sequences of polar-orbiting Terra and Aqua images from MODIS to derive horizontal motion vector winds using water vapour and thermal infrared images in polar regions.

ADM Aeolus will be launched in 2007 with the expected capability to measure 3D wind fields.

Comments: Surface albedo can be estimated from shortwave broadband or multi-spectral radiometer measurements with good horizontal resolution. Clouds, aerosols and atmospheric gases affect the accuracy achievable, which is currently acceptable over 16-day time periods, where spatially complete spectral and broadband surface albedo of snow-free land surfaces has been demonstrated and validated using MODIS observations on Terra at 1' (~2 km) spatial resolution.

Summary of Statement of Guidance for Global NWP

Global NWP centres:

- have shown strong positive impact in middle and high latitudes from assimilation of MODIS-derived polar wind motion vectors;
- have shown strong positive impact from advanced microwave sounding instruments (such as AMSU-A) operationally;
- will take advantage of AIRS high spectral resolution sounder with improved vertical resolution and expecting further benefits from future instruments as they become operational (such as IASI, CrIS);

Data access and timeliness:

The successful EUMETSAT ATOVS Retransmission Service (EARS) has been renamed the EUMETSAT Advanced Retransmission Service and will carry AVHRR and ASCAT products in addition to ATOVS. EARS ATOVS data are now available with a delay of less than 30 minutes; the data are used operationally at some NWP centres and planned at others. Planning has begun for other Regional ATOVS Retransmission Systems (RARS) in Asia, Australia, and South America with a goal for an Integrated Global Data Dissemination Service (IGDDS). WMO hosted a global RARS Workshop in 1-2 December 2005 with participation by Europe, Canada, Americas and Asia-Pacific. WMO Space Programme is planning, with Members and CGMS, the development of Advanced

Dissemination Methods (ADMs) and an Integrated Global Data Dissemination Service (IGDDS), to include: (1) the extension and enhancement of EARS; (2) the implementation of similar systems, with a goal of achieving timely retransmission of local data sets covering the globe; (3) an equivalent system for NPP data; (4) expansion of EARS and equivalent systems to include IASI data; and (5) establishment of equivalent systems for the LEO data from satellites of other agencies.

NPOESS plans are for data delivery in less than 30 min and are thus consistent with the stated timeliness requirements for NWP.

Additionally, ERS-2 GOME and scatterometer data are now available in near real time (within 30 minutes) in the coverage region of ESA (e.g. Europe and North Atlantic) and cooperating ground stations.(e.g. Beijing, Perth,..).

Regional (mesoscale) NWP

In general, most of the above comments made by ET SAT for the Global NWP application area are also relevant for Regional NWP. Particular comments are described below.

3-D Winds

The term single level satellite winds is not accurate. Winds from the current GOES satellite series are derived for 3 levels…low, mid and high)

In the GOES-R era, the quality of satellite cloud drift and moisture drift winds will be significantly improved due to better definition of the representative wind height. The improved spatial, and temporal resolution will also allow for better definition of targets for wind derivation. Improved image navigation will further improve the quality of satellite derived winds.

3-D humidity field

Comments: Polar and geostationary satellites provide estimates of total column water vapour probably accurate to within 5-10%.

Progress: Vertical resolution of moisture soundings in cloud-free areas will be improved with the deployment of advanced infrared sounders or interferometers aboard future satellites (starting with AIRS on Aqua in June 2002). HES improved spectral resolution and radiometric accuracy will provide temperature and moisture profiles in clear air with near radiosonde quality. Also, the inherent flexibility of the HES will lend itself to providing targeted observations.

Clouds

Progress: GOES-R series ABI channels at 1.61 (1 km resolution) and 8.5 microns (2 km resolution) will help provide improved information on cloud top phase with high temporal refresh rate. The ABI channel at 2.25 microns (1 km resolution) will provide improve information on cloud top particle size. The ABI, together with HES on GOES-R will provide improved information on cloud top height.

3-D temperature field

Progress: The use of radiances (radiation measurements) over land is operational in some NWP centres.

Comments: If Microwave data onboard geostationary sounding data and IR interferometric data can be used in Regional NWP model, the assimilation results should be improved.

In the GOES-R era, improved spatial, spectral and temporal resolution of the Hyperspectral Environmental Suite (HES) will improve the value of GOES soundings in NWP models. HES improved spectral resolution and radiometric accuracy will provide temperature and moisture profiles in clear air with near radiosonde quality. Also, the inherent flexibility of the HES will lend itself to providing targeted observations.

Precipitation

Progress and comments: Precipitation can be derived from active and ground based and space based microwave radiometers. TRMM/PR products are already assimilated at some NWP centres.

Summary of Statement of Guidance for Regional NWP

Progress: NWP centres rely both on surface-based and *in situ* observing systems and on space-based systems.

Comments:

- Weather radars supply the highest resolution information, but the coverage is spatially limited, vertically and horizontally. The weather radar data assimilation is still challenge issue for regional NWP centres;
- Satellites supply information at high horizontal resolution; infrared sounding coverage is limited primarily by clouds. Smaller footprint size allow more opportunity to obtain more sounding data over partly cloudy area;
- Accurate moisture fluxes are critical for good mesoscale forecasts, especially of clouds and precipitation; higher spectral resolution sounders of next generation GEO satellites would be able to provide moisture fluxes information; the forecasts thus rely heavily upon wind and humidity observations;
- Satellite data assimilation need to be further developed in order to take full benefits of GEO observations;
- Regional models utilize, fields from global model as boundary conditions which rely heavily on satellite data. Also regional models assimilate satellite data, in particular those from the new generation of GEO satellites.

Data access and timeliness:

The successful EUMETSAT ATOVS Retransmission Service (EARS) has been renamed the EUMETSAT Advanced Retransmission Service and will carry AVHRR and ASCAT products in addition to ATOVS. EARS ATOVS data are now available with a delay of less than 30 minutes; the data are used operationally at some NWP centres and planned at others. Planning has begun for other Regional ATOVS Retransmission Systems (RARS) in Asia, Australia, and South America with a goal for an Integrated Global Data Dissemination Service (IGDDS). WMO hosted a global RARS Workshop in 1-2 December 2005 with participation by Europe, Canada, Americas and Asia-Pacific. WMO Space Programme is planning, with Members and CGMS, the development of Advanced Dissemination Methods (ADMs) and an Integrated Global Data Dissemination Service (IGDDS), to include: (1) the extension and enhancement of EARS; (2) the implementation of similar systems, with a goal of achieving timely retransmission of local data sets covering the globe; (3) an equivalent system for NPP data; (4) expansion of EARS and

equivalent systems to include IASI data; and (5) establishment of equivalent systems for the LEO data from satellites of other agencies.

NPOESS plans are for data delivery in less than 30 min and are thus consistent with the stated timeliness requirements for NWP.

Additionally, ERS-2 GOME and scatterometer data are now available in near real time (within 30 minutes) in the coverage region of ESA (e.g., Europe and North Atlantic) and cooperating ground stations.(e.g. Beijing, Perth,..).

Synoptic Meteorology

Geostationary satellites

Comments:

- Lightning data can help to improve the accuracy;
- The main weakness of geostationary satellites for synoptic meteorology remains their marginal capability for detecting precipitation.
- Indirect quantitative estimates of precipitation rate (QPE) from geostationary IR imagery, such as NOAA's autoestimator and hydroestimator will be improved due to better spatial, and temporal resolution and additional channels on the ABI. The geostationary lightning mapper on the GOES-R series will help distinguish active convection from dead anvil cirrus, and thus further improve QPE. Studies have also shown some correlation between change in total lightning flash rate and rainfall rate.

Polar-orbiting satellites

Progress: Surface winds over oceans provided either by microwave imagers and alitmeters - wind speed only - or scatterometers - speed plus direction - are widely used because of their good accuracy (except for very strong winds) in light of the importance of the wind parameter for marine users. The horizontal resolution is good at synoptic scales, while the temporal resolution is marginal to acceptable depending on the swath width of the instrument. ASCAT on Meteop will double swath of the sacatterometer of ERS. TRMM(vertical resolution of TRMM/PR is good).

Wind profilers

Progress: Wind profilers are still emerging as a tool in synoptic meteorology. Operational networks have been established in the USA and Japan,

Special case of tropical cyclones

Comments: Polar orbiting satellites also provide sea surface temperature measurements through clouds using passive microwave radiometers such as TMI, SSM/I and AMSR, and often detect a cold water wake behind a topical cyclone that can impact the path of a subsequent storm. AMSU has been used to estimate tropical cyclone intensity.

Summary of Statement of Guidance for Synoptic Meteorology

Comments: Information that best complements the content of data assimilation models (data not entering or not well treated in NWP schemes) are found in satellite images and derived products, as well as radar pictures; their usage is reinforced by their good temporal and spatial resolution.

Nowcasting and Very Short Range Forecasting

Clouds and Weather

Comments: Geostationary lightning mappers planned for the GOES-R Series, and under consideration for MTG and FY-4, have the following advantages over most current ground based systems: While most ground based systems only detect cloud to ground lightning over land, the geostationary lightning mapper on GOES-R will detect total lightning flash rate over land and over adjacent ocean areas. The total lightning flash rate together with the change in flash rate can be used as proxy for thunderstorm updraft strength and therefore provide an assessment of thunderstorm severity. The change in lightning flash rate has also been shown to be correlated with rainfall rate in some cases.

3-D Wind Field

Comments: In the GOES-R era, the quality of satellite cloud drift and moisture drift winds will be significantly improved due to better definition of the representative wind height. The improved spatial, and temporal resolution will also allow for better definition of targets for wind derivation. Improved image navigation will further improve the quality of satellite derived winds.

3-D Temperature and Humidity Fields

Progress: Geostationary infrared soundings are also helping to expand coverage in some regions by making measurements hourly and thus creating more opportunities for finding cloud-free areas. Vertical resolution has been substantially improved in cloud-free areas with the launch of high-resolution infrared sounders on EOS-Aqua, and is planned to continue with METOP, NPP, and NPOESS. Satellite sounding data are currently under utilised over land, but progress is anticipated in the near future. Radio-occultation measurements for planned satellites will complement other systems through high accuracy and vertical resolution in the stratosphere and upper troposphere, thus helping to improve analyses around the tropopause.

Comments: In the GOES-R era, improved spatial, spectral and temporal resolution of the Hyperspectral Environmental Suite (HES) will improve the quality of GOES soundings. The improved spectral resolution and radiometric accuracy will provide temperature and moisture profiles in clear air with near radiosonde quality. Also, the inherent flexibility of the HES will lend itself to providing targeted observations. The Severe Weather/Mesoscale Sounding mode will allow for covering a 1000 km by 1000 km area in 4 minutes. Additionally, MSG products for atmospheric stability are now available operationally.

Summary of Statement of Guidance for Nowcasting and VSRF

Comments:

- One key Nowcasting & VSRF parameter should be added, i.e., stability parameters;
- Well-defined high spatial and temporal resolution multispectral imagery and hyperspectral IR data from space will provide important immediate benefit to nowcasting phenomena such as areas of cloud, fog and severe convective weather;
- With the huge increase in satellite data volume coming within the next decade, forecasters will need to use automated decision aids to help focus their attention on relevant events (such as increase in lightning flash rate, rapid de-stabilization indicated by HES, or detection of an enhanced V signature).

Sea Surface Temperature

Progress: Improved spatial and temporal resolution of the Advanced Baseline Imager (ABI) in the GOES-R series, together with the capability of improved atmospheric correction to address cloud contamination, will result in improved sea surface temperatures with high temporal refresh rate.

Comments:

- There are improved imagers for both IR and microwave, so the SST accuracy can be improved;
- Snow cover. Research suggests snow cover may be important, particularly at short lead times (intraseasonal-to-seasonal); current and future imagers both Vis/IR and microwave with improved spatial resolution and accuracy, can improve snow products;
- Enhancements from satellite wind vector and snow cover, snow water equivalent and surface topography estimates, from autonomous systems such as *Argo*, and from enhanced surface flux reference sites, are providing a substantial contribution;
- In the GOES-R era, the quality of satellite cloud drift and moisture drift winds will be significantly improved due to better definition of the representative wind height. The improved spatial, and temporal resolution will also allow for better definition of targets for wind derivation. Improved image navigation will further improve the quality of satellite derived winds.

Aeronautical Meteorology:

Comments:

- Add one parameter requiring highly accurate forecast information on lightning.
- With the higher resolution in the water vapour channels on ABI, gravity waves that cannot be detected by the current GOES will be displayed on GOES-R imagery.
- Geostationary lightning mappers planned for the GOES-R Series have the following advantages over most current ground based systems: While most ground based systems only detect cloud to ground lightning over land, GOES-R will detect total lightning flash rate over land and over adjacent ocean areas. The total lightning flash rate together with the change in flash rate can be used as proxy for thunderstorm updraft strength and therefore provide an assessment of thunderstorm severity. The capability to detect lightning over ocean areas will help provide more efficient trans-oceanic flight planning.
- MSG cloud products are helpful to identify the supercooled clouds.
- Additional channels on the GOES-R ABI will help detect aerosols and thus help with determination of slant range visibility.

APPENDIX VI

EXISTING STATEMENT OF GUIDANCE FOR OTHER WMO PROGRAMMES REVIEW

Atmospheric Chemistry (updated July 2004)

H2O

Progress**:** Current GOES sounders provide operational total column water vapour and these products will be improved in the GOES-R series.

Volatile Organic Compounds (VOCs)

Comments: current satellite instruments (*e.g*. MIPAS) can observe only a few components of the VOC family (*e.g.* C_2H_6).

JCOMM Programme Areas

Comments: GOES and MSG measurements can detect the SST diurnal cycle at present. GEOS-R HES will have a capability to provide coastal water imaging with resolution around 350 – 400 meters which can obtain high resolution ocean colour in the coastal region.

Agricultural Meteorology

Comments: AMSR-E has the capability to measure the surface soil moisture; future missions SMOS and Hydros both have L-band observation to provide for measurements of soil moisture. At present soil measurement by the C-band scatterometer on ERS-2 is available.

APPENDIX VII

RECOMMENDATIONS FOR THE EVOLUTION OF SPACE-BASED SUB-SYSTEM OF GOS

REVIEW OF PROGRESS AND ACTIONS ON EVOLUTION OF THE SPACE-BASED SUB-SYSTEM OF THE GLOBAL OBSERVING SYSTEM (GOS)

1. This document provides a summary of progress and actions concerning the evolution of the space-based sub-system of the GOS, through an update of relevant sections of the Implementation Plan (IP) for the Evolution of the GOS.

2. The IP was updated by ET-ODRRGOS at its meeting 12-16 July 2004 and, following minor revision by ICT at its meeting 6-10 September 2004, was endorsed by CBS-XIII in February 2005. The section of the IP covering the space-based sub-system of the GOS was reviewed in October 2005 in discussions involving Dr P Menzel, Dr J Eyre and the WMO Space Programme ET-SAT-1. This version of the updated IP for the space-based sub-system of the GOS was reviewed by the ET-EGOS and ET-SAT in a joint session on 7 December 2005. Two new concerns are included as a result of the review and two new tasks (S21 - (Lightning and S22 – Formation Flying) have been added to the Implementation Plan.

RECOMMENDATIONS FOR THE EVOLUTION OF SPACE-BASED SUB-SYSTEM OF GOS

A balanced GOS

Concern 1 – LEO/GEO Balance

There has been commendable progress in planning for future operational geostationary satellites. In addition to the plans of China, EUMETSAT, India, Japan, Russian Federation and USA, WMO has been informed of the plans of the Republic of Korea to provide geostationary satellites. The Republic of Korea has made a formal declaration to WMO and is now considered part of the space-based sub-system of the GOS. These developments increase the probability of good coverage of imagery and sounding data from this orbit, together with options for adequate back-up in case of failure. Additionally, it would be appropriate to have regional discussions for optimized operations of geostationary and polar-orbiting satellites comprising the operational space-based sub-system of the GOS including close cooperation on instruments for future satellite missions.

Concern 2 – Achieving Complementary Polar Satellite Systems

EUMETSAT has recently initiated planning for the post-EPS era (i.e., first element in orbit in ~2019) through a thorough assessment of the user requirements for all observations that might usefully be made from low earth orbit. This is to be complemented with a remote sensing assessment of the missions needed to meet these requirements. It is expected that some of these missions will be implemented through satellite missions/systems provided by EUMETSAT, whilst other “missions” may be achieved by cooperation with other partners (e.g., NOAA/EUMETSAT Joint Polar System, complementary with GMES requirements, or acquisition of data in partnership with other space agencies). Through this process, the goals of GEOSS could be greatly advanced. WMO Space Programme Office is encouraged to consider how this process might best be facilitated, to discuss any obstacles to progress, and to identify short-term opportunities for engagement with this process. In addition, noting the polar plans of China and Russia, WMO SPO should also extend coordination efforts to include these agencies.

Calibration

S1. Calibration - There should be more common spectral bands on GEO and LEO sensors to facilitate inter-comparison and calibration adjustments; globally distributed GEO sensors should be routinely inter-calibrated using a given LEO sensor and a succession of LEO sensors in a given orbit (even with out the benefit of overlap) should be routinely inter-calibrated with a given GEO sensor.

Comment: A major issue for effective use of satellite data, especially for climate applications, is calibration. The advent of high spectral resolution infrared sensors (AIRS, IASI, CrIS) will enhance accurate intercalibration. Also regarding visible intercalibration, MODIS offers very comprehensive onboard shortwave solar diffuser, solar diffuser stability monitor, spectral radiometric calibration facility, that can be considered for inter-comparison with geosynchronous satellite data at visible wavelengths. MERIS appears to have merit in this area due to its programmable spectral capability, if implemented. GOES-R selected ABI channels have been selected to be compatible with VIIRS on NPOESS. This only deals with optical sensors, and other sensor types (e.g., active, passive, MW) should be considered.

Progress: CGMS-XXXI (2003) discussed GCOS Climate Monitoring Principles, inter-calibration of visible sensors, and inter-calibration of IR sensors on all GEOs with HIRS and AVHRR (reporting on the last item remains as a permanent action of CGMS). CGMS-XXXII (2004) considered improved infrared inter-calibration capabilities using AIRS data; the implications for GCOS Climate Monitoring Principles were discussed. The WMO Space Programme hosted a workshop in July 2005 in Darmstadt, Germany where a strategy for a global space-based inter-calibration system was drafted; it will be presented to space agencies for consideration, endorsement, and possible implementation. It was noted that the building blocks for a calibration / validation system include (1) on-board calibration devices (e.g., black bodies, solar diffusers), (2) in situ measurements of the state of the surface and atmosphere (e.g. the Cloud and Radiation Testbed (CART) site, aircraft instruments with NIST calibrations), (3) radiative transfer models that enable comparison of calculated and observed radiances, and (4) assimilation systems that merge all measurements into a cohesive consistent depiction of the earth-atmosphere system. A strategy was drafted. The WMO Space Programme presented at CGMS in November 2005 a strategy for achieving operational intercalibration of the space component of the global observing system that addresses the climate and weather forecasting needs.

Next Actions: Discussion and planning with space agencies will be continued via CGMS. CGMS will continue inter-calibration activities with current sensors (e.g. AVHRR, HIRS, MODIS, AIRS) and expand to IASI in 2006.

GEO satellites

S2. GEO Imagers - Imagers of future geostationary satellites should have improved spatial and temporal resolution (appropriate to the phenomena being observed), in particular for those spectral bands relevant for depiction of rapidly developing small-scale events and retrieval of wind information.

Progress: The following geostationary satellite operators have reported at CGMS that they will have at least SEVIRI-like capability by 2015: NOAA (2012), EUMETSAT (present), Russian Federation (2007), and CMA (2012).

Next Actions: WMO Space Programme will continue discussions with space agencies, via CGMS, especially with IMD and JMA.

S3. GEO Sounders - All meteorological geostationary satellites should be equipped with hyper-spectral infrared sensors for frequent temperature/humidity sounding as well as tracer wind profiling with adequately high resolution (horizontal, vertical and time).

Comment: This was to be demonstrated by GIFTS. However, for budgetary reasons, NASA has recently curtailed the GIFTS mission to assemble and vacuum test an Engineering Design Unit; realization of a GIFTS demonstration in geostationary orbit is a

task to be undertaken by the international community, possibly within the International Geostationary Laboratory (IGeoLab).

Progress: All operators reported plans at CGMS in 2004: NOAA has firm plans including this capability for the GOES-R series; EUMETSAT has it under consideration for the MTG series; China and India have plans for capability similar to current GOES sounder before 2010. CGMS endorsed the concept of the International Geostationary Laboratory (IGeoLab) that would be a joint undertaking to provide a platform for demonstrations from geostationary orbit of new sensors and capabilities. GIFTS is one of two systems being considered for IGeoLab. Roshydromet and Roskosmos are negotiating with the USA regarding the possibility to install GIFTS on board of the subsequent geostationary satellite "ELEKTRO". A task team evaluating two test instrument proposals for IGeoLab met in early June 2005 in Silver Spring, MD. This meeting was the outgrowth of an action from the Consultative Meetings on High-level Policy on Satellite Matters (CM) hosted by WMO in January 2005, where the Space Agencies endorsed the concept of IGeoLab and requested that the two proposals (the Geostationary Imaging Fourier Transform Spectrometer – GIFTS and the Geostationary Observatory for Microwave Atmospheric Sounding - GOMAS) be further explored. Instruments of this type in geosynchronous orbit are high priority enhancements to the Global Observing System (GOS) for meeting existing user requirements in numerical weather prediction (NWP), nowcasting, hydrology and other applications areas. In September 2005 thermal vacuum testing of the GIFTS Engineering Design Unit (EDU) was started in Logan, Utah. This will demonstrate several key technologies working together (active cooling, Focal Plane Array detectors (FPA), Fourier Transform Systems (FTS), high speed Analog to Digital converters (A/D), lightweight optics, operation at cryogenic temperatures). Information from the GIFTS TV will be shared with international community to help with instrument performance specifications.

Next Actions: WMO Space Programme is continuing pursuit of a GIFTS demonstration on IGeoLab with space agencies. See note in Next Action for S-13. Additionally, plans from all space agencies for hyperspectral geostationary sounding should be in place by CGMS 2006.

S4. GEO System Orbital Spacing - To maximize the information available from the geostationary satellite systems, they should be placed "nominally" at a 60-degree sub-point separation across the equatorial belt. This will provide global coverage without serious loss of spatial resolution (with the exception of Polar Regions). In addition this provides for a more substantial backup capability should one satellite fail. In particular, continuity of coverage over the Indian Ocean region is of concern.

Comment: In recent years, contingency planning has maintained a 5-satellite system, but this is not a desirable long-term solution.

Progress: WMO Space Programme continues to discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, the strategy for implementation towards a nominal configuration with attention to the problems of achieving required system reliability and product accuracy.

Next Actions: This issue will be addressed at a two-day optimization workshop to be held at WMO in second quarter of 2006

LEO satellites

S5. LEO data timeliness - More timely data are needed to improve utilization, especially in NWP. Improved communication and processing systems should be explored to meet the timeliness requirements in some applications areas (e.g. Regional and Global NWP).

Progress: The successful EUMETSAT ATOVS Retransmission Service (EARS) has been renamed the EUMETSAT Advanced Retransmission Service and will carry AVHRR and ASCAT products in addition to ATOVS. EARS ATOVS data are now available with a delay of less than 30 minutes; the data are used operationally at some NWP centres and planned at others. Planning has begun for other Regional ATOVS Retransmission Systems (RARS) in Asia, Australia, and South America with a goal for an Integrated Global Data Dissemination Service (IGDDS). WMO hosted a global RARS Workshop in 1-2 December 2005 with participation by Europe, Canada, Americas and Asia-Pacific. WMO Space Programme is planning, with Members and CGMS, the development of Advanced Dissemination Methods (ADMs) and an Integrated Global Data Dissemination Service (IGDDS), to include: (1) the extension and enhancement of EARS; (2) the implementation of similar systems, with a goal of achieving timely retransmission of local data sets covering the globe; (3) an equivalent system for NPP data; (4) expansion of EARS and equivalent systems to include IASI data; and (5) establishment of equivalent systems for the LEO data from satellites of other agencies.

NPOESS plans are for data delivery in less than 30 min and are thus consistent with the stated timeliness requirements for NWP.

Additionally, ERS-2 GOME and scatterometer data are now available in near real time (within 30 minutes) in the coverage region of ESA (e.g., Europe and North Atlantic) and cooperating ground stations.(e.g. Beijing, Perth,..).

Next Actions: WMO SPO to pursue further actions to implement IGDDS and RARS.

S6. LEO temporal coverage - Coordination of orbits for operational LEO missions is necessary to optimize temporal coverage while maintaining some orbit redundancy.

Progress: This is now the subject of a permanent action of CGMS. WMO Space Programme will collaborate with space agencies, via CGMS, on a target system that will be implemented and to take steps towards achieving it. Matters related for contingency planning in the AM and PM polar-orbits will be included.

Next Actions: Target system agreed upon by CGMS in 2006.

S7. LEO Sea Surface Wind - Sea-surface wind data from R&D satellites should continue to be made available for operational use; 6-hourly coverage is required.

Comment: QuikScat scatterometer data have been available to the NWP community since 1999, and will continue through the life of QuikScat (NASA has no current plans for a successor SeaWinds scatterometer). ERS-2 scatterometer will be followed by ASCAT on METOP. Oceansat-2 has scatterometer capability that may be made available to the world community (this availability needs to be confirmed).

In the NPOESS and METOP era, sea surface wind should be observed in a fully operational framework. Therefore it is urgent to assess whether the multi-polarisation passive MW radiometry is competitive with scatterometry.

Progress: 3 months of data has been made available to Windsat science team. Windsat data have been distributed to several NWP centres in 2005. Early assessments of its polarimetric capabilities to provide information on sea surface wind direction suggest that, while good information is available at high wind speed, this technology will not be competitive with scatterometry at low wind speed.

Next Actions: WMO Space Programme to take note of recent WindSat performance studies to assess implications to the GOS and provide feedback to NOAA by February 2006.

S8. LEO Altimeter - Missions for ocean topography should become an integral part of the operational system.

Progress: Agreement has been reached to proceed with Jason-2 (2008). TOPEX/Poseidon and Jason-1 continue to provide global ocean topography data to the NWP community. ESA has plans for a Sentinel-3 ocean mission that will include an altimeter.

Next Actions: WMO Space Programme to discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, the continuity of operational provision after Jason-2. Plans for operational follow-on should be reported at CGMS in 2006.

S9. LEO Earth Radiation Budget - Continuity of ERB type global measurements for climate records requires immediate planning to maintain broadband radiometers on at least one LEO satellite.

Comment: Plans for ERB-like measurements after Aqua remain uncertain. There are also concerns about the continuity of absolute measurements of incoming solar radiation. This is a high priority item in the GCOS implementation plan.

Progress: WMO Space Programme to discuss with space agencies, via CGMS. The second NPOESS satellite is scheduled to carry the CERES instrument (likely launch in 2013), but NPOESS program is currently under review and likely to be re-configured. FY-3A will have a proto-type Earth radiation budget instrument in 2007.

Next Actions: WMO Space Programme should advise CGMS of these developments and lead a discussion of possible gaps in coverage at CGMS in 2006.

R&D satellites

S10. LEO Doppler Winds - Wind profiles from Doppler lidar technology demonstration programme (such as Atmospheric Dynamics Mission - Aeolus) should be made available for initial operational testing; a follow-on long-standing technological programme is solicited to achieve improved coverage characteristics for operational implementation.

Comment: Plans for Aeolus demonstration are proceeding on schedule, but there are no plans for operational follow on.

Progress: EUMETSAT is considering the requirements for observations of the 3D wind field as part of their planning for post-EPS missions. ESA plans to work with ECMWF to prepare for the assimilation of Doppler winds into NWP model and to give feedback as to their impact.

Next Actions: WMO Space Programme will discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, to assure demonstration with Aeolus and initiation of operational systems for wind profile measurement. Plans for continuity of a Doppler Winds capability following Aeolus should be discussed by CGMS satellite operators in 2006.

S11. GPM - The concept of the Global Precipitation Measurement Missions (combining active precipitation measurements with a constellation of passive microwave imagers) should be

supported and the data realized should be available for operational use, thereupon, arrangements should be sought to ensure long-term continuity to the system.

Progress: TRMM continues to provide valuable data for operational use. Early termination of TRMM after 2004 was averted after user community appeals for its continuation. NASA has assured continued operation into 2009. At CGMS-XXXII, NASA, ESA and JAXA reported plans for a GPM mission in 2008 (now 2010). In 2005, ESA's European GPM was not selected as the next Earth Explorer Mission. At the fifth International planning workshop WMO expressed it support and its readiness to facilitate partnerships to expand the GPM constellation. It was recognized that ISRO's Megha-tropique has a passive microwave capability that is not yet part of the GOS but could be useful in the GPM constellation (availability needs to be confirmed). Other R&D and operational satellites in polar orbit may contribute to the constellation with their microwave radiometers.

Next Actions: WMO Space Programme is continuing discussions with space agencies, via CGMS and at CM, regarding plans for GPM.

S12. RO-Sounders - The opportunities for a constellation of radio occultation sounders should be explored and operational implementation planned. International sharing of ground support network systems (necessary for accurate positioning in real time) should be achieved to minimize development and running costs.

Progress: CHAMP and SAC-C data have been available to some centres but not in near real time (NRT). NWP OSE has shown positive impact with small number of occultations. Climate applications are being explored. Near real time dissemination of CHAMP data is planned for 2006. Plans for near real time distribution of METOP/GRAS and COSMIC data are also in place.

Next Actions: Plan for operational follow-on to COSMIC should be drafted by CGMS in 2006. Plans for a shared ground support network should also be drafted by CGMS in 2006

S13. GEO Sub-mm - An early demonstration mission on the applicability of sub-mm radiometry for precipitation estimation and cloud property definition from geostationary orbit should be provided, with a view to possible operational follow-on.

Progress: EUMETSAT, NESDIS and WMO prepared a paper for CGMS on the International Geostationary Laboratory (IGeoLab) that would be a joint undertaking to provide a platform for demonstrations from geostationary orbit of new sensors and capabilities. Geo sub-mm is one of two systems being considered for IGeoLab. A task team evaluated the IGeoLab possibilities for a Geostationary Observatory for Microwave Atmospheric Sounding (GOMAS) as well as other possible instruments. This type of instrument in geosynchronous orbit is high priority for meeting existing user requirements in numerical weather prediction (NWP), nowcasting, hydrology and other applications areas. The task team is pursuing definition of feasible options for a geo sub mm instrument; the WMO Space Programme will seek partners for development of the recommended Geo sub mm instrument with space agencies and will report progress at CGMS. An IGeoLab Focus Group meeting was held on 24 October 2005 and the results were reported to CGMS XXXIII where the concept was endorsed.

GOMAS is a candidate for an ESA Explorer core mission, to be determined in mid-2006.

Next Actions: WMO Space Programme will continue dialogue with space agencies, via CGMS.

S14. LEO MW - The capability to observe ocean salinity and soil moisture for weather and climate applications (possibly with limited horizontal resolution) should be demonstrated in a research mode (as with ESA's SMOS and NASA's Aqua, Aquarius, and Hydros) for possible operational follow-on. Note that the horizontal resolution from these instruments is unlikely to be adequate for salinity in coastal zones and soil moisture on the mesoscale.

Progress: ERS scatterometer data sets have provided monthly global soil moisture maps since 1991 at 50 km resolution. WindSat and AMSR-E are being studied for possible utility of 6 and 10 GHz measurements for soil moisture for sparsely vegetated surfaces. SMOS is scheduled for launch in late 2007. Aquarius is scheduled for launch in 2008 and Hydros in 2009.

Next Actions: WMO Space Programme will discuss at CGMS progress and options for provision of soil moisture and salinity products including real time delivery of soil moisture products for NWP.

S15. LEO SAR - Data from SAR should be acquired from R&D satellite programmes and made available for operational observation of a range of geophysical parameters such as wave spectra, sea ice, land surface cover.

Progress: The wave spectra from ENVISAT are available in near real time from an ESA ftp server. CSA's RADARSAT data are used in deriving ice products by the National Ice Center.

Next Actions: WMO Space Programme to discuss with space agencies, via CGMS, (1) broader access by WMO Members to ENVISAT SAR data, (2) availability of SAR data from other agencies, and (3) continuity of such missions. Assessment of status and plans should completed by CGMS in 2006.

S16. LEO Aerosol - Data from process study missions on clouds and radiation as well as from R&D multi-purpose satellites addressing aerosol distribution and properties should be made available for operational use.

Comment: Terra and Aqua carry the MODIS sensor that is providing global aerosol products over ocean and most land regions of the world at 10 km spatial resolution. Additional R&D satellites currently providing aerosol optical thickness and optical properties include Terra/MISR, PARASOL, EP-TOMS, and Aura/OMI, CALIPSO will carry an R&D lidar for monitoring the vertical distribution of aerosols along the orbital ground track of the spacecraft, which is in the A-train orbit along with Aqua, PARASOL, CloudSat, and Aura. NASA's Glory mission (2008) as well as NPOESS has added APS, an aerosol polarimetry sensor. ESA and JAXA are preparing the Earthcare (cloud/aerosol mission) for launch in 2012.

Next Actions WMO Space Programme will continue discussions with space agencies, via CGMS and at CM, regarding availability of these data for operational use.

S17. Cloud Lidar - Given the potential of cloud lidar systems to provide accurate measurements of cloud top height and to observe cloud base height in some instances (stratocumulus, for example), data from R&D satellites should be made available for operational use.

Comment: GLAS data are currently able to determine vertical distribution of cloud top altitude along the nadir ground track of ICESat, but this spacecraft operates in ~100 day epochs and is not continuous. CALIOP on CALIPSO should make these data routinely available in the A-train orbit (Aqua, PARASOL, CloudSat, and Aura).

Next Actions WMO Space Programme will discuss with space agencies, via CGMS and at CM, near real time operational use of these data and operational follow-on planning.

S18. LEO Far IR - An exploratory mission should be implemented, to collect spectral information in the Far IR region, with a view to improve understanding of water vapour spectroscopy (and its effects on the radiation budget) and the radiative properties of ice clouds.

Next Actions WMO Space Programme to discuss with space agencies, via CGMS.

S19. Limb Sounders - Temperature profiles in the higher stratosphere from already planned missions oriented to atmospheric chemistry exploiting limb sounders should be made operationally available for environmental monitoring.

Progress: MIPAS and SCIAMACHY data are available in near real time from the ESA ftp server. NPP is scheduled to carry OMPS with ozone limb sounding in 2009.

Next Actions: WMO Space Programme will discuss with space agencies, via CGMS, progress/plans for distribution of data from MIPAS and SCIAMACHY on ENVISAT, from MLS and HIRDLS on Aura, and from similar instruments.

S20. Active Water Vapour Sensing - There is need for an exploratory mission demonstrating high-vertical resolution water vapour profiles by active remote sensing (for example by DIAL) for climate monitoring and, in combination with hyper-spectral passive sensing, for operational NWP.

Next Actions: WMO Space Programme will discuss with space agencies, via CGMS.

S21. Lightning Observation – There is a requirement for space borne lightning observations. Several initiatives for operational implementation exist. These should be encouraged to fruition.

Comment: NASA's observations of lightning from OrbView-1/OTD and TRMM/LIS has demonstrated that 90% of lightning occurs over land, and that it is heavily tied to deep convection. In addition to its importance in severe storms and warnings for safety, lightning is an importance source of NO_X and thus contributes to elevated levels of tropospheric ozone. The vision for the space-based sub-system of the GOS approved by the Extraordinary session of CBS in 2002 included GEO lightning under the need for "Several R&D satellites serving WMO Members".

Progress: The dynamics of lightning occurrence and its importance for nowcasting has been recognized by NOAA that plans to include a lightning sensor on GOES-R, and under consideration for MTG and FY-4, in the future.

Next Actions: WMO Space Programme will discuss with space agencies, via CGMS.

S22. Formation Flying – Advantages of formation flying need to be investigated

Comment: NASA has already demonstrated both a morning constellation (involving Landsat 7, EO-1, SAC-C, and Terra) and an afternoon constellation (Aqua, PARASOL, and Aura, soon to be joined by CloudSat (2006), CALIPSO (2006), and OCO (2008)). These multi-agency and multi-country constellations demonstrate the added value of coordination of Earth observations to make a polar orbiting system greater than the sum of the parts, but able to launch when sensors and spacecraft are ready and available.

Next Actions: The utility of data from sensors flying in formation need to be assessed. WMO Space Programme will discuss with space agencies, via CGMS

APPENDIX VIII

Suggestions on the GCOS Implementation Plan for consideration by GCOS JPO

Key Action 10: Parties need to ensure that their climate-observing activities which contribute to GCOS adhere to the GCOS Climate Monitoring Principles.

Comments: space agencies and satellite operators should adhere to the GCOS climate monitoring principles relevant to the satellite observations.

Key Action 14: Parties need to: (a) ensure the continued operation of satellite measurements of the Earth radiation budget and solar irradiance (e.g., the NASA Earth Radiation Budget Experiment); and (b) support research to extend and improve current capabilities for monitoring clouds as a high priority.

Comments: (a) operational space agencies should seek to achieve that at least 1-2 operational satellites carry an Earth radiation budget and solar irradiance instrument with high accuracy, and ensure data continuity; (2) space agencies should pay high attention to onboard calibration system of VIS/IR instruments, which enable instrument measurements to achieve reliable and comparable cloud data sets reflecting cloud property changes.

Key Action 15: Parties need to: (a) fully establish a baseline network for key greenhouse gases; (b) improve selected satellite observations of atmospheric constituents; and (c) extend existing networks to establish a global baseline network for atmospheric optical depth.

Comments: Space agencies should give high attention to the transition of the relevant atmospheric constituents measurement instruments with adequate accuracy to operational use.

Key Action 23: Parties are urged to adopt an internationally coordinated approach to the development of integrated global climate products and to make them accessible to all Parties. As far as possible, these products should incorporate past data covering at least the last 30 years in order to serve as a reference for climate variability and change studies.

Comments: The traceability of all the satellite observation (e.g., calibration change and sensor onboard degration, orbital elements, instruments specification change, etc) are key issues for the establishment of the long-term product records. Space agencies are encouraged to try their best to provide all the historical satellite observational data parameters for the past and current satellite systems, and try their best to keep stable satellite observations (orbital draft control, stable onboard calibration, less sensor degration, etc.) for the future satellite missions.

APPENDIX IX

ET SAT-1 WORK PROGRAMME

1. Review and update expected performance for satellites systems presently contributing to the space-based global observing system (Deadline 28 February 2006).

2. Review Terms of Reference for the THORPEX Observing System Working Group and provide comments if appropriate to the Chairman OPAG IOS (Deadline 28 February 2006).

3. Review and update the information contained in ET SAT-1 Document 5 and provide information to the WMO Space Programme Office (Deadline 28 February 2006).

4. Review the GCOS Implementation Plan and provide comments to the WMO Space Programme Office for use at the GCOS Experts' meeting 9-11 January 2006 (Deadline 6 January 2006).

5. Provide additional input on "formation flying" as a particular way of operating spacecraft in low Earth orbit.

6. Review the Latest Statement of Guidance for Hydrology and provide comments and progress. (Deadline ETSAT-2).