CGMS-XXXIV
WMO WP-6
Prepared by WMO
Agenda item: D.1

EVOLUTION OF THE GOS

(Submitted by WMO)

Summary and Purpose of Document

The paper recalls first of all the current baseline for the WMO WWW Global Observing System (GOS), with reference to the agreed vision of the GOS to 2015, and the status of evolution of the GOS towards full implementation of this vision.

Several issues, that are listed in the Implementation Plan, are expected to be discussed by CGMS XXXIV.

The paper then reports on recent discussions held within the joint second session of the Expert Teams on Satellite Systems (ET-SAT-2) and on Satellite Utilization and Products (ET-SUP-2) which concluded on the need to update and redefine the scope of the GOS, in order to take the needs of climate monitoring fully into account. In view of the outcome of these discussions, the ICT-IOS agreed that the relevant Expert Teams (ET-EGOS, ET-SAT, ET-SUP) would "initiate an update of the space-based GOS baseline with 2025 as a new horizon, and expand its scope beyond World Weather Watch in order to include sustained observations of additional variables required for climate monitoring, and ultimately address the needs of other programmes as well."

CGMS Members are invited to note this decision and to comment on their capacity and readiness to contribute to a future expanded space-based GOS, as suggested.

Appendix: Extract from the Implementation Plan for Evolution of the space and surface subsystems of the GOS

DISCUSSION

Baseline for the Global Observing System

1. The WMO World Weather Watch (WWW) Global Observing System (GOS) is defined in the "Manual of the GOS", which is part of the WMO Regulatory Material. Furthermore, the Extraordinary session of the Commission for Basic Systems in 2002 (CBS-Ext. 02) agreed to a vision of the evolution of the GOS to 2015 together with an Implementation Plan for this evolution. A summarized description of this GOS baseline is provided in Table 1 below.

Table 1: Summarized description of the GOS baseline (space segment only)

The description of the space-based GOS specified by the Manual on the GOS is in normal characters, while additional requirements contained in the CBS Vision to 2015 is in underlined and italic characters

Satellites	Payload	Observations to be delivered
At least 6 operational GEO satellites Near-equally spaced	VIS and IR imagery IR sounding *Some hyperspectral IR sounders*	Fields of atmospheric temperature and humidity; Temperatures of sea and land surfaces; Wind fields at the surface and aloft; Cloud amount, cloud type, cloud top height and temperature, and cloud water content; Precipitation; Snow and ice cover; Total column ozone; Vegetation cover Radiation balance data
At least 4 operational LEO satellites sun-synch. (2 am + 2 pm) *optimally spaced in time*	VIS, IR, MW imagery IR and MW sounding Other e.g., (scatterometer, altimeter) *UV imagery* *Radio occultation* *At least 3 with hyper-spectral IR sounder* *At least 3 MW imager or scatterometer*	
2 LEO satellites (e.g. among the 4)	Altimeter	Ocean surface topography
R&D satellites (without guarantee of continuity nor replacement policy)	VIS, IR MW imagery IR and/or MW sounding Other missions of relevance to WMO requirements *Radio-occultation* *Wind lidar* *Active and passive MW precipitation measurement* *Advanced hyperspectral capabilities* *Lightning detection (GEO)* *Possibly MW (GEO)*	(to the extent possible) improved information on T,Q fields improved information on wind fields Soil moisture distribution; Improved information on sea ice type and extent; Improved information on snow cover and water content; Wave heights, directions and spectra; Improved accuracy and frequency in rainfall monitoring; Three-dimensional cloud water/ice fields; Height of cloud base Improved monitoring of the Earth radiation budget; Sea-surface temperatures of improved accuracy; Distribution of particulate matter in the atmosphere, including volcanic ash; Ocean surface height; Ocean surface salinity; Ocean colour, related to marine pollution and biological properties; Sea and land ice topography; Improved information on ozone distribution;

Satellites	Payload	Observations to be delivered
		Improved information on land cover and vegetation mapping; Flood and forest fire monitoring; Information on fields of chemically-active atmospheric constituents; Information on carbon dioxide and other greenhouse gases Lightning detection

Implementation Plan for Evolution of the GOS to 2015

2. The Implementation Plan for the Evolution of the Space and Surface-based subsystems of the Global Observing System (IP EGOS) contains recommendations towards full implementation of this vision to 2015, as well as a record of actions and progress. It is kept under review by the Expert Team on the Evolution of the GOS (ET-EGOS) with input from ET-SAT and ET-SUP as concerns the space-based subsystem.

3. The recommendations contained in the IP EGOS call for actions on a number of issues which are being pursued by the WMO Space Programme in cooperation with CGMS members, and some of these actions are addressed in dedicated papers submitted to CGMS XXXIV.

4. CGMS XXXIV is expected to consider specifically the following issues:

- optimization of the space-based GOS,
- GSICS,
- Igeo Lab,
- RARS implementation and expansion,
- Compared value of scatterometry and microwave imagery for sea surface wind,
- Continuity of altimetry missions,
- Continuity of Earth Radiation Budget measurements,
- Cooperation on ground support facilities for radio-occultation missions,
- Plans for SAR imagery data.

5. Furthermore, the following issues are to be discussed by CGMS:

- Preparatory mission for transition of Wind Doppler lidar to operations,
- Timely implementation of GPM,
- Near-real time access, for operational use, to R&D data on sea surface wind, GPM, salinity and soil moisture, SAR imagery, aerosols, cloud characteristics (base, top), limb sounding.

6. The latest update of the Introduction and of the Space-based component section of the Implementation Plan is attached as Appendix to the present document, for reference.

Changing the baseline for the GOS

7. Besides the ongoing evolution of the GOS towards its agreed target configuration for 2015, several factors should be considered and may trigger a further evolution of the GOS, namely:

(a) WMO decision to integrate all WMO Global Observing Systems, this integration being one of the 11 Expected Results of the new WMO Strategic Plan as agreed by the 58th Executive Council (EC-LVIII). As concerns its space-based component, the WWW GOS is already addressing more than just WWW needs. It is thus envisaged that integration of the space-based component of the various Global Observing

Systems will be completed by expanding the WWW GOS to cover the needs of other programmes.

(b) Among these other programmes, special attention should be paid to the Global Climate Observing System (GCOS) that relies heavily on space-based observation. The impact of including climate monitoring is discussed in WMO WP-37. GCOS has formulated requirements to monitor a number of Essential Climate Variables (ECV) in a continuous and homogeneous way. Some of these ECV are beyond the current operational scope of the WWW GOS but should be taken into account in the definition of the scope of the GOS. This would apply, for example, to the following variables:

- atmospheric composition (ozone profile, distribution of GHG and aerosols);
- wave height and sea state;
- sea surface salinity;
- ice sheet elevation;
- fraction of Absorbed Photosynthetically Active Radiation (fAPAR) and Leaf Area Index (LAI).

(c) The need to optimize the space-based observation effort at global scale, which was discussed at the CGMS-WMO optimization workshop on 28-29 August 2006 addressed in WMO WP-04. While this workshop was mainly focused on how to best implement the current GOS baseline, some of its recommendations were also suggesting to update this baseline, e.g., as concerns the requirement for Radio-Occultation sounding or the precise distribution of sun-synchronous orbital planes. Another aspect of optimization is the relative emphasis to be given to LEO and GEO observing capability.

(d) The vision of the GOS to 2015 was developed in 2001 and agreed by CBS in early 2002. In view of the tremendous development of space capabilities and of the need for long-reaching plans in this domain, it would be appropriate to initiate the development of an updated vision of the space-based component of the GOS to 2020.

(e) An updated description of the space-based component of the GOS should also include the emerging GSICS, which is seen as a new component in addition to the LEO operational, GEO operational and R& D components of the GOS.

8. At the joint ET-SAT and ET-SUP session, it was recognized that including climate monitoring objectives into the GOS baseline would have far-reaching implications. Climate monitoring requires continuous observation of a number of variables that are currently measured by R&D missions to the extent possible, and without guarantee of long-term continuity.

9. In expanding the scope of the GOS with effect to include new observations to be delivered by the GOS, consideration should be given to the concept of "sustained" availability of these observations, as opposed to "operational" availability. It is understood that "sustained" availability should imply at least plans for long-term continuity and replacement policy; without involving the operational real-time operational continuity constraints.

10. Reviewing the outcome of ET-SAT and ET-SUP, the Implementation/Coordination Team for Integrated Observing Systems (ICT IOS) has acknowledged that expanding the GOS baseline to encompass climate monitoring needs was as a necessary step towards the integration of all WMO Global Observing Systems. ICT-IOS thus agreed that the relevant Expert Teams (ET-EGOS, ET-SAT, ET-SUP) would "initiate an update of the space-based GOS baseline with 2025 as a new horizon, and expand its scope beyond World Weather Watch in order to include sustained observations of additional variables required for climate monitoring, and ultimately address the needs of other programmes as well."

11. Through the integration process, it is understood that the GOS would no longer be exclusively the WWW GOS but the WMO GOS.

Conclusion

12. CGMS Members are invited to note this important action taken by WMO and to comment on their capacity and readiness to contribute to a future expanded space-based GOS, as suggested.

IMPLEMENTATION PLAN FOR EVOLUTION OF THE SPACE AND SURFACE BASED SUBSYSTEMS OF THE GLOBAL OBSERVING SYSTEM

(Extracted from draft version 2.0, October 2006)

1. Introduction

1.1 This Implementation Plan has been prepared by the WMO/CBS/OPAG-IOS Expert Team on the Evolution of the Global Observing System (ET-EGOS, formerly the Expert Team on Observational Data Requirements and Redesign of the Global Observing System, ET-ODRRGOS).

1.2 The Plan is prepared and updated in the following way:

1.2.1 Using the CBS Rolling Review of Requirements (RRR) process, user requirements for observations are compared with the capabilities of present and planned observing systems to provide them. Both user requirements and observing system capabilities are collated in a comprehensive, systematic and quantitative way in the WMO/CEOS database, which attempts to capture observational requirements to meet the needs of all WMO programmes. The comparison of user requirements with observing system capabilities for a given “application area” is called a “Critical Review”. The output of the Critical Review process is reviewed by experts in the relevant application and used to prepare a Statement of Guidance (SOG), the main aim of which is to draw attention to the most important gaps between user requirements and observing system capabilities, in the context of the application. This has been done systematically for (currently) 11 “application areas”: global NWP, regional NWP, synoptic meteorology, nowcasting and very short range forecasting, seasonal and inter-annual forecasting, aeronautical meteorology, climate monitoring, ocean applications, agrometeorology, hyrodology and water resources, and atmospheric chemistry. Thus a wide range of applications within WMO programmes have already been addressed. The latest versions of SOGs are available through the WMO web site.

1.2.2 The “gap-analysis” provided by these SOGs is then reviewed by ET-EGOS. The key issues emerging from them are used to formulate recommendations for action and, following endorsement by CBS, these recommendations form the basis of an Implementation Plan (IP), through which progress to meet the recommendation is recorded and appropriate actions are proposed. The IP is a living document and is reviewed regularly to take account of progress in implementation, and of changes in user requirements and observing system networks and technologies.

1.3 The IP is also informed from a number of other sources:

1.3.1 ET-EGOS works closely with the CBS Rapporteurs on Global and Regional Observing System Experiments (OSEs) to take note of conclusions emerging from impact studies, through which real and hypothetical changes to the GOS are assessed for their impact on NWP performance. In particular ET-EGOS takes note of the conclusions of the WMO-sponsored Workshops on “the Impact of Various Observing Ssystems on NWP”. The conclusions of the workshops in Toulouse (2000) and Alpbach (2004) are recorded in WMO/TDs 1034 and 1228 respectively. In addition, ET-EGOS commissions impact studies to answer specific questions when necessary.

1.3.2 ET-EGOS takes note of developments in observing system technology. Candidate observing systems (space-based and surface-based) for the coming decade were studied and reported in WMO/TD 1040.

1.3.3 The IP is informed by advice from a number of other bodies including: other CBS Expert Teams, the World Weather Watch Programme, the WMO Space Programme, JCOMM, the WMO AMDAR Panel, GCOS and representatives of the WMO Regions.

1.3.4 The scope and assumptions of the IP are as follows:

- It addresses both surface-based and space-based sub-systems of the GOS.
- It responds to observational requirements of all WMO programmes to which the GOS might reasonably be expected to contribute.
- It responds to a vision of the GOS in 2015 and beyond as set out in section 5.
- It envisages that the future GOS will build upon existing sub-systems, both surface- and space-based, and will capitalize on existing and new observing technologies not presently incorporated or fully exploited; each incremental addition to the GOS will be reflected in better data, products and services from the National Meteorological and Hydrological Services (NMHSs).
- It responds to those elements of the GCOS Implementation Plan which call for action by WMO Members (through CBS) or by the WMO Space Programme. (A cross-check between the GCOS Implementation Plan and this IP has been performed.)
- It takes note of the GAW Strategic Implementation Plan but does not attempt to duplicate its actions.
- It does not explicitly express the need for aspects of continuity of current observing systems – it is concerned primarily with evolution rather than continuity. However it is recognized that aspects of continuity of observing systems are of key importance for many applications, including operational weather forecasting and climate monitoring.
- It recognises the special challenges and issues concerning developing countries (see section 4).

1.5 In preparing this IP it has become clear the scope of changes required to the GOS in the next decade are massive and will need new approaches for science, data handling, product development, training and utilization.

1.6 The IP currently contains a set of 44 recommendations, each with corresponding comments on progress and accompanying actions. There are 22 recommendations for the surface-based sub-system of the GOS (see section 2) and 22 for the space-based sub-system of the GOS (see section 3).

2. Evolution of surface-based sub-system of GOS

(not included in the present extract.)

3. 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 component 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. On the other hand, current plans for LEO missions are unlikely to fulfill all identified requirements. It would be timely for the WMO Space Programme and/or CGMS to study the balance between polar and geostationary systems and to advise if there is scope for optimizing this balance between the two systems in the long term.

> **Next Actions:** WMO has convened a “CGMS-WMO optimization workshop” with CGMS satellite operators on 28-29 August 2006. The workshop will review the planned locations of geostationary satellites as well as the equatorial crossing times of the sun-synchronous polar-orbiting satellites, with their respective payloads. The issue of GEO-LEO optimization will be brought forward.

A balanced GOS - 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, complementarity with GMES missions, 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 the Russian Federation, WMO Space Programme should also extend coordination efforts to include these agencies.

Next actions: This will be addressed at the CGMS Optimization workshop mentioned above.

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. GCOS Implementation Plan (GIP) Action C10 calls for continuity and overlap of key satellite sensors. 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 XXXIII (Tokyo, November 2005) supported the strategy defined at the WMO Workshop (Darmstadt, July 2005) for a Global Space-based Inter-Calibration System (GSICS) that is intended to ensure comparability of satellite measurements provided through different instruments and satellite programmes and to tie these measurements to absolute references. GSICS activities will include: regular processing of VIS-IR-MW radiances from co-located scenes of GEO and LEO satellites, with common software tools as well as: pre-launch instrument characterization; on-orbit calibration against on-board, space or earth-based references; calibration sites and field campaigns; radiative transfer modelling. A GSICS Implementation Plan was issued in April 2006 and was formally endorsed at the GSICS Implementation Meeting convened by WMO (Geneva, 23 June 2006). The 58th WMO Executive Council underlined the importance of GSICS and was happy to note that China, Japan, Russian Federation and the United States as well as EUMETSAT were engaged to contribute to GSICS. The GSICS Implementation meeting nominated a GSICS Executive Panel, led by Dr Mitch Goldberg from NOAA.

Next Action: A GSICS operation plan will be prepared with the aim to start initial operations in the first half of 2007.

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. This will be addressed at the CGMS Optimization workshop mentioned above.

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: 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.

Progress: All operators reported plans at CGMS in 2005: NOAA has firm plans including this capability for the GOES-R series by 2012; EUMETSAT has it under consideration for the MTG series around 2016; China for its FY-4 series by 2012. Based on the experience gained from classical IR sounding from GEO satellites and from hyperspectral Infrared sounding from LEO satellites, the impact of hyperspectral sensors on GEO satellites is expected to be very positive. It would be helpful to proceed with a direct demonstration mission in advance of the planned operational series in order to optimise this impact. For the meantime, 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 considering with the USA the possibility to install GIFTS on board of the geostationary satellite “ELEKTRO-L 2” planned for launch in 2010. There remains however a funding issue to manufacture a space qualified instrument on the basis of the current engineering model.

Next Actions: The IGEOLAB GIFTS proposal and the plans for operational hyperspectral sounding from the GEO orbit will be reviewed at CGMS XXXIV (November 2006, Shangai).

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 the CGMS optimization workshop mentioned above.

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. A RARS has started operations in Asia-Pacific area, and planning has begun for a RARS in South-America. Following the global RARS workshops held in Darmstadt in December 2004, in Geneva in December 2005 and in September 2006, the primary goal is to achieve quasi-global coverage for timely retransmission of ATOVS datasets. The RARS approach is expected to be expanded to IASI and other time-critical data, including an equivalent system for NPP data.

NPOESS initial plans are for 80% of global data acquisition in less than 15 min and would thus be consistent with the stated timeliness requirements for NWP, provided that provisions are made for the timely redistribution of these data towards NWP centres.

As regards polar winds, plans are being developed to improve the timeliness through the use of direct broadcast imagery received at high-latitude stations.

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 Space Programme to pursue further actions to implement RARS at a global scale and to encourage the implementation of similar plans to allow the derivation of polar winds with improved timeliness

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: This will be addressed at the CGMS Optimization workshop mentioned above. Target system to be 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: GCOS (GIP, Action A11) calls for continuous operation of AM and PM satellite scatterometers or equivalent. 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). Oceansat-2 has scatterometer capability that may be made available to the world community (this availability needs to be confirmed). The relative performance of the multi-polarisation passive MW radiometry versus scatterometry requires further assessment.

Progress: ERS-2 scatterometer will be followed by ASCAT on METOP, sea surface wind will thus be observed in an operational framework from 2006 onwards.
The revised NPOESS baseline includes a microwave imager/sounder to provide wind speed and direction information at sea surface starting with NPOESS-C2 in 2016.

Three 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 in 2006. This shall be discussed at CGMS XXXIV in 2006.

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

Comment: GCOS (GIP, Action O12) requires continuous coverage from one high-precision altimeter and two lower-precision but higher-resolution altimeters.

Progress: Agreement has been reached to proceed with Jason-2 (2008). Jason-1 continues 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. This will be addressed at the CGMS Optimization workshop mentioned above. 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 for GCOS (GIP, Action A24).

Progress: FY-3A will have a prototype Earth Radiation Budget Unit (ERBU) in 2007. The first NPOESS satellite is scheduled to carry the CERES instrument (likely launch in 2013).

Next Actions: Continuity before and after NPOESS-C1 will be addressed at the CGMS Optimization workshop mentioned above. WMO Space Programme will express concern at CGMS XXXIV if the risk of a gap is confirmed.

R&D satellites

S10. **LEO Doppler Winds** - Wind profiles from Doppler lidar technology demonstration programmes (such as ADM-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.

Progress: Plans for ADM-Aeolus demonstration are proceeding on schedule, and ESA and ECMWF are developing software for the assimilation of Doppler winds into NWP models. There are currently no plan for either a preparatory mission or an operational follow on. EUMETSAT is considering the requirements for observations of the 3D wind field as part of their planning for post-EPS missions.
Next Actions: WMO Space Programme will discuss with space agencies, via CGMS and WMO Consultative Meetings on High-level Policy on Satellite Matters, to ensure that the demonstration with ADM-Aeolus can be followed by a transition to operational systems for wind profile measurement. Plans for continuity of a Doppler Winds capability following ADM-Aeolus should be discussed by CGMS satellite operators in 2006 WMO Space Programme participates in an ESA/ESTEC ADM-Aeolus workshop on 25-27 September 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.

Comment: GCOS (GIP Action A7) requires stable operation of relevant operational satellite instruments for precipitation and associated products.

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. 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. GPM was addressed at the 6th Consultative Meeting (Buenos Aires, January 2006) and its importance was stressed. The GPM core satellite is now planned for launch in December 2012.

Next Actions: WMO Space Programme is continuing discussions with space agencies, via CGMS and at CM, regarding plans for GPM. The GEO work plan 2006 includes an action, co-led by CEOS and WMO, to advocate the timely implementation of the GPM mission.

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.

Comment: GCOS (GIP Action A20) requires sustained, operational, real-time availability of GPS RO measurements.

Progress: CHAMP and SAC-C data have been available to some centres. NWP OSEs have 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 for 2006.

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

S13. GEO Sub-mm for precipitation and cloud observation- 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: 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.
GOMAS was not accepted by ESA as a core Explorer mission. Alternative projects may be discussed at CGMS XXXIV.

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

S14. LEO soil moisture and ocean salinity - 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, and NASA/CONAE Aquarius/SAC-D) 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. EUMETSAT plan an operational global NRT soil moisture product from Metop/ASCAT data. 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 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 be 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 carries 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) 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. Recommendation S18 is to be found in Section "Process studies" below

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.

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 a demonstration mission of the potential of 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 global observations of lightning. Several initiatives for operational space-based implementation exist. These should be encouraged to fruition.

Comment: NASA's observations of lightning from OrbView-1/OTD and TRMM/LIS have 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 component 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 CMA that plans a lightning mapper on FY-4. It is under consideration by EUMETSAT for MTG however EUMETSAT are reviewing requirements and implementation options for lightning observations and the potential role of ground-based observations to meet requirements is being re-assessed.

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, Aura, CloudSat (2006) and CALIPSO (2006), soon to by joined by 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

Process studies

In reviewing the Implementation Plan for the Evolution of the Global Observing System, and not withstanding other potential requirements, the need for following process study mission was identified:

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