WORLD METEOROLOGICAL ORGANIZATION

Workshop on the Re-design and Optimization of the Space-based Global Observing System

WMO Headquarters, Geneva, 21-22 June 2007

FINAL REPORT

OVERVIEW

The meeting was opened on Thursday 21 June by Dr. D. E. Hinsman, Director of the WMO Space Programme. Dr Hinsman welcomed the participants and was pleased to note the strong representation of R&D space agencies, as encouraged by CGMS. Upon proposal by NOAA, supported by CEOS, Dr Hinsman was nominated Chairman of the session.

The provisional agenda was approved as contained in Annex 1. The list of participants is enclosed as Annex 2.

Workshop participants included qualified high-level representatives of operational and R&D space agencies, CEOS constellation leads, the Chairpersons of CEOS, of the WMO Open Programme Area Group for Integrated Observing Systems (OPAG/IOS) and of its Expert Team on Evolution of the Global Observing system (ET-EGOS), and the Directors of GCOS Secretariat and of the WMO Space Programme. Such representation was felt appropriate to address the issue in a broad and constructive manner, and it was expected that the outcome of the workshop would ultimately result in recommendations to be forwarded to the appropriate levels of WMO, CGMS and CEOS.

The Chairman recalled the scope of the workshop. The Chairman of ET-EGOS then recalled the Rolling Requirements Review process, the background of the current vision for the GOS in 2015 and the current Implementation Plan for Evolution of the Surface and Space-based Subsystems of the GOS. In order to further set the scene, a presentation was then given on the main issues that had been identified through the first Optimization workshop. These issues were then reviewed in more detail through a series of thematic presentations followed by discussions. The thematic presentations addressed the observation strategy for passive radiometric temperature and humidity sounding, radio-occultation sounding, ocean surface topography, Earth radiation budget, atmospheric composition, and sea surface wind respectively. A comprehensive gap analysis was then presented, addressing the adequacy of existing or planned observation capabilities with respect to requirements, through a typology of 29 instrument categories.

The workshop then held a joint session, via videoconference, with the US National Academies' Panel on international perspective on satellites and climate, as part of a discussion on options to ensure the climate record from NPOESS and GOES-R spacecraft

The workshop then prepared its conclusions, which are reported below.

SCOPE OF THE WORKSHOP

There is an on-going recurring process of reviewing the recommendations and priorities for the implementation of the evolution of the GOS towards the agreed vision for 2015, as a result of the Rolling Requirements Review and its associated gap analysis.

In addition, the workshop recognizes the particular relevance of reviewing the vision itself, as requested by CBS, setting 2025 as a new horizon and widening the requirements basis in order to address the needs for satellite observations for climate in an integrated and synergetic way with the observations for operational meteorology. This is the main scope of the workshop.

CROSS-CUTTING REMARKS

Need for a vision

On the basis of currently approved WMO and GCOS requirements, there is a need to define an observation strategy for the various Essential Climate Variables (ECV) that are not already properly addressed by operational systems. Like for the historical operational GOS, it is felt necessary to derive a vision of the recommended high-level architecture of the global space-based infrastructure that would allow fulfilling the requirements in the most efficient way. An agreed vision provides individual space agencies with guidance allowing them to define their own missions in accordance with globally identified priorities, and serves as a basis for future multilateral discussions amongst space agencies. It helps identifying the possible role of each individual agency in the global system, reducing the gaps and maximizing efficiency.

In some application areas (e.g. ocean surface topography) such a vision is available and widely shared; in other areas the vision is still being developed or refined

The vision should describe a realistic and efficient way to meet the requirements; it must be forward looking, without limiting itself to what is immediately achievable.

The vision should seek to optimize the global effort, with the understanding that global optimization can only be achieved through timely data sharing among all contributing programmes.

Constellations

The word constellation usually designates a set of comparable spacecraft launched and operated in a coordinated way.

For the purposes of CEOS, the word Constellation has been used in a wider context: A CEOS Constellation is an organizing construct to allow planning, implementation and utilization of space based observations in the context of the Global Earth Observing System of Systems (GEOSS). A Constellation is defined by the particular part of the Earth system that it will observe. A Constellation may include a set of space and/or related ground segment capabilities from different partners that are mobilized in a coordinated way for greater efficacy.

Study teams have been established and international cooperation among space agencies has been stimulated to explore four representative Constellation prototypes including Atmospheric Composition, Global Precipitation, Land Surface Imaging and Ocean Surface Topography. Overall, the CEOS constellations are aimed at responding to the space-based observation needs in support of the societal benefit areas of GEOSS including weather and climate.

The workshop welcomed this initiative to coordinate efforts within the space community to meet the needs of essential application areas.

From R&D to operational programmes

The space-based observations of climate variables that are not covered by operational meteorological systems have been relying so far on R&D missions, since it involved the development of new sensors and since much of the activity was oriented towards scientific research on climate processes. For many years, many climate observations have thus been coincident with R&D missions. R&D space agencies have successfully provided, and continue to provide, a tremendous contribution to climate monitoring.

Nowadays, this approach raises some questions since climate monitoring has developed as a routine activity. The GCOS Climate Monitoring Principles (GCMPs) require long-term continuity of measurements, which is not the primary objective of R&D programmes.

In addition to R&D activities, which are obviously required to further progress in science and technology, there is a need to recognize climate observations as operational programmes, subject to clarification of the word “operational”.

Operational missions and long-term continuity

In the meteorological context, operational activities are understood as (quasi) real-time services provided in a continuous manner that should not suffer any interruption or delay. Every reasonable effort should be taken to avoid breaks in service. Operational meteorological satellite missions should be designed with provisions for:

- timely data availability for the WMO community
- in-orbit back-up
- re-launch policy

For climate monitoring applications, not only must every reasonable effort be taken to avoid breaks in service, but the evolution of remote-sensing capability must proceed in such a way as to assure long-term continuity of the data and instruments that are necessary for observing long-term climate change. On the other hand, the real-time aspect is less stringent. Noting the present wording of the Manual on the GOS in this respect (See Text box below) the workshop recommended that the reference to contingency arrangements be reviewed in the Manual on the GOS in order to adequately reflect the continuity constraints of climate monitoring applications.

Extract from the Manual on the GOS, Part IV, § 2.1.3:

Contingency arrangements

The satellite operators, working together under the auspices of the Coordination Group for Meteorological Satellites (CGMS) or otherwise, should ensure the continuity of operation and the data dissemination and distribution services of the satellites comprising the Baseline Space Segment.

Research and Development satellites

NOTE: Research and Development satellites provide, when possible, information for operational use. The purposes of research and development satellites are to acquire a defined set of research data, to test new instrumentation and/or to improve existing sensors and satellite systems.

Although neither long-term continuity of service nor a reliable replacement policy are assured, these satellites provide such information as…etc.

Climate and weather applications

In order to adequately address Climate monitoring and weather requirements, they should be given equally high priority in the GOS.

THEMATIC ISSUES

Passive radiometric sounding

NWP impact experiments show a dramatic degradation of the analysis with only 1 satellite equipped with IR and MW sounding instead of 2, and a significant benefit of having 3 sounding packages, with well distributed orbits. In order to achieve near-global coverage in a 6-hour cycle, it is required to have three satellites equipped with sounders, with even distribution of the orbital planes. For complete coverage in less than 6 hours, more satellites are required.

Radio-occultation sounding

Radio-occultation sounding brings an essential complement to passive radiometric sounding since it provides accurate temperature information for the high troposphere and the lower stratosphere domains, where radiometric sounding is less accurate, and useful humidity information for the lower troposphere.

Radio-occultation sounding would provide best benefit with a high number of satellites (e.g. 24). It is clearly recommended to aim at a constellation of one or several clusters of small satellites. In the case of several clusters implemented by different operators, there is scope for sharing some ground reference facilities.

An operational follow-on to the COSMIC constellation should be a first step.

Ocean altimetry

A set of space-based altimetry sensors allows observing basically 3 scales of phenomena:
- sea level rise (climate monitoring and coastal impact)
- waves (marine meteorology and storm forecasting)
- currents (mesoscale and large scale oceanic circulation, and seasonal forecast)

An optimal trade-off between precision and coverage can be achieved in a consistent way through the following architecture, which is thus recommended as a baseline:

- one high-precision reference altimeter system with orbit and coverage that avoid tidal aliasing;
- two altimetry systems flying on higher inclination orbits to maximize global coverage.

In the near future, the Jason series will provide the precision measurements, while the Sentinel-3 series (sun-synchronous around 10:00 D) and possibly the HY-2 series could offer prospects for long term coverage for the higher inclination components but these plans still need to be confirmed and would require provisions for long-term continuity. In addition, recalling the prior commitment from CNSA to contribute to the GOS through HY-1, confirmation should be sought that HY-2 data will be made available to WMO Members in a timely manner. Before such missions are implemented, essential contribution will be made by SARAL, and Cryosat-2.

Earth Radiation Budget

There is an absolute need to ensure continuity, with overlap between consecutive missions, of at least one broadband SW-LW radiometer and a Total Solar Irradiance sensor in Low Earth Orbit.

The broadband radiometer shall have capability of multi-angle viewing and shall fly on platform with advanced imagers providing information on clouds, aerosols and water vapour to help scientific interpretation of the fluxes. A CERES type sensor is suitable.

Imagers on geostationary satellites will enable to account for the diurnal cycle.

Scientific cooperation is needed to complete the vision of an appropriate architecture for this thematic mission.

Atmospheric composition

Three main categories of measurements are required:

- Ozone, including stratospheric ozone chemistry and surface UV
- Greenhouse gases and aerosols that need to be measured for climate.
- Air quality, linked with reactive gases and aerosols in the Planetary Boundary Layer (PBL), which is a growing concern for health as well.

An Atmospheric Composition constellation should focus on scientific cooperation, enhancing the utilisation of existing and planned missions, developing new standards for quality and interoperability of future missions, and proposing an overall global architecture.

The future observation architecture would enable :

- Continuous measurement of trace gases, aerosols and clouds in upper troposphere and stratosphere.

- Improved accuracy and coverage of radiatively active gases and aerosols in the boundary layer, their short and long term temporal and spatial variation

- Accurate tracking transcontinental and oceanic transport of tropospheric pollutants and their precursors.

- Contribution to global watch for volcanic eruptions, fire and aerosol monitoring for environmental forecasts and assessments.

Sea surface wind vector

While sea surface wind speed can be measured with dual polarimetric MicroWave Imagers (MWI), wind direction requires either full polarization MWI or scatterometry.

Scatterometry provides more reliable direction information at low wind speed, which is a significant advantage for oceanographic modelling. Furthermore, C-band scatterometer measurements are less prone to rain contamination. In other conditions, polarimetric MWI performs comparably. Scatterometry and MWI are two complementary techniques that can be usefully employed in parallel.

It is recommended to maintain at least two scatterometers to ensure a minimum coverage in all conditions and to employ 2 MWI with full polarization to improve the coverage towards the breakthrough requirements. In addition, other MWI with only dual polarization will contribute to – namely- wind speed measurements.

Ocean salinity, soil moisture and all-weather SST

A presentation on a Low frequency MW radiometry mission showed that the following parameters could be measured to a level that meets their breakthrough requirements by a 4-channel MW imager (in the region 1.4 to 10.8 GHz):

- Ocean salinity
- Sea Surface Temperature (SST)
- Precipitation over ocean and sea-ice
- Sea surface wind
- Soil moisture

This illustrates how, by considering parameters in (synergistic) groups, missions could cover the measurement of multiple parameters to a level that satisfies GOS requirements. Such conclusions are considered as useful inputs for space agencies in their selection of candidate new missions.

GAP ANALYSIS

The Gap Analysis presents a comprehensive comparison between current / foreseen capabilities and requirements. It makes recommendations on achieving an observation strategy but these do not directly 'map' to re-design & optimization of the space-based GOS. The workshop furthermore noted that these recommendations are based on assumptions such as launches being successfully completed on schedule and satellites achieving their nominal in-orbit lifetime. Where assumptions are already seen to be out-of-date or over-optimistic, then such comments should be added as "Qualifying remarks".

- Action: Workshop participants agreed to provide feedback to Dr B. Bizzarri.

PANEL DISCUSSION

The WMO workshop held a joint session, through videoconference, with the US National Research Council's Panel on international perspective on satellites and climate, as part of an investigation of options to ensure the climate record from NPOESS and GOES-R after re-certification of these programmes.

GCOS had clearly formulated the requirements for climate as well as a detailed Implementation Plan and its associated Satellite Supplement.

With limited financial and human resources, response to GCOS requirements can only be achieved through enhanced international cooperation, overcoming technical, financial and political challenges.

The descoping of the NPOESS mission with respect to earlier commitments has a large impact on the global community and the whole planning of climate activities needs to be reconsidered.

International cooperation for climate should involve global mission planning, with international contributions in such a way that implementation problems encountered by an individual agency do not dramatically affect the global system. Such cooperation should also imply data exchange and interoperability, including e.g. intercalibration.

Consortia shall be encouraged to develop products, as well as to use common standards and formats. Initiatives such as the Regional Specialized Satellite Centres for Climate Monitoring (RSSC-CM) and the CEOS constellations should be supported.

Among specific items addressed were:

- How do we sustain quality climate data from space;
- Mitigation options for NPOESS and what roles can complementary instruments play from other satellites;
- The importance of spectrally resolved radiances from both polar and geostationary satellites (hyperspectral VIS/NIR & IR);
- The need for organizations to work together with synergies among international satellite programmes and the importance of multilateral agreements; this in particular addressed climate;

- The importance of re-analysis;
- The need to keep valuable space assets in operation after they have passed their design lifetime, e.g. Aura and Aqua provide hyperspectral data for a variety of applications, including chemistry;
- Climate monitoring is now recognised as an objective for the WMO Global Observing system;
- There is a need for hyperspectral IR and microwave sounders in the dawn / dusk orbit;
- The Global Space-based Inter-Calibration System (GSICS) is expected to have a profound impact on the use of multiple satellite data for climate analysis;
- We must determine how to preserve the heritage of past and current instruments while we advance to future instruments for extending climate records;
- There are a number of planned missions in Europe that will be of great value for climate analysis, and the operational centres' plans to make full use of those satellites' data;
- The importance of continuity of MW SST measurements.

With regard to the future NPOESS payload, the workshop emphasized:

- The need to remanifest the hyperspectral IR and MW sounder on the early morning orbit
- The need for continuity of MW SST measurements to be addressed by the future Microwave Imager Sounder

OTHER BUSINESS

Statement by JMA

JMA informed the workshop on the status of preparation for its next generation of geostationary satellites tentatively named MTSAT Follow-On (FO). JMA is planning to procure two satellites together, to launch FO-1 in 2014 and put it into operation by the end of 2015 at 140°E. Within a couple of years after the launch of FO-1, JMA would launch FO-2 for in orbit stand-by. Each satellite will have an expected lifetime of 7 years.

VIS/IR Imagery being the primary mission of the FO, JMA is planning to have a multi-channel imager like GOES-R/ ABI or the advanced imager onboard MTG. It would include sixteen or more channels, the tentative spatial resolution being 0.5 km for visible and 2 km for near-infrared and infrared channels. The scanning rate would be less than 10 minutes for Full Disk. Rapid Scanning for specified area would be done by command, in addition to Full Disk scanning.

The workshop noted with interest the intention of JMA to explore with JAXA the feasibility of cooperation on the development of a geostationary hyperspectral sounder.

CONCLUDING REMARKS

The workshop noted that discussion had allowed significant progress towards initiating redesign of the space-based GOS while ensuring essential linkage with relevant CEOS activities.

The outcome of this workshop and the gap analysis will be reviewed by the third session of ET-EGOS and of the Expert-Team on Satellite Systems (ET-SAT), with the anticipation that, on this basis, a proposal for a new vision and corresponding Implementation Plan be developed and submitted to the 14^{th} session of the WMO Commission for Basic Systems (CBS-14). A report on these activities will be made available to the 35^{th} plenary meeting of CGMS, the 8^{th} session of the WMO Consultative Meetings on High-level Policy on Satellite Matters (CM-8) and to the CEOS Strategic Implementation Team (SIT).

Additionally, the workshop anticipated that the forthcoming reviews may lead to suggest additional consolidation activities in the coming year.

ANNEX 1

AGENDA

Session 1: Thursday, 21 June (9h00-12h40), WMO HQ, Salle B, Geneva

(9h00)	**1.**	**Introduction** *(D. Hinsman)* - Welcome and practical arrangements - Scope of the meeting
(9h10)	**2.**	**Recall of GOS Vision to 2015 and Implementation Plan for the Evolution of the Space-based sub-system of the GOS** *(J. Eyre, ET-EGOS Chairman)*
(9h30)	**3.**	**Presentation of the discussion framework** *(J.Lafeuille)*
	4.	**Thematic presentations** (15 mn each + 10 mn for discussion)
(9h50)	**4.1**	**Impact of ATOVS observations from multiple satellites** *(J. Eyre)*
(10h15)	**4.2**	**Observation strategy for radio-occultation sounding** *(B.Bizzarri)*
(10h40)		*Coffee break*
(11h00)	**4.3**	**Observation strategy for ocean surface topography and sea state** *(S. Wilson)*
(11h25)	**4.4**	**Observation strategy for the Earth Radiation Budget** *(B. Bizzarri)*
(11h50)	**4.5**	**Observation strategy for atmospheric chemistry** *(E. Hilsenrath)*
(12h15)	**4.6**	**Strategy for sea surface wind observation by scatterometer and MW imager** *(B. Bizzarri)*
12h40		*Lunch Break*
13h40		*Transfer to UNOG for the afternoon session*

Session 2: Thursday 21 June, 14h00-14h55, UNOG, Room A206

(14h00)	**5.**	**Gap analysis** *(B. Bizzarri)*
(14h40)	**6.**	**Initial discussion on observation strategies and gap analysis**

Session 3: Thursday 21 June, 15h00-18h00, Geneva time (UTC+2)
Joint session with the US National Academies' Panel on Satellites and Climate
through video-conference between UNOG, Geneva and Washington, D.C:

	7.	**Options to ensure the climate record from NPOESS and GOES-R spacecraft : Panel session on international perspective**
(15h00)	**7.1**	**Introduction to the Panel** *(J. Purdom)*
(15h05)	**7.2**	**Context of the NRC Panel and the "Decadal Survey"** *(A. Busalacchi)*
(15h35)	**7.3**	**CEOS Strategy on climate observations from space** *(B. Ryan)*
(16h00)	**7.4**	**WMO Optimization of the Global Observing System** *(D. Hinsman)*
(16h25)	**7.5**	**Satellites and climate modeling** *(T. Hollingsworth)*
(16h40)	**7.6**	**Closing remarks on the presentations** *(J. Purdom)*
(16h45)		*Coffee break*
(17h00)	**7.7**	**Panel questions and discussions**
(17h55)	**7.8**	**Closing remarks of the joint session**

Session 4: Friday, 22 June (9h00-16h00), WMO HQ, Salle B

(9h00)	**8.**	**Consolidation of recommended observation strategies taking into account the outcome of Sessions 1, 2 and 3 :** **- Impact on GOS configuration** **- proposed update to GOS description** **- Identification of open issues**
(10h30)		*Coffee break*
(11h00)	**8.**	**(continued)**
(11h30)	**9.**	**Cross-cutting aspects and related recommendations**
(12h00)		*Lunch Break*
(13h30)	**10.**	**Consolidation of gap/adequacy analysis and specific recommendations to agencies**
(15h30)	**11.**	**Conclusions of the workshop and way forward**
(16h00)		*Adjourn*

Annex 2

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