CGMS

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DRAFT VISION FOR THE GOS TO 2025 AND OUTCOME OF THE OPT-2 WORKSHOP

In response to CGMS Actions 34.04, 34.07 and 34.08
and CGMS Recommendation 34.22

Following CGMS-34 discussions on the optimization of the space-based GOS and on the response to GCOS requirements, the WMO Commission for Basic Systems (CBS) discussed these issues and agreed to initiate a re-design of the space-based GOS, which triggered an important sequence of actions.

The Workshop on the Re-design and Optimization of the Space-based Global Observing System (OPT-2) was convened in June 2007 and reviewed the critical issues identified at the first optimization workshop held in 2006, in the light of a detailed gap analysis. Its final Report (Annex 1) addresses the strategy to ensure continuity of essential climate observation variables.

The outcome of the OPT-2 workshop was the basis for developing a draft vision for the GOS to 2025, by the relevant OPAG-IOS Expert Teams. The draft vision calls upon optimizing the existing operational GEO and LEO components, consolidating the altimetry measurement strategy, enhancing atmospheric sounding with an operational Radio Occultation constellation, refining sea surface wind observation, and bringing several new missions to an operational status: global precipitation, Earth Radiation Budget, atmospheric composition, specific imagery for ocean colour and vegetation and possibly missions in Molniya orbits.

Implementing such a new vision would require enhanced cooperation and coordination among operational and R&D agencies in order to optimize the effort, and to ensure timely availability and consistent quality of data worldwide. This new vision, which contributes to the integration of the WMO global observing systems, would further reinforce the importance of the space-based GOS as a major component of the GEOSS.

CGMS satellite operators are invited to comment on this development, to support its refinement until CBS 2008 and to plan to contribute to its implementation in the coming decade.

DRAFT VISION FOR THE GOS TO 2025
AND OUTCOME OF THE OPT-2 WORKSHOP

1 BACKGROUND

1.1 CGMS and CBS conclusions

When reviewing the outcome of the first WMO-CGMS workshop on optimization of the space-based GOS and the related recommendations of the Expert Team on Satellite Systems (ET-SAT), CGMS-XXXIV agreed on Action 34.04 which requested "*WMO to organize a second workshop on optimization of GEO and LEO satellite plans in order to monitor progress on implementing the recommendations of the first workshop and extend considerations to detailed instrument capability, taking into account the possibility to fulfil some missions through a suite of instruments and several platforms.*" The Action furthermore recommended to *"involve R&D agencies in addition to operationally-oriented ones".*

At the same meeting, CGMS reviewed a draft response prepared by WMO to GCOS requirements and considered that it would constitute the preliminary CGMS response to GCOS, while agreeing on Action 34.07 which invited "*WMO, with the support of ET-SAT, to refine the response to GCOS requirements on the basis of [CGMS-XXXIV] WMO-WP-37"* and Action 34.08, which requested *"WMO to coordinate with CEOS to ensure that CGMS and CEOS provide consistent responses to GCOS requirements and complement each other's efforts."*

The conclusions of ET-SAT and CGMS discussions were brought to the attention of the Commission for Basic Systems (CBS) at its extraordinary session in November 2006 (CBS.Ext 06) and CBS subsequently agreed on the following request that triggered an important sequence of actions: CBS requested "*OPAG-IOS to commence an update of the baseline of the space-based GOS up to 2025 as a new horizon, and expand its scope beyond the World Weather Watch in order to include sustained observations of additional variables required for climate monitoring, and ultimately to address the needs of other WMO Programmes.*"

1.2 Actions taken

- The capabilities of current and planned instruments were analyzed, with their planned availability, and compared to World Weather Watch and GCOS requirements. This resulted in the gap analysis presented to CGMS-XXXV as WMO-WP-05.
- The main issues resulting from the first optimization workshop were reviewed and possible responses were identified as a basis for discussion for a second workshop (Discussion framework document).
- The workshop was convened on 21 and 22 June with participants from operational and R&D space agencies: CMA, CNSA, ESA, EUMETSAT, JAXA, JMA, NASA, NOAA, USGS, as well as representatives of GCOS, of the Committee on Earth Observation (CEOS), the Chairman of OPAG-

IOS, the Chairman of ET-EGOS, and the WMO Space Programme. The workshop report is contained in Annex 1.

- CEOS provided an important contribution to the workshop, namely in two application areas (ocean surface topography and atmospheric composition), by the relevant CEOS Constellation leads.
- Based on the outcome of the workshop, in July 2007, the Expert Team on Evolution of the GOS (ET-EGOS) initiated drafting a new "Vision for the GOS to 2025". This preliminary draft vision is contained in Annex 2.
- In September 2007, the Expert Team on Satellite Systems (ET-SAT) reviewed the space-based part of this vision. It expressed the need for OSSEs to quantify some proposals and stressed that one should highlight the benefit of the proposed enhancements of the space-based GOS for WMO and co-sponsored programmes in order to strengthen the case. A draft table resulting from ET-SAT is contained in Annex 3.

2 HIGHLIGHTS OF THE OPT-2 WORKSHOP CONCLUSIONS

The workshop has emphasized the importance of developing a new vision of the GOS where observation of Essential Climate Variables (ECV) would be ensured through operational missions or otherwise long-term sustained missions rather than relying only on R&D missions with no plan for continuity.

The workshop recommended in particular including the following changes into the space-based GOS baseline to include:

- Core operational infrared and microwave sounding on at least three well separated sun-synchronous orbital planes (mid-morning, early afternoon and early morning);
- Constellation of small satellites for radio-occultation sounding;
- Ocean altimetry constellation including at least one high-precision reference altimeter mission and two additional altimetry systems flying on higher inclination orbits;
- Absolute continuity for at least one broadband Short-wave/Long-wave radiometer for Earth radiation monitoring and one Total Solar Irradiance sensor in Low Earth Orbit (LEO) with complementary measurements in geostationary and LEO orbits;
- At least two scatterometers and two full polarization microwave imagers for sea surface wind;
- Further refinement of an observation strategy for atmospheric composition.

The workshop also considered a number of other missions addressed in the gap analysis (See WMO-WP-05), including e.g. global precipitation measurement.

It recalled that global optimization of satellite mission planning could only be efficiently achieved if satellite operators could ensure data quality and timely availability. In this respect the workshop recommended to seek confirmation from CNSA of the availability of HY-2 data for the GOS.

3 NEW VISION OF THE GOS TO 2025

This section summarizes the changes contained in the draft vision, resulting from ET-EGOS and ET-SAT discussions, compared with the current "Vision to 2015".

3.1 Optimizing the geostationary constellation

The geostationary component of the space-based GOS should be enhanced through systematically including IR hyperspectral sounding in the baseline payload.

Geostationary coverage of the globe should be optimized in ensuring no more than 60° longitude separation between consecutive locations of geostationary satellites equipped with the baseline VIS-IR imagery and hyperspectral sounding package.

3.2 Optimizing the core LEO sun-synchronous constellation

Instead of recommending four operational LEO sun-synchronous satellites optimally spaced in time, two in a.m. and two in p.m., it is recommended that the core VIS-IR-MW imagery and IR-MW sounding mission in sun-synchronous orbits be deployed over three orbital planes around 13:30, 17:30 and 21:30 Equatorial Crossing Time (ECT). This should ensure regular sampling of the atmosphere avoiding too large a temporal gap around dawn and dusk, as required by NWP and GCOS.

Redundancy should be available around these orbital planes, to the extent possible.

IR Hyperspectral sounding should be systematically included in the baseline payload.

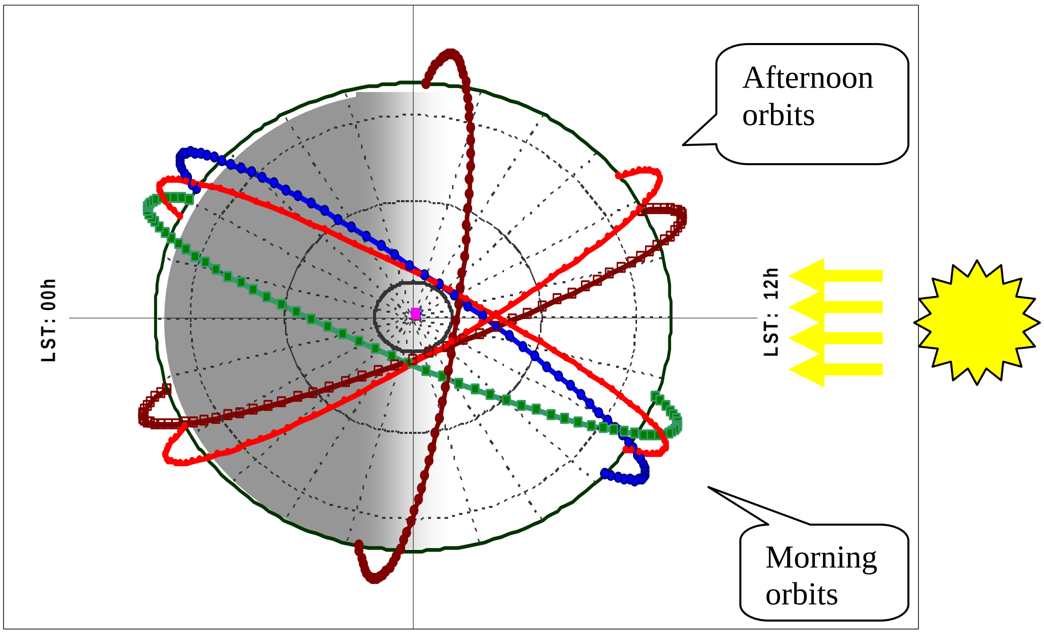

Figure 1: Example of 3-orbit configuration with redundancy for IR/MW sounding and core imagery missions (Northern hemisphere view)

Radio-occultation sounding (ROS) should not necessarily be included in this core sun-synchronous constellation, since a dedicated constellation on a diversity of orbital configuration can be envisaged for the ROS mission (See below).

3.3 Reviewing the ocean altimetry observation strategy

While the current Vision to 2015 includes provisions for altimeters on two LEO satellites without particular considerations to the orbital and payload configuration, the community is now in a position to specify its need more precisely, as promoted by the CEOS Ocean Surface Topography Constellation, i.e. an observation strategy relying on two components:

- At least one high-precision reference altimeter mission with orbit and coverage ensuring that data are free of tidal aliasing (e.g. Jason-type non-sun synchronous inclined orbit)
- At least two additional altimetry systems flying on higher inclination orbits to maximize global coverage (e.g. ENVISAT/RA or Sentinel-3).

3.4 Implementing a Radio-Occultation Sounding constellation

The potential of ROS has now been demonstrated as a complement to passive IR/MW radiometric sounding, which is necessary in particular to enhance the performance in the stratosphere. A high number of instruments is required to achieve the required coverage and temporal sampling; an order of magnitude of 12 or 24 satellites has been suggested on the basis of preliminary considerations, but this needs to be refined through OSSEs.

It is considered that the required configuration would best be implemented through a constellation based on several clusters of similar or comparable instruments deployed across different inclined orbits. The modular aspect of such a constellation and the possibility to share the use of ground support equipment (time references) provide scope for international cooperation to share the effort of implementing and operating this constellation.

3.5 Refining the Ocean Surface Wind observation strategy

Experience gained on Ocean Surface Wind observations provides now some ground to recommend an observation strategy based on two components:

- Two scatterometers on well separated orbits ensuring the provision of wind vectors (speed and direction) over the global ocean with typically a six-hour refresh cycle;
- Two conical scanning microwave imagers with full polarization ensuring a wider coverage of the globe, although bearing in mind that microwave imagery cannot provide reliable direction information for low winds.

Additional microwave imagers with only two-channel polarization, which would be implemented to address other observation needs such as precipitation, or sea surface temperature, would not provide wind direction information but would provide useful wind speed information to be assimilated in addition to the two components mentioned above.

3.6 Additional missions to observe Essential Climate Variables

Additional missions shall be considered on an operational basis in order to provide long-term continuity of observations for Essential Climate Variables (ECV) that were not initially identified as operational requirements for the GOS. In some cases these observations are relying on sensors that are fully “operational” from a technology point of view; however such observations were not listed as operational requirements so far. This includes the following observation missions:

(i) Global Precipitation Measurement (GPM). The GPM concept, based on a core spacecraft with dual frequency radar on a 65 degree inclination orbit combined with a wide constellation of microwave imaging sensors on several higher inclination orbits, should become an integral part of the GOS design;

(ii) Earth Radiation Budget (ERB). ERB should be measured through a constellation of sensors including at least one broad-band multi-angle viewing radiometer in LEO and a Total Irradiance Sensor, together with auxiliary measurements in LEO to facilitate contextual interpretation of the measurements, and some geostationary sensors allowing accounting for the diurnal cycle. It is recommended to further refine the observation strategy with the ERB community in order to provide more precise guidance on the required capabilities;

(iii) Atmospheric composition. While the need to include appropriate payload for measuring atmospheric composition is clearly acknowledged, namely for stratospheric ozone, other greenhouse gases and aerosol monitoring (profile and total column), and for air quality in the low troposphere, further analysis is needed to define a recommended observation strategy that could be used as a guidance for future plans;

(iv) Specific imagery missions are also needed on an operational basis. Narrow-band sensors are necessary for ocean colour and vegetation monitoring (Leaf Area Index and fraction of Absorbed Photosynthetically Active Radiation). High-resolution VIS/IR imagers are also necessary e.g. for land use monitoring and support to disaster reduction. Synthetic Aperture Radar (SAR) provides unique information in support of some disaster reduction activities, ice shelf and iceberg detection.

(v) Satellites in Highly Elliptical Orbits would complement the GOS for quasi permanent coverage of the high latitudes including the polar ice shelf, subject to successful demonstration (See IGeolab HEO in WMO-WP-03).

3.7 Cross-cutting aspects

Implementing such a new vision with its multiple and diverse components would enhance the observing capability to its required level, but it would inevitably require more investments and operating resources. This can only be achieved through increased cooperation among operational and R&D agencies, taking advantage of the growing community of space-faring nations that are able to contribute to the space-based GOS. Partnerships should also be encouraged among agencies for extending the operation of functional R&D and other satellites beyond their nominal lifetime to the maximum useful period.

Cooperation should aim at optimizing the effort, through global planning facilitating the definition of individual agencies' plans. It should ensure timely availability of data worldwide, and consistent data quality and comparability through harmonized calibration and cross-calibration practices.

An important feature of the proposed vision is that a number of missions that have been provided for a long time in the framework of R&D missions would in the future be performed on an operational basis. This transition from R&D missions to operations includes two aspects. On one hand a technological aspect, since the relevant instruments must reach the proper technology readiness level in order to be able to support operational missions. On the other hand, the transition has a strategic dimension which is linked with the change of purpose and its consequences on the need for long-term commitment and compliance with different user requirements. This change of status has a number of pre-requisites, such as the identification of a user community with clear requirements, the demonstration of an expected benefit that provides rationale for long-term funding, the availability of implementing agencies or consortium of agencies, with adequate expertise, mandate, funding and user relationship.

4 CONCLUSIONS

The vision for the space-based GOS to 2025 that is being developed will contribute to the integration of the WMO Global Observing System and would further reinforce the importance of the space-based GOS as a major component of the GEOSS.

CGMS satellite operators are invited:

- To comment on this development,
- To support activities towards finalizing the vision for submission to the CBS in November 2008, and
- To plan to contribute to its implementation in the coming decade.

CGMS should also note the request from the workshop to confirm the availability of data from satellite missions contributing to the GOS.

ANNEX 1

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 recognised 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 recognized 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 14th session of the WMO Commission for Basic Systems (CBS-14). A report on these activities will be made available to the 35th plenary meeting of CGMS, the 8th 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 2

VISION FOR THE GOS IN 2025

Initial draft proposal from ET-EGOS-3

(July 2007)

Role of the GOS

In 2025, the GOS will continue to provide effective global collaboration in the collection and exchange of observations to meet the needs of Members. It will continue to be implemented through a composite and increasingly complementary system of observing systems.

1. In terms of broad general trends:

- The WWW/GOS is expected to evolve to a WIGOS that will integrate its current functionalities together with other observing systems which are not dedicated to the weather forecasting (climate monitoring, oceanography, chemistry, hydrology, weather and climate research). Provision shall be made for continuity of observations of all operational weather variables and Essential Climate Variables, adhering to GCOS climate monitoring principles.
- This implies that more meteorological observing platforms will be shared by instruments for different applications, then more meteorological observations will be performed on “platforms of opportunities”, or using some infrastructures which have been set up for non-meteorological purposes (like GPS surface stations, or the possibility to measure the rainfall rate from the attenuation of the mobile phone radio electric signals).
- The trend to develop fully automatic observing systems will be confirmed (for example likely to affect the radiosondes as well).
- Some level of targeted observations should be achieved in 2025, but there is still a lot of uncertainty on what level can be achieved. Targeting will not be just “putting more observations in sensitive areas or around special weather events”: it will involve a close interaction between “observation performing” and “assimilation” (for example an adaptative data selection scheme taking into account the local meteorological situation and all the available satellite data, before deciding what to use in the assimilation process). It may also involve an earlier selection during the data collection process.
- In 2025, a much larger amount of surface observations is expected to be exchanged globally (such as radar or GPS surface network data).
- An improved calibration ensuring data consistency and reference to absolute standards is expected.
- Sustainability of essential components of the GOS will be secured with many of the R&D systems integrated as operational systems

2. In terms of space-based observing systems:

At least 6 operational geostationary satellites:
- With no more than 60° longitude difference between neighbouring locations
- All with IR/VIS multi-spectral imager
- All with IR hyper-spectral sounder

Operational polar-orbiting sun-synchronous satellites on 3 orbital planes (around 13:30, 17:30, 21:30 ECT) with redundancy

- All with IR/VIS multi-spectral imager
- All with MW sounder
- All with IR hyper-spectral sounder

Other satellites on appropriate orbits (not excluding the geostationary and polar orbits above) contributing to operational observations for weather and climate on a long-term basis:

- Two sun-synchronous satellites with scatterometer
- Two sun-synchronous satellites with conical scanning full polarimetric MW imager
- At least two sun-synchronous satellites with narrow-band VIS/NIR imagers for ocean colour and vegetation
- Constellation of high-resolution VIS/IR imagers for Land Surface Imaging
- Constellation of clusters of small satellites for radio occultation (RO)
- A constellation for altimetry including two altimeters on sun-synchronous orbits and a high-precision reference altimeter system avoiding tidal aliasing
- Constellation of LEO satellites for precipitation measurements through combined use of active instrument in a low inclination orbit and passive microwave instruments on several high-inclination orbit
- Constellation of sensors for Earth Radiation Budget including at least one broad-band multi-angle viewing radiometer in LEO and a Total Irradiance sensor, together with auxiliary LEO measurements and geostationary sensors (TBD)
- A constellation of instruments/missions to address atmospheric compositions
- Optionally geostationary lightning detection
- Optionally satellites in Highly Elliptical Orbit (HEO) ensuring Polar Regions coverage

Several R&D satellites and operational pathfinders including

- LEO with wind Doppler lidar
- GEO microwave
- LEO Low-frequency microwave radiometer addressing salinity and soil moisture

Improved availability and timeliness through operational cooperation among agencies.

3. In terms of surface-based observing systems:

- **Radiosondes**: Optimized utilization, especially in terms of horizontal coverage, which will decrease in data dense areas; supplemented by AMDAR ascent/descents for most of the airports worldwide; supplemented also by profilers for some atmospheric layers. Radiosonde data disseminated at higher vertical resolution than now.
- **GUAN**: A subset of radiosonde stations to be maintained for climate monitoring. A GCOS Reference Upper Air Network (GRUAN) to serve as a reference network for other radiosonde sites, calibration and validation of satellite records and other applications.
- **Aircraft data**: Aircraft instruments able to observe humidity in addition to temperature and wind; available from most airports worldwide and able to replace radiosondes near most of these airports. Data available also on small aircrafts flying on short distances. Could be supplemented by UAVs, but not on a regular basis (maybe to help targeting strategies).
- **Surface observations**: Larger variety of surface networks (e.g.: road network); multi-applications networks; higher level of reliability and availability.
- **GSN**: A subset of surface stations to be maintained for climate monitoring.
- **Radar**: Observing systems will produce the same products as now but with increased data coverage; used by more applications (even global NWP may assimilate radar data with some benefits).

- **Profilers** will be developed and used by more and more applications; a large variety of techniques to be used (lidars, radars, microwave instruments…); these observing techniques to be developed into a consistent network of remote-sensing observations, integrated with other surface networks.
- **GPS** receiver networks will be developed, and locally used (by tomography techniques) to measure also the vertical structure of the humidity field (complementing then radiosondes and aircraft).
- **Long range lightning detection systems** will provide cost-effective, homogenized, global data with a location accuracy of about 2 km, significantly improving coverage in data sparse regions including oceanic and polar areas.
- **Marine observations**: Sustained systems providing high temporal and vertical (sub-surface) resolution data using two-way high data rate satellite data telecommunication systems to collect the in situ observational data; cost-effective multi-purpose in situ observing platforms; new observing technology (e.g. ocean gliders)
- **Atmospheric composition**: Surface-based observations of atmospheric composition (including balloon-borne and aircraft measurements) will be provided by an integrated three-dimensional global atmospheric chemistry measurement network, with a complementary satellite component. New measurement strategies will be combined to provide near real time data delivery.
- **Hydrology**: The surface based observations of hydrological parameters at the global level are expected to diminish, however the exchange of data within the river basins would substantially increase.

ANNEX 3

DRAFT VISION TO 2025 AS REVISED BY ET-SAT/SUP-3

Observing capability	Expected outcome	WMO programmes
At least 6 operational geostationary satellites		
• With no more than 60° longitude difference between neighbouring locations	Optimize viewing angle with near-global coverage	WWW DRR WCP GCOS, WCRP
• All with IR/VIS multi-spectral imager	Weather and hazard monitoring (incl fires), SST, radiative fluxes	
• All with IR hyper-spectral sounder	Mesoscale permanent sounding, advanced AMV,contribution to chemistry	
Some with lightning detection	Severe warning lead time,	AMP/AEM, DRR, WWW
Operational polar-orbiting sun-synchronous satellites on 3 orbital planes (around 13:30, 17:30, 21:30 ECT with redundancy)		
• All with IR/VIS multi-spectral imager	Land and atmosphere and ocean observation (SST) demonstrated by MODIS, MERIS…	All major WMO programmes
• All with MW sounder	Temporal sampling of T,Q profiles for NWP and GCOS (average 4 hours	
• All with IR hyper-spectral sounder		
• Two with UV radiometer	O3	WWW, GCOS
Other satellites on appropriate orbits (not excluding the geostationary and polar orbits above) contributing to operational observations for weather & climate on a long-term basis		
• Two sun-synchronous satellites with scatterometer	At least 12-hourly ocean surface wind vector coverage (depending on swath and latitude) and soil moisture , ice type ??	WWW, GCOS, JCOMM
• Two sun-synchronous satellites with conical scanning full polarimetric MW imager	Complement surface wind coverage (+ benefit to many other parameters e.g. Sea ice, SST, precipitation)	WWW, JCOMM, GCOS
• At least two sun-synchronous satellites with narrow-band VIS/NIR imagers for ocean colour and vegetation	ocean colour and vegetation (fAPAR, LAI), surface albedo,burn scars, clouds and aerosols	JCOMM, GCOS, DRR, AREP, WCRP
• Constellation of high-resolution VIS/IR imagers for Land Surface Imaging	Land use, vegetation status (Landsat and SPOT type applications)	AMP/AgM, DRR, GCOS, HWRP
• Constellation of clusters of small satellites for radio occultation (RO)	T and moisture sounding in LS, space weather	WWW and GCOS
• A constellation for altimetry including two altimeters on sun-synchronous orbits and a high-precision reference altimeter system avoiding tidal aliasing	Sea level, sea state, ocean currents, ice shelf	WWW, JCOMM, GCOS

• Constellation of LEO satellites for precipitation measurements through combined use of active instrument in a low inclination orbit and passive microwave instruments on several high-inclination orbit	Temporal precipitation	GCOS, WWW, HWRP, DRR, WCRP
• Constellation of sensors for Earth Radiation Budget including at least one broad-band multi-angle viewing radiometer in LEO and a Total Irradiance sensor, together with auxiliary LEO measurements and geostationary sensors (TBD)	Earth Radiation Budget	GCOS, WCRP, WWW(SIA)
• Satellites in Highly Elliptical Orbit (HEO) ensuring Polar Regions coverage.	Polar AMV and cloud monitoring at high latitudes, sea ice (missions and justification vs polar satellites to be explained)	WWW, ??
• A constellation of instruments/ missions to address atmospheric compositions (TBD)	O3 and GHG profiles, aerosols, cloud properties	*GCOS, AREP, WWW*
SAR (interferometric ?)	oil spills, floods, other hazards, earthquake and faults monitoring, sea ice leads, damage assessment, sea state, ice shelf and icebergs	WWW and DRR, JCOMM
One imager for special viewing (AATSR like)	High resolution SST, cloud properties, albedo	GCOS
Several R&D satellites and operational pathfinders including:		
• LEO with wind Doppler lidar (if not operational ?)	Wind & aerosols profiles	WWW, GCOS AMP/AeM,
• GEO microwave sub-mm	Precipitation high temporal sampling, cloud properties	WWW
• LEO Low-frequency microwave radiometer addressing salinity and soil moisture (if not operational ?)	salinity and soil moisture	
Cross-cutting aspects		
Improved availability and timeliness through operational cooperation among agencies.		
Expanded community of agencies contributing to the GOS		
Partnerships among agencies for extending the operation of functional R&D and other satellites to the maximum useful period		