WCRP Space mission Requirements

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1- Background and Study Objectives

In 2002, WCRP initiated a study to update the space mission requirements for climate research, with respect both to satellite missions themselves and to the use of Earth Observation data from them. A workshop organised by WCRP took place in November 2002 and this initiative was briefly reported at the CEOS 2002 Plenary in Frascati, Italy. A report (ref. WCRP Informal Report N° 8/2003) was presented in February 2003 at the third meeting of the Consultative Group on High Level Policy on Satellite Matters (CM-3) held in Geneva between WMO and Heads of Space Agencies. Conclusions and recommendations on priorities for space missions, on data management issues and interactions between space agencies and WCRP were endorsed by the WCRP Joint Scientific Committee (JSC) in Reading in March 2003. Further work was requested including, in particular, the definition of a strategy for the development of quality climate products.
The WCRP initiative was further encouraged by CEOS Chair and pursued with the support of an informal working group (see Annex) composed of representatives of the main space agencies and the various WCRP core projects, and other interested scientists which met on 20-22 October 2003 in Geneva.
The present report summarises the main results from this on-going reflection including the comments made at the 17th CEOS Plenary held on 20-22 November 2003 in Colorado Springs.

2- WCRP Space Strategy Objectives

For climate research, the value of space missions comes mostly from the capability to produce globally integrated, high quality and reliable data products requiring the merged analysis of measurements from the whole constellation of operational and research / demonstration Earth observation satellites complemented by data from in situ observing networks. To this end, as an overall priority, the Working Group re-affirmed that the WCRP "Space strategy" should be established along the main following lines:

- To ensure that operational agencies maintain the continuity of existing operational space systems and upgrade operational sensors as appropriate to achieve better performance and meet WCRP requirements for long term, consistent and well-calibrated data sets.
- To encourage space agencies to develop new research / precursor sensors providing better quality space measurements (in terms of accuracy, resolution, coverage…) for those measurements already existing but requiring major improvements to meet WCRP specifications and/or to explore new techniques / technologies for measurements not yet derived from space but in great demand by WCRP scientists.

- To support the progressive transfer of appropriate research / precursor sensors to operational platforms when they have been adequately validated. WCRP encourages space agencies to consider means or mechanisms to ensure long-term continuation, without gaps and preferably with some overlapping of these measurements whenever needed.
- To ensure that adequate / major efforts and resources are devoted to the integration of satellite data into global, quality climate products required by WCRP projects.

The Working Group strongly supports the "GCOS Climate Monitoring Principles" related to satellite systems, in particular:

- *The importance of precise satellite-to-satellite cross-calibration of sensor and validation of products*
- *The need for in-orbit sensor redundancy (highly important for some measurements)*
- *The need for a sound mission and / or sensor replacement strategy to generate long time series measurements required for change detection and assessment of trends.*

3- Space Mission Requirements

3.1 Continuity of existing operational missions

(i) Meteorological missions

Operational GEO (Geostationary Earth Orbit) and LEO (Low Earth Orbit) satellites have to be part of a coherent observing system and should provide *compatible* observations. As a first step, space agencies should ensure the use of common channels for some families of sensors (imagers, sounders) embarked on-board the various satellites; This would greatly ease the data analysis, sensor cross-calibration and product validation activities essential for climate research and would also be of benefit to NWP activities.
Continuity is an essential requirement for climate study as well as for climate and weather forecasting: the Group stressed the need for robust contingency plans, in particular for the GEO constellation.
The Group identified the need for coordinated definition of future GEO missions and, in particular for innovative instrumentation such as microwave instrumentation for precipitation measurement and sensors for atmospheric composition and chemistry.

(ii) High resolution optical missions

The Group noted that, *to-day*, there is no continuity ensured for the high resolution, large coverage, multi-spectral optical Landsat / SPOT classes of missions, widely used for local and regional applications and recommended that new missions be rapidly initiated to provide service continuity. Information from these platforms / sensors is needed for the characterisation / feature discrimination and operational monitoring of land, coastal zones and ice surfaces. This situation is even more critical with the loss of Landsat-7 in 2003 and that no follow on of SPOT-5 has been announced or is planned.

3.2 Continuity of existing research missions

TRMM: *The Working Group expressed its deep concern at news that NASA might consider it necessary on safety grounds to terminate the TRMM operations in Spring 2004*. It recommended that TRMM operations be continued for as long as possible in order to collect the longest possible and unique precipitation data set over the tropical regions for climate study (and also in preparation

for later GPM / Megha Tropiques missions). The Group also felt that the benefit for society, including saving of life and property by improved forecasts of extreme meteorological events that could result from continued operation of TRMM, should be put in balance with the risk to life and property related to an uncontrolled re-entry.

Radar altimetry: Polar orbiting altimeters, after ENVISAT, are required to complement Jason-1 and 2 missions deployed in inclined orbits, to provide polar coverage and assure proper mapping of the meso-scale oceanic circulation. Re-processing of all altimeter data sets should be performed with the improved gravity field information as derived from GRACE and later from GOCE.

Ocean colour/Sea surface temperature/Ocean surface winds/Sea-Ice: Daily global coverage must be provided for these four classes of parameters, implying that, at least, *two* sensors are simultaneously operational in orbit. Specific additional requirements have been identified by the Working Group for the associated spaceborne sensors in terms of performance (e.g. high spectral sensitivity / spatial resolution / measurement accuracy / wide geographical coverage…).
This in-orbit redundancy requirement is important as illustrated by the recent failure of ADEOS-2 which makes difficult the adequate provision of ocean surface winds. Scientific and operational users have to rely now only on the aging NASA QuickSCAT mission until METOP–1 with ASCAT on-board is launched in the 2005/2006 timeframe. With the associated loss of GLI (Global Land Imager), POLDER (POLarisation and Directionality of the Earth's Reflectances) and AMSR (Advanced Microwave Scanning Radiometer) on ADEOS-2, this further reduces the number of operational ocean colour sensors and advanced passive microwave radiometers simultaneously in-orbit for multiple scientific and operational applications.

Radiative measurements: continuity and in-orbit redundancy of total solar irradiance measurements are essential and should be ensured until the NPOESS timeframe. Similarly, continuity of existing sensors for the earth radiation budget (CERES, ScaRaB) should be guaranteed until the NPOESS timeframe.

Atmospheric chemistry: preparation of follow on sensors to current ones flown on ENVISAT and the EOS satellites should start *now*, given the time delay (5-7 years) required for the development of new space instrumentation.

Ice sheets: a follow on to the ICESat mission for the determination of decadal variation of ice thickness should be considered in view of the possible reduced lifetime of the ICESat, in particular to allow for overlapping measurements of ice sheets and sea-ice with ESA CryoSat to be launched in 2004/5.

3.3 Continuity of firmly planned missions

Numerous missions are currently under development with firm launch date targets. Most of them are research demonstration (i.e. for qualification of advanced technologies, validation of new measurement techniques, improvement of measurement accuracies…) with a 2-3 year design lifetime (although with often a 5-year goal). This nominal lifetime may not be sufficient, in a number of cases, for comprehensive validation/impact studies using data assimilation in operational forecasting models and certainly not for climate change detection requiring long term monitoring.

The Working Group recommended that space agencies put in place a specific programme with appropriate resources/funding to allow, whenever justified:

- *Extension of useful lifetime (if technically feasible), or*
- *Launch of replicate mission(s) or sensor(s) at appropriate time intervals, or*
- *Transition to operational missions*

The Working Group identified the following priority missions for consideration :

- *ADM-Aeolus* which will provide for a nominal period of 3 years, and for the first time, consistent global wind profiles of primary importance for climate models, process studies and NWP.
- *Cryosat* which is expected to complement ICESat. Both missions are planned for a 3-year lifetime and should be operated in conjunction to provide combined sets of measurements over ice sheets.
- *Aura chemistry and Aqua Formation (Aqua, Cloudsat, CALIPSO, PARASOL)* missions for the study of atmospheric chemistry processes, water cycle and cloud radiative processes.
- *Soil Moisture and Ocean Salinity (SMOS) mission*, an ESA Earth Explorer mission recently approved in cooperation with France and Spain. The Group once again emphasised the need to fully validate the measurement technique (in particular as regard the horizontal resolution and achievable accuracy). The approval of SMOS will allow cross comparison of results with the previously approved NASA Aquarius mission.

The Group noted with great satisfaction that the NASA ESSP candidate HYDROS mission, in cooperation with Canada, had very recently been approved. It will increase the frequency of observations provided by SMOS/Aquarius and allow for cross-comparison of results. Improving assimilated soil moisture data will provide better initial conditions for seasonal forecasting.

3.4 Approval for missions under consideration

The Group re-affirmed its support for missions to *study the water cycle and cloud radiative processes*, namely, the international Global Precipitation Measurement (GPM) mission, including the EGPM component and the Megha-Tropiques mission, a co-operation between ISRO and CNES. The Working Group noted with satisfaction the encouraging progress achieved on GPM but expressed its deep concern about the alarming situation of Megha-Tropiques. This mission, in a low inclination orbit, would allow study of the atmospheric water cycle and energy budget in tropical regions and, in particular, monitoring of the diurnal variations of convective systems in these regions, therefore complementing the GPM sun-synchronous constellation.
The Working Group urged space agencies to explore possible options for the timely implementation of Megha-Tropiques in conjunction with GPM. The Group also considered that there is a need to reinforce the plans for the measurement of minor atmospheric constituents, particularly those entering the cycles of greenhouse gases, and to take advantage of promising novel techniques. In this instance, it strongly supported the JAXA GOSAT (Greenhouse Gas Observation SATellite) candidate mission for measurement of greenhouse gases distribution. These requirements, which are common with IGBP, are in fact very well expressed by the IGOS theme on atmospheric chemistry (IGACO).

The Group was pleased to note that ISRO has started preliminary discussions about a CLIMATSAT mission for the study of Tropical Atmospheric Composition and Indian Ocean Monsoon. ISRO was encouraged to pursue the definition of CLIMATSAT and report on progress to the Group.

3.5 Need for new research missions/measurements

The Working Group confirmed and expanded the recommendations made at the First WCRP Workshop, namely:

- Improved characterisation of polar stratospheric clouds and aerosols (use of high frequency MW Radiometers for studies of clouds was recommended)
- Higher accuracy and resolution measurements in the Upper Troposphere/Lower Stratosphere considering new active techniques (radio occultation and lidar)
- Improved characterisation of troposphere composition considering both GEO and LEO capabilities
- Higher resolution gravity field building upon current GRACE and forthcoming GOCE missions
- Snow cover water equivalent and snow cover wetness for which there is a NASA ESSP Cold Land Processes Pathfinder (CLPP) mission proposal under definition using active and passive microwave techniques.
- High resolution, all-weather surface temperature from passive microwave radiometers having resolutions similar to those of infrared sensors.

The Group referred to the Calls for Ideas and Mission Concepts regularly issued by space agencies and recommended that some coordination between space agencies be exercised (joint or coordinated Calls, reciprocal participation in evaluations, harmonisation of selected missions …) to optimise the benefits for the climate community.

4- Data management Aspects

The Group noted that the conditions for access to high-resolution imagery (e.g. for the ice community) have not improved since the first meeting of the Group. It recommended pursuing a vigorous action *through the WMO Space programme* to obtain preferential conditions for the provision of large quantities of data for climate research purposes, some of them having little market value for other purposes.

Data processing and high level product generation is specifically reported under § 6.

Timely data delivery was re-emphasised by the Group and, in particular, the delivery time for some of the data needed for assimilation in global models which should not exceed *3 hours* from observation. It was recalled that an effective way to make use of a number of space data for climate monitoring is direct assimilation in operational NWP systems, and that monitoring of data in near-real time by operational systems can provide rapid feedback to space agencies in instances of degradation of instrument performance or ground segment processing.

The Group discussed extensively the need and the importance of sensor calibration and product validation and concluded that further major efforts and resources should be devoted to these activities, and this has to be a continuous activity, throughout the mission lifetime, involving climate scientists and space instrumentation and data processing specialists. A specific proposal was made by the Group for operational missions which are of crucial importance for climate research:

"Space agencies should consider an international effort in order to meet the GCOS and WCRP needs for cross-calibration, overlap, and continuity for operational satellites. Meeting these objectives within budgetary constraints will likely require innovative approaches. Such approaches

may wish to consider a cooperative mission using a subset of the common passive frequencies in the visible, infrared, and microwave spectrum and optimal orbital configuration to serve as a common radiance transfer standard."

The Group once again emphasised the importance of archiving and re-processing of historical archives since today several decades of data from a number of sensors/missions are archived. An archiving and periodic re-processing strategy has to be defined in close cooperation with climate scientists who have to be involved in all stages of the evolution of the data products (see also § 6).

5- Interactions with space Agencies

A close interaction between WCRP and space agencies at all levels (strategic, programme management and day to day work) is recognised as a key factor of progress in the domain of climate research. WCRP has developed longstanding relationships with major space agencies active in Earth Observation, and this has been formalised by its association with CEOS and its participation in the IGOS partnership. The recently approved WMO Space Programme is a new channel to take into account WCRP priorities. WCRP is one of the WMO supported programmes, and takes part in the annual meetings of the above mentioned Consultative Group on satellite matters. The IGOS partnership is a key mechanism for developing the cooperation between WCRP and agencies involved in Earth Observation, both on the space and the "user" side, and the active involvement of WCRP in several "IGOS themes" is an efficient way to express its requirements in the various climate related domains. The absence, for good reasons, of a climate "theme" does not however allow for a coordinated expression of the climate research community in this framework.

The interaction of WCRP with space agencies is evolving very nicely with an increasing participation of WCRP representatives in advisory committees of space agencies (for example the JSC Chair has been nominated as a member of the ESA Earth Sciences Advisory Committee) and the wish to have this practice extended to other agencies is clearly stated (in a first instance this is applicable to the committees put in place to prepare the GPM mission). Reciprocally, representatives of space agencies are invited to take part in the scientific committee meetings of WCRP and its core projects, and special attention will be given to the representation of the space component in these committees.

At the individual project level, a close cooperation already exists for a number of them, some of WCRP projects being directly funded by space agencies. The development of the Coordinated Enhanced Observation Period (CEOP), initiated by GEWEX, and the implication of major space agencies in its funding and management is a very good example. The proposed climate data re-analysis project mentioned below clearly cannot be conducted without this type of close cooperation.

6- Strategy for development of climate products

Investigations of the causes of the observed climate variability, as a basis for developing a climate change prediction capability, requires, *as a first step,* the **systematic re-processing** of the global, long-term observations of varying climate parameters from operational satellites in combination with other data sources.

Significant effort is already underway to assemble quantitative measures of climate forcing changes for the past several decades. The satellite-observed climate record of the past 20+ years, together with observations over the next 10 years by more advanced instruments are or will be available, but these data have not been and are not being analyzed in the coordinated and systematic fashion

needed to provide the foundation for monitoring and understanding the causes of climate variability.

Only the analysis of an integrated collection of observations from many systems can provide the required detail and long-term, global coverage. A coordinated program for a comprehensive analysis of the climate variations over the satellite observation period (since the 1970's) is therefore needed.

A program for the coordinated analysis and systematic re-analysis of all of the global observations can be built on the several existing WCRP and national global satellite projects and should involve the satellite-operating agencies with the objective to provide the most complete quantitative description of the climate forcing changes and climate response that can be achieved. The datasets produced would be global, covering a period of 20-30 years with consistent time-space resolution that resolves weather-scale variability (e.g. sampling intervals of 3-12 hr and 25-100 km). Immediate release of the "cleaned-up" input datasets and the re-analyzed data products would greatly stimulate climate research and become of significant importance for model evaluations.

An initial draft plan concerning the global energy and water cycle and the "faster" atmospheric responses to change was presented and discussed by the Group. This plan can serve as a prototype for a WCRP Plan which would include other key climate processes and the observation of some aspects of the slower climate components.

The next specific tasks to be performed as part of consultations within WCRP and with space agencies are:

- To define the scope of the analysis (time-space resolution and / or sampling, time period, state variables and diagnosed exchange quantities)
- To list specific datasets to be included in the processing or to be used for evaluation
- To propose a draft schedule for specific analysis tasks
- To define modeling tasks
- To list expected outcomes ("cleaned-up" input datasets, data products and analysis results, evaluations of quality, identification of problems)
- To describe the types of contributions sought
- To list possible space agency contributions
- To describe the benefits of participation.

The Group concluded that an international collaborative effort is mandatory to re-process the existing data sets into a physically consistent set of high quality climate products. The Group recommended that a proposal for *a Coordinated, Integrated Observational Analysis Strategy for the World Climate Research Programme* be elaborated by the WCRP Project Directors/Offices in cooperation with space agencies on the basis of the above approach and submitted when ready to JSC and CM for decision. The link with the European GMES (Global Monitoring for Environment and Security) initiative, aiming at the provision of global environmental information, should be ensured in order to avoid duplications.

7- Overall conclusions and Recommendations

The Group noted with satisfaction that significant progress has been achieved since the first report of the WCRP study was released in early January 2003, including:

- New important space missions for climate research launched in 2003 (NASA SORCE and ICESat, Canadian SCISAT-1) and several planned in 2004/2005 (Cryosat, Aura, Calipso, Parasol…)
- Final approval given for the development and launch of new important missions in the second half of this decade (SMOS, Aquarius, HYDROS …) in line with previous WCRP recommendations
- Numerous missions of high importance for climate research currently under definition for decisions in 2004/2005 (GPM, GOSAT, ESA Earth Explorers including WALES, EarthCare, ACE+, SPECTRA…).

The WCRP Working Group recommendations, in the short-term, include the following priorities:

- Continuation of TRMM operations for as long as possible
- Final decision to proceed with the GPM mission including the EGPM component
- Identification of alternative option(s) for the timely implementation of Megha-Tropiques
- Final decision on GOSAT implementation
- Provision of continuity for high resolution optical imagery mission of the Landsat / SPOT class
- Detailed definition and work plan for a strategy for the development of quality climate products with the involvement of CEOS WGISS
- Involvement of CEOS Cal/Val Working Group for an enhanced Cal/Val programme focusing on sensor cross-calibration
- Release by space agencies of coordinated Calls for Ideas / Mission concept for climate research and coordinated selection
- Development of innovative instrumentation for atmospheric chemistry and precipitation measurements from GEO

The Group reiterated the general recommendations expressed last year and strongly recommended that clear mechanisms be identified by space agencies to ensure data continuity for experimental missions whenever appropriate for climate research. This is also valid for operational missions of importance for climate research.

Although this aspect was not discussed in detail during the workshop, the Group also felt very concerned with the alarming situation concerning frequency allocation and urged space agencies to take the appropriate initiatives with their appropriate authorities to protect frequency bands of high importance for climate measurements.

The CEOS Plenary in November 2003 expressed its appreciation of the work performed by the WCRP satellite working group and recommended that a closer interaction be established with the corresponding GCOS activities. A proposal was made to further discuss the above recommendations at a future CEOS SIT meeting.

One should also mention that the content of the present report is relevant to the on-going activities of the Ad-hoc Intergovernmental Group on Earth Observations (GEO) set up in July 2003 by the Earth Observation Summit, and is taken into account by its User Requirements and Data Utilisation subgroups.

Annex

WCRP Working Group on satellite matters

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