CONCEPT FOR THE
PHYSICAL VIEW OF THE ARCHITECTURE FOR CLIMATE MONITORING FROM SPACE

WMO WP-XX

The Physical View of the "Climate Constellation" should be a virtual constellation composed of virtual sub-constellations providing the observations to derive a single or a group of ECVs. The sub-constellations will belong to either CEOS members or CGMS members or a combination of both. At present, there is already a set of CEOS virtual sub-constellations covering a set of ECVs and reporting to the CEOS SIT (Strategic Implementation Team). CGMS should establish its own virtual sub-constellations covering atmospheric-related ECVs which will become sub-constellations in the overall system. In the future, new virtual sub-constellations may be required as new ECVs and GFCS observational requirements emerge. Each virtual sub-constellation will have the responsibility for the generation of Fundamental Climate Data Records [FCDRs] (and Thematic Climate Data Records [TCDRs] when appropriate). The CEOS and CGMS sub-constellations should report to the CEOS-CGMS Joint Working Group on Climate on scientific, coordination, and technical issues. The CEOS-CGMS Joint Working Group on Climate will have the responsibility to "follow" the generation of the Climate Data Records (CDRs) thus enabling stewardship for those CDRs where satellite data are utilized. The CEOS-CGMS Joint Working Group on Climate will also have the responsibility: to continue the analyses conducted for each ECV to include new data sets; to respond to reports from the individual sub-constellations; and to inform and recommend appropriate actions by any space agency or organization involved in CDR production.

Action proposed:

CGMS-CEOS Working Group Climate to provide comments on the proposed Concept, in view of a discussion at WGClimate-9 and CGMS-46

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1 INTRODUCTION

The Architecture for Climate Monitoring consists of two parts: a generic (ECV-independent) logical view that represents the functional components (called Pillars) of the assumed requirements baseline (based on GCOS documentation) and a companion physical view that is designed to capture the current and planned physical implementation arrangements on an ECV-by-ECV basis and will also include future GFCS observational requirements. Consensus has been achieved on the overall logical view as described in the *Strategy Towards an Architecture for Climate Monitoring from Space, 2013.* The logical view comprises the following 4 Pillars: Pillar-I: Sensing the Earth environment from space; Pillar-II: Climate record creation and presentation; Pillar-III: Applications; and Pillar-IV: Decision making. Up to now, the main emphasis over the last years has been on Pillar-II and concentrated on the establishment of an inventory of the available climate data records held by space agencies. The physical view has yet to be defined. The purpose of this paper is to propose the physical view for Pillars-I and II (in this document called Physical View), in concept, and seek CGMS's approval. The reason for limiting at this moment the Physical View to Pillars-I and II is that those pillars are under the responsibilities of the space agencies. The physical view of Pillars III and IV will have to be established by those entities dealing with applications, e.g. GFCS and decision making-industry, and governments.

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2 BACKGROUND

The *Strategy Towards an Architecture for Climate Monitoring from Space, 2013* ("Strategy 2013" henceforth) focuses on satellite observations for climate monitoring from space, and the need for an international architecture that ensures delivery of these observations over the time frames required for analysis of the Earth's climate system and providing the required data sets for the provision of climate services. The strategy, however, is not sufficient, in and of itself, and therefore also presents a logical architecture that represents an initial step in the development of a physical architecture – an end-to-end system – capable of delivering the necessary observations for climate monitoring from space.

The proposed architecture calls for a constellation of research and operational satellites, broad, open data-sharing policies and contingency planning. It includes agreements that are essential for bringing the same continuity to long-term and sustained climate observations that we have today for weather observations. The task of climate monitoring, however, has requirements that must extend beyond the capabilities of one-time research missions and operational satellite systems in existence today.

3 CLIMATE CONSTELLATION, SUB-CONSTELLATIONS AND VIRTUAL CONSTELLATIONS

The physical architecture should capture the current and planned implementation strategies, on an Essential Climate Variable (ECV)-by-ECV basis since each ECV will be either a single climate variable or a set of climate variables. For example, the ECV entitled "sea surface temperature" is a single ECV while the ECV entitled "cloud properties" includes six different ECV products (cloud amount, cloud top temperature, cloud top pressure, cloud optical depth, cloud water path and cloud effective particle radius). Thus, an optimum "macro-scale" space system configuration and its components would be in the form of sub-constellations for each ECV or groups of ECVs, as well as the respective ground systems from the combined perspective of the logical and physical architectures (Strategy 2013, p.35).

CEOS has developed the concept of "Virtual Constellations" aiming to foster partnerships in addressing key observational and scientific gaps on specific themes, and prepare for the routine collection of critical observations. A CEOS Virtual Constellation is a set of space and ground segment capabilities operating together in a coordinated manner, in effect a virtual system that overlaps in coverage in order to meet a combined and common set of Earth Observation requirements. The individual satellites and ground segments can belong to a single owner or to multiple owners. The Constellation concept builds upon or serves to refocus already existing projects and activities. The Constellations effort provides a unique forum to achieve political visibility and increase mutual benefit among space and other environmental agencies. There are currently seven CEOS Virtual Constellations (suggested virtual constellation abbreviations are shown:

1. Atmospheric Composition Virtual Constellation - (AC-VC)
2. Ocean Surface Topography Virtual Constellation– (OST-VC)
3. Precipitation Virtual Constellation – (P-VC)

4. Land Surface Imaging Virtual Constellation – (LSI-VC)
5. Ocean Color Radiometry Virtual Constellation – (OCR-VC)
6. Ocean Surface Vector Wind Virtual Constellation – (OSVW-VC)
7. Sea Surface Temperature Virtual Constellation – (SST-VC)

The above seven CEOS Virtual Constellations should be able to provide almost 70% of the ECVs. Thus, the virtual constellation approach is deemed the most appropriate approach for sub-constellations, i.e. a sub-constellation should be virtual and the Climate Constellation will be comprised of virtual sub-constellations.

CGMS has established over the last 40 years five Working Groups that report at regular CGMS Plenary meetings. The five Working Groups are (and suggested virtual constellation abbreviations are shown):

1. International TOVS Working Group - Vertical Temperature Virtual Constellation – (VTP-VC)
2. International Radio-Occultation Working Group – Radio-Occultation Virtual Constellation – (RO-VC)
3. International Precipitation Working Group - Precipitation Virtual Constellation – (P-VC)
4. International Winds Working Group - Atmospheric Motion Vector Virtual Constellation – (AMV-VC)
5. International Clouds Working Group - Clouds Virtual Constellation – (C-VC)

The above five Working Groups activities should be expanded to include production of specific ECVs. If the five Working Groups also establish virtual sub-constellations as indicated, then almost 20% of the remaining ECVs could be provided. It might be necessary to combine the CEOS virtual constellation on Precipitation with the activities of the International Precipitation Working Group of CGMS.

Thus, a Climate Constellation comprised of CEOS and CGMS virtual sub-constellation would provide almost 90% of all ECVs. The remaining ECVs not yet covered could be through additional virtual sub-constellations and allow CEOS and CGMS to provide observational data for 100% of ECVs requiring satellite observations.

4 GOVERNANCE

At the core of good governance is a clear articulation of roles and responsibilities, including decision-making and resource commitments, coupled with structures of accountability for outcomes. For long-term governance, it is strongly recommended to use and strengthen existing coordination mechanisms first and resist the temptation to create a new mechanism or body that is duplicative (Strategy 2013, p33/34). Fortunately, the virtual sub-constellation approach allows the use of the CEOS and CGMS virtual constellation structures to be responsible for the creation of Fundamental Climate Data Records (FCDRs). Creation of FCDRs is best performed by space agencies operating the specific sensor.

The generation of Higher-Level Climate Information Records such as climate indices often needs the combination of both FCDRs originating from space-borne and ground-based systems, as well as modelling components. Thus, an activity producing CDRs might be best placed in an organization that combines information, such as reanalysis centres, climate service centres or environmental agencies. Therefore, the generation of CDRs would most likely not be made within space agencies but there should be a governance mechanism to link the individual FCDR producers to the CDR producer. This linking mechanism should be within the responsibility of CEOS and CGMS and it should provide the interface. The CEOS-CGMS Joint Working Group on Climate has already demonstrated considerable expertise in analyzing data sets and performing gap analyses. To utilize this existing mechanism would be very advantageous. Therefore, the CEOS-CGMS Joint Working Group on Climate should have overall responsibility and coordinate amongst all virtual sub-constellation and "follow" the generation of the Climate Data Records (CDRs) thus enabling stewardship for those CDRs where satellite data are utilized. The CEOS-CGMS Joint Working Group on Climate should also have the responsibility: to continue the analyses conducted for each ECV to include new data sets; to respond to reports from the individual sub-constellations; and to inform and recommend appropriate actions by any involved space agency or organization involved in CDR production.

5 OTHER ACTIVITIES - CALIBRATION (CEOS WGCV, GSICS, AND QA4EO)

The need for minimal uncertainty in climate monitoring, together with the need to combine data from a variety of sources (space and *in situ*), and emerging products with data assimilation, have placed “traceability” and its quantification at the top of the agenda. Inter-calibration enables consistency among satellite measurements to be achieved. Without traceability to stable reference standards, inter-calibration is, however, exposed to the risk of drifting over time and such drifts may obscure the climate trend over several decades. Therefore, strategies are being developed to improve traceability to SI units and evaluate biases with sufficient accuracy that enables time series of data sets to be appropriately and reliably linked.

5.1 Activities of the CEOS Working Group on Calibration and Validation (WGCV)

The mission of the WGCV is to ensure long-term confidence in the accuracy and quality of EO data and products, and to provide a forum for the exchange of information, for coordination, and for cooperative activities on calibration and/or validation. It is instrumental in the establishment of a common technical language amongst the users of EO data and customers of satellite-derived products. The WGCV coordinates and supports joint experiments and the sharing of facilities, expertise and resources. The group also addresses the need to standardize ways of combining data from different sources to ensure the interoperability required for the effective use of existing and future EO systems. Thus, the WGCV and its thematic subgroups contribute to improving the performance of all Earth Observation programmes.

5.2 Activities of the Global Space-based Inter-Calibration System (GSICS)

The Global Space-based Inter-Calibration System (GSICS) was initiated in 2005 by the WMO and the CGMS with a goal to ensure consistent calibration of satellite measurements from different instruments and missions contributing to the Global

Observing System (GOS), and tie the measurements to SI units. GSICS has defined and implemented procedures for operational, in-orbit satellite instrument inter-calibration. This consists of relating the measurements of one instrument to those of a reference instrument with a stated uncertainty, when both instruments are viewing the same scenes at the same time, from the same viewing angle. For satellite data time series in an archive, the overlapping records of two satellite instruments can be compared once a number of effects, such as diurnal cycle, are taken into account. Earth-based or celestial targets are also used as a complement. GSICS inter-calibration allows biases to be removed among satellite measurements. Fifteen operational or research and development (R&D) space agencies are contributing to GSICS.

5.3 QA4EO – A Quality Assurance for Earth Observation (QA4EO)

The fundamental principle of the Quality Assurance Framework for Earth Observation (QA4EO) is that "all EO data and derived products have associated with them a documented and fully traceable quality indicator (QI)". The QA4EO seeks to ensure that this universally applicable principle is implemented in a consistent manner throughout all EO.

A framework document provides information on the principles and concepts that underpin the QA4EO philosophy. It is complemented by a set of key guidelines to support the adoption of the QA4EO ethos for operational working. These are further enhanced by numerous community-specific guidelines that assist in the practical implementation of QA4EO at the working level.

With the proposed physical view of the Architecture, it will be important for the calibration activities of all three above entities to be expanded to all virtual sub-constellation regardless of CEOS or CGMS ownership. The combined impact of all three calibration activities will improve each FCDR and thus also improve CDRs.

6 USER COMMUNITIES

The most relevant and comprehensive set of specific user requirements has been provided by GCOS within their supplement *Systematic Observation Requirements for Satellite-Based Products for Climate* (GCOS-154) to the GCOS Implementation Plan (GCOS-138), applicable to climate change and long-term variability monitoring. The GCOS requirements were given for a set of Essential Climate Variables (ECV) where the feasibility of satellite measurements has been demonstrated. The CEOS-CGMS Joint Working Group on Climate has conducted its first gap analysis using available space agency data sets compared to those GCOS ECVs and its first report should be available in the second half of 2017. Thus, the first report should provide a preliminary indication of the ability of CEOS and CGMS to produce FCDRs that could be used as CDRs for climate change and long-term variability monitoring as well as input into climate information services. The first report should also allow the identification of missions and instruments that would constitute an initial Climate Constellation.

The GFCS adds another dimension to the requirements that is the direct link to the user's applications. It defines climate services as climate information prepared and delivered to meet users' needs. The GFCS describes a need for climate information that encompasses many application areas ranging from disaster risk reduction, agriculture and food security, water resources, health to energy applications and highlights the needs to support developing countries in particular. From this broad range of applications it is clear that the needs of decision makers will be very diverse. Thus, the need for tailored services, including observational but also prediction components, will certainly arise from the implementation of the GFCS. The GFCS further states that decision makers in many developing countries do not have the information that would help.

7 ACTIONS AND/OR RECOMMENDATIONS FOR CONSIDERATION BY CGMS PLENARY SESSION

CGMS to approve the proposed Physical View for the Climate Constellation.

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