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CONSULTATIVE MEETINGS
ON HIGH-LEVEL POLICY ON SATELLITE MATTERS

ITEM: 6

ELEVENTH SESSION

GENEVA, SWITZERLAND, 19 MAY 2011

Original: ENGLISH

PROGRESS REPORT ON DEVELOPMENT OF A SPACE-BASED ARCHITECTURE FOR CLIMATE MONITORING

(Submitted by the WMO Secretariat)

Summary and Purpose of Document

The purpose of this document is to present progress on developing an architecture for climate monitoring from space, and to seek additional guidance and support from the eleventh session of the Consultative Meeting on High-level Policy on Satellite Matters (CM-11) to advance its further development.

ACTION PROPOSED

The eleventh session is invited to:

(a) Note the development of an initial WMO concept document (v.1.1) for an architecture for climate monitoring from space;

(b) Note progress on collaborative efforts to prepare a report describing a coordinated strategy for an architecture for climate monitoring from space;

(c) Review draft Resolution (3.7/1) for consideration by the Sixteenth Session of the WMO Congress (Cg-XVI).

Appendices: A. Architecture for Climate Monitoring from Space, Concept Document, v.1.1

B. Draft Resolution 3.7/1 (Cg-XVI)

DISCUSSION

Introduction and Background

1. Over the last decade, an increasing amount of attention has been given to climate monitoring, and in particular, the role that satellites can play in global monitoring of the Earth's climate and its variability and change. And although significant strides have been made in defining requirements and how space-based observations can address these requirements, few efforts have been undertaken to establish either international agreements on the sustained and continuous monitoring of climate from space, or the development of an international architecture capable of monitoring climate change and its variability over the timeframes necessary for such analysis.

2. As a result, the tenth session of the Consultative Meeting on High-level Policy on Satellite Matters (CM-10), convened two panels which explored space agency involvement and coordination of climate observations (Panel 1), and the way forward for space agency collaboration on climate (Panel 2). These panels and the resultant discussions and deliberations generated a commitment among participants to work together in a collaborative way to address the requirements of monitoring the Earth's climate from space. CM-10 also suggested that this collaboration be done in a manner which would leverage existing capabilities and coordination mechanisms, and welcomed prospects of further discussion among the Committee on Earth Observation Satellites (CEOS), the Coordination Group for Meteorological Satellites (CGMS), the Global Climate Observing System (GCOS), the Group on Earth Observations (GEO), the World Climate Research Programme (WCRP), and the WMO Space Programme.

Progress since CM-10

3. Following the deliberations of CM-10, the sixty-second Session of the WMO Executive Council (EC-LXII), invited the WMO Space Programme, in coordination with GCOS and with the support of relevant technical commissions, to work with space agencies, CGMS, CEOS, and GEO in order to develop an architecture for sustained, space-based climate monitoring as a component of the future WMO Integrated Global Observing System (WIGOS) and the Global Framework for Climate Services (GFCS), for consideration by next Congress.

4. Given this direction, the WMO Space Programme developed first a draft outline, and subsequently an initial concept document for an architecture for climate monitoring from space. The draft outline was circulated to CGMS, CEOS and submitted to the Commission for Basic Systems (CBS) Ext.(10) in November 2010. CBS agreed that the proposed architecture should enhance, and be modelled after, the end-to-end system which has been created for weather observations, research, modelling, forecasting, and services, and that it should be part of the space-based component of the WIGOS. Other components of this end-to-end system would include the inter-calibration activities of the Global Space-based Inter-calibration System (GSICS), additional calibration and validation activities to be conducted in coordination with the Commission for Instruments and Methods of Observation (CIMO), the product generation efforts as done within the Sustained Co-Ordinated Processing of Environmental satellite data for Climate Monitoring (SCOPE-CM) and the training and capacity building activities of the WMO/CGMS Virtual Laboratory (VLab).

5. A first version of the concept document was issued in December 2010 and presented to the WMO/GCOS-sponsored Workshop on Continuity and Architecture Requirements for Climate Monitoring (January 2011). The document was then updated for submission to the Sixteenth WMO Congress, as contained in Appendix A.

6. A key outcome of the Continuity and Architecture Requirements Workshop was the establishment of an *ad hoc* Writing Team comprised of representatives from CEOS, CGMS and the WMO Secretariat to prepare a report describing a coordinated strategy for an architecture for climate monitoring from space.

7. In March 2011, the Writing Team met in Geneva to launch development of the report. Discussions regarding intended audiences, scope and content, milestones and timelines and writing assignments for the report occurred during this meeting. It was also determined that GCOS, GEO and WCRP, rather than serve on the Writing Team, would provide technical reviews of the report. Composition of the Writing Team (Table 1) shows a fairly good balance of both operational and research and development space agencies, as well as geographic distribution. Drafting of the report is underway, and will be completed by September 2011, such that the report can be delivered to both CEOS and CGMS in time for their plenary meetings in October and November 2011.

Name	**Agency/Institution**
Mark Dowell (Chair)	EC/JRC
Pascal Lecomte	ESA
Robert Husband	EUMETSAT
Joerg Schulz	EUMETSAT
Daniel Alejandro Vila	INPE
Yoshihiko Tahara	JMA
Eric Lindstrom	NASA
Richard Eckman (alternate)	NASA
John Bates	NOAA
Suzanne Hilding	NOAA
Chuck Wooldridge (alternate)	NOAA
Jerome Lafeuille	WMO
Barbara Ryan	WMO

Table 1

8. Lastly, during the deliberations at the Continuity and Architecture Workshop, and in follow-up discussions, it was determined that each organization participating in the effort is welcome to address the architecture issue internally in accordance with its own practices and schedule. In this regard, at its sixth meeting, the Expert Team on Satellite Systems (ET-SAT-6) expressed strong support to the proposed process to develop an architecture for climate monitoring from space, as a joint effort with space agencies, CEOS, CGMS, GCOS, GEO and WCRP. It did suggest a minor amendment to the draft resolution to emphasize that the existing concept document (v.1.1) drafted by WMO should be used as a starting point but is expected to be superseded by the joint document to be elaborated by the Writing Team, and also expressed their wish to review the draft document from the Writing Team in parallel with the review by GCOS, GEO and WCRP.

CONCLUSIONS

9. Participants in this process are to be commended for their willingness to work both collaboratively across organizational boundaries and under rather tight timelines. Expectations are high that these efforts will provide the seminal work for what will ultimately become a robust architecture for the sustained observation and monitoring of climate and its variability.

10. The eleventh session is invited to:

(a) Note the development of an initial WMO concept document (v.1.1) for an architecture for climate monitoring from space;
(b) Note progress on collaborative efforts to prepare a report describing a coordinated strategy for an architecture for climate monitoring from space;
(c) Review draft Resolution (3.7/1) for consideration by the Sixteenth Session of the WMO Congress (Cg-XVI).

ARCHITECTURE FOR CLIMATE MONITORING FROM SPACE
CONCEPT DOCUMENT v.1.1

1. Introduction

The purpose of this document is to provide a basis for consultation and, ultimately agreement, on processes and capabilities to be implemented or maintained, and activities to be pursued, in order to monitor climate from space in a globally coordinated and efficient framework.

Section 2	recalls the motivation for such an architecture.
Section 3	describes key building blocks of the architecture in an end-to-end approach.
Sections 4 to 8	describe the contents of each component.
Section 9	suggests roles and responsibilities to lead this process.

2. Motivation

Facing the need to know and understand the evolution of climate in order to alleviate or prepare for its impact, e.g. for programmes like the Global Framework for Climate Services (GFCS), monitoring climate variables is a prerequisite, and space-based observation has an essential role in this respect.

Meteorological satellites have considerably evolved over the past fifty years and are now used for a variety of applications that span time scales from nowcasting to climate prediction, and include land, ocean, atmosphere and environmental applications. Instruments on research satellites have laid the groundwork for the development of operational satellite systems and resultant environmental applications are growing vigorously.

Specific climate payloads have been flown with success by both operational and research agencies over the last several decades. Operational meteorological missions are enhanced with some climate monitoring instruments, for example for Earth Radiation Budget or Ozone monitoring. In response to the Global Climate Observing System (GCOS) Implementation Plan and its Satellite Supplement, the Committee on Earth Observation Satellites (CEOS) presented a comprehensive assessment of satellite capabilities for selected Essential Climate Variables (ECVs). There remain, however, challenges regarding the sustainability and/or continuity of selected missions and measurements to provide a continuous, long-term record of climate.

Responding to these challenges requires defining and implementing an architecture through a mechanism that accounts for the different roles and responsibilities of the respective entities while responding to the essential need for continuous and sustained operation. Given the important contribution of R&D programmes to climate observation, compounded with the increasing convergence of operational and research activities, the future space-based observing system has to rely on a strong partnership between research and operational entities.

3. A structured approach

3.1 Functional components

Taking as a starting point the requirements expressed by GCOS, and possible additional requirements in the future, the following functional components are considered:

- Analysis of user requirements;
- Observing capabilities;
- Essential Climate Variable (ECV) product generation and analysis;
- Data management, access and dissemination;
- User interface;
- Coordination and governance.

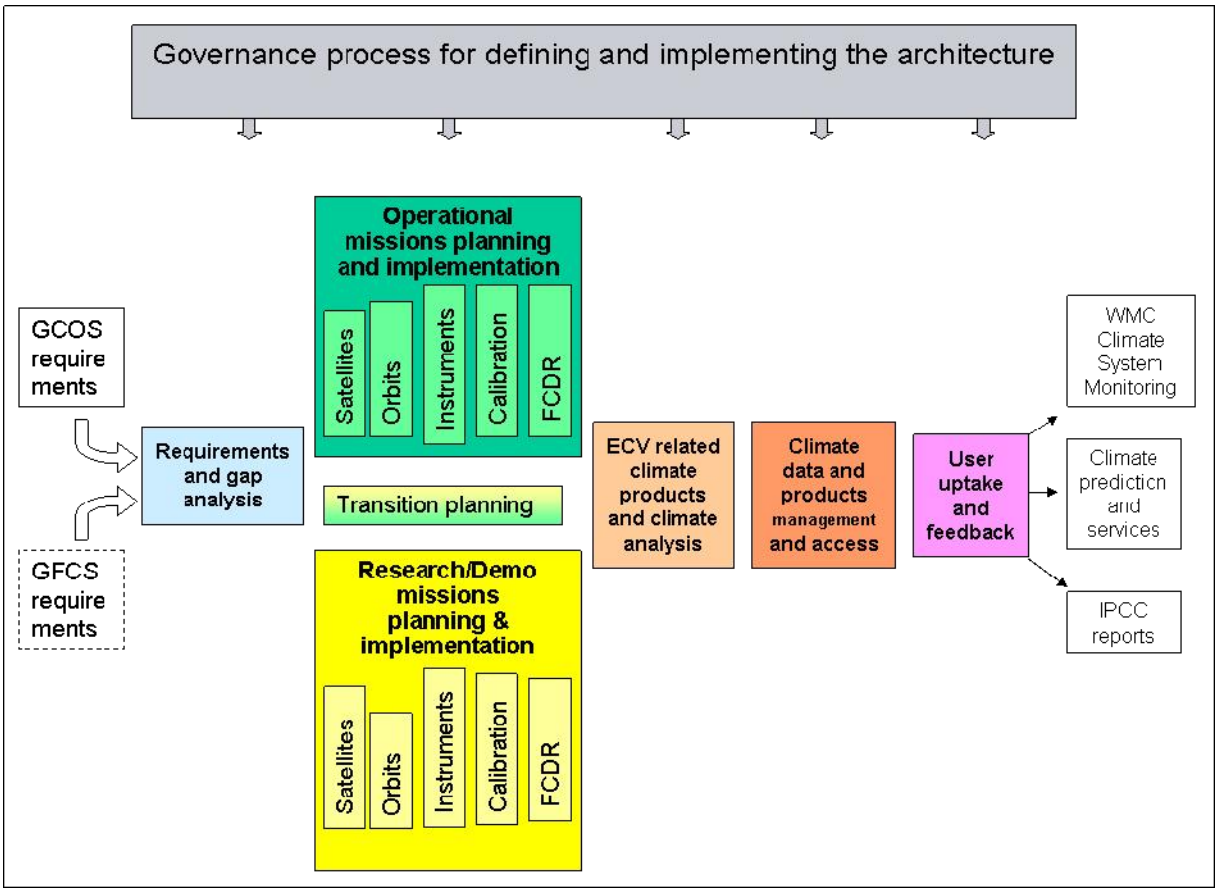

Figure 1: Key components of an end-to-end architecture

3.2 Cross-cutting considerations

The present concept document stays deliberately at high-level, since the detailed design will be developed at a later stage and should be evolving. The architecture should be defined in a long-term perspective. Building on existing assets, and taking into account the currently existing or planned capabilities, it should highlight the incremental effort needed.

In its concept, it should acknowledge:

- The evolving science and the need to ensure linkage with the science community;
- The evolving technology, avoiding being bound to current technical approaches;
- A Research-and-Operations (R&O) process, to be integrated in the evolving architecture.

The architecture should recognize and build upon the leadership exerted by CEOS, the Coordination Group for Meteorological Satellites (CGMS), the Group on Earth Observations (GEO), and the WMO Space Programme. Noting the necessary balance between best-effort and commitment, agreement should be sought on a process, supported by an implementation plan.

The development process should be responsive to evolving user needs. Robustness of systems and processes are necessary to support sustained acquisition and processing of mature observations and products. Quality assurance should be an integral part of each sub-system.

4. User requirements analysis component

4.1 Input

User requirements for observations are expressed by representative user communities, and kept under regular review following well established processes (GCOS Implementation Plan and Satellite Supplement, Rolling Review of Requirements (RRR)).

The requirements address geophysical variables (e.g. ECVs) rather than value-added products. Requirements are not for specific instruments either; they are in principle technology-free, thus not limited to space-based observation. Requirements should specify: variables, units, resolution (space and time), accuracy, continuity. They are consolidated in a database maintained by WMO and linked to the CEOS Missions, Instruments and Measurements (MIM) database.

The GCOS Implementation Plan reflects the needs of the United Nations Framework Convention on Climate Change (UNFCCC). Additional observational requirements for climate monitoring, however, may be driven by the WMO Climate System Monitoring and by climate applications for mitigation and adaptation purposes in the context of GFCS (e.g. for downscaling). The World Climate Research Programme (WCRP) requirements may also provide a relevant input.

4.2 Requirements analysis

An analysis is needed to select the subset of requirements that can be addressed from space, compare the requirements with the inventory of existing/planned observation capabilities, and perform a Gap Analysis.

5. Observation capabilities component

A comprehensive architecture should encompass operational capabilities and research or demonstration capabilities. In addition to these research and operational capabilities, a process should also be defined to facilitate transition from research to operational status when appropriate, and also recognize both research and operational activities are essential. Quality assurance should be inherent to these elements.

5.1 Operational capabilities

Operational status is understood as offering a clear long-term continuity perspective, which entails the in-principle commitment that the capability, or an equivalent one, will be maintained, enabling to serve an operational community in a sustained manner.

Operational missions should address all ECVs including atmosphere, ocean, land, and cryosphere, to the extent there are mature observation capabilities. They should follow the GCOS Climate Monitoring Principles for satellite observations. An important feature is mission robustness, which may imply provisions for relaunch, contingency planning, overlap between consecutive missions when appropriate.

CGMS is providing technical coordination of operational programmes. The current baseline agreed by CGMS defines committed elements in geostationary and low-Earth orbit. An evolution of the CGMS baseline is underway to better serve climate monitoring, guided by the WMO Vision for the Global Observing System (GOS) in 2025. The baseline for the space-based observing system can be described in terms of actual constellations (sets of satellites with coordinated orbits), or in terms of virtual constellations (sets of instruments distributed on different satellites but supporting similar missions) mapped with the ECVs. The future CGMS baseline, detailing missions, orbits and assignments, should ultimately be the foundation of the space-based component of the WMO Integrated Global Observing System (WIGOS).

5.2 Research and demonstration capabilities

R&D missions are twofold: Missions for climate research (atmospheric/climate process studies) and missions for technology demonstration. By definition, R&D missions are not bound to any firm perspective of continuity. Research missions respond to a science plan developed in consultation with the climate community.

Space agencies have developed plans at the national level or in international partnerships. CEOS is leading a coordinated response on behalf of space agencies to climate needs, and has implemented several Virtual Constellations mapped with selected ECVs.

5.3 Transition process

Attention is required to avoid misunderstanding of the "Research to Operations" paradigm.

Research and operations are equally important to successfully deliver climate-related measurements. An operational follow-on should be considered for capabilities that have been successfully demonstrated from the point of view of performance, reliability, affordability, maturity, user uptake, and societal benefit. This does not prejudge any transfer of tasks or budgets among entities, which is an internal matter for each agency or country. Joint ventures among R&D and operational entities are strongly encouraged.

The goal is that parties are ultimately in a position to make long-term commitment. The appropriate level for a long-term commitment may be the national government (e.g. WMO Member through its Permanent Representative) since an individual agency may not have the mandate to commit beyond a programme life cycle or a budget cycle.

5.4 Quality assurance: calibration/inter-calibration

Quality assurance considerations are applicable to all observation components (See the Quality Assurance Framework for Earth Observation (QA4EO)). The aim should be to generate Fundamental Climate Data Records (FCDRs). This shall build on:

- Global Space-based Inter-calibration System (GSICS) involving CMA, CNES, EUMETSAT, ISRO, JAXA, JMA, KMA, NASA, NIST, NOAA, ROSHYDROMET;
- CEOS Working Group on Calibration Validation (including Cal/Val sites);
- GCOS Reference Upper-Air Network (GRUAN) and national initiatives such as the ARM (USA), SADE (France) etc. may support this activity;
- WMO-BIPM collaboration plans addressing measurement challenges in observations for climate monitoring (see proceedings of the first WMO-BIPM workshop, Geneva, 30 March-1 April 2010, WMO-TD No. 1557).

6. ECV product generation and analysis component

The goal is to ensure sustained provision of validated and quality-controlled ECV products (Thematic Data Records). A number of initiatives are currently contributing to that goal, including:

- Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM);
- Climate Change Initiative (CCI) of the European Space Agency;
- World Data Centres (e.g. GAW DLR Data Centre on Aerosols).

These initiatives, however, are not addressing all the ECVs. There is a need for maintaining a mapping of the available/planned production of ECV products as well as "Additional Climate Variables (ACVs) if required.

For established, peer review validated products, production should be ensured in a sustained mode and quality controlled. New products shall be developed to fill gaps on priority needs, with a process for transitioning to a sustained mode according to their maturity, as assessed by a maturity index. Plans should be made for reprocessing. These products are inputs for climate monitoring analyses as part of e.g. the WMO Annual Statement of the Global Climate or the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports.

7. Data management, access and dissemination component

The scope is to ensure timely accessibility of observations and products in compliance with agreed interoperability standards.

Metadata, catalogue interfacing, and formats should be standardized in compliance with the Global Earth Observation System of Systems (GEOSS) interoperability standards (e.g. the WMO Information System (WIS) standards for WMO Members). Data should be properly catalogued and openly retrievable from data centres. In addition, acknowledging dual use of many data for both climate applications and real-time services, active data distribution should also be considered in accordance with standard practices and protocols (e.g. Direct Readout or rebroadcast).

8. User interface component

User interface should be maintained in order to seek feedback, monitor deliverables and compare with user requirements. Linkages shall be maintained in particular with the science community, the WMO Climate System Monitoring, climate assessment and climate prediction, and the GEOSS user community. Provisions shall be made to support user uptake, through capacity building including training. The annual WMO Statements on the Status of the Global Climate are an example of operational deliverables to the WMO Members, UN agencies and the general public.

9. Coordination functions

At the level of each component, coordination is needed. Tentative leads are suggested below for the respective components:

Function	Suggested WMO Involvement
Requirement identification	GCOS and WCRP
User requirements analysis	(To be determined, involving CBS)
Observation capabilities	CGMS, GSICS, and CBS and CIMO Working Groups
ECV Product generation	SCOPE-CM
Data Dissemination and Access	(To be determined, involving CBS and WIS
User Interface	GCOS, WCRP, and GFCS

An overall governance mechanism will be needed in order to:

- Manage evolution of the plan and maintain a long-term Vision;
- Monitor the commitments of each contributor, ensuring a smooth interaction among components;
- Maintain proper link with GEO/GEOSS, support communication, outreach, and provide visibility to this collaborative endeavour.

Document Change Record		
Version	Date	
Draft Outline 1	14 October 2010	Update for CBS-Ext-10/Doc. 4.2(3) discussion
Draft Outline 2	15 October 2010	Creation of document for CGMS discussion as CGMS WMO-WP-09
Draft Outline 3	6 December 2010	Update for CEOS discussion
Version 1	20 December 2010	Creation report for WMO/GCOS Workshop discussion
Version 1.1	March 2011	Update for Cg-XVI/Doc. 3.7 discussion

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DRAFT RESOLUTION 3.7/1 (Cg-XVI)

Res. 3.7/1 (Cg-XVI) - DEVELOPMENT OF AN ARCHITECTURE FOR CLIMATE MONITORING FROM SPACE

THE CONGRESS,

Noting:

(1) Article 2 of the Convention of the World Meteorological Organization,

(2) Resolution 5 (Cg XIV) - WMO Space Programme,

(3) Resolution 30 (Cg-XV) - Towards enhanced integration between WMO observing systems,

(4) Draft Resolution 3.1.1/1 (Cg-XVI) - Global Observing System,

(5) Draft Resolution 11.1/x (Cg-XVI) - Global Framework for Climate Services,

Considering:

(1) The benefits that have been achieved through the coordinated, collaborative and cost-effective approach to the planning and operation of an end-to-end system for weather observations, modelling, analysis and forecasting,

(2) The increasingly important role that space-based observations are playing in the long-term monitoring of the Earth's environment,

(3) The substantial investment that Members have made in Earth-observation satellites to monitor and study weather, water, climate and related natural disasters,

(4) The importance of long-term, sustained and coordinated observations of the Earth's climate, climate change and variability for the world's population, and particularly those at most risk,

(5) The benefits in efficiency, sustainability and cost-effectiveness that could be achieved through increased coordination of efforts among all parties involved in the planning and implementation of space-based observational capabilities and related operational processing activities for climate monitoring,

(6) The underpinning role that observations will play in the Global Framework of Climate Services (GFCS),

(7) The importance of integration of ground-based and space-based observations in the successful implementation of the WMO Integrated Global Observing System (WIGOS),

Appreciating:

(1) The important contributions Members, their satellite operators, international partner organizations and programmes make toward observing, and coordinating observations of the Earth from space,

(2) The relevant work undertaken by the Global Climate Observing System (GCOS) to identify the requirements associated with the Essential Climate Variables (ECVs) for the long-term and sustained observation of the Earth's climate system,

(3) The invitation made by the sixty-second session of the Executive Council to the WMO Space Programme, in coordination with GCOS and with the support of relevant technical commissions, to work with space agencies, the Coordination Group for Meteorological Satellites (CGMS), the Committee on Earth Observation Satellites (CEOS), and the Group on Earth Observations (GEO) in order to develop an architecture for sustained, space-based climate monitoring as a component of the future WIGOS and GFCS, for consideration by the Congress,

(4) The early work done by the WMO Space Programme to develop a concept and initiate a dialogue among interested parties for an architecture for climate monitoring from space,

Recognizing:

(1) The WMO Space Programme provides Members with an appropriate framework to advance, in partnership with CEOS, CGMS, GCOS, GEO, the World Climate Research Programme (WCRP) and other partner organizations the development of an architecture for climate monitoring from space,

(2) The end-to-end system implemented by Members to support weather monitoring and forecasting, which includes the review of observational requirements, satellite observations, intercalibration, as well as product generation and training and user-engagement, can be leveraged for climate monitoring,

(3) The different, but complementary roles and responsibilities, of satellite operators and their coordinating mechanisms for activities which cover the spectrum of research and development and operational missions,

(4) That GEO is a strong advocate for sustained and coordinated observing systems,

Decides that an architecture be developed on the basis of the concept given in the annex to this resolution to provide a framework for the sustained and coordinated monitoring of the Earth's climate from space;

Decides further:

(1) That the development be undertaken as a major initiative of the WMO Space Programme, as an important component of WIGOS, with the support of relevant technical commissions, and in coordination with satellite operators, CEOS, CGMS, GCOS, GEO and WCRP;

(2) That the results will be made available for the deliberations and final approval by the Executive Council;

Requests:

(1) The Executive Council to monitor, guide, support and finally approve, at its sixty-fourth session, the development of an architecture for climate monitoring from space;

(2) Technical commissions to:

(a) Guide the technical aspects of the development activities;

(b) Update WMO Regulatory Material, including development of the Manual on WIGOS;

(c) Provide the technical lead for the architecture through the Commission for Basic Systems (CBS), the Commission for Instruments and Methods of Observation (CIMO), and the Commission for Climatology (CCl);

(3) Members to:

(a) Provide experts to participate in the development, implementation and operation of an architecture for climate monitoring from space;

(b) Provide voluntary contributions to the WMO Space Programme Trust Fund for the further advancement of the architecture development efforts;

(c) Share relevant experience and cooperate with one another in leveraging the existing end-to-end weather monitoring system to serve climate monitoring needs;

(d) Continue to enhance and integrate their national climate monitoring capabilities;

(4) The Secretary-General to:

(a) Ensure management and support of the architecture for climate monitoring from space development efforts;

(b) Support the review and update of WMO Regulatory Material, including the development of the Manual on WIGOS;

Invites Partner Organizations, including but not limited to, CEOS, CGMS, GCOS, GEO and WCRP to collaborate with WMO on the development of an architecture for climate monitoring from space.

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