

## **WMO-RELATED ISSUES ON CLIMATE ARCHITECTURE**

Discussions on the development of an “Architecture for Climate Monitoring from Space” which aimed to engage “R&D space agencies” in the same way as operational space agencies were engaged in weather monitoring began around 2005-2009.

This led to the adoption of [Resolution 19 \(Cg-XVI\)](#) at the World Meteorological Congress in 2011, which requested WMO to “to develop an architecture ... for climate monitoring as a component of the future WIGOS and GFCS, for consideration by Congress”, as a “major initiative of the WMO Space Programme”, and “in coordination with satellite operators, CEOS, CGMS, GCOS, GEO and WCRP”.

On 6 February 2019, WMO held a [Workshop on the WMO Role in the Architecture for Climate Monitoring from Space](#) to review the status of the implementation of the architecture for climate monitoring from space.

This led to the preparation of a draft resolution which will be submitted to the 18<sup>th</sup> World Meteorological Congress in June 2019 (Cg-18) in response to Resolution 19 (Cg-XVI), and which is contained in the annex to this working paper.

The draft resolution has been reviewed and endorsed by the [10<sup>th</sup> Meeting of the Joint CEOS/CGMS Working Group on Climate \(WGClimate\)](#) and acknowledged by CEOS at the [34<sup>th</sup> Meeting of the CEOS Strategic Implementation Team](#) and is now brought to the attention of CGMS.

**Action/Recommendation proposed:** to acknowledge the draft resolution contained in the annex to this working paper and to maintain their efforts towards full implementation of the space-based climate observing system component in accordance with the Vision for WIGOS in 2040.



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**AGENDA ITEM 6: EARTH SYSTEM OBSERVATIONS AND PREDICTIONS**

**AGENDA ITEM 6.1: WMO Integrated Global Observing System**

**SPACE-BASED OBSERVATIONS**

**DRAFT RESOLUTIONS**

**Draft Resolution 6.1(5)/1 (Cg-18)**

**IMPLEMENTATION OF THE  
ARCHITECTURE FOR CLIMATE MONITORING FROM SPACE**

THE WORLD METEOROLOGICAL CONGRESS,

**Recalling** Resolution 5 (Cg-XIV) – WMO Space Programme, which initiated a new major WMO Space Programme as a cross-cutting programme to increase the effectiveness and contributions from satellite systems to WMO Programmes,

**Recalling** Resolution 19 (Cg-XVI) – Development of an Architecture for Climate Monitoring from Space, which requested WMO to develop the architecture for climate monitoring from space as:

- (1) A component of the future WMO Integrated Global Observing System (WIGOS) and the Global Framework for Climate Services (GFCS), for consideration by Congress,
- (2) A major initiative of the WMO Space Programme and as an important component of WIGOS and in coordination with satellite operators, 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) and the World Climate Research Programme (WCRP),

**Recalling further**

- (1) The Abridged Final Report with Resolutions of the Seventeenth World Meteorological Congress (WMO-No. 1157), paragraph 4.2.4.16, in which Congress underscored the need for the satellite operators and the Secretariat to pursue the development of the Architecture for Climate Monitoring from Space with a view to ensure seamless continuity of climate monitoring satellite programmes, comparability of measurements, provisions for continuity and contingency, and traceability to reference standards,
- (2) Resolution 1 (EC-68) – WMO support to the Paris Agreement, in which Executive Council decided to further address the provision of reliable, long-term, high-quality observations of global atmospheric composition changes through the revised GCOS Implementation Plan addressing Systematic Observations in support of the United Nations Framework Convention on Climate Change (UNFCCC), the Global Atmosphere Watch (GAW) and

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related information on trends and distribution of greenhouse gases in the atmosphere and through the Integrated Global Greenhouse Gas Information System (IG3IS),

- (3) Decision 7 (EC-69) – WMO support to implementation of the Paris Agreement,
- (4) Decision 14 (EC-69) – Support the development of actions based on the Global Climate Observing System Implementation Plan,
- (5) Resolution 2 (EC-70) – WMO integrated approach to high-level climate-science-related policy processes,
- (6) Decision 35 (EC-70) - Architecture for climate monitoring from space,

**Noting** the significant progress that has been made in observing the Earth globally and synoptically with higher temporal, spectral and spatial resolutions, which before the advent of satellites was all but impossible,

**Noting also** the essential nature of combining space-based observations for climate monitoring with ground-based observations in an integrated observing system,

**Convinced** of the pivotal role of satellite data to contribute to scientifically sound, evidence-based policy- and decision-making for sustainable development,

**Noting** that space-based observations will be vital for the successful implementation of the Paris Agreement,

**Having assessed** progress made on the implementation of the Architecture for Climate Monitoring from Space (hereafter/thereafter referred to as "Architecture") as provided in INF. 6.1(5),

**Taking note** that the Architecture provides an overall framework for assuring that the space-based component of the WMO Integrated Global Observing System will provide vital observations and products for climate monitoring in line with user requirements,

**Noting further** that the Architecture has been reviewed by GCOS, CEOS, CGMS and by the Joint CEOS/CGMS Working Group on Climate,

**Appreciates** the progress made with the implementation of the Architecture and confirms its importance,

**Considers favourably** the significant contributions made by CEOS and CGMS satellite operators in the implementation of the Architecture,

**Endorses** the approach taken for the implementation of the Architecture;

**Urges** CEOS and CGMS satellite operators to maintain their efforts towards full implementation of the space-based climate observing system component in accordance with the Vision for WIGOS in 2040.

**Requests** the Secretary-General to take appropriate action through the WMO Space Programme and in partnership with WMO Members for the further implementation of the Architecture;

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## **IMPLEMENTATION OF THE ARCHITECTURE FOR CLIMATE MONITORING FROM SPACE**

### **Introduction**

Initial discussions on the development of an "Architecture for Climate Monitoring from Space" (hereafter/thereafter referred to as "Architecture") began more than ten years ago, with the aim to extend the success of the space-based Global Observing System of the World Weather Watch to serve the long-term climate monitoring needs.

In 2011, the Sixteenth World Meteorological Congress adopted Resolution 19 (Cg-XVI), which requested the World Meteorological Organization (WMO) to develop such an Architecture to provide the basis for processes and capabilities to be implemented, and activities to be pursued, to monitor climate from space in a globally coordinated and efficient framework.

The present document reports the status of the implementation of the Architecture and provides an outlook on future activities.

### **Architecture Concept**

An ad-hoc group on the Architecture was established by the Committee on Earth Observation Satellite (CEOS), the Coordination Group for Meteorological Satellites (CGMS) and WMO and held three meetings from 2011 to 2013. This resulted in an initial description of the Architecture concept based on four pillars (I. Sensing, II. Climate data record creation and preservation, III. Applications, IV. Decision-making) which establishes a logical framework<sup>1</sup> for its implementation. The CEOS Working Group on Climate (WGClimate) was established in 2010 and enhanced to become a Joint CEOS/CGMS Working Group on Climate in 2013 to coordinate the implementation of the architecture and provide a unique interface from the Space Agency coordination mechanism to the UNFCCC.

Requirements for climate monitoring from all users are collected under the WMO Rolling Review of Requirements (RRR) process in which the climate monitoring WMO Application Area is overseen by the Global Climate Observing System (GCOS)<sup>2</sup>, and the climate science WMO Application Area is overseen by the World Climate Research Programme (WCRP). In addition, data requirements for climate services and adaptation measures should be expressed by the Global Framework for Climate Services (GFCS) through GCOS.

The Architecture responds to requirements expressed by GCOS and at its fourth pillar realises the benefits for policy- and decision making based on climate monitoring data, products and services. Those benefits can be measured in terms of their contributions to the implementation of goals set out in global development agendas, in particular, the Paris Agreement, the 2030 Agenda for Sustainable Development, and the Sendai Framework for Disaster Risk Reduction.

Climate data records of Essential Climate Variables (ECVs) provide the empirical evidence needed to understand and predict the evolution of climate, to guide mitigation and adaptation measures, to assess risks and enable attribution of climate events to underlying causes, and to underpin climate services. They are required to support the work of the United Nations

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<sup>1</sup> M. Dowell, P. Lecomte, R. Husband, J. Schulz, T. Mohr, Y. Tahara, R. Eckman, E. Lindstrom, C. Wooldridge, S. Hilding, J. Bates, B. Ryan, J. Lafeuille, and S. Bojinski, 2013: Strategy Towards an Architecture for Climate Monitoring from Space. Pp. 39. This report is available from: [www.ceos.org](http://www.ceos.org); [www.cgms-info.org/](http://www.cgms-info.org/).

<sup>2</sup> See user requirements in GCOS, "The Global Observing System for Climate: Implementation Needs", GCOS-200, [https://library.wmo.int/opac/doc\\_num.php?explnum\\_id=3417](https://library.wmo.int/opac/doc_num.php?explnum_id=3417), 2016.

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Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC)<sup>3</sup>.

### **Sensing (Pillar I)**

CEOS and CGMS agencies operate the satellites of the space-based Global Observing System (GOS) component of the WMO Integrated Global Observing System (WIGOS) and are responsible for ensuring collection, calibration, validation and long-term preservation of the raw data for the ECV data records under Pillar I of the Architecture.

CGMS agencies are committed to ensure the sustained availability of data from satellites that form the CGMS Baseline<sup>4</sup>. The 'Baseline' constitutes the commitments and plans of CGMS members to provide observations, measurements, and services.

The status of the global observing system for climate and future implementation needs are reflected by GCOS<sup>5</sup>, in accordance with the RRR process.

High-level targets to guide the evolution of WIGOS are provided in the "Vision for WIGOS in 2040" based on inputs from all WMO application areas<sup>6</sup>. Climate monitoring missions that will be required to become operational in this time frame, such as the Greenhouse Gas (GHG) monitoring missions in support of the Paris Agreement, are included in the WIGOS 2040 Vision document.

The CGMS Baseline is updated every four years considering the evolving programmatic plans of CGMS members and the WMO Gap Analysis of the CGMS Baseline against the WIGOS 2040 Vision.

The WMO Gap Analysis is supported by the Observing Systems Capability Analysis and Review (OSCAR) tool, that maintains a list of all relevant Earth Observation satellites and their sensors in a dedicated database (OSCAR/Space)<sup>7</sup>.

The RRR process drives the planning, development and operational deployment of new elements of the space-based observing system component of WIGOS.

### **Climate Data Record Creation and Preservation (Pillar II)**

WGClimate implements this task by encouraging collaborative activities between CEOS and CGMS space agencies to generate, validate, provide access and archive climate data records.

WGClimate compiles and annually updates a web-based ECV Inventory<sup>8</sup>. On the basis of a gap analysis a Coordinated Action Plan is created which guides action of CEOS and CGMS agencies to address the identified gaps and shortcomings and to further improve the delivery of climate data records. This includes activities to enhance the sustainability and secure the sustainment of needed measurements into the future. Sensor information required for the gap analysis is provided by OSCAR/Space and the CEOS Missions, Instruments, and Measurements (MIM)<sup>9</sup>

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<sup>3</sup> See <https://gcos.wmo.int/en/essential-climate-variables>.

<sup>4</sup> See CGMS/DOC/18/1028862, v.1., [www.cgms-info.org](http://www.cgms-info.org).

<sup>5</sup> See GCOS, "The Status of the Global Observing System", GCOS-195, [https://library.wmo.int/pmb\\_ged/gcos\\_195\\_en.pdf](https://library.wmo.int/pmb_ged/gcos_195_en.pdf), 2015.

<sup>6</sup> Reference to the relevant Cg-18 document.

<sup>7</sup> See <http://oscar.wmo.int>.

<sup>8</sup> See <http://climatemonitoring.info/ecvinventory/>.

<sup>9</sup> See <http://database.eohandbook.com/>.

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Database. Presently, the Inventory contains more than 900 existing and planned climate data sets.

Through WGClimate, CEOS and CGMS also provide a comprehensive answer in response to actions raised by the GCOS Statement of Guidance<sup>10</sup>.

Inter-agency mechanisms, such as the Global Space-based Inter-Calibration System (GSICS) and the CEOS Working Group on Calibration & Validation (WGCV), support the calibration, inter-calibration and validation of satellite data.

The Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM), a network of agencies and operators of meteorological and environmental satellite systems with interfaces to WMO, WCRP, GCOS, CGMS, CEOS and GEO, provides a means to follow up to on the WGClimate Coordinated Action Plan. It facilitates international cooperation on sustainable and, ultimately, sustained generation of climate data records from satellite data.

The open access to and sharing of climate related observations is mandated by several WMO resolutions [25 (Cg-XIII), 40 (Cg-XII), and 60 (Cg-XVII)] and the sharing of the data sets takes place through a wide range of dissemination channels, including those offered by the WMO Information System (WIS) with the Global Telecommunications System (GTS) at its core. Growing international adherence to data and metadata standards have facilitated significant advances.

A major challenge is the need for long term archiving and curation of climate data records. The continuing increase in affordable high-performance computing and storage capabilities and the growing capabilities of big data applications offer possible solutions.

### **Applications (Pillar III)**

The data sets created under Pillar II of the Architecture inform climate science and a growing range of operational applications and services, such as the Copernicus Climate Change Service (C3S), are provided under Pillar III by WMO, WCRP, GFCS, the Regional Climate Centres, National Meteorological and Hydrological Services (NMHSs) and other entities in WMO Member countries.

At the international policy level, findings based on the ECV data records contribute to flagship climate publications. These include the annual WMO Statement on the State of the Global Climate<sup>11</sup>, which is submitted to the Conference of Parties of the UNFCCC, the European Commission Copernicus Climate Change Service's "European State of the Climate" and the IPCC Assessment Reports about the state of scientific, technical and socio-economic knowledge on climate change with the aim to inform policy- and decision making.

For more practical applications, WMO and WGClimate conducted a dedicated study on the use of Climate Data Records<sup>12</sup>. The study highlights a range of near-term uses from projecting near-term energy demand to drought assessments and disease early warning and demonstrates the direct and immediate value of climate data records to society beyond improved climate knowledge.

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<sup>10</sup> See WGClimate, "Space Agency Response to GCOS Implementation Plan", ESA-ECO-EOPS-WGCL-RP-17-0061. Version 2.2.1, 2018.

<sup>11</sup> See <https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate>.

<sup>12</sup> "Satellite for Climate Services: Case Studies for Establishing an Architecture for Climate Monitoring from Space", WMO-No. 1162, 2015.

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Capacity-building, education and training to enhance and promote the use of climate data records are provided through coordinated inter-agency mechanisms, including the WMO-CGMS Virtual Laboratory for Education and Training in Satellite Meteorology and the CEOS Working Group on Capacity Building & Data Democracy (WGCapD).

The proposed Space Climate Observatory (SCO)<sup>13</sup> will contribute to the Architecture by focussing its activities on the further implementation of Pillar III.

Through the RRR process, provider and users of these applications and services are encouraged to communicate the need for enhanced or missing data sets back to WMO.

#### **Decision-Making (Pillar IV)**

The applications and services provided under Pillar III of the Architecture inform the definition and implementation of adaptation and mitigation measures by end users at all levels, from governments to individual users, with the expectation that actions based on well-informed decisions will lead to socioeconomic benefits.

To support policy and decision making, GCOS has defined seven Global Climate Indicators that summarize the key information for the most relevant domains of climate change, including temperature and energy, atmospheric composition, ocean and water as well as the cryosphere<sup>14</sup>.

Through their Joint WGClimate, CEOS and CGMS regularly address the UNFCCC Subsidiary Body on Scientific and Technical Advice (SBSTA), reporting on specific CEOS and CGMS contributions to the systematic observation of the climate system. In particular, an annual statement on progress is provided at each Conference of the Parties (COP) SBSTA meeting and the feedback received informs discussions on the planning of the future space-based observing system component.

CEOS agencies support specific policy relevant activities such as forest monitoring through the Global Forest Observations Initiative (GFOI). At local and regional levels, the agencies support National Forest Monitoring Systems (NFMS), providing fully measured, reported and verified (MRV) information for the United Nations initiative on Reducing Emissions from Deforestation and Forest Degradation (REDD+) in developing countries.

#### **Further Implementation of the Architecture**

Recently, the Architecture has demonstrated its ability to respond to emerging requirements, following the successful conclusion of negotiations on the Paris Agreement in 2015, aiming to reduce carbon emissions.

These additional requirements include the monitoring, at local scales, of Greenhouse gases, in particular CO<sub>2</sub> and CH<sub>4</sub>, which are the primary anthropogenic drivers of climate change. Advances in space-based remote sensing methods provide new opportunities to augment the ground-based GHG network spatially and temporally. Furthermore, space agencies responded by supporting a series of pioneering space-based instruments designed to estimate column concentrations of CO<sub>2</sub> and CH<sub>4</sub><sup>15</sup>.

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<sup>13</sup> See <https://www.spaceclimateobservatory.org>.

<sup>14</sup> See <https://gcos.wmo.int/en/global-climate-indicators>.

<sup>15</sup> See WGClimate, "Space Agency Report in Support of the Paris Agreement", WGCL/REP/18/1036930, Version 1.0, 22 November 2018.

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To initiate the development of an operational GHG monitoring system that integrates satellite and ground-based measurements with modelling and data assimilation components, CGMS and CEOS enlisted the CEOS Atmospheric Composition Virtual Constellation (AC-VC) team to write a Whitepaper describing a constellation architecture for monitoring CO<sub>2</sub> and CH<sub>4</sub> from space<sup>16</sup>. The Whitepaper proposes the development of a prototype atmospheric CO<sub>2</sub> and CH<sub>4</sub> inventory in 2021, to support the 2023 UNFCCC global stocktake and provide a baseline for use in the 2028 and future stocktakes. In 2018, CEOS and CGMS tasked the Joint CEOS/CGMS Working Group on Climate to coordinate activities of CEOS and CGMS to define and implement an integrated global carbon observing system and to ensure that these activities are integrated into a broader approach on greenhouse gas monitoring, i.e. WMO IG<sup>3</sup>IS, GCOS, and GEO Carbon and GHG Initiative. This targeted activity on the GHG constellation represents a concrete example of the realisation of the Architecture.

### **Conclusion**

The implementation of the Architecture for Climate Monitoring from Space has strongly advanced since 2011, in line with the aims of Resolution 19 (Cg-XVI).

CEOS and CGMS agencies have established the Joint CEOS/CGMS Working Group on Climate, which is a decisive asset for the implementation of the Architecture. The ECV Inventory is a core element of the Architecture and has been proven useful for detecting gaps and shortfalls in the sustained availability of climate data records for GCOS ECVs and for the planning of future measurements from space.

The Architecture provides the logical framework for implementing, tracking and exploiting GCOS ECV climate data records. Case studies led by WMO demonstrate practical applications as well as decision- and policy-making benefits from the sustained availability and usage of the climate data records. In addition, the Architecture has demonstrated its ability to respond to newly emerging requirements, such as in support of the implementation of the Paris Agreement.

WMO, in cooperation with CEOS and CGMS satellite operators and WMO Members, will continue to provide the leadership necessary to continue the implementation of the Architecture in support of present and future climate monitoring needs, in particular in the implementation of GFCS, and to ensure that space-based observations will fully contribute to the successful attainment of global development agendas for the benefit of all WMO Members.

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<sup>16</sup> CEOS AC-VC Greenhouse Gas Team Whitepaper “A Constellation Architecture for Monitoring Carbon Dioxide and Methane from Space”, see [http://ceos.org/document\\_management/Virtual\\_Constellations/ACC/Documents/CEOS\\_AC-VC\\_GHG\\_White\\_Paper\\_Version\\_1\\_20181009.pdf](http://ceos.org/document_management/Virtual_Constellations/ACC/Documents/CEOS_AC-VC_GHG_White_Paper_Version_1_20181009.pdf).