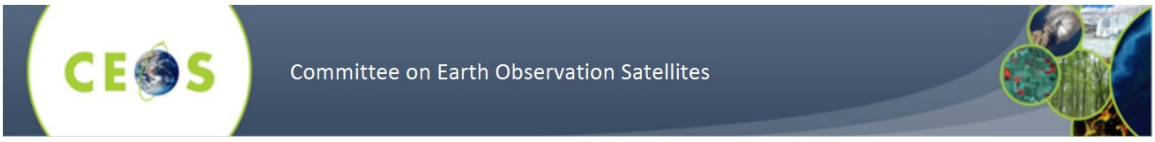

Statement of Space Agency Contributions in Support of the Paris Agreement

Prepared by the Joint CEOS/CGMS Working Group Climate

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1 Introduction

The 2015 United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement (UNFCCC, 2015a) came into force on 4th November 2016. It is expected that the Paris Agreement will drive climate policy during the next two decades and beyond. The agreement addresses climate change issues by asking all parties to the UNFCCC to reduce the total emission of greenhouse gases to the atmosphere (mitigation) and to increase the resilience of Parties to adverse effects of climate change (adaptation).

CEOS together with the Coordination Group on Meteorological Satellites (CGMS) is regularly addressing 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 meetings.

This document is detailing existing and potential future contributions of the Committee on Earth Observation Satellites (CEOS) agencies in support of the implementation of the Paris Agreement that will foster the relation to UNFCCC. Section 2 provides a short summary of the Paris Agreement also considering the role that satellite data and derived products can play in the context of the Paris Agreement. Section 3 recapitulates analysis performed by other organisations, section 4 describes the CEOS contribution and section 5 provides some conclusions.

2 The Paris Agreement

The Paris Agreement defines three major aims (Art. 2):

1. Limiting the temperature increase to well below 2°C and targeting 1.5°C above pre-industrial levels;
2. Improving the ability to adapt to adverse impacts of climate change;
3. Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate resilient development.

The first two aims have a direct relation to needs for observations to which CEOS can make significant contributions. The third aim is out of scope of this document and will not be further addressed. While Article 2 of the agreement defines the major aims, Articles 3-15 specify the ways to achieve these aims. Articles 4-12 describe specific actions that need to be performed to implement the Paris Agreement and

Articles 13-15 are describing the elements and the process to assess the progress on the implementation of the Paris Agreement. The remaining Articles cover procedural matters facilitating the implementation of the Paris Agreement.

The agreement addresses the topics mitigation including commitments made by the Parties (National Determined Contributions (NDCs)), adaptation, loss and damage, technology transfer, reporting and the financial support and capacity building needed to implement the actions. Systematic observations of the climate system are only mentioned once (Art. 7, paragraph 7(c)) on strengthening the cooperation on enhancing action on adaptation by strengthening scientific knowledge on climate to the benefit of climate services and support to decision making. However, many parts of the agreement can only be successfully implemented when underpinned by findings from systematic observations of the climate system. This is in particular true for the Global Stocktake that should lead to a progressive reduction of greenhouse gas emissions that will allow the Parties to reach the formulated aims over time. Inputs to the Global Stocktake are the NDC results, the state of adaptation efforts, and the mobilisation and provision of support. In addition, the reports of the Intergovernmental Panel on Climate Change (IPCC) and reports of the Subsidiary Bodies including SBSTA are considered.

Satellite data and derived products as well as reporting on their usage have the potential to support NDC reports, e.g., by contributing to the provision of global and regional constraints on greenhouse gas sources and sinks. They can also support assessment of progress in adaptation by monitoring changes on the Earth Surface, e.g., forestation, changes in disaster impacts, evolution of urban areas, etc. Results achieved through the analysis of satellite data provide significant information to IPCC reports via peer reviewed literature on the use of satellite data and products for GCOS ECVs fostering an improved understanding of the climate system. Finally this and the international coordination activities related to climate observations from space also provide significant input to SBSTA reports on the evolution of systematic observations of the climate system.

3 Analysis by GCOS and GEO

The Global Climate Observing System (GCOS) and the Group on Earth Observations (GEO) undertook exercises to analyse their current and potential future contribution and activities in support of the implementation of the Paris Agreement. Considering that CEOS is using GCOS as the major provider of observational needs for space-based climate monitoring, it is important that CEOS monitors the evolution

of such needs and the initiation of new GCOS activities. Likewise CEOS is supporting many GEO initiatives including the cross-cutting climate theme.

A major outcome of the GCOS analysis (GCOS, 2018) is that observations are vital for a successful implementation of the Paris Agreement. Observational needs to support adaptation to climate change need to be developed and will form a dedicated new GCOS activity. Observations of many GCOS Essential Climate Variables (ECV) are seen as very important as they contribute directly and indirectly to mitigation and adaption questions by fostering an improved understanding of the climate system. In particular, atmospheric composition data together with suitable models for fluxes of greenhouse gases are seen as important for the support to the emission and removal estimates submitted to UNFCCC and also for providing information on the change of natural greenhouse gas sources and sinks.

Major outcome of the GEO analysis (GEO, 2018) is that GEO contributes to key areas of the Paris Agreement such as adaptation and loss & damage. However, a recent workshop called for a more integrated approach to climate across the GEO Work Programme, in particular to better address adaptation questions. The GEO community may play an important role in providing guidance to national adaptation planning processes on the use of Earth Observation data and information.

4 CEOS Contributions to the Paris Agreement

Space agencies continue to improve their systematic observation of the climate system, now over several decades, strengthening scientific knowledge on climate, supporting provision of knowledge-based information to climate services and to support decision making. Space agencies are doing this by implementing the Architecture for Climate Monitoring from Space (Dowell et al., 2013) – developed by a team comprised of representatives from CEOS, CGMS, and the World Meteorological Organization (WMO). This architecture involves the identification of existing and potential future gaps in the provision of the climate data requested by the UN's Global Climate Observing System Programme (GCOS) that will also address additional observational needs related to the Paris Agreement. It is expected that additional observations and data products will be needed to support the monitoring of adaptation and that GCOS will provide new observational requirements for them.

The consolidation of space agency efforts through the establishment of the Joint CEOS/CGMS Working Group on Climate has resulted in a significant increase in efficiency in responding to the needs of Systematic Observations as required by the Convention. Using the web-based Inventory of more than 900

existing and planned climate data records of Essential Climate Variables (ECV) observable from space published in 2017, the Working Group Climate consolidated its first gap analysis. The analysis traced climate data records to contributing satellite instruments, achieved a full assessment of climate data records against GCOS criteria, and, for eight ECVs including carbon dioxide and methane assessed how the use of past and current satellite measurements could be further optimised, and identified gaps in planned future measurements which would prevent the continuation of climate data records. From a space agency perspective, the identification of gaps and their traceability to products and instruments registered in CEOS and WMO databases provides a sufficient basis for future planning. CEOS and CGMS foresee annual updates of the web-based Inventory and incremental gap analyses addressing specific sets of ECVs performed by the Working Group Climate that will further improve the ability of space agencies for a targeted response to the evolving needs as defined by GCOS.

4.1 Adaptation (Article 7)

The planning of adaptation to adverse climate change impacts requires systematic observations for the whole climate system as well as specific information at local scales. The observations are used in very diverse applications at different space and time scales supporting adaptation measures. These include:

- Climate resilience requires to be prepared for dealing with climate related disasters such as flood and storms as well as disease outbreaks. Key elements are Early Warning Systems that use weather forecasts directly depending on satellite observations provided by CEOS and CGMS agencies, as well as higher resolution information at local scales (e.g. water resources, land cover and land use);
- Climate resilience on seasonal timescales, e.g., reacting to drought conditions needs long time series information, e.g., on soil moisture, plus actual development of drought related indicators, e.g., coming from crop monitoring as well as a reliable seasonal forecast. All mentioned elements strongly depend on CEOS and CGMS satellite data and products;
- Longer term changes in weather patterns can lead to extreme weather conditions, e.g., for temperature, precipitation etc., and can also lead to slow changes, e.g., shifts in wet season onset and duration in areas depending on Monsoon related rainfall. Longer term changes in ocean and land surface properties also have profound impact on climate resilience of countries. To monitor and understand such developments of the climate system, climate data records of GCOS ECVs with extreme high quality are needed. The continuous improvement of satellite-

derived global, regional and local data records provided by CEOS and CGMS agencies is helping to establish facts that can be used to determine key impacts on vulnerable sectors, geographical zones, and also incurred cost resulting from impacts of extreme events.

The UNFCCC Parties have identified flooding, sea level rise, drought and higher temperatures as main sources of concern for the future. It is expected that GCOS will derive specific requirements for the related ECVs being used for the described applications. Also the development of climate indicators derived from ECV data by GCOS provides some prioritisation to CEOS in terms of what ECVs need to be maintained to be useful for adaptation related applications. It is also expected that end products, in particular in high spatial and temporal resolution are provided directly from high-resolution satellite data records and by reanalysis outputs. It is important that CEOS provides the data important for the assimilation into models that are used for the reanalysis.

Of increasing importance in the context of adaptation is the monitoring of urban areas where more than 50% of the global population lives. CEOS will work with GCOS on how observations from space can support observations supporting the monitoring of the implementation and impact of adaptation and mitigation activities. For instance remotely sensed data may help with observations on urban greening and can also support sea level inundation through better information on local sea level rise.

4.2 Other Articles related to Observations

4.2.1 Global Temperature (Article 2)

On mitigation the Paris Agreement has formulated the aim of constraining the increase of global average surface air temperature to 1.5°C. This directly implies the need for global observations of surface air temperature, which is not possible to be derived from satellite data and is rather provided by station data today. However, satellite data can help to improve the quality of interpolation of surface air temperature between measurement stations, and supports the verification of model-extrapolations to unobserved regions, such as the Polar Regions, Africa, and the oceans.

To explain and predict changes of the global average surface air temperature an as complete as possible understanding of the Earth's energy budget is needed. GCOS has emphasised the importance of the climate system energy cycle in its last Implementation plan (GCOS, 2016) and CEOS using its inventory of ECV climate data records is analysing how well space based data have been used to provide information on energy cycle components. CEOS will work with GCOS to establish best possible ECV climate data records for energy cycle related ECVs.

4.2.2 Nationally Determined Contributions (Article 4)

Parties to the Paris Agreement defined Nationally Determined Contributions (NDCs) to a global GHG emissions reduction effort. Each party agreed to report their GHG emissions and removals to the UNFCCC, which will evaluate progress toward the NDCs at 5-year intervals through the global stocktake, the first of which is scheduled for 2023. These emission reports are based on bottom-up inventories that employ a statistical analysis of emissions and removals by known GHG sources and sinks. When implemented rigorously, these bottom-up inventories can accurately quantify emissions sources and sinks within each country. However, many developing nations do not have the resources needed to compile comprehensive inventories in the presence of rapid economic, social, or environmental change. Other emission sources and natural sinks are poorly constrained in bottom-up inventories due to uncertainties in the "activity data" or "emission factors" used in their derivation.

Atmospheric measurements of the concentrations of CO_2 and CH_4 complement conventional, bottom-up inventory methods by providing an integrated constraint on the net amount of each gas exchanged between the surface and the atmosphere. These data therefore provide additional information for compiling bottom-up inventories as well as a synergistic approach for improving NDCs. At global scales, atmospheric CO_2, CH_4 and other well-mixed GHGs are characterized by precise, accurate, ground-based *in situ* measurements from a network managed by the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) program. This network now includes about 145 stations that span the globe, but still does not have the spatial resolution and coverage needed to identify or quantify sources emitting CO_2 and CH_4 into the atmosphere on the scale of individual nations, or to quantify removals by natural sinks.

Recent advances in space-based remote sensing methods are providing new opportunities to augment the spatial and temporal resolution and coverage of the ground based GHG network. Measurements collected by space-based sensors are being analysed to estimate the column-averaged dry air mole fractions of CO_2 and CH_4 (hereinafter XCO_2 and XCH_4, respectively) at high spatial resolution over the globe. The primary challenge of this approach is the need for unprecedented levels of precision and accuracy to resolve the small XCO_2 and XCH_4 variations associated with natural and anthropogenic and natural emission sources and natural sinks. Space agencies responded to this challenges by supporting a series of pioneering space-based experiments designed to estimate XCO_2 and XCH_4. Data from the space-based sensors have fostered the development of end-to-end modelling systems for estimating surface CO_2 and CH_4 fluxes from atmospheric measurements on scales ranging from that of individual power plants to continents. This can

help to reduce uncertainty of national emission inventory reporting, identify additional emission reduction opportunities and provide nations with timely and quantified guidance on progress towards their emission reduction strategies and pledges for their NDC's, and track changes in the natural carbon cycle caused by human activities and climate change.

4.2.3 Greenhouse Gas Sinks/Reservoirs/Sources and REDD+ (Article 5)

CEOS continues to provide systematic satellite observations for forest monitoring through the Global Forest Observations Initiative (GFOI) and is supporting countries in the use of observations for their National Forest Monitoring Systems (NFMS) to provide fully measured, reported and verified (MRV) information for the United Nations initiative on Reducing Emissions from Deforestation and Forest Degradation (REDD+) in developing countries.

In addition, CEOS works on the provision of ECV climate data records for fire disturbance, soil carbon, wetlands, permafrost, land use and above-ground biomass which are linked to the new GCOS ECV (GCOS, 2016) on anthropogenic greenhouse gas fluxes. All of these ECVs are essential to better understand the global carbon cycle including all exchanges of matter between the atmosphere, ocean and land. Above-ground biomass has been identified as a gap in the first CEOS/CGMS gap analysis (CEOS; 2018a) and several recommendations have been made to enable the future production of a climate data record for this ECV.

4.2.4 Loss and Damage (Article 8)

The Paris Agreement emphasises the importance of averting, minimising and addressing loss and damage associated with the adverse impacts of climate including extreme weather and slow onset events, and the role of sustainable development in reducing the risk of loss and damage. The role of observations has already been discussed in section 4.1 on adaptation to climate change. In addition, observations can support the analysis of the linkage of events that lead to loss and damage to climate variability and change. Operational attribution systems are under development for the use in climate services and need all kinds of observations including satellite data. The analysis of GEO with respect to the Paris Agreement (GEO, 2018) indicates that a considerable number of GEO activities plan to contribute to the loss and damage mechanism including the development of early warning systems. Here a potential for increased collaboration between CEOS and GEO on the use of satellite data in such systems exists.

In addition, space agencies have initiated a series of activities supporting Disaster Risk Management (DRM), with a focus on Disaster Risk Reduction, more efficiently by optimizing and better coordinating satellite Earth observations. While improvements to the International Charter or Sentinel Asia for example can offer

enhanced post-crisis support, it's critical that space agencies invest in disaster preparedness and prevention. It's in this context that CEOS created a specific Working Group on Disasters.

The overarching goals of CEOS are to increase and strengthen satellite Earth observation contributions to the various DRM phases and to inform politicians, decision-makers, and major stakeholders on the benefits of using satellite Earth Observations in each of those phases. To achieve these goals, CEOS Agencies have agreed to a series of objectives/actions that will improve the coordination of Earth Observations satellites, improve satellite Earth Observation data distribution, and foster the use of satellite data by DRM users. The Working Group on Disasters has defined a global satellite observation strategy for DRM and developed and strengthened relationships with stakeholders and end-users through a series of concrete actions addressed by single-hazard pilot projects.

Current activities addressed floods that is of high relevance to the Paris Agreement. Satellites offer the ability to map floods from space, enabling disaster responders to know what is happening in regions where they may not have information from people on the ground. This flood mapping, when combined with computer simulations of past floods, can also be used to assess the risk of flooding and the changes in that risk over time as climate changes, oceans rise, urban areas expand, and the land subsides. CEOS has worked for several years to move forward the state-of-the-art for satellite based flood risk reduction, designing new approaches and facilitating user uptake so that flood risk management can better benefit from satellite data.

Local administrations noted the benefits of the use of optical and radar images for flood mapping including access to the International Disaster Charter data. Equally important are the aspects of capacity building and access to new techniques for young professionals working for the local administrations. As a result of this work, a number of participating countries have developed or improved their capacity to not only use flood maps derived from EO imagery but also to develop their own products.

4.2.5 Global Stocktake (Article 14)

While the detailed content of the global stocktake and the model to conduct it is under development by the Parties it is evident that observations are needed to support it. In particular, what is already described under section 4.2.2 and other sections above is suitable to support the global stocktake. GCOS in its own analysis (GCOS, 2018) indicates that its climate indicators could be beneficial for the global stocktake. Although the aim of the agreement is only formulated in terms of global average surface air temperature it is clear that a wide range of satellite-based data records will be needed to support the global stocktake.

The 47th session of SBSTA (SBSTA, 2017) noted the increasing capability of satellite and in situ data to systematically monitor greenhouse gas concentrations and emissions. CEOS has been active in the UNFCCC context in implementing its Strategy for Carbon Observations from Space (CEOS, 2014). In 2018, CEOS provided a first comprehensive analysis of the state-of-the art of space based atmospheric greenhouse gas monitoring capabilities in support of international, regional and national climate policy (CEOS; 2018b). This analysis provides a reference for individual agencies planning missions in this domain as well as for the broader coordination of virtual and dedicated constellations of space-based CO_2 and CH_4 sensors among space agencies through CEOS and CGMS. To build a strong foundation for the space-based elements of an operational atmospheric CO_2 and CH_4 monitoring system that can be implemented within the next few years and to maximize its impact towards the achievement of Nationally Determined Contributions (NDCs) and for stocktaking, a series of specific steps is recommended to space agencies. This includes the design and implementation of a prototype system, based on available space-based assets, in time to inform the first global stocktake in 2023 and an operational system in time to support the second global stocktake in 2028. This system shall integrate the satellite observing capability, in situ observations, modelling components, prior information and ancillary data. Space agencies will continue to work together through CEOS and CGMS to build and maintain the necessary partnerships with the relevant stakeholders to address the user needs and the overall system implementation goals.

In addition, CEOS agencies were actively engaged in the refinement process of the IPCC GHG Inventory guidelines. The Second Order Draft of IPCC GHG Inventory Guidelines was released in July 2018 for government and expert review and now contains information on the potential contributions of space-based observations to the quality improvement of GHG emission estimates, in particular with the planned new satellite missions.

CEOS will continue to work with GCOS, the UNFCCC, and emerging climate services to further develop what is needed to support the stocktake in the future.

4.3 Open Access to data

As described above observational data are needed in support of the implementation of the Paris Agreement. Many articles of the Paris Agreement (Articles 3, 7, 12, and 13) emphasise the importance of providing access to or sharing data. Open access to climate related observations has also been mandated by several WMO resolutions (25 (Cg-XIII), 40 (Cg-XII), and 60 (Cg-XVII)).

The CEOS Strategic Guidance (CEOS, 2013) states that within the scope of CEOS the agencies desire to provide and share high-quality data, as well as information tools, to an expanding global user community on a full and open basis, and in accordance with the principles of Data Democracy as enunciated by CEOS at its 2010 Plenary in Rio de Janeiro.

To facilitate open and easy access to space data, CEOS is improving discovery, provides interoperability arrangements, coordinates data access portals in specific topical areas, and promotes the use of open-source tools for data handling. CEOS has formed a specific Working Group on Information Systems & Services to better coordinate and incorporate standard data discovery and access mechanisms, and adaptation of these mechanisms to the tools employed by the user community.

4.4 Capacity Development (Article 11) and Education and Public Awareness (Article 12)

CEOS has a dedicated working group on capacity building and data democracy that builds upon the CEOS Data Democracy Initiative. This is an effort to increase the capacity of institutions in less developed countries for effective use of Earth Observation data for the benefit of society and to achieve sustainable development.

CEOS facilitate activities that substantially enhance international education and training in Earth System Science including climate and the observation techniques, data analysis, and interpretation skills required for the use and application of Earth Observation data to meet societal needs. The CEOS activities respond well to Article 11 and 12 of the Paris Agreement by exploiting the cumulative capabilities of CEOS Agencies establishing unified and unique capacity building activities. Thus is done by partnering with locally-based and managed regional partners to increase effectiveness and decrease duplication of efforts, by using threads such as disaster response or climate change to build capacity through discussion of a focused subject. The activities focus on user needs for data and capabilities, including information technology infrastructure, to inform actions/plans for delivering the appropriate data and training for the effective use of Earth Observation data.

CEOS entities are also working to increase data accessibility, especially in under-served communities. The work of several CEOS working groups is to ensure a seamless transition from the technical matters relating to data accessibility to the matters relating to systemic and individual capacity development. This includes publication of resources, datasets, and software made available to under-served communities, promotion of data dissemination systems to effectively reach areas that lack consistent internet access or redundant systems in case of emergencies, which is important in the light of disasters leading to loss and damage as

described above. In addition, workshops and training activities to provide individual and institutional capacity to effectively use available Earth Observation resources is within the remit of CEOS.

4.5 The Transparency Framework (Article 13)

One of the aims of the Transparency Framework is to provide clarity and tracking of progress towards achieving Parties' individual nationally determined contributions. The observations discussed above are essential to support this aim because they enable evidence for progress or not. Information derived from observations including satellite data will form an important part of the reporting to the global stocktake. CEOS together with CGMS can play an important role providing data of a quality that is able to support the stocktake. However, it is expected that the process of implementing the Paris Agreement will lead to new requirements for observational data that will be incorporated into the GCOS Implementation plan.

5 Conclusion

The 2015 United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement will drive climate policy during the next two decades and beyond. The agreement aims at limiting the temperature increase to well below 2°C and targeting 1.5°C above pre-industrial levels, improving the ability to adapt to adverse impacts of climate change and to make finance flows consistent with a pathway towards low greenhouse gas emissions and climate resilient development.

The first two aims will require support from observations including satellite data. Systematic observations of the climate system will be needed to support NDC reports by contributing to the provision of global and regional constraints on greenhouse gas sources and sinks. They will also be needed to support progress in climate change adaptation by monitoring changes on the Earth Surface, e.g., forestation, changes in disaster impacts, evolution of urban areas, etc. Results achieved through the analysis of satellite data provide significant information to IPCC reports via peer reviewed literature on the use of satellite data and products for GCOS ECVs fostering an improved understanding of the climate system. Finally this and the international coordination activities related to climate observations from space also provide significant input to SBSTA reports on the evolution of systematic observations of the climate system. The described support to the implementation of the Paris Agreement involves new challenges in particular in the use of space-based data in applications supporting adaptation activities and the specification of NDCs. It is expected that GCOS will start a new activity on adaptation that will result in new observation needs and requirements that CEOS shall respond to in the future.

The Joint CEOS/CGMS Working Group on Climate together with CEOS' working groups on Calibration/Validation, Disasters, Information Systems & Services, and Capacity Building are an established structure that is capable of efficiently responding to the needs that arise from the implementation of the Paris Agreement. The implementation of the Architecture for Climate Monitoring from Space plays a central role in ensuring that the needed observations at the needed quality are also made in the future, that derived data products respond to the needs of applications for which the data are used and that the applications provide the information needed by decision and policy making. In the context of the Paris Agreement this means that space-based observations with undoubted quality used in the process of the global stocktake can play a supporting role of providing evidence for the success of the implementation of the Paris Agreement.

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