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Space and Climate Change

(*Contribution from the World Meteorological Organization and the Global Climate Observing System Secretariat*)

Note by the Secretariat

The information contained in the annex to this note has been provided by the World Meteorological Organization (WMO) in collaboration with the Secretariat of the Global Climate Observing System (GCOS) as background information for agenda item 12. It recalls the major steps taken over the past three decades in the area of climate change through global initiatives taken by WMO and other UN organizations, up to the third World Climate Conference to be held in Geneva from 31 August to 4 September 2009, with emphasis on the space-based component of these activities.

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Annex

Space-Based Observation and Climate Change

(*Contribution provided by the World Meteorological Organization and the Global Climate Observing System Secretariat*)

Introduction

Climate variability and change impact society significantly and will continue to do so in the future. The award of the Nobel Peace Prize to the Intergovernmental Panel on Climate Change (IPCC) in December 2007 is not only a recognition of the outstanding quality of the work of this scientific body but also an acknowledgement of the profound impact that climate change may have on the sustainability of a number of human activities and the resulting threat to the stability of our society.

Space-borne observation provides an irreplaceable source of data to study, detect and monitor climate change, to predict its evolution and anticipate its consequences. As the United Nations authoritative voice on weather, water and related climate matters, the World Meteorological Organization is heavily involved in climate related activities with a number of partners within and outside the UN system. Satellites logically play an important role in many of these programmes. Furthermore, WMO has established a Space Programme to address space-related issues in a cross-cutting fashion with the overall goal to develop space-based observation in an integrated way, to enhance the availability and accessibility of space-based data and products and to promote their use.

The present contribution briefly recalls the main climate activities pursued by WMO and its partners, and highlights on-going initiatives related to the use of satellites in these programmes.

Activities of WMO and its Partners on Climate Change

Major initiatives have been taken over the past three decades to support research on climate processes, monitor climate variability and change, formulate assessments, raise awareness and –more recently- to provide support to decision making on adaptation to climate impacts, and on mitigation actions. The World Climate Conferences convened by WMO are essential milestones that frame these global initiatives.

The first World Climate Conference held in February 1979 identified climate variability and change as an issue of concern worldwide and triggered three major programmes:

- The World Climate Programme (WCP) of WMO
- The World Climate Research Programme (WCRP) as a partnership among WMO, the International Oceanographic Commission of UNESCO (IOC) and the International Council for Science (ICSU)

- The IPCC, formally established by WMO and the United Nations Environment Programme (UNEP) in 1988.

The second World Climate Conference in November 1990 added momentum to address these actions building on the first assessment report provided by the IPCC, which resulted in 1992 in the establishment of :

- The United Nations Framework Convention on Climate Change (UNFCCC)
- The Global Climate Observing System (GCOS), a joint programme of WMO, IOC, UNEP and ICSU.

The third World Climate Conference (WCC-3) now under preparation by WMO, will be held in Geneva from 31 August to 4 September 2009. It will focus on the technical and scientific basis needed to effectively address climate related risks such as droughts, floods, heat waves, famine and disease outbreaks. The expected outcome of WCC-3 is to establish a framework to guide the development of climate services that would link the science-based climate predictions and information with climate-risk management and climate change adaptation throughout the world, with special attention to the least developed countries that are among the more exposed to climate induced risk.

Use of Space-Based Observation for Climate Activities

GCOS Satellite Requirements

Global monitoring of climate requires sustained, high-quality datasets and derived products from satellites, as recognized by the GCOS Implementation Plan ("Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC", GCOS-92, October 2004). Full implementation of the GCOS Implementation Plan will result in a system that provides global observations of the Essential Climate Variables (ECVs) and their associated products as needed to assist Parties in meeting their responsibilities under the UNFCCC. In addition, it should provide the systematic and sustained observations needed by the World Climate Research Programme (WCRP) and the Intergovernmental Panel on Climate Change (IPCC).

Specifically, the system proposed by GCOS will provide information to:

- Characterize the state of the global climate system and its variability;
- Monitor the forcing of the climate system, including both natural and anthropogenic contributions;
- Support the attribution of the causes of climate change;
- Support the prediction of global climate change;
- Enable projection of global climate change information down to regional and local scales;
- Enable characterization of extreme events important in impact assessment and adaptation, and the assessment of risk and vulnerability.

Both satellite and surface measurements are vital components of this system, and complement each other. GCOS has detailed and quantified its requirements for satellite observations as a supplement to the GCOS Implementation Plan (GCOS-107). Table 1 provides the list of ECVs considered particularly feasible for sustained monitoring from satellites in the three domains (Atmospheric, Oceanic, Terrestrial).

Domain	Essential Climate Variables
Atmospheric (over land, sea and ice)	Precipitation, Earth radiation budget (including solar irradiance), Upper-air temperature, Wind speed and direction, Water vapour, Cloud properties, Carbon dioxide, Ozone, Aerosol properties.
Oceanic	Sea-surface temperature, Sea level, Sea ice, Ocean colour (for biological activity), Sea state*, Ocean salinity*.
Terrestrial	Lakes*, Snow cover, Glaciers and ice caps, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI)*, Biomass*, Fire disturbance, Soil moisture*.

Table 1: ECVs largely dependent upon satellite observations. This listing is based on the GCOS Implementation Plan and covering all ECVs considered in this report. ECVs denoted with an asterisk (*) were not included in the original table in the Implementation Plan. Note that soil moisture was not listed as an ECV, but was recognized as an emerging ECV and has been included here.

Furthermore, GCOS Climate Monitoring Principles have been defined for the generation of satellite climate data records, recognizing in particular the need for overlaps in missions and for in situ measurements for calibration and validation purposes. These principles have been formally approved by WMO and by the Coordination Group for Meteorological Satellites (CGMS).

Response to GCOS Needs by Space Agencies

A constructive dialogue has been established among GCOS and Space Agencies, with the support of the Committee on Earth Observation Satellites (CEOS) and the Coordination Group for Meteorological Satellites (CGMS).

CEOS has developed and is implementing an Action Plan in response to GCOS satellite requirements through new satellite mission planning, development of new products and improved availability of data and products from existing and past missions. Within the overall CEOS response, individual agencies, such as ESA, EUMETSAT and NOAA, are seeking to engage specific responses within their own organisation in terms of reviewing adherence to the GCOS Climate Monitoring Principles, specifically seeking to transform the basic satellite records into so called satellite “fundamental climate data records” of calibrated and geo-referenced measurements, supported by the entire range of metadata, and in some cases, the production of reanalysed time series of the ECVs.

CGMS has been actively engaged in two specific projects initiated in collaboration with WMO as indicated below.

WMO Space Programme response to GCOS

Vision for the Global Observing system

In response to these challenging requirements, WMO developed in 2007 and 2008 a "Vision of the Global Observing System (GOS) in 2025". The Vision defines a high-level observing architecture that WMO Members should agree to maintain, ensuring its long-term continuity through voluntary commitments, in accordance with established practices that made the success of the current GOS and Global Telecommunications System (GTS). In the new Vision, the space-based component will be considerably enhanced in order to encompass the needs of GCOS in the atmospheric, oceanic and terrestrial domains, as well as hydrological and environmental services or related disaster monitoring. It will reinforce the importance of the space-based GOS as a major component of the Global Earth Observation System of Systems (GEOSS) of the Group on Earth Observation (GEO). The new Vision has been recommended by the WMO Commission for Basic Systems (CBS) in March 2009 and is being submitted to the WMO Executive Council on 3-12 June 2009.

Particularly new features of the space-based component of this new vision include:

- Long-term sustained operation of ocean surface altimetry and wind scatterometry;
- Global precipitation measurement through combined use of active (radars) and passive (radiometry) microwave measurements;
- Continuous measurements of the earth radiation budget components, and essential atmospheric chemistry components including carbon dioxide, ozone and aerosols;
- Radio-occultation measurements from space-based Global Navigation Satellite System (GNSS) receivers, since they enable the retrieval of benchmark measurements of temperature and humidity profile in the upper atmosphere.

Several of these missions are currently conducted or planned by space agencies on a research basis only; therefore the big challenge of this vision is a change of paradigm whereby these missions would evolve from a research to an operational status, in order to achieve long term sustained operation, which raises a number of technical, programmatic and financial issues. This process should go along with a strong user interaction to promote early use of new data and to support emerging operational practices. Partnership with space agencies, the Coordination Group for Meteorological Satellites (CGMS) and the Committee on Earth Observation Satellites (CEOS) will continue to be essential for the implementation of this Vision.

Satellite Intercalibration

A key objective to better serve the needs of climate research and monitoring is to ensure that satellite data can be shared at the global level and merged into consistent data records. High and stable measurement accuracy is critical for climate monitoring. The Global Space-based Inter-Calibration System (GSICS) project was launched in 2005 by WMO and CGMS in order to meet these requirements. Within GSICS, eight participating agencies (CMA, CNES, EUMETSAT, JMA, KMA,

NASA, NIST, NOAA) are cooperating under the aegis of WMO and CGMS to develop and implement a comprehensive calibration strategy for space-based instruments with the aim to ensure consistency of satellite measurements from different instruments and programmes, to tie these measurements to absolute references and SI standards, and enable recalibration of archived data.

Intercomparison of radiances from geostationary and low-Earth orbit instrument pairs are performed on a routine basis through correlation studies of Simultaneous Nadir Observations (SNO). A common set of tools and procedures is being developed and operated by each of the geostationary satellite operators to perform comparable calibrations on a routine basis for geostationary and reference polar-orbiting space-based radiometers. (http://gsics.wmo.int).

Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring

The Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) initiative has a goal to foster cooperation among satellite agencies and other scientific and technical entities towards the delivery of high-quality climate products related to Essential Climate Variables (ECV) in a sustained mode, through a validated and quality-controlled process, responding to GCOS requirements. Five satellite operating agencies (CMA, ESA, EUMETSAT, JMA, NOAA) are involved in SCOPE-CM, together with CEOS, GCOS and WMO. Pilot projects have been undertaken, which pave the way for possible long-term commitments for the delivery of such climate products.

WCRP and the GEWEX

WMO, UNESCO/IOC and ICSU are jointly supporting the World Climate Research Programme (WCRP), which includes the Global Energy and Water Cycle Experiment (GEWEX) as one of its core programmes. The GEWEX-CEOP, Coordinated Energy and water cycle Observations Project has undertaken to quantify critical atmospheric, surface, hydrologic and oceanographic data during the time period 2001 – 2007 through the combined use of Research and Development remote sensing satellites (including Terra, Aqua, ENVISAT, TRMM, LANDSAT-7), operational meteorological satellites (NOAA and other operational satellite series) and 35 in situ reference sites. CEOP has also developed a distributed and centralized data integration function in cooperation with the Committee on Earth Observation Satellites (CEOS) Working Group on Information Systems and Services (WGISS) called the WGISS Test Facility-CEOP Distributed Data Integration System (developed at the Japanese Space Agency and the Remote Sensing Technology Center of Japan). This service is providing on-line access to space and surface-based data related to the reference sites for climate research purpose.

Global Atmospheric Watch

The depletion of the stratospheric ozone layer, increases in tropospheric ozone, acid deposition, rising greenhouse gas concentrations, and changes in the radiative balance of the earth-atmosphere energy system, all reflecting the influence of human activity on the global atmosphere, have faced us with the need to better understand the complex mechanisms of interaction between the atmosphere, ocean and

biosphere. This has led WMO to establishing in 1989 the Global Atmospheric Watch (GAW) programme.

GAW provides data for scientific assessments and for early warnings of changes in the chemical composition and related physical characteristics of the atmosphere that may have adverse affects upon our environment. Monitoring priorities have been given to greenhouse gases for possible climate change, ozone and ultraviolet radiation for both climate and biological concerns, and certain reactive gases and the chemistry of precipitation for a multitude of roles in pollution chemistry.

GAW relies on a combined and synergetic use of surface-based and space-based measurements. Nadir-viewing space based instruments have been providing a near-continuous record of total column ozone since 1978. Aerosol optical depth is being measured over oceans and, more recently over continents as well. Limb-viewing instruments have established a 20-year record of stratospheric profiles of O3, aerosol extinction, H2O, NO2 (occultation) and a 10-year record of stratospheric O3 and ClO with good coverage (emission) and HCl, HF, CH4, O3, H2O, NO2, aerosol extinction (occultation). In the troposphere, space-based observations of O3, water vapour, and CO are being made. Advanced instrumentation on research satellites offer promise of measurement of more chemical constituents and better accuracy, subject to further development in retrieval and modelling.

Coordination of efforts of space agencies is facilitated in this area by CEOS through the initiative named CEOS Atmospheric Composition Constellation (ACC).

Cryosphere Watch

The cryosphere collectively describes elements of the Earth System containing water in its frozen state and includes solid precipitation, snow cover, sea ice, lake and river ice, glaciers, ice caps, ice sheets, permafrost, and seasonally frozen ground. The presence of frozen water in the atmosphere, on land, and on the ocean surface affects energy, moisture, gas and particle fluxes; clouds; precipitation; hydrological conditions; and, atmospheric and oceanic circulation. Elements of the cryosphere also contain important records of past climate, providing benchmarks for interpreting modern climate change. The cryosphere exists on all latitudes of the Earth and occurs in approximately one hundred countries of the world. While the cryosphere is an integrative element within the climate system and provides one of the most useful indicators of climate change, it is arguably the most under-sampled domain in the climate system.

The cryosphere, its changes, and its impacts, not only have received increased scientific scrutiny in recent years, but also now receive constant coverage by the media, creating an unparalleled demand for authoritative information on past, present and future state of the world's snow and ice resources. Building on the findings and momentum of the 2007-2008 International Polar Year, WMO, with the co-operation of other national and international bodies and organizations, is considering establishing a Global Cryosphere Watch (GCW) in order to provide an integrated, authoritative, continuing assessment of the cryosphere.

Here again, space-based capabilities are important components of the observing system in combination with surface-based observation. Satellites are particularly helpful over Polar Regions for ice sheet monitoring, sea ice detection and characterization. In addition to near-polar orbiting satellite missions such as Icesat

and Cryosat-2, consideration is being given to possible missions in Highly Elliptical Orbits (HEO) that would provide quasi-geostationary observation over high latitudes.

Related Issues

Satellites now provide a vital means of obtaining observations of the climate system from a near-global perspective, and comparing the behaviour of different parts of the globe. It is evident that the future of the global climate observing system depends critically upon a major satellite component. Nevertheless, while there are good expectations for the continuity of data records for some variables linked to meteorological satellites, there is a lack of plans for continuity of measurement of many of the Essential Climate Variables needed by the UNFCCC. Important efforts are required to bring the new Vision of the GOS to reality.

Moreover, for satellite data to contribute fully and effectively to the determination of long-term records, they must be part of a system implemented and operated so as to ensure that these data are accurate and adequately homogeneous for climate. Finally, in addition to meeting the needs of the UNFCCC, the real-time and near-real-time information obtained through such a system would provide an equally large benefit to the needs of many other key societal benefit areas.

Standardization thus needs to be actively pursued at different levels:

- Standard calibration methods enabling different satellite systems and operators to deliver consistent data sets over time
- Standard data format and metadata to facilitate data discovery and wide access by users throughout the globe
- Harmonized procedures for quality control, product validation, traceability and documentation.

These objectives are proposed in the context of the WMO Integrated Global Observing Systems (WIGOS) that has identified the three areas of standardization listed above as a prerequisite for a smooth integration of the various WMO or co-sponsored observing systems and for the optimization of their societal benefit.

With increasing reliance on space-based observation, including passive radiometric measurements in the microwave region, it is vital to preserve those parts of the electromagnetic spectrum that are used for these measurements. Passive measurements are extremely sensitive to interference because of the weakness of the natural signal. Moreover, these measurements have to be made at specific wavelengths determined by the absorption spectrum of atmospheric constituents; these wavelengths being fixed by Nature they are a limited resource. These issues have been reviewed by WMO and the International Telecommunications Union (ITU) in a joint Handbook on “Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction “ (2008).

Conclusion

Bearing in mind the challenges facing our society through the current and anticipated evolution of our climate, satellite observation must be acknowledged as an essential tool to best tackle these challenges. Members are invited to support on-going efforts of WMO and its partners and co-sponsored observing systems, such as GCOS, to enhance space-based Earth Observation missions and to promote their applications towards the efficient delivery of climate services to society.