Coordinated Response from Space Agencies Involved in Global Observations to the Needs Expressed in the Global Climate Observing System (GCOS) Implementation Plan

Update on Climate Actions

Developed by the Committee on Earth Observation Satellites (CEOS)

Submission from South Africa on behalf of
the Committee on Earth Observation Satellites
To
The U.N. Framework Convention on Climate Change
Subsidiary Body on Scientific and Technological Advice

1 Introduction

1.1 Purpose of Report

In 2004, the Conference of the Parties of the U.N. Framework Convention on Climate Change (UNFCCC) invited Parties that support space agencies involved in global observations to request these agencies to provide a coordinated response to the needs expressed in the Global Climate Observing System (GCOS) Implementation Plan. The UNFCCC Subsidiary Body on Scientific and Technological Advice (SBSTA) in 2005 welcomed and accepted the offer from the Committee on Earth Observation Satellites (CEOS), on behalf of Parties supporting space agencies, to provide a detailed report at its 25th session in December 2006. The SBSTA subsequently invited CEOS to provide an updated progress report at its 29th session in December 2008.

This document is that coordinated response and progress report by CEOS, on behalf of space agencies involved in global observations, on its Climate Action Plan in support of the space component of GCOS. This progress report reviews the criticality of Earth observing satellites for climate monitoring, understanding, prediction, and attribution of causes of climate change. It then describes how CEOS identified 20 (initially 21, but two were subsequently combined) high priority Climate Actions for immediate implementation and a number of priority 2 and 3 actions, and how it organized an international effort to address the Actions. It then summarizes the current status of these Actions. Finally, the report reviews the key accomplishments thus far and future plans. In addition, the 2008 CEOS Earth Observation Handbook is submitted as a supplement to this progress report. The 2008 edition of the Handbook focuses on the needs of climate change and presents the main capabilities of satellite Earth observations, their applications, and a systematic overview of present and planned Earth observation satellite missions and their instruments.

By supporting the space-based observations of the GCOS, the CEOS Climate Action Plan contributes to the SBSTA's work on methodological and scientific matters as they relate to the Convention and the Kyoto Protocol process. In particular, the CEOS Climate Action Plan addresses the research and systematic observation issue of the methods and science work. The Convention calls on Parties to promote and cooperate in research and systematic observation of the climate system, including through support to existing international programs and networks.

The report emphasizes the importance of space observations for measuring changes in the climate system on a global basis. These measurements will provide governments throughout the world information essential to developing mitigation and adaptation strategies for climate change. The CEOS Climate Action Plan includes the development of several Constellations of satellites to provide critical information to countries throughout the world on changes in regional land cover and precipitation, and in global sea level.

An overview of CEOS is provided in Appendix 1.

1.2 Background

GCOS was established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. It is co-sponsored by the

- World Meteorological Organization (WMO),
- Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO),
- United Nations Environment Programme (UNEP), and
- International Council for Scientific Unions (ICSU).

GCOS published its Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS_IP), GCOS-92, in 2004, and followed up with a Satellite Supplement to the GCOS Implementation Plan ("Systematic Observation Requirements for Satellite-based Products for Climate - Supplemental details to the satellite-based component of the GCOS Implementation Plan", GCOS-107, September 2006).

The GCOS IP lists a number of Essential Climate Variables (ECVs) for which sustained and climate quality measurements are needed to track and analyze climate change.

Table 1. Essential Climate Variables that are both currently feasible for global implementation and have a high impact on UNFCCC requirements.

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface:**	Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour.
	Upper-air:	Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties.
	Composition:	Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases[2], Aerosol properties.
Oceanic	**Surface:**	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure.
	Sub-surface:	Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.
Terrestrial[3]	River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance.	

In its document "Satellite Observation of the Climate System – the Committee on Earth Observation Satellites (CEOS) Response to the Global Climate Observing System (GCOS) Implementation Plan", CEOS reviewed the requirements for satellite observations of the climate system as outlined in GCOS-107, evaluated the adequacy of the current observations system to meet these requirements, and developed an action plan to address inadequacies.

The CEOS report identified 59 actions (listed in Appendix 2) that cover key aspects of climate-related observation of the atmosphere, ocean and land. The report emphasized the importance of satellite measurements of the highest reliability to provide the long term records needed to monitor climate change. The CEOS Climate Actions fall into the following six key categories:

1. Ensuring continuity of climate-relevant satellite measurements (13 actions);
2. Taking a systematic approach to generating Fundamental Climate Data Records (FCDRs) (11 actions);
3. Preserving climate data records (4 actions);
4. Ensuring access to climate data products (10 actions);
5. Coordinating international communities and interaction with users (10 actions); and
6. Addressing future measurement needs (11 actions).

In 2007, CEOS Members initiated work in close coordination with GCOS and the Group on Earth Observations (GEO), and with other relevant *fora*, such as the Coordination Group for Meteorological Satellites (CGMS) and the WMO, to jump-start a first set of about 20 high priority actions. To this end, CEOS has assembled international teams, involving all concerned agencies, to implement the 20 high priority Climate Actions and to initiate work on some of the priority 2 and 3 actions.

The CEOS Action Plan is part of a broader CEOS response to the observational requirements of the Global Earth Observation System of Systems (GEOSS). It deals specifically with the Climate Societal Benefit Area (SBA) of GEOSS under GEO Climate Work Plan activity **CL-06-02: Key Climate Data from Satellite Systems.** This Task is led by the USA, CEOS, GCOS and WMO and it establishes actions securing the provision of key data for climate studies and forecasting from satellite systems.

The results to date of the CEOS Action Plan are summarized in this report.

2 Importance of Satellite Component of GCOS for Climate

The conventional (non-satellite) observational systems of the GCOS include atmospheric, oceanic, and terrestrial components. The atmospheric component includes the GCOS Surface Network (GSN), which provides the basic weather measurements of the surface climate in which we live; the GCOS upper air network (GUAN), which measures temperature, humidity, and winds aloft; and the Global Atmosphere Watch (GAW) global ozone network. The surface ocean network provides information about the patterns of ocean surface temperature, pressure, winds, salinity, sea level, waves and sea ice that are important both to the global climate and its regional distribution. Its main systems are: (a) the GCOS baseline network of tide gauges; (b) an enhanced drifting buoy array; (c) an enhanced Tropical Moored Buoy network; (d) an enhanced Voluntary Observing Ships Climatology (VOSClim) network; and (e) a globally-distributed reference mooring network. The sub-surface ocean network provides critical information on ocean climate variability and change and includes: (a) the Argo profiling float array; (b) the systematic sampling of the global ocean full-depth water column; (c) the Ship-of-Opportunity Expendable Bathythermograph (XBT) trans-oceanic sections; and (d) the Tropical Moored Buoy and reference mooring networks. The climate observing system in the Terrestrial Domain remains the least well-developed component of the global system. GCOS is working to set up reference and baseline networks to measure the terrestrial ECVs.

While the conventional observing networks provide critical climate measurements at a number of points around the globe, they have severe limitations when it comes to observing global climate change. For the most part, the atmospheric observations are limited to the land areas of the Earth and are highly concentrated in the major population centers of the developed countries. Ocean areas – 70% of the globe – are largely undersampled in terms of the atmospheric measurements. And there are also large holes in the coverage of surface and sub-surface ocean measurements. Developing a reliable picture of global climate change from an observing system that has such large gaps in coverage is a formidable task.

Only satellites provide the global coverage needed to observe and document global climate change. A single radiometer on a polar orbiting satellite observes the entire earth on a daily basis. Instruments on geostationary satellites monitor the diurnal cycle of the disk of Earth below them. Together the polar and geostationary environmental satellites maintain a constant watch on the entire globe.

The global constellation of Earth observing satellites includes both operational and research satellites. The operational satellites include polar and geostationary satellites operated by the USA, Europe, China, Russia, Japan, India and soon Korea. Designed originally for weather observations, these satellites are now the core of the space component of GCOS. Since they are operational, they are replaced upon failure of systems, and thus provide the continuity of records needed to determine if the climate is changing and at what rate. The operational satellites are manifesting more special climate sensors – ozone, for example – and improving the accuracy of their observations to meet the stringent accuracy requirements for climate. Research satellites provide critical data, but only for the duration of their mission. They provide platforms for evaluating and demonstrating the capabilities of advanced instruments. Proven research sensors are eventually flown operationally as a result of the research to operations process. Examples of

such research satellite programs include the National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS), The European Space Agency's (ESA) Earth Explorers, and Japan Aerospace Exploration Agency (JAXA) Global Change Observation Mission (GCOM).

3 Development of the CEOS Climate Action Plan

3.1 The climate actions

The CEOS report "Satellite Observation of the Climate System – the Committee on Earth Observation Satellites (CEOS) Response to the Global Climate Observing System (GCOS) Implementation Plan" identified 59 Climate Actions (Appendix 2) to support the necessary improvements in the space component of the GCOS. These actions comprise the CEOS Climate Action plan. CEOS teams, in coordination with GCOS, reviewed these actions and decided to initially focus on 20 of the highest priority actions, including specific actions for each climate domain - atmospheric, oceanic, or terrestrial – and more general cross-cutting actions. The domain-relevant actions were selected because they could be started immediately and were capable of delivering significant outcomes within a 1-2 year timescale. The cross-cutting actions were chosen because they are critical, ongoing climate activities that involve all the CEOS agencies. An additional 32 actions were classified as priority 2 because they required additional information from potential contributors in order to be suitably defined and would not necessarily deliver significant results in the 1-2 year timescale. Five actions were labelled priority 3 because they were considered premature at this stage.

The subjects of the high priority actions for each climate domain are listed in the following table.

Table 2. Subjects of High Priority Actions for Each Climate Domain

Atmospheric Domain	Subject
A-3	Cloud properties and trends
A-4	Improved precipitation measurements: The Precipitation Constellation
A-5	Absolute, spectrally resolved radiance measurements
A-6	Earth Radiation Budget Sensor
A-7	Total Solar Irradiance Sensor
A-8	Ozone Mapping and Profiler Sensor limb instrument
A-9	Aerosol Polarimetry Sensor
Oceanic Domain	
O-1	Microwave and Vis/IR (Infrared) observations of sea ice
O-2	Generation of sea ice data records
O-4 and O-5	Future Ocean Surface Topography Constellation for sea level and altimeter to fill potential gap in sea level measurements
O-6	Missions to maintain continuity and improve sea surface temperature record
Terrestrial Domain	
T-1	Basis for future Land-surface Imaging Constellation
T-4	Improving quality of FCDRs and ECVs from the Advanced Very High Resolution Radiometer (AVHRR) record

The high priority cross-cutting actions are focused on improving international coordination mechanisms for space-based climate observations, developing and maintaining on-going working relationships with GEO and GCOS, assuring adherence to GCOS Climate Monitoring Principles, improving the accuracy and intercomparability of satellite observations of the Earth, and providing easy access to climate data.. These actions have already led to the initiation of a CEOS Plan for Virtual Constellations in support of GEOSS and improved coordination within CEOS and of CEOS agencies with GEO and GCOS. A major accomplishment in 2007 was the development by the **CEOS Working Group on Information Services and Systems (WGISS)** of a capability for climate data users throughout the world to access any data on Essential Climate Variables contributed to the CEOS International Directory Network by CEOS agencies. **ESA** is currently proposing a programme that will address about half of the GCOS defined ECVs through the satellite data archives in ESA, its member states and other partners. Strong cooperation through CEOS is needed and foreseen.

3.2 Implementation process for climate actions

To carry out the Climate Actions, CEOS named a Climate Coordinator, organized Climate Action Teams, consisting of representatives from the CEOS agencies, and selected a lead agency and leader for each Team. The Climate Coordinator is responsible for coordinating the Climate Action program, reporting to the CEOS Strategic Implementation Team, and preparing this report to the UNFCCC. CEOS developed reporting forms and a schedule for gathering progress reports from the Climate Action Teams. Each of the agencies contributing to the Climate Actions agreed to undertake tasks to implement the Actions. The Team Leaders coordinate the activities of agencies contributing to their Climate Actions, serve as liaisons between the CEOS Climate Coordinator and team members, and act as rapporteurs for their Climate Actions.

4 Status of High Priority Actions for Each Domain

4.1 Introduction

This section discusses the status of the high priority actions in the CEOS Climate Action Plan for each Domain (Atmospheric, Oceanic, and Terrestrial). An overview of each Domain is presented, which includes a high level summary of the actions and results in that Domain. This is followed by a report on each Climate Action in the Domain, which includes the Action Statement, the importance/significance of the Action for climate information, and the status of the Actions.

4.2 Atmospheric domain

4.2.1 Overview of atmospheric domain actions

The seven high priority Atmospheric Domain Climate Actions include improving information on clouds, precipitation, earth radiation budget, solar irradiance, ozone profiles, and aerosols. Cloud information is being improved by developing improved cloud data records from long-term records of the operational vis/IR imagers and sounders and by creating new datasets from recent research satellite missions that fly cloud radars and lidars. **ESA** and **JAXA** are preparing the EarthCARE mission, a follow-on to CloudSAT/ CALIPSO, for flight in 2013. Planning, led by **NASA** and **JAXA**, has started on a **Precipitation Constellation** that will include both radar and passive microwave components. **NOAA** and **NASA** have developed plans for re-manifesting important climate sensors – Clouds and the Earth's Radiant Energy System (CERES), Total Solar Irradiance Sensor (TSIS), Ozone Mapping and Profiler Suite (OMPS)-Limb, and the Aerosol Polarimetry Sensor (APS) - that were dropped from its National Polar-orbiting Operational Environmental Satellite System (NPOESS) program. **JAXA** started developing the Global Change Observation Mission (GCOM) series. The Second generation Global Imager (SGLI) on GCOM-C1 observes global cloud and aerosol properties and is capable of performing polarimetric observation of aerosol. GCOM-W1 carries the Advanced Microwave Scanning Radiometer-2 (AMSR2) to observe water vapor, cloud liquid, and precipitation.
NASA and the **National Physical Laboratory** (UK) have initiated planning of a satellite mission to obtain highly accurate benchmark measurements of the Earth's reflectance and emission spectra to detect the slow changes in climate.

4.2.2 Action A-3

4.2.2.1 Action statement: CEOS will support in 2007 investigations of cloud properties and cloud trends from combined satellite imager plus sounder measurements of clouds (with horizontal as well as vertical information) using Cloudsat/ Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) for validation.

4.2.2.2 Importance/significance of this action for climate information

This action provides more reliable information on long-term changes in clouds and their properties. Inadequate knowledge about what will happen to clouds in a greenhouse world is one of the major causes of uncertainty in model predictions of global climate change. The recent

launch of satellites – Cloudsat and CALIPSO - with active sensors (radars and lidars) to observe clouds represents a giant step forward in observing capability. For the first time, it is possible to measure the vertical structure of clouds. But the new sensors also permit reliable checks on the inferences of cloud properties and their trends from the much longer record of passive instruments – imagers and sounders – as is being done in this action.

4.2.2.3 Status of the action

The **Canadian Space Agency (CSA)** is supporting CloudSat-CALIPSO Cal/Val and modelling work being led by Environment Canada (EC). During winter 2006/07 the Canadian CloudSat-CALIPSO Validation Project (C3VP) was held in southern Ontario and Quebec with CSA, EC (Canada), and National Research Council (NRC) co-investment. This campaign included a fixed surface site and the NRC's Convair-580 aircraft. The Convair was instrumented with remote sensing devices similar to those onboard the satellites as well as numerous direct cloud sampling probes. Total flight time exceeded 100 hours. The primary objective of C3VP was to verify CloudSat and CALIPSO retrievals of cold season cloud and precipitation. Other validation activities in 2007 with similar objectives were the radar/lidar observations at Eureka (80°N) associated with Polar Environment Atmospheric Research Laboratory/International Polar Year (PEARL/IPY) studies and five additional flights by the Convair in November near southern Baffin Island as part of the Storm Studies in the Arctic experiment. The use of the EC (Canada) radar network to validate CloudSat precipitation products across Canada on an ongoing basis was started in 2007. The results from these activities will ultimately work toward development of improved cloud/precipitation parameterizations in large-scale numerical models with applications to energy and water budget studies.

In the summer of 2007, as part of the Tropical Composition, Cloud and Climate Coupling (TC-4) Experiment, **NASA** fielded the ER-2, WB-57F, and DC-8 to investigate the processes controlling the distribution of tropical cirrus as well as the microphysical and optical properties of those clouds. In addition, the observations were meant to provide calibration and validation of A-Train satellites. Special sessions presenting TC-4 and some preliminary results took place at the fall 2007 meeting of the American Geophysical Union (AGU) in San Francisco. In addition, a TC-4 Science Team meeting was held in late February 2008. Substantial progress has been made refining our understanding of measurements of cirrus cloud microphysical and optical properties made by in-situ instruments and relating those measurements to cloud measurements by satellites. Furthermore, a number of cloud process modeling studies have made use of the TC-4 observations.

NOAA has developed a new tool that uses CALIPSO observations to characterize the performance of passive cloud detection, cloud typing and cloud height algorithms. The performance relative to CALIPSO is stratified by the CALIPSO-based cloud height and cloud emissivity. This information is critical for understanding why different climatologies from different sensors disagree. NOAA has applied this tool to data collected from August 2006 to both Meteosat Second Generation (MSG)/ Spinning Enhanced Visible and Infra-red Imager (SEVIRI) and NOAA-18/AVHRR, and plans to also utilize CloudSat for verification of passive cloud measurements.

NASA and **NOAA** are supporting an effort to study combined imager and sounder cloud property estimation; Moderate Resolution Imaging Spectroradiometer (MODIS) plus Atmospheric Infrared Sounder (AIRS) cloud properties will be studied initially and then generalized to AVHRR plus the High Resolution Infrared Radiation Sounder (HIRS), AVHRR plus the Infrared Atmospheric Sounding Interferometer (IASI), and the Visible Infrared Imager radiometer Suite (VIIRS) plus the Cross-track Infrared Sounder (CrIS). As part of this work (1) Pathfinder Atmospheres-extended (PATMOS-x) outputs are being planned for HIRS cloud properties to assist with cloud fraction estimates within a HIRS field of view and (2) enhanced cloud top products based on a combination of AVHRR and IASI data are being developed through interaction with scientists working within **EUMETSAT's** Satellite Application Facility Network (CM SAF and NWC SAF) plans this enhanced product for review in 2010 (Product Consolidation Review) and 2011 (Operational Readiness Review). Validation will be performed against ground based cloud radar and lidar and CloudSat/CALIPSO products.

The **French Centre National d'Eétudes Spatiales (CNES**) is operating two R&D satellites to monitor cloud properties: Calipso (with **NASA**) and Parasol. A thematic data center, ICARE, located in Lille (France) is supported CNES and other French institutes to produce and distribute global satellite data sets on atmospheric clouds, aerosols and water vapor. **CNES** also supports scientists to monitor cloud properties using imager/sounder satellite data: Parasol-Modis algorithms for global cloud properties, Calipso (Caliop and IIR) and Cloudsat algorithms and validation for cloud properties, HIRS and AIRS for cirrus global properties and trends, anddevelopment of a Calipso simulator for climate models.

In October 2007, in Lille (France), the A-Train 2007 Symposium was organized by **CNES** and other French institutes and gathered 270 international scientists working on A-Train data for aerosol and cloud measurements. Several sessions dealt with cloud global observations and modelling. Results have confirmed the importance of the vertical information given by the Calipso lidar and the Cloudsat radar. Climate modellers already use A-Train data on clouds to prepare the future CFMIP climate model intercomparison exercises.

In November 2007, a reprocessing of the entire Polder-1/Polder-2 archive was completed in the ICARE data center to produce all atmosphere products (aerosols and clouds) with the latest generation of science algorithms used to process the Parasol data, such that a consistent Polder-1, Polder-2 and Parasol archive is now available.

In 2007 and 2008, several experimental campaigns have been conducted by French scientists with instrumented airplanes to study the microphysical and radiative properties of clouds and to validate cloud parameters measured by Calipso and Cloudsat: Astar (Spitzberg) in April 2007 (mixed phase clouds with the German Polar2 aircraft), Circle-2 (midlatitudes) in May 2007 (cirrus clouds with the German Falcon20 and the French Falcon20), Polarcat (Sweden) in April 2008 (ice arctic clouds with the French ATR42 aircraft).

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plus the Infrared Atmospheric Sounding Interferometer (IASI), and the Visible Infrared Imager radiometer Suite (VIIRS) plus the Cross-track Infrared Sounder (CrIS). As part of this work (1) Pathfinder Atmospheres-extended (PATMOS-x) outputs are being planned for HIRS cloud properties to assist with cloud fraction estimates within a HIRS field of view and (2) enhanced cloud top products based on a combination of AVHRR and IASI data are being developed through interaction with scientists working with the EUMETSAT Polar System (EPS)/ Meteorological Operational satellite programme (MetOp) processing in Darmstadt Climate Monitoring (CM-) Satellite Applications Facility (SAF) plans this enhanced product for review in 2010 (Product Consolidation Review) and 2011 (Operational Readiness Review).

ESA and **JAXA** are jointly developing the EarthCARE satellite, a follow-up missionto CloudSAT/ CALIPSO. Phase-B will becompleted in 2009 and launch is scheduled for 2013.

4.2.3 Action A-4

4.2.3.1 Action statement: CEOS agencies will ensure continued improvements to precipitation determinations demonstrated by Tropical Rainfall Measuring Mission (TRMM) and planned by Global Precipitation Measurement (GPM) in 2010. The Japan Aerospace Exploration Agency (JAXA) and the National Aeronautics and Space Administration (NASA) will lead a CEOS study team to establish, by 2007, the basis for a future Global Precipitation Constellation.

4.2.3.2 Importance/significance of this action for climate information

Precipitation is arguably the most important climate variable, affecting agricultural production, flooding and droughts, and water resources. Improved information of climatic precipitation trends will enable countries throughout the world to prepare plans to mitigate and adapt to precipitation changes. The research satellite TRMM demonstrated the ability of radar to measure precipitation from space. Extension of radar observations coupled with passive microwave measurements from a constellation of satellites will provide the detailed maps of global precipitation needed to monitor trends and check on model predictions of precipitation.

4.2.3.3 Status of the action

In June 2007, **NASA and JAXA** established the CEOS Precipitation Constellation (PC) at the 1st CEOS PC Workshop held in Washington, DC. Thirty representatives from 15 international organizations and space agencies confirmed their participation. A 2007 PC Work Plan was finalized and accomplishments were documented in the 2007 PC Final Report. The 2nd CEOS PC Workshop was held in Tokyo, Japan in June 2008 with nearly 30 CEOS space agency and user community participants. The 2008 PC Work Plan and PC Implementation Plan have been finalized. Recent accomplishments from the PC include:

- The 7th GPM International Planning Workshop, in December 2007, which was hosted by JAXA. The workshop, which was attended by 146 participants from 15 countries, had an agenda that included a review of the GPM program/project and data utilization from an Asian perspective.
- X-Calibration Working Group (WG) meeting in January 2008 which was held in coordination with the WMO CGMS/ Global Space-Based Inter-Calibration System

(GSICS). The WG is supported by NASA, JAXA, NOAA, the U.S. Naval Research Laboratory (NRL), and the Indian Space Research Organization (ISRO). This is an important step in establishing how PC data should be intercalibrated at the antenna and brightness temperature stage.

- Progress in moving GPM from formulation to implementation phase at NASA and JAXA through completion of numerous technical and programmatic milestones. JAXA entered Phase C in 2Q2008. NASA will do so in the first quarter of 2009 following the completion of the GPM Mission Preliminary Design Review in forth quarter of 2008.
- The 2nd CEOS Precipitation Constellation Workshop, in June 2008, which was hosted by JAXA. The workshop, which was attended by 26 participants from nine agencies, had an agenda that included a review and discussion of the Workplan for 2008 and the 10 year implementation plan.
- Initiating four CEOS Category 1 Actions of which two have been completed as of July 14, 2008.
    - DA-07-03_2: Coordinate international GPM ground validation (GV) activities and establish the scope of joint GV projects during the year.
    - CL-06-02_2: Make precipitation data available to a broad additional group of users who are more familiar with Geographic Information Systems (GIS) than the satellite data formats. **COMPLETED**
    - DA-07-03_6: Precipitation Processing System (PPS) assumes TRMM data processing. **COMPLETED**
    - DA-07-03_1: Complete the initial phase of the first intercomparison study undertaken by the Precipitation Measurement Missions (PMM) Science Team intercalibration working group in coordination with the CGMS/GSICS (see above).

The 2008 PC Work Plan includes 38 joint activities with 18 deliverables. These will be reported on in the 2008 PC Final Report

The **International Precipitation Working Group (IPWG)** held the 2nd International Workshop on Space-based Snowfall Measurement (March 31 - April 4) in Steamboat Springs, CO. Some key recommendations from the workshop include:

- Recommendation 1: Encourage the generation of community Cloud Resolving Model/ Numerical Weather Prediction (NWP) model profile databases that represent natural variability.
- Recommendation 2: Use "modeling chains" as a basic research tool to develop an understanding of the relationship between snowfall and radiative transfer.
- Recommendation 3: Recognize "Data Assimilation" as a necessary component of snow analysis from space-based measurements.
- Recommendation 4: Continue community efforts to study and develop high-latitude surface emissivity data bases (10-200 GHz) including error estimates are strongly recommended.
- Recommendation 5: Use combined active and passive satellite data for snowfall detection/retrieval.

- Recommendation 6: Develop future space borne measurement platforms with high sensitivity to detect reflectivity down to within 100-200 m of the surface and with a sensitivity of -20- -30 dBz.
- Recommendation 7: Study promising (118 GHz oxygen absorption band and window frequencies between 130 and 170 GHz).
- Recommendation 8: Enhance high level coordination of international Ground Validation programs for snowfall.
- Recommendation 9: Establish MW transmission links with parallel particle probing, inter-sensor validation in radiance/reflectivity space, and statistically robust datasets for dedicated validation of (frozen) cloud processes.

Launch year of GPM has been changed from 2010 to 2013.

4.2.4 Action A-5

4.2.4.1 Action statement: CEOS will plan by 2011 to make absolute, spectrally resolved measurements of radiance emitted and reflected by the Earth to space for information on variations in both climate forcings and responses.

4.2.4.2 Importance/significance of this action for climate information

Accurate decadal-length records are essential for climate change detection, attribution, and for testing climate prediction accuracy. This action will result in high accuracy, hyperspectral benchmark measurements of solar reflected and infrared emitted radiance that can be used to monitor climate change, test climate model predictions, and improve climate change fingerprinting and attribution. Such measurements will also serve as an orbiting calibration observatory that can be used to calibrate other solar and infrared space-borne sensors (e.g. VIIRS, CrIS, Landsat, Geostationary, CERES) and thereby improve to climate accuracy a wide range of sensors across the GEO observing system.

4.2.4.3 Status of the action

In the US, the Climate Absolute Radiance and Refractivity Observatory (CLARREO) Mission has been recommended in the NRC Decadal Survey as a key component of the future climate observing system. **NASA** and **NOAA** share responsibility for CLARREO. The NOAA component involves the continuity of measurements of incident solar irradiance and Earth energy budget by flying the TSIS and CERES sensors that were removed from NPOESS. The NASA portion involves the measurement of spectrally resolved thermal IR and reflected solar radiation at high absolute accuracy. Coupled with measurements from on-board Global Positioning System (GPS) Radio Occultation (RO) receivers, these measurements will provide a long-term benchmarking data record for the detection, projection, and attribution of changes in the climate system. In addition, the International System of Units (SI) traceable radiances will provide a source of absolute calibration for a wide range of visible and IR Earth observing sensors, greatly increasing their value for climate monitoring.

After the initial CLARREO workshop held in 2007, NASA scientists have been actively disseminating CLARREO related information at major conferences. One segment of CLARREO is the potential collaboration between **NASA** and **NPL** (UK) on the TRUTHS for the solar

reflective spectrum. CEOS is facilitating this potential collaboration through the Working Group on Calibration/Validation (CEOS/WGCV) and the CEOS/SIT (Strategic Implementation Team), since both NASA and NPL are active CEOS members.

The early study phase of CLARREO has been initiated by NASA. Dialogue between NASA and NPL has been established, although it is still too early to develop formal associations. It is expected that during the next year a clear definition of CLARREO will emerge and the potential for a mission in partnership with the Traceable Radiometry Underpinning Terrestrial- and Helio-Studies (TRUTHS) team will be evaluated in collaboration with NPL.

4.2.5 Action A-6

4.2.5.1 Action statement: CEOS agencies will participate in re-planning, by 2007, the Earth Radiation Budget Sensor (ERBS) removed from the planned payload of NPOESS.

4.2.5.2 Importance/significance of this action for climate information

Continuity of earth radiation budget measurements will be assured. The Earth's radiation budget is the dominant control of the earth's climate. These measurements of the net input of solar energy and loss of heat energy, and their variations over the globe and with time, are first order quantities for diagnosing our climate system.

4.2.5.3 Status of the action

The **NOAA, US Department of Defense (DoD), and NASA** NPOESS program recently decided to place the CERES instrument on the NPOESS Preparatory Project (NPP) in 2010. This will assure continuity of measurements between NASA research satellites and first NPOESS spacecraft's CERES instrument. The President's FY2009 budget request for **NOAA** includes funds to build another CERES instrument to fly on the first NPOESS planned for 2013 launch.

4.2.6 Action A-7

4.2.6.1 Action statement: CEOS agencies will participate in re-planning, by 2007, TSIS removed from the planned payload of NPOESS.

4.2.6.2 Importance/significance of this action for climate information

Continuity of total solar irradiance measurements will be assured. Such observations are crucial to determine whether the sun's output is changing, thus possibly enhancing or offsetting greenhouse warming.

4.2.6.3 Status of the action

The President's FY2009 budget request for **NOAA** includes support for instrument development and ongoing analyses to identify a suitable satellite platform, such as the NPOESS C1 satellite in 2013, for hosting the TSIS instrument.

4.2.7 Action A-8

4.2.7.1 Action statement: CEOS agencies will participate in re-planning, by 2007, the OMPS limb instrument removed from the planned payload of NPOESS.

4.2.7.2 Importance/significance of this action for climate information

The sensor will measure the vertical distribution of ozone concentrations in the stratosphere. It will monitor the ozone layer and the slow recovery of the ozone hole as chlorofluorocarbon (CFC) concentrations decrease over the coming decades as a result of actions taken by the international community under the Montreal Protocol on substances that deplete the Ozone Layer to limit CFC emissions into the atmosphere. It will also monitor interactions between climate change and the ozone layer.

4.2.7.3 Status of the action

NOAA and NASA have added the OMPS-Limb portion of the sensor back to the OMPS-Nadir portion on NPP as a research instrument. NPP is scheduled for launched in 2010. Thus far, resources have not been identified for re-manifesting OMPS-Limb on NPOESS.

4.2.8 Action A-9

4.2.8.1 Action statement: CEOS agencies will participate in re-planning, by 2007, the APS instrument removed from the planned payload of NPOESS.

4.2.8.2 Importance/significance of this action for climate information

The APS is the only instrument currently capable of making measurements that can distinguish various species of aerosols. Such differentiation is important since atmospheric aerosols (particles) can either enhance or counteract global warming, depending on their composition. Aerosols also impact cloud properties, which could lead to changes in cloud radiative forcing of climate.

4.2.8.3 Status of the action

NASA is developing an APS instrument which is scheduled to be launched on the GLORY mission in 2009. **NOAA** is monitoring that developmental process closely before making a decision to move forward on this sensor.

JAXA started development of Second generation Global Imager (SGLI) on GCOM-C1, which is capable of performing polarimetric observation of aerosol. Development of GCOM-C1 is in Phase-B and its tentative launch year is JFY 2013.

The **CNES** is operating the Parasol satellite which can monitor global aerosol properties. Parasol data and aerosol products are produced and distributed by the ICARE thematic data center, together with other satellite aerosol products (Modis, MSG/Seviri, Calipso…).

In 2007, **CNES** began a Phase 0 study for a Parasol follow-on instrument, called 3MI (Multiviewing multichannel multipolarization imager), for climate aerosol monitoring in the frame of the Eumetsat Post-EPS programme. 3MI is an alternative concept, simpler and cheaper, for aerosol monitoring. Another possibility for accurate and complete aerosol measurements would be to combine 3MI and APS. **NOAA** has declared an interest in the results of the 3MI phase 0 study.

On October 2007 the 25th, a "Polarization meeting"entrained **NASA, CNES,** US and European scientists to begin informal scientific-programmatic discussions about the future of polarization missions devoted to aerosol (and cloud) monitoring. It was decided to develop a common simulator/testbed for the analysis of future polarization missions.

By 2008, the Parasol satellite had produced more than 3 years of global aerosol measurements, and its mission was extended to Spring 2010 inside the A-Train. This will permit simultaneous aerosol measurements from Parasol and Glory (launch in 2009) and comparisons the advantages of the two instrumental concepts.

4.3 Oceanic domain

4.3.1 Overview of oceanic domain actions

Oceanic domain actions will result in improved climate data records for sea ice, sea level, and sea surface temperature. **NOAA** has developed a new microwave retrieval system for sea ice and **ESA** will use its Soil Moisture and Ocean Salinity (SMOS) observations to monitor thin sea ice. CEOS agencies are coordinating a reprocessing of microwave observations to obtain more reliable sea ice trends. NOAA and the **European Organisation for the Exploitation of Meteorological Satellites** (EUMETSAT) are leading a CEOS study team to establish the basis for a future **Ocean Surface Topography Constellation** that could lead to operational sea level measurements. The **Centre National d'Etudes Spatiales** (CNES) and the **ISRO** will cooperate on a new polar-orbiting altimeter aimed at filling a potential data gap beyond 2008, and **ESA** plans to fly an altimeter on its Sentinel-3 mission in 2013. **ESA** and **JAXA** are both planning to fly advanced IR radiometers for high quality Sea Surface Temperature (SST) observations. **JAXA** plans to launch an Advanced Microwave Scanning Radiometer-2 (AMSR2) on the GCOM-W1 satellite in 2012 that will measure sea ice and ocean temperature.

4.3.2 Action O-1

4.3.2.1 Action statement: CEOS agencies will examine their respective plans to maintain provision of microwave brightness temperatures and visible/infrared radiances for the sea ice Essential Climate Variable (ECV).

4.3.2.2 Importance/significance of this action for climate information

This action will lead to much improved mapping of sea ice concentrations and albedo changes resulting from global warming. As sea ice melts, the ocean surface reflects much less solar

radiation than did the ice, leading to greater absorption of solar radiation. This results in a positive feedback on the greenhouse forcing and more rapid warming of the polar oceans.

4.3.2.3 Status of the action

NOAA plans to launch polar-orbiter NOAA-N' (NOAA-19) on February 2009 with onboard Advanced Microwave Sounding Unit (AMSU) and Microwave Humidity Sounder (MHS) sensors, AVHRR (infrared/visible) and HIRS (infrared). This is a follow on mission to NOAA-18. According to plans, there would be a continuous provision of microwave and visible/IR radiances in the future to monitor sea ice with the Advanced Technology Microwave Sounder (ATMS), CrIS and VIIRS that will fly onboard the NPP mission (polar orbit), scheduled for 2010 and the NPOESS starting 2015. Onboard NPOESS are two microwave sensors; the same ATMS flying on NPP as well as a conical Microwave Imager & Sounder (MIS), in addition to the CrIS and VIIRS sensors.

JAXA plans to launch the GCOM-W1 satellite in the beginning of 2012 with onboard Advanced Microwave Scanning Radiometer-2 (AMSR2), which will continue the current measurements of AMSR-E.

The heritage for these sensors are SSMI, SMMIS, AMSU, MHS, AMSR-E for ATMS, and AMSR2, HIRS, MODIS, AVHRR, IASI, AIRS, for CrIS and VIIRS. All these sensors provide a good mapping of sea ice covered areas.

For SMOS, **ESA** is conducting a study on assessment and validation of retrieval and processing, with the aim to:

- Quantify the following influences of sea ice on the global climate system:
    - Surface heat and brine flux by retrieving regions of thin ice, its thickness and of open water regions (together with the Advanced Microwave Scanning Radiometer - EOS (AMSR-E)).
    - Freshwater flux and albedo changes due to melt and melt pond retrievals.
    - Use of SMOS data for retrieval of surface and atmospheric parameters in Polar Regions; use of these data for assimilation into circulation models of atmosphere and ocean for both climate and NWP research.

4.3.3 Action O-2

4.3.3.1 Action statement: Relevant CEOS space agencies will consult with the science community on appropriate retrieval algorithms of passive microwave observation for reprocessing sea-ice products. Norway has expressed interest in committing to operational production of a global sea ice ECV (an initiative by the Norwegian Meteorological Institute, and coordinated by the **Norwegian Space Center**). **ESA** is currently reprocessing the relevant ERS and Environmental Satellite (ENVISAT) archive to complement Canada's Radarsat in the context of the World Climate Research Programme's (WCRP) Climate and the Cryosphere (CliC) core project.

4.3.3.2 Importance/significance of this action for climate information

This action leads to a more coordinated international approach to measure sea ice from satellites. By consulting with the sea ice science community, CEOS agencies will have the benefit of the best available algorithms for reprocessing microwave observations to obtain a reliable record of sea ice trends over the past few decades.

4.3.3.3 Status of the action

The **EUMETSAT**/ Ocean and Sea Ice (OSI) SAF project is conducting a sea ice reanalysis project to elevate the passive microwave sea ice products into one coherent, CDR-quality product, including error estimates or quality flags. The SMMR-SSM/I data is reanalyzed using dynamic tiepoints for handling sensor and inter sensor variations and data quality flags and error estimates are given for all observations. The project is in co-operation with **UK Met Office** and **NOAA's National Snow and Ice Data Center (NSIDC)**.

The **NCS** project on a service for global ECV sea ice products based on OSI SAF daily products is ongoing. The project is developing an operational monitoring service (EuroCryoClim), which includes production of global sea ice products, including an historical time series, and will enter a demonstration phase in September 2008.

NOAA has evaluated and implemented operationally a novel approach to determining sea ice concentration from microwave measurements. This method is based on the emissivity spectrum (retrieved using a variational algorithm) instead of the brightness temperatures. This has the advantage of eliminating the atmospheric contamination from the signal before it is used. This algorithm called the Microwave Integrated Retrieval System (MIRS), is applied routinely to NOAA-18 and METOP-A data and recently has been extended to the Defense Meteorological Satellite Program satellite F16 (DMSP F16) SSMIS data. The fact that the algorithm is applied uniformly to microwave sensors, makes it a candidate for climate processing. A by-product of the sea ice concentration retrieved from MIRS, is the simultaneous determination of the sea ice age (multi/first year).

NOAA's NSIDC has started a project to improve consistency and accuracy assessment of the Scanning Multichannel Microwave Radiometer (SMMR)-SSM/I time-series to provide continuity with AMSR-E and future NPOESS and GCOM sea ice products.

ESA is currently conducting the GlobIce project as part of the Data User Element. The project is in phase one and ESA has already delivered some 20000 satellite products to the project.

4.3.4 Actions O-4 and O-5

4.3.4.1 Action statement:

NOAA and **EUMETSA**T will lead a CEOS study team to establish, by 2007, the basis for a future **Ocean Surface Topography Constellation** that satisfies the threshold requirements for the sea level ECV (and those of the sea state ECV). This will include consideration of a future Jason-3 mission and requirements for new altimeter technologies to improve spatial resolution and extend observations in coastal regions (and over lakes and rivers for the lakes ECV). The **Centre National d'Etudes Spatiales** (CNES) and the **Indian Space Research Organization** (ISRO) will cooperate on a new polar-orbiting altimeter aimed at filling a potential data gap beyond 2008. **ESA** and the **European Union** (EU) will lead planning for Sentinel-3 carrying an altimeter to complement spatial/temporal coverage of the sea level (and sea state) ECVs (and possibly sea ice extent and thickness, river, and lake level with the altimeter operating in Synthetic Aperture Radar (SAR) mode beyond 2012).

4.3.4.2 Importance/significance of this action for climate information

Sea level increase due to climate change is a major threat to most nations. Accurate observations are crucial for assessing the rate of sea level rise, enabling threatened countries to prepare for this threat. This climate action would take satellite sea level measurements out of the research arena and place it on an operational basis, thus guaranteeing that global sea level would be routinely monitored from satellites on a continuous basis. The CNES/ISRO altimeter would fill a potential gap in sea level measurements until the **Ocean Surface Topography Constellation (OST)** or the ESA Sentinel-3 is flying.

4.3.4.3 Status of the action

In January 2008, the OST Constellation Team, led by **NOAA** and **EUMETSAT,** held a workshop to develop a strategy for implementation (over the next 15 years) of the recommendations from the Venice Symposium. The team has developed an approach to assure continuity of ocean sea level measurements beyond Jason-2 (launched June 2008). The approach identifies a launch date for Jason-3 depending on whether or not it is a clone of Jason-2.

The team also held a workshop on Mesoscale and Submesoscale Oceanic Processes: Explorations with Wide-Swath Interferometry Radar Altimetry in April 2008 at the Scripps Institution of Oceanography. They discussed the capabilities needed to meet needs for the Surface Water-Ocean Topography (SWOT) Mission recommended by the NRC Decadal Survey in the 2013-16.

EUMETSAT awarded a contract for preparation of a Mission Requirement Document (MRD) for the Constellation to encompass requirements for both the high accuracy (Jason) altimetry mission and complementary high inclination missions; it will address multi-mission product error budget, coverage & latency, orbits optimization, overlap requirements, and overall availability & reliability requirements; first draft is due early October and final early 2009.

Development of the following altimetry missions is ongoing:

- Cryosat-2 – November 2009 – will be operated over oceans
- Satellite with ARgos and ALtika (SARAL)/AltiKa – Late 2009/10
- HY-2A – June 2010
- Sentinel-3A; -3B – 2012; 2014

Commitment to timely sharing of data following the commissioning phase for each of the missions under development continues to be a major open issue.

Missions on orbit

- **ESA:** Altimeter on 13-yr-old European Remote Sensing satellite (ERS-2) continues to operate, but with direct readout only since 2003; 9 stations now routinely receive data.
- **The United States Navy (USN):** Altimeter on 10-yr-old GEOSAT Follow-On (GFO) continues to operate, but on an intermittent basis due to insufficient power when in eclipse and an overheating reaction wheel when in full sun.
- **ESA:** Altimeter on 6-yr-old ENVISAT continues to operate, but with some degradation in quality due to loss of the auxiliary S-band channel; main Ku-band channel operating with full performance.
- **CNES/NASA:** Altimeter system on 6-yr-old Jason still operating with full performance.
- **CNES/NASA (with EUMETSAT/NOAA):** The Ocean Surface Topography Mission (OSTM)/Jason-2 launch on 20 June 2008 was successful and all systems are checking out on orbit satisfactorily.

Missions in development

- **ESA:** CryoSat-2 satellite undergoing final development activities including completion of instruments prior to integration; launch now scheduled for November 2009.
- **ISRO/CNES:** Launch of SARAL with AltiKa is planned for late 2009, but may slip to mid-2010.
- **China's State Oceanic Administration (SOA) -- with CNES:** HY-2A completed Preliminary Design Review (PDR) last January; inclusion of CNES' Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) in HY-2A payload awaits Chinese Government approval; launch planned for June 2010.
- **ESA:** Sentinel-3 PDR underway this summer with launch of S-3A in 2012 and S-3B in 2014.

Missions in planning

- **EUMETSAT/NOAA/CNES/European Commission (EC):**
  - Consensus has been reached on Jason-3 as the immediate follow-on to OSTM/Jason-2, with a Jason-CS approach to be considered as a "Jason-4".
  - On 1 July the EUMETSAT Council adopted an Initiating Resolution for Jason-3; this formally initiates a Program Preparation which is to be presented and opened for funding at its meeting in December 2008; this will address the EUMETSAT contribution to the European half of the joint Jason-3 mission.
  - While the CNES contribution to the European half of the joint Jason-3 mission is in place, an EC (Europe) contribution remains an issue for resolution.

- NOAA has included an initiative its FY10 budget submission to the Administration to cover the U.S. half of the joint Jason-3 mission.

- **NASA/CNES:**
  - Following a NASA/CNES planning meeting on 20 May 2008, a follow-on technical meeting in September will initiate a feasibility study of the SWOT mission; this was recommended by the recent NRC Decadal Survey for launch in the 2013-16 timeframe.
  - Results from the workshop, *Mesoscale and Submesoscale Oceanic Processes: Explorations with Wide-Swath Interferometry Radar Altimetry* held at the Scripps Institution of Oceanography on 28-30 April 2008, indicate that the anticipated performance of the SWOT measurement system is indeed sufficient to observe the sub-mesoscale (i.e. <100 km).
  - SWOT risk reduction studies are being funded by NASA in FY08 – including measurement requirements for global water storage change, a study of orbits, wet troposphere errors, calibration schemes, satellite bus options; a task plan for FY09 activities for FY09 has been approved.

4.3.5 Action O-6

4.3.5.1 Action statement: An ATSR-like instrument is planned on ESA's Sentinel 3, presently scheduled for launch in 2012. JAXA will lead planning for Global Change Observation Mission-Water (GCOM-W) and GCOM-C (Climate) to maintain continuity of the sea surface temperature ECV.

4.3.5.2 Importance/significance of this action for climate information

This action leads to continuity the Along Track Scanning Radiometer (ATSR) type sea surface temperature measurements. The ATSR has been shown to provide more accurate sea surface temperature measurements than traditional IR instruments.

4.3.5.3 Status of the action

The Advanced Microwave Scanning Radiometer-2 (AMSR2) onboard **JAXA's** GCOM-W1 will provide all-weather microwave SST that complements infrared SST measurements. Development of GCOM-W1 is in Phase-C and of AMSR2 is in review process to proceed to Phase-D. The target launch date of GCOM-W1 is in Japanese Fiscal Year (JFY) 2011. The Second-generation Global Imager (SGLI) onboard GCOM-C1 will provide infrared SST measurement with 500m (coast) and 1km (offshore) spatial resolution. Development of GCOM-C1 is in Phase-B and its tentative launch date is in JFY 2013. The **ESA** Sentinel-3 satellite, which will carry the OLCI (Ocean and Land Colour Instrument) and SLST (Sea and Land Surface Temperature), is currently under implementation. OLCI is a 15-band instrument with 300m (coastal areas) and 1km (open ocean) spatial resolution. SLST has 9 spectral bands and 0.5-1km spatial resolution.

4.4 Terrestrial domain

4.4.1 Overview of terrestrial domain actions

CEOS agencies are evaluating approaches to filling the current Landsat-class data gap and developing a plan for a future Land-Surface Imaging Constellation. CEOS agencies are also reprocessing the 30 year AVHRR data record. By using better satellite intercalibration methods, a more stable time series of AVHRR radiance measurements will be obtained leading to improved time series of land ECVs.

4.4.2 Action T-1

4.4.2.1 Action statement: CEOS agencies will determine which alternative approach best fills the current Landsat-class data gap and will explore the potential of integrating high-resolution data from multiple platforms (e.g., China-Brazil Earth Resources Satellite (CBERS), Indian Remote Sensing (IRS) satellite, Landsat, Satellite Pour l'Observation de la Terre (SPOT), and others) based on the results of a CEOS study team led by the United States Geological Survey (USGS) that will establish, by 2007, the basis for a future **Land-Surface Imaging Constellation.**

4.4.2.2 Importance/significance of this action for climate information

Observations from Landsat-class satellites are crucial for monitoring land cover change due to climate change and deforestation processes. Implementation of this action will enable societies throughout the world will be able to monitor regional trends in their land cover and develop prevention, mitigation, and adaptation programs. Continuity of Landsat-class (mid-resolution optical) imagery of the global land surface has been maintained since 1972. Such continuity is currently threatened by technical problems with Landsat 7 and the uncertain future of the aging Landsat-5. Most potential gaps in this important historical data record can likely be filled by data collected from many other mid-resolution optical land surface imaging satellite systems operated by CEOS agencies. CEOS agencies are developing a strategy – the **Land Surface Imaging Constellation (LSI)** - for maintaining continuity of this data record far into the future.

4.4.2.3 Status of the action

The **LSI Constellation Study Team** met in Sanya, China in February and set three goals for 2008. These are:

1. **Complete Unfinished Tasks from 2007**
    a. Establish agreements among the space agencies that currently operate mid-resolution LSI systems to cooperate more fully in the operation of those systems.
    b. Develop preliminary standards for future mid-resolution LSI systems.
    c. Contribute needed data to the Forest Resource Assessment 2010 (FRA2010) Project.
2. **Initiate a New RADAR Focus Area**
3. **Compile Regional Mid-Resolution Data Sets over Selected (TBD) Areas**

Implementation of these tasks will result in an on-going cooperative project among CEOS space agencies that operate mid-resolution optical LSI satellite systems to develop common and complimentary data acquisition strategies that will maximize global coverage, shorten revisit cycles, increase cloud-free data over partly cloudy regions, and help mitigate negative impacts resulting from failure of one or more mid-resolution satellite systems. Indeed, it is a goal of the cooperative project to develop a consensus and cooperative international strategy for mitigating impact on the user community in the event of failure of one or more mid-resolution LSI satellite systems.

4.4.3 Action T-4

4.4.3.1 Action statement: CEOS will work to enhance the quality of the Fundamental Climate Data Records (FCDRs) and the Essential Climate Records (ECVs) generated from the AVHRR record to meet threshold requirements.

4.4.3.2 Importance/significance of this action for climate information

This action will lead to an improved 30 year record of land surface properties - in particular, vegetation – from the archived AVHRR measurements. Using better satellite intercalibration methods, a more stable time series of AVHRR radiance measurements (FCDRs) will be obtained, resulting in a more accurate record of vegetation trends as well as other ECVs derived from AVHRR measurements.

4.4.3.3 Status of the action

NOAA has made progress in incorporating all available historical AVHRR reflectance calibration coefficients into its calibration testing system. In addition, the PATMOS-x processing system is being readied for a new version that incorporates lessons learned from the analysis of the previous version. The surface reflectance fields, used by the MODIS Atmospheres processing, have also been adopted by PATMOS-x to increase consistency of NOAA's time-series with those from MODIS.

The **EUMETSAT Satellite Applications Facility (SAF) on Land Surface Analysis (LSA SAF) as started** the operational dissemination of the first Metop-AVHRR based Land Surface Analysis (LSA) SAF products (Land Surface Temperature and Downward surface Longwave flux) as "pre-operational" in February 2008. The Metop-AVHRR based surface albedo, snow cover and vegetation (LAI, FVC, fAPAR) products are under development. The first products will be assessed at the Operations Readiness Review in November 2008. The **EUMETSAT SAF on Climate Monitoring** is planning to generate a Surface albedo data set (1982-2011) based on AVHRR GAC data in cooperation with NOAA. This dataset will likely been made available in 2011.

The **Canadian Centre for Remote Sensing (CCRS)** is testing a new AVHRR data processing system called CAPS (Canadian AVHRR Processing System). CAPS aims to achieve GCOS-required pixel location accuracy (including ortho-rectification) close or better than 1/3 FOV. AVHRR-GEO files analogous to MOD03 geolocation files will be generated. Generating clear-sky composites and Bidirectional Reflectance Distribution Function (BRDF) from historical

AVHRR 1-km data over Canada is expected to begin in June 2008 once the testing phase is completed. In addition, **CCRS** is making progress towards the development of a new dynamical scheme for aerosol retrieval and atmospheric correction over land using large in-land water bodies and aerosol climate statistics obtained from MODIS.

Experts from **NOAA, NASA, USGS** and **CCRS** attended a meeting hosted by CCRS and sponsored by the CSA in Ottawa, June 4-5, 2008 in support of implementation of CEOS-GEO action CL-06-02_1 "Measurement consistency for 1-5 km sensors (MODIS, ATSR, and AVHRR)". The major purpose of the meeting was to determine the status, necessary actions and progress toward achieving consistency in radiometric calibration of medium/coarse resolution sensors and developing AVHRR 1-km long-term records for North America. The meeting also served as a useful introductory step toward the NOAA-organized workshop on historical AVHRR calibration to be held later in 2008.

5 Cross cutting actions

5.1.1 Overview of cross cutting actions

The cross cutting actions are focused on improving international coordination mechanisms for space-based climate observations, developing and maintaining on-going working relationships with GEO and GCOS, assuring adherence to GCOS Climate Monitoring Principles, improving the accuracy, and intercomparability of satellite observations of the Earth, and providing easy access to climate data. These actions have already led to the initiation of CEOS Plan for Virtual Constellations in support of GEOSS, improved coordination within CEOS and of CEOS agencies with GEO and GCOS, and a satellite climate data access system for users throughout the world. The cross cutting actions encompass all the climate domains - atmosphere, ocean, and land. They represent community efforts that involve all CEOS agencies.

Cross-cutting actions directed by the **CEOS Working Group on Information Services and Systems (WGISS)** will establish an international climate information system that will enable all countries to easily access the accurate and relevant climate data sets that will result from the domain climate actions as well as past climate data records residing in national archives. The status of these actions is reported below.

5.1.2 Action C-10

5.1.2.1 Action statement: CEOS agencies will coordinate their efforts in designing future data archives and data dissemination systems, ensuring that past data holdings (including associated metadata) are preserved, assessing standards and protocols, and incorporating new information technology (IT) developments as much as possible. Practical actions in response to this cross-cutting need will be developed by CEOS' Working Group on Information Systems and Services (WGISS) in line with the technical solutions adopted by GEO.

5.1.2.2 Importance/significance of this action for climate information

This action will ensure the preservation of past climate data in various archives and make them more easily accessible.

5.1.2.3 Status of the action

This is the ongoing work of **WGISS**, almost in its entirety, and has been for many years. The "new" approach - achieving compatibility with GEO - has been enthusiastically undertaken. WGISS held a parallel meeting with the GEOS Architecture and Data Committee (ADC) and also attended the ADC meeting.

5.1.3 Action C-20

5.1.3.1 Action statement: CEOS agencies will endeavour to ensure global, easy, and timely access to climate-related products, including by developing countries.

5.1.3.2 Importance/significance of this action for climate information

This action will provide all countries of the world with free, easy, and timely access to climate data records.

5.1.3.3 Status of the action

Much attention has been placed on issues of data access for all countries. In the past year, Brazil and China launched a new service that would make data of Africa from their CBERS satellite available free of charge to end-users throughout Africa. In addition, the United States agreed to make its 35 year archive of Landsat data available electronically on line at no charge.

5.1.4 Action C-21

5.1.4.1 Action statement: CEOS will establish a programme in 2007 to document the data archive and access arrangements in place for each of the FCDRs contributed by space agencies. WGISS will lead this effort in order to evaluate practical solutions to current obstacles and issues.

5.1.4.2 Importance/significance of this action for climate information

This action will allow users of climate data to easily navigate through vast climate archives to access the key data sets they are interested in.

5.1.4.3 Status of the action

For FCDRs, the CEOS International Directory Network (IDN) created a portal that provides pointers to every FCDR/ECV that any CEOS agency has entered into the CEOS IDN.

The capability is a “living” one, in that whenever a new FCDR/ECV is entered into the CEOS IDN by a CEOS member agency, that data set will be available in the Portal, its archive and access arrangements in place and reachable through a link.

6 Summary of Key Accomplishments and Future Plans

CEOS agencies have made great strides in implementing the CEOS Climate Action Plan.

In the Atmospheric Domain, CEOS agencies are improving information on clouds, precipitation, Earth Radiation Budget, Solar Irradiance, ozone profiles, and aerosols. Improved cloud data records are being obtained from reprocessing the long term records of the operational vis/IR imagers and sounders and by -creating new datasets from recent research satellite missions that fly cloud radars and lidars. Planning, led by NASA and JAXA, has started on a **Precipitation Constellation** of satellites that will include both radar and passive microwave components. NOAA and NASA have developed plans for re-manifesting important climate sensors – CERES, TSIS, OMPS-Limb, and APS - that were dropped from its NPOESS program. NASA and NPL (UK) have initiated planning of a satellite mission to obtaining highly accurate benchmark measurements of the Earth's reflectance and emission spectra to detect the slow changes in climate.

In the Ocean Domain, CEOS agencies are generating improved climate data records for sea ice, sea level, and sea surface temperature. NOAA has developed a new microwave retrieval system for sea ice and ESA will use its SMOS observations to monitor thin sea ice. CEOS agencies are coordinating a reprocessing of microwave observations to obtain more reliable sea ice trends. NOAA and EUMETSAT are leading a CEOS study team to establish the basis for a future **Ocean Surface Topography Constellation** that could lead to operational sea level measurements. CNES and the ISRO will cooperate on a new polar-orbiting altimeter aimed at filling a potential data gap beyond 2008, and ESA plans to fly an altimeter on its Sentinel-3 mission in 2013. ESA and JAXA are both planning to fly advanced IR radiometers for high quality SST observations.

In the Terrestrial Domain, CEOS agencies are evaluating approaches to filling the current Landsat-class data gap and developing a plan for a future **Land-Surface Imaging Constellation**. CEOS agencies are also reprocessing the 30 year AVHRR data record. By using better satellite intercalibration methods, a more stable time series of AVHRR radiance measurements will be obtained leading to improved time series of land ECVs.

The Cross-Cutting actions are focused on improving international coordination mechanisms for space-based climate observations, developing and maintaining on-going working relationships with GEO and GCOS, assuring adherence to GCOS Climate Monitoring Principles, and improving the accuracy and intercomparability of satellite observations of the Earth. These actions have already led to the initiation of CEOS Plan for Virtual Constellations in support of GEOSS, improved coordination within CEOS and of CEOS agencies with GEO and GCOS, and a satellite climate data access system for users throughout the world.

Future plans include continuation and completion of Priority 1 Climate Actions and initiation of activities in support of the Priority 2 Actions. The planned initiation of Priority 2 and 3 Actions include:

Action A-1: CEOS agencies will review the capability of passive microwave sensors to make scatterometer-quality measurements and will work to ensure A.M. and P.M. satellite coverage of surface wind speed and direction by 2015.

Action A-2: CEOS will strive to ensure continuity of GPS RO measurements with, at a minimum, the spatial and temporal coverage established by COSMIC by 2011. CEOS will continue efforts to exploit the complementary aspects of radiometric and geometric upper-air determinations of temperature and moisture.

Action A-10: CEOS agencies will participate in planning, by 2011, the operational follow-on to the chemistry missions planned for the next 5 to 7 years.

Action A-11: CEOS agencies will commit to reprocessing the geostationary satellite data for use in reanalyses projects before the end of the decade.

Action C-7: CEOS agencies will increase their cooperation in ensuring stability, accuracy, and inter-comparability of their respective satellite observations. These observations will be tied to irrefutable international standards in order to enhance the utility of space programmes for climate applications.

Action C-8: CEOS agencies will contribute to development of GSICS under development by CGMS and WMO to better integrate calibration efforts. Furthermore, CEOS agencies will continuously pursue establishment of reference measurements in space, complementing those on the ground and in the air, which will enable absolute inter-calibration of radiance measurements.

Action C-9: CEOS will charge its WGCV to promote existing in situ networks, identify new opportunities for product validation, and support both validation research and operational validation projects at an adequate level.

Action O-10: ISRO will lead planning of Oceansat-2, ESA and the EU of Sentinel-3, and JAXA of GCOM-C, which are all new missions planned to carry an ocean colour sensor.

Action O-11: Relevant CEOS agencies will examine their respective plans to maintain continuity of the 25-km-resolution ocean colour global product.

Action O-15: ESA will fly SMOS in 2009 to demonstrate measurement of the sea surface salinity (and soil moisture) ECV; NASA/CONAE will fly Aquarius/SAC-D in 2009 to demonstrate measurement of the sea surface salinity ECV.

Appendix 1: The Committee on Earth Observation Satellites[1]

Overview

The Committee on Earth Observation Satellites (CEOS) was created in 1984, in response to a recommendation from a Panel of Experts on Remote Sensing from Space, under the aegis of the Economic Summit of Industrialised Nations Working Group on Growth, Technology and Employment. This group recognized the multidisciplinary nature of satellite Earth observation and the value of coordination across all proposed missions.
CEOS combined the previously existing groups for Coordination on Ocean Remote-Sensing Satellites (CORSS) and Coordination on Land Observation Satellites (CLOS), and established a broad framework for coordinating all spaceborne Earth observation missions.

Purpose

CEOS coordinates civil spaceborne observations of the Earth. Participating agencies strive to address critical scientific questions and not to plan satellite missions which unnecessarily overlap each other.

CEOS has three primary objectives in pursuing this goal:

- to optimize benefits of spaceborne Earth observations through cooperation of its Members in mission planning and in development of compatible data products, formats, services, applications and policies;
- to serve as a focal point for international coordination of space-related Earth observation activities;
- to exchange policy and technical information to encourage complementarity and compatibility of observation and data exchange systems.

Participants

Members: Governmental organisations that are international or national in nature and are responsible for a civil spaceborne Earth observations program currently operating, or at least in Phase B or equivalent of system development, will be eligible for membership in CEOS.

Associates: CEOS Associates are either:

- Governmental organisations that are international or national in nature and currently have a civil space-segment activity in Phase A/pre-Phase A or equivalent of system development, or a significant ground-segment activity that supports CEOS objectives; or

[1] Adapted from the *2005 CEOS Earth Observation Handbook*, http://www.eohandbook.com/eohb05/ceos/part4_1.html, CEOS, (last update: 2005)

- Other existing satellite coordination groups and scientific or governmental bodies that are international in nature and currently have a significant programmatic activity that supports CEOS objectives.

CEOS Plenary

Currently, **28 members** (space agencies) along with **20 associates** (other national and international organisations) participate in CEOS planning and activities. Participating agencies meet in Plenary annually, with activities and coordination occurring throughout the year. The Plenary reviews progress on the various projects and activities being undertaken within CEOS. The Chair of CEOS rotates at the annual Plenary. The CEOS Chair for 2008 is the South African Council for Scientific and Industrial Research (CSIR). For 2009, the Geo-Informatics and Space Technology Development Agency (GISTDA), of Thailand, will undertake CEOS Chairmanship.

CEOS Secretariat

A permanent Secretariat, chaired by the current CEOS host organisation, provides most of the coordination between plenary sessions and is maintained by:

- the European Space Agency (ESA) jointly with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT);
- the National Aeronautics and Space Administration (NASA) jointly with the National Oceanic and Atmospheric Administration (NOAA) of the United States;
- the Ministry of Education, Culture, Sports, Science and Technology (MEXT) jointly with the Japan Aerospace Exploration Agency (JAXA);

and is chaired by the current CEOS host organisation in support of the CEOS Plenary. As part of the ongoing contribution to CEOS Secretariat activities, ESA is responsible for the CEOS Handbook, NASA for the CEOS Annual Report and website content, and MEXT/JAXA for the CEOS Newsletter, Brochure and maintenance of the website.

CEOS Working Groups

Working Group on Calibration and Validation (WGCV): The objectives of the WGCV are to enhance coordination and complementarity, to promote international cooperation and to focus activities in the calibration and validation of Earth observations for the benefit of CEOS Members and the international user community. WGCV addresses sensor specific calibration/validation and geophysical parameter/derived products validation. WGCV meets approximately every nine months. The subgroups of WGCV are as follows:

- The Infrared and Visible Optical Sensors Subgroup;
- The Microwave Sensors Subgroup;
- The SAR Subgroup;
- The Terrain Mapping Subgroup;
- The Land Product Validation Subgroup
- The Atmospheric Chemistry Subgroup.

For more information see http://wgcv.ceos.org

Working Group on Information Systems and Services (WGISS): The objective of WGISS is to facilitate data and information management and services for users and data providers in dealing with global, regional, and local issues. In particular, it addresses the capture, description, processing, access, retrieval, utilisation, maintenance and exchange of spaceborne Earth observation data and supporting ancillary and auxiliary data and information, enabling improved interoperability and interconnectivity of information systems and services. WGISS meets approximately every six months.

The two subgroups of WGISS are the 'Technology & Services', and the 'Projects and Applications' Subgroups. WGISS has started a new initiative called the WGISS Test Facility which offers a framework for partnership with selected international science and EO projects to test and develop information systems and services to meet their requirements. The Global Observation of Forest Cover (GOFC) international science project was the first test of this concept. More recent implementations include WTF-CEOP – which aims to provide assistance to the CEOP (Coordinated Enhanced Observing Period) science community in the development of data services associated with satellite data integration.

For more information see http://wgiss.ceos.org

Working Group on Education and Training (WGEdu): The CEOS Working Group on Earth Observation, Education, Training, and Capacity Building (WGEdu) has developed a Strategy for EO Education and Training in order to establish an effective coordination and partnership mechanism among CEOS agencies and institutions offering education and training around the world. The key objective of the strategy is to facilitate activities that substantially enhance international education and training in Earth System Science and the observation techniques, data analysis and interpretation required for its use and application to societal needs. The Group has developed a CEOS Education portal to provide easy access to data sets available for these purposes.

For more information see http://wgedu.ceos.org

Strategic Implementation Team: The CEOS Strategic Implementation Team (SIT) was created in 1996 to advance the involvement of CEOS in the development of the Integrated Global Observing Strategy (IGOS). The SIT's responsibility is to address the composition and function of the space component in an IGOS. This includes the identification of the interactive mechanisms required to enhance space-based and in-situ observing systems through facilitating cooperation between provider and user communities. The SIT provides a forum where the heads of space agencies can meet to develop agreements on programme commitments - in order to address gaps or overlaps in mission planning.

The SIT Chairman is elected by the CEOS Plenary for a two-year term. The U.S. National Oceanic and Atmospheric Administration commenced their 2-year chairmanship late in 2007.

The CEOS Virtual Constellations for GEOSS: The CEOS Virtual Constellations for GEOSS consist of specialist teams assembled to provide focused resources and attention to particular implementation domains which have been designated as a special priority for CEOS, and where it is possible to foresee tangible results in the near-term. The Virtual Constellations concept seeks to engage the agencies responsible for a number of (existing or future) satellites or instruments and their observations, and to ensure coordination in their operation and exploitation, so that they have the potential for integration of data and derived information to contribute to a specific output (e.g. Climate Data Record).

CEOS undertook a substantial effort to pilot four virtual constellations that were identified as one of the tasks in the 2007-2009 GEO Workplan. Thus far, Constellations for Atmospheric Composition, Precipitation, Land Surface Imaging and Ocean Surface Topography have been implemented. Currently, there are plans underway for a new constellation for Ocean Color.

Each Constellation has a lead or leads from space agencies with a heritage of operations in the relevant EO domain, and a team of participants from other space agencies willing to contribute through CEOS. The Constellations might be considered to be a cross-cutting activity within CEOS. Some studies do map directly onto specific GEOSS space segment requirements (e.g. the Precipitation Constellation directly serves the GEOSS targets of 3-hourly global precipitation measurements and for implementation of the GPM and other supporting missions). The outputs of the other studies span the targets of several SBAs – including Climate in all cases and the provision of observations for Essential Climate Variables – and are equally important in providing resources and attention to the issue of continuity of space-based observations for key measurements of ocean, atmosphere, and land.

Appendix 2: CEOS Actions in Response to the GCOS IP

Priority 1

Atmospheric Domain

Action A-3: CEOS will support in 2007 investigations of cloud properties and cloud trends from combined satellite imager plus sounder measurements of clouds (with horizontal as well as vertical information) using Cloudsat/CALIPSO for validation.
Action A-4: CEOS agencies will ensure continued improvements to precipitation determinations demonstrated by TRMM and planned by GPM in 2010. The Japan Aerospace Exploration Agency (JAXA) and the National Aeronautics and Space Administration (NASA) will lead a CEOS study team to establish, by 2007, the basis for a future Global Precipitation Constellation.
Action A-5: CEOS will plan by 2011 to make absolute, spectrally resolved measurements of radiance emitted and reflected by the Earth to space for information on variations in both climate forcings and responses.
Action A-6: CEOS agencies will participate in re-planning, by 2007, the Earth Radiation Budget Sensor (ERBS) removed from the planned payload of NPOESS.
Action A-7: CEOS agencies will participate in re-planning, by 2007, the Total Solar Irradiance Sensor (TSIS) removed from the planned payload of NPOESS.
Action A-8: CEOS agencies will participate in re-planning, by 2007, the OMPS limb instrument removed from the planned payload of NPOESS.
Action A-9: CEOS agencies will participate in re-planning, by 2007, the APS instrument removed from the planned payload of NPOESS.

Oceanic Domain

Action O-1: CEOS agencies will examine their respective plans to maintain provision of microwave brightness temperatures and visible/infrared radiances for the sea ice ECV.
Action O-2: Relevant CEOS space agencies will consult with the science community on appropriate retrieval algorithms of passive microwave observation for reprocessing sea-ice products. Norway has expressed interest in committing to operational production of a global sea ice ECV (an initiative by the Norwegian Meteorological Institute, and coordinated by the Norwegian Space Center). The European Space Agency (ESA) is currently reprocessing the relevant ERS and Envisat archive to complement Canada's Radarsat in the context of WCRP's Climate and the Cryosphere (CLiC) core project.
Action O-4: The National Oceanic and Atmospheric Administration (NOAA) and EUMETSAT will lead a CEOS study team to establish, by 2007, the basis for a future Ocean Surface Topography Constellation that satisfies the threshold requirements for the sea level ECV (and those of the sea state ECV). This will include consideration of a future Jason-3 mission and requirements for new altimeter technologies to improve spatial resolution and extend observations in coastal regions (and over lakes and rivers for the lakes ECV).
Action O-5: The Centre National d'Etudes Spatiales (CNES) and the Indian Space Research Organization (ISRO) will cooperate on a new polar-orbiting altimeter aimed at filling a potential data gap beyond 2008. ESA and the European Union (EU) will lead planning for Sentinel-3 carrying an altimeter to complement spatial/temporal coverage of the sea level (and sea state)

ECVs (and possibly sea ice extent and thickness, river, and lake level with the altimeter operating in Synthetic Aperture Radar (SAR) mode beyond 2012).
Action O-6: An ATSR-like instrument is planned on ESA's Sentinel 3, presently scheduled for launch in 2012. JAXA will lead planning for Global Change Observation Mission-Water (GCOM-W) and GCOM-C (Climate) to maintain continuity of the sea surface temperature ECV.

Terrestrial Domain

Action T-1: CEOS agencies will determine which alternative approach best fills the current Landsat-class data gap and will explore the potential of integrating high-resolution data from multiple platforms (e.g., China-Brazil Earth Resources Satellite (CBERS), Indian Remote Sensing (IRS) satellite, Landsat, Satellite Pour l'Observation de la Terre (SPOT), and others) based on the results of a CEOS study team led by the United States Geological Survey (USGS) that will establish, by 2007, the basis for a future Land-Surface Imaging Constellation.
Action T-4: CEOS will work to enhance the quality of the FCDRs and the ECVs generated from the AVHRR record to meet threshold requirements.

Cross-Cutting Actions

Action C-1: CEOS will review the prevailing institutional arrangements in place for the planning and implementation of cooperative efforts by space agencies in the domain of climate (among others) by 2007. In particular CEOS agencies will review the ways to improve coordination of future remote sensing tasks that address the upcoming space-based measurement challenges, so as to avoid duplication of efforts while taking cooperation between the international partners to a higher level.
Action C-3: CEOS will work with GCOS to periodically evaluate climate needs and their realization.
Action C-4: CEOS agencies will adjust their internal procedures and mechanisms relative to satellite mission planning and operating processes in order to ensure adequate adherence to the GCMPs.
Action C-6: CEOS will consider the GCMPs and relevant ECV requirements in defining criteria that will serve as the foundation for the CEOS Constellation studies being initiated in 2006 and beyond.
Action C-15: CEOS agencies will encourage funding of climate change research at an adequate level for multiple groups to analyze data records, reprocess climate variables, and perform reanalysis.
Action C-16: CEOS agencies will consider, in the context of the Constellations, ways and means to support the transfer of demonstrated observations from research satellites into operational capabilities. In particular, CEOS will encourage "convergence" of climate-observing requirements (usually for high-quality data) with operational requirements (usually for rapid and ensured data availability), and support institutional arrangements that would help transfer ECVs from research to operations.
Action C-20: CEOS agencies will endeavour to ensure global, easy, and timely access to climate-related products, including by developing countries.
Action C-22: CEOS agencies will continue their efforts, both individually and through the CEOS Working Group on Education and Training (WGEdu), to build capacity.

Priority 2

Atmospheric Domain

Action A-1: In 2007 CEOS agencies will review the capability of passive microwave sensors to make scatterometer-quality measurements and will work to ensure A.M. and P.M. satellite coverage of surface wind speed and direction by 2015.

Action A-2: CEOS will strive to ensure continuity of GPS RO measurements with, at a minimum, the spatial and temporal coverage established by COSMIC by 2011. CEOS will continue efforts in 2007 to exploit the complementary aspects of radiometric and geometric upper-air determinations of temperature and moisture.

Action A-11: CEOS agencies will commit in 2007 to reprocessing the geostationary satellite data for use in reanalyses projects before the end of the decade.

Oceanic Domain

Action O-7: CEOS agencies will examine their respective plans to maintain provision of microwave brightness temperatures for the sea surface temperature ECV.

Action O-8: Relevant CEOS agencies will examine their respective plans to maintain continuity of a 10-km-resolution sea surface temperature data sets global product.

Action O-9: CEOS agencies will cooperate to support the combination of all existing sea surface temperature data sets into a global FCDR.

Action O-10: ISRO will lead planning of Oceansat-2, ESA and the EU of Sentinel-3, and JAXA of GCOM-C, which are all new missions planned to carry an ocean colour sensor.

Action O-11: Relevant CEOS agencies will examine their respective plans to maintain continuity of the 25-km-resolution ocean colour global product.

Action O-12: CEOS agencies will cooperate to support the combination of all existing ocean colour data sets into a global FCDR.

Action O-13: In consultation with GCOS and the relevant user communities, CEOS agencies will explore the means to secure, by 2011, continuity of the 1-km-resolution global ocean colour product needed to fulfil the target GCOS requirements.

Action O-14: CEOS agencies will cooperate with the user community to support efforts aimed at building on the decade-long satellite sea state records and making a comprehensive use of future altimeter- and SAR-bearing missions.

Action O-17: CEOS agencies will undertake planning for reprocessing past data to improve FCDRs and legacy databases (e.g., AVHRR Pathfinder, ATSR, Sea Level Pathfinder, and the sea ice ECV) in close coordination and partnership with existing advisory groups and reanalysis centres. All Level 2 data products for use in reanalysis should be properly accompanied by estimates of their uncertainty.

Action O-18: CEOS, through its Working Group on Calibration and Validation (WGCV) and in the context of developing standards for on-going missions and for the Constellations, will recommend best practices for pre-launch and onboard calibration of ocean sensors and for validation of space-based ocean observations with in situ sensors, including the establishment and maintenance of calibration and validation sites and networks. This will facilitate the combination of data from different sources and enable the establishment of global data sets and long-term series.

Action O-19: CEOS agencies, in cooperation with other partners, will support planning for a follow-on to GODAE by 2007.

Terrestrial Domain

Action T-2: CEOS agencies will assess the feasibility of generating global historic and continuing ECVs at fine resolutions for land cover and glacier change.
Action T-3: CEOS (led by USGS and NOAA), in cooperation with relevant stakeholders, will explore the feasibility, by 2007, of retrieving and reprocessing the 1-km AVHRR data record from various centralized archives (NOAA and High Resolution Picture Transmission (HRPT) stations).
Action T-5: CEOS agencies will undertake research to support satellite technology development, such as lidar or P-band sensors, that are capable of retrieving biomass and LAI globally that meet GCOS requirements. CEOS agencies will also support research to improve algorithms that do not currently meet GCOS threshold requirements. New satellite technology and algorithms should be available by 2015.
Action T-6: CEOS will assess the feasibility of collecting operational multi-angle observations. Research will be carried out by CEOS agencies to improve radiation transfer schemes for albedo and fAPAR, especially under cloudy conditions.

Cross-Cutting Actions

Action C-2: CEOS agencies will work with GEO to leverage progress and results from the implementation actions for climate to benefit all other relevant SBAs.
Action C-5: CEOS agencies will review their respective satellite data records with particular attention to adherence to the GCMPs and will consider undertaking necessary corrective actions within available resources.
Action C-7: CEOS agencies will increase their cooperation in ensuring stability, accuracy, and inter-comparability of their respective satellite observations. These observations will be tied to irrefutable international standards in order to enhance the utility of space programmes for climate applications.
Action C-8: CEOS agencies will contribute to development of GSICS under development by CGMS and WMO to better integrate calibration efforts. Furthermore, CEOS agencies will continuously pursue establishment of reference measurements in space, complementing those on the ground and in the air, which will enable absolute inter-calibration of radiance measurements.
Action C-9: CEOS will charge its WGCV to promote existing in situ networks, identify new opportunities for product validation, and support both validation research and operational validation projects at an adequate level.
Action C-10: CEOS agencies will coordinate their efforts in designing future data archives and data dissemination systems, ensuring that past data holdings (including associated metadata) are preserved, assessing standards and protocols, and incorporating new information technology (IT) developments as much as possible. Practical actions in response to this cross-cutting need will be developed by CEOS' Working Group on Information Systems and Services (WGISS) in line with the technical solutions adopted by GEO.
Action C-11: CEOS agencies will systematically consult with appropriate scientific and user advisory groups in establishing detailed specifications for each FCDR and derived products, including associated uncertainties.

Action C-12: CEOS agencies will consult on appropriate rules to ensure sustained, open accessibility to FCDRs in order to allow the periodic reprocessing and generation of homogeneous products.
Action C-13: CEOS agencies will generate, within available resources, independently processed data sets and products.
Action C-14: Recognising that space agencies are responsible for only a portion of the value chain involved in the generation of FCDRs, CEOS will explore ways to strengthen linkages to the communities involved in climate product generation and use, e.g., through framework agreements with major reanalysis centres.
Action C-17: CEOS agencies will maintain R&D efforts aimed at confronting the knowledge challenge posed by climate and climate change, and strive to overcome the current scientific and technical limitations of climate-quality measurements.
Action C-18: CEOS agencies will ensure that data acquired through research satellites are fully used for the benefit of creating and/or improving the FCDRs of all ECVs.
Action C-19: CEOS agencies will continue to devote particular efforts to the reprocessing and improvement of these fundamental data sets.
Action C-21: CEOS will establish a programme in 2007 to document the data archive and access arrangements in place for each of the FCDRs contributed by space agencies. WGISS will lead this effort in order to evaluate practical solutions to current obstacles and issues.

Priority 3

Atmospheric Domain

Action A-10: CEOS agencies will participate in planning, by 2011, the operational follow-on to the chemistry missions planned for the next 5 to 7 years.
Action A-12: CEOS will determine options by 2010 for continuing improvements to wind determinations demonstrated by MODIS and to be demonstrated by ADM Aeolus.

Oceanic Domain

Action O-3: New space-based measurements and products, including ice thickness and ice drift, will be considered by CEOS agencies as part of their future research missions.
Action O-15: ESA will fly SMOS in 2007 to demonstrate measurement of the sea surface salinity (and soil moisture) ECV; NASA/CONAE will fly Aquarius/SAC-D in 2009 to demonstrate measurement of the sea surface salinity ECV.
Action O-16: CEOS agencies will cooperate in developing future plans for an Ocean Salinity Constellation.

Appendix 3: Acronyms (*To be completed*)

Acronym	Spelled out Acronym
A	
AGU	American Geophysical Union
AIRS	Atmospheric Infrared Sounder
AMSR	Advanced Microwave Scanning Radiometer
AMSR2	Advanced Microwave Scanning Radiometer-2
AMSU	Advanced Microwave Sounding Unit
APS	Aerosol Polarimeter (also Polarimetry) Sensor
ASCAT	Advanced Scatterometer
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
B	
BRDF	Bidirectional Reflectance Distribution Function
C	
C^3VP	Canadian CloudSat-CALIPSO Validation Project
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAPS	Canadian AVHRR Processing System
CBERS	China-Brazil Earth Resources Satellite
CCRS	Canada Center for Remote Sensing
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and the Earth's Radiant Energy System
CFC	Chlorofluorocarbon
CGMS	Coordinating Group for Meteorological Satellites
CLARREO	Climate Absolute Radiance and Refractivity Observatory
CliC	Climate and Crysophere
CM-SAF	Satellite Application Facility on Climate Monitoring
CNES	Centre National d'Etude Spatiales
CrIS	Cross-track Infrared Sounder (kilo channel on NPP/NPOESS)
CSA	Canadian Space Agency
D	
DMSP F16	Defense Meteorological Satellite Program satellite F16
DOD	Department of Defense (also DoD)
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
E	
EC (Canada)	Environment Canada

EC (Europe)	European Commission
ECVs	Essential Climate Variables
ENVISAT	Environmental Satellite
EOS	Earth Observing System
EPS	EUMETSAT Polar System
ERBS	Earth Radiation Budget Sensor
ERS-2	European Remote Sensing satellite
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
F	
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FCDRs	Fundamental Climate Data Records
FRA2010	Forest Resource Assessment 2010
G	
GAW	Global Atmosphere Watch
GCOM	Global Change Observation Mission
GCOM-C	Global Change Observation Mission-Climate
GCOM-W	Global Change Observation Mission-Water
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEOSAT	Geodetic Satellite
GEOSS	Global Earth Observation System of Systems
GFO	GEOSAT Follow-On
GIS	Geographic Information System
GMES	Global Monitoring for Environment and Security
GPM	Global Precipitation Measurement
GPS/RO	Global Positioning System/Radio Occultation
GSICS	Global Space-Based Inter-Satellite Calibration System
GSN	GCOS Surface Network
GUAN	GCOS upper air network
GV	Ground Validation
H	
HIRS	High Resolution Infrared Radiation Sounder
I	
IASI	Infrared Atmospheric Sounding Interferometer
ICSU	International Council of Scientific Unions
IOC	Intergovernmental Oceanographic Commission
IPWG	International Precipitation Working Group

IPY	International Polar Year
IR	Infrared
IRS	Indian Remote Sensing
ISRO	Indian Space Research Organization
J	
JAXA	Japan Aerospace Exploration Agency
JFY	Japanese Fiscal Year
K	
L	
LAI	Leaf Area Index
LSA SAF	Land Surface Analysis Satellite Applications Facility
LSI	Land-Surface Imaging
M	
METOP	Meteorological Operations Platform (also Metop)
MHS	Microwave Humidity Sounder
MIRS	Microwave Integrated Retrieval System
MIS	Microwave Imager & Sounder
MODIS	Moderate Resolution Imaging Spectroradiometer
MRD	Mission Requirement Document
MSG	Meteosat Second Generation
N	
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPL	National Physical Laboratory (UK)
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRC	National Research Council
NRL	Naval Research Laboratory
NSCAT	NASA Scatterometer
NSIDC	National Snow and Ice Data Center
NWP	Numerical Weather Prediction
O	
OLCI	Ocean and Land Colour Instrument
OMPS	Ozone Mapping and profiler Suite
OSI SAF	Ocean and Sea Ice Satellite Application Facility
OST	Ocean Surface Topography
OSTM	Ocean Surface Topography Mission
P	

PATMOS-x	Pathfinder Atmospheres - Extended
PC	Precipitation Constellation
PDR	Preliminary Design Review
PEARL	Polar Environment Atmospheric Research Laboratory
PMM	Precipitation Measurement Missions
PPS	Precipitation Processing System
Q	
R	
S	
SAR	Synthetic Aperture Radar
SARAL	Satellite with ARgos and ALtika
SBA	Societal Benefit Area
SBSTA	UNFCCC Subsidiary Body on Scientific and Technological Advice
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SGLI	Second-generation Global Imager
SI	International System of Units
SLST	Sea and Land Surface Temperature
SMMR	Scanning Multichannel Microwave Radiometer
SMOS	Soil Moisture and Ocean Salinity
SOA	State Oceanic Administration
SPOT	Satellite Pour l'Observation de la Terre
SSM/I	Special Sensor Microwave Imager
SSM/IS	Special Sensor Microwave Imager Sounder
SST	Sea Surface Temperature
SWOT	Surface Water-Ocean Topography
T	
TC-4	Tropical Composition, Cloud and Climate Coupling
TRUTHS	Traceable Radiometry Underpinning Terrestrial- and Helio- Studies
TRMM	Tropical Rainfall Measuring (also Measurement) Mission
TSIS	Total Solar Irradiance Sensor
U	
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	United States
USN	United States Navy
USGS	United States Geological Survey

V	
VIIRS	Visible/Infrared Imager/Radiometer Suite (NPP/NPOESS)
VOSClim	Voluntary Observing Ships Climatology
W	
WCRP	World Climate Research Programme
WG	Working Group
WGCV	Working Group on Calibration/Validation
WMO	World Meteorological Organization
X, Y, Z	
XBT	Expendable Bathythermograph