25 November 2005

ENGLISH ONLY

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

SUBSIDIARY BODY FOR SCIENTIFIC AND TECHNOLOGICAL ADVICE
Twenty-third session
Montreal, 28 November to 6 December 2005

Item 9 of the provisional agenda
Research and systematic observation

Progress report on preparing a coordinated response from space agencies involved in global observations to the needs expressed in the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC*

Revised submission by Argentina on behalf of the Committee on Earth Observation Satellites

1. The Conference of the Parties, by its decision 5/CP.10, expressed its appreciation to the Global Climate Observing System for preparing the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC.*[1] It 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 implementation plan. In response to this invitation, Argentina, the Chair of the Committee on Earth Observation Satellites (CEOS), on behalf of CEOS, submitted a document for consideration by the Subsidiary Body for Scientific and Technological Advice at its twenty-third session.

2. In accordance with the procedure for miscellaneous documents, this submission is reproduced[*] in the language in which it was received from the CEOS secretariat and without formal editing.

[1] <http://www.wmo.ch/web/gcos/gcoshome.html>.

[*] This submission has been electronically imported in order to make it available on electronic systems, including the World Wide Web. The secretariat has made every effort to ensure the correct reproduction of the text as submitted.

FCCC/SBSTA/2005/MISC.17/Rev.1

GE.05-64364

THE RESPONSE OF SPACE AGENCIES TO THE GCOS IMPLEMENTATION PLAN

THE WAY AHEAD

DEVELOPED BY THE COMMITTEE ON EARTH OBSERVATION SATELLITES (CEOS)

SUBMITTED TO UNFCCC SBSTA ON BEHALF OF CEOS BY ARGENTINA'S DELEGATION TO UNFCCC SBSTA

DRAFT VERSION 2.1

1. Introduction

Through the Committee on Earth Observation Satellites (CEOS), Space Agencies worldwide are able to provide a concerted response to the requirements for satellite and associated data, set out in the GCOS Implementation Plan on behalf of the climate community. In this respect, CEOS can provide a coordinated input to the needs of the parties to the UNFCCC as articulated through GCOS.

A starting point for this dialogue is the understanding that the GCOS Implementation Plan is an agreed statement of the requirements for data for the monitoring of and research into climate and climate change. In this respect, not only is GCOS assumed to speak for the parties to the UNFCCC, but it is also assumed that the GCOS Implementation Plan fully encompasses the needs of the World Climate Research Programme (WCRP) for systematic (sustained) observations.

Additionally, insofar as the requirements of the Climate chapter of the Ten-Year Implementation Plan of the Global Earth Observation System of Systems (GEOSS), adopted at the third Earth Observation Summit in February 2005 are also those set out by GCOS, the CEOS response to the GCOS Implementation Plan should also be considered to be synonymous with its response to the GEOSS climate needs. Providing that care is taken to maintain consistency between the various requirements set out above, there is an opportunity for CEOS to generate a single, coherent document that addresses all these issues. This short paper sets out the general principles behind the approach to be taken by space agencies in preparing such a document, and the process through which it will be generated.

2. Approach

The GCOS Implementation Plan (GCOS) sets out a number of recommendations which can be divided into two classes, the first of a more general nature and the second, longer, list comprising a more specific statement of data needs in the domains of atmosphere, oceans/ice and the land surface. At this stage it is not intended to provide a detailed response from CEOS to the specific data needs; this will need a careful examination of the requirements and it is intended to respond at this detailed level to the UNFCCC COP-12 in 2006. This paper sets out an overall response to the more general points raised by the report and the approach to be adopted over the coming year.

3. GENERAL REPONSE OF CEOS AGENCIES

CEOS Agencies are keenly aware of the need for good data management and of the long-term requirements which form the basis of the GCOS Climate Monitoring Principles[1] , and respect them in the implementation of their programmes. The ten basic principles were approved by the UNFCCC COP (Decision 5/CP.5) and the complete set of twenty adopted by the Congress of the WMO in May 2003 and by CEOS at its 17th Plenary, also in 2003. While the principles are fully agreed and accepted by Space agencies, they remain however far from being completely implemented by them.

The only truly operational series of Earth observing satellites is that organized through the Co-ordinated Group on Meteorological satellites (CGMS), as part of the WMO Global Observing System. These comprise the geostationary and polar orbiting satellites of the World Weather Watch. While research and development agencies are indeed members of CGMS, they cannot undertake through their mandate to operate on the same basis as the weather satellite data providers. To date, issues of continuity, overlap, cross-calibration and so on are undertaken by R&D agencies on a best efforts basis. A typical mission involves a significant amount of effort dedicated to these activities and the funding agencies are mindful of the need to follow the GCOS Climate Monitoring Principles to the greatest extent possible. In particular, issues such as secure maintenance of archives, calibration and validation of sensors, continuity of measurements, etc., are addressed.

There are also points which relate to the ability to investigate, monitor and understand the Earth system to the greatest possible extent through, for example, diurnal sampling of earth system processes, the elimination of random errors and time-dependent biases in the satellite data and the need for peer review of algorithms and new products. Again space agencies are conscious of these and strive to ensure that their data are as fit for this purpose as possible. The research community addressing these questions is hence also accommodated to the extent possible.

But in all the above to date the mechanisms have been, as stated, on a best-efforts basis given the various mandates of the agencies involved. With the increasing importance assigned to understanding and monitoring of climate change, CEOS agencies will be invited at Plenary to revisit the degree to which their programmes can operate on this basis, and examine where greater agreement can be reached in committing to the GCOS Climate Monitoring Principles. Agencies are unlikely to be able to adhere in all aspects to the Principles, but the degree to which they agree on a more formal scheme of adherence will be examined in the coming year.

One particular question which should also be addressed is the issue of transition from research into operational domains. This is not a new problem: but it remains unresolved. Space agencies should revisit the approach to this issue – on both global and regional scales (since certain specific solutions have been implemented regionally). Agencies should then review how best the requirement for operational continuity and security of data can be addressed both for the operational users and, not to be forgotten, for the research community who also has a less well-publicised need for long-term series of satellite data.

CEOS also plans to address the processing level and availability of data products derived from satellite observations. As the utilization of data from Earth observing satellites becomes ever more sophisticated, the need to integrate such data with other sources becomes increasingly important. In addition, as strategies for the assimilation of data into continuous models become more important, even in the research domain, the requirements placed on agencies will be examined. Closely related to this is the increasing requirement for near real time access to data, not only for operational purposes but also for research programmes. This is increasingly relevant as continuous assimilation becomes the norm and as the rates at which data are generated and assimilated become convergent.

4. ADDRESSING THE SPECIFIC DATA RECOMMENDATIONS OF THE GCOS IP

4.1 GENERAL

The Implementation report makes some thirty-nine detailed recommendations that have space agencies either as primary or secondary actors, helpfully enumerated in correspondence between GCOS and CEOS. Of these some 3 recommendations are cross-cutting, 12 relate to atmospheric data, 6 to ocean data and 18 to data relating to the land surface.

The generic issues refer, *inter alia*, to the need to maintain and adapt instrument capabilities in accordance with GCOS principles, to data archive procedures, partnership with product generators, open access to data and the generation of error estimates on products as a matter of course. CEOS has also been asked to provide advice to the climate community in areas such as anticipated or potential gaps in data supply and product generation, data and metadata archive needs and availability of products.

Each of the generic points raised by the GCOS IP will be addressed in detail in the coming year. In addition, the Essential Climate Variables (ECV) set out in the Plan where satellite data is either a primary or secondary source will be dealt with similarly and a detailed response, variable by variable, will be prepared for presentation at the 2006 COP-12.

An outline of the approach to be adopted in each of the three physical domains (atmosphere-oceans/ice and land) addressed by the Plan is given below.

4.2 SPECIFIC POINTS IN EACH OF THE DOMAINS

4.2.1 ATMOSPHERE

The GCOS Implementation Report notes that satellite observations play a crucial role in attaining global coverage of virtually all atmospheric climate variables and through their incorporation in globally integrated analyses. The atmospheric observing networks for climate are largely based on those of a) the WMO World Weather Watch (WWW) for surface and upper-air observations and b) the WMO GAW for the atmospheric composition. The GCOS implementation strategy has placed an initial emphasis on the full implementation of baseline networks, including the GCOS Surface Network (GSN) and the GCOS Upper Air Network (GUAN) and the expansion of the GAW to provide a global distribution. These networks need to be gradually augmented and their data and associated metadata must be carefully managed in order to encompass all the ECVs. Integration of these data must be accomplished through the process of reanalysis, which by incorporating historical data with consistent algorithms provides the potential to yield homogeneous, consistent, multi-variate products with global coverage.

The report also notes outstanding issues requiring research, including monitoring water vapour, understanding the 3D character of clouds, monitoring the composition and distribution of aerosols, estimating surface wind speed and direction, estimating high temporal resolution precipitation amount and type especially over the oceans and at high latitudes, synthesizing quality assured greenhouse gas and ozone data, and developing consistent unbiased homogeneous reanalysis products for all ECVs.

Five-year milestones include centres to monitor and analyse all ECV data, a fully operational GSN and GUAN, a reference network of high-quality, high-altitude (5 hPa) radiosondes, BSRN with global coverage, maintaining atmosphere surface pressure measurement from from all drifting buoys, a homogeneous record of active and passive microwave observations for precipitation and water vapour, global ground-based GPS total column water monitoring system, sustained homogeneous Earth Radiation

Budget satellite observations, a baseline network for key greenhouse gases based on GAW, and a coordinated long-term programs for reanalysis

CEOS will study these issues and milestones in detail and coordinate a response amongst participating agencies. In particular, CEOS will encourage (a) space agencies to embrace the concept of a Global Space based Inter-calibration System (GSICS) that improves the use of space-based global observations for weather, climate and environmental applications through operational inter-calibration of the space component of the WWW's GOS and GEOSS and (b) members to establish reference measurements on ground, in air, and in space that will enable absolute inter-calibration. This inter-calibration system would quantitatively relate the radiances from different sensors viewing the same target to allow consistent measurements to be taken over the globe by all elements of the space-based component of the WWW's GOS. In addition it would provide the ability to retrospectively re-calibrate archive satellite data using the operational inter-calibration system in order to make satellite data archives worthy for climate studies. This would evolve to an end-to-end capability consisting of: on-board calibration devices (e.g. black bodies, solar diffusers); in situ measurements of the state of the surface and atmosphere (e.g. the Cloud and Radiation Test-bed (CART) site; aircraft instruments with calibrations meeting national standards (e.g. NIST); radiative transfer models that enable comparison of calculated and observed radiances; and assimilation systems that merge all measurements into a cohesive consistent depiction of the Earth-atmosphere system.

GCOS has introduced the concept of a reference network that augments the GUAN by providing highly detailed and accurate observations at a small number of GUAN stations. The principal aims of this network are to provide: long-term high quality climate records, anchor points to constrain and calibrate data from more spatially-dense global networks (including satellites), and a larger suite of co-related variables than can be provided as benchmark observations.The key property of a reference network is deliberate redundancy of measurements that fully characterize the physical properties of the atmospheric column at a small set of sites. Measurement redundancy, whereby the same atmospheric property is measured by at least two separate instruments simultaneously, will provide strong constraints on instrument biases and properties across a range of timescales from synoptic to inter-annual to enable explicit calculation of these effects. The capability of reference sites will increase with the level of measurement redundancy. A critical aspect of this measurement redundancy is active monitoring so that problems can be identified and rectified in real-time. The reference sites would give high priority to temperature, water vapour, wind speed and direction, cloud properties, and Earth radiation budget. CEOS will consider how these important aspects of a reference network can be initiated and sustained.

The anticipated accuracies, resolutions, and cycle times for some of the atmospheric parameters derived from satellite systems planned for this decade are summarized in the following table; these include temperature and humidity profiles (from infrared and microwave radiometers) and upper winds (from tracking the movement of cloud and water vapour features). Infrared radiometers provide the highest quality profiles but only in clear sky conditions. Microwave radiometers provide data under cloudy conditions but have lower vertical resolution. Observations from both are currently widely available over the oceans, but over land varying surface emissivity is currently limiting soundings to the upper atmosphere. Upper wind observations are provided on a global basis but only where suitable tracers are available and usually only at one level in the vertical. Improvements in resolution and capability are expected over the next 5-10 years; better utilization of sounding data over land is also near at hand.

As the space based remote sensing system of the future develops and evolves, four critical areas (all dealing with resolution) are being addressed in order to achieve the desired growth in knowledge and advanced applications. They are: (1) spatial resolution – what picture element size is required to identify the feature of interest and to capture its spatial variability; (2) spectral coverage and resolution – what part of the continuous electromagnetic spectrum at each spatial element should be measured, and with what spectral resolution, to analyze an atmospheric or surface parameter; (3) temporal resolution – how often does the feature of interest need to be observed; and (4) radiometric accuracy – what signal to noise is required and how accurate does an observation need to be. Higher temporal resolution is becoming possible with detector array technology; higher spatial resolution may come with active cooling of infrared detectors so that smaller signals can be measured with adequate signal to noise. Higher spectral resolution is being demonstrated through the use of interferometers and grating spectrometers. Advanced microwave radiometers measuring moisture as well as temperature profiles are being introduced in polar orbit; a geostationary complement is being investigated. Ocean colour observations with multispectral narrow band visible measurements are being studied. Active sensors are being planned to supplement passive sensors with measurements of ocean height and atmospheric motions. The challenge of the future is to further the progress realized in the past decades so that environmental remote sensing of the oceans, atmosphere, and earth increases our understanding the processes affecting our lives and future generations. CEOS members will remain engaged in this evolution of the satellite remote sensing capabilities.

Element and Instrument	**Horiz Res** [1]	**Vert Res** [2]	**Cycle** [3]	**Delay** [4]	**Accuracy**
	(km)	(km)	(hr)	(hr)	(rms)
Humidity Sfc – 300hPa					
NOAA & METOP (ATOVS)[6]	50	3	6	2	15%
METOP (IASI) & NPOESS (CrIS)	15	1	12	2	10%
Humidity below 50hPa					
METOP(GRAS) & NPOESS (GPSOS)	500	~1	12	2	10%
Temperature Sfc - 10hPa					
NOAA & METOP (ATOVS) [6]	50	3	6	2	1.5°K
METOP (IASI) & NPOESS (CrIS)	15	1	12	2	1°K
Temperature 500hPa – 10hPa					
METOP(GRAS) & NPOESS (GPSOS)	500	~1	12	2	1°K
Wind Sfc – 200hPa					
MSG (SEVIRI) & GOES (Imager)	50/100	One level[5]	1	2	2-5m/sec

Notes: 1. The horizontal interval between consecutive measurements (sampling distance).
2. The vertical interval between consecutive measurements.
3. Cycle is time interval between measurements and assumes 2 satellites in polar orbit.
4. Delay is the time delay between the observation and receipt of data by the end user.
5. Satellite winds are single level data with vertical sampling typically ~1km
6. For ATOVS, 1-4 profiles are provided per second per satellite (per 100km2)

As an example showing the importance of satellite data contributions, consider the performance of numerical weather prediction models in the past twenty five years. Through better assimilation and inter-comparison of satellite radiances it has been possible to achieve considerable improvement in NWP models. The figure below shows the evolution of the ECMWF 3, 5, and 7 day forecast anomaly correlations for 500 hPa heights; southern hemisphere data sparse regions are forecast equally well as northern hemisphere data rich regions through utilization of satellite remote sensing measurements.

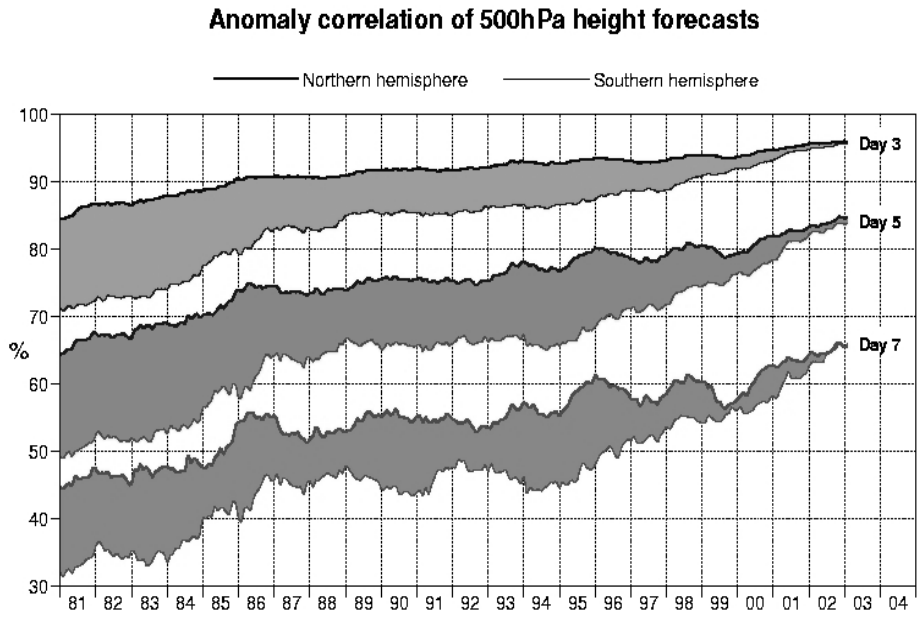


Fig. 1 Improvement in anomaly correlation over time showing the improvement of Southern Hemisphere forecasts due to ingestion of satellite data (courtesy ECMWF).

These types of improvements can be realized in climate applications if inter-calibrations and reference measurements systems are initiated and maintained

4.2.2 OCEANS and ICE

The Implementation Report identifies six detailed recommendations relating to ocean and ice data, with space agencies as primary or secondary actors.

Most of them pertain to the continuity of observations of Essential Climate Variables which critically depend upon satellite observations, namely Sea Surface Temperature (SST) from both IR and passive microwave sensors in polar and geostationary orbits, Sea Surface Height (SSH) from a coherent set of altimetry missions, including one high-precision altimeter and two lower-precision, but higher spatial resolution altimeters, Visible Spectral Radiance (Ocean Color) with adequate sensors, and Sea Ice with passive microwave, synthetic aperture radar, visible and IR sensors. To a large extent all these have to link with *in situ* networks.

Other recommendations relate to space agencies supporting research and development of new improved technologies, research and analysis of ocean color data for biological activity, and research programs aimed at demonstrating the feasibility of satellite retrieval of global fields of Sea Surface Salinity. These activities are assumed to be implemented in cooperation with other international entities and research programs.

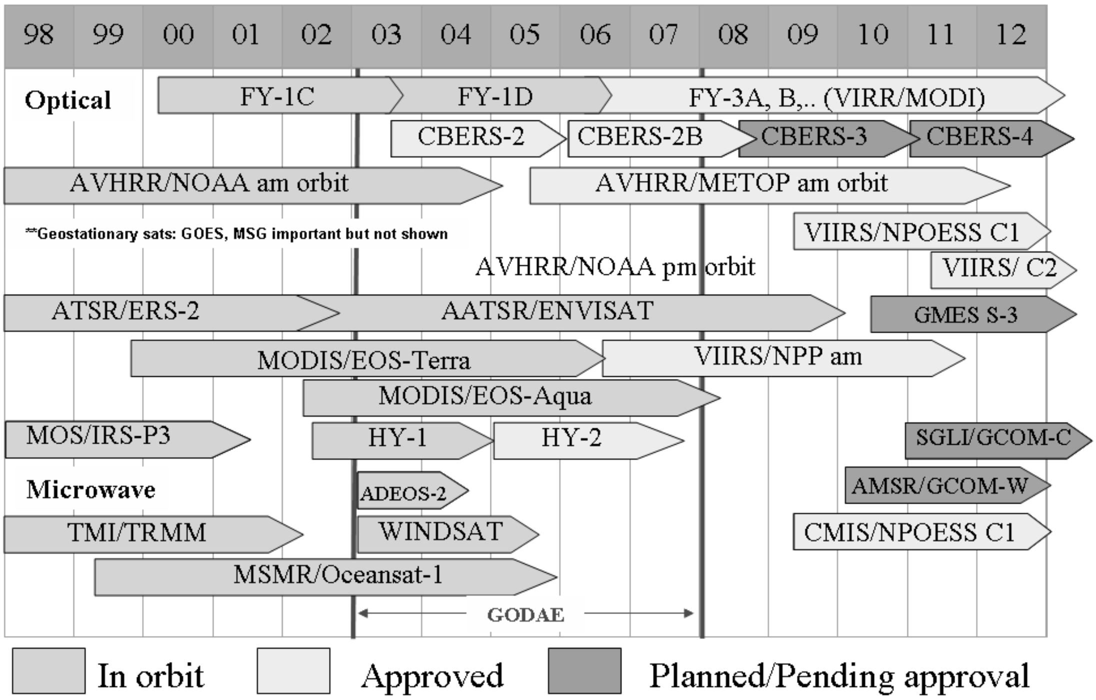


Fig.2 Available Sea Surface Temperature data from Earth observing satellites

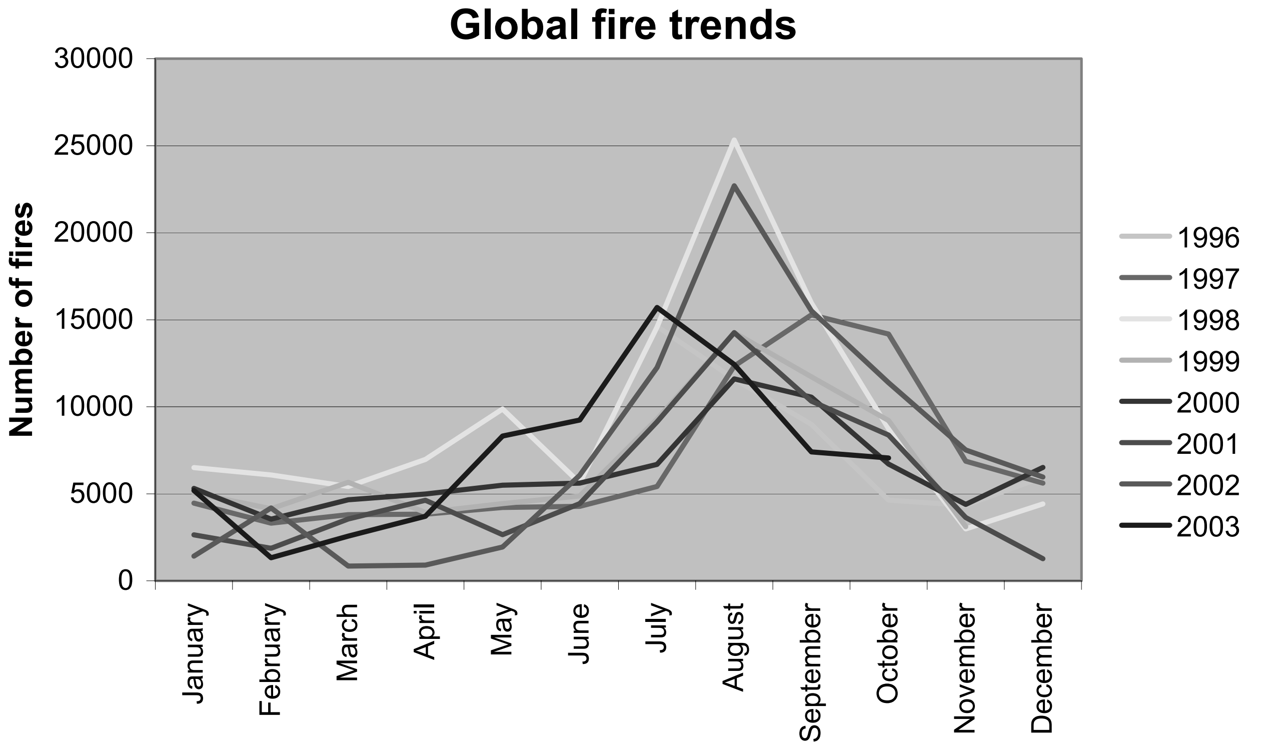
CEOS intends to prepare during the course of next year a comprehensive set of responses to these recommendations, which address well-known issues at stake in all CEOS agencies involved in ocean remote sensing. Progress in the past two years within the framework of the Global Earth Observation System of Systems makes it possible to further advance toward the establishment of a sustained, operational, space-based ocean observing system. CEOS agencies closely cooperate within their respective mandates in order to identify potential discontinuity in ocean observation and they actively work at finding ways to progressively transfer responsibility of demonstrated satellite systems from R&D agencies to operational agencies. The continuity of Sea Surface Temperature (SST) observations, and particularly the high-accuracy SST data gathered by the ATSR instrument on board the European Space Agency's ERS-1, ERS-2 and ENVISAT series, is a remarkable example of this coordination (Figure above). Similarly the continuity of high-accuracy Sea Surface Height (SSH) gathered by the NASA-CNES Topex/Poseidon mission, followed by the CNES-NASA Jason-1 mission and to be continued with the NASA-NOAA-CNES-EUMETSAT Jason-2 mission illustrates the effort to transition observations from experimental to operational status. Also current plans indicate good prospects for ocean color observation from a number of platforms in the coming decade.

CEOS member agencies from the United States, Japan, Europe, India and other parts of the world contribute to the current set of ocean observing sensors and missions. Strategies and action plans in response to GCOS implementation Plan will be further developed and outlined in detail, through consultation with those and other partners, based on their existing long term plans.

4.2.3 LAND SURFACE

Space observations have been playing an increasingly important role for terrestrial aspects of the carbon cycle. At moderate resolutions (250m-1km) there are many CEOS observational assets in the optical part of the spectrum; products needed for the GCOS IP are being regularly created using their data notably by NASA's MODIS and ESA's MERIS. These products include vegetation index, APAR, LAI , NPP and fires; land cover products are also being regularly generated at these resolutions and there are firm plans of both US and European CEOS members to create these products on a continuing basis. Several other CEOS agencies also are providing data with similar characteristics. Considerable efforts have been made by some CEOS agencies to create improved internally consistent longer term ECVs through the reprocessing of data from multiple sensors.

Moderate resolution optical observations are apparently secure for the longer term. For example the VIIRS (Visible Infrared Imager Radiometer Suite) instrument, which is part of the new US operational polar orbiter NPOESS (National Polar Orbiter Environmental Satellite System), and which will also be flown earlier on the NPOESS Preparatory Project, has most of the crucial spectral bands needed for monitoring vegetation. It has somewhat less capability for monitoring fire than MODIS, but the resultant



products should be adequate.

Fig. 3: An example of time series of data: annual statistics of monthly global fire events derived from the Along Track Scanning Radiometer series of sensors (ESA).

The CEOS Working Group on Calibration and Validation is cooperating with GOFC-GOLD, a GTOS Panel, to develop internationally accepted protocols for global validation of several terrestrial products. The availability of ultra-fine resolution images considerably assists validation and JAXA's Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) instrument on its ALOS platform with its 2.5 m resolution should contribute valuably to this capability.

Representatives of some CEOS agencies with geostationary satellites are cooperating through a GOFC-GOLD initiative to develop a consistent global product for monitoring the diurnal variability of fire. Progress has been made in developing a burned area product but significant validation efforts are still needed.

Fine resolution products with spatial resolutions in the 10-50m range are essential because of the need to monitor land cover change, the main driver of which is localized human activities only detectable at these resolutions. There has been a substantial loss of capability in this regard, because of the significantly reduced ability of Landsat 7 to monitor change. Although there are many assets with comparable technical capabilities, including those of Brazil, China, India and France none have Landsat's comprehensive acquisition strategy or on board storage capacity to provide similar regular global coverage. CEOS agencies have had discussions on the integrated use of fine resolution assets to help substitute for Landsat 7's acquisition but no definitive plans have as yet been developed.

Radars are important for monitoring land cover change especially in cloudy areas and increasingly in INSAR mode for monitoring biomass. Such capabilities are currently available from ESA's ENVISAT and Canadian Radarsat-1, and will be available following the successful launch of JAXA's ALOS satellite, German-European TerraSar-X and Canada's Radarsat-2 in the near future, and the completion and placement in orbit of the Italian Cosmo-Skymed and Argentine SAOCOM missions.

Progress has recently been made in monitoring lake levels using fine-footprint spaceborne laser altimetry from NASA's ICESat and in the future from ESA's Cryosat. Such observations also show promise for estimating the stage of large rivers and hence in estimating discharge.

5. THE WAY FORWARD

Section 3 summarised the general response and approach of Space Agencies to the GCOS Implementation Plan – and Section 4 presented a preliminary discussion of the response to the specific requirements for climate observations. The initial dialogue between CEOS and GCOS regarding the development of a full response from Space Agencies to COP-12 has focused on definition of an approach which will:

a) encompass both the general considerations requested by GCOS (and in particular, adoption of the GCOS Climate Monitoring Principles in all future Earth observation satellite programmes) and the specific observational requirements for climate data on the atmosphere, oceans, cryosphere, and land surface;

b) be understandable to both the Space Agency and the climate science communities – and to the decision-makers and politicians determining national and regional priorities for science and observation programme funding;

c) facilitate development of an Implementation Plan, against which Space Agency progress can be measured in the coming years; this Plan should incorporate a single, consistent set of requirements supported by the climate community – and which the community has a duty of care to maintain as current;

d) avoid generic statements of good-will (eg regarding recognition of the Climate Monitoring Principles by space agencies) and focus instead on defining an implementation framework which will foster and support a variety of types of contribution – from the space programmes of many nations: large and small, developed and developing.

The outline approach involves CEOS and GCOS working together to define a series of the highest priority, calibrated (likely multi-decadal) datasets required by the GCOS Implementation Plan. Each dataset will be carefully specified in terms of quality, calibration, and validation parameters – of the sort evoked by the Climate Principles. The report to COP-12 will identify how well current and planned observing systems and data holdings satisfy the GCOS requirements for these datasets. CEOS will work with GCOS and WCRP to define what the scientific and economic implications are of any shortfalls in provision; and implementation measures will be defined – in equally quality-specific terms – to resolve these shortfalls. Ideally each of these actions will be priced with a ROM (rough order of magnitude) cost – consistent with the approach adopted in costing the GCOS Plan.

We can expect the implementation plan to raise a variety of measures required of the space agencies, the in-situ observations community, and the climate science community, eg:

- reanalysis of existing data holdings to meet quality standards;
- application of quality/integratability standards to current data;
- intercomparability studies and perhaps even spacecraft dedicated to these studies;
- in-situ and calibration - validation initiatives;
- guarantees of future continuity of key measurements to a certain specification;
- filling measurement gaps and creating new capabilities.

Such measures should provide ample opportunity for the participation of as many national and regional agencies as possible – reflecting their various budgets and priorities.

CEOS is internally well structured to be able to address the issues raised above. Within the CEOS framework, its Strategic Implementation Team (SIT) has been created specifically to allow a focussed response to issues such as those raised by the GCOS IP. Additionally, the Working Groups of CEOS (on Calibration-Validation and on Information Systems) will support the work of SIT in their specific areas of expertise.

We should parenthetically draw attention to the proposed relation between CEOS and GEO/GEOSS. Climate is not being treated in isolation by CEOS: it is one of the nine social benefit areas identified by GEO, which has been content to see the climate requirements elucidated by GCOS. CEOS will offer to respond to the other GEO areas of benefit in a similar way.

CEOS will endeavour to incorporate feedback received from COP-11 into the definition of the Implementation Plan and would be pleased to report on progress to the COP-12 meeting planned for November 2006.

- - - - -