

GLOBAL MONITORING OF ESSENTIAL CLIMATE VARIABLES
In response to recommendation 35.06

CGMS is informed of the contents and status of an ESA initiative under the umbrella of its Earth Watch Programme.

ESA has many data in its archives which are needed to obtain essential climate information.

This initiative responds to the well-defined requirements emanating from the states signatory of the UNFCCC. It will implement actions which have been agreed between space Agencies co-ordinated by CEOS, and the Global Climate Observing System GCOS, by a formal process over the last 3 years.

It will implement a range of activities including data preservation, re-calibration and re-processing of long term records, algorithm development, product generation and validation.



GLOBAL MONITORING OF ESSENTIAL CLIMATE VARIABLES

[An ESA contribution to GCOS in the framework of GMES]

1 INTRODUCTION

Climate change is arguably the greatest challenge facing mankind in the twenty-first century. Observations from space provide unique information that is essential for understanding, mitigating and adapting to climate change.

In view of the current politically important negotiations concerning the post-Kyoto era, Europe has the opportunity to show leadership in the use of space for climate monitoring. ESA has many data in its archives which are needed to obtain essential climate information.

This Earthwatch Element for Global Monitoring of Essential Climate Variables will capitalize on previous investments in the space and ground segment in ESA, its Member states and its European partners (eg. Eumetsat, EC). It will ensure the delivery of appropriate climate information as a direct response to the well-defined requirements emanating from the sovereign states signatory to the UNFCCC. It will implement actions which have been agreed between space agencies co-ordinated by CEOS and GCOS, in a formal requirements definition process over the last three years. It will implement a range of activities including data preservation, re-calibration and re-processing of long term records, algorithm development, product generation and validation.

2 BACKGROUND AND CONTEXT

The Parties to the UNFCCC have placed responsibility for defining and specifying the requirements for observations relevant to climate change with the Global Climate Observing System (GCOS). GCOS has issued two Adequacy Reports to the UNFCCC on the global climate observing systems, and in its second report in 2003 GCOS established a list of Essential Climate Variables (ECV) that are both feasible and have a high impact on the UNFCCC requirements. Each ECV is derived from a Fundamental Climate Data Record (FCDR). The FCDR is a long-term data record, involving a series of instruments, with potentially changing measurement approaches, but with overlaps and calibrations necessary to allow the generation of homogenous products, providing a measure of the intended variable that is accurate and stable enough for climate monitoring. The FCDRs concretely define what is needed from satellite observations in order to arrive at the ECVs. During 2005-2007, GCOS and space agencies (co-ordinated by CEOS) set out a formal response to the needs for space-based observations defined by GCOS, culminating in a report to the UNFCCC in Bali in 2007 which was received with acclaim by the Conference of the Parties.

A process has hence been established which demonstrated direct traceability from the political imperatives of the signatories to the UNFCCC, through its technical advisory bodies (eg. GCOS), to space agencies which in turn have an agreed set of priority observations defined in conjunction with GCOS. As such, a coherent end to-end definition of requirements is

therefore in place where the needs in terms of space data products are internationally well defined and scientifically agreed. This Element of the European Earthwatch Programme will implement the steps necessary to generate a consistent set of ECVs.

3. OBJECTIVES AND SCOPE

The objective of this Earthwatch Programme Element is to realize the full potential of the long-term global Earth Observation archives that ESA together with its Member states have established over the last thirty years, as a significant and timely contribution to the ECV databases required by UNFCCC. It will ensure that full capital is derived from ongoing and planned ESA missions for climate purposes, including ERS, Envisat, the Earth Explorer missions, relevant ESA-managed archives of Third-Party Mission data and, in due course, the GMES Space Component.

The essential feature of this element will be to implement a coherent and continuous suite of actions that encompasses all steps necessary for the systematic generation of relevant ECVs, and ensures their regular updating on timescales corresponding to the increasingly urgent needs of the international climate change community.

These actions will be carried out in full co-ordination with other key existing international activities that support and complement the proposed initiative. Such existing activities include the long-term global data products available in the scientific community (eg. as a result of WCRP and IGBP), and the Global Network of Regional Specialized Satellite Centers for Climate Monitoring (RSSC-CM) established in the framework of WMO's Global Observing System (GOS) as well as the Eumetsat SAF network).

The scope of this element is not to provide climate services, but to undertake the activities necessary to ensure that the existing space assets and data archives, as well as forthcoming satellite missions, can be used in an optimum way in climate modelling and research. It will thus contribute fundamentally to both the basic and applied research that underpins the development of such services. The development and provision of services (e.g. information products, climate assessments, attribution and predictions) to end users and stake-holders, belongs within the scope of GMES and other user-oriented servicing programmes.

4. ACTIVITIES FORESEEN

The objectives of this programme element will be achieved by five main activities (further described below).

Activities 1 & 2, will rely upon and will, as necessary, complement data archiving and preservation activities carried out within related ESA frameworks, particularly Earthnet and the Long Term Data Preservation plan.

Activities 3, 4 and 5, constituting the major effort of this element, will take full account of relevant prototype activities that have been carried out in other ESA and non-ESA programmes, notably the Data User Element of the Earth Observation Envelope Programme.

The GCOS requirements for each ECV have been analysed, taking into account its role in the climate system & models, to identify what actions (including none) should be undertaken within this ESA initiative. This analysis leads to sets of ECVs grouped into 3 main categories:

- ECVs for which ESA Missions play a primary role (total 18)
- ECVs for which ESA Missions play a significant secondary role (total 3)
- ECVs not addressed in this ESA initiative (total 5, all central to operational meteorology)

The ECVs cover the Atmospheric (surface, upper air, composition), Oceanic (surface, sub-surface) and Terrestrial domains. For each ECV, the main satellite sources that can contribute to the FCDR, and the global products to be generated from the (multi-mission) FCDR (or action required enable this) have been identified. The priorities in terms of ECVs to be addressed within this element will be set in conjunction with the formal representatives of the climate user community, focused through GCOS. This element will focus on those ECVs for which data from ESA missions, and relevant national missions, are of particular importance.

Based on this analysis the following five main activities will be implemented to achieve the overall objective:

1) Gathering, collating and preserving the long-term time series in ESA's distributed archives.

The ESA Executive has presented a European strategy for Long-Term EO Data Preservation and access (LDTP) which aims to focus discussion and establish an overall LTDP system implementation plan for the next 5–10 years. A European long term data preservation workshop in May 2008 established the cooperation scheme to ensure coherency in the preservation of ESA and other European EO missions data. A critical and highly demanding requirement for climate users is to dramatically reduce the turn-around time for production and delivery of EO data products derived from all FCDRs. This typically needs to be one order of magnitude faster than at present. To achieve this, an adequate infrastructure based on very high computing technologies will be implemented. This will, to the maximum extent possible, capitalize on existing, shared, national facilities to achieve cost-efficiency and effectiveness. It will, in particular, allow for smooth plug-in of newly developed algorithms and easy access to all necessary auxiliary data information, as well as timely delivery of global products to the final users in the most adequate way (e.g. use of on-line archives, adequate network infrastructure and/or use of large capacity media).

2) (Re-)Processing periodically the basic EO-data sets from each individual mission and applying the most up-to-date algorithms and cal/val corrections

GCOS has formulated explicit requirements for cal/val and re-processing for each individual ECV. These primarily concern requirements for accuracy, spatial and temporal resolution, and stability (the ability of the data record to detect long-term trends of climate variables). These ECV requirements will be used to derive specific performance and functional requirements for re-processing and calibration of both ESA and non-ESA EO

data archives in order to constitute the necessary FCDRs. Engineering calibration and inter-calibration activities between instruments will follow the corresponding guidelines developed by the CEOS WGCV (Working Group Calibration Validation).

3) Integrating the calibrated data sets derived from individual contributing EO mission and sensors to constitute the most comprehensive and well-characterized global long term records possible for each ECV

These activities will address the stringent GCOS requirements for consistency and consistent inter-calibration when assembling and processing the FDCR components to generate ECVs. The FDCRs are, by definition, comprised of data from different satellites, different sensors, different Space Agencies: each with different performance characteristics, most notably, different spatial and temporal sampling, different time extents, and different stability. Given the size of the data sets involved (global, long time series), and the need for frequent reprocessing, this represents a series of massive and highly complex tasks which, for most of the ECVs considered here, has not yet been undertaken on the scale, and with consistency, necessary to achieve the GCOS goals. To ensure scientific integrity, provide transparency and mitigate technical risks, these activities will be organized on a project basis, per ECV, or per ECV group. Each will start with detailed specifications of the required output high level products, formal specifications of the algorithms to be implemented, and the necessary input data (FCDRs). This will result in validated high-level global data products for each ECV, as requested by the end users and GCOS.

4) Assessing the trends and consistency of the ECV records in the context of climate models and assimilation schemes

These activities will facilitate the exploitation and assessment of global ECV data products by ingesting them (via data assimilation), together with other data sources, into the context of “Earth System Models”. The activity will focus on developing the capabilities necessary for EO-based data products to be more extensively used in climate reanalysis. It will aim to bridge the “last mile” between EO data and their exploitation in models. This will, as necessary to meet the specific objectives of this programme element, include activities such as developing assimilation software tools, conducting observing system experiments (OSEs), user training, and transferring new capabilities from research to operational environments. The actual production of climate re-analysis is the responsibility of the user organizations, and is thus beyond the scope of this ESA programme.

All such activity in this programme element will be conducted in close consultation and cooperation with relevant climate research and modelling organizations. It will make maximum use of capabilities already existing within the user communities, and will build synergies with other programmes dedicated to climate research, modelling and prediction. Through these activities the EO data products generated within this programme element will be confronted with models and with independent in-situ data. This is an essential step in the overall calibration and validation loop for ECVs. It will allow biases and trends inherent in the satellite observing system to be identified and separated from the long-term climate record. It will provide essential feedback for improving the EO processing systems within this programme element and will also furnish consistent inputs for improving and developing climate models within other programmes.

5) **Developing improved algorithms and models for production of the required variables from emerging data sources, consistent with the long term record**

The GCOS requirement is to provide long-term global observations for a wide variety of Essential Climate Variables, while constantly improving the stability, accuracy, and where possible, spatial and temporal sampling. This will demand a major sustained, and coordinated scientific effort to review, improve, and in some cases to develop new underlying processing, retrieval and validation methods. This will be organized in a manner which is adapted to the working practices of the international scientific community, and will focus research effort on to those areas which offer the greatest prospect of achieving the desired performance improvements within each field, for each ECV and FCDR. These activities will engage the climate research and modelling user communities along with the EO data community into a structured scientific dialogue, which is essential for meeting the objectives of this programme element. The outputs will be formal scientific specification of algorithms, proto-type software, documentation, and reference data, which can be passed to industry for integration within operational systems. These outputs are essential, pre-requisite inputs for activities 1-4.

In addition to the main activities described above, sustained and dedicated actions to generate and disseminate a substantial volume of effective communication and educational materials on the specific subject of Earth Observation and climate change will be undertaken.

The single most important role of this element will be to implement active feedback between each of the five steps identified above. This will move from the present static situation of ad-hoc or isolated fixed-term projects, to a long-term cyclical process of systematic updating, regeneration and reanalysis of the underlying fundamental data records, and the production of fully up to date, complete and consistent records of the relevant Essential Climate Variables.

The Scientific integrity of this ESA initiative vis-à-vis UNFCCC and its Subsidiary Body for Scientific and Technical Advice (SBSTA) will be assured by establishing a dedicated mechanism for obtaining Scientific Advice from the European and international climate research and modelling user communities, in consultation with GCOS. Wide user consultations and engagement will be conducted throughout the programme, in close cooperation with the the major climate research and modelling centres in Europe and with the major international climate research programmes, notably WCRP and IGBP. This will include the creation of a small team of experts appointed by the ESA Executive to provide specialist scientific advice on the overall progress of the element. The broader advice of the ESA Earth Science Advisory Committee will be also sought regularly.

ESA will strive to ensure that the international science community will benefit from *free and unrestricted access to all EO data products generated under this programme element*, with ESA data, and with data provided by CEOS partners, subject to the applicable data access conditions of the respective space agencies.

5. INDICATIVE TIMETABLE

The indicative outline timetable is as follows

Start of activities: January 2009

Start of Scientific consultations with Climate Research communities: January 2009

Start of Development of improved models and algorithms: January 2009

Start of Data gathering and (Re-) Processing activities: January 2009

Start of Integrating calibrated data sets for ECVs: January 2010

Start of Assessing trends & consistency of ECVs in climate models: September 2010

Mid-term Programme Element status review: December 2011

6. STATUS OF PROGRAM

This program will be proposed for approval at the next ESA Council at Ministerial level taking place at the Hague (NL) on 25-26 November 2008.

7. REFERENCES

Further information about the various ESA missions can be found on the following WWW address:

www.esa.int