The Need for a Comprehensive, Integrated and Sustained Climate Observational System

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1. MAIN USES OF CLIMATE DATA

The Global Climate Observing System (GCOS) was established in 1992 by the World Meteorological Organization, the Intergovernmental Oceanographic Commission of UNESCO, the United Nations Environment Programme, and the International Council for Science. A prerequisite to designing and implementing a comprehensive, integrated and sustained GCOS is to identify the principal uses and users of the observations in order to justify such a costly, long-term, internationally collaborative operation. Such uses are:

a. monitoring the climate in order to quantify natural climatic fluctuations on a range of temporal and spatial scales and to detect climate change;

b. attribution of climate change to particular causes, in particular to human-related causes;

c. detection (and attribution) of the environmental impacts of climate change;

d. diagnostic studies to advance understanding of the behaviour of the climate system and its component parts, including the mechanisms of natural climate variability;

e. development and testing of hypotheses relating to local and global climate variations and to the degree of predictability of climatic phenomena;

f. process studies. Special data are needed for detailed research into a wide variety of complex dynamical, physical, chemical and biological processes, which help govern the state and evolution of the climate system. These often need to be highly resolved in time and space and therefore gathered for a limited period over a restricted area. Note, however, that continuous global data sets provide an excellent and often necessary context for the more focused process-study field campaigns;

g. a wide range of uses for climate models, including boundary conditions, initialization, data assimilation, and validation, leading to their improvement, including for seasonal-to-interannual climate predictions. A very wide array of observations of all components of the climate system is needed for these highly-specialised and important purposes.

2. REQUIREMENTS FOR CLIMATE DATA

Observations, therefore, need to be fit for purpose and set in a framework that will achieve best value. A Global Climate ***Observational*** System is needed that must go beyond simply making observations (i.e. a climate ***observing*** system). A sustained (operational) system needs to be oriented strongly towards the delivery of global and regional products and services. The objective of GCOS is to be such an end-to-end system ranging from observations

to the processing, management, dissemination and care of observations that are necessary to achieve reliable and useful products for specified uses and users.

Specific requirements

GCOS and others, including the sectoral Global Ocean Observing System (1993) and Global Terrestrial Observing System (1996), have published specific and detailed requirements for essential climate observations. The Second Report on the Adequacy of the Global Observing System for Climate in Support of the UNFCCC (GCOS-82, WMO/TD No. 1143, April 2003) gives such lists for the atmosphere, oceans and land, and a corresponding list of variables which depend heavily on satellite observations. The report concludes that although there have been recent improvements in implementing the global observing systems for climate, especially in the use of satellite information and the provision of some ocean observations, nevertheless, serious deficiencies remain: e.g. atmospheric networks are not operating with the required global coverage and quality; ocean networks lack global coverage and commitment to sustained operation; global terrestrial networks are not fully implemented. Note that satellite data are still not being analyzed and therefore exploited to a sufficient degree.

The report also prescribes twenty ***GCOS Climate Monitoring Principles***. The 'ten basic principles' were adopted by the UNFCCC, 1999. Ten further principles are aimed specifically at satellite systems. A widespread, disciplined adherence to these principles is necessary to achieve the homogeneous climate record needed for future use, especially for assessing climate change.

Satellite mission requirements

Observations from satellites require some special considerations. Since it began in 1980, the World Climate Research Programme (WCRP) has been a major user of satellite data and one of the main drivers in the planning and development of new Earth Observation instruments and space missions. A WCRP *ad hoc* Satellite Working Group has produced an 'Update of Space Mission Requirements for WCRP' (January 2003), which highlights priorities for future space missions and related data management.

Satellite data offer an unprecedented potential for climate research provided that separate sensor/satellite data are integrated into high-quality, globally-integrated climate products that above all must be homogeneous in time over decades for monitoring, detection and attribution. The potential would be further enhanced by new space missions focusing on the water cycle and cloud radiative processes, on ocean salinity and soil moisture, and also by reinforcing other areas where missions are already planned but where major observational issues remain.

Climate research requires not only exploratory missions to improve understanding of climate processes, but also long-term monitoring programmes (including analysis, re-analysis cycles) essential to assess the characteristics of the present climate, for use in experimental climate prediction studies, and to detect natural and human-induced trends. Increased resources are needed to achieve more effective exploitation of current and planned satellite observations through increased international cooperation on developing integrated analyses and products. The transition from research to operational systems is also an important practical issue.

The IGOS themes

The Integrated Global Observing Strategy Partnership (1998) recognises that it is not practical to define a comprehensive global system that, in a single step, would satisfy all needs for environmental information. Rather, it has adopted a thematic approach which allows for the development of an overall global strategy for observing selected fields, and for a framework to encourage new developments in priority areas for climate studies, such as the water cycle, the carbon cycle and the oceans. In particular, an Integrated Global Water Cycle Observations (IGWCO) theme is being developed, building on the experiences gained in the WCRP's Global Energy and Water Cycle Experiment (GEWEX) which has helped generate global data sets for clouds, precipitation, soil moisture, evaporation/evapotranspiration, and energy and radiation budgets. The Coordinated Enhanced Observing Period (CEOP), initiated by GEWEX, is the first major component of the IGWCO theme. A key challenge is to compile and integrate the extremely high volume of new satellite data, products from operational weather forecasting and climate models, and the data collected at the globally-distributed and heterogeneous CEOP surface reference sites, to produce data sets suitable for research into water and energy cycles, understanding monsoon systems, improving weather and climate predictions, and applications for water resource management.

3. SOME CRITICAL DEFICIENCIES

a. A commitment is needed to create a comprehensive, reliable, end-to-end, ***Global Climate Observational System*** which will produce long-term, high-quality, temporally homogeneous data sets and products. This should include a strategic plan for the progressive, coordinated, periodic analyses and re-analyses, which are necessary to incorporate lessons from new measurements and research, and for the support to enable archival institutions to do this. At the present time, we do not even have an adequate climate observing system for any climate variable.

b. Exchange of climate data and information is, arguably, a bigger challenge than making the observations - **and is currently highly inadequate**. Proper climate monitoring requires homogeneous data on daily (sometimes sub-daily) time scales upwards to be gathered and exchanged world-wide in a timely fashion, complemented by the production and dissemination of analyses and related products. There needs to be full global coverage of the observations and a commitment by (developed) countries best placed to use them to provide analyses and related products to all countries.

c. In spite of the growing efforts of space agencies there remains a gap between their data production and the means available in the research community to process and exploit satellite data fully and efficiently.

d. By way of specific example (there are many others), the IPCC Third Assessment Report, 2001, states categorically that: 'There are insufficient data to establish trends in precipitation over the oceans'.

e. Special attention is needed for remote, data-sparse regions where conventional observations are a challenge or simply not possible. Remote areas (e.g. polar, sub-polar and mountain regions) may be vulnerable to, and

provide early indicators of, climate change. Satellites can provide observations for some remote areas, but not of everything; e.g. sea-ice thickness and snow water equivalent are problematic. Also, 'ground truthing' is vital. So for many satellite missions suitable for climate-change studies, an integrated view of the needs for the satellite and *in-situ* data is essential. Some of the key products must therefore integrate from both types of data.

f. Almost all current climate data sets, whether fit for purpose or not, lack error estimates. Not only are these needed to assess the ability of a given climate monitoring system to adequately detect climate change or variation signals, but also to provide crucial information on the performance of the measurement systems thereby providing early warning of developing problems.