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SUBSIDIARY BODY FOR SCIENTIFIC AND TECHNOLOGICAL ADVICE
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Bonn, 1–10 June 2009

Item 6 of the provisional agenda
Research and systematic observation

Report on progress with the Global Climate Observing System implementation plan

Submission from the secretariat of the Global Climate Observing System

1. The Conference of the Parties (COP), by its decision 5/CP.10, expressed its appreciation to the Global Climate Observing System (GCOS) for preparing the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (hereinafter referred to as the GCOS implementation plan). By the same decision, the COP requested the secretariat of the GCOS to provide information to the Subsidiary Body for Scientific and Technological Advice (SBSTA) on how the actions identified in the GCOS implementation plan are being implemented.

2. At its twenty-third session, the SBSTA requested the GCOS secretariat to provide a comprehensive report at its thirtieth session on progress with the GCOS implementation plan (FCCC/SBSTA/2005/10, para. 94), in addition to the regular reporting requested by the COP in decision 5/CP.10. In response to this request, the GCOS secretariat submitted the progress report contained in this document.

3. In accordance with the procedure for miscellaneous documents, this submission is attached and reproduced* in the language in which it was received and without formal editing.

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FCCC/SBSTA/2009/MISC.7

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SUBMISSION FROM THE SECRETARIAT OF THE GLOBAL CLIMATE OBSERVING SYSTEM

Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008

April 2009

GCOS Secretariat

GCOS-129

(WMO-TD/No. 1489, GOOS-173, GTOS-70)

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Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008

Foreword

On behalf of the sponsors, Steering Committee and Secretariat of the Global Climate Observing System (GCOS), I am pleased to present this Report on the past five years of progress on implementation of the global observing system for climate in support of the United Nations Framework Convention on Climate Change (UNFCCC).

The goal of GCOS is to provide comprehensive information on the total climate system, involving a multidisciplinary range of physical, chemical and biological properties, and atmospheric, oceanic, hydrologic, cryospheric and terrestrial processes. It is designed to meet the totality of international and national needs for climate-related observations including, in particular and in a very focused way, the needs of the Parties to the UNFCCC, for the purposes of the Convention. It serves as the climate observing component of the Global Earth Observation System of Systems (GEOSS) and it underpins the "climate knowledge" element of the initiative "Acting on Climate Change: The UN System Delivering as One".

GCOS is a joint undertaking of the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the United Nations Environment Programme (UNEP), the International Council for Science (ICSU) and, in respect of its terrestrial observing components, the Food and Agriculture Organization of the UN (FAO). It is built, as a system of systems, on all the climate-relevant components of their various individually and jointly sponsored global observing systems, including, in particular:

- The WMO Integrated Global Observing System (WIGOS);
- The Global Ocean Observing System (GOOS);
- The Global Terrestrial Observing System (GTOS); and
- The World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP) and other research programmes that include observing activities, data systems and observing system research.

GCOS was established, in parallel with the negotiation of the UNFCCC, in the early 1990s and its implementation is carried out by the various national meteorological, hydrological, oceanographic, space, environmental, research and other Earth observing agencies of the more than 190 Member countries of its sponsors (WMO, IOC, UNEP, ICSU and FAO) with support from other national, regional and international coordination and capacity building organizations and mechanisms. Following two UNFCCC-sponsored assessments (in 1998 and 2003) of its adequacy for meeting the needs of the Convention, the Conference of the Parties, through its Decision 11/CP.9, requested the GCOS Secretariat, under the guidance of the GCOS Steering Committee, to coordinate the development of a phased 5- to 10-year implementation plan for the integrated global observing systems for climate. The resulting Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (published in October 2004 as GCOS-92 and now referred to as IP-04) was endorsed by the GCOS sponsors and by the Subsidiary Body for Scientific and Technological Advice (SBSTA) which, at its 23rd (December 2005) session, invited the GCOS Secretariat to provide a comprehensive report at its 30th session (June 2009) on progress with the implementation of the Plan.

This Progress Report responds to the request by SBSTA 23. It was prepared by a broadly-based group of experts under the leadership of Professor Paul Mason with the strong support of the GCOS Panel Chairs and Secretariat and, especially, the Secretariats of three main component observing systems (WIGOS, GOOS and GTOS). The Committee on Earth Observation Satellites (CEOS) provided especially valuable assistance, both in respect of coordinated implementation of the space-based elements of the Plan and in assessment of progress.

The Report concludes that implementation of the various observing systems in support of the UNFCCC has progressed significantly over the last five years but that sustaining the funding of many important systems is fragile, there has been only limited progress in filling observing system gaps in developing countries, and there is still a long way to go to achieve a fully implemented global observing system for climate. The essential findings are provided in the Executive Summary and the details, for each of the 131 specific Actions identified in the IP-04, are included in the main Report. Many of the conclusions in the Report are based on a measure of expert judgement and interpretation of information from National Reports and other sources so the GCOS Steering Committee and Secretariat would welcome additional information and views on its conclusions to ensure that the further planning of GCOS is as well informed as possible[1].

The preparation of the 2004-2008 Progress Report has helped to identify a number of important priorities for the next five years if GCOS is to be further developed to serve optimally the evolving needs of the UNFCCC. These include, in particular:

- The urgent need for funding support for implementation of the GCOS Regional Action Plans developed over the period 2001-2006;
- Immediate attention to the design and implementation of the national and local-scale networks needed for impact assessment and adaptation to climate change;
- The appointment of GCOS National Coordinators in many more than the present 14 countries which have well established national coordination arrangements for climate observations;
- Much stronger and higher-level commitment of Parties to the GCOS Cooperation Mechanism for supporting GCOS implementation in developing countries;
- Finding new mechanisms for ensuring sustained long-term operation of essential *in situ* networks, especially for the oceanic and terrestrial domains, that are presently supported from project-timescale research funding;
- Strong support for the further development and promulgation of observational standards for the full range of terrestrial climate variables;
- Continued encouragement for the coordinated implementation and long-term continuity of the cross-cutting space-based component of GCOS;
- Strong support for the observational and research-based “Global Framework for Climate Services” proposed for endorsement by World Climate Conference Three;
- Reaffirmation of the value of the UNFCCC National Reports on observations as a mechanism for fostering, focussing and guiding GCOS implementation at the national level.

The GCOS Steering Committee and Secretariat will continue to advise on, and guide, the further development of GCOS in support of the observational needs of the UNFCCC and individual Parties to the Convention. The GCOS Steering Committee believes that an updated version of IP-04 is needed to assist continued progress. With the support of the GCOS sponsors, and if so desired by SBSTA, they would be pleased to consult widely, including especially through the September 2009 OceanObs’09 Conference, and prepare an updated Implementation Plan (IP-09) by the end of 2009 for consideration by SBSTA in 2010.

John W. Zillman

(Chairman, GCOS Steering Committee)

April 2009

[1] See page 15.

Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008

April 2009

Executive Summary

- **The increasing profile of climate change has reinforced world-wide awareness of the importance of an effective Global Climate Observing System.**
- **Developed Countries have improved many of their climate observation capabilities, but national reports suggest little progress in ensuring long-term continuity for several important observing systems.**
- **Developing Countries have made only limited progress in filling gaps in their *in situ* observing networks, with some evidence of decline in some regions, and capacity building support remains small in relation to needs.**
- **Both operational and research networks and systems, established principally for other purposes, are increasingly responsive to climate needs including the need for timely data exchange.**
- **Space agencies have improved both mission continuity and observational capability, and are increasingly meeting the identified needs for data reprocessing, product generation, and access.**
- **The Global Climate Observing System has progressed significantly over the last five years, but still falls short of meeting all the climate information needs of the UNFCCC and broader user communities.**

This *Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008* responds to a request of the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the UN Framework Convention on Climate Change (UNFCCC) at its twenty-third session (December, 2005)[2]. SBSTA invited the Global Climate Observing System (GCOS) Secretariat to "provide a comprehensive report at its thirtieth session (June 2009) on progress with the GCOS Implementation Plan". This Report addresses progress since late 2004 in implementing the Actions called for in the 2004 Implementation Plan[3] (hereinafter referred to as 'IP-04'), that is, Actions intended to maintain, strengthen, or otherwise facilitate global observations of the climate system for the purposes of the Convention.

The IP-04 was designed to help provide global observations of a set of Essential Climate Variables (ECVs) identified in the *Second Report on the Adequacy of the Global Observing System for Climate in Support of the UNFCCC*[4]. The forty-four atmospheric, oceanic, and terrestrial ECVs were selected on the basis of their relevance for climate and the feasibility for sustained global observation at that time. In addition, it was noted that implementation of the Actions specified in the IP-04 would ensure the provision of the sustained global observations required by the World Climate Research Programme (WCRP) and the Intergovernmental Panel on Climate Change (IPCC). At the same time, consistent with the GCOS being based on existing observation systems and observations often made

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[2] UNFCCC (2006): Report of the Subsidiary Body for Scientific and Technological Advice on its twenty-third session, held at Montreal from 28 November to 6 December 2005 (doc. FCCC/SBSTA/2005/10, para. 94) (see Appendix 4).

[3] GCOS (2004): *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC*, GCOS-92, October 2004, http://www.wmo.int/pages/prog/gcos/Publications/gcos-92_GIP.pdf. (hereinafter referred to as 'IP-04').

[4] GCOS (2003): *Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC*, GCOS-82, April 2003, http://www.wmo.int/pages/prog/gcos/Publications/gcos-82_2AR.pdf.

for purposes other than climate, it was also noted that implementing the IP-04 would provide wider-ranging benefits in environmental monitoring and prediction. The objectives of the IP-04 are consistent with the overall objectives of the Global Climate Observing System (GCOS) established jointly by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU) in 1992.[5] The GCOS includes observations from all domains – atmospheric, oceanic, and terrestrial – which are then transformed into products and useful information through analysis and integration in both time and space.

This document is a report on progress on a wide-ranging set of Actions aimed at strengthening the component systems and national activities that comprise the GCOS system of systems. The aim of the GCOS is to provide, through existing operational and research observing, data management, and information distribution systems (and further enhancements to these systems), a comprehensive and coordinated system of climate-relevant observing systems that meets the total national and international needs for climate observations. The observing systems on which GCOS is built include, *inter alia*:

- The WMO World Weather Watch (WWW) Global Observing System (GOS) and the Global Atmosphere Watch (GAW) for the atmospheric variables, along with other WMO climate-related observing systems (now collectively referred to as the WMO Integrated Global Observing System (WIGOS));
- The IOC/WMO/UNEP/ICSU Global Ocean Observing System (GOOS) for physical, chemical and biological properties of the ocean;
- The Food and Agriculture Organization (FAO)/UNEP/UNESCO/WMO/ICSU Global Terrestrial Observing System (GTOS) for land surface ecosystem, hydrological, and cryospheric measurements; and those of
- The World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP) and other research programmes that include observing activities, data systems and observing system research.

The IP-04 identified in total 131 Actions: 32 specific Actions in the atmospheric domain, 41 in the oceanic domain, 37 in the terrestrial domain, and 21 overarching/cross-cutting Actions that apply across all domains. In its Executive Summary, the IP-04 also identifies a set of 'Key Actions', each of which comprises one or more Actions in the main text of the IP-04. The time horizon for many activities is long (for example, it takes more than a decade to develop and launch a satellite system) but, on the basis of a comprehensive assessment by the GCOS Steering Committee, it is clear that most of the Actions set down in the IP-04 have been enthusiastically embraced at both international and national levels (cf. Figure 1 which summarizes overall progress on a scale from good to none).[6] Agents for Implementation identified in the IP-04 have taken significant steps to attain the specified objectives. In some areas, however, progress since 2004 remains limited or absent. The domain sections of this Report give detailed assessments of progress.

Since the IP-04 was aimed at meeting the larger-scale climate information needs of Parties, it only noted the important additional needs for national-scale climate services, but did not address them in detail. With increasing attention being given to adaptation, the national and local-scale requirements will need to be addressed in more detail in updates to the IP-04.

Although the individual activities identified in the IP-04 are coordinated through a variety of international programmes, organizations and agencies, success depends almost entirely on national[7]

[5] GCOS (1995): *Plan for the Global Climate Observing System (GCOS), Version 1.0*, GCOS-14, May 1995, http://www.wmo.int/pages/prog/gcos/Publications/gcos-14.pdf.

[6] For explanation of all terms used, see Appendix 2 of the Report.

[7] Whenever reference is made to "national activities" in the context of this report, this also includes activities by multi-governmental Agents for Implementation, such as the European Space Agency (ESA), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and European Centre for Medium-Range Weather Forecasts (ECMWF).

and regional entities. The successful implementation of the IP-04, therefore, depends directly upon the response of the many Agents for Implementation to the overall coordinated plan, and ultimately, also, upon a wide range of national actions and observing systems.

This Progress Report is intended to inform Parties to the UNFCCC, as well as all other involved bodies and Agents for Implementation, and also provide the GCOS Steering Committee and sponsors (WMO, IOC, UNEP and ICSU) with a foundation upon which to base an updated version of the IP-04.

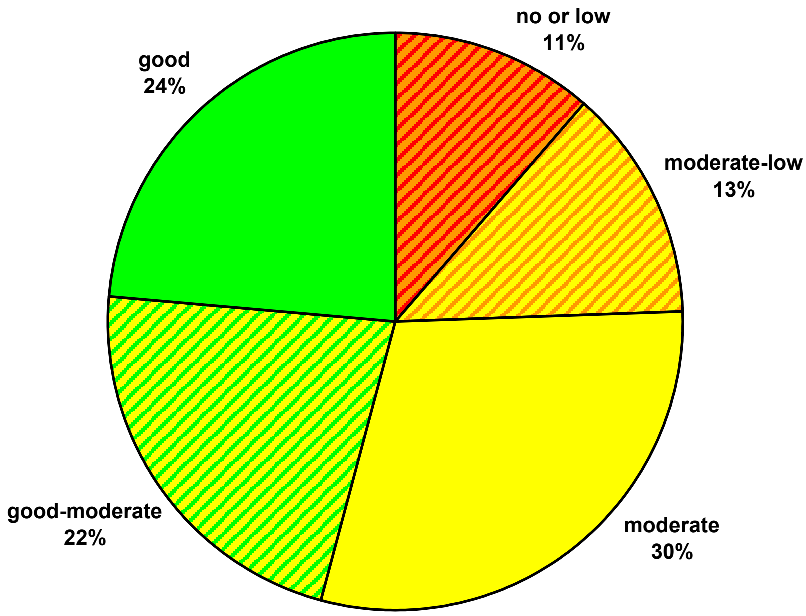

Figure 1: Progress assessment on all 131 Actions in the IP-04

As sources of information, this Report uses performance reports from GCOS monitoring centres and component observing systems and their technical advisory bodies, and information on national activities related to systematic observation for climate ('National Reports') provided by Parties[8] in response to UNFCCC SBSTA[9] and COP Decision 11/CP.13. It does not assess expenditures associated with implementation of the various Actions taken by the identified Agents for Implementation. In most cases, the Actions have involved many different national bodies and, for the most part, the incremental cost information associated with the Actions is not readily available.

While the overall concept, structure, and function of GCOS have remained essentially unchanged since 2004, some activities and events occurring over the intervening five years have significantly influenced its continued development. These include: publication of the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC); the formal establishment of the Group on Earth Observations[10] (GEO) and the adoption of the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan; the initiation, in 2005, of the five-year UNFCCC

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[8] Australia, Belgium, Belize, Canada, Denmark, European Commission, Finland, France, Germany, Greece, Ireland, Italy, Japan, Lithuania, Netherlands, Poland, Portugal, Russia, Slovakia, Spain, Sri Lanka, Sweden, Switzerland, United Kingdom, United States; All reports are available at http://unfccc.int/methods_and_science/research_and_systematic_observations/items/4499.php

[9] UNFCCC (2008): Report of the Subsidiary Body for Scientific and Technological Advice on its twenty-seventh session, held in Bali from 3 to 11 December 2007 (doc. FCCC/SBSTA/2007/16, para. 36); and UNFCCC (2006): Report of the Subsidiary Body for Scientific and Technological Advice on its twenty-third session, held at Montreal from 28 November to 6 December 2005 (doc. FCCC/SBSTA/2005/10, para. 94).

[10] http://www.earthobservations.org

Nairobi Work Programme; and the 2008 "Acting on Climate Change: The UN System Delivering as One" initiative.[11]

Progress on Overarching and Cross-cutting Actions

The 21 overarching and cross-cutting Actions in the IP-04 address vital issues as they seek to ensure wide recognition of, and response to, climate observation and related needs. The sponsors of GCOS, their subsidiary bodies, and almost all of the international organizations involved with climate observations have either formally or informally adopted the IP-04 and have incorporated the relevant components within their own planning processes. This commitment to action represents a significant degree of international consensus and support for the IP-04. The Actions encompass a broad range of activities, including planning, coordination, and adherence to the GCOS Climate Monitoring Principles (GCMPs), as well as data management, processing, analysis, and archiving. These Actions by themselves are often not very costly, but require careful adoption, sustained attention, and long-term engagement. Overall, progress on the specific overarching and cross-cutting Actions since the publication of the IP-04 has been quite good (see Table 1) as a result of engagement by Agents for Implementation at all levels. Over the past five years:

- **The sponsors of GCOS, their subsidiary bodies, and almost all of the international organizations involved with climate observations have either formally or informally adopted the IP-04** and have incorporated the relevant components within their own planning processes.
- **National Reports and other sources of information provide substantial evidence for increased attention to the needs for climate observations**, especially in those countries with formal national coordination mechanisms for GCOS.
- **Regional Action Plans have been prepared for all developing country regions but, with few exceptions, support for implementation of the projects presented in the Plans has been disappointing**. Overall capacity-building support to developing countries has fallen well short of needs.
- **A few research networks have become sustained, but many other networks remain fully in the research category**, with little assurance of long-term continuity for essential observations
- **There has been good commitment to the GCOS Climate Monitoring Principles (GCMPs) by many operators of networks and systems, including satellite agencies.** However, overall, the extent of adherence to the GCMPs remains partial, mostly for financial reasons.
- **The space agencies have been very responsive to the IP-04 and they are advancing their own matching implementation plans** (e.g., the 2006 CEOS Response[12] to the IP-04 and its Satellite Supplement[13]) detailing the coordinated response of individual satellite operators to the overall GCOS objectives.
- **There has been progress in the provision of datasets in support of analysis and reanalysis.** Atmospheric reanalysis has progressed well and has played an increasingly important role in the WCRP and the assessment work of the IPCC.
- **There has been good progress in the assembly of historical data records and in acquiring and archiving palaeoclimatic records. Moderate to good progress has also been achieved in the provision of data to international data centres and their archival, exchange, and supply to users for most ECVs**. Meeting the full range of objectives expressed in the IP-04 will require much more attention to building capacity in developing and least-developed countries, to ensure better observational coverage and use of climate data, especially on regional and national scales where information is required for the purposes of adaptation.

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[11] United Nations System Chief Executives Board for Coordination (2008): *Acting on Climate Change: The UN System Delivering as One*, http://www.un.org/climatechange/pdfs/Acting%20on%20Climate%20Change.pdf .
[12] CEOS (2006): *Satellite Observation of the Climate System* - The Committee on Earth Observation Satellites (CEOS) Response to the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC, October 2006, http://www.ceos.org/pages/CEOSResponse_1010A.pdf.
[13] GCOS (2006): *Systematic Observation Requirements for Satellite-based Products for Climate*, GCOS-107, September 2006, http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf.

Table 1: Assessment of Progress on the 21 Overarching and Cross-cutting Actions in the IP-04

Assessment Categories	No or Low Progress	Moderate to Low Progress	Moderate Progress	Good to Moderate Progress	Good Progress
Number of Actions	2	1	12	2	4
Percent of Actions[14]	10%	5%	57%	10%	19%

Progress on Atmospheric Domain Actions

Observing the atmosphere is critical for monitoring climate change, for determining forcing of the climate system by greenhouse gases and aerosols, and for attributing climate change to natural and anthropogenic influences. Data are also essential for improving the skill of the climate prediction models used for impact, adaptation and vulnerability assessments. Mitigation of climate change needs to be based upon reliable determination of sources and sinks of greenhouse gases, which needs observations of the changing distribution of these gases. 88% of the Actions in the atmospheric domain show progress in the range from moderate to good.

- **Overall, there has been steady progress in maintaining and enhancing the atmospheric observing systems for climate.** This is largely based on efforts by the National Meteorological Services (NMSs) and other national operators of networks and systems (both ground and space-based) providing surface and upper-air meteorological observations, measurements of greenhouse gases and measurements of other aspects of atmospheric composition. Improved instruments, international coordination, and reprocessing and exploitation of datasets have led to an increasingly important contribution of satellite systems to global climate monitoring.

- **The global trends of declining *in situ* meteorological network performance prevailing through the 1990s have been halted or reversed in all regions.** In spite of the overall progress, however, some regions of the world, Africa in particular, have seen no significant improvement in observational coverage. Good progress in the implementation of *in situ* networks for atmospheric composition ECVs has been made.

- **Despite good overall progress, there remain some specific issues where methodological, technical or institutional problems persist.** For example: continuing scientific challenges related to the measurement of precipitation and clouds; inadequate exchange of climatologically-relevant data, including near-real time data; insufficient rescue of historical data and metadata.

- **Increased emphasis has been placed on establishing reference networks to anchor the broader surface and upper-air networks.** Important steps have been taken towards establishment of the GCOS Reference Upper Air Network (GRUAN) to measure essential properties of the atmospheric column. In addition, many countries are setting up national climate networks of geographically well-distributed surface stations that provide high-quality observations of many, if not all, of the surface-based climate variables.

An evaluation of progress has been made against each of the 32 Actions in the atmospheric domain, with a summary given in Table 2 and further details stated in the main Report.

[14] Rounded to integer percentages.

Table 2: Assessment of Progress on the 32 Atmospheric Domain Actions in the IP-04

Assessment Categories	No or Low Progress	Moderate to Low Progress	Moderate Progress	Good to Moderate Progress	Good Progress
Number of Actions	1	3	8	14	6
Percent of Actions[15]	3%	9%	25%	44%	19%

Progress on Oceanic Domain Actions

The ocean plays critical, but generally not obvious, roles in the fundamentally coupled ocean-atmosphere-land Earth climate system. The ocean varies strongly on interannual and decadal time scales, and will undergo much greater changes from these over the next few decades than will result from climate change over the same period. Sea level is a critical variable for low-lying regions; globally, it is driven by volume expansion or contraction due to changes in sub-surface ocean density, and by exchange of water between the oceans and other reservoirs, such as land-based ice, and the atmosphere. Developing confidence in forecasts of oceanic variability and change will require accurate datasets over the entire world ocean. The composite surface and sub-surface ocean observing networks, as described in the IP-04, include global monitoring of certain ECVs where this is feasible. In some other cases, monitoring of ECVs depends on observations from reference stations or sites, or in case of sub-surface ocean carbon, nutrients and tracers, on repeat ship-based surveys.

- **Useful progress has been identified in almost every Action called for in the IP-04, but many Actions remain incomplete.** 86% of the Actions in the oceanic domain show progress in the range from moderate to good.
- **The ice-free upper 1500 m of the ocean are being observed systematically for temperature and salinity for the first time in history**, because both the Argo profiling float and surface drifting buoy arrays have reached global coverage at their target numbers.
- **Most *in situ* networks have made progress**. There has been a substantial increase in the number of tide gauges now reporting both in near-real time and with tsunami-detection capability. Several new moored reference site moorings have been deployed, and the tropical moored array continues to develop in the Atlantic and Indian Oceans. Full ocean depth observations of physical and carbon ECVs have had good progress, but the number of Voluntary Observing Ships reporting marine meteorological observations has declined.
- **Most *in situ* observing activities continue to be carried out under research agency support and on research programme time limits**. A particular concern is the fragility of the financial arrangements that support most of the present effort; there has been very limited progress in the establishment of national ocean or climate institutions tasked with sustaining a climate-quality ocean observing system. Thus, the primary Agents for Implementation for ocean observations and analyzes remain the national and regional research organizations, with their project-time-scale focus and emphasis on principal investigator-driven activities.
- **Important progress in provision of critical ocean satellite data of sea-surface ECVs has been made, but not for all variables, and data access remains to be ensured.** The Committee on Earth Observation Satellites (CEOS) has adopted a strategy of Virtual Constellations for ocean topography, surface vector wind, and ocean colour, and serious space agency engagement to progress these Constellations is underway.
- **Important progress has been achieved in development of historical ocean reanalysis and in high-resolution ocean forecasting capabilities.** A number of products are now available and being evaluated. Issues with the historical dataset have been identified and are being studied.
- **Promising developments in improved methods and standards will allow wider measurement of biological and chemical ECVs and consideration of new ECVs in the years**

[15] Rounded to integer percentages.

ahead. Ocean *in situ* and satellite sensor and platform developments continue and some new system capabilities are now feasible for broad use. Outreach to the ocean ecosystem, fisheries and biogeochemistry communities is ongoing and community plans will be developed for basin-scale sustained observations of feasible ECVs through the OceanObs'09 Conference. Community efforts on ocean metadata are ongoing.

- **Data sharing remains incomplete, particularly for tide gauges and biogeochemical ECVs.** Data archaeology needs to continue. Although progress has been made in some respects on recovery of the ocean historical dataset, continuing efforts in data rescue, digitization and data sharing are needed. Full access to at least the GLOSS Core Network of tide gauges remains to be achieved. More timely and complete data sharing within the ocean water column repeat survey community is needed.

Progress related to the 41 oceanic domain Actions identified in the IP-04 has been evaluated. While the details of each assessment are given in the full Report, Table 3 provides a summary overview of progress.

Table 3: Assessment of Progress on the 41 Oceanic Domain Actions in the IP-04.

Assessment Categories	No or Low Progress	Moderate to Low Progress	Moderate Progress	Good to Moderate Progress	Good Progress
Number of Actions	4	5	15	8	9
Percent of Actions[16]	10%	12%	37%	20%	22%

Progress on Terrestrial Domain Actions

Increasing significance is being placed on terrestrial data for estimating climate forcing and better understanding of climate change and variability, as well as for impact and mitigation assessment. The recognition of this has led to substantial progress in a number of areas in the terrestrial domain: 56 percent of terrestrial domain Actions show progress in the range from moderate to good, although advances are still limited or absent in others.

- **There has been significant progress in defining internationally accepted standards for the terrestrial ECVs.** The GTOS Secretariat has been reporting regularly to SBSTA on collaboration with the International Organization for Standardization (ISO) in that regard.

- **Progress in establishing institutional support for *in situ* networks has been slow**, leading to networks that are still poorly coordinated and harmonized, despite considerable effort of the research community to keep them running.

- **The objective of creating a comprehensive and well coordinated reference network for *in situ* observations of the fullest possible range of terrestrial ECVs is a continuing, yet still a largely unmet challenge.** Such a network would provide the observational data and associated details relevant to their application in model validation, process studies, and the validation of observations derived from Earth observation satellites.

- **The establishment of several Global Terrestrial Networks (GTNs) in a number of areas (e.g. Hydrology, Glaciers, Permafrost), where data collection takes place largely through *in situ* measurements has significantly improved the coordination and global coverage of these observations**, though gaps still remain.

- **Observations taken for purposes other than climate, but with climate relevance, are often not made available**, sometimes due to their economic or national strategic value. This has for instance, led to a declining number of reports of river discharge. However some networks, such

[16] Rounded to integer percentages.

as for glaciers (GTN-G), have shown remarkable resilience and now operate very effectively. Similar progress has been made in the production of fire-related global datasets.

- **Good progress has been made in guaranteeing short-term continuity in the availability of high-resolution optical observations from satellites**, a gap highlighted in previous GCOS reports. Long-term commitment to continuity of this class of missions, though crucial to successful maintenance of the observation records, has yet to be secured.

- **The increasing commitment of space agencies to produce fundamental climate data records from existing systems has led to improved availability of global datasets, such as burned area and land cover.** The community now increasingly uses these datasets. Substantial gaps remain in quality control, which need to be addressed through intercomparison and validation.

- **The analysis of historical records, both *in situ* and satellite based, has been progressing slowly and needs the urgent consideration of space agencies together with the potential users.**

Progress against each of the 37 terrestrial Actions in the IP-04 has been evaluated, and the details on each assessed Action are given in the main Report. Table 4 summarises the evaluation of terrestrial Actions.

Table 4: Assessment of Progress on the 37 Terrestrial Domain Actions in the IP-04

Assessment Categories	**No or Low Progress**	**Moderate to Low Progress**	**Moderate Progress**	**Good to Moderate Progress**	**Good Progress**
Number of Actions	8	8	4	5	12
Percent of Actions[17]	22%	22%	11%	13%	32%

[17] Rounded to integer percentages.

Progress Report[18] on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008

April 2009

1 Introduction and Background

This Report responds to the request of UNFCCC SBSTA which, at its 23rd session (Montreal, 2005), invited the Global Climate Observing System (GCOS) Secretariat to "provide a comprehensive report at its thirtieth session (June 2009), on progress with the GCOS Implementation Plan,[19] in addition to the regular reporting requested by the Conference of the Parties (COP) in decision 5/CP.10".[20] It addresses the progress since late 2004 in implementation of the 131 Actions called for in the Implementation Plan (hereinafter referred to as 'IP-04'), that is, Actions intended to maintain, strengthen or otherwise facilitate global observations of the climate system. The time horizon for many activities is long (for example to develop and launch a satellite system requires more than a decade) but most of the Actions proposed in the IP-04 have been enthusiastically embraced in both international planning and national[21] actions, and significant steps have been taken to attain the specified objectives. In some areas, however, progress since 2004 remains limited or absent.

It was noted in the 2003 Second Adequacy Report,[22] that "Without urgent action and clear commitment of additional resources by the Parties, the UNFCCC and intergovernmental and international agencies, the Parties will lack the information necessary to effectively plan for and manage their response to climate change." The IP-04 was designed to help provide these global observations of the Essential Climate Variables (ECVs) and their associated products. The forty-four ECVs in the atmospheric, oceanic and terrestrial domains (see **Table 5**) were selected based on their relevance for climate, and depending on the feasibility at that time of sustained, global observations. In addition, it was noted that implementation of the IP-04 would ensure the provision of the sustained global observations required by the World Climate Research Programme (WCRP) and the Intergovernmental Panel on Climate Change (IPCC). At the same time, consistent with the GCOS being based on existing observation systems and observations often made for purposes other than climate, it was also noted that implementing the IP-04 would provide wider-ranging benefits in environmental monitoring and prediction. Specifically the proposed system was designed to provide information to:

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

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[18] This Report is available for review and technical comment until 20 June 2009 on the GCOS Secretariat website (http://gcos.wmo.int).
[19] GCOS (2004): *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC*, GCOS-92, October 2004, http://www.wmo.int/pages/prog/gcos/Publications/gcos-92_GIP.pdf (hereinafter referred to as 'IP-04').
[20] UNFCCC (2006): Report of the Subsidiary Body for Scientific and Technological Advice on its twenty-third session, held at Montreal from 28 November to 6 December 2005 (doc. FCCC/SBSTA/2005/10, para. 94) and Appendix 4.
[21] Whenever reference is made to "National activities" in the context of this report, this also includes activities by multi-governmental Agents for Implementation, such as ESA and EUMETSAT.
[22] GCOS (2003): *Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC*, GCOS-82, April 2003, http://www.wmo.int/pages/prog/gcos/Publications/gcos-82_2AR.pdf

The concept of the GCOS was established in 1992 by the

- World Meteorological Organization (WMO);
- Intergovernmental Oceanographic Commission (IOC) of UNESCO;
- United Nations Environment Programme (UNEP); and
- International Council for Science (ICSU).

At the same time the WMO-IOC-UNEP-ICSU Memorandum of Understanding established a GCOS Steering Committee, supported by a Secretariat, to advise on the development of GCOS.

The planning and implementation of the GCOS has been based, inter alia on:

- The 1995 GCOS Plan[23] (GCOS-14);
- The 1998 *Report on the Adequacy of the Global Climate Observing Systems*[24] (GCOS-48);
- The 2003 Second Adequacy Report (GCOS-82) which introduces the concept of Essential Climate Variables (ECVs);
- The ten 2001-2006 GCOS Regional Workshops[25] (GCOS-106, -100, -97, -94, -86, -85, -80, -78, -74, -62) and associated ten Regional Action Plans; and
- The 2004 IP-04 (GCOS-92) and its Satellite Supplement[26] (GCOS-107).

Table 5: List of Essential Climate Variables as given in the 2004 *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (IP-04).

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, 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[27]	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.	

The GCOS includes observations from all domains – terrestrial, oceanic, and atmospheric – which are then transformed into products and useful information through analysis and integration in both

[23] GCOS (1995): *Plan for the Global Climate Observing System (GCOS), Version 1.0,* GCOS-14, April 1995, http://www.wmo.int/pages/prog/gcos/Publications/gcos-14.pdf.
[24] GCOS (1998): *Report on the Adequacy of the Global Climate Observing Systems*, GCOS-48, October 1998, http://www.wmo.int/pages/prog/gcos/Publications/gcos-48.pdf.
[25] All reports published by GCOS are available at http://www.wmo.int/pages/prog/gcos/index.php?name=publications
[26] GCOS (2006): Systematic Observation Requirements for Satellite-based Products for Climate - Supplemental details to the satellite-based component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC", GCOS-107, September 2006, http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf.
[27] Soil moisture was recognized as an emerging ECV in the IP-04.

time and space. Since no single technology or source can provide all the needed observations, measurements of the ECVs are provided by a composite system of *in situ* instruments on the ground, on ships, buoys, floats, ocean profilers, balloons, samplers, and aircraft, and from all forms of remote sensing, especially from satellites. Metadata (i.e., information on where, when and how the observations are taken) are absolutely essential, as are historical and palaeo-climatic records that set the context for the interpretation of current trends and variability.

Implementation of the IP-04 is aimed to provide all the larger-scale climate information needs of Parties and, as such, includes provision of the national-scale observational needs adequate for broad-scale consideration of impacts and adaptation. Recognising the primary importance and challenge of implementation at that level of coverage, the Plan noted other needs related to detailed national-scale climate services, but did not elaborate such needs. With increasing attention being given to adaptation, these additional needs will have to be further stressed in updates to the IP-04.

Although these individual activities are coordinated internationally through a variety of programmes, organizations and agencies, success will depend mainly on national and regional entities that are turning the IP-04 into reality. Collectively, all of these entities are referred to in the IP-04 as the 'Agents for Implementation'. The successful implementation of the GCOS therefore depends directly upon the response of the many Agents for Implementation to the overall coordinated plan and ultimately upon a wide range of national actions and observing systems.

This document is a report on the progress in the component systems that comprise the GCOS system of systems, and related national activities. The aim of the GCOS is to provide, through existing operational and research observing, data management and information distribution systems, and further enhancements to these systems, a comprehensive and coordinated system of climate-relevant observing systems that includes, *inter alia*, the:

- WMO Integrated Global Observing System (WIGOS);
  - WWW Global Observing System (GOS) for atmospheric physical and dynamical properties;
  - Global Atmosphere Watch for atmospheric constituent and chemical properties; and
  - other WMO climate related observing systems;
- IOC/WMO/UNEP/ICSU Global Ocean Observing System (GOOS) for physical, chemical and biological properties of the ocean;
- FAO/UNEP/UNESCO/WMO/ICSU Global Terrestrial Observing System (GTOS) for land surface ecosystem, hydrosphere, and cryosphere measurements; and
- WCRP and IGBP and other programmes that include observing activities, data systems and observing system research.

GCOS involves the coordination of sustained systems which together provide the comprehensive global observations required for monitoring the climate system by the respective organizations and technical coordination bodies in charge. The GCOS seeks to address the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, terrestrial, hydrological, and cryospheric components. The GCOS has been recognized as the climate observing component of the Global Earth Observation System of Systems (GEOSS).

This Progress Report on the status of the 131 Actions identified in the IP-04 is intended to inform Parties as well as all other involved bodies and Agents for Implementation, and also to provide the GCOS Steering Committee with a foundation upon which to base an updated IP-04. As sources of information, performance reports from GCOS monitoring centres and component observing systems and their technical advisory bodies, and information on national activities related to systematic observation for climate ('National Reports') provided by Parties[28] in response to UNFCCC SBSTA[29] and COP Decision 11/CP.13 were used.

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[28] Australia, Belgium, Canada, Denmark, European Commission, Finland, France, Germany, Greece, Ireland, Italy, Japan, Lithuania, Netherlands, Portugal, Russia, Slovakia, Spain, Sri Lanka, Sweden, Switzerland, United Kingdom, United States; All reports are available at http://unfccc.int/methods_and_science/research_and_systematic_observations/items/4499.php

Progress against each Action has been assessed by the GCOS Steering Committee in narrative form, as well as by using overall indicators of progress for each Action on a scale from good to none. Details on the assessment process are given in the box below. Appendix 1 lists progress indicators for all Actions, and a definition of the indicators is given in Appendix 2.

This Report does not assess expenditures associated with implementation of the various Actions taken by the identified Agents for Implementation. In most cases, the Actions have involved many different national bodies and, for the most part, the incremental cost information associated with the Actions is not readily available.

The assessment of progress was greatly assisted by active engagement of the space agencies which, developed the 2006 CEOS Response to the IP-04, a comprehensive response to the satellite-related needs formulated in the IP-04 and its Satellite Supplement.

Methodology of Progress Assessment:

Basis: The Action text as given in the IP-04 (presented as grey boxes in this Report)

Sources of Information:

- Performance reports and other relevant input from GCOS and component systems monitoring centres and their technical advisory bodies;
- National Reports to the UNFCCC on activities related to GCOS (23 special reports on national GCOS activities, and another 13 national reports as part of the mandatory (4^{th}) National Communications to the UNFCCC);
- Additional information provided to the GCOS Steering Committee by GCOS panels and other experts.

Progress assessment:

- Indicators of progress (cf. Appendix 2 for definitions): Good (green), Good-Moderate (green/ yellow), Moderate (yellow), Moderate-Low (yellow/orange), Low (orange), None (red);
- Although all available sources of information were carefully analyzed, the assessment by the GCOS Steering Committee is in many cases subjective.

2 Contextual Developments since 2004

The overall structure and function of the GCOS remain sound. The following paragraphs elaborate some activities and events that have occurred in the last five years that have influenced the development of GCOS and that are continuing to significantly influence its evolution.

Intergovernmental Panel on Climate Change

The publication of the IPCC Fourth Assessment Report (AR4) in 2007, together with widespread acknowledgment of the issue of climate change and the need to respond to its impacts, has emphasized and strengthened national engagement on climate-related issues. In particular, the AR4 highlighted the inevitability of significant climate change at the regional level and hence the need for a greatly-strengthened information base for impact and vulnerability assessments, adaptation planning and support to mitigation measures that are being considered “post Kyoto”. To ensure that the GCOS, WCRP and IGBP benefited from the insights gained from the AR4, the three international programmes organized a joint workshop with 66 AR4 lead authors in Sydney, Australia, in October

[29] UNFCCC (2006): Report of the Subsidiary Body for Scientific and Technological Advice on its twenty-third session, held at Montreal from 28 November to 6 December 2005 (doc. FCCC/SBSTA/2005/10, para. 95) and Appendix 4.

2007[30]. In terms of observational needs, this workshop, and a survey preceding the event, provided strong support for the requirements and targets set in the IP-04. In addition, participants raised a number of areas which needed additional emphasis or new measurements. These needs will be considered in detail in updates of the IP-04.

Group on Earth Observations and the Global Earth Observing System of Systems

With the principal objective to enhance international coordination of Earth observation and to emphasize the importance of Earth observation for decision-making, the 1st Earth Observation Summit in 2003 established the Group on Earth Observations[31] (GEO), with the aim to implement the Global Earth Observation System of Systems (GEOSS) within ten years. The GEOSS 10-Year Implementation Plan, adopted by GEO members in February 2005 and organized along nine 'Societal Benefit Areas' (SBAs), describes a strategy for coordinated comprehensive and sustained observations of the Earth system in order to improve monitoring of the changing state of the planet, increase understanding of complex Earth processes, and enhance the prediction of the impacts of environmental change, including climate change. Implementation of GEOSS also includes end-user products for nine SBAs – weather, climate, water, agriculture, disasters, biodiversity, ecosystems, energy, and health. Further, the GEOSS strategy foresees building a comprehensive data architecture for a system of observing systems. GEO has been established outside the UN system; its membership includes 77 member nations and the European Commission as of 9 March 2009. It also has the participation of a number of other participating organizations. GEO 'Communities of practice' have been established for Societal Benefit Areas. The Integrated Global Observing Strategy (IGOS) Themes and their reports, which have provided valuable community statements of needs, have been incorporated into GEO and most of them continue to inform the process as GEO Communities of practice. Provisions for enhanced coordination of data exchange and access are being put in place. GCOS has been identified as the climate observing component of GEOSS.

Increasing attention to observations in support of adaptation

The five-year UNFCCC Nairobi Work Programme was initiated in 2005 to improve understanding and assessment of impacts, vulnerability and adaptation to climate change by all Parties, in particular developing countries. The Programme recognizes the importance of improved collection, management, exchange, access to and use of observational data and other relevant information on current and historical climate and its impacts. The Programme promotes the improvement of observations, including monitoring of climate variability, as well as supports capacity building in relation to data and observations, and their use in supporting informed decisions on practical adaptation actions within the context of sustainable development.

The 2005 G-8 Summit in Gleneagles, UK, expressed the desire of the G-8 to strengthen international cooperation on global Earth observations. It also committed the G-8 to support efforts to help developing countries and regions obtain full benefit from GEOSS and GCOS, including "placement of observational systems to fill data gaps, developing of in country and regional capacity for analyzing and interpreting observational data, and development of decision-support systems and tools relevant to local needs". It also noted that the G-8 would specifically work to strengthen the existing climate institutions in Africa through GCOS. In 2008, the G-8 at their Summit in Hokkaido, Japan, pledged to accelerate their efforts to strengthen observations in response to the growing need for information on climate change.

Linked to the Nairobi Work Programme and the 2005 G-8 Summit, the Climate for Development in Africa Programme (ClimDev Africa) was conceived in 2006 as an integrated, multi-partner, Africa-led programme designed to mainstream climate information into development practices throughout Africa, thereby promoting sustainable development and helping to achieve the Millennium Development Goals (MDGs). ClimDev Africa addresses Africa-wide needs in three principal areas:

[30] GCOS, WCRP, IGBP (2008): *Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report*, GCOS-117, January 2008, http://www.wmo.int/pages/prog/gcos/Publications/gcos-117.pdf.

[31] http://www.earthobservations.org

1. Widely available climate information, packaging and dissemination;
2. Quality analyses for decision support and management practices; and
3. Informed decision making, awareness and advocacy.

Progress in ClimDev Africa has been facilitated by the GCOS Secretariat and its sponsors, particularly WMO, in collaboration with donors, countries, and regional bodies. It is now led by the African Union, the African Development Bank and the UN Economic Commission for Africa. Despite endorsement by Heads of State of the African Union and by the Conference of African Ministers of Finance, Planning, and Economic Development, and despite substantial interest on the part of prospective donors, this important Programme was slow to get underway. In November 2008 the sponsors issued a Framework Programme Document with a view to the commencement of the Programme in early 2009.

Coordinated UN Action on Climate Change[32]

Following the December 2007 adoption of the Bali Action Plan and a series of meetings, including the UN General Assembly, the UN Secretary General in May 2008, through the UN Chief Executives Board for Coordination and its High Level Committee on Programmes, initiated a process to ensure a coherent and coordinated UN system response to the challenge of climate change. In the first instance, this involved the identification of five focus areas:

1. Adaptation;
2. Capacity building;
3. Finance (mitigation, adaptation);
4. Reducing emissions from deforestation and forest degradation in developing countries (REDD); and
5. Technology Transfer;

and four cross-cutting areas of UN system activity:

1. Science, assessment, monitoring and early warning;
2. Supporting global, regional and national action;
3. Public awareness; and
4. Climate-neutral UN;

with one or more of the UN system agencies and programmes assigned convening/facilitating roles for developing a coordinated UN-wide approach for each. Most activities in the cross-cutting area of 'science, assessment, monitoring and early warning' ('climate knowledge') will, of necessity, rely heavily on observational support from the GCOS.

3 Progress in Overarching and Cross-cutting Areas

The overarching and cross-cutting Actions in the IP-04 address vital issues as they seek to ensure wide recognition and engagement of climate needs. The Actions encompass a broad range of activities, including planning, coordination, adherence to the GCMPs, and management, processing, analysis, and archiving of data. These Actions by themselves are often not very costly but require careful adoption, sustained attention and long-term engagement. Progress since the publication of the IP-04 has been good and stems from the engagement by the Agents for Implementation at all levels. In summary:

There has been extensive engagement of the Actions in the IP-04. The sponsors of GCOS, their subsidiary bodies, and almost all of the international organizations involved with climate observations

[32] United Nations System Chiefs Executives Board for Coordination (2008): *Acting on Climate Change: The UN Delivering as One*, http://www.un.org/climatechange/pdfs/Acting%20on%20Climate%20Change.pdf.

have either formally or informally adopted the IP-04 and have incorporated the relevant components within their own planning processes.

National Reports and other sources of information provide substantial evidence for increased attention to the needs for climate observations, especially in those countries with formal national coordination mechanisms for GCOS.

Regional Action Plans have been prepared for all developing country regions but, with few exceptions, support for implementation of the projects presented in the Plans has been disappointing. Overall capacity-building support to developing countries has fallen well short of needs.

A few research networks have become sustained, but many other networks remain fully in the research category, with little assurance of long-term continuity for essential observations

There has been good commitment to the GCOS Climate Monitoring Principles (GCMPs) by many operators of networks and systems, including satellite agencies. However, overall, the extent of adherence to the GCMPs remains partial, mostly for financial reasons.

The space agencies have been very responsive to the IP-04 and they are advancing their own matching implementation plans (e.g., the 2006 CEOS Response to the IP-04[33]) detailing the coordinated response of individual satellite operators to the overall GCOS objectives.

There has been progress in the provision of datasets in support of analysis and reanalysis. Atmospheric reanalysis has progressed well and has played an increasingly important role in the WCRP and the assessment work of the IPCC.

There has been good progress in the assembly of historical data records and in acquiring and archiving palaeoclimatic records. Moderate to good progress has been achieved in the provision of data to international data centres and their archival, exchange, and supply to users for most ECVs. Meeting the full range of objectives expressed in the IP-04 will require much more attention on building capacity in developing and least-developed countries, to ensure better observational coverage and use of climate data, especially on regional and national scales where information is required for the purposes of adaptation.

Moderate Progress

Action C1[34] International response to the IP-04

Action: Participating international and intergovernmental organizations are asked to respond to the Actions in this Plan.
Who: International and intergovernmental organizations.
Time-Frame: Inclusion in plans by 2007 and continuing updates as appropriate.
Performance Indicator: Actions incorporated in plans

The sponsors of GCOS, their subsidiary bodies and almost all of the international organizations involved with climate observations have either formally or informally adopted the IP-04 and have incorporated the relevant components within their own planning processes. This commitment to action represents a significant degree of international consensus and support for the IP-04. These decisions have resulted in effectively establishing the necessary international framework for standards and coordination for the collection of atmospheric and oceanic ECVs. In the terrestrial domain, the GTOS Secretariat has taken the initial steps in a process for establishing standards and has made progress in incorporating these standards in much of its programme. With some of the *in situ* terrestrial observations it is especially difficult to establish international planning because of a lack of international bodies with appropriate technical responsibilities. Various other international organizations and science programmes have launched initiatives reflecting Actions called for in the IP-04.[35]

The space agencies, working through CEOS, the Coordination Group for Meteorological Satellites (CGMS) and the WMO Space Programme have been very responsive and have produced implementation plans that largely incorporate as appropriate the space-based Actions called for in the IP-04 and its Satellite Supplement.

[33] CEOS (2006): *Satellite Observation of the Climate System* - The Committee on Earth Observation Satellites (CEOS) Response to the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC, October 2006; http://www.ceos.org/pages/CEOSResponse_1010A.pdf.
[34] In this Report, grey-boxed text and Action numbers are reproduced from the original IP-04
[35] See doc. FCCC/SBSTA/2005/MISC.14 for an initial review in 2005

Since the IP-04 outlines a comprehensive programme that marshals contributions from virtually all countries and organizations dealing with Earth observations, it requires continuing and strengthened coordination and performance monitoring. Increasing national engagement, for example through the establishment of national GCOS coordination mechanisms, would enable better coordination and engagement of all national agencies and others bodies responsible for relevant observations.

Since the IP-04 was prepared, GEO has been established on a permanent basis and the GEOSS 10-Year Implementation Plan Reference Document has been published.[36] GEO has identified the GCOS as the climate observing component of GEOSS and supports the IP-04. GEO has assisted in linking communities from the various Societal Benefit Areas (SBAs) and has helped focus actions on enabling interoperability of data and analysis products. In the context of GEO, the GCOS Secretariat has made efforts to highlight the multi-purpose character of observations for climate in almost all SBAs.

Low Progress

Action C2 National planning

Action: Undertake national coordination and produce national plans for contributions to the global observing system for climate in the context of this Plan.
Who: Parties, in concert with the UNFCCC and international and intergovernmental organizations.
Time-Frame: Planning by 2007 with continuing updates as needed.
Performance Indicator: Number of national reports on climate observations submitted in national communications to the UNFCCC.

The importance of establishing effective national planning and coordination mechanisms cannot be overstated. However, to date, only 14 out of 192 Parties to the UNFCCC have formally appointed a National GCOS Coordinator.[37] Most countries have, however, identified focal points for a range of atmospheric observations. A number of countries, e.g. Switzerland and China, have also produced comprehensive national plans for their contributions to GCOS. These coordination mechanisms have proved to be beneficial in bridging across the diverse national agencies for parts of the national climate observing programmes, and have led to improved engagement. Many countries, when considering their climate observation programmes, have systematically used the IP-04 as guidance.

As noted in the *Synthesis of UNFCCC National Reporting on Systematic Observation*,[38] 23 of the 41 Annex-I Parties have provided National Reports. In addition, information on systematic climate observations from another 13 Annex-I Parties (as part of their regular National Communication) and from 1 Non-Annex-I Party was considered for this Report. For the most part, the national reports were prepared in line with UNFCCC Decision 11/CP.13 which requested Annex-I Parties to provide a detailed report on systematic observations in accordance with a revised format exhibited as Annex 1 to that Decision. The national reports illustrate the progress made in some countries in organizing the wide range of government bodies and other institutions, unique to each country, required to implement the observing strategy called for in the IP-04. The essential information in the reports will be covered below in the discussions pertaining to individual IP-04 Actions.

Moderate Progress

Action C3 Regional Action Plans

Action: Complete development and alignment of Regional Action Plans for climate observations in the context of this Plan.
Who: Regional organizations and associations in cooperation with GCOS.
Time-Frame: 2005.
Performance Indicator: Availability of Regional Action Plans for climate observations.

The ten Regional Action Plans,[39] prepared under the GCOS Regional Workshop Programme[40] between 2001 and 2006, all call attention to elements of the IP-04 in developing regions of particular need, in particular to the key atmospheric, oceanic and terrestrial observations needed to ensure global-scale coverage and to observations meeting regional and national priorities for particular types of information, e.g. for agricultural applications. Such regional details meeting national priorities will be important as countries and regions seek to consider adaptation and to understand likely climate

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[36] GEO (2005): Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan and Reference Document, GEO-1000R, February 2005, 209pp.
[37] Australia, Canada, China, Denmark, Finland, France, Germany, Mali, the Netherlands, New Zealand, Portugal, the Russian Federation, Switzerland, and the USA
[38] GCOS (2009): *Synthesis of National Reports on Systematic Observation for Climate*, GCOS-130, April 2009, http://www.wmo.int/pages/prog/gcos/Publications/gcos-130.pdf.
[39] http://www.wmo.int/pages/prog/gcos/index.php?name=rwp
[40] GCOS (2006b): *Final Report of the GCOS Regional Workshop Programme*, GCOS-111B, August 2006, http://www.wmo.int/pages/prog/gcos/Publications/gcos-111B.pdf.

change impacts. Common needs of all regions covered by Regional Action Plans include sustaining and improving operational observing networks; recovering historical data; improving national and regional co-ordination; education, training, and capacity building; and national planning and reporting. Some implementation progress has been made in most regions, with greater progress generally in those regions in which the earliest workshops were held. However, much remains to be done, and many of the Action Plans are becoming dated and in need of revision. Constraints to continued progress are the need for donor engagement in project funding and for sustaining committed leadership at the regional level. Regional Action Plans have been responsible for some important implementation initiatives in the Pacific Islands, Africa (i.e., the ClimDev Africa Programme) and the Caribbean. Of potential high relevance is the evolving ClimDev Africa Programme with an overall four-year budget of 134 million US$. A regional GCOS programme, including a regional GCOS office, has been established in the Pacific region.[41] In Eastern and Central Europe and the Mediterranean Basin, projects that were outlined in the respective Regional Action Plans were implemented, involving satellite training workshops and data rescue activities. Some projects have been implemented in part, e.g., the upgrading of selected GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN) stations in Africa.

Action C4 National reporting

Moderate Progress

Action: Report to the UNFCCC on systematic climate observations using an updated Supplementary Reporting Format and guidelines.
Who: Parties with the UNFCCC Secretariat.
Time-Frame: As soon as possible in conjunction with national communications.
Performance Indicator: Percentage of Parties reporting according to the required format.

The updated national reporting guidelines[42] were recommended by UNFCCC SBSTA at its 23rd session (Montreal, 2005) and adopted at COP-13 (Bali, 2007) in decision 11/CP.13. For this Report, 23 Parties (as of 31 January 2009) have compiled National Reports using the updated guidelines. From this valuable input, together with reports from data and monitoring centres, partner observing systems, and information given by 13 Annex-I Parties as part of their regular (fourth) National Communications, the GCOS Secretariat has sought to provide this compilation of progress toward implementation of the IP-04.

Action C5 Reporting on implementation

Good Progress

Action: Maintain oversight of implementation of national plans for systematic climate observations and products and report on progress.
Who: GCOS with its partners.
Time-Frame: Third Adequacy Report 2010.
Performance Indicator: Completion of Third Adequacy Report.

Consistent with Action C5, this Progress Report is intended to provide an overview of GCOS implementation. Along with the results from the 2007 joint GCOS-WCRP-IGBP workshop in Sydney[43], this Report will be the basis for updating the IP-04.

Action C6 GCOS Project Office

Low Progress

Action: Establish an International Project Office.
Who: GCOS sponsors with advice from GCOS Steering Committee and with support from the Parties.
Time-Frame: Establish Office in 2005.
Performance Indicator: Establishment of an Office by GCOS sponsors and resource support from Parties.

Monitoring of observing system performance over time occurs through coordination among the technical bodies responsible for the observing systems, together with the operation of monitoring centres by volunteering Parties. The International Project Office was intended to provide an overview of this monitoring activity so as to assist in seeking corrective action and support the GCOS Cooperation Mechanism (GCM). This has only been partly achieved, mainly through the existing GCOS Secretariat. The Secretariat has continued to receive basic core support from WMO. This support provides for the Secretariat Director, an administrative assistant, and minor support for office activities. Over the last four years, donor support for some temporary technical staff, for meetings,

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41 http://pi-gcos.org
42 UNFCCC (2008): *Decision 11/CP.13 Reporting on global observing systems for climate*, FCCC/CP/2007/6/Add.2 http://www.wmo.int/pages/prog/gcos/documents/Decision_11-CP13.pdf.
43 GCOS, WCRP, IGBP (2008): *Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report*, GCOS-117, January 2008, http://www.wmo.int/pages/prog/gcos/Publications/gcos-117.pdf.

and for some technical cooperation projects has allowed the Secretariat, with the cooperation of national institutions, to accomplish some of the critical functions that were envisioned for the International Project Office. Donor support is vital for the operation of the GCOS Secretariat, but given its *ad hoc* nature, a continued programme of support to GCOS at the present level is not guaranteed. The GCOS Steering Committee continues to stress the need for support to the GCOS Secretariat, and also to the staff dealing with the performance of the component systems of GCOS (in particular the climate components of WIGOS, GOOS and GTOS).

Moderate Progress

Action C7 Research networks and systems

Action: Ensure an orderly process for sustained operation of research-based networks and systems for ECVs.
Who: System operators and research entities in cooperation with the GCOS Secretariat and the relevant international programmes (e.g., WCRP).
Time-Frame: Continuous.
Performance Indicator: Number of sustained networks and systems.

The GCOS hierarchy of networks and systems provides a basis for the GCOS implementation strategy, where each component addresses a particular need for climate data and derived information. This hierarchy ranges from globally sparse reference networks through basic global coverage with baseline networks to recognition and use of the comprehensive networks that are essential at a national and regional scale. Amongst these networks and systems, the research community is often heavily involved, especially in the case of some reference networks and systems which support mainly applications outside climate. Although many of the research networks and systems depend on limited-term funding, few, if any, have ceased functioning. Many research programmes seem to have come to a better understanding that sustained operation is crucial to climate monitoring and detection of environmental change, and is essential for advancing research itself. At the same time, research funding is often strictly for term activities, and either a transition to operational support or the potential for regular renewal of such funding is needed.

A few research networks have become sustained (e.g., the TAO Triton buoy network and the Baseline Surface Radiation Network (BSRN)), but many other research networks remain fully in the research category. There has also been increasing attention by space agencies to undertake a transition of research-based instruments to operational use, but much remains to be done.

Moderate Progress

Action C8 Adherence to the GCMPs

Action: Ensure all climate observing activities adhere to the GCMPs.
Who: Parties and agencies operating observing programmes.
Time-Frame: Continuous, urgent.
Performance Indicator: Extent to which GCMPs are applied.

The wide consideration of the IP-04 by many operators of observing networks and systems, including space agencies, has improved progress in the adherence to the GCOS Climate Monitoring Principles (GCMPs)[44] in all domains, for both *in situ* and satellite-based observations. These operators have usually achieved valuable progress with little extra cost, but only a few have had resources to fully implement the Principles. At the same time, there is an increasing realization that adherence to these principles gives needed benefit to the application of the observations by all users, not just those directly applying the data to climate specific applications (e.g., agriculture and other Societal Benefit Areas). This is due to the widespread value of records of change of geophysical variables over all time scales. Overall the extent of adherence to the GCMPs, albeit improved, remains partial therefore, continued effort to apply the GCMPs to all observations will be a continuing objective. Many Parties report on actions aimed at complying with the GCMPs as far as possible.

Moderate-Low Progress

Action C9 Implementation in developing countries / Capacity building

[44] http://www.wmo.int/pages/prog/gcos/index.php?name=monitoringprinciples

Action: Support the implementation of the global observing system for climate in developing countries and countries with economies in transition. **Who:** Parties, through their participation in multinational and bilateral technical cooperation programmes, and the GCOS Cooperation Mechanism. **Time-Frame:** Continuous. **Performance Indicator:** Resources dedicated to climate observing system projects in developing countries and countries with economies in transition.

Whilst some real progress has been made in assisting some developing countries and countries with economies in transition, it is hard to judge whether the extent and level of sustained support for capacity building has actually increased. The wide range of funding sources makes a comprehensive assessment of global support of GCOS objectives difficult. The Regional Actions Plans developed under GCOS leadership were intended to assist and focus the strengthening of observations in developing countries. This has happened to a limited degree with some engagement of both additional national and donor support, but much more dedicated support is needed to implement the projects identified in these Plans (see Action C3). Under the GCOS Cooperation Mechanism, regular meetings have been held to assist donors in coordinating their activities in support of this Action and a GCOS Implementation Manager has assisted in the operational recovery of observing systems in several countries. In the 23 National Reports received, a number of countries including Australia, Belgium, Canada, Finland, France, Germany, Ireland, Japan, the Netherlands, Sweden, Switzerland, UK, USA and the European Commission report on specific activities contributing to this Action.

Moderate Progress

Action C10 Earth observation satellites

Action: Ensure continuity and over-lap of key satellite sensors; recording and archiving of all satellite metadata; maintaining currently adopted data formats for all archived data; providing data service systems that ensure accessibility; undertaking reprocessing of all data relevant to climate for inclusion in integrated climate analyses and reanalyses. **Who:** Parties operating satellite systems. **Time-Frame:** Urgent, continuing. **Performance Indicator:** Data and products conform to climate standards.

The space agencies have been very responsive to the IP-04 and its Satellite Supplement, and they are advancing their own matching implementation plans (e.g., the 2006 CEOS Response to the IP-04[45]) detailing the coordinated response of individual satellite operators to the overall GCOS objectives. For example, specific steps have been taken to provide access by all nations to all satellite products. Since 2004, there have also been some setbacks in ensuring mission continuity, but remedial action by space agencies has been prompt to fill expected gaps between satellite missions. Current plans still have some possible future gaps, but these have been identified by the space agencies and they are looking at ways of avoiding them. Overall, significant initial progress has been made in responding to climate needs in the missions planning process (many details are noted in the domain sections 4-6), but owing to the long end-to-end time scales of satellite missions, full implementation will inevitably take some years to establish.

Separate from mission continuity and overlap, agencies have also given increased emphasis to the calibration of instruments and the intercomparison of sensors between satellites. The development of the Global Space-based Inter-Calibration System (GSICS), jointly between the WMO Space Programme, CGMS and the CEOS Working Group on Calibration and Validation (WGCV), is expected to meet many of these needs. GSICS is designed to ensure the generation of well-calibrated fundamental climate data records (FCDRs). Maintaining archives of the basic data records and metadata from past and current missions and reprocessing of datasets is also being given increasing attention in many agencies. For example, ESA member states are subscribing to a programme aimed at implementation of ECVs from their past and future missions. EUMETSAT, in conjunction with other agencies and WMO, has been supporting the SCOPE-CM initiative (Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring, formerly referred to as ‘R/SSC-CM’), with a focus on the generation of long-term ECV products. Many agencies are undertaking a range of reprocessing activities, although attention to ensuring common product benchmarks between the activities of different agencies is sometimes inadequate.

[45] CEOS (2006): *Satellite Observation of the Climate System* - The Committee on Earth Observation Satellites (CEOS) Response to the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC, October 2006; http://www.ceos.org/pages/CEOSResponse_1010A.pdf.

Notwithstanding the progress made, there is an ongoing need for space agencies to achieve the funding needed to sustain both the required future missions and the production of the resulting FCDRs.

Moderate Progress

Actions C11, C12 and C13 Data records, analysis and reanalysis

Action: Prepare the datasets and metadata, including historic data records, for climate analyses and reanalyses.
Who: Parties with the International Data Centres (e.g., WDCs), working together with technical commissions and the scientific community.
Time-Frame: Now and ongoing.
Performance Indicator: New or improved datasets available for analysis or reanalysis.

Action: Establish sustainable systems for the routine and regular analysis of the ECVs, as appropriate and feasible, including measures of uncertainty.
Who: Parties sponsoring internationally-designated analysis centres with guidance from WCRP, IGBP and IPCC, with oversight by GCOS.
Time-Frame: Now and ongoing, with most ECVs addressed by 2009.
Performance Indicator: Quality and range of analyses of the ECVs.

Action: Establish a sustained capacity for global climate reanalysis and ensure coordination and collaboration between reanalysis centres.
Who: National and international agencies, with coordination and oversight by GCOS and WCRP.
Time-Frame: Established programmes across all domains by 2009, ongoing activity thereafter.
Performance Indicator: Reanalysis centres established and/or endowed with long-term and coordinated programmes; cyclical flow of products of improving quality and widening range.

Moderate progress has been made in the provision of datasets, including metadata and historical records, for climate analyses of the atmosphere, as an ongoing activity of National Meteorological Services and other operational agencies mostly in the atmospheric and ocean space domains. Datasets provided by space agencies and research programmes are also essential, and progress has been made in sustained provision of these datasets and their availability in international data centres. For ocean and terrestrial datasets and metadata, progress is uneven, occurring within particular climate analysis and reanalysis groups with low international coordination.

Work toward the attainment of climate-quality atmospheric (including atmospheric constituents) and ocean ECV analyses is progressing. The success for some of the terrestrial ECVs is more limited but significant effort is underway for others, especially those dependent on satellite data.

Atmospheric reanalyses are progressing well, and the inclusion of atmospheric constituent data is becoming a new feature in the programmes. The Global Ocean Data Assimilation Experiment (GODAE) has demonstrated the potential for operational ocean analysis. Ocean reanalysis activities are being coordinated under the WCRP CLIVAR research programme, and are being routinely produced. However, measures of uncertainty in ocean reanalyses are not routinely reported, and comparison exercises show large differences, pointing to the need for further research. Progress is also being made in attaining new historical datasets and in managing the more complete datasets for use in reanalysis.

Reanalysis activities have continued throughout the reporting period, and collaboration between centres remains active. Lack of sustained long-term funding has nevertheless inhibited coordination between centres over their production schedules for new reanalyses. All reanalyses need to have evaluation teams and documentation of the products and their quality. Future funding for the reanalysis activity should be sustained, where possible, thereby recognizing the need to maintain technical competence in between reanalysis cycles. Each centre's reanalysis cycle should ideally be timed to follow on from others so as to aid progressive improvement in both observational databases and data assimilation systems.

Moderate Progress

Action C14 Historical data records

Action: Collect, digitize and analyze the historical atmospheric, oceanic and terrestrial data records from the beginning of instrumental observations in a region and submit to International Data Centres.
Who: Parties, working through the WMO Commission for Climatology (CCl), the WMO Commission for Hydrology (CHy), other appropriate coordinating bodies (e.g., GCOS and GTOS), the appropriate national agencies, and designated International Data Centres.
Time-Frame: Complete by 2009.
Performance Indicator: Data receipt at designated International Data Centres.

Some good progress has occurred as shown in the National Reports of several countries. Thus, several Parties (e.g. Portugal, Slovakia, Switzerland, UK, Belgium) reported concerted efforts to preserve long-term climate records and to extend the data record in time through digitizing historical data records and compiling individual observations from documentary archives. These are compiled nationally in many instances and are in some cases organized regionally. However, this Action will need sustained attention, and will take many years to complete for all ECVs. Coordination among nations to prioritise which datasets should be rescued first would help in filling gaps in space or time earlier rather than later. More detail may be found in the domain sections below.

Good Progress

Actions C15, C16 and C17 Palaeoclimate

Action: Undertake research initiatives to acquire high-resolution palaeo-climate data by extending spatial coverage into new regions, extending temporal coverage back in time and exploiting new sources.
Who: Parties' national research programmes in cooperation with WCRP and IGBP.
Time-Frame: Continuing.
Performance Indicator: Reports in scientific literature.

Action: Improve synthesis of palaeo-climate and palaeo-environmental data on multidecadal to millennial timescales, including better chronologies for existing records, particularly from the tropics, Asia, the Southern Hemisphere and the Southern Ocean.
Who: Parties' national research programmes in cooperation with WCRP and IGBP.
Time-Frame: Continuing.
Performance Indicator: Reports in scientific literature.

Action: Preserve palaeo-climate and palaeo-environmental data in archival databases.
Who: World Data Centre for Paleoclimatology in cooperation with national research programmes.
Time-Frame: Continuing.
Performance Indicator: Completeness of archival databases and availability of data to the research community through International Data Centres.

Palaeoclimatic studies use changes in climatically sensitive indicators to infer past changes in global climate on time scales ranging from decades to millions of years. Such data (e.g., tree ring width) are a "proxy" for climatic conditions in the past. Studies since the 2001 IPCC Third Assessment Report draw increased confidence from additional data showing coherent behaviour across multiple indicators in different parts of the world. However, uncertainties generally increase with time into the past due to increasingly limited spatial coverage.

Progress has been made in acquiring new palaeoclimatic (proxy) data records, and in archiving those in the World Data Center for Paleoclimatology.[46] 441 new dataset contributions have been archived during the period 2005-2008. The Center also archives a number of syntheses of data that have been used in the scientific literature and the IPCC AR4. The data in Table 6 come from a variety of sources, including the best reconstructions and datasets of pre-instrumental climate available today. Global coverage of proxy data remains limited in many regions of the world (see Figure 2).

Table 6: International contributions to the World Data Center for Paleoclimatology (source: US National Report on Systematic Observations for Climate - September 2008).

	Total Number of Available Datasets	Number of Available Datasets per Length of Time Series	
Palaeoclimatic Data		**>100 years**	**>300 years**
Borehole Data	837		837
Corals	147	108	39
Fauna	220		220
Ice Cores	23		23
Insecta	7		7
Palaeolimnology	78		78
Palaeooceanography	1434		1434

[46] http://www.ncdc.noaa.gov/paleo

Plant Macrofossils	296		296
Pollen	1661		1661
Tree Ring	2860	1185	1675
Other Palaeoclimatic Data	5		5
Total	**7568**	**1293**	**6275**

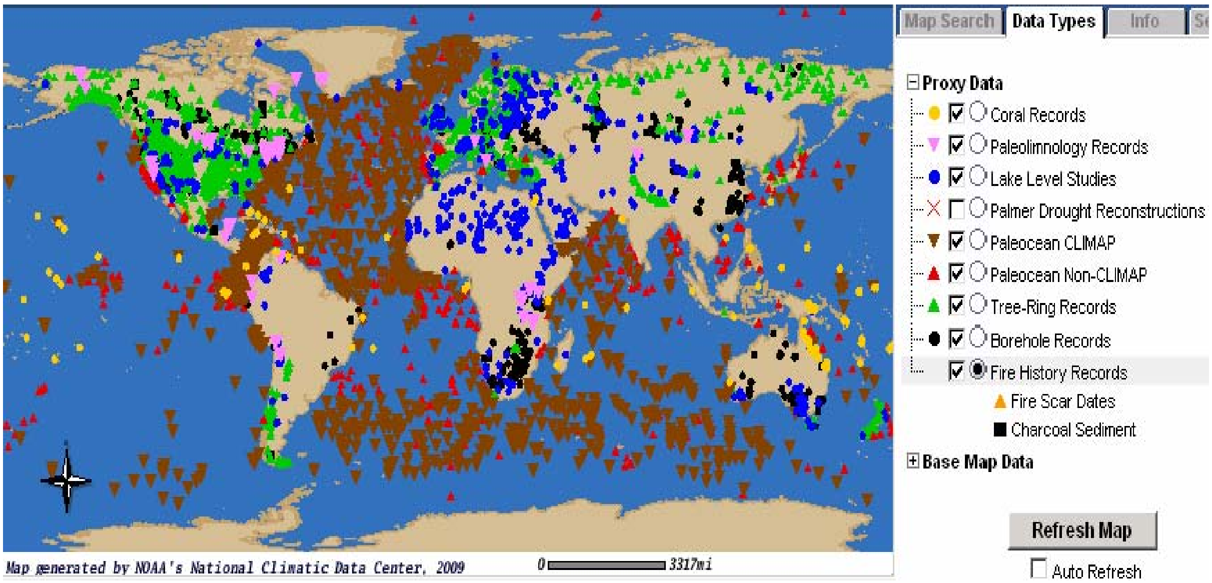

Figure 2: Coverage of data currently available in the World Data Centre for Paleoclimatology (excluding borehole records) (source: http://www.ncdc.noaa.gov/paleo).

Good-Moderate Progress

Action C18 Metadata standards

Action: Develop standards and procedures for metadata and its storage and exchange.
Who: International technical commissions with scientific advisory bodies.
Time-Frame: Guidance complete by 2006.
Performance Indicator: Number of ECVs with standards.

WMO, working through its Commissions for Climatology (CCl) and Basic Systems (CBS) has developed standards and guidance for metadata acquisition and management.[47,48] JCOMM, in cooperation with IODE, has also instituted an initiative to recommend standards and best practices for ocean data management including metadata specifications for describing datasets. WMO is also in the process of developing a WMO Core Metadata Profile, based on an ISO metadata standard. In 2008, WMO has been recognized by ISO as a standard-setting international body and is working, in collaboration with GTOS and FAO, on the establishment of metadata standards for terrestrial data (see Action T1). In the framework of the WMO Information System (WIS) and existing recommendations for a WMO metadata standard, a draft metadata profile for hydrological data has been developed by the Global Runoff Data Centre (GRDC) which was subsequently endorsed by the WMO Commission for Hydrology (CHy) in November 2008.

Moderate Progress

Action C19 International data centres

Action: Ensure timely, efficient and quality-controlled flow of all ECV data to International Data Centres.
Who: Parties with coordination by appropriate technical commissions and international programmes.
Time-Frame: Urgent, continuing.
Performance Indicator: Data receipt at centres and archives.

As shown in the atmospheric domain section 4, whilst overall data receipt has improved, data receipt from some regions remains insufficient. In the oceanic domain, the flow of ECV data is very good with

[47] WMO (1995): *Manual on Codes*, WMO-No. 306, http://www.wmo.int/pages/prog/www/WMOCodes/ManualCodes.html.
[48] WMO (2003): *Guidelines on Climate Metadata and Homogenization*, WMO/TD-No. 1186, http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp_series/documents/WCDMP-53.pdf.

the exception of gaps with some ocean hydrography data, some ocean carbon data, and some sea-level data. With the exception of hydrological data from some regions and glacier and permafrost data, the receipt of data for the terrestrial domain also remains inadequate, particularly in developing countries. This is certainly, at least in part, due to the many separate government departments being involved in the process in most countries, and the deficiencies in international and national coordination of observation needs for climate. Details of the data receipt at international data centres are further discussed in the domain sections.

Moderate Progress

Action C20 Data policies

Action: Ensure that data policies facilitate the exchange and archiving of all ECV data.
Who: Parties and international agencies and appropriate technical commissions and international programmes.
Time-Frame: Urgent, continuing.
Performance Indicator: Data receipt at GCOS data centres.

Consistent with Action C19, there has been progress in ensuring effective exchange and archiving of data for most ECV categories. Most of the 23 Parties indicate no hindrance to the required data exchange in their National Reports. Some countries, based on their own national policies, continue to not exchange data for certain ECVs but remain encouraged to at least exchange sufficient data to assist in enabling global coverage. IOC has adopted a policy for data exchange monitored through IODE. GEO is addressing the issue of general data policies and the objective of free and open data exchange through the development of GEOSS Data Sharing Principles.

Good-Moderate Progress

Action C21 Data services

Action: Develop modern distributed data services that can handle the increasing volumes of data and which can allow feedback to observing network management.
Who: Parties' national services committing to International Data Centre operation and high data volume providers such as space agencies through appropriate technical commissions and international programmes.
Time-Frame: Long-term objective, 2014.
Performance Indicator: Development of plans and initial steps at some centres.

The WMO Information System (WIS) is a major initiative supporting this Action in all domains related to WMO. The GEOSS Architecture Working Group is also contributing to planning and system development in this area. Overall progress in ocean data services has been substantial, and some limited progress can also be noted in other areas.

4 The Atmospheric Climate Observing System

Growth and decay of weather systems and changes-in-state of water between snow, rain, cloud and vapour give the atmosphere a unique role in the climate system. Heat, moisture and chemical species are moved around rapidly by winds. Cloud and water vapour feedbacks are major factors in determining the sensitivity of the climate system to forcings, such as from rising levels of greenhouse gases and from aerosols. To characterize the atmosphere at the land- and ocean-surface, measurements of temperatures, water vapour, wind, pressure, daily precipitation amounts and atmospheric composition ECVs, such as carbon dioxide, methane and aerosols, are needed. As precipitation is episodic and can be very localized, high-resolution observations are needed to create an accurate picture. Satellite observations are a unique source of global information on many ECVs, but in most cases do not extend sufficiently far back in time to give a full historical perspective and need to be complemented by *in situ* measurements, especially at lower levels over land. Instrumental and palaeo-reconstructions of temperature and precipitation are essential to provide the long-term perspective.

The three-dimensional structure of the atmosphere determines the nature and movement of weather systems. In the troposphere and lower stratosphere, balloon-borne instruments combined with groundtracking devices in a radiosonde network have traditionally measured temperature, water vapour and wind. Satellite measurements of radiances now complement these observations but require interpretation in geophysical terms for most applications. Because natural modes of variability, such as El Niño and the North Atlantic Oscillation, alter atmospheric circulation and storm tracks, it is vital to determine and understand such processes as they can obscure climate change detection.

Summary of Progress

Overall, there has been steady progress in maintaining and enhancing the atmospheric observing systems for climate. This is largely based on efforts by the national operators of networks and systems (both ground and space-based) providing surface and upper-air meteorological observations, measurements of greenhouse gases and measurements of other aspects of atmospheric composition. The global trend of declining *in situ* meteorological network performance prevailing through the 1990s has been halted or reversed in all regions. In spite of the overall progress, it must be stressed that some regions of the world, Africa in particular, have seen no significant improvement in observational coverage.

One facet of the progress made has been improved reception of *in situ* observational data in international data centres. This is at least in part due to enhanced engagement by centres dedicated to monitoring *in situ* network performance, acting in liaison with both the network operators and the programmes responsible for the networks. For example, the work of the existing GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN) Monitoring, Analysis and Archive Centres has been complemented by the establishment of nine CBS Lead Centres for GCOS covering all regions worldwide. Good progress in the implementation of Global Atmosphere Watch (GAW) networks for atmospheric composition ECVs has also been made. Nevertheless, there remain significant gaps in both network coverage and the frequency of reporting from existing stations, which is of particular concern with respect to understanding and predicting regional climate and climate change.

Despite good overall progress, there remain some specific issues where methodological, technical or institutional problems persist. For example, accurate, frequent and consistent measurements of precipitation are yet to be achieved globally; regular exchange of climatologically-relevant data, including near-real time data, is still inadequate; and there significant room remains for improvement in the rescue of historical data and metadata.

A new development since 2004 has been increased emphasis on establishing reference-type networks that would provide anchor points for broader GCOS surface and upper-air networks. In particular, for observing the atmospheric column, important steps have been taken towards establishment of the GCOS Reference Upper Air Network (GRUAN). In addition, several Parties are in the process of setting up national climate networks of geographically well-distributed surface stations that provide high-quality observations of many, if not all, of the surface-based climate variables.

Regarding satellite systems, improved instruments, international coordination and exploitation of datasets have led to an increasingly important contribution to global climate monitoring. Reprocessing and analysis of satellite-based climate data records is an ongoing activity required to improve the description of climate variability and trends. Observational capabilities of future satellite systems need to ensure continuity of the climate record, as well as provide new or improved measurements of some ECVs, such as cloud properties, aerosols and greenhouse gases. The space agencies working through CEOS, CGMS, and the WMO Space Programme have carefully set a path for the future to ensure a viable and homogenous flow of global remote sensing data which covers the needs of GCOS. In addition, they have developed important initiatives to ensure better calibration of instruments and reprocessing of the past climate record. All this requires extraordinary international cooperation, collaboration and commitment. It also requires an active and focused research programme and funding commitments by nations that are operating satellites.

Meeting the full range of objectives expressed in the IP-04, and especially the broader objectives of GCOS at the national level, will require much more attention on building capacity in developing and least-developed countries to ensure better observational coverage and use of climate data, especially on regional and national scales where information is required for the purposes of adaptation.

Detailed Progress

Surface Observations

Observation of climate variables at the surface of the Earth characterizes the part of atmosphere in which we live and where virtually all land-based biodiversity exists. As such, measurements of these variables are of particular importance for determining the impacts of climate change, and for taking measures to counter or adapt to these impacts. Assessing the reliability of climate change model predictions depends on the quality of such observations, and their resolution in space and time. Mitigation of climate change needs to be based upon reliable determination of sources and sinks of greenhouse gases, which needs observations of the changing distribution of these gases.

Good-Moderate Progress

Action A1 Full implementation of the GCOS Surface Network

Action: Detailed analysis of causes of GSN faults, followed by full implementation of the GSN
Who: National Meteorological Services, in coordination/cooperation with WMO CBS, with advice from the AOPC
Time-Frame: Complete operation of GSN by 2007 and receipt of all archival data by 2008.
Performance Indicator: Data archive statistics at WDC Asheville and National Communications to UNFCCC.

Approximately 95% of meteorological stations in the GCOS Surface Network (GSN), which is a subset of the WMO Global Observing System (GOS), are operating, and the percentage of transmitted data (CLIMAT) has grown from 60% (2001) to about 80% (2007). Great regional differences remain, however (see Figure 3). Upon receipt, data are quality-controlled by the GSN Monitoring Centres at Deutscher Wetterdienst (DWD) and Japan Meteorological Agency (JMA), which regularly report on progress. Further, nine CBS Lead Centres for GCOS Data, hosted by National Meteorological Services and covering all WMO Regions, were established in 2007, providing an important mechanism for improving the number and quality of GSN data received, through specific contacts with station operators in countries. Another contributing factor has been support to the GSN (and to the GCOS Upper-Air Network (GUAN), cf. Action A15) in developing countries through the GCOS Cooperation Mechanism.

The GSN Analysis and Archive Centre at NCDC provides further analysis of GSN data in the context of the larger synoptic network. Its activities also include the important collection of historical GSN data from countries (see Figure 4). Although the submission of historical data to the Archive Centre has generally improved due to targeted contacting of countries by the GCOS and WMO Secretariats and the Archive Centre, many records remain of limited duration or are unavailable.

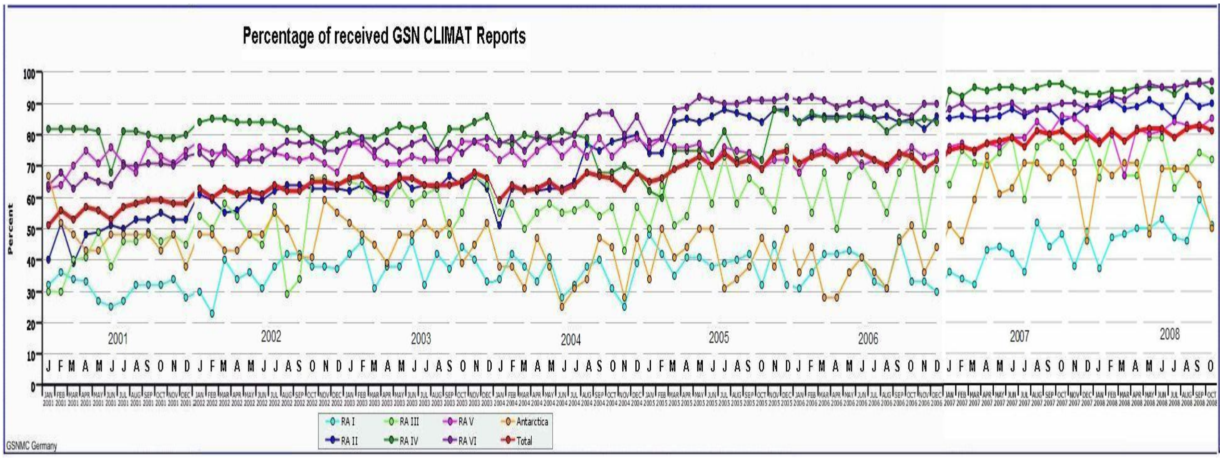

Figure 3: Percentage of received GCOS Surface Network (GSN) data at DWD and JMA between 2001 and 2008 (RA I: Africa, RA II: Asia, RA III: South America; RA IV: North and Central America; RA V: Australia and Pacific; RA VI: Europe) (Source: GSN Monitoring Centre, DWD).

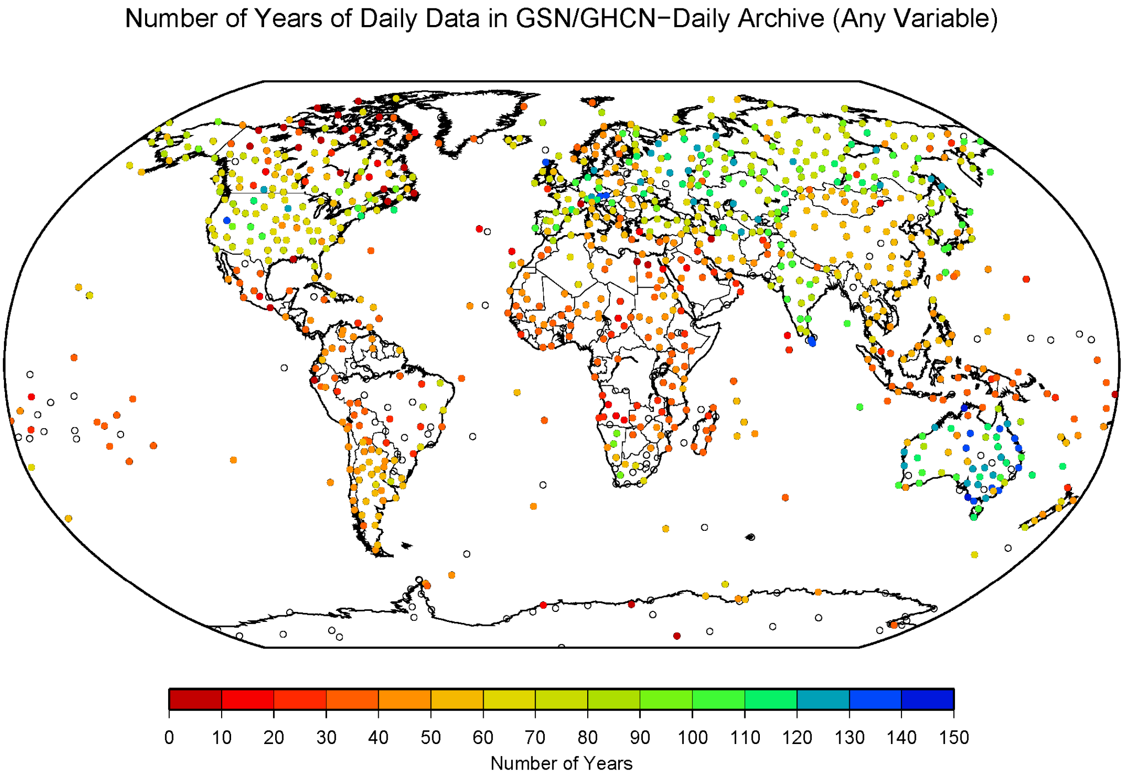

Figure 4: Length of historical climate time series for GSN stations available at the GSN Archive Centre, NCDC (Source: NCDC).

Action A2 WMO Basic Synoptic Surface Network

Moderate-Low Progress

Action: Obtain major progress in implementation and systematic operation of the full WWW/GOS RBSN in compliance with the GCMPs.
Who: National Meteorological Services, in cooperation/coordination with WMO CBS, WMO CCl, WMO RAs and WMO WWW.
Time-Frame: Continuous, with 10% improvement in receipt of RBSN data by 2009.
Performance Indicator: Data archive statistics at WDC Asheville.

Action A3 Apply GCOS Climate Monitoring Principles to surface networks

Moderate Progress

Action: Apply the GCMPs to all surface climate networks.
Who: National Meteorological Services, in coordination with WMO CBS, WMO CCl, WMO RAs and GCOS Secretariat.
Time-Frame: Continuous.
Performance Indicator: Quality and homogeneity of data and metadata submitted to International Data Centres.

There is evidence of only moderate progress in network performance. The basic synoptic surface network of about 10 000 meteorological stations worldwide within the WMO Global Observing System (GOS) includes the Regional Basic Synoptic Network (RBSN) of about 4000 stations. All networks are operated by National Meteorological Services and coordinated by the WMO Commission for Basic Systems and Regional Associations. Global reception rates determined in the annual monitoring exercise of WMO have gradually improved for the RBSN, reaching 80% in October 2008, while substantial regional differences persist, e.g., relatively low data reception rates in Africa (56%), in South America (65%) and in the Australia/Pacific region (73%). Table 7 summarises the reception rate of surface meteorological data for each WMO Region over the period 2004 to 2008.

Table 7: Reception rate of standard surface meteorological data in the Regional Basic Synoptic Network in WMO Regions (RA) during annual monitoring exercises of WMO.

	Oct 2004	Oct 2005	Oct 2006	Oct 2007	Oct 2008
Africa (RA I)	53 %	55 %	54 %	54 %	56%
Asia (RA II)	84 %	88 %	89 %	89 %	91%
South America (RA III)	62 %	58 %	61 %	63 %	65%
North America, Central America and the Caribbean (RA IV)	86 %	81 %	79 %	79 %	83%
South-West Pacific (RA V)	69 %	69 %	72 %	73 %	73%
Europe (RA VI)	94 %	93 %	95 %	95 %	96%
Total	**77 %**	**78 %**	**79 %**	**78 %**	**80%**

Parties in their National Reports noted efforts to apply the GCOS Climate Monitoring Principles to all observations, despite limited resources and pressures on time (cf. also A4). WMO continues to emphasize the importance of the GCMP in its efforts at standardization of observations through its Technical Commissions.

Action A4 Guided transition to automated surface stations

Good Progress

Action: Develop guidelines and procedures for the transition from manual to automatic surface observing stations that incorporates the GCMPs.
Who: WMO CIMO in cooperation with the WMO CCl, WMO CBS, and the GCOS GSN Monitoring Centres through the AOPC and the GCOS Secretariat.
Time-Frame: Complete by 2006.
Performance Indicator: Quality and homogeneity of data and metadata submitted to International Data Centres; adoption noted in National Communication.

Many observing facilities (over both land and ocean) are being changed from traditional manual operation to automatic or quasi-automatic operation. These changes have been demonstrated, as reported by many Parties, to insert potential inconsistencies and inhomogeneities into the climate record, and are addressed as one element of the GCMPs. To give detailed advice on such transitions, “Guidelines and Procedures to Assist in the Transition from Manual to Automatic Surface Observing Stations” have been developed by the WMO CBS Expert Team on Requirements for Data from Automatic Weather Stations and have been published in May 2008. The WMO Commission for Instruments and Methods of Observation (CIMO) is in the process of developing complementary guidelines that will focus on the instrument perspective of such transitions.

Action A5[49] Atmospheric pressure sensors on ocean drifting buoys

Good Progress

Action: Seek cooperation from organizations operating drifting buoy programmes to incorporate atmospheric pressure sensors.
Who: Parties deploying drifting buoys and buoy-operating organizations, coordinated through JCOMM with OOPC and AOPC.
Time-Frame: Continuous.
Performance Indicator: Percentage of buoys with sea-level pressure (SLP) sensors.

Observation of surface air pressure from the synoptic networks is complemented over the oceans by Voluntary Observing Ships (VOS) and buoy measurements. As of February 2009, 549 buoys were measuring sea-level pressure (SLP) from a total of 1122 drifting surface buoys (see Figure 5). This is a significant improvement on the situation in 2003, when only 272 out of 913 drifters measured sea-level pressure. Most of the buoys measuring sea-level pressure are located in the middle and high latitudes where the pressure measurements are much more critical to the global analysis. There is nevertheless still scope for improvement.

[49] See also Action O10.

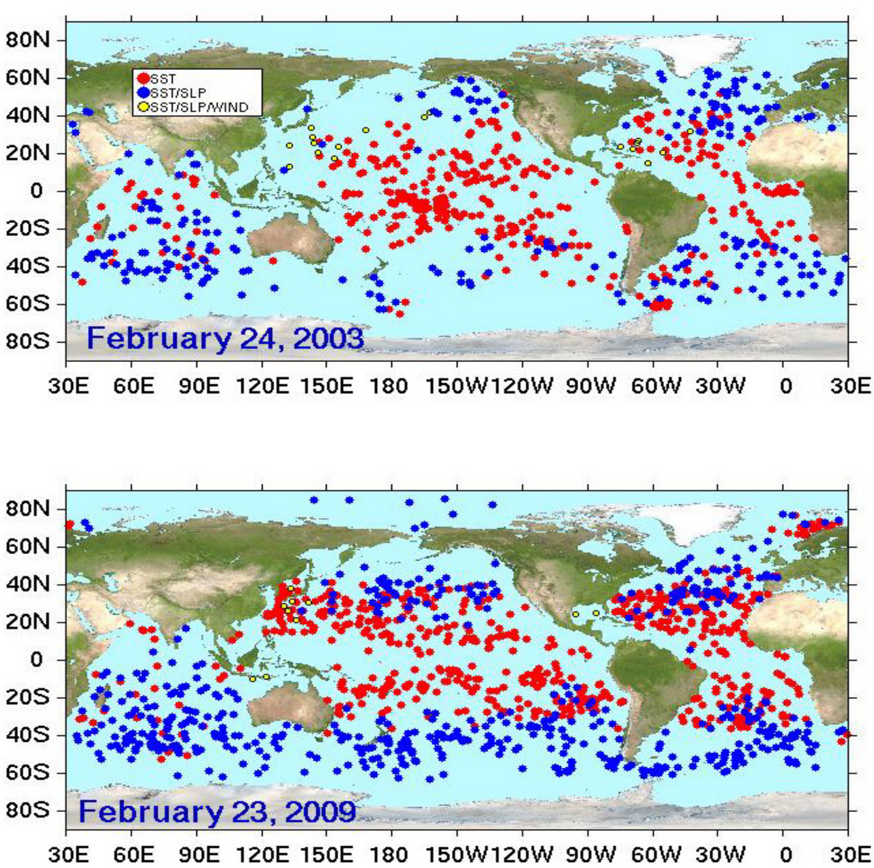

Figure 5: Status of Global Drifting Surface Buoy Array in 2003 and 2009. Red dots denote drifters without pressure sensors, blue dots denote drifters with pressure sensors.[50]

Action A6 Precipitation data available worldwide

Good-Moderate Progress

Action: Submit precipitation data from national networks to the International Data Centres.
Who: National Meteorological Services with coordination through the WMO CCl.
Time-Frame: Continuous with 20% improvement in receipt by 2009.
Performance Indicator: Percentage of nations providing all precipitation data to the International Data Centres.

Major progress has been made in the submission of precipitation data from national networks to the international data centres, with 175 countries having delivered precipitation data (see Figure 6), although the target of 20% increase in reception compared to 2004 has not been achieved. Significant gaps in coverage remain, and more prompt submission of data is also required. To this end, efforts are underway, through WMO, to encourage access to sub-daily (hourly if possible) precipitation data from all countries, in order to support studies of climate variability and extreme events.

[50] http://www.aoml.noaa.gov/phod/dac/gdp_maps.html

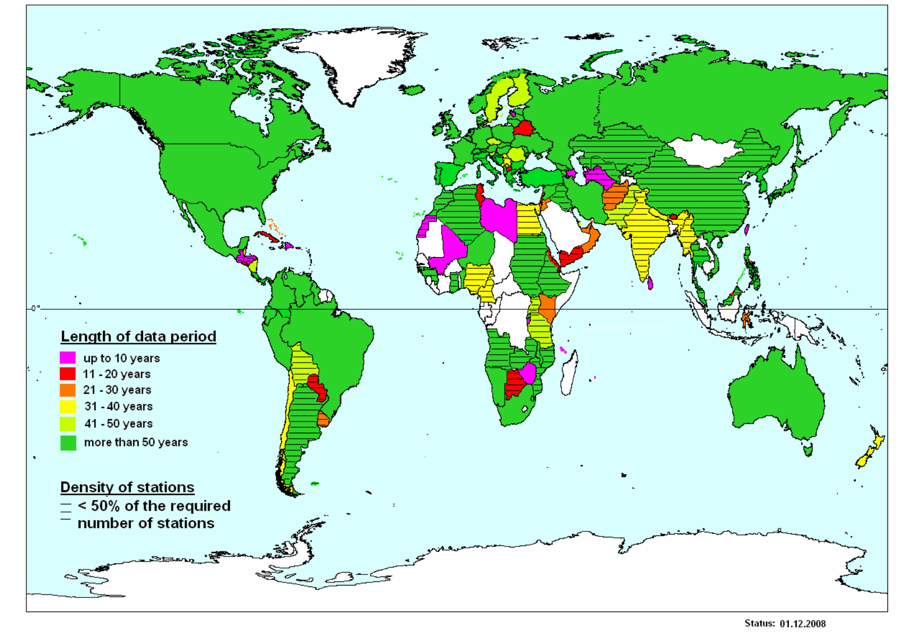

Figure 6: Precipitation *in situ* datasets available on a country basis in the Global Precipitation Climatology Centre (GPCC) database, as of December 2008 (white areas: no data available or very low station density).

Moderate Progress

Action A7 Continuity of precipitation measurements from space

Action: Ensure stable operation and processing of relevant operational satellite instruments for precipitation and the continuity of associated products.
Who: Space agencies through CGMS and CEOS with WMO Space Programme and GCOS.
Time-Frame: Continuous.
Performance Indicator: Long-term homogeneous satellite-based global precipitation products.

The NASA/JAXA Global Precipitation Mission (GPM) will provide a replacement and improvement over current missions but currently, there are no plans for continuity. GPM will combine active precipitation measurements with a constellation of passive microwave imagers. Currently, high quality microwave measurements with 3h time resolution cover ~40% of the globe, whereas GPM is designed to achieve >80% coverage. The planned GPM baseline constellation was reconfigured in 2006 to capitalize on advances in microwave sounder retrievals to improve sampling over land. The GPM core satellite is currently planned for launch in spring 2013. This implies high probability for a major gap in active radar (TRMM-type) precipitation measurements from space, since the TRMM mission is approaching the end of its lifetime. There is also a need for a long-term commitment beyond GPM. Research on the development of algorithms to use the AMSU/MHS microwave sounder instruments for snowfall rate determination is progressing.

Moderate Progress

Action A8 Precipitation measurements on ocean moorings

Action: Develop and deploy precipitation-measuring instruments on the Ocean Reference Mooring Network.
Who: Parties deploying moorings in cooperation with JCOMM and OOPC.
Time-Frame: Coordination finalized by 2005, implementation complete by 2009.
Performance Indicator: Number of instruments deployed and data submitted to International Data Centres.

The Global Ocean Reference Mooring Network has deployed 36 surface moorings measuring surface ECVs, with 22 equipped to measure precipitation. These are largely concentrated in the tropical Pacific Ocean, and so global coverage remains to be improved.

Moderate Progress

Action A9 Improve precipitation measurements

Action: Develop and implement improved methods for observing precipitation that take into account advances in technology and fulfil GCOS requirements.
Who: Parties' national research programmes through WCRP in cooperation with GCOS.
Time-Frame: Continuous.
Performance Indicator: Implemented methods; improved (in resolution, accuracy, time/space coverage) analyses of global precipitation.

Reasonable progress has been made. Many countries have active research and quasi-operational programs for incorporating precipitation gauge and radar data into analysis schemes to improve the measurement of precipitation. Often these efforts are regional in nature (e.g., European OPERA programme). The applications of these analysis products for climate objectives remain a major step to be accomplished. WMO CIMO has conducted and published a laboratory intercomparison of rainfall intensity gauges, and is presently finishing a field intercomparison of rainfall intensity gauges. The report of the latter intercomparison is expected to be available in summer 2009. CIMO is currently working on the topic of solid precipitation and assessing the need for a solid precipitation intercomparison.

In addition, there have been some efforts at intercomparison of existing rainfall instruments, but further work is needed, including solid precipitation measurements. Planning by the WMO CIMO is directed towards meeting these needs.

Some of these technological and scientific advances in observing precipitation on prototype, experimental or regional basis are:

- Polarized Doppler-Radar can distinguish forms of precipitation with higher accuracy than ordinary radar systems and is currently being implemented by National Meteorological Services;
- The use of signal analysis from mobile telephone networks especially for remote areas and developing countries;
- Microwave tomography using dual frequency attenuation;
- Development of precipitation estimates over the oceans using hydrophones.

There is progress in the creation of integrated precipitation datasets, largely research-based and with issues of continuity, and with full assessment of quality yet to be performed, for example:

- The Global Precipitation Climatology Project (GPCP) dataset provides information about the distribution and variability of global precipitation on a daily basis, particularly over the tropical oceans, with relevance for studying inter-annual variability also on a regional scale;
- The PEHRPP Project (Program to Evaluate High-Resolution Precipitation Products[51]) makes an international effort to obtain higher spatial (0.25 degree) and temporal (3-hourly) resolution precipitation data on regional scales, with a focus on satellite-based data;
- The HOAPS climatology (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data) provides a global climatology twice daily from July 1987 to 2005, of sea-surface evaporation and precipitation as well as related sea surface and atmospheric state parameters.

Good-Moderate Progress

Action A10 Availability of high frequency pressure and wind data

Action: Ensure availability of 3-hourly mean sea-level pressure and wind speed and direction data from GSN stations.
Who: National Meteorological Services with coordination from the AOPC, WMO CBS.
Time-Frame: Provide data by 2006.
Performance Indicator: Data availability in International Data Centres.

There has been a sharp rise in reporting 3-hourly data over the past five years. In July 2008, WMO sent a letter to all National Meteorological Services emphasizing the importance of high-frequency ground-based observations (beyond the standard three to six hour reporting for synoptic observations) in order to improve regional climate modelling and the prediction and analysis of extreme events. Furthermore, the letter asked for real-time submission of data as well as submission of historical climate records to the International Data Centres. Almost all Parties reported compliance with the request for the routine exchange of at least three-hourly data from GSN stations. Currently, roughly a fifth of the stations in the full WMO basic synoptic surface network, i.e., around 2000 stations, report on a 3-hourly or hourly basis to the World Data Centre for Meteorology, Asheville (see Figure 7).

[51] http://essic.umd.edu/~msapiano/PEHRPP

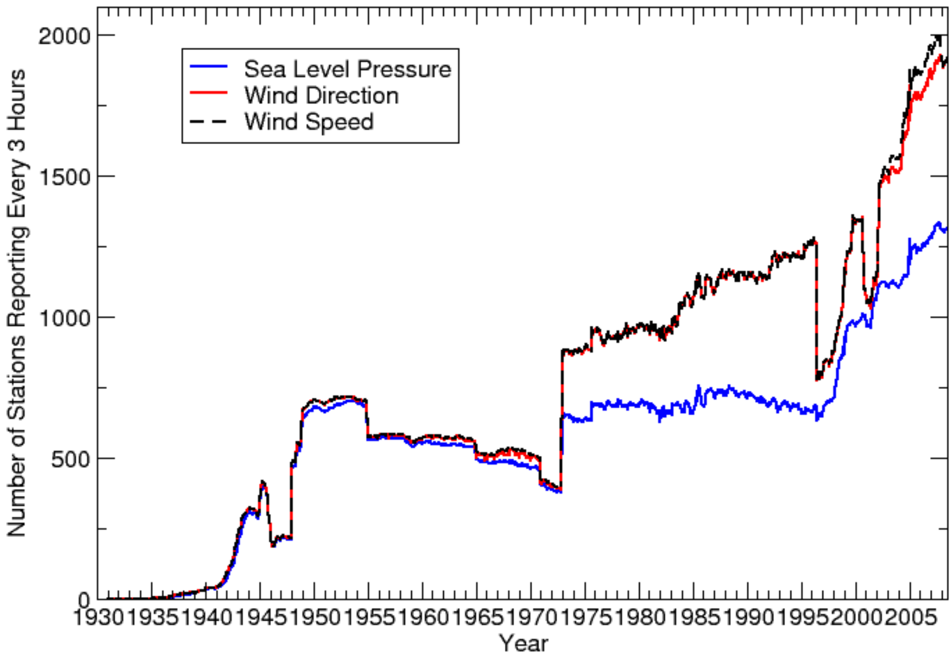

Figure 7: Number of stations in the Regional Basic Synoptic Network reporting every 3 hours, as received by the World Data Centre for Meteorology, Asheville (Source: NCDC).

Action A11[52] Continuous measurements of wind from space

Good-Moderate Progress

Action: Ensure continuous operation of AM and PM satellite scatterometer or equivalent observations.
Who: Space agencies through CGMS and CEOS with WMO Space Programme and GCOS.
Time-Frame: Continuous.
Performance Indicator: Long-term satellite observations of surface winds.

This issue is being fully engaged by space agencies. In accord with the 2006 CEOS Response to the IP-04, CEOS agencies are starting to review the capability of passive microwave sensors to make scatterometer-quality measurements in 2009, and are working towards ensured morning (A.M.) and afternoon (P.M.) satellite coverage of surface wind speed and direction by 2015. Actions in this area are being coordinated within the CEOS Ocean Surface Vector Wind Virtual Constellation. Launch of Metop in October 2006 has provided operational scatterometer data from the ASCAT instrument in the A.M. orbit, with ensured continuity of coverage until around 2020. Complementary scatterometer coverage is still provided by QuikScat in an early A.M. orbit, but this instrument is well beyond its expected lifetime. Wind speed information is provided by passive microwave sensors, and NESDIS has reprocessed the Fundamental Climate Data Record (FCDR) from these sensors.

Action A12 Availability of air humidity data worldwide

Good Progress

Action: Submit water vapour data from national networks to the International Data Centres.
Who: National Meteorological Services through WMO CBS and GCOS Analysis and Monitoring Centres with input from AOPC.
Time-Frame: Complete analysis of global-scale data by 2006.
Performance Indicator: Data availability in analysis centres and archive.

Significant progress has been made in the availability, and use of, water vapour data from global and national networks. NCDC holds historical data from over 20 000 synoptic stations globally in its Integrated Surface Dataset (ISD). In near-real time, a considerably larger volume of data is available from the synoptic network, for use in operational atmospheric analysis and reanalysis. Water vapour data are included in datasets held by NCAR, ICOADS, CRU and the reanalysis centres. The first near-global analyses of these data have been published by Dai (2006)[53] and Willett et al. (2008)[54]. Willett's analysis was based on an intermediate, 5°x5° gridded monthly mean anomaly dataset for the period 1973-2003 (HadCRUH). Good agreement has been demonstrated between reanalysis products and HadCRUH.

[52] See also Action O23.
[53] Dai A. (2006): Recent climatology, variability and trends in global surface humidity. J. Climate, **19,** 3589-3606.
[54] Willett, K.M. et al. (2008): Recent Changes in Surface Humidity: Development of the HadCRUH Dataset. J. Climate, **21,** 5364-5383.

Low Progress

Action A13 Sunshine data available worldwide

Action: Submit sunshine data from national networks to International Data Centres. **Who:** National Meteorological Services and others, in cooperation with the GCOS GSN Analysis Centres. **Time-Frame:** Submit national historical data by 2007. **Performance Indicator:** Data availability in International Data Centres.

No concerted action has so far been undertaken. The World Radiation Data Centre (WRDC) in St. Petersburg, Russia, hosts solar radiation and sunshine data. The Centre has been receiving solar radiation data from about 400 stations located in 56 countries, and operates an archive with 1118 stations that have provided data over 44 years, mostly consisting of global, direct and diffuse solar radiation as well as sunshine duration. Basic quality checks of the incoming data streams are also performed at WRDC, but there are issues with data access and regular data submission. In addition, there are plans to establish a Global Surface Radiation Network of some 300 stations worldwide, and WRDC may serve as the central data archive for such a network (see also Action A14).

Good-Moderate Progress

Action A14 Global high-quality measurements of surface radiation

Action: Expand the BSRN network to obtain global coverage and establish formal analysis infrastructure. **Who:** Parties' national services and research programmes operating BSRN sites in cooperation with AOPC and the WCRP/GEWEX Radiation Panel. **Time-Frame:** Plan completed 2004, BSRN fully operational by 2009. **Performance Indicator:** Published plan and the number of BSRN stations submitting data to International Data Centres.

There has been reasonable progress through the continued development of the Baseline Surface Radiation Network (BSRN). In 2008, the BSRN archive was re-established at the Alfred Wegener Institute (AWI) in Bremerhaven, Germany, following a period of uncertainty after 15 years of operation at ETH Zurich, Switzerland. In April 2008, there were 40 BSRN stations in operation (compared to 35 in 2004) and more sites are expected to join the network thereby improving geographical coverage, although some gaps remain. In a GCOS-WCRP agreement in 2004, BSRN was recognized as the GCOS Baseline Network for Surface Radiation.

Upper-Air Observations

Observation of climate variables in the free troposphere and lower stratosphere characterizes the part of the atmosphere where dynamic and chemical processes relevant to weather and climate occur. As such, measurements of these variables are of particular importance for use in model predictions, as well as for validating satellite-based atmospheric profile information. Assessing the reliability of model-based predictions of climate change depends on the stability and accuracy of the individual measurements, as well as on their temporal and spatial (horizontal/vertical) coverage.

Good-Moderate Progress

Action A15 Full implementation of GCOS Upper-Air Network

Action: Complete implementation of GUAN, including infrastructure and data management. **Who:** National Meteorological Services operating GUAN stations in cooperation with GCOS Secretariat and WMO CBS. **Time-Frame:** Complete 2006. **Performance Indicator:** Percentage of data archived in WDC Asheville.

There has been a gradual improvement of data received from radiosonde soundings of the atmosphere from stations in the GCOS Upper Air Network (GUAN), which is a subset of the WMO Global Observing System (GOS), with a significant rise in the percentage of ascents that reach the 10 hPa stratospheric level, as shown by the GUAN Monitoring Centre at ECMWF (see **Figure 8** and Figure 9). In 2007, only 2 out of 164 GUAN stations were truly silent, although data received from some stations continues to be infrequent (Figure 10). Sustained support to GUAN in developing countries has been provided through the GCOS Cooperation Mechanism.

Further, nine CBS Lead Centres for GCOS Data covering all WMO Regions were established in 2007, providing an important mechanism for improving the number and quality of GUAN (and GSN) data received, through specific contacts with station operators in countries. Statistics show slightly rising reception rates between 2004 and 2008 for all regions of the world, with the clearest positive trend in South America.

Research programmes, such as the AMMA Radiosonde Programme in West Africa[55] have contributed to this recent improvement over previously data-sparse areas At least two GUAN stations are included in AMMA. Continuing the station operation after the end of the research programme may be a challenge.

Good-Moderate Progress

Action A16 Implement the GCOS Reference Upper-Air Network

Action: Specify and implement a Reference Network of high-altitude, high-quality radiosondes, including operational requirements and data management, archiving and analysis.
Who: Parties' National Meteorological Services and research agencies, in cooperation with AOPC and WMO CBS.
Time-Frame: Specification and plan by 2005. Implementation completed by 2009.
Performance Indicator: Plan published. Data management system in place. Network functioning. Data availability.

Planning for the GCOS Reference Upper Air Network (GRUAN) was initiated at workshops held in Boulder and Seattle (USA) in 2006 and 2007[56]. Under the auspices of the AOPC Working Group on Atmospheric Reference Observations (WG ARO), the concept of GRUAN was expanded to not only include high-quality radiosondes-based measurements of temperature, pressure and humidity, but also other reference-type measurements, such as of ozone or through GPS delay and lidars. GRUAN largely builds on existing global networks, such as GUAN, BSRN and NDACC. Four centres volunteered to be the Lead Centre for developing the GRUAN, and the Meteorological Observatory Lindenberg (MOL) operated by DWD (Germany) was selected. The MOL provides 3.5 full-time staff in support of GRUAN. The GRUAN initiation meeting[57] was held in February 2008, having led to the selection of an initial set of 14 GRUAN candidate sites. Implementation of the Network is continuing under the auspices of AOPC, its WG ARO and the GRUAN Lead Cemtre.

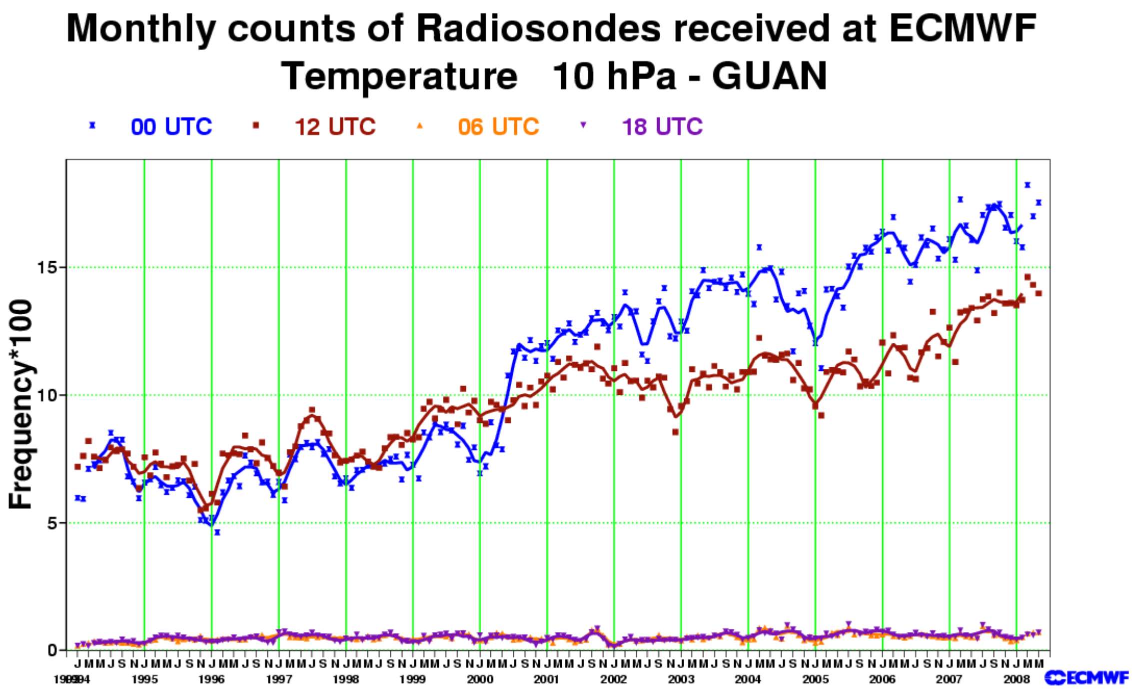

Figure 8: Frequency of receipt of temperature data from GUAN radiosondes reaching the stratospheric level of 10 hPa at GUAN Monitoring Centre 1994-2008 (Source: ECMWF).

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[55] Parker, D.J. et al. (2008): The AMMA Radiosonde Program and its Implications for the Future of Atmospheric Monitoring over Africa. Bull. Am. Met. Soc. **89**, 1015-1027 (July 2008).

[56] GCOS (2007): *GCOS Reference Upper-Air Network: Justification, requirements, siting and instrumentation options.* GCOS-112, April 2007, http://www.wmo.int/pages/prog/gcos/Publications/gcos-112.pdf.

[57] GCOS (2008): *Report of the GCOS Reference Upper-Air Network Implementation Meeting*. GCOS-121, February 2008, http://www.wmo.int/pages/prog/gcos/Publications/gcos-121.pdf.

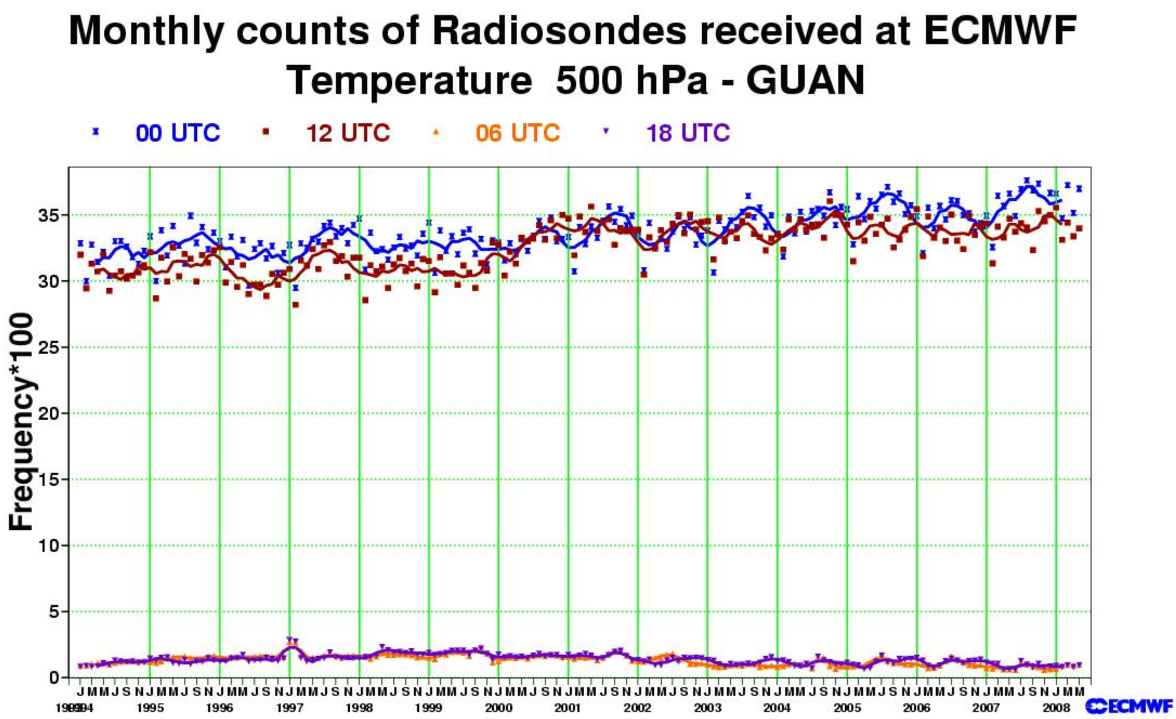

Figure 9: Frequency of receipt of temperature data from GUAN radiosondes reaching the tropospheric level of 500 hPa at GUAN Monitoring Centre 1994-2008 (Source: ECMWF).

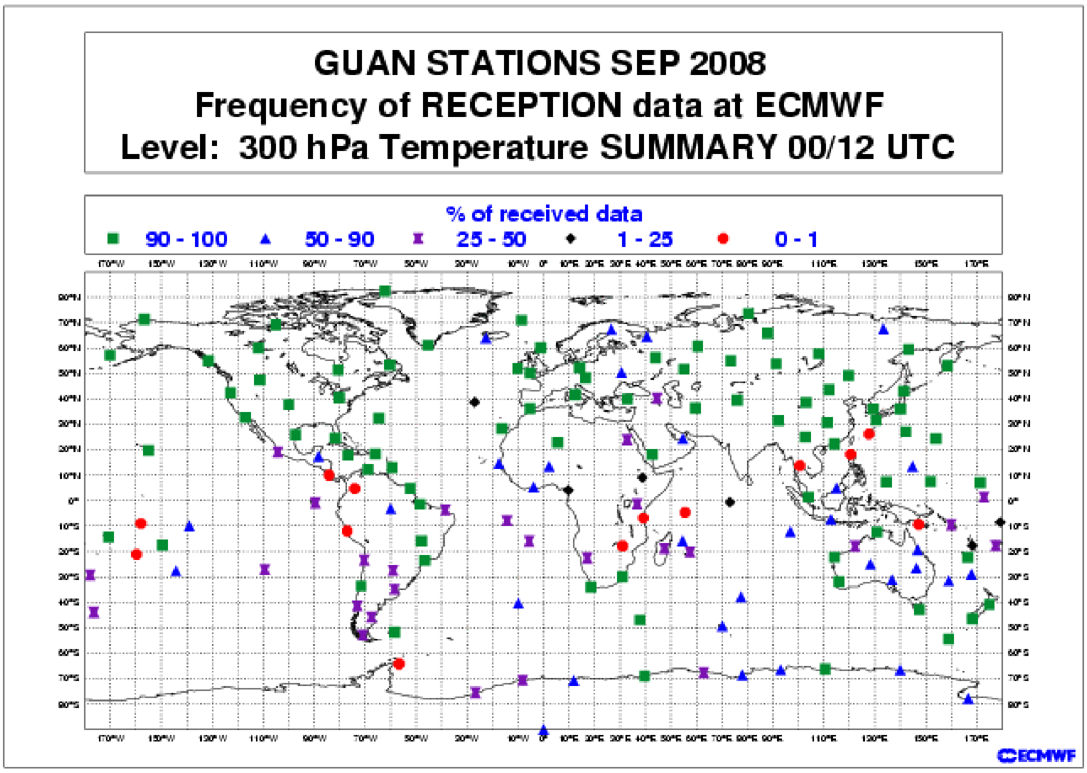

Figure 10: Percentage of reception for GUAN temperature data at 300hPa level at GUAN Monitoring Centre in September 2008 (Source: ECMWF).

Action A17 WMO Basic Synoptic Upper-air Network

Moderate-Low Progress

Action: Improve implementation of the WWW/GOS radiosonde network compatible with the GCMPs and in full compliance with coding conventions.
Who: National Meteorological Services in cooperation with WMO CBS and WMO RAs.
Time-Frame: Continuing.
Performance Indicator: Percentage of real-time upper-air data with no quality problems.

The basic synoptic upper-air network of about 1300 upper-air meteorological stations worldwide within the WMO Global Observing System (GOS) includes the Regional Basic Synoptic Network (RBSN). In the RBSN, which is subject to regular monitoring, receipt of radiosonde data has improved over the last eight years and reached the level of about 600 ascents at 00 and 12 UTC (Figure 11 and Figure 12). The percentage of data available from the RBSN increased from 67% in October 2004 to 72% in October 2008 (see Table 8). Data availability was relatively satisfactory for the northern and eastern parts of Asia, North America, and many countries in Europe and the Pacific region, but generally insufficient for most of the other parts of the world. Low reception rates shown for Africa are a particular concern.

Table 8: Reception rate of standard upper-air radiosonde data in the Regional Basic Synoptic Network in WMO Regions (RA) during annual monitoring exercises of WMO.

	Oct 2004	Oct 2005	Oct 2006	Oct 2007	Oct 2008
Africa (RA I)	36 %	36 %	33 %	29 %	29%
Asia (RA II)	66 %	77 %	80 %	81 %	80%
South America (RA III)	46 %	47 %	43 %	49 %	45%
North America, Central America and the Caribbean (RA IV)	86 %	88 %	89 %	88 %	90%
South-West Pacific (RA V)	63 %	57 %	59 %	71 %	63%
Europe (RA VI)	80 %	80 %	79 %	78 %	83%
Total	**67 %**	**70 %**	**71 %**	**71 %**	**72%**

As noted for the GUAN, there has been a significant rise in the number of soundings reaching 10 hPa (see Figure 8), indicating improvements in radiosonde operation. Many Parties also reported the compliance of their upper-air observational programmes with the GCMPs. Overall quality of observations has been improved, for example through a reduction in reported bias of upper-level temperatures. Coding errors of synoptic radiosonde data does not present a problem, but the transition from the current (TEMP) coding standard to the more comprehensive (BUFR) standard has been slow.

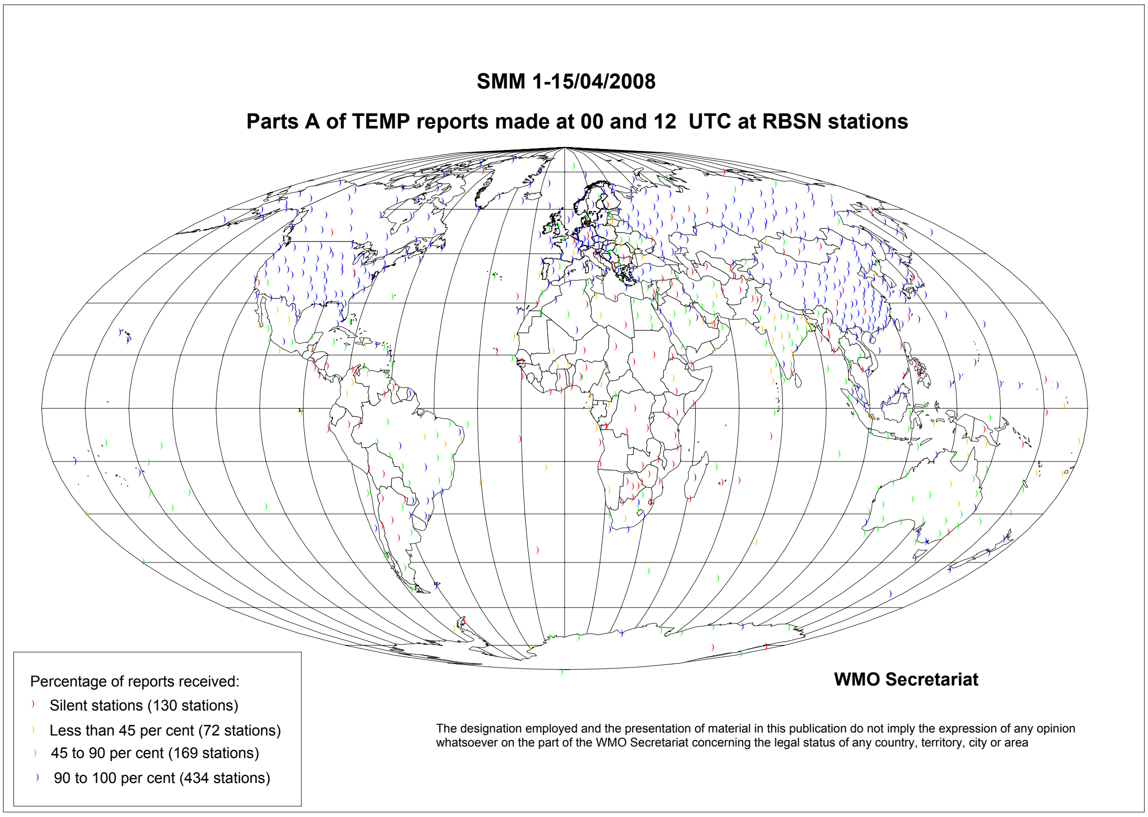

Figure 11: Global upper-air data receipt from the Regional Basic Synoptic Network (RBSN) during the Special Main Telecommunication Network Monitoring (SMM) Exercise of WMO 1-15 April 2008.

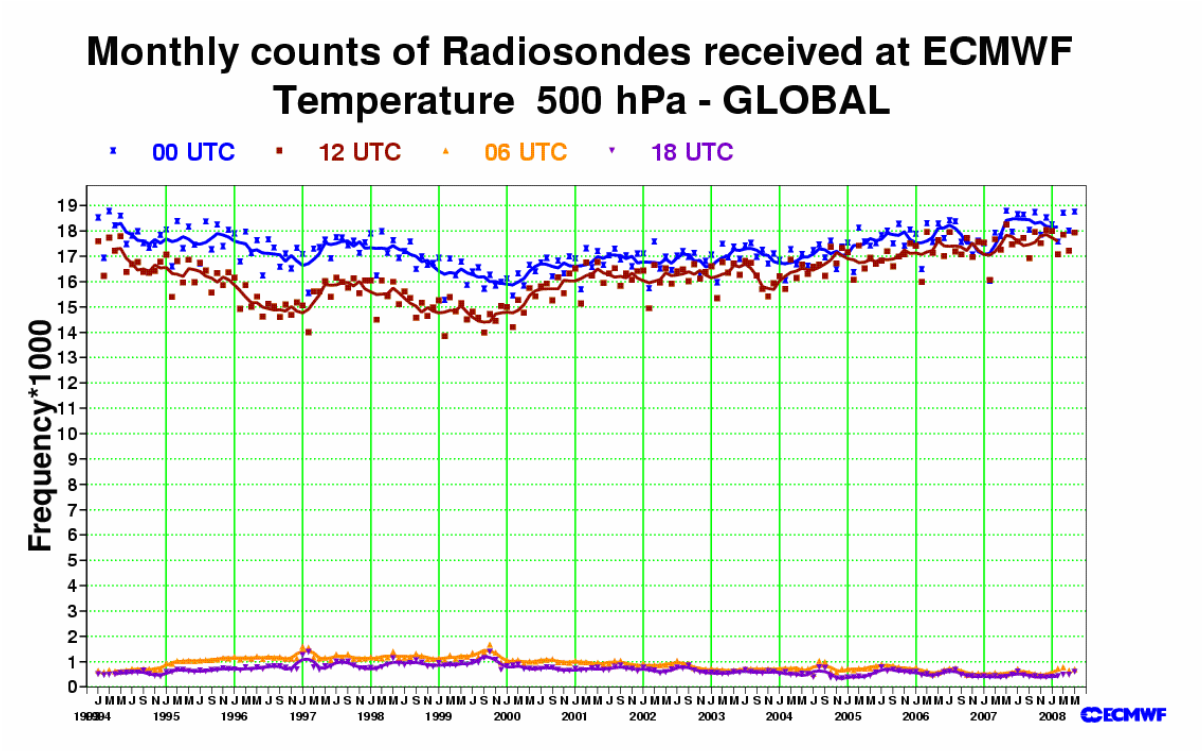

Figure 12: Frequency of 500 hPa temperature data receipt in the RBCN 1994-2008 (Source: ECMWF).

Moderate Progress

Action A18 Information on radiosonde observations available worldwide

Action: Submit metadata records and inter-comparisons for radiosonde observations to International Data Centres.
Who: National Meteorological Services in cooperation with WMO CBS, WMO CIMO and AOPC.
Time-Frame: 2009.
Performance Indicator: Percentage of sites giving metadata to WDC Asheville.

Some progress has been made in the submission of metadata. For example, radiosonde metadata for Russia, including its Antarctic stations, have been provided to the GUAN Lead Centre at NCDC. Metadata records have been updated for 109 GUAN stations since 2004. The updated records are stored in the Integrated Global Radiosonde Archive (IGRA) metadata database at NCDC. The IGRA metadata database contains at least some metadata records for the 161 GUAN stations (2008). Many Parties reported that they were complying with this Action.

In 2005, a radiosondes intercalibration and intercomparison campaign was organized on Mauritius, since a new generation of radiosondes is being introduced into most of the global upper air network. Six operational radiosonde systems participated in this intercomparison. The intercomparison in Mauritius demonstrated that errors identified in the WMO Intercomparison of GPS Radiosondes in Brazil (2001) have mostly been rectified. A major radiosondes intercomparison campaign is planned for 2010, including operational and research instruments, under WMO CIMO auspices and with participation by the GRUAN community.

Proxy radiosonde metadata derived from analyses of the records of individual stations allows detection of break points and biases in the datasets by comparison with background fields from reanalysis[58].

Good Progress

Action A19 Satellite measurements of upper-air temperature

Action: Continue the system of satellites following the GCMPs to enable the continuation of MSU-like radiance data.
Who: Space agencies.
Time-Frame: Continuing.
Performance Indicator: Quality and quantity of data; availability of data; monthly maps and products.

Significant progress in ensuring the microwave (MSU-type) record has been made. The passive microwave instrument AMSU on Aqua, Metop, and NOAA-K, L, N, and N', enabling estimates of upper-atmosphere temperatures, has extended the MSU record[59]. The ATMS instrument, planned for the NPP/NPOESS series of satellites, is similar to AMSU but will require careful intercalibration with the other microwave instruments, since the polarization and spatial sampling is different. The microwave sounders on the Chinese FY-3 polar orbiters will provide further operational coverage in the morning and afternoon orbits for the coming decade or more. The follow-on mission to the Metop (Post-EPS) will continue the record as a priority. Adherence to the GCMPs is recognized by the space agencies and facilitated by the existence of multiple platforms in orbit.

Good Progress

Action A20 GPS Radio Occultation measurements

Action: GPS RO measurements should be made available in real time, incorporated into operational data streams, and sustained over the long-term. Protocols need to be developed for exchange and distribution of data.
Who: Space agencies, in cooperation with CGMS, WMO CBS, the WMO Space Programme and AOPC.
Time-Frame: Exchange standards and protocols by 2006.
Performance Indicator: Volume of data available and percentage of data exchanged.

GPS-based meteorology has transitioned from research into a near global operational status. GPS RO measurements of the temperature- and humidity-sensitive atmospheric refractive index are now routinely available in near real-time and assimilated into operational numerical weather prediction and reanalysis systems. In the example shown in Figure 13, more than 600 occultations were available in

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[58] See e.g., Haimberger et al. (2008): Towards elimination of the warm bias in historic radiosonde temperature records - Some new results from a comprehensive intercomparison of upper-air data, J. Climate, **21**, 4587-4606.
[59] See e.g., Christy et al. (2003): *Error estimates of Version 5.0 of MSU/AMSU bulk atmospheric temperatures*, J. Atmos. Oceanic. Technol., **20**, 613-629.

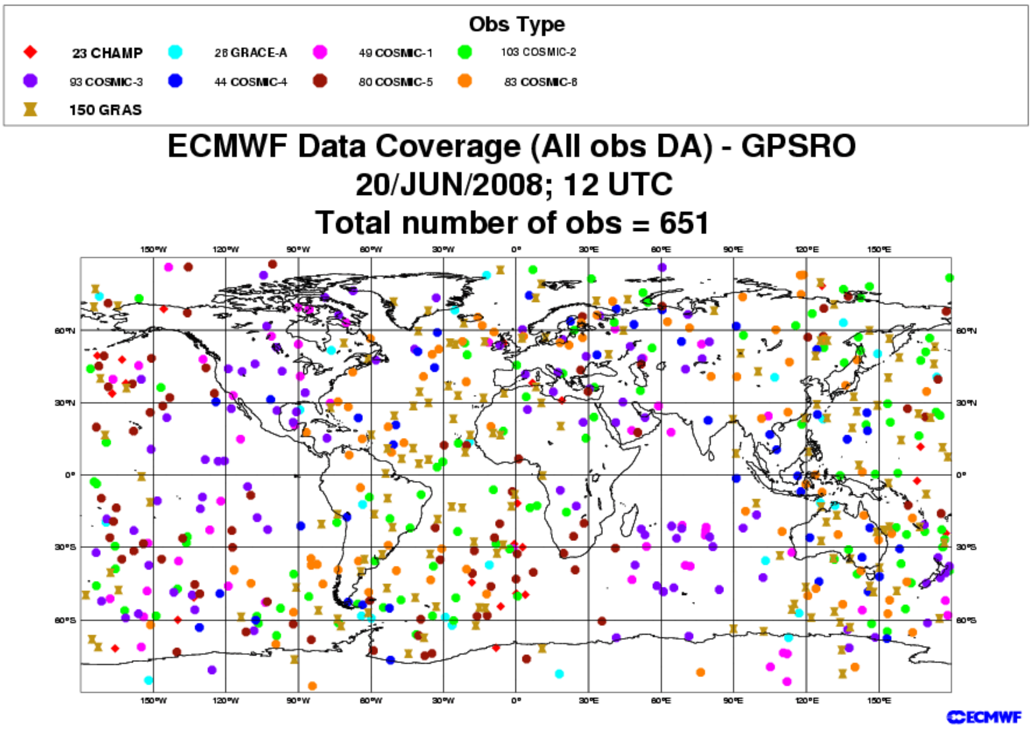

Figure 13: Data coverage by GPS Radio Occultation as received within a six-hourly period in June 2008 (Source: ECMWF).

a 6h period from GPS receivers. GRAS is the first instrument for which there is continuity until the end of the next decade, alone providing more than 600 occultations per day. A follow-on to the six-satellite COSMIC constellation is under discussion by space agencies, but has yet to be confirmed.

Moderate-Low Progress

Action A21 Facilitate exchange of ground-based GPS data

Action: Develop standards and protocols for exchange of data from the networks of ground-based GPS receivers.
Who: WMO CIMO and WMO CBS in cooperation with national agencies.
Time-Frame: Exchange standards and protocols finished by 2005. Implementation continuing (part exists already).
Performance Indicator: Number of sites providing data.

Some ground based networks of GPS receivers are being created and the data has started to be analysed. Ground-based GPS data based on signal delay provides information on the humidity content of the atmosphere, and shows promise in being used in meteorological/climatological applications. To date, a global standard for the exchange of data from GPS networks has not been developed, although guidelines providing the basis for such a standard exist. The IGS (International Global Navigation Satellite System (GNSS) Service) has developed useful guidelines for setting up an IGS station.

There are a number of national and regional networks, maintained by operational as well as research institutions, of GPS receivers which supply real-time raw GPS data. For example, in the framework of the EUMETNET E-GVAP project, data from more than 400 GPS sites are used by the UK Met Office, who run an operational network installed and used mainly for non-meteorological purposes. The current guidelines recommend, inter alia, that at least one receiver in the network be collocated with a radiosonde site for quality control.

Moderate Progress

Action A22 Satellite observations of clouds, aerosols, radiation and water vapour

Action: Ensure continuation of a climate data record of visible and infrared radiances, e.g., from the International Satellite Cloud Climatology Project, and include additional data streams as they become available. **Who:** Space agencies, for processing. **Time-Frame:** Continuous. **Performance Indicator:** Long-term availability of global homogeneous data at high frequency.

There has been moderate progress in both the planning of satellite missions and the sustained generation of products using current missions that address this Action.

A continuous climate record of visible and infrared radiance forms the basis for observing several key ECVs, such as cloud properties, radiative properties and aerosols. The 2006 CEOS Response to the IP-04 stated that the space agencies would support investigations of cloud properties and cloud trends from combined imager and sounder measurements of clouds, using Cloudsat/CALIPSO for validation. A dedicated workshop on the AVHRR climate data record was held in November 2008.

ISCCP is currently planned to continue operations through June 2012. However, funding is in place to re-engineer the processing system for transfer from NASA to NOAA in 2010, to be followed by at least one year of parallel operations. A complete reprocessing of the data products, using the 10-km-sampled radiances instead of the 30-km-sampled radiances will also be completed in 2010. Progress has been made since 2004 in assessing the reliability of climate trends derived from ISCCP products, such as cloud cover, cloud properties and radiative fluxes. The cirrus climatology produced by the University of Wisconsin (USA) has also been a significant achievement in this area.

The EUMETSAT Climate Monitoring Satellite Application Facility (CMSAF) entered its operational phase in February 2007, with secure funding until 2012. CMSAF operationally generates cloud products, radiation products (surface fluxes, surface albedo, top of the atmosphere radiation fluxes) and global water vapour products.

One of the pilot projects within the SCOPE-CM initiative addresses the sustained generation of VIS/IR AVHRR cloud products for climate.

Several instruments are being implemented by space agencies in order to provide continuity of the visible and infrared climate data record. On the Metop platform, the combination AVHRR/Infrared Atmospheric Sounding Interferometer (IASI) is already in place; for NPOESS, a combination of Visible Infrared Imaging Radiometer Suite (VIIRS) and Cross-track Infrared Sounder/Advanced Technology Microwave Sounder (CrIS/ATMS) is being implemented. A first launch of this combination on NPP is currently scheduled for 2010.

Good Progress

Action A23 Cloud observations research

Action: Research to improve cloud property observations in three dimensions. **Who:** Parties' national research and space agencies in cooperation with the WCRP. **Time-Frame:** Continuous. **Performance Indicator:** New cloud products.

Current and planned activities are underpinning significant research advances. There is very active research, international in scope, developing methods to observe cloud properties and utilize them in climate analysis efforts. Cloud research is based both on dedicated satellite missions and on detailed measurements from ground sites.

Key satellites, Cloudsat and CALIPSO, were launched in 2006, and are providing novel insight into three-dimensional cloud properties, including cloud phase (liquid/solid) and aerosol cloud interactions. The lifetime of the Cloudsat radar is expected to approach three years, and CALIPSO is planned for three years of operation.

Beyond Cloudsat/CALIPSO, the EarthCARE satellite is being developed with a payload of two active sounders (lidar and radar) and two complementary passive instruments (multi-spectral imager and a broadband radiometer). Its launch is currently scheduled for 2013. EarthCARE aims to provide vertical profiles of cloud and aerosol parameters as well as to distinguish different types of clouds and aerosols.

Development of the Japanese Global Change Observation Mission (GCOM) series has started. The Second generation Global Imager (SGLI) on GCOM-C will observe global cloud and aerosol properties and is set to perform polarimetric observations of aerosols. GCOM-W will carry the Advanced Microwave Scanning Radiometer-2 (AMSR-2) to observe water vapour, cloud liquid phase, and precipitation.

Within the US ARM (Atmospheric Radiation Measurement) programme, active research is being pursued on three dimensional properties of clouds using ground-based instrumentation. For example, cloud tomography by microwave sensors is being used to capture the spatial variation of cloud water at a resolution of a few tens of meters in the vertical and a few hundred meters in the horizontal. The ARM is also investigating the combination of ground-based cloud radar observations and satellite-based visible and microwave radiometry to provide insight into cloud properties around ARM sites.

Another example is the European CLOUDNET project, in which Doppler cloud radar, laser ceilometer or Doppler lidar measurements have been combined with the aim of retrieving cloud phase and cloud droplet size. Finally, the Year of Tropical Convection is a WMO-coordinated initiative involving coordinated observations and modelling, aimed at improving both numerical weather forecasting and climate prediction.

Moderate Progress

Action A24 Continuous observations of the Earth's radiation budget

Action: Ensure continuation of Earth Radiation Budget observations.
Who: Space agencies, coordinated through WMO Space Programme, CEOS and CGMS.
Time-Frame: Present.
Performance Indicator: Long-term data availability at archives.

Continuity of measurements of the Earth's radiation budget has yet to be achieved but some encouraging progress is being made in working towards planned continuity. The continuity of monitoring the incoming solar irradiance is necessary to derive the Earth's radiation budget and since it can only be measured from space, a suite of satellite instruments has been flown for that purpose.

Recent results for total solar irradiance suggests a value 5 W/m2 smaller than the figure of 1366 W/m2 generally assumed and used in climate models, which highlights the need for ongoing, well-calibrated measurements of solar irradiance and associated research activities. Continuity of Earth radiation budget measurements has been thrown into doubt by problems in the funding of the NPOESS systems, but significant progress has been made in reinstating the planned measurements.

In particular, the Total Solar Irradiance Sensor (TSIS) instrument has been re-manifested. The CERES instrument is planned to fly on NPP (2010), but long-term continuity of these measurements on NPOESS still needs to be determined. A prototype ERB instrument package on the FY-3A (launched in 2008) and FY-3B (launch in 2010) and the Scanner for Radiation Budget (ScaRaB) instrument on the French/Indian Megha-Tropiques mission (launch in 2010) provide some CERES-type capability, but will not attain the same level of accuracy and coverage. Realization of an Earth radiation budget instrument on the Metop follow-on is unlikely as this was considered low mission priority. However, the Geostationary Earth Radiation Budget (GERB) instrument is now a standard payload on the Meteosat series of meteorological satellites.

Measuring total solar irradiance, current instruments are deployed on ACRIMSat, SOHO and SORCE. A TIM instrument is scheduled for the GLORY mission in 2009 with planned lifetime of 3-5 years. TSIS will continue the 35 year record of total solar irradiance, and there are plans to deploy this instrument on NPOESS-1 (current launch date: 2013) to continue, albeit with a likely gap, the 9 year visible and infrared spectral irradiance record most likely obtained from the SORCE mission by 2011.

Atmospheric Composition Observations

Human activities have always interacted with the atmosphere, but the growth of population and industrialization in the 19th and 20th century has led to dramatic changes in chemical composition of the atmosphere, with consequences for the Earth system. Observations of atmospheric composition have been providing scientific evidence to: the increase in greenhouse gases and aerosols and their effects on climate forcing; the decrease in stratospheric ozone and the concurrent increase in surface ultraviolet radiation; the occurrence of summer smog over most cities in the world, including developing countries; enhanced aerosol and photo-oxidant levels due to biomass burning and other agricultural activity, among others. Sustained, high-quality measurements of the atmospheric composition ECVs (both in situ and space-based) need to be strengthened to better understand and predict the effects on the climate system, and to underpin policy-level abatement/mitigation measures.

Action A25 Integrated global observations for atmospheric composition

Good-Moderate Progress

Action: Establish a plan for and implement a consistent surface- and satellite-based global observing system for the atmospheric composition ECVs, based on common standards and procedures, and encourage data submission to WDCs.
Who: Parties' national services, research agencies and space agencies, under the guidance of WMO GAW in coordination with AOPC.
Time-Frame: Plan ready by 2005, implementation 2006-2015.
Performance Indicator: Published plan, availability of globally-consistent data.

Action A26 Vertical profiles for greenhouse gases, ozone and aerosols

Good-Moderate Progress

Action: Develop and implement a comprehensive plan to observe the vertical profiles of GHGs, ozone and aerosols utilizing commercial and research aircraft, pilotless aircraft, balloon systems, kites, ground-based lidars and satellites.
Who: Parties' national services, research agencies and space agencies, under the guidance of WMO GAW in coordination with AOPC.
Time-Frame: Plan by 2005, implementation 2006-2015.
Performance Indicator: Published plan, availability of globally-consistent data.

The climate component of the IGOS Partners Atmospheric Chemistry Theme, the 2004 IGACO Theme Report[60] provides a detailed set of requirements for measurements of atmospheric composition, including all relevant ECVs. Building on this, the WMO GAW Strategic Plan 2008-2015[61] guides implementation of global observing system for the atmospheric composition ECVs following the requirements in the IGACO report and the Satellite Supplement to the IP-04.

The GAW strategic plan strives for the following main programme developments:

- Integration of observations of surface-based, balloon-borne, aircraft, satellite and other remote sensing observations;
- Near real-time (1-2 hours after observation) delivery of data such as total ozone, ozone sounding and aerosol observations;
- Fusion of observational systems, data assimilation and modelling, databases and products delivery into coherent data processing chains, according to a GAW quality management system;
- Assimilation of the ECVs (aerosols, ozone and greenhouse gases) in atmospheric transport and numerical weather prediction models, and the generation of related products and services.

Since 2004, agreements between WMO GAW and the GCOS Steering Committee have led to the designation of four new GCOS networks on atmospheric composition ECVs (CO_2, CH_4, ozone), as discussed in Action A27 and A30. Furthermore, there have been important launches of both operational and research missions providing enhanced measurement of atmospheric composition, and major commitments and initiatives towards future missions such as the GMES Sentinels and the CEOS Atmospheric Chemistry Virtual Constellation are underway, as discussed in Action A32.

Regular assessments of the status of networks as well as the establishment of dedicated IGACO offices for the thematic foci on ozone/UV, aerosols, greenhouse gases and air quality/long-range transport of air pollution are foreseen. Projects on kites and pilotless aircraft exist, but there is no

[60] IGACO (2004): *An Integrated Global Atmospheric Chemistry Observation Theme for the IGOS Partnership* -- Report of the Integrated Global Atmospheric Chemistry Observation Theme Team, ESA SP-1282 / WMO GAW Report No. 159 (WMO/TD No. 1235), ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw159.pdf.
[61] WMO GAW (2007): *WMO Global Atmosphere Watch Strategic Plan: 2008 - 2015*, WMO GAW Report No. 172, ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw172-26sept07.pdf.

systematic initiative. Information on atmospheric composition profiles is also provided by the existing lidar networks such as EARLINET and NDACC (see also Action A31). In addition, within the GAW surface based ozone total column ozone network, there is work on the extraction of ozone vertical profiles from Brewer spectrophotometer instruments.

The WMO GAW programme supports regular meetings of working groups for each of the chemical ECVs, and for designated GAW World Data Centres, to review data quality objectives and data archiving and dissemination issues (cf. footnote 61).

IGACO-related activities are ongoing: for example, the GAW/IGACO-O3/UV initiative has developed an implementation plan[62] and organised several meetings on measurement quality, data exchange and data homogeneity. In May 2009, a joint WMO GAW / IO3C (International Ozone Commission) meeting on absorption cross-section will involve both communities of satellites and ground based measurements.

Activities that contribute to these plans include:

- the European programmes IAGOS (Integration of routine Aircraft measurements into a Global Observing System) and ICOS (Integrated Carbon Observing System) as a continuation of the ten-year MOZAIC programme (to measure atmospheric ozone, aerosols and in future greenhouse gases routinely from commercial aircraft platforms), and CarboEurope (European *in situ* measurements to determine the terrestrial carbon balance), respectively;

- the routine greenhouse gas observations made by the Meteorological Research Institute of JMA, NIES and Japan Airlines;

- the CO_2 profiles provided by routine small aircraft flask samples by NOAA ESRL.

Good-Moderate Progress

Action A27 Global network for CO_2 and CH_4 observations

Action: Establish the GCOS/GAW baseline network for CO_2 and CH_4, and fill the gaps.
Who: Parties' national services, research agencies and space agencies under the guidance of WMO GAW and its Scientific Advisory Group for Greenhouse Gases in cooperation with the AOPC.
Time-Frame: Specification by 2005 and implementation by 2009.
Performance Indicator: Plan.

WMO GAW CO2 and CH4 Monitoring Networks were established in October 2005 by the GCOS Steering Committee as GCOS Comprehensive Networks. This includes development of a 5-year strategic plan for these networks by the GAW community. The results from these observations are reported annually in the WMO Greenhouse Gas Bulletin. Statistics from the World Data Centre for Greenhouse Gases (WDG-GG) at JMA indicate a steady increase of submitted station data to the archive, however, there has been limited progress in expanding the networks, e.g., in polar regions during the IPY. Figure 14 shows the global distribution of in situ observations of carbon dioxide as of late 2007.

Good-Moderate Progress

Action A28 Integrated analyses of CO_2 and CH_4 observations

Action: Develop plans for an Integrated Data Analysis Centre (WIDAC) for CO_2 and CH_4.
Who: WMO GAW and its WDC-GG in consultation with the AOPC.
Time-Frame: 2007.
Performance Indicator: Establishment of data analysis centre.

Integration of greenhouse gas observations and their assimilation in models has occurred within the NOAA Carbon Tracker system, as well as under the European GMES initiative. The NOAA ESRL Carbon Tracker system combines measurement and modelling systems in order to keep track of the sources and sinks of atmospheric CO2 globally from January 2000 through December 2007. It provides freely accessible online tools, e.g. weekly and monthly averaged estimates of net CO2 exchange between the terrestrial biosphere and the atmosphere. A series of halo-compounds and hydrocarbons have recently been added to the analysis of a subset of air samples. Another CO2 and CH4 tracking system has been developed by the EU-funded GEMS (Global and regional Earth-

[62] WMO GAW (2008): *IGACO-Ozone and UV Implementation Plan*, GAW Report No. 182.

system Monitoring using Satellite and in situ data) project, which operates comprehensive data analysis and modelling systems for monitoring the global distributions of atmospheric constituents (e.g., CO2, CH4, aerosols, ozone) that are important for applications related to climate, air quality and UV radiation.

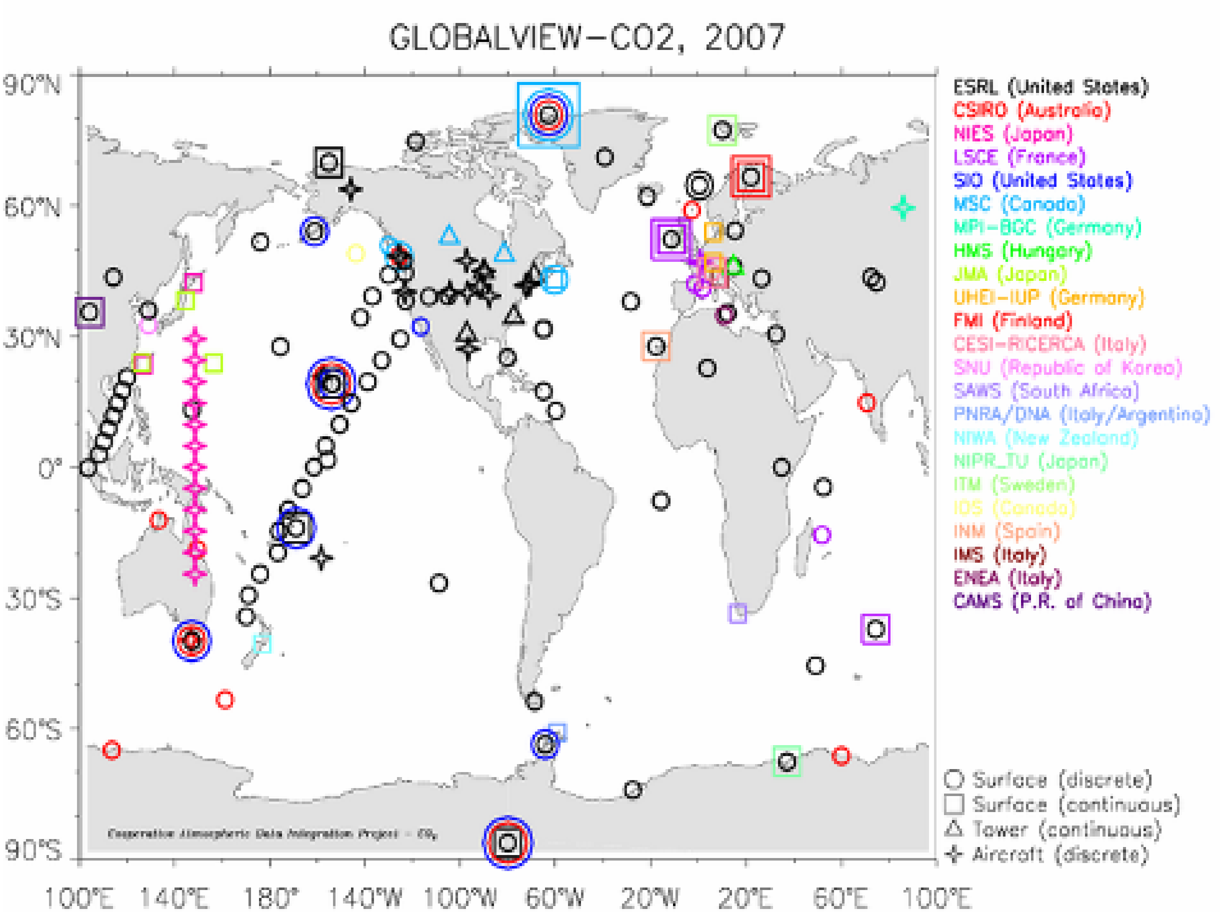

Figure 14: Global *in situ* observations of carbon dioxide (late 2007).

A WMO/IAEA panel of experts has convened every two years since 1975 to review data needs, data quality objectives and progress in integrated analyses using carbon cycle models. This group is steward of the evolving class of inverse modelling-observational systems aimed at tracking carbon air-surface exchange globally using a top-down approach (i.e., infer surface fluxes from atmospheric concentration gradients).

Good-Moderate Progress

Action A29 Halocarbon Intercomparison Study

Action: Complete an International Halocarbon Inter-comparison Study, linking measurement scales for CFCs of major networks as an initial step in an ongoing quality assurance programme. **Who:** Parties' national research agencies and national services, through WMO GAW. **Time-Frame:** Report in 2007; subsequent inter-comparisons 2007-2012. **Performance Indicator:** Report of inter-comparison data.

A number of projects have engaged this objective. The AGAGE (Advanced Global Atmospheric Gases) Experiment, as a major contribution to global observations of halocarbons, collaborates with the System for Observation of Halogenated Greenhouse Gases in Europe (SOGE). Through transfer of AGAGE calibrations and sharing of AGAGE technology, this has placed AGAGE and SOGE data on common calibration scales with comparable precisions, accuracy and measurement frequency.

The IHALACE (International HALocarbons in Air Comparison Experiment) took place in 2006-2007, with evaluation in 2008, under the WMO GAW programme. Similar intercomparison studies are expected to continue in order to establish a calibration matrix that relates the calibration of each laboratory to one another and enable the construction of an integrated, global halocarbon database. NOAA ESRL and the Scripps Institution of Oceanography, University of San Diego, USA, are maintaining calibration standards for CFCs. There are also efforts led by WMO GAW to unify these standards.

Action A30 Implementation of Baseline Ozone Observing Networks

Good-Moderate Progress

Action: Define and implement the Baseline Ozone Observing Network for balloon vertical profiles and total column ozone and initiate implementation.
Who: Parties' national research agencies and national services through WMO GAW and partners, in consultation with AOPC.
Time-Frame: Agree on balloon sondes network by 2005, implementation thereafter.
Performance Indicator: Network specification. Percentage of data submitted to International Data Centres.

In 2007, 63 sites from the existing aeronomic networks SHADOZ, GAW and NDACC, as well as the 132 sites measuring total ozone with Dobson and/or Brewer spectrophotometers, have been recognized as the GCOS Global Baseline Total Ozone Network and GCOS Global Baseline Profile Ozone Network, respectively. As of January 2007, 79% of SHADOZ, GAW and NDACC sites, 57% of the Dobson Ozone Network sites and 85% of the Brewer Ozone Network sites were reporting. These statistics are not produced on a routine basis, and therefore, no earlier data reception rates for these networks are available.

Action A31 Strategy to monitor and analyze aerosols

Moderate Progress

Action: Develop and implement a coordinated strategy to monitor and analyze the distribution of aerosols and aerosol properties.
Who: Parties' national services, research agencies and space agencies, with guidance from AOPC in cooperation with WMO GAW, WCRP, IGBP.
Time-Frame: Define a baseline network for aerosol optical depth by 2006 with data archived at the WMO World Data Centre for Aerosols (Ispra, Italy), with proposal for implementation by 2009.
Performance Indicator: Strategy document, followed by implementation of strategy, availability of globally-consistent aerosol optical depth data.

Progress has been made by WMO GAW in coordinating the diverse communities engaged in aerosol observations, such as in harmonising data products, terminology, documentation and data access. GCOS through the AOPC panel has encouraged the WMO GAW programme to establish a coordinated, systematic global observing network for aerosol properties in collaboration with other partners, with a view to GCOS recognition of such a network. An "International experts workshop on coordination of global aerosol observations and links to users" is planned by WMO for April 2009 to develop an implementation strategy for a baseline network for aerosol optical depth. Quasi-operational availability of aerosol data (e.g., from MODIS, AERONET) supports the analysis of aerosol properties, and is being used in assimilation into models and for model validation.

The Galion[63] (GAW Atmospheric LIDAR Observation Network) has been founded as a network of aerosol lidar networks with participation of seven global and regional networks, and with commitment to long-term operation.

Action A32 Satellite atmospheric composition measurements

Good-Moderate Progress

Action: Develop and implement a strategy to enable use of satellite data on atmospheric composition for climate by scientific users, regardless of source.
Who: Space agencies, in conjunction with CEOS and CGMS, IGOS-P, and WMO Space Programme.
Time-Frame: 2005 for strategy, 2007 for facilitated use of data regardless of source.
Performance Indicator: Written strategy by 2005; straightforward use of data regardless of source by broad range of scientific users.

Considerable progress has been made with the launch or planning of new operational instruments, such as GOME-2 on Metop, a number of high-spectral resolution infrared sounders and the GMES Sentinel series. There are also dedicated research-class missions addressing atmospheric composition, such as Aura and GOSAT (regrettably, an additional expected mission, OCO, suffered a launch failure). Under the auspices of the CEOS Atmospheric Composition Virtual Constellation (ACC), a series of workshops devoted to coordination across space agencies on satellite datasets and missions related to atmospheric composition was organized through 2007 and 2008. The 2008 workshop specifically focussed on the quality of datasets and gaps in the record. In addition, a series

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[63] WMO (2007): *Plan for the implementation of the GAW Aerosol Lidar Observation Network GALION*, GAW Report No. 178, March 2007, ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw178-galion-27-Oct.pdf .

of instruments addressing atmospheric composition measurements is currently flying or in the planning stage, thereby ensuring continuous data supply in this area.

The development of international data exchange systems, such as WIS and the GEO Portal, and the existence of WMO Resolution 40 on data exchange as well as development of the GEO Data Exchange Principles is expected to facilitate the use of satellite data on atmospheric composition for climate. There is increasing recognition by space agencies of the importance of facilitating data access (see footnote 33).

The WDC-RSAT (World Data Centre for Remote Sensing of the Atmosphere) has been established at DLR, Germany, as a new WMO GAW World Data Centre. WDC-RSAT aims to store or link to all satellite data related to atmospheric composition.

5 The Oceanic Climate Observing System

The ocean plays critical, but generally not obvious, roles in the fundamentally coupled ocean-atmosphere-land Earth climate system. Perhaps the most obvious uncoupled role is through sea level, which directly affects society at the coasts. Less obviously, but very importantly, transport of heat from the tropics toward the poles is a major factor in determining the surface temperature of many nations; east-west transport of water in the tropical Pacific controls the onset and evolution of El Nino events; transport along and under ice shelves may determine how rapidly they separate from land. The ocean holds about 50 times more carbon than the atmosphere, and its sediments thousands of times more.

The ocean also varies on decadal time scales and will experience greater changes than will result from climate change over the same period. The upwelling zones of the ocean provide nutrients that support some of the most biologically productive zones of the planet, and there is growing evidence that oceanic physical and chemical changes strongly control ocean ecosystems and may affect them more in the decades ahead. Tracking the heat and carbon stored and the exchanges of heat, moisture, momentum and greenhouse gases with the atmosphere are vital for understanding and forecasting the evolution of climate variability and change. Observing changes in the biogeochemical system and in marine ecosystems is critical to projecting their future states, as well as the ocean's ability to continue to provide food to vulnerable societies.

Sea level is a critical variable for low-lying regions, and globally is driven by volume expansion or contraction due to changes in sub-surface ocean density, and by exchange of water between the oceans and other reservoirs, such as land-based ice and the atmosphere. Local sea-level changes can also be strongly influenced by regional and local circulation changes, by isostatic rebound from the last glaciation period, and by land use changes. Sea-surface temperature is a critical variable for the coupled atmosphere-ocean system. In addition to the surface atmospheric variables, others of note include sea ice, sea-surface salinity, and partial pressure of carbon dioxide (pCO_2). Ocean colour is used to indicate biological activity. Ocean life is dependent on the biogeochemical status of the ocean, which is affected by changes in its physical state and circulation. Sea ice is important as an indicator of climate change as well as through its albedo feedback and its impact on polar ecosystems. Melting or forming sea ice affects salinity and hence density and ocean currents. Technology is developing rapidly to permit additional observations in coastal regions and for boundary currents, narrow straits and shallow regions (choke points where flow is limited), biogeochemical variables, primary productivity, and other ecosystem variables.

The composite surface and sub-surface ocean observing networks, as described in the IP-04, include global monitoring of certain ECVs where this is feasible. Monitoring of other ECVs depends on observations from reference stations or sites, or, in the case of sub-surface ocean carbon, nutrients and tracers, repeat ship-based surveys. Very recently, there have been significant contributions to sub-surface ocean measurements, particularly in data-sparse areas near ice margins from animal-mounted conductivity, temperature and depth (CTD) devices. The global ocean observing system put in place for climate will also support global weather prediction, global and coastal ocean prediction, and marine environmental monitoring, and thus merits sponsorship from a range of sources.

Summary of Progress

Useful progress has been identified in almost every Action called for in the IP-04, but many Actions remain incomplete. 86% of the Actions had moderate to good progress. The activities described here have been taken forward under sponsorship from a wide range of national research and operational agencies. Coordination often occurs via participation in international research and operational groups. The Joint Commission for Oceanography and Marine Meteorology of the IOC and WMO is a technical commission with responsibility for the coordination of many of the data collection, data system and services development activities.

The ice-free upper 1500 metres of the ocean are being observed systematically for temperature and salinity for the first time in history, because both the Argo profiling float and surface drifting buoy arrays have reached global coverage at their target numbers.

Most in situ networks have made progress. There has been a substantial increase in the number of tide gauges now reporting both in near real-time and with tsunami-detection capability. Several new moored reference site moorings have been deployed, and the tropical moored array continues to develop in the Atlantic and Indian Oceans. Full ocean depth observations of physical and carbon ECVs have had good progress. However, the number of Volunteer Observing Ships reporting marine meteorological observations has declined.

Most in situ observing activities continue to be carried out under research agency support and on research programme time limits. A particular concern is the fragility of the financial arrangements that support most of the present effort; there has been very limited progress in the establishment of national ocean or climate institutions tasked with sustaining a climate-quality ocean observing system. Thus, the primary Agents for Implementation for ocean observations and analyses remain the national and regional research organizations, with their project-time-scale focus and emphasis on principal investigator-driven activities.

Important progress has been made in the provision of critical ocean satellite data of sea-surface ECVs has been made, but not for all variables, and data access remains to be ensured. CEOS has adopted a strategy of Virtual Constellations for ocean topography, surface vector wind, and ocean colour, and serious agency engagement to advance these Constellations is underway.

Important progress has been achieved in the development of historical ocean reanalysis and in high-resolution ocean forecasting capabilities. A number of products are now available and being evaluated. Issues with the historical dataset have been identified and are being studied.

Promising developments in improved methods and standards will allow wider measurement of biological and chemical ECVs and consideration of new ECVs in the years ahead. Ocean in situ and satellite sensor and platform developments continue, and some new system capabilities are now feasible for broad use. Some of these are identified in the relevant section below. Outreach to the ocean ecosystem, fisheries and biogeochemistry communities is ongoing, and community plans will be developed for basin-scale sustained observations of feasible ECVs through the OceanObs'09 conference. Community efforts on ocean metadata are ongoing.

Data sharing remains incomplete, particularly for tide gauges and biogeochemical ECVs. Data archaeology needs to continue. Although progress has been made on recovery of the ocean historical dataset, continuing efforts in data rescue, digitization and data sharing are needed. Full access to at least the GLOSS Core Network of tide gauges remains to be achieved. More timely and complete data sharing within the ocean water column repeat survey community is desired.

The marine surface observing effort requires greater engagement, since support from commercial vessels is diminishing, in part due to security concerns (related to acts of piracy) of vessel operators.

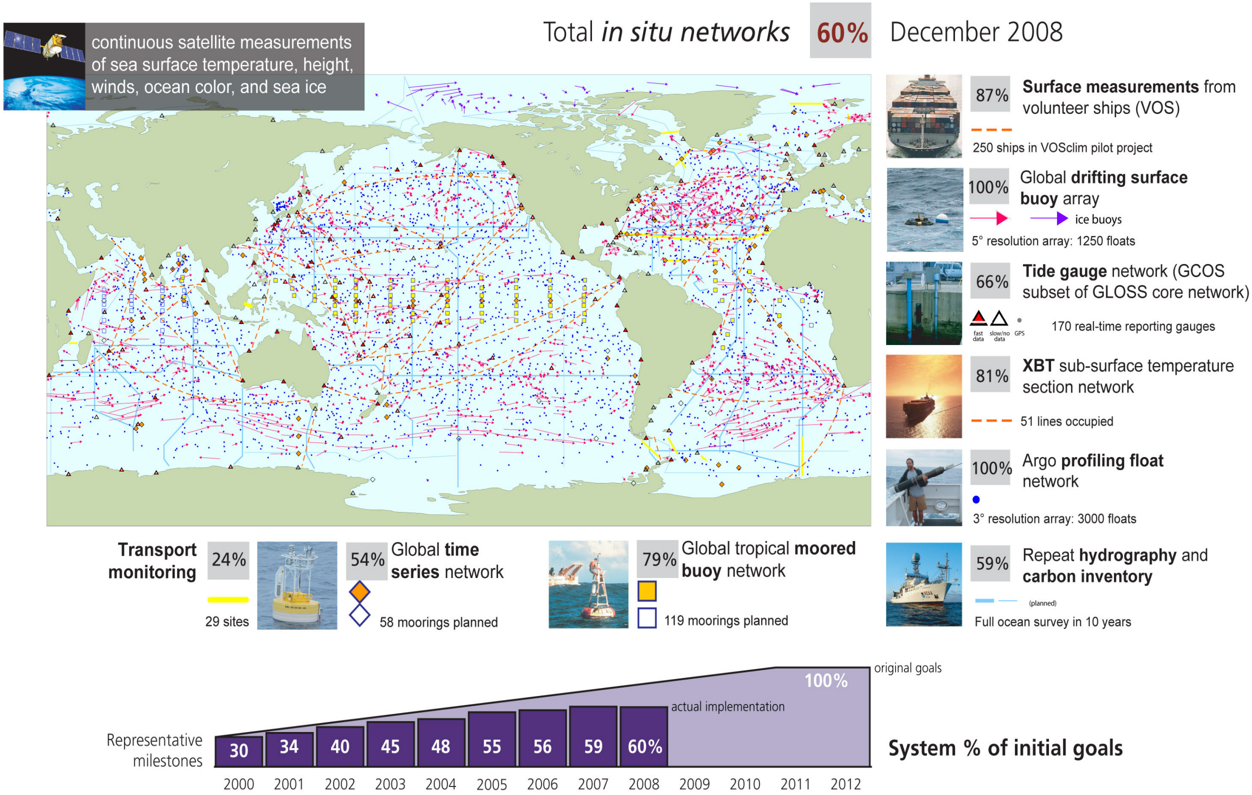


Figure 15: Status of the *in situ* global ocean observing system. By December 2008, total implementation reached 60% of its initial goals. Note that gaps between individual systems are significant despite the overall impression of dense *in situ* coverage of the oceans. Implementation has progressed steadily but slowly, falling short of the original goals.

Detailed Progress

Action O1 Increasing national and multi-national participation

Moderate Progress

Action: Continue to seek national and multinational participation in the implementation of the global ocean observing system for climate.
Who: IOC in consultation with GCOS, GOOS, and JCOMM.
Time-Frame: Continuous.
Performance Indicators: Extent of national and multinational participation in the recommendations of this Plan.

The IP-04 has been accepted by the IOC Assembly (IOC-XXIII, June 2005) and adopted as the work plan of the JCOMM Observations Programme Area (JCOMM-II, September 2005). As a result of regular national reporting through these bodies and the parallel 2007 request from the UNFCCC to Parties to report using revised guidelines on the global climate change observing systems (see footnote 42), regular system monitoring through JCOMM, and the reports from CEOS to the UNFCCC (e.g., the 2006 CEOS Response to the IP-04), the state of implementation of the global ocean observing system for climate is followed at the intergovernmental level. A particular shortcoming is that there has been very limited progress in the establishment of national ocean or climate institutions tasked with sustaining a climate-quality ocean observing system. Thus, the primary Agents for Implementation for ocean observations and analyses remain principal investigator proposals to their national and regional research organizations, with their project-time-scale focus. It is however encouraging that, through these institutions and their support, improvements have occurred. There has been a slow increase in overall *in situ* network activity from approximately 48% in 2004 to 60% in 2008 towards the target densities (see Figure 15). Currently, 73 countries consider themselves to be participating in the Global Ocean Observing System (GOOS), most of them through participation in the Global Sea Level Network (GLOSS).

Action O2 Regular review of Ocean Plan

Good Progress

> **Action:** Review relevance and effect of Plan, and revise the Oceanic Section of the Plan every 5 years.
> **Who:** OOPC, in cooperation with participating partners.
> **Time-Frame:** Report by 2009.
> **Performance Indicator:** Report published.

Consultation with user groups on the effectiveness of the system is ongoing. Community feedback to date reveals that: all Actions continue to be needed; the capability to observe some ECVs has increased; expansion of the observing activities is now technically feasible; and a few additional ECVs need to be considered. Action is well under way to update the plan for 2009, via actions of the GCOS Steering Committee, and preparations for the OceanObs'09 Conference (21-25 September 2009, Venice, Italy).

Action O3 Research and development in support of ocean observations

Good Progress

> **Action:** Promote and facilitate research and development (new improved technologies in particular), in support of the global ocean observing system for climate.
> **Who:** Parties' national ocean research programmes and space agencies, in cooperation with GOOS, GCOS, and WCRP.
> **Time-Frame:** Continuing.
> **Performance Indicator:** More cost-effective and efficient methods and networks; strong research efforts related to the observing system; number of additional ECVs feasible for sustained observation; improved utility of ocean climate products.

Major progress has been made in the advancement of ocean science and the development of new observing technology. Annex-I Parties continue to support strong research programmes in climate, including ocean climate. There is continuing technological development for sensors to observe oceanic ECVs, including, e.g., additional measurements from surface drifting buoys, profiling Argo-type floats and animal-mounted instruments. Both the ocean reanalysis and near real-time ocean analysis communities have contributed to evaluation of the IP-04 and made suggestions for updates of the Plan. Space agencies continue to develop new sensors and sensors with increased observing capability. This Action will need ongoing attention.

Action O4 Partnerships with ocean research community to implement ocean observations

Good Progress

> **Action:** Promote and build partnerships with ocean research institutions and science teams.
> **Who:** OOPC with WCRP and SCOR science programmes, and with POGO and other marine research institutions.
> **Time-Frame:** Continuing.
> **Performance Indicator:** Effective and productive partnerships, measured in terms of capacity delivered.

Good working relationships exist between ocean research institutions, the ocean science community and the other observing system partners. The various physical climate marine communities were involved in the development of the IP-04, and continue to work together in planning and executing future physical climate observations in the oceanic domain. The OceanObs'09 conference will take place with one goal being to increase connections between all marine communities involved in basin-scale ocean observations, physical climate, biogeochemistry, carbon, ecosystems, and fisheries. Community white papers have been solicited in order to encourage the development of a plan for ongoing activities in the coming decade.

Ongoing implementation of the observing system critically depends on a continuing high level of cooperation and coordination between the commercial, research and operational marine communities.

Action O5 Coastal observations in support of the UNFCCC

Moderate-Low Progress

> **Action:** Ensure the GOOS Coastal Ocean Observing System implementation plan is responsive to UNFCCC needs.
> **Who:** GOOS Steering Committee with GOOS Regional Alliances and GOOS Panels.
> **Time-Frame:** Continuing.
> **Performance Indicator:** Regional and coastal needs met.

A GOOS coastal ocean module implementation strategy has been completed, and outlines steps to be taken nationally and regionally to meet the local priority societal needs for coastal zone information in including climate impacts and adaptation. Implementing the activities identified through these planning processes in all countries will however be very challenging. There is much need for resources, including funding, technical/scientific capabilities, and necessary institutional arrangements. A new Panel for Integrated Coastal Observations (PICO) has been established by the GOOS Scientific Steering Group, is a partner to OOPC, and has primary responsibility for the development of coastal plans and implementation. The planned update of the IP-04 would include specific mention of observations in support of climate in the coastal ocean.

Oceanic Domain – Surface

As noted above, the ocean surface variables have direct relevance to the climate system and are key elements for describing the coupling between the oceans and the atmosphere.

Moderate Progress

Action O6 Improved climate measurements from Voluntary Observing Ships

Action: Improve metadata acquisition and management for a selected, expanding subset of VOS (VOSClim) together with improved measurement systems.
Who: Parties' national services and ocean research agencies through JCOMM VOSClim.
Time-Frame: VOSClim metadatabase in place by 2006. Continuing improvement to data streams.
Performance Indicator: Greater use of VOS data in climate products. Successful completion of initial phase of VOSClim.

Progress has been made in expanding the VOSClim and its management, but access to metadata still needs improvement. The number of ships recruited to the VOSClim programme providing enhanced metadata for climate purposes has progressed to beyond the original goals (now 259 ships compared to the 200 originally targeted). Not all of the recruited ships report the additional elements required, and some difficulties remain for broad public access to the metadata. Overall, the number of ships participating in the Voluntary Observing Ship (VOS) scheme has been in decline as National Meteorological Services put less emphasis on gathering this type of data, and as commercial concerns about the safety of ships and their crews has increased. Potential solutions to these issues are under discussion within WMO. The JCOMM has also developed a pilot project for the real-time serving of metadata on ocean temperature measurements taken by all the observing networks. The National Marine Data and Information Service of China has taken primary responsibility for serving the data (see also Action O10).

Good Progress

Action O7 Updating plans for sustained ocean satellite observations

Action: IGOS-P Ocean Theme Team to publish update of the Ocean Theme and, as appropriate, restating the satellite requirements and explicitly noting requirements for climate.
Who: IGOS-P through WMO Space Programme, CGMS, CEOS in consultation with OOPC and GCOS.
Time-Frame: Continuous.
Performance Indicators: Updated Ocean Theme document; Satellite agency commitments to oceanic climate measurements.

The Integrated Global Observing System Partnership (IGOS-P), as a closing task, merged its Theme activities with GEO in 2007, and no update to Ocean Theme document is planned at the present time.

The 2006 CEOS Response to the IP-04 and the Satellite Supplement proposed the establishment of Virtual Constellations of satellite observations for ocean surface topography and altimetry, ocean colour radiometry and ocean surface vector wind, supported by the space agencies as a coordinated and collaborative effort.

Good Progress

Action O8 Implementation of ocean surface reference mooring network

Action: Complete and maintain a globally-distributed network of ~29 surface moorings as part of a Surface Reference Mooring Network.
Who: Parties' national services and ocean research agencies responding to the OceanSITES plan.
Time-Frame: 15 moorings deployed by 2009, network complete by 2014.
Performance Indicator: Moorings operational and reporting to archives.

National commitments through research programmes to maintain a Surface Flux Reference Mooring Network have led to some increase in the number of sites established. The total number of surface flux reference sites coordinated under the global OceanSITES programme is now 20 (operating and reporting data to OceanSITES archives, see Figure 16). This only includes those sites which have updated the metadata description for the site in 2009 and have committed to archiving data according to OceanSITES standards at one of the two OceanSITES Global Data Assembly centres (Coriolis, France or NDBC, USA). A further 12 sites are planned or are not yet reporting data. OceanSITES also coordinates a larger number of generic atmospheric, water column, and ocean transport reference sites.

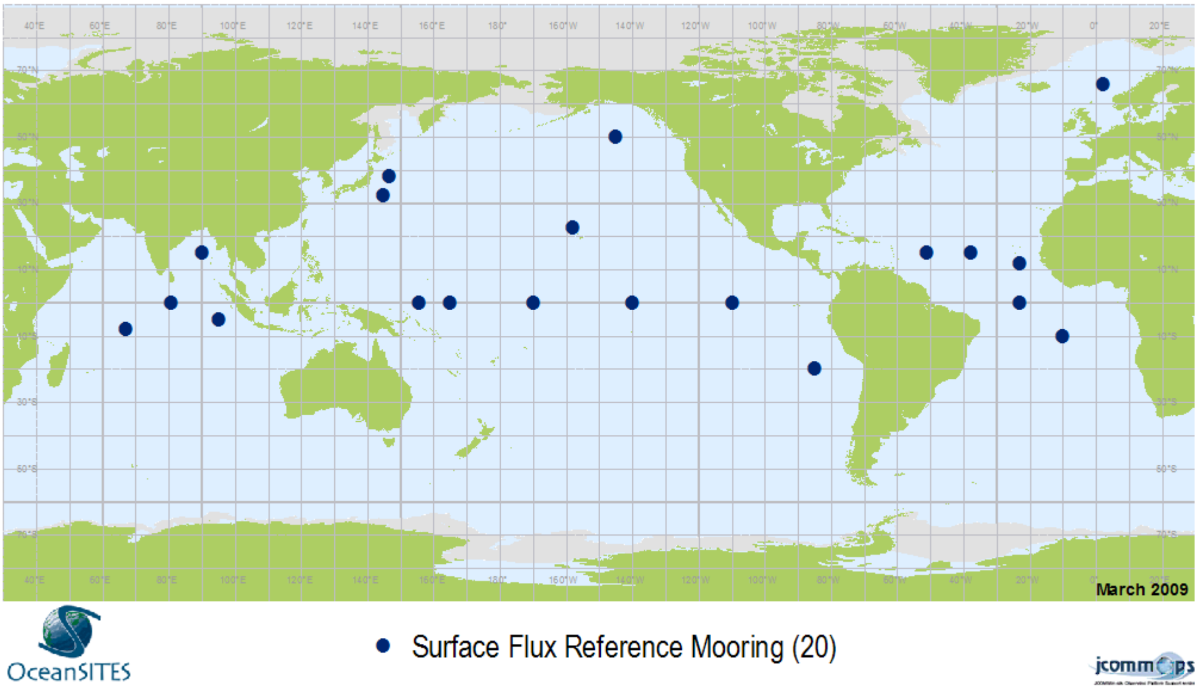


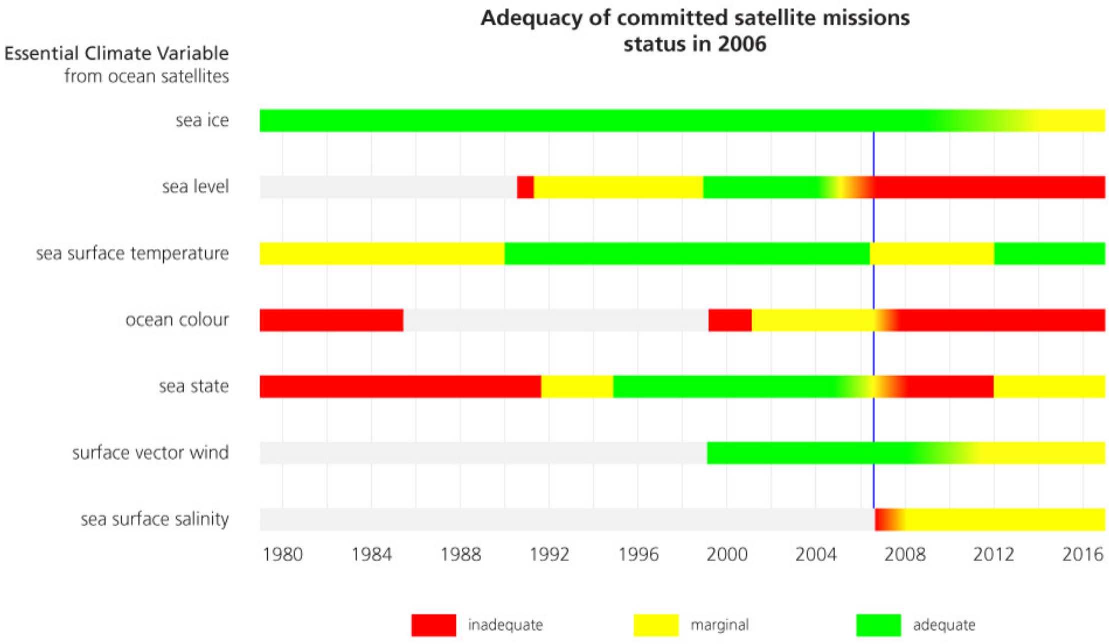
Figure 16: Status of reporting ocean surface flux reference time series measurements coordinated through the global OceanSITES programme, in March 2009.

Action O9 Sustained satellite observations of sea-surface temperature

Moderate Progress

Action: Ensure a continuous mix of polar orbiting and geostationary IR measurements combined with passive microwave coverage. To link with the comprehensive *in situ* networks noted in O10.
Who: Space agencies coordinated through CGMS, CEOS, and WMO Space Programme.
Time-Frame: Continuing.
Performance Indicator: Satellite plans and performance.

Current coverage of sea-surface temperature by IR and passive microwave missions is good. Operational commitments exist by various space agencies for the continuity of IR instruments (e.g., HIRS, AIRS, AVHRR, VIIRS) on satellites, and further research-based IR sensor missions are planned. However, continuity of appropriate microwave missions is not secured. A very good satellite SST record of climate quality, which has been extended and improved substantially during the period 2004-2008, is the ATSR/AATSR record from ERS-1, ERS-2 and Envisat. Comparable data will be available also from the Sentinel 3a, b missions of ESA, to be launched in the period after 2013. These will provide long-term continuity for high quality IR SST. These instruments were designed specifically to measure SST to the quality required for climate monitoring. The GHRSST project has generated multiple very high-resolution datasets for global SST, although this is not an operational programme.



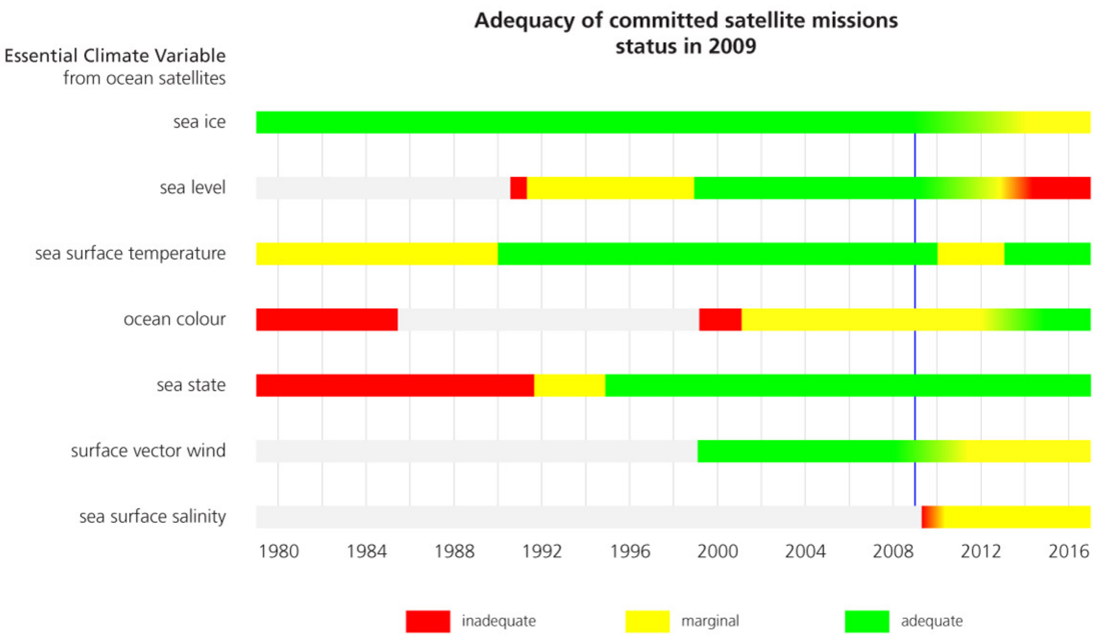


Figure 17: Improvement in the commitments by satellite agencies to continuous climate-quality measurements of sea-surface ECVs by satellite has been substantial since 2006 (top, 2009 in bottom figure). The colour bars indicate the adequacy of committed satellite missions by the research and operational space agencies for the requirements set in IP-04 and the Satellite Supplement. Marginal adequacy meets the requirements but relies on missions that are past their planned lifetime or with no redundancy.

Action O10[64] Global *in situ* observations of sea-surface temperature

Good Progress

Action: Obtain global coverage, via an enhanced drifting buoy array (total array of 1250 drifting buoys equipped with atmospheric pressure sensors as well as ocean temperature sensors), a complete Tropical Moored Buoy network (~120 moorings) and the improved VOSClim ship fleet.
Who: Parties' national services and research programmes through JCOMM, Data Buoy Cooperation Panel, and Tropical Mooring Implementation Panel.
Time-Frame: Complete by 2009.
Performance Indicator: Data submitted to analysis centres and archives.

The global surface drifting buoy array[65] has maintained its target of 1250±50 since November 2005, but obtaining the desired even spatial coverage is still challenging in areas of low ship traffic and surface current divergence (see Figure 5). The global tropical moored array[66] had 75 of 119 planned moorings reporting in June 2008, maintaining full arrays in the tropical Pacific and Atlantic Oceans and beginning coverage in the eastern tropical Indian Ocean. Surface observations from the Volunteer Observing Ship (VOS) fleet overall have declined in recent years.[67] However, the number of ships recruited to the VOSClim programme, providing enhanced metadata for climate purposes, has progressed to beyond the original goals (at present 259 vessels contribute; the original target was 200 ships). High spatial resolution observations of sea-surface temperature and salinity are provided on a limited number of sections from commercial and research vessels operating underway instruments.

Action O11 Implement highly accurate sea-level gauge network

Good-Moderate Progress

Action: Implement the GCOS subset of the GLOSS Core Network, with geocentrically-located high-accuracy gauges. Ensure real-time exchange and archiving of data. Ensure historical sea-level records are recovered and exchanged.
Who: Parties' national agencies coordinated through GLOSS of JCOMM.
Time-Frame: Complete by 2009.
Performance Indicator: Data availability at International Data Centres, global coverage.

In March 2009, there were 118 near real-time reporting tide gauges and a further 29 fast-delivery tide gauges in the GCOS/GLOSS network, 147 out of a total of 170 planned stations. These provide high-frequency sea level (hourly or better reports) which are necessary for understanding both sea-level variability and rise. A further 37 had some data in the international archives (see Figure 18). This is a marked improvement from the 62 near real-time tide gauges and 29 fast delivery gauges operational in 2005, 91 of the 170 stations. The number of geo-referenced tide gauges, measuring local land movements in order to observe absolute sea-level change, has increased from 64 to 93 between 2005 and 2009.

Since 2003, a limited number of historical records were recovered and added to the data archives. These include sites in Indonesia, New Zealand, Spain, the UK, France, Germany, and Sweden (see also Action O13).

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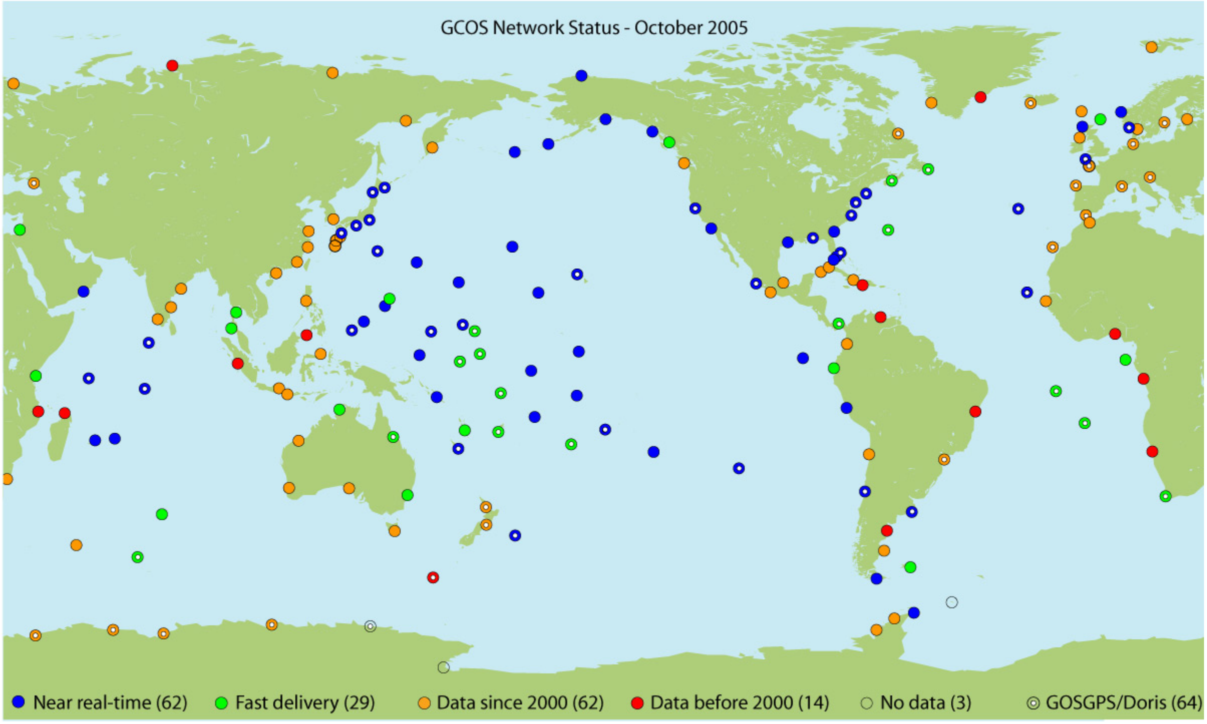
[64] See also Action A5.
[65] http://www.aoml.noaa.gov/phod/dac/dacdata.html
[66] http://www.jcommops.org/network_status/
[67] Kent et al. (2008): *The Case for Maintaining Surface Meteorological Data Collection from Voluntary Observing Ships, accessible via* http://www.ioc-goos.org/index.php?option=com_oe&task=viewDocumentRecord&docID=2097.



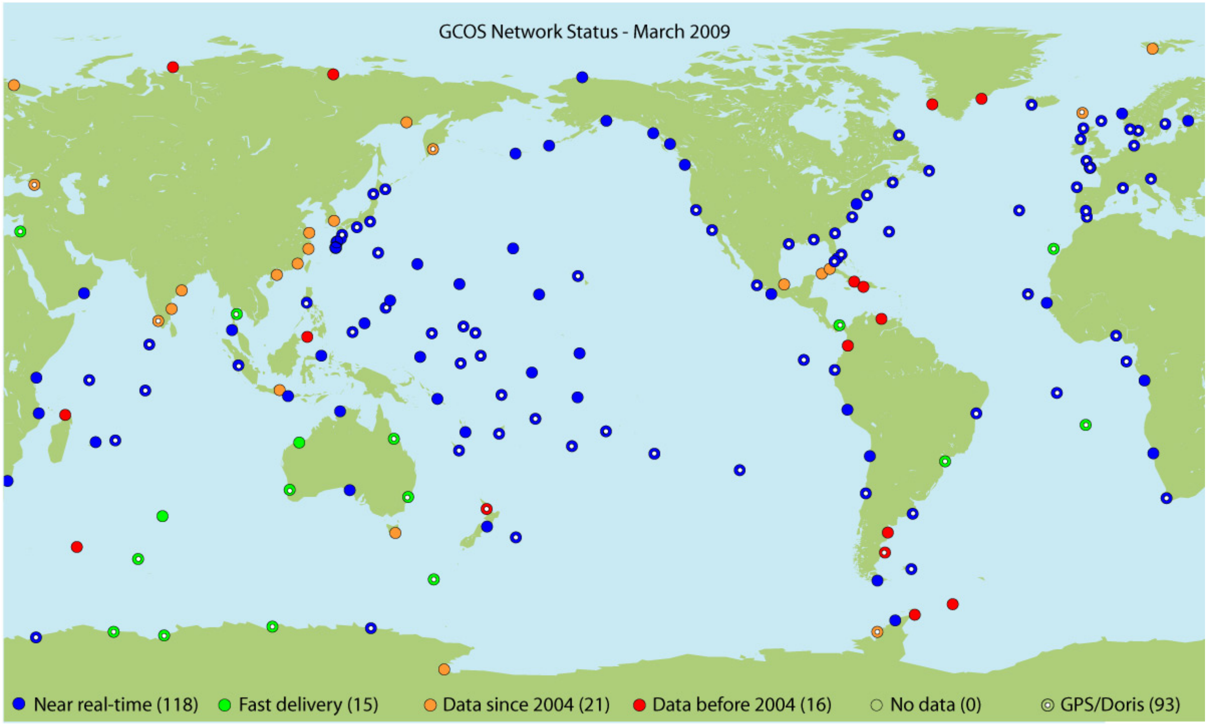


Figure 18: Status of reporting of the sea-level gauges in the GCOS subset of the GLOSS Core Network in 2005 (top) and 2009 (bottom). "Near real-time" and "Fast Delivery" stations provide high-frequency sea level (hourly or better reports) which are necessary for understanding of sea-level variability in addition to mean sea-level rise. Near real-time stations (blue) provide data typically within 1 hour of collection; Fast delivery (green) within one month. The improvements in the African tide gauge network are notable. Improvements of the reporting of high frequency sea level from Russia, China, India, Denmark, Norway, in the Caribbean are being sought to complete the global network. These reports are not currently provided due to various reasons, including perceived national security issues and lack of funding. Delayed-mode data within 5 years (orange) or greater (red) include monthly averages provided to the Permanent Service for Mean Sea Level (PSMSL). White dots are placed on tide gauges that are geo-referenced, measuring local land movements, in order to measure absolute sea-level change.

Good-Moderate Progress

Action O12 Sustained observations of sea level from space

Action: Ensure continuous coverage from one high-precision altimeter and two lower-precision but higher-resolution altimeters.
Who: Space agencies with coordination through CGMS, CEOS, and WMO Space Programme.
Time-Frame: Continuous.
Performance Indicator: Satellites operating, and provision of data to analysis centres.

The successful launch in June 2008 of Jason-2 has continued high-accuracy altimetry for sea-level rise monitoring and calibration of other altimeter data. Planning for Jason-3 is complete but commitments are still being sought (as of March 2009). The planning and strategy for implementation of an ongoing effort to provide continuity of ocean sea level and altimeter measurements is focused on a future CEOS Ocean Surface Topography Virtual Constellation that will be designed to satisfy the threshold requirements for the sea-level and sea-state ECVs. Satellite operators have held an initial workshop to outline a strategy (see also progress against Action A11). While the current status is good and confirmed approval exists for altimeters on the ESA Sentinel 3a,b, CryoSat-2, on the CNES/ISRO SARAL and the CNSA HY-2 satellites, firm plans are not in place to ensure overall continuity of climate-quality sea-surface height measurements from satellites.

Moderate Progress

Action O13 Full access to sea-level data in coastal zones

Action: Ensure high-frequency sea-level observations are available for all coastal regions (including historical records) and submitted to the international archive.
Who: National agencies coordinated through GLOSS and the GOOS Coastal Ocean Observations Panel.
Time-Frame: Continuous.
Performance Indicator: Data availability at archives and national reports to UNFCCC.

There is a growing number of real-time reporting sea-level stations, primarily funded for tsunami warning purposes, with 108 near real-time reporting stations as part of the global tsunami warning network, a significant increase from the 70 available in 2004. Considerable network gaps still exist in the Caribbean, South America and North Africa. A growing number of nations endorse the free and open exchange of high frequency sea-level data (both real time and research quality) though with notable exceptions. A diplomatic solution may be needed for some countries in order to close some of the gaps in the observing network and make data exchange feasible.

Moderate Progress

Action O14 Building national capacity to measure sea level

Action: Include sea-level objectives in the capacity-building programmes of GOOS, JCOMM, WMO, other related bodies, and the system improvement programme of GCOS.
Who: Parties providing capacity-building funds and programmes.
Time-Frame: Continuous.
Performance Indicator: Number of projects, global coverage.

Capacity building in measuring sea level has seen some improvement. Since 2003, IOC/GLOSS has directly carried out several implementation and capacity building activities. These include:

- 8 technical visits to provide advice on feasibility of installations/upgrades of national sea-level station networks;[68]
- 4 training courses in sea-level observation and analysis;[69]
- 31 visiting fellowships in the IOC "Fellowship programme in sea-level science and applications" (2007-2009);
- publication of the Manual on Sea Level Measurement and Interpretation;[70]
- upgrade/installation of 25 real time sea-level stations in Africa and the Indian Ocean.

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[68] The Global Sea Level Observing System, Reports on Technical Missions, http://www.gloss-sealevel.org/publications/tech_mission_reports.html.
[69] The Global Sea Level Observing System, GLOSS Activities and Technical Training, http://www.gloss-sealevel.org/training/.
[70] IOC (2006): *Manual on Sea Level Measurement and Interpretation -- Volume IV: An Update to 2006*. IOC Manuals and Guides 14 / JCOMM Technical Report No. 31, June 2006, http://unesdoc.unesco.org/images/0014/001477/147773e.pdf.

Network developments will not succeed without consideration of factors other than initial investment in hardware. Such factors include the development of a local skill-base to maintain the equipment, the national commitment to ongoing funding for the maintenance and the collective ability to make maximum use of products generated from the data. This implies local technical training, including recognition of the importance of benchmark infrastructure and regular calibrations. Appreciation of the importance of the monitoring at government and national academic level is essential. Sea-level networks have been installed previously at great expense in some parts of the world, but have subsequently failed owing to a lack of resources for maintenance after the first few years, and also due to a lack of local appreciation of the importance of a coherent network.

Moderate-Low Progress

Action O15 Develop programme for *in situ* observations of sea-surface salinity

Action: Develop a robust programme to observe sea-surface salinity to include VOS ships, research ships, reference moorings, and drifting buoys.
Who: Parties' national services and ocean research programmes through IODE and JCOMM in collaboration with CLIVAR.
Time-Frame: Programme plan by 2007.
Performance Indicator: Plan published.

A variety of research-funded activities are underway, investigating the feasibility of accurate long-term surface measurements of sea-surface salinity, all in pilot project phase at present. Plans will depend on the success of these pilot projects. The global ocean surface underway data (GOSUD) project is currently assembling and archiving surface temperature and salinity data in both real time and delayed mode. However, the *in situ* validation requirements are not well documented, and arrangements to archive this data remain incomplete.

Good-Moderate Progress

Action O16 Research sea-surface salinity measurements from satellites

Action: Research programmes to demonstrate feasibility of utilizing satellite data to help resolve global fields of SSS.
Who: Space agencies in collaboration with the ocean research community.
Time-Frame: Feasibility studies complete by 2009.
Performance Indicator: Reports in literature and to OOPC.

Two satellite research programme-funded salinity missions have been approved for launch, the ESA SMOS (estimated launch date July 2009) and the US/Argentina Aquarius missions (estimated launch 2010).

Moderate Progress

Action O17 International strategy for measuring pCO_2

Action: Develop and implement an internationally-agreed strategy for measuring surface pCO_2.
Who: IOCCP in consultation with OOPC, implementation through national services and research programmes.
Time-Frame: Implementation strategy for mid-2005; initial pilot network to begin early 2006.
Performance Indicator: Regular pCO_2 flux maps produced beginning in 2006.

The space and time sampling requirements for a global surface carbon dioxide partial pressure (pCO_2) network have been determined and reviewed internationally. A major international project (SOCAT) has been initiated to compile new and archived data into a common format quality-controlled database and to make data streams interoperable. New data is publicly released according to regional or national policy: in near real-time by US-funded programmes, and after two years by European-funded programmes.

Regional multi-platform observing networks have been developed in the North Atlantic and North Pacific. Projects are being developed to expand the network to other ocean regions. Regional and global CO_2 flux maps are being produced on a regular basis. Comparison of the various flux map products and evaluation of the associated uncertainties is just beginning.

Good-Moderate Progress

Action O18 Implement plans for sustained ocean colour satellites

Action: Implement plans for a sustained and continuous deployment of ocean colour satellite sensors together with research and analysis. **Who:** Space agencies through the IGOS-P and in consultation with the IOCCG. **Time-Frame:** Satellite programme implemented by 2009. **Performance Indicator:** Global coverage with consistent sensors operating according to the GCMPs.

Ocean colour satellite instruments have provided a good record up to 2008 but improvements in data access and sustained product generation are still needed. Continuity after 2008 is not fully assured, however, in September 2008, CEOS approved a new Ocean Colour Radiance Virtual Constellation to provide calibrated ocean-colour radiances at key wavelength bands. It is expected that this Constellation activity will help ensure a continued record and quality product generation. Ocean colour data are used to derive products related to ocean biology and biogeochemistry.

Low Progress

Action O19 Implement sea state (wave) reference measurements

Action: Implement a wave measurement component as part of the Surface Reference Mooring Network. **Who:** Parties operating moorings, coordinated through the JCOMM Expert Team on Waves and Surges. **Time-Frame:** Deployed by 2009. **Performance Indicator:** Sea state measurement in the International Data Centres.

Small-scale pilot projects for the measurement of some wave parameters from drifting buoys and for the evaluation of wave measurements from a variety of fixed moorings were established in October 2008, growing from a continuing dialogue between JCOMM ETWS and the OceanSITES team as well as the Data Buoy Cooperation Panel (DBCP). No open-ocean reference sites measuring wave heights/frequency have yet been established. Investigation of the feasibility of some types of wave information from surface drifters is being investigated.

Good-Moderate Progress

Action O20[71] Develop global integrated surface current analyses

Action: Establish an international group to assemble surface drifting buoy motion data, ship drift current estimates, current estimates based on wind stress and surface topography fields and to prepare an integrated analyses of the surface current field. **Who:** OOPC will work with JCOMM and WCRP. **Time-Frame:** 2008. **Performance Indicator:** Number of global current fields available routinely.

This Action has been discussed by the relevant bodies, and internationally-coordinated action on data assembly is advancing slowly, but does not include satellite-derived data. Several research surface current products are being produced, based on satellite altimetry and wind and *in situ* surface drifter data.

Moderate-Low Progress

Action O21 Establish improved coordination of sea-ice research, observations and products

Action: Establish improved interactions between existing sea-ice research programmes (e.g., WCRP/CliC) and operational sea-ice groups (e.g., JCOMM Expert Team on Sea Ice). **Who:** GCOS in consultation with JCOMM and WCRP. **Time-Frame:** By end of 2005. **Performance Indicators:** Preparation of a quantitative summary comparison of sea-ice products.

There are now ongoing interactions between the AOPC-OOPC SST/Sea Ice working group and the JCOMM Expert Team on Sea Ice as well as the Global High-Resolution SST (GHRSST) project. A new sea ice group has been established under the WCRP Climate and Cryosphere project (CliC). The new Global Cryosphere Watch programme will include coordination of sea ice analysis efforts. There is a need to improve coordination among these various programmes.

[71] See Action A11.

Action O22 Establish frameworks for internationally-coordinated ocean observations in the Arctic

Moderate-Low Progress

Action: Establish an Arctic GOOS Regional Alliance (GRA).
Who: GOOS in cooperation with GCOS, WCRP (including CliC).
Time-Frame: 2005, 2007-09.
Performance Indicators: (a) development of an Arctic sustained observing and climate product plan (by end 2005); (b) implementation of the plan during the IPY.

Based on this Action, EuroGOOS decided to foster an Arctic GOOS Regional Alliance. A report by the EuroGOOS Arctic Task Team[72] was presented to the Intergovernmental IOC-WMO-UNEP Committee for GOOS (I-GOOS), and an Interim Regional Alliance asked the Seventh Session of I-GOOS for endorsement. Neither I-GOOS-VIII nor the subsequent IOC Assembly were in favour of the establishment of an Arctic GOOS Regional Alliance. Instead, a EuroGOOS Regional Operational Oceanographic System (ROOS) was established to coordinate Arctic observations, data management, analyses and forecasts between European participants. The Arctic ROOS has today a key role in developing European GMES marine core services in the Arctic.

The Arctic Council has initiated the development of a Sustained Arctic Observing System (SAON). This system will contain a wide range of natural and social variables, including climate observations. GOOS and EuroGOOS have participated in the process, preparing advice to the Arctic Council.

A variety of Arctic Ocean research observing activities are underway through International Polar Year (IPY) sponsorship. Interactions are continuing in the development of agreements to sustain a subset of these activities post-IPY.

Action O23 Sustained sea-ice observations from space

Good-Moderate Progress

Action: Ensure sustained satellite (microwave, SAR, visible and IR) operations: improve the *in situ* observations from sea-ice buoys, visual surveys (SOOP and Aircraft), and ULS. Implement observations in the Arctic and Antarctic.
Who: Parties' national services, research programmes and space agencies, coordinated through the WMO Space Programme, IGOS-P Cryosphere Theme, CGMS, and CEOS; National services for *in situ* systems coordinated through JCOMM.
Time-Frame: Continuing.
Performance Indicator: Sea-ice data in International Data Centres.

There has been improvement in sea ice concentration algorithms from satellite data on the part of several space agencies and associated groups, such as NOAA, the EUMETSAT Ocean and Sea Ice Satellite Application Facility, the ESA GlobIce programme and the GMES Polar View service. A suite of new satellite systems, including SMMR-SSM/I, SMOS, Sentinel-1A, -1B (radar imaging), Sentinel-3A, -3B (optical, IR imaging and altimetry) and CryoSat-2 are expected to improve future sea-ice observations. Improvements in the *in situ* validation record are still needed.

Action O24 Development of integrated sea-ice products and analyses

Moderate Progress

Action: Promote development of integrated sea ice analysis products and reanalysis using historical data archives.
Who: JCOMM, WCRP/CliC, and IGOS-P Cryosphere Theme.
Time-Frame: Plan and commitment in place by 2007.
Performance Indicator: Improved sea-ice products.

Initial work on this Action has been pursued through a work plan for the AOPC-OOPC SST/Sea Ice working group[73]. Implementation of this plan remains to be completed. At the same time, plans for such integrated products are being put in place by space agencies, for example the EUMETSAT Ocean Sea Ice Satellite Application Facility. The new WMO Global Cryosphere Watch will provide additional consideration of this Action.

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[72] EuroGOOS (2005): *The Arctic Ocean and the Need for an Arctic GOOS*. EuroGOOS Publication No. 22.
[73] GCOS SSTS&SI Working Group (2006): *GCOS SST & Sea Ice Working Group activities on sea ice*, http://ocean.dmi.dk/GCOS/documents/SSTSI_activities_v01.pdf.

Oceanic Domain – Sub-surface

Systematic sampling of the global ocean at all depths is needed to fully characterize oceanic climate variability, to enable seasonal-interannual forecasts and to make experimental forecasts of decadal variability and change. Overall good progress has been made to that end, although many deficiencies remain, with many oceanic regions heavily under-sampled.

Action O25 Implement systematic global full-depth water column ship-based sampling

Good-Moderate Progress

Action: Perform the systematic global full-depth water column sampling of 30 sections repeated every 10 years.
Who: National research programmes in cooperation with OOPC and CLIVAR and the International Ocean Carbon Coordination Project.
Time-Frame: Continuing.
Performance Indicator: Data submitted to archives. Percentage coverage of the sections.

Good progress has been achieved (scheduled percentage of the decadal survey has been completed), and a planning process is in place for a post-CLIVAR hydrography programme (GOSHIP). GOSHIP will be presented at OceanObs'09. Agreements for free and open exchange of data remain incomplete (see Figure 19). The adequacy of the initially-conceived network to resolve decadal changes in ocean carbon inventory requires further research.

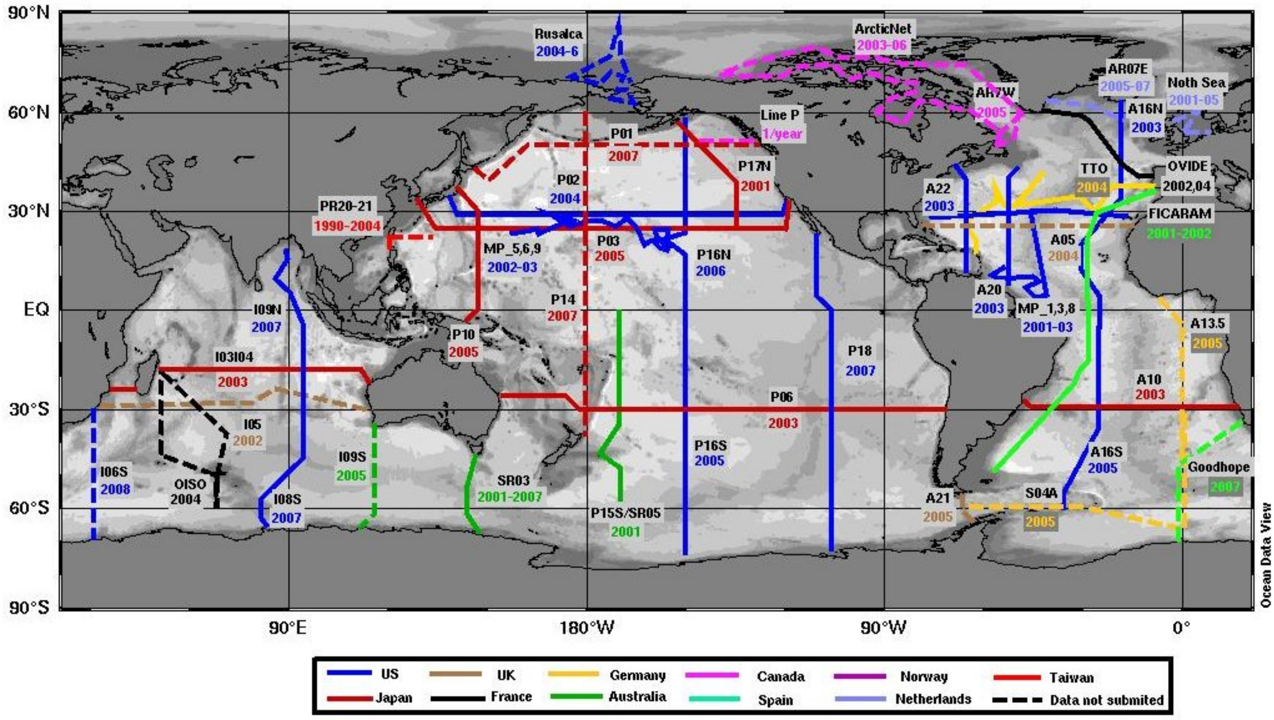

Figure 19: Map of completed International Repeat Hydrography Program sections, with colours indicating the country responsible. The dashed lines indicate data not submitted to the internationally-agreed data archive[74]. Data from certain hydrographic lines led by scientists from nearly all the countries involved in the Program have not yet been submitted to the international data archive. These data are initially held by individual researchers before being submitted to the archive.

Action O26 Implement repeat trans-oceanic temperature sections from volunteer ships

Moderate Progress

Action: Perform the 41 Ship-of-Opportunity XBT/XCTD trans-oceanic sections.
Who: Parties' national agencies coordinated through the Ship Observations Panel of JCOMM.
Time-Frame: Continuing.
Performance Indicator: Data submitted to archive. Percentage coverage of the sections.

[74] http://cdiac.ornl.gov/oceans/RepeatSections/repeat_map.html

Progress continues. In 2007, 56% of the number of XBTs targeted in the IP-04 were carried out, with 35 of the 41 lines having been sampled. The evolution of the IP-04 based on changing patterns of maritime commerce will be undertaken for OceanObs'09.

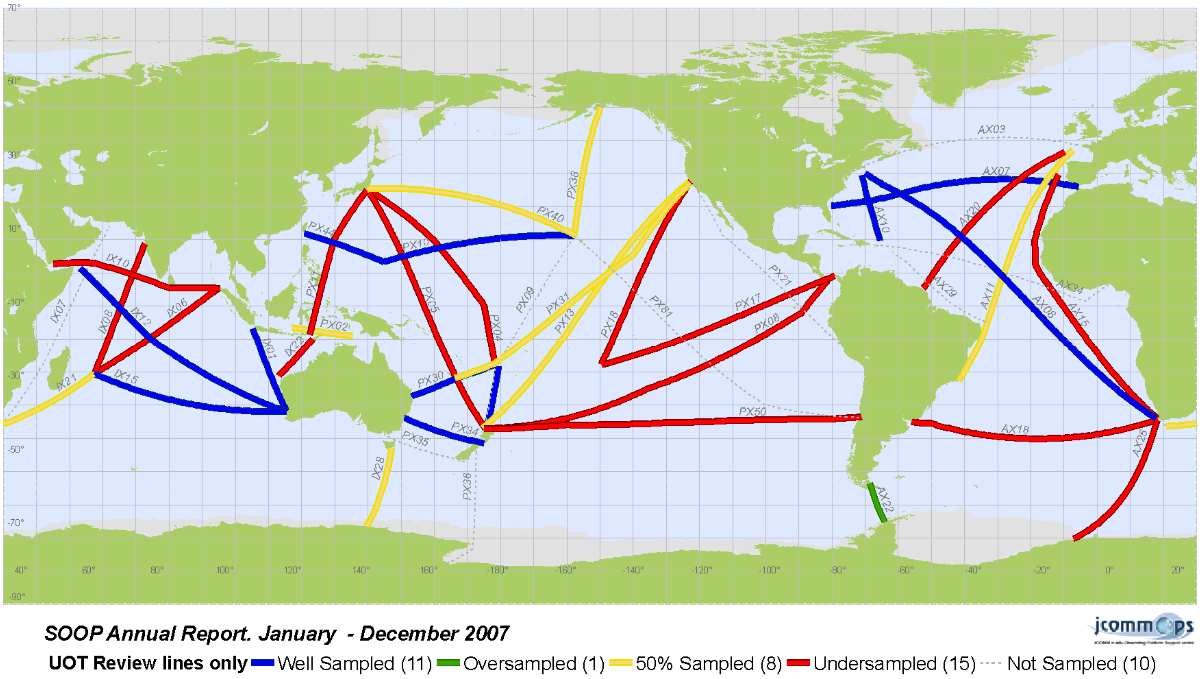

Figure 20: Status of trans-oceanic temperature sections taken using expendable instruments (XBT) from commercial ships. Blue are well-sampled, yellow are 50% sampled, and red are undersampled[75].

Action O27 Full implementation of Argo profiling float array

Good Progress

> **Action:** Deploy the planned 3000 Argo float array, reseeding the array with replacement floats to fill gaps and maintain density (estimated 800 per year).
> **Who:** Parties participating in the Argo Pilot Project and in cooperation with the Observations Coordination Group of JCOMM.
> **Time-Frame:** Complete 3000 float array attained by 2007.
> **Performance Indicator:** Number of reporting floats. Percentage of network deployed.

The objective of having a 3000 global float array was reached in November 2007. There currently are about 3300 floats operating. More than 600 of these are either in marginal seas, high latitudes, over-sampled regions, or reporting data of uncertain quality, and so are not contributing to the core network mission of global observations evenly distributed in the open ocean from 60°N to 60°S. More floats (about 600) are needed in the Southern Hemisphere, especially the South Indian and South Atlantic to reach target spatial distribution.

Continuing operations to deploy replacements for the limited-lifetime floats, of which about 700 are needed per year, requires charter vessels in some areas of the world ocean, where they cannot be accommodated via normal operations by commercial and research fleets. Additional observing programme support would greatly assist in maintaining the array.

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[75] JCOMM (2008): *SOOP Annual Report January to December 2007*, SOT semestrial survey 2007, http://www.jcommops.org/FTPRoot/SOT/SOOP/survey/2007-Final-Draft/PDF-2007-SOOP-finaldraft-report.pdf.

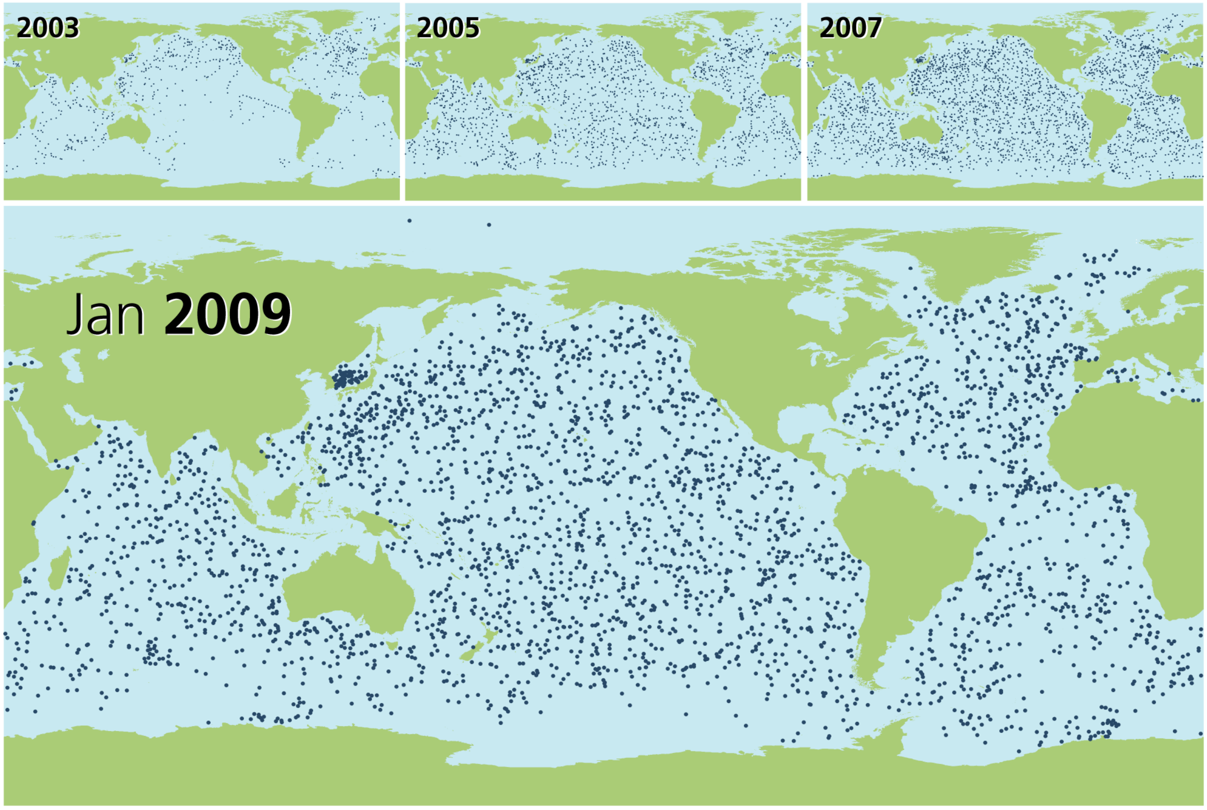

Figure 21: Global map of progress in the implementation of the Argo profiling float array since 2003. In January 2009, there were 3291 floats operating, at close to target density in most ocean basins. Areas of low density include the western Indian Ocean, the Southern Ocean, and the South Atlantic. About 700 float deployments per year are necessary to maintain the target density, due to the limited lifetime of Argo floats.

Moderate Progress

Action O28 Maintain and expand the Tropical Moored Buoy arrays

Action: Maintain the current Tropical Moored Buoy arrays, expand the Atlantic array, and develop the Indian array – total array projected as ~120 moorings.
Who: Parties national agencies coordinated through the Tropical Mooring Panel of JCOMM.
Time-Frame: Array complete by 2009.
Performance Indicator: Data acquisition at International Data Centres.

There were 75 of 119 planned moorings reporting data in real time in June 2008. From 2005 to 2007, eight new moorings were installed in the Indian Ocean in a collaborative activity involving India, Indonesia, France and the USA. The TAO portion of the tropical Pacific array is being transitioned to an operational entity.

Low Progress

Action O29 Develop integrated ocean current dataset

Action: Develop and implement a pilot project designed to assemble the *in situ* and satellite altimetry data into a composite [current] dataset and to assimilate the data into models and to create climate variability and trend analyses.
Who: Parties' national ocean research programmes and space programmes through GODAE.
Time-Frame: Pilot project complete by 2009.
Performance Indicator: Plans and commitments.

Little progress has been made on this Action. GODAE has explored the idea of taking this on as a future pilot project.

Moderate Progress

Action O30 Research and technology development for autonomous observations of biogeochemical and ecosystems ECVs

Action: Work with research programmes to develop autonomous capability for biogeochemical and ecological ECVs.
Who: Parties' national ocean research programmes in cooperation with the Integrated Marine Biogeochemistry and Ecosystem Research, Surface Ocean – Lower Atmosphere Study, and Land-Oceans Interactions in the Coastal Zone of IGBP.
Time-Frame: Continuing.
Performance Indicators: Systems available for the ECV pCO_2, nutrients, and phytoplankton with other ecosystem parameters available for use in reference network applications.

There has been impressive progress in the development and use of *in situ* sensors for these variables. The Alliance for Coastal Technology has carried out workshops and done substantial documentation of a variety of sensors. The OceanSensors08 workshop pointed to promising new sensors and existing sensors with improved long-term performance being validated for extended autonomous moored or float deployment for oxygen, pH, pCO_2, and chlorophyll. This is a continuing research action, and this observing community will be engaged via the OceanObs'09 conference.

Low Progress

Action O31 Reference network for biogeochemical and ecosystem ECVs

Action: Develop and deploy in a reference network robust autonomous *in situ* instrumentation for biogeochemical and ecosystem variables.
Who: Parties' national research programmes in coordination with the IGBP and with the IOCCG.
Time-Frame: *In situ* observation capability developed as a matter of research priority and deployed by 2009.
Performance Indicator: Progress to global coverage with consistent sensors to GCMP.

There has only been little progress on this Action. Pilot programs have been undertaken for oxygen on profiling floats, but 'Ferrybox'-type VOS lines as envisaged by the IP-04 are only operating in limited regional areas. IOCCG has established a working group to examine the feasibility of placing optical/ biogeochemical sensors on Argo floats.[76] This working group is involved in the preliminary steps before a BIO-Argo type programme can be developed (although no concrete plans to develop such a programme exist at the moment). Some promising possibilities were raised by the Census of Marine Life and the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), amongst others.

Moderate Progress

Action O32 Monitor implementation of ocean data policy

Action: Monitoring the implementation of the IOC Data Policy.
Who: IOC.
Time-Frame: Continuous.
Performance Indicator: Reports by the Executive Secretary (IOC) on the implementation of the IOC Data Policy.

IODE requests national reporting on adherence to the IOC data policy, but no independent verification of compliance is taking place. However, there is evidence of improved adherence to free and open exchange of data in the data centres and archives. The IOC oceanographic data exchange policy encourages timely, free, and unrestricted access to data and metadata that are essential for public protection and benefit, and for non-commercial use in research and education. It also calls for the enhancement of developing country access to and benefit from data, metadata, and products.

Moderate Progress

Action O33 Implement comprehensive ocean data management procedures

Action: Develop and implement comprehensive data management procedures.
Who: IODE and JCOMM.
Time-Frame: Project plan by 2007.
Performance Indicator: Plan published.

[76] http://www.ioccg.org/groups/argo.html

A plan for comprehensive data management procedures has been published[77] as well as an IOC data strategy.[78] The JCOMM plan recognizes the contribution of the joint JCOMM-IODE pilot project for end-to-end data management as well as recommending a wide spectrum of other data management activities that are needed and being addressed. Details of the procedures are in preparation by IODE and JCOMM in cooperation with the WMO Commission for Instruments and Methods of Observation, and will be a part of a pilot project in the WMO Integrated Global Observing Systems (WIGOS) for oceanographic and marine meteorological data. Wider implementation of the plan by ocean data managers is needed.

Moderate-Low Progress

Action O34 Develop an international standard for ocean metadata

Action: Undertake a project to develop an international standard for ocean metadata.
Who: IODE and JCOMM in collaboration with WMO CBS and ISO.
Time-Frame: Standard developed by 2009.
Performance Indicator: Publication of standard for an agreed initial set of the ECVs. Plan to progress to further ECV.

The JCOMM Meta-T pilot project has started for temperature reports. An Ocean Data Acquisition System is underway for the platform metadata. The International Standards Organization (ISO) ocean and meteorological profiles are under review and implementation of these profiles across both WMO and IOC is beginning. Limited progress has been made in developing standards for ocean metadata for other ocean ECVs.

Moderate Progress

Action O35 Develop innovative ocean data transmission and exchange

Action: Undertake a project to apply the innovations emerging from the Future WMO Information System initiative, and innovations such as OPeNDAP to develop an ocean data transport system for data exchange between centres and for open use by the ocean community generally.
Who: JCOMM.
Time-Frame: Report by 2009.
Performance Indicator: Report published.

The JCOMM end-to-end data management project prototyped connections under the WMO Information System between ocean and meteorological data. The continuing pilot project under the WMO Integrated Global Observing Systems (WIGOS) is now underway to extend this work.

Low Progress

Action O36 Implement a system of ocean data and analysis centres

Action: Plan and implement a system of regional, specialized and global data and analysis centres.
Who: Parties' national services under guidance from IODE and JCOMM.
Time-Frame: Plan finished by 2007, implementation following.
Performance Indicator: Plan published.

The JCOMM Strategy identifies a number of activities to improve ocean data and analysis centres. At present, there is strong cooperation between data centres of IODE and the WDCs-Oceanography. This relationship will change with the ICSU review of the WDC system. The cooperation of IODE and JCOMM in the WMO Integrated Observing System (WIGOS) pilot project will improve documentation of best practices, data and metadata standards, terminology, quality control procedures and access to datasets. IODE and JCOMM co-sponsored a meeting on ocean data management standards, and a follow-on activity is underway to identify, evaluate and recommend best practices and standards for ocean data management.

Good Progress

Action O37 Ocean data rescue

Action: Support data rescue projects.
Who: Parties' national services with coordination by IODE through its GODAR project.
Time-Frame: Continuing.
Performance Indicator: Datasets in archive.

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[77] JCOMM (2008): *JCOMM Data Management Plan*. JCOMM Technical Report No. 40, http://www.jcomm.info/components/com_oe/oe.php?task=download&id=5205&version=1.0&lang=1&format=1.

[78] IOC (2007): *IOC Strategic Plan for Oceanographic Data and Information Management (2008-2011)*. IOC Manuals and Guides No. 51, http://www.ioc-unesco.org/components/com_oe/oe.php?task=download&id=6139&version=1.0&lang=1&format=1l.

The Global Ocean Data Rescue (GODAR) project of the IODE has continued successful rescue of historical oceanographic profile and plankton data from before 1992, resulting in a continuing increase in the number of profiles available online through the World Ocean Database (see Figure 22). These have been helped by international projects, such as GTSPP, and by a number of national programmes, notably in the USA, UK, the Netherlands and Germany.

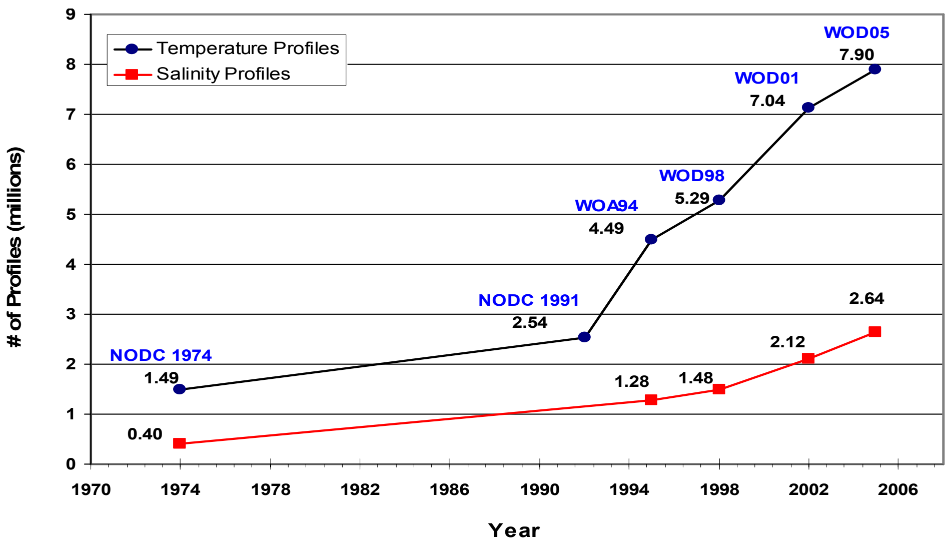

Figure 22: Ocean temperature and salinity profile data available in World Ocean Data Centre (Source: S Levitus, IODE-XIX).

Action O38 Enhanced telecommunication links with ocean sensors

Moderate Progress

Action: Develop enhanced and more cost-effective telecommunication capabilities, including two-way communications for dynamic control of systems, instruments and sensors.
Who: Parties, coordinated through JCOMM.
Time-Frame: 2007.
Performance Indicator: Capacity to communicate data from ocean instrumentation to ocean data centres.

Pilot projects to improve telecommunication capabilities under DBCP, SOT and the Argo programme are working towards transmission of high-resolution data (e.g., Iridium, Argos3) and are already showing promising results. Issues associated with sufficient bandwidth, two-way telecommunication and transmission costs are being addressed.

Action O39 Better coordination of ocean data assembly and analyses

Moderate Progress

Action: Develop plans for and coordinate work on data assembly and analyses.
Who: JCOMM, in collaboration with CLIVAR, CliC, GODAE, and other relevant research and data management activities.
Time-Frame: Plan available by 2006.
Performance Indicator: Number of ocean climatologies and integrated datasets available.

A number of *ad hoc* data assembly and integration efforts have taken place in the GODAE and WCRP CLIVAR Global Synthesis and Observations Panel (GSOP) communities, but there is no agreed integrated dataset for the production of ocean analysis products.

There has been partial progress by various groups in the scientific community in resolving data quality problems in the dataset for reanalysis. Organized efforts include a workshop by the JCOMM/SOT/SOOP for XBT fall rates, and within the Argo team dealing with the pressure problem in floats deployed in the North Atlantic.

Good-Moderate Progress

Action O40 Projects for global ocean products from model data assimilation

Action: Develop plans and pilot projects for the production of global products based on data assimilation into models. All possible ECVs.
Who: Parties' national services and ocean research agencies through CLIVAR, the CLIVAR Global Synthesis and Observations Panel, and GODAE.
Time-Frame: 2008.
Performance Indicator: Number of global oceanic climate analysis centres.

Progress with data assimilation has progressed well, but more attention is needed to ensure climate quality. A few of the GODAE[79] research groups produce highest feasible resolution global assimilated products in near real-time. Intercomparison efforts are underway, but in order to increase the number of scientific users, additional measures of reliability are required. The major focus of GODAE has been shorter-term ocean forecasts for non-climate purposes; expansion into climate temporal and global scales is therefore an important step. A workshop on observing system evaluation using these models was held in November 2007, and further activities in this area are planned as the products mature.

There is little to no progress in the development of data assimilation for a large number of the ECVs other than altimetry, temperature and salinity.

Good Progress

Action O41 Reanalysis of ocean climate data

Action: Undertake pilot projects of reanalysis of ocean data.
Who: Parties' national research programmes coordinated through OOPC and WCRP.
Time-Frame: 2010.
Performance Indicator: Number of global ocean reanalyses available.

Currently about 10 different groups are producing ocean climate reanalyses. These efforts are organized around the WCRP CLIVAR Global Synthesis and Observations Panel (GSOP), with regular intercomparison exercises. The development of these intercomparisons, of ocean climate indices from the reanalysis products, and investigation of observing system requirements are all underway, and research into improved methods continues. Several studies have been published on the initiation of coupled ocean-atmosphere forecasts with ocean reanalyses.

6 The Terrestrial Climate Observing System

The terrestrial part of the climate system provides human beings with important resources such as food, fibre, forest and water. At the same time, variability and change in fundamental properties of the hydrological and biogeochemical cycles are coupled with the climate system and affect the livelihood of millions of people. The primary way in which the terrestrial domain features in climate variability and change is through changes in water storage, carbon storage and changes in land cover, such as deforestation. Precipitation, evapotranspiration, groundwater, soil moisture, lake levels, glaciers and river discharge constitute critical components of the hydrological cycle, with often direct impact on water availability and, for instance, droughts and floods.

Land has a wide variety of natural features, slopes, vegetation and soils that affect water budgets, carbon fluxes and reflective properties of the surface. Land is often covered by vegetation; importantly, by now, almost 40% of the Earth surface has been under some form of management. Land use changes the characteristics of the land surface and thus can induce important local climate effects, especially through changes in albedo, roughness, soil moisture and evapotranspiration. When large areas are concerned (tropical deforestation) regional and even global climate may be affected. Land is covered by snow and ice on a seasonal basis, and it features glaciers, ice sheets, permafrost, and frozen lakes. Snow and ice-albedo play an important role in the feedback to climate. Further, as land-based ice, such as a glacier, melts, it affects river and contributes directly to sea-level rise. Disturbances to land cover (vegetation change, fire, disease and pests) have the capacity to alter climate and the ground (e.g., permafrost) but also respond to climate in a complex manner through

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[79] http://www.clivar.org/organization/gsop/gsop.php

changes in biogeochemical and physical properties. Precise quantification of the rate of change is important to determine whether feedback or amplification mechanisms through terrestrial processes are operating within the climate system. There is thus increasing significance being placed on terrestrial data for both fundamental climate understanding as well as impact and mitigation assessment.

Foundations exist for both the *in situ* observation networks and the space-based observing components of the terrestrial domain ECVs but these still need to be strengthened. Improving the understanding of the terrestrial components of the climate system, of the causes and responses of this system to change, and assessing the consequences of such change in adapting to and mitigating climate change is vital to society. Better observations of the terrestrial carbon-related variables have assumed greatly increased relevance in the context of implementing the UNFCCC Bali Road Map.

Summary of Progress

Increasing significance is being placed on terrestrial data for estimating climate forcing and better understanding of climate change and variability, as well as for impact and mitigation assessment. The recognition of this has led to substantial progress in a number of areas in the terrestrial domain. 56% of the Actions show moderate to good progress although advances are still limited or absent in others.

There has been significant progress in defining internationally accepted standards for the terrestrial ECVs, forming the basis of an international framework for the development and promulgation of such standards in all countries.

Progress in establishing institutional support for *in situ* networks has been slow, leading to networks that are still poorly coordinated and harmonized, despite the considerable effort of the research community to keep them running.

The objective of creating a comprehensive and coordinated reference network for *in situ* observations of the fullest possible range of terrestrial ECVs is a continuing, yet largely unmet challenge. Such a network would provide the observational data and associated details relevant to their application in model validation, process studies, and the validation of observations derived from Earth observation satellites. Progress in establishing such a composite network is vital for the integration of *in situ* and satellite observations and required validation activities.

There are still significant issues involved in making available *in situ* data that have more than just climate value. This has, for instance, led to a declining number of reports of river discharge. However some networks, such as for glaciers (GTN-G), have shown remarkable resilience and operate now very effectively. Similar progress has been made in the production of fire-related global datasets.

Significant progress has been made in guaranteeing short-term continuity in the availability of high-resolution optical observations, a gap highlighted in previous GCOS reports (Second Adequacy Report; IP-04). However, long-term commitment to continuity of this class of satellite missions, though crucial to successful maintenance of the observation records, has yet to be secured.

The increased commitment of space agencies to produce fundamental climate data records from existing systems has led to improved availability of global datasets of, e.g., burned area, fAPAR, and land cover. The community now increasingly uses these datasets. Nevertheless substantial gaps remain in quality control, which need to be addressed through intercomparison and validation.

The analysis of historical records, both *in situ* and satellite based has been slow and needs the urgent consideration of space agencies together with the potential users.

Detailed Progress

Action T1 Intergovernmental terrestrial framework

Good-Moderate Progress

Action: Create an intergovernmental mechanism for terrestrial observations. **Who:** WMO, in consultation with FAO, ICSU, UNEP and UNESCO will form an inter-agency working group and explore options and propose a mechanism (e.g., an intergovernmental technical commission for terrestrial observations). **Time-Frame:** Develop proposal by 2006. **Performance Indicator:** Presentation of plan to governing bodies of participating organizations.

Following a request by the UNFCCC[80] to the GTOS Secretariat regarding the development of an international framework that would facilitate the preparation of guidance materials and standards in the terrestrial domain, three implementation options were proposed in 2007. These included an option that involves the International Organization for Standardization (ISO). With additional guidance provided by the SBSTA 27, GTOS and partners reached a consensus to proceed with developing a joint UN-ISO based framework for setting and maintaining standards for terrestrial observations of ECVs. The proposed framework foresees the establishment a joint steering group, with specific roles for the participating UN organizations (in defining the requirements for standardization and providing technical inputs) and for the ISO (in leading the standards development effort). The ISO recognition of WMO as a standards-setting organization further strengthens the foundation for the proposed framework. Implementation of the framework is underway, whereas the engagement of national bodies in the use of the developed standards remains an ongoing challenge.

Action T2 Sponsorship of Global Terrestrial Network for Hydrology

Good Progress

Action: Find sponsors and a host for the GTN-H. **Who:** TOPC, in cooperation with WMO CHy and National Hydrological Services. **Time-Frame:** 2006. **Performance Indicator:** Contact names and location for the GTN-H secretariat.

The GTN-H[81] has been sponsored since 2001 chiefly by WMO through its Hydrology and Water Resources Programme, and partly by GCOS. It serves as a forum for institutions (see Figure 23) with an interest in global-scale hydrological observations for the purpose of climate research, climate applications and studies of the hydrological cycle, as well as for the integration of different hydrological datasets for the generation of products. The GTN-H has been recognized as the observational arm in the IGOS Water strategy and, following the IGOS Theme transition into GEO, will now also work within the context of the GEOSS. Since 2008, GTN-H is chiefly coordinated by the State University New York, USA, with assistance from WMO and GCOS Secretariats.

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80 UNFCCC (2004): Report of the Conference of the Parties on its ninth session, held at Milan from 1 to 12 December 2003. Addendum. Part two: Action taken by the Conference of the Parties at its ninth session (doc. FCCC /CP/2003/6/Add.1, decision 11/CP.9, para. 8).

81 http://www.gtn-h.net

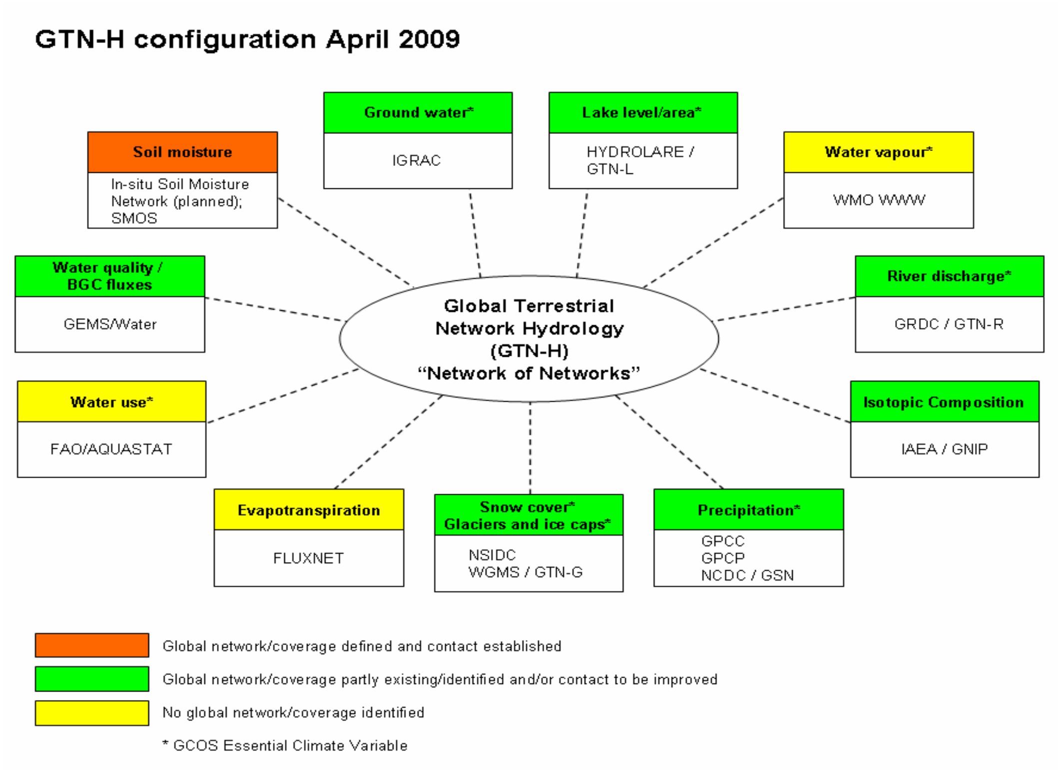

Figure 23: Configuration of the Global Terrestrial Network for Hydrology (GTN-H) (April 2009).

Action T3[82] Reference sites for measuring biogeochemical properties

Moderate-Low Progress

Action: Develop a global network of some 30 sites based on a progressive evolution of existing reference sites to monitor key biomes and provide the observations required for the calibration and validation of satellite data.
Who: Parties' national services and research agencies, in cooperation with the IGBP, WCRP and in association with TOPC and GTOS.
Time-frame: Plan prepared by 2007 with progressive establishment of sites thereafter.
Performance Indicator: Preparation of a plan and the establishment of sites.

Action T29 Network for calibration and validation of vegetation ECVs

Moderate-Low Progress

Action: Establish a calibration/validation network of *in situ* observing sites for fAPAR and LAI (reference sites).
Who: Parties' national and regional research centres, in cooperation with space agencies coordinated by CEOS WGCV, GCOS and GTOS.
Time-Fame: Network operational by 2006.
Performance Indicator: Data available to analysis centres.

Establishment of the reference sites for biogeochemical properties (Action T3) were intended to provide time series of variables ranging from soil characteristics to vegetation and ecosystem parameters. There is also value in these sites meeting, at the same time, the calibration/validation needs considered in Action T29. There has been little global coordination on the setup of the 30 reference sites and overall, limited progress has occurred, although some national and regional initiatives are encouraging.

In most of cases the current terrestrial monitoring networks need to be enhanced by securing continuity, expanding the global coverage, improving their quality, standardize the instrumentation, and including additional variables. All these points are essential for satellite product validation. The current best running global network containing long-term record of information of vegetation ECVs (Albedo, fAPAR, LAI, Biomass) is FLUXNET.[83] There is good coverage of different vegetation types and climate regions, but issues remain with the long-term continuity of the sites. Information gathered

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[82] See also Actions A16, A27, A30 and T29.
[83] http://www.fluxnet.ornl.gov/fluxnet/index.cfm

and processed by the FLUXNET network has multiple uses in the development and application of global carbon and vegetation models, including evaluation/validation, calibration, process parameterization, and data assimilation.

The CEOS WGCV Land Product Validation (LPV) subgroup is coordinating the use of a number of these sites for, inter alia, qualitative validation and intercomparison purposes. They deal with four areas: fire and burned scar detection, biophysical products, land cover mapping, albedo and surface radiation.

An important unresolved issue for both fAPAR and LAI products is the extent to which the essentially point observations measured at ground validation sites can be compared with remote sensing measurements from low to medium-resolution sensors in order to provide a meaningful validation. Comparisons between remote sensing products and field measurements cannot be conducted directly, but must involve the estimation of effective variables to account for the structure and heterogeneity of plant canopies as well as the differences in spatial representativeness of both types of observations. Significant differences have been observed between existing space-derived products Evaluation and benchmarking of space-derived fAPAR and LAI products against field measurements is actively being pursued (cf. Action T28). More investigations are required before a consensus can be reached on best practices and standard products (cf. Action T30).

Moderate Progress

Action T4 Establish Global Terrestrial Network for Rivers

Action: Confirm locations of GTN-R sites, determine operational status of gauges at all GTN-R sites, ensure that the GRDC receive daily river discharge data from all 380 sites within one year of their observation (including measurement and data transmission technology used).
Who: National Hydrological Services, through WMO CHy in cooperation with TOPC, GTOS and the GRDC.
Time-Frame: 2006 for finalization of network and reporting of any historical records, complete compliance, i.e., one-year time lag by 2009.
Performance Indicator: Reports to WMO CHy on the completeness of the GTN-R record held in the GRDC including the number of stations and nations submitting data to the GRDC, National Communication to UNFCCC.

The Global Terrestrial Network for River Discharge (GTN-R) initiative was launched by the Global Runoff Data Centre (GRDC), in collaboration with the Secretariats of WMO and GCOS, with the aim of enabling access to near real-time river discharge data for selected gauging stations around the world, thereby capturing the majority of the freshwater flux into the oceans. River discharge measurements are described in detail in WMO guidance material.[84]

GRDC has initially proposed the river discharge baseline stations in the GTN-R network. This network is now being adjusted in consultation with National Hydrological Services, and a total of 185 stations have been confirmed, with the status of another 265 stations not yet clarified (see Figure 24). 21 countries responded to a request letter by WMO (sent in 2005 to 82 countries), among which 10 countries provided historical data for stations, 11 countries submitted metadata, and three countries now provide daily near real-time river discharge data. Clearly, further efforts are needed to finalize the baseline GTN-R, and additional resources are required to implement and manage the network.

[84] WMO (2006):Technical Regulations of Hydrology (WMO-No.49); WMO (2009):Guide to Hydrological Practices (WMO-No.168).

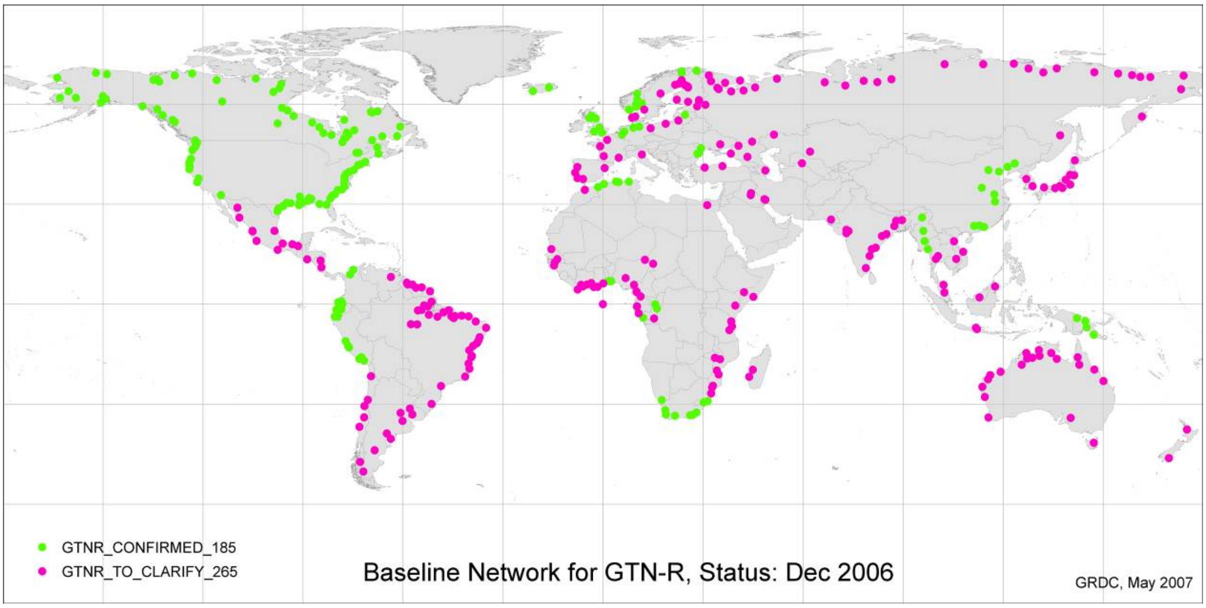


Figure 24: Global Terrestrial Network for Rivers (GTN-R); status as of December 2006.

Action T5 Create world data centre for lakes

Good Progress

Action: Create a lake information data centre.
Who: TOPC in consultation with WMO CHy and National Hydrological Services.
Time-Frame: Operational by 2006.
Performance Indicator: Commitment by host country.

The International Data Centre on the Hydrology of Lakes and Reservoirs (HYDROLARE) was established at the State Hydrological Institute in St. Petersburg, Russia, under the auspices of WMO. An agreement on the establishment of HYDROLARE was signed between ROSHYDROMET and WMO on May 2008.

The main objective of HYDROLARE is the establishment, development and regular update of a global database on the hydrological regime of lakes and reservoirs in order to foster the development of a global monitoring system on lakes and reservoirs for all applications including climate. A priority list of lakes to be monitored for climate, the Global Terrestrial Network Lakes (GTN-L), has been established. Further applications of the database will be preservation and management of water resources, and scientific and educational purposes.

Action T6 Regular near real-time data submission to lake data centre

Low Progress

Action: Submit weekly/monthly lake level/area data for the 150 GTN-L lakes to the International Data Centre; submission of weekly/monthly altimeter-derived lake levels by space agencies to the International Data Centre.
Who: National Hydrological Services, through WMO CHy; space agencies; the new global lake information data centre.
Time-Frame: Continuous.
Performance Indicator: Completeness of database: National Communications to UNFCCC.

The recently established HYDROLARE data centre has yet to fully engage in the collection of lake data but potential data sources are currently being identified. For example, the French LEGOS/GOHS group has recently developed a water level database[85] on major rivers, lakes and wetlands. The water level time series, which start in 1993 and undergo regular updates, are based on altimetry measurements from Topex/Poseidon, Jason-1, ERS-2, Envisat and GFO satellites, and from Cryosat-2 (scheduled launch date in November 2009), which is particularly suited in its design to lake and river level observations. The database includes water levels for over 130 lakes and man-made reservoirs, which are partly overlapping with the list of GTN-L lakes.

[85] http://www.legos.obs-mip.fr/en/soa/hydrologie/hydroweb/

Low Progress

Action T7 Submission of historical data to international lake data centre

Action: Submit weekly/monthly lake level and area data measured during the19th and 20th centuries for the 150 GTN-L lakes to International Data Centre.
Who: National Hydrological Services, in cooperation with WMO CHy and the new global lake information data centre.
Time-Frame: Completion of archive by 2009.
Performance Indicator: Completeness of database, National Communications to UNFCCC.

A prototype database system was developed in March 2008, and first test operations of HYDROLARE were carried out. Historical observational data on hydrology of lakes and reservoirs for Russia and the Former Soviet Union were loaded into the database. Additional data from other countries and sources (see Action T6), based on a priority list of major lakes and reservoirs, will be included into the database from 2009 on. Likewise, the database system will be fully established in 2009 and WMO member countries will be requested to contribute data and information on lakes and reservoirs. The construction of long-term records from these data remains a long-term challenge.

No Progress

Action T8 Data on water temperature and freezing state to lake data centre

Action: Submit weekly surface and sub-surface water temperature, date of freeze-up and date of break-up of 150 priority lakes in GTN-L.
Who: National Hydrological Services; space agencies in response to request from TOPC through the WMO.
Time-frame: Continuous.
Performance Indicator: Completeness of database, reporting to UNFCCC.

No progress, but activity in this area has been recommended by the HYDROLARE Steering Committee in June 2007.

Moderate Progress

Action T9 Information on irrigation and water resources

Action: Archive and disseminate information related to irrigation and water resources through FAO's on-line AQUASTAT database and other means.
Who: FAO.
Time-Frame: By 2010.
Performance Indicator: Availability of AQUASTAT database.

The database on water resources and irrigation is available from the AQUASTAT website.[86] It contains the global map of irrigation areas on a scale of 10*10 km, developed by the FAO in cooperation with the University of Frankfurt, Germany (see Figure 25). It is the only global map of irrigated areas updated on a regular basis. Currently, FAO is in the process of delineating watersheds and river basins from SRTM data. Global coverage is foreseen for 2010. Quality control and adequate estimation of the uncertainties are an issue.

Moderate-Low Progress

Action T10 Strengthen snow observing networks and data availability

Action: Strengthen and maintain existing snow-cover, snowfall observing sites and recover historical data.
Who: National Meteorological and Hydrological Services and research agencies, in cooperation with WMO CHy, WMO CBS and WCRP, with oversight by TOPC and AOPC.
Time-Frame: Continuing.
Performance Indicator: Data submission to national centres such as the National Snow and Ice Data Center (USA).

The submission of *in situ* snow observations has continued to show some decline due to financial pressures in many countries, leading to closures of remote observation stations in the Northern Hemisphere. Data receipt from those remaining stations has also been an issue, with few stations including snow data in their submissions to the Global Telecommunication System (GTS), and not all providing the WMO reports (SYNOP) that normally include snow.

[86] http://www.fao.org/nr/water/aquastat/main/index.stm

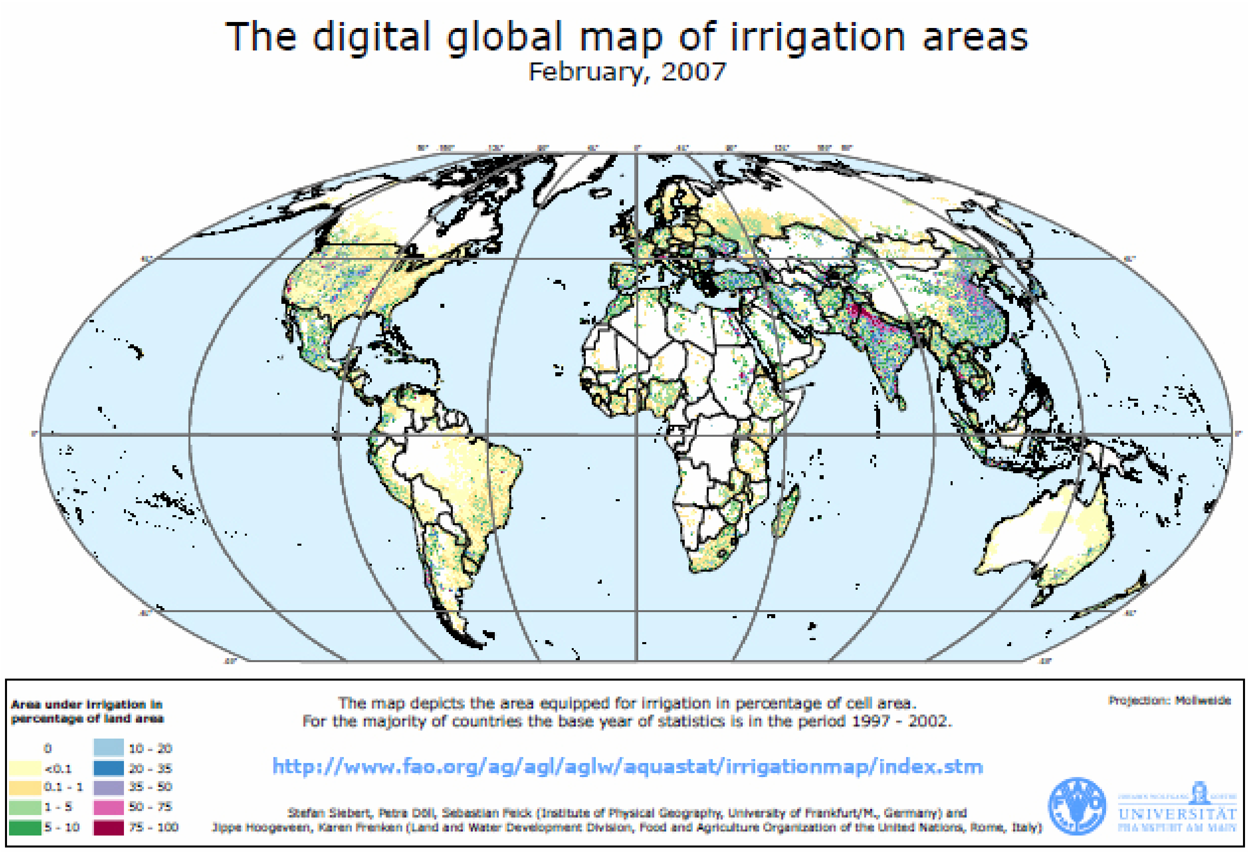


Figure 25: Digital global map of irrigation areas (Source: FAO; University of Frankfurt/M (Germany)).

Some progress in the area of dataavailability has however been achieved: for example, the Canadian Meteorological Centre has produced a global daily 1/3 degree snow-depth analysis from the data available on the GTS. These data are available from NSIDC for the period March 1998 to the present.

In situ snow depth data for the United States are available through NCDC. An in situ dataset (station and transect) for North America for the period 1980 to 2004 for more than 15 000 locations is available from NSIDC, and updates are expected to follow. NSIDC has updated the Russian station snow depth data until 2000 for over 200 stations. There is a new effort within Asia-CliC to obtain station snow depth data from as many sources in Eurasia as possible. Snow water equivalent is observed in many countries by national, state, provincial and private networks on a 10-30 day basis. However, no systematic and global monitoring of snow-related data is performed, and no single central archive for snow information exists, with many national databases being not readily accessible.

Some countries report enhanced efforts to improve snow depth and snowfall observations in their National Reports. For example, Environment Canada in cooperation with NOAA is undertaking studies to obtain accurate measurements from automatic stations by developing algorithms, testing snow targets for acoustic snow depth sensors, and evaluating various wind shields. Canada also has emphasised the compilation of historical snow depth and snow-course data. Efforts such as these should allow for improved datasets in the future.

Moderate Progress

Action T11 Hemispherical snow cover analyses

Action: Obtain integrated analyses of snow cover over both hemispheres.
Who: Space agencies through CliC and IGOS–P Cryosphere, with advice from TOPC and AOPC.
Time-Frame: Continuous.
Performance Indicator: Availability of snow-cover products for both hemispheres.

Daily Northern Hemisphere snow-cover extent maps exist since May 1999 from the NOAA Interactive Multisensor Snow and Ice Mapping System (IMS), with weekly maps for the Northern Hemisphere available since 1966 at 25 km resolution approximately. Moderate-Resolution Imaging

Spectroradiometer (MODIS) snow products include level-2 swath data at 500 m resolution, and gridded daily and 8-day composites at 500 m. These data are available for both Northern and Southern Hemispheres since 2000.

Action T12 Establish standards for snow observations

Moderate-Low Progress

Action: For snow cover and snow water equivalent, establish standards and protocols, design an optimum procedure and designate International Data Centre responsibilities.
Who: TOPC/AOPC, with WCRP, WMO and IGOS-P Cryosphere.
Time-Frame: Planning complete by 2007.
Performance Indicator: The completed SWE network and a functioning inclusion of remote sensing measurements will be the main indication of successful implementation.

There is no globally complete archive for *in situ* data of snow water equivalent but NSIDC is the main institution that tries to meet this need. WMO provides some guidance on standards and data exchange protocols of snow cover and snowfall,[87] but a comprehensive set of common standards is yet to be established. As part of their work on establishing standards for all terrestrial ECVs, GTOS Secretariat is leading their development. The 2007 IGOS Cryosphere Theme Report also contains observational capabilities and requirements for terrestrial snow parameters.

Action T13 Continuity of glacier observations globally

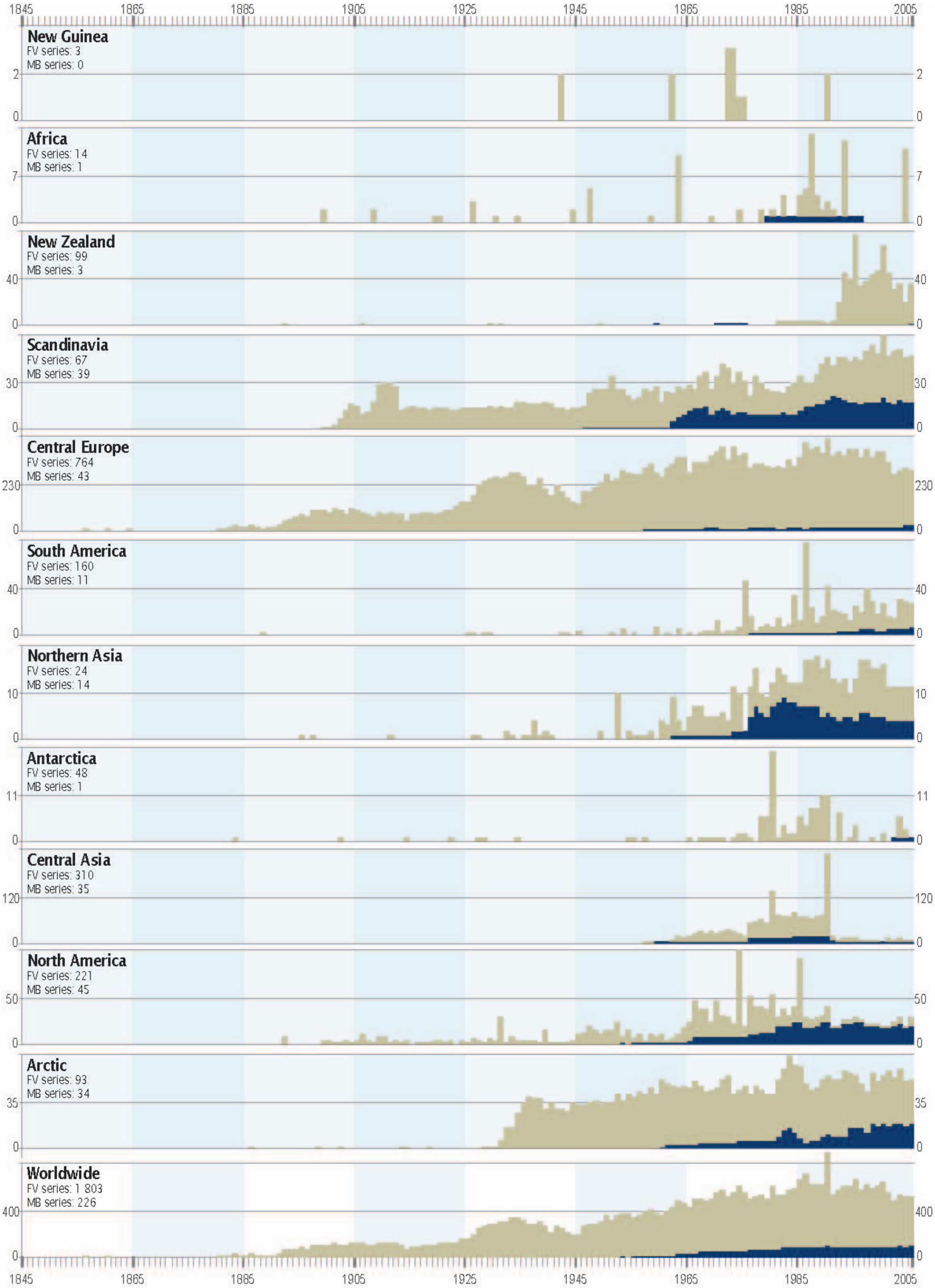
Good Progress

Action: Maintain current glacier observing sites and add additional sites and infrastructure in South America, Africa, the Himalayas and New Zealand; ensure continued functioning of WGMS.
Who: Parties' national services and agencies coordinated by GTN-G, WGMS, USGS and IGOS-P Cryosphere.
Time-Frame: Continuing, new sites by 2009.
Performance Indicator: Completeness of database held at WGMS.

Overall performance of glacier monitoring within the GTN-G has had some improvements (see Figure 26). Observational networks (especially mass balance, cf. WGMS Glacier Mass Balance Bulletin[88], p. 1-4) are improving in South America and New Zealand. Re-establishment of observations at Mt. Kenya have begun but large gaps continue to exist in Central Asia. The ESA GlobGlacier project is speeding up satellite-based glacier inventory work and supports the development of analysis tools involving full digital terrain information (from SRTM, ASTER, SPOT etc.). National funding of the World Glacier Monitoring Service in Switzerland is now secured for the future within the framework of GCOS Switzerland. International participation in the funding should also improve. Support from UNEP[89] is very good and greatly improving the visibility of glacier monitoring, but remains project-oriented.

The Global Land Ice Measurements from Space (GLIMS) initiative has built a database of glacier outlines and related attributes, derived primarily from satellite imagery, such as from ASTER and Landsat. Each snapshot of a glacier is from a specific time, and the database is designed to store multiple snapshots representative of different times. As of January 2009, the database at NSIDC contains outlines for approximately 83 000 glaciers, covering 260 000 km2. Of these, 549 glaciers have outlines from more than one point in time. This database enables analysis of global and regional glacier area and its distribution, glacier change, distribution of glaciers by classification, and other indices.

[87] WMO (2008):*Guide to Meteorological Instruments and Methods of Observation* (CIMO Guide), WMO-No. 8, 2008, http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO%20Guide%207th%20Edition,%202008/CIMO_Guide-7th_Edition-2008.pdf.
[88] http://www.wgms.ch
[89] http://www.grid.unep.ch/glaciers/



Temporal overview on the number of reported length change (light brown bars) and mass balance surveys (dark blue bars). Note that the scaling of the number of observations on the y-axis changes between the regions. The total number of length change (FV) and mass balance (MB) series are listed below the name of the region.
Source: WGMS (2008), Fig. 4.8; data from WGMS.

Figure 26 Glacier length change and mass balance surveys contributing to the Global Terrestrial Network Glaciers (GTN-G) (Source: WGMS).

Good-Moderate Progress

Action T14 Sustained observations of snow and ice from space

Action: Ensure continuity of current spaceborne cryosphere missions.
Who: Space agencies, in cooperation with IGOS-P Cryosphere.
Time-Frame: New sensors to be launched following demise of ICESat and CryoSat in next 3-5 years.
Performance Indicator: Appropriate follow-on missions agreed.

Continuity of satellite-based cryosphere measurements has been maintained and although some gaps in scope of the coverage of missions are expected, plans are proceeding for improved future measurements. ICESat2 is under consideration with a launch date of 2015 and Cryosat 2 is scheduled for launch in November 2009.

Concerning glacier mapping, the following mission plans are worth noting: (i) the Sentinel 2a,b mission series has been approved by ESA in 2008 and scheduled for launch from 2012, with a lifetime of at least a decade. Furthermore, continuity beyond the first two missions is foreseen. Imagery of up to 10 m resolution in 14 channels over a wide swath will be delivered; (ii) the Landsat Data Continuity Mission (LDCM) was approved by NASA, with a sensor very similar to Landsat7 ETM+ (proposed launch is July 2012).

In summary, the situation is good, but an additional data gap might occur between the likely failure of Landsat 5 and the LDCM in 2012. However, the situation is improving following the launch of microwave sensors (TerraSar-X, COSMO-Skymed) and optical sensors (RapidEye constellation, Disaster Monitoring Constellation, etc.) to augment the ongoing ERS and Envisat radar imagery already in service. However these sensors are new and there is no heritage and experience of using them for climate applications.

Good Progress

Action T15 Standards for permafrost measurements from boreholes

Action: Define, publish and apply international observing standards and practices for borehole measurements.
Who: GTN-P and International Permafrost Association.
Time-Frame: Complete by 2005.
Performance Indicator: Published guidelines.

Draft guidelines[90] for permafrost measurements have been published by the GTOS Secretariat as part of its response to the need for improved terrestrial standards and observation guidelines, which are expected to be finalized by April 2009.

Good-Moderate Progress

Action T16 Full implementation of global permafrost observations

Action: Maintain the current 125 CALM sites, ensure that all the other 287 boreholes in the GTN-P are active and reporting; add 150 additional sites as identified by GTN-P including the high mountains of Asia, Europe, Southern Hemisphere and North American alpine and lowlands as part of the IPY Thermal State of Permafrost campaign, ensure that all use standards as defined by the IPA and provide data to the NSIDC.
Who: Parties' national services/research institutions, with coordination through GTN-P and International Permafrost Association, data holding by Geological Survey of Canada and NSIDC. IGOS-P cryosphere to ensure continuity and associated Earth observation derived variables.
Time-Frame: Continuing. Addition of new sites during the IPY by 2008 with subsequent follow-on.
Performance Indicator: Completeness of database. Initiation of new sites.

The collection of permafrost data has shown some improvement, especially in polar regions, due to the International Polar Year 2008-2009. Through the Global Terrestrial Network for Permafrost (GTN-P) as the primary international programme concerned with monitoring permafrost parameters, efforts have been made over the past decade to re-establish a borehole temperature monitoring programme to monitor, detect, and assess long-term changes in the active layer and the thermal state of permafrost, particularly on a regional basis.

Borehole metadata and summary data are available on the GTN-P website[91] hosted by the Geological Survey of Canada's permafrost website. The CALM network is currently coordinated through the University of Delaware, USA. Metadata and ancillary information are available for each site, including climate, site photographs, and descriptions of terrain, soil type, and vegetation. Data

[90] GTOS (2008):*Assessment of the Status of the Development of Standards for the Terrestrial ECVs – Permafrost and seasonally-frozen ground* (draft, 17 September 2008), GTOS-62, http://www.fao.org/gtos/ECV-T07.html .
[91] http://www.gtnp.org

are transferred or linked periodically to a permanent archive at the National Snow and Ice Data Center (NSIDC).

The borehole network currently has approximately 500 candidate sites, many of which are instrumented with data loggers. These include approximately 150 new borehole and active layer sites needed to obtain representative coverage in the Europe/Nordic region, the Russian Federation and Central Asia (Mongolia, Kazakhstan, China), in the Southern Hemisphere (South America, Antarctica), and in the North American mountain ranges and lowlands.

Low Progress

Action T17 Routine mapping of seasonal freeze and thaw of soils

Action: Implement operational mapping of seasonal soil freeze/thaw.
Who: Parties' national services and NSIDC, with guidance from GTN-P and International Permafrost Association with IGOS-P Cryosphere.
Time-Frame: Complete by 2010.
Performance Indicator: Actions using published guidelines.

There is currently no accepted protocol for using satellite data for detecting seasonal soil freeze and thaw. Passive microwave remote sensing sensors, especially low frequency and high-resolution sensors, could be further developed to detect the timing, frequency, duration, and areal extent of near surface soil freeze/thaw. Combined with products from other sensors, including surface temperature and snow depth and well-established ground-based measurements, a comprehensive frozen soil algorithm could be used to detect and simulate soil thermal regime and freeze/thaw depth at regional and global scales.

Good Progress

Action T18 Find best practice for retrieving albedo from space

Action: Test prototype algorithms to retrieve the directional hemispherical reflectance factor (or black sky albedo) from geostationary satellites on a daily and global basis.
Who: Space agencies, especially EUMETSAT, in cooperation with the algorithm developers and the CEOS WGCV.
Time-Frame: Complete algorithm testing by 2005.
Performance Indicator: Availability of full suite of algorithms and associated processing chains that apply these algorithms.

Moderate-Low Progress

Action T21 Implement global retrievals of albedo from space

Action: Implement globally coordinated and linked data processing to retrieve the directional hemispherical reflectance factor (or black sky albedo) from geostationary satellites on a daily and global basis from archived (and current) satellite data.
Who: Space agencies, through the CGMS and WMO Space Programme.
Time-Frame: Back-process archived data by 2009, then continuous.
Performance Indicator: Completeness of archive.

Prototypes algorithms have been successfully tested for the new generation of sensors onboard geostationary satellites such as SEVIRI (in the EUMETSAT Land Satellite Application Facility (LandSAF)), as well as older sensors, with the perspective of using the ensemble of geostationary satellites for global coverage. There are plans to produce such albedo products on a long-term basis within the LandSAF. More studies are required to perform detailed (inter-)comparison analysis against recent albedo products, such as those available from MODIS, MISR and MERIS.

Under the auspices of CGMS a single prototype dataset linking albedo retrievals from different geostationary sensors in a homogeneous way has been produced, but not on an operational basis.

Good-Moderate Progress

Action T19 Calibration and validation of albedo products

Action: Obtain *in situ* calibration/validation measurements and collocated albedo products from all space agencies generating such products.
Who: Space agencies in cooperation with CEOS WGCV.
Time-Frame: Full benchmarking/intercomparison by 2007.
Performance Indicator: Publication of inter-comparison/validation reports.

This Action has been addressed on a case by case basis, and intercomparisons are ongoing under the auspices of the CEOS WGCV Land Product Validation subgroup. It would be appropriate, however, to perform the exercise over AERONET sites, given the sensitivity of surface albedo retrievals to aerosol optical depths and aerosol properties. The GTOS ECV report on standards[92] gives a comprehensive account of the status (see also Action T29).

Low Progress

Action T20 Albedo from space for use in climate models

Action: Identify the most appropriate satellite derived albedo for specific climate models.
Who: CEOS WGCV, in cooperation with GEWEX and the Project for Intercomparison of Land-surface Parameterization Schemes.
Time-Frame: Testing by 2007/8.
Performance Indicator: Data available to analysis centres.

Preliminary studies have been conducted at ECMWF using existing land surface schemes. More work is needed to refine climate model requirements regarding geophysical product specifications. Better coordination of the initiatives from various space agencies (ESA GlobAlbedo; NASA VIIRS, AVHRR; EUMETSAT SEVIRI, and other geostationary satellites) is required. Specific attention should be devoted to high-latitude snow-covered surfaces as they have a high impact both on short (weather forecast) and long time scales (climate model predictions). Intercomparisons between products are required to assess their differences and implications for downstream applications.

Good Progress

Action T22 International standards for land cover maps

Action: Establish international standards and specifications for the production of land-cover characterization maps.
Who: FAO, UNEP, GLCN and ISO (TC-211) in collaboration with GOFC-GOLD.
Time-Frame: Standards and specifications by 2005. Operation continuing.
Performance Indicator: Publication of standards.

The FAO/UNEP Land Cover Classification System (LCCS; under ISO) provides the required standards and specifications. The ESA GlobCover project (300 m resolution global land cover), amongst other initiatives, uses this classification.

Good Progress

Action T23 Methods for land cover map accuracy assessment

Action: Produce reliable accepted methods for land-cover map accuracy assessment.
Who: CEOS WGCV, in collaboration with GOFC-GOLD and GLCN.
Time-Frame: By 2005 then continuously.
Performance Indicator: Protocol availability.

Protocols and methods have been developed. However, they are not often applied to the generated land cover maps. Furthermore, metadata is usually not provided along with the land cover maps. However, some maps are partly validated (e.g., ESA GlobCover2). Protocols and specific software have been developed by the FAO GLCN programme to harmonize reporting of accuracy at national and sub-national levels.

Good Progress

Action T24 Sustained fine-resolution land imaging from space

Action: Commit to continuous 10-30 m resolution optical satellite systems with data acquisition strategies at least equivalent to the Landsat 7 mission for land cover.
Who: Space agencies.
Time-Frame: Continuing.
Performance Indicator: Operational plans, data availability.

A Landsat Data Continuity Mission (LDCM) has been approved, but the long-term future of Landsat successor missions is not yet secured. Additional coverage will be provided by the ESA Sentinel 2 mission series (launches from 2012) and the China/Brazil CBERS 3 and 4 (launch scheduled for 2010 and 2013).

Low Progress

Action T25 Development of *in situ* reference network for land cover

Action: Develop an *in situ* reference network and apply CEOS WGCV validation protocols for land cover.
Who: Parties' national services, research institutes and space agencies, in cooperation with GOFC-GOLD, CEOS/WGCV, FAO GLCN and the GTOS web-based data system TEMS.
Time-Frame: Network established by 2009.
Performance Indicator: Availability of validation statistics.

Very limited progress globally, but a system of 10 km square Landsat samples at one degree latitude and longitude intersections is being established for the FAO Global Forest Resource Assessment FRA 2010. This will provide some initial data and capacity building to support national staff in the analysis of land cover and forest extent. Very high-resolution satellite data can be used as surrogate

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[92] GTOS (2008):*Assessment of the Status of the Development of Standards for the Terrestrial ECVs – Albedo and reflectance anisotropy* (draft, 22 November 2008), GTOS-63, http://www.fao.org/gtos/ECV-T08.html .

data in case of inaccessible terrain, but is not fully reliable. In specific regions, under the FAO GLCN programme, validation databases are set up.

FAO is also providing support to national forest monitoring and assessments (NFMAs) based on systematic field sampling, combined with the use of remote sensing for wall-to-wall or sample based mapping. The focus of NFMAs is state and change (deforestation, forest degradation, drivers of change) of forests and trees. 20 countries, 18 of which are tropical countries including Brazil, are engaged in setting up forest monitoring processes,.

Moderate-Low Progress

Action T26 Annual land cover products

Action: Generate annual products documenting global land-cover characteristics at resolutions between 250 m and 1 km, according to internationally-agreed standards and accompanied by statistical descriptions of the maps' accuracy.
Who: Parties' national services, research institutes and space agencies through GLCN in collaboration with GOFC-GOLD research partners, and the IGOS land theme (IGOL).
Time-Frame: By 2005, then continuously.
Performance Indicator: Dataset availability

There are three global land cover products at the requested resolution: the ESA GlobCover, a 300 m resolution product (2005 epoch, FAO/UNEP land classification scheme), with limited validation; the Global Land Cover 2000 product; and the NASA MODIS MOD12Q1 Land Cover Product which supplies an IGBP land cover classification map of the globe, along with an assessment of the quality or confidence that is placed in that classification. Annual production of global products has yet to be achieved.

Low Progress

Action T27 Regular fine-resolution land cover maps

Action: Generate maps documenting global land cover at resolutions between 10 m and 30 m every 5 years, according to internationally-agreed standards and accompanied by statistical descriptions of the maps' accuracy.
Who: Space agencies, in cooperation with GCOS, GTOS, GLCN and other members of CEOS.
Time-Frame: First by 2005, then continuously.
Performance Indicator: Availability of operational plans, funding mechanisms and eventually maps.

GlobCover is the first detailed high-resolution (300 m) land cover map at global level, generated by ESA in partnership with FAO and UNEP. However, no global product is available at the required 10-30 m resolution. Through GLCN and other initiatives, high-resolution land cover maps are produced and periodically updated on a country by country basis. Moreover, regional land cover maps are being undertaken for vulnerable areas, such as mountainous regions (e.g., the Himalayas) and river deltas (e.g., Nile).

Currently, the European GMES land monitoring core service is planning a medium-resolution product (approx. 30 m) for Europe and a higher-resolution product (approx. 1 m) for urban areas. The US and some other countries also have a comparable national land-imaging programme. No concerted action towards a global product has been achieved, however.

While it is not yet clear what methodology will be put in place under the UNFCCC in connection with the proposed implementation of Reducing Emissions from Deforestation and forest Degradation in developing countries (REDD), relevant space agencies under CEOS have agreed to supply, on a regular basis, the high-resolution data necessary for the generation of fine-resolution land cover maps to support such a methodology.

Good Progress

Action T28 Availability of vegetation parameter products from space

Action: Make fAPAR and LAI products available as gridded products at 250 m to 1 km resolution.
Who: Space agencies, coordinated through CEOS WGCV, with advice from GCOS/GTOS.
Time-Frame: 2005.
Performance Indicator: Agreement on operational product.

Gridded global fAPAR products are available from several satellite sources,[93] e.g. MODIS, SeaWiFS, MERIS, VGT and MISR at resolutions mostly greater than 1 km, while LAI is routinely produced[94] only from MODIS, MISR and ATSR/VGT. Since the 'standard' spatial resolution of most past and current global sensors is of the order of 1.2 km, it is not possible to generate products at the 1 km resolution without oversampling of the data. Some more recent sensors have the capability of observing land

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[93] GTOS (2008):*Assessment of the Status of the Development of Standards for the Terrestrial ECVs – fAPAR* (draft, 27 October 2008), GTOS-65, http://www.fao.org/gtos/ECV-T10.html (Table 3).
[94] GTOS (2008):*Assessment of the Status of the Development of Standards for the Terrestrial ECVs – LAI* (draft, 22 November 2008), GTOS-66, http://www.fao.org/gtos/ECV-T11.html (Table 2).

surfaces at spatial resolutions of the order of 250 to 300 m, but in most cases these data have not been systematically processed (or even acquired).

Since LAI is usually produced in tandem with fAPAR, the spatial scales of these paired products is the same. The main product generation is carried out through ESA and NASA, although European projects (CYCLOPES and Geoland) also generate products. Significant differences are found in both fAPAR and LAI from different sources, because different inversion methodologies are used. Understanding and resolving differences between these products is an active area of current research, and so far, there is no agreement on the most appropriate methodologies to produce operational products. There are currently no universally accepted measures of the validity or accuracy of each product, but the CEOS WGCV LPV subgroup is developing protocols.

Low Progress

Action T30 Benchmark LAI measurements from space

Action: Evaluate the various LAI satellite products and benchmark against ground truth to arrive at an agreed operational product.
Who: Parties' national and regional research centres, in cooperation with space agencies and CEOS WGCV and TOPC.
Time-Frame: Benchmark by 2006/7.
Performance Indicator: Agreement on operational product.

Little progress has been made but the CEOS WGCV Land Product Validation subgroup is now leading this activity. Stable, reliable measurements of LAI are hard to achieve even in situ, and there is no consensus on how the essentially point-based measurements available from ground validation sites can be meaningfully compared with measurements from medium-resolution satellite sensors. The evaluation and benchmarking of these products is also complicated by scale and resolution, as well as conceptual issues (e.g., effective variables, see Action T29) that are rarely taken into account or even fully appreciated.

Good-Moderate Progress

Action T31 Methodology for forest inventories

Action: Develop methodology for forest inventory information and begin acquisition of data.
Who: Parties and FAO.
Time-Frame: By 2009.
Performance Indicator: Availability of consistent statistical information.

The most widely-used source on global forest biomass and carbon stocks is probably the FAO Global Forest Resources Assessments, which are produced at five-year intervals. The latest is FRA 2005 and the new FRA 2010 is well underway and will be published in 2010. These assessments are based on reporting by individual countries. Original data and methods are described in detail in the individual country reports to FAO. Special global assessments of biomass and carbon stocks are compiled based on FRA data, with global estimates adjusted to take into account countries that did not report on biomass and carbon stocks. There is no reporting on statistical uncertainty, but the report includes a discussion on data quality and a plausibility analysis.

CEOS supports the Forest Carbon Monitoring Initiative as one of its 2009/2010 priorities. While it is not yet clear what methodology will be put in place under the UNFCCC in connection with the proposed implementation of REDD, space agencies under CEOS have agreed to supply imagery for forest mapping to support such a methodology.

Moderate-Low Progress

Action T32 Reanalyze historical fire measurements from space

Action: Reanalyze the historical fire disturbance satellite data (1982 to present).
Who: Space agencies, working with research groups coordinated by GOFC-GOLD.
Time-Frame: By 2010.
Performance Indicator: Establishment of a consistent dataset.

The GTOS GOFC-GOLD is planning a global fire assessment for 2010 which should address this Action. Its success depends on the reprocessing of the historical data satellite record to correct for known limitations (calibration, sensor sensitivity, directional effects and atmospheric correction). Such an assessment has been carried out for Africa, but overall quality of the results yet to be evaluated.

Good Progress

Action T33 Continuous fire measurements from space

Action: Continue the generation of active fire and burnt area products.
Who: Space agencies, in collaboration with GOFC-GOLD.
Time-Frame: Continuous.
Performance Indicator: Availability of data.

The generation of active and burnt area products has proceeded effectively. An overview of satellite-derived burnt area, active fire and FRP products that are developed globally is given in a recent GTOS report.[95] Not all of those products are operational.

Action T34 Apply common validation protocols to fire measurements

Moderate Progress

Action: Apply CEOS WGCV and GOFC-GOLD validation protocol to fire disturbance data.
Who: Space agencies and research organizations.
Time-Frame: By 2006.
Performance Indicator: Publication of accuracy statistics.

The GTOS GOFC-GOLD programme is working towards establishing validation protocols, in collaboration with the CEOS WGCV Land Product Validation group, by the end of 2009. Subsequently, a concerted effort will be needed to implement them. This is being done with some of the regional networks, and expanded participation by the community is needed. An accuracy assessment of past fire records back to 1982, and at available resolutions, is also needed.

Action T35 Fire products available worldwide

Moderate-Low Progress

Action: Make gridded fire and burnt area products available through a single International Data Centre.
Who: United Nations-affiliated Global Fire Monitoring Center (GFMC), through GOFC-GOLD.
Time-Frame: Continuous.
Performance Indicator: Continued operation of the GFMC.

The idea of a centralized facility for all fire data remains desirable but has yet to be engaged. The Global Fire Monitoring Centre provides valuable community service through a repository of fire-related field experiments, process studies and analyses, but does not host a central fire data archive. However, progress has been made in the availability of satellite-derived fire products: for example, MODIS fire products (active hotspots and burned area) are openly available through NASA data portals, and the European L3JRC and ESA GlobCarbon and World Fire Atlas products are also made available to the scientific community. A Fire Information Management System (FIRMS) is being established by FAO to disseminate information to national and local entities to support early warning, fire management and appropriate response mechanisms in forest and agricultural systems.

Action T36 Terrestrial metadata collection

Good Progress

Action: Expand TEMS to support the metadata collection, collation and publication needs of the terrestrial ECVs and associated data centres.
Who: Parties' national services and research programmes contributing to TEMS, in cooperation with GTOS, GOSIC, and GCMD, and in consultation with the GCOS Secretariat.
Time-Frame: By 2006.
Performance Indicator: Number of stations and nations submitting data to TEMS, Communication to UNFCCC.

TEMS functionality has been expanded in 2006 to allow individual users to update their site information and metadata. It now features 2040 monitoring sites, 40 networks, 1200 contact persons, 120 environmental variables and 55 socio-economic indicators. In addition, TEMS has been supplemented with additional thematic modules (such as hydrology, biodiversity and mountains) and variables (such as coastal) to cover the needs of the users. TEMS has been linked to the Global Observing Systems Information Center (GOSIC[96]) and other related data centres, such as the Global Change Master Directory[97] to provide users with access to data.

Action T37 Develop soil moisture products

Good Progress

Action: Develop an experimental soil-moisture product from existing networks and satellite observations.
Who: Parties' national services and research programmes, through IGWCO and TOPC in collaboration with space agencies.
Time-Frame: 2009: development of an experimental product; 2011: quasi-operational production of a soil-moisture product.
Performance Indicator: Availability of validated global satellite derived product and functioning GTN-SM providing observations to an associated archive centre.

A number of research products are available and routinely produced from scatterometers and radiometers[98]. The most significant operational development is the availability of a soil moisture product derived from ASCAT data, e.g., within the EUMETSAT Hydrology Satellite Application Facility. The operational product became available in 2008 but data can be reprocessed from as early

[95] GTOS (2008):*Assessment of the Status of the Development of Standards for the Terrestrial ECVs – Fire disturbance* (draft, 21 November 2008), GTOS-68, http://www.fao.org/gtos/ECV-T13.html (Table 3).
[96] http://gosic.org
[97] http://gcmd.nasa.gov
[98] E.g., http://www.geo.vu.nl/users/holt/lprm/ ; http://nsidc.org/data/ae_land3.html

as 2006. ASCAT is an operational instrument scheduled to fly on the Metop satellite series for at least 15 years, and it is building on the data series established with scatterometers on ERS-1 and ERS-2 from the early 1990s. Greater capability should be possible in the future with products from the ESA SMOS mission in 2009 (launch scheduled for July) and the NASA/CONAE Aquarius mission in 2010.

Appendix 1 Summary of Progress by Action

Table 9: Overarching and Cross-cutting Areas: Summary of progress on Actions

Actions	Progress
Action C1 International Response to the IP-04	Moderate Progress
Action C2 National planning	Low Progress
Action C3 Regional Action Plans	Moderate Progress
Action C4 National reporting	Moderate Progress
Action C5 Reporting on implementation	Good Progress
Action C6 GCOS Project Office	Low Progress
Action C7 Research networks and systems	Moderate Progress
Action C8 Adherence to the GCMPs	Moderate Progress
Action C9 Implementation in developing countries / Capacity building	Moderate-Low Progress
Action C10 Earth observation satellites	Moderate Progress
Actions C11, C12 and C13 Data records, analysis and reanalysis	Moderate Progress
	Moderate Progress
	Moderate Progress
Action C14 Historical data records	Moderate Progress
Actions C15, C16 and C17 Palaeoclimate	Good Progress
	Good Progress
	Good Progress
Action C18 Metadata standards	Good-Moderate Progress
Action C19 International data centres	Moderate Progress
Action C20 Data policies	Moderate Progress
Action C21 Data services	Good-Moderate Progress

Table 10: Atmospheric Domain: Summary of progress on Actions

Actions	Progress
Action A1 Full implementation of the GCOS Surface Network	Good-Moderate Progress
Action A2 WMO Basic Synoptic Surface Network	Moderate-Low Progress
Action A3 Apply GCOS Climate Monitoring Principles to surface networks	Moderate Progress
Action A4 Guided transition to automated surface stations	Good Progress
Action A5 Atmospheric pressure sensors on ocean drifting buoys	Good Progress
Action A6 Precipitation data available worldwide	Good-Moderate Progress
Action A7 Continuity of precipitation measurements from space	Moderate Progress
Action A8 Precipitation measurements on ocean moorings	Moderate Progress
Action A9 Improve precipitation measurements	Moderate Progress

Actions		Progress
Action A10	Availability of high frequency pressure and wind data	Good-Moderate Progress
Action A11	Continuous measurements of wind from space	Good-Moderate Progress
Action A12	Availability of air humidity data worldwide	Good Progress
Action A13	Sunshine data available worldwide	Low Progress
Action A14	Global high-quality measurements of surface radiation	Good-Moderate Progress
Action A15	Full implementation of GCOS Upper-Air Network	Good-Moderate Progress
Action A16	Implement the GCOS Reference Upper-Air Network	Good-Moderate Progress
Action A17	WMO Basic Synoptic Upper-air Network	Moderate-Low Progress
Action A18	Information on radiosonde observations available worldwide	Moderate Progress
Action A19	Satellite measurements of upper-air temperature	Good Progress
Action A20	GPS Radio Occultation measurements	Good Progress
Action A21	Facilitate exchange of ground-based GPS data	Moderate-Low Progress
Action A22	Satellite observations of clouds, aerosols, radiation and water vapour	Moderate Progress
Action A23	Cloud observations research	Good Progress
Action A24	Continuous observations of the Earth’s radiation budget	Moderate Progress
Action A25	Integrated global observations for atmospheric composition	Good-Moderate Progress
Action A26	Vertical profiles for greenhouse gases, ozone and aerosols	Good-Moderate Progress
Action A27	Global network for CO_2 and CH_4 observations	Good-Moderate Progress
Action A28	Integrated analyses of CO_2 and CH_4 observations	Good-Moderate Progress
Action A29	Halocarbon Intercomparison Study	Good-Moderate Progress
Action A30	Implementation of Baseline Ozone Observing Networks	Good-Moderate Progress
Action A31	Strategy to monitor and analyze aerosols	Moderate Progress
Action A32	Satellite atmospheric composition measurements	Good-Moderate Progress

Table 11: Oceanic Domain: Summary of progress on Actions.

Actions		Progress
Action O1	Increasing national and multi-national participation	Moderate Progress
Action O2	Regular review of Ocean Plan	Good Progress
Action O3	Research and development in support of ocean observations	Good Progress
Action O4	Partnerships with ocean research community to implement ocean observations	Good Progress
Action O5	Coastal observations in support of the UNFCCC	Moderate-Low Progress
Action O6	Improved climate measurements from Voluntary Observing Ships	Moderate Progress
Action O7	Updating plans for sustained ocean satellite observations	Good Progress
Action O8	Implementation of ocean surface reference mooring network	Good Progress
Action O9	Sustained satellite observations of sea-surface temperature	Moderate Progress
Action O10	Global *in situ* observations of sea-surface temperature	Good Progress

Actions		Progress
Action O11	Implement highly accurate sea-level gauge network	Good-Moderate Progress
Action O12	Sustained observations of sea level from space	Good-Moderate Progress
Action O13	Full access to sea-level data in coastal zones	Moderate Progress
Action O14	Building national capacity to measure sea level	Moderate Progress
Action O15	Develop programme for *in situ* observations of sea-surface salinity	Moderate-Low Progress
Action O16	Research sea-surface salinity measurements from satellites	Good-Moderate Progress
Action O17	International strategy for measuring pCO_2	Moderate Progress
Action O18	Implement plans for sustained ocean colour satellites	Good-Moderate Progress
Action O19	Implement sea state (wave) reference measurements	Low Progress
Action O20	Develop global integrated surface current analyses	Good-Moderate Progress
Action O21	Establish improved coordination of sea-ice research, observations and products	Moderate-Low Progress
Action O22	Establish frameworks for internationally-coordinated ocean observations in the Arctic	Moderate-Low Progress
Action O23	Sustained sea-ice observations from space	Good-Moderate Progress
Action O24	Development of integrated sea-ice products and analyses	Moderate Progress
Action O25	Implement systematic global full-depth water column ship-based sampling	Good-Moderate Progress
Action O26	Implement repeat trans-oceanic temperature sections from volunteer ships	Moderate Progress
Action O27	Full implementation of Argo profiling float array	Good Progress
Action O28	Maintain and expand the Tropical Moored Buoy arrays	Moderate Progress
Action O29	Develop integrated ocean current dataset	Low Progress
Action O30	Research and technology development for autonomous observations of biogeochemical and ecosystems ECVs	Moderate Progress
Action O31	Reference network for biogeochemical and ecosystem ECVs	Low Progress
Action O32	Monitor implementation of ocean data policy	Moderate Progress
Action O33	Implement comprehensive ocean data management procedures	Moderate Progress
Action O34	Develop an international standard for ocean metadata	Moderate-Low Progress
Action O35	Develop innovative ocean data transmission and exchange	Moderate Progress
Action O36	Implement a system of ocean data and analysis centres	Low Progress
Action O37	Ocean data rescue	Good Progress
Action O38	Enhanced telecommunication links with ocean sensors	Moderate Progress
Action O39	Better coordination of ocean data assembly and analyses	Moderate Progress
Action O40	Projects for global ocean products from model data assimilation	Good-Moderate Progress
Action O41	Reanalysis of ocean climate data	Good Progress

Table 12: Terrestrial Domain: Summary of progress on Actions

Actions		Progress
Action T1	Intergovernmental terrestrial framework	Good-Moderate Progress

Actions		Progress
Action T2	Sponsorship of Global Terrestrial Network for Hydrology	Good Progress
Action T3	Reference sites for measuring biogeochemical properties	Moderate-Low Progress
Action T29	Network for calibration and validation of vegetation ECVs	Moderate-Low Progress
Action T4	Establish Global Terrestrial Network for Rivers	Moderate Progress
Action T5	Create world data centre for lakes	Good Progress
Action T6	Regular near real-time data submission to lake data centre	Low Progress
Action T7	Submission of historical data to international lake data centre	Low Progress
Action T8	Data on water temperature and freezing state to lake data centre	No Progress
Action T9	Information on irrigation and water resources	Moderate Progress
Action T10	Strengthen snow observing networks and data availability	Moderate-Low Progress
Action T11	Hemispherical snow cover analyses	Moderate Progress
Action T12	Establish standards for snow observations	Moderate-Low Progress
Action T13	Continuity of glacier observations globally	Good Progress
Action T14	Sustained observations of snow and ice from space	Good-Moderate Progress
Action T15	Standards for permafrost measurements from boreholes	Good Progress
Action T16	Full implementation of global permafrost observations	Good-Moderate Progress
Action T17	Routine mapping of seasonal freeze and thaw of soils	Low Progress
Action T18	Find best practice for retrieving albedo from space	Good Progress
Action T21	Implement global retrievals of albedo from space	Moderate-Low Progress
Action T19	Calibration and validation of albedo products	Good-Moderate Progress
Action T20	Albedo from space for use in climate models	Low Progress
Action T22	International standards for land cover maps	Good Progress
Action T23	Methods for land cover map accuracy assessment	Good Progress
Action T24	Sustained fine-resolution land imaging from space	Good Progress
Action T25	Development of *in situ* reference network for land cover	Low Progress
Action T26	Annual land cover products	Moderate-Low Progress
Action T27	Regular fine-resolution land cover maps	Low Progress
Action T28	Availability of vegetation parameter products from space	Good Progress
Action T30	Benchmark LAI measurements from space	Low Progress
Action T31	Methodology for forest inventories	Good-Moderate Progress
Action T32	Reanalyze historical fire measurements from space	Moderate-Low Progress
Action T33	Continuous fire measurements from space	Good Progress
Action T34	Apply common validation protocols to fire measurements	Moderate Progress
Action T35	Fire products available worldwide	Moderate-Low Progress
Action T36	Terrestrial metadata collection	Good Progress
Action T37	Develop soil moisture products	Good Progress

Appendix 2 Definition of Progress Indicators

Good Progress

Good progress:
In a global context, most or all results required by the Action and set by Action Performance Indicator have been achieved.

Good-Moderate Progress

Good-moderate progress:
In a global context, the majority of results required by the Action and set by the Action Performance Indicator have been achieved, although some deficits remain.

Moderate Progress

Moderate progress:
In a global context, many of the results required by the Action and set by the Action Performance Indicator have been achieved, many implementation steps are in the process of being addressed, but are yet to be performed.

Moderate-Low Progress

Moderate-low progress:
In a global context, some of the results required by the Action and set by the Action Performance Indicator have been achieved, but many deficits are only in the process of being addressed, or persist.

Low Progress

Low progress:
In a global context, only a limited number of the results required by the Action and set by the Action Performance have been achieved, and substantial deficits remain, with only a few being addressed.

No Progress

No progress:
In a global context, no progress has been made against this Action.

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Appendix 4 Conclusions by UNFCCC SBSTA 23 (Research and Systematic Observation)[99]

UNFCCC
SUBSIDIARY BODY FOR SCIENTIFIC AND TECHNOLOGICAL ADVICE
Twenty-third session
Montreal, 28 November to 6 December 2005
Agenda item 9 (Research and Systematic Observation)

87. The Subsidiary Body for Scientific and Technological Advice (SBSTA) took note of the submissions from Parties on the report on progress made towards implementing the initial ocean climate observing system, and on the final report on the analysis of data exchange issues in global atmospheric and hydrological networks, contained in document FCCC/SBSTA/2005/MISC.15 and Add.1.

88. The SBSTA welcomed with appreciation the report from the Global Climate Observing System (GCOS) secretariat on progress with the Implementation Plan for the Global Observing System for Climate in Support of the United Nations Framework Convention on Climate Change (hereinafter referred to as the GCOS implementation plan) contained in document FCCC/SBSTA/2005/MISC.14; the report from the Committee on Earth Observation Satellites (CEOS) on preparing a coordinated response from space agencies involved in global observations to the needs expressed in the GCOS implementation plan, contained in document FCCC/SBSTA/2005/MISC.17; and a progress report on developing a framework for the preparation of guidance materials, standards and reporting guidelines for terrestrial observing systems for climate, prepared by the Global Terrestrial Observing System (GTOS) secretariat and contained in document FCCC/SBSTA/2005/MISC.16.

89. The SBSTA noted that there is now an excellent foundation upon which to improve the global observing systems for climate. It urged Parties to further implement the GCOS implementation plan, including the capacity-building elements.

90. The SBSTA urged those Parties that have not already done so to designate GCOS national coordinators and GCOS national focal points.

91. The SBSTA welcomed the information in document FCCC/SBSTA/2005/MISC.14, that almost all of the international agencies identified in the GCOS implementation plan have formally or informally acknowledged their roles in the GCOS implementation plan and are actively engaged in developing and/or refining their specific work plans. This commitment to action represents a substantial degree of international consensus and support for the GCOS implementation plan.

92. The SBSTA welcomed and accepted the offer from the CEOS, on behalf of the Parties supporting space agencies involved in global observations, to provide a detailed report on a coordinated response to the needs expressed in the GCOS implementation plan at SBSTA 25 (November 2006).

93. The SBSTA welcomed the efforts by the GTOS secretariat to develop a framework for the preparation of guidance materials, standards and reporting guidelines for terrestrial observing systems for climate and encouraged GTOS to continue its work. It also called on the GTOS secretariat to assess the status of the development of standards for each of the essential climate variables in the terrestrial domain. The SBSTA invited the GTOS secretariat to report on its progress by SBSTA 26 (May 2007).

94. The SBSTA requested the GCOS secretariat to provide a comprehensive report at its thirtieth session (June 2009), on progress with the GCOS implementation plan, in addition to the regular reporting requested by the Conference of the Parties (COP) in decision 5/CP.10.

[99] UNFCCC (2006): Report of the Subsidiary Body for Scientific and Technological Advice on its twenty-third session, held at Montreal from 28 November to 6 December 2005 (doc. FCCC/SBSTA/2005/10).

95. The SBSTA noted that the report referred to in paragraph 8 would be heavily dependent upon obtaining timely information on national implementation activities. Therefore, the SBSTA invited Parties to submit to the secretariat, by 15 September 2008, additional information on their national activities with respect to implementing the plan.

96. The SBSTA welcomed the ongoing efforts of the Group on Earth Observations (GEO) and invited the GCOS and the GEO to continue to coordinate closely on the implementation of the GCOS implementation plan and the Global Earth Observation System of Systems (GEOSS) 10-year implementation plan. The SBSTA encouraged Parties included in Annex I to the Convention to facilitate the participation of developing country Parties in implementation activities wherever possible.

97. The SBSTA agreed to revise the “UNFCCC reporting guidelines on global climate change observing systems”[100] in order to reflect priorities of the GCOS implementation plan and incorporate the reporting on essential climate variables Parties also noted the need to revise the more comprehensive supplementary reporting format[101]. The SBSTA agreed to consider this issue at its twenty-fifth session. It invited the GCOS secretariat to submit to SBSTA by September 2006, a proposal on ways and means to address these needs.

98. The SBSTA noted the importance of the oceanic observations in contributing to meeting the needs of the Convention. The SBSTA requested Parties in a position to do so to address the need for continued, sustained and enhanced support for the implementation of the global ocean observing system for climate. It noted in particular the need for sustained support to operationalize the system and need for the collection and archiving of marine data and metadata.

99. The SBSTA reiterated that data exchange is fundamental to the needs of the Convention. It noted with concern that many of the problems of data exchange, as referred to in the final report on the analysis of data exchange issues in global atmospheric and hydrological networks[102], still remain. The SBSTA urged Parties to implement the possible remedy options identified in that report.

100. The SBSTA urged Parties and invited relevant intergovernmental organizations and international bodies, such as the World Meteorological Organization and the International Council for Science, to provide active support to international data centres in their efforts to obtain permission from countries for the release of the data and the rescue of historical climate records.

101. The SBSTA noted the regional workshop programme will be completed in early 2006. It invited the GCOS secretariat, in cooperation with the Regional Workshop Advisory Committee, to report on the results of the programme at its twenty-fifth session.

102. The SBSTA reiterated the need to strengthen capacities in the field of climate observations, data analysis and data management. The SBSTA also reiterated the importance of, and continued need for, capacity-building, including through the GEO, the GCOS cooperation mechanism, and regional activities, to enable developing countries to apply climate observations, inter alia, for impact assessment and preparation for adaptation.

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[100] FCCC/CP/1999/7, chapter III

[101] FCCC/SBSTA/2000/14, paragraph 59 [N.B.: the updated Reporting Guidelines can be found at http://www.wmo.int/pages/prog/gcos/index.php?name=unfcccguidelines].

[102] Available at http://www.wmo.int/pages/prog/gcos/Publications/gcos-96.pdf .

Appendix 5 List of Acronyms

AATSR	ADVANCED ALONG TRACK SCANNING RADIOMETER
ACC	ATMOSPHERIC COMPOSITION VIRTUAL CONSTELLATION (CEOS)
ACRIMSAT	ACTIVE CAVITY RADIOMETER IRRADIANCE MONITOR SATELLITE (NASA)
AERONET	AEROSOL ROBOTIC NETWORK
AGAGE	ADVANCED GLOBAL ATMOSPHERIC GASES EXPERIMENT
AIRS	ATMOSPHERIC INFRARED SOUNDER (NASA)
AMMA	AFRICAN MONSOON MULTIDISCIPLINARY ANALYSIS
AMSR	ADVANCED MICROWAVE SCANNING RADIOMETER (JAXA)
AMSR-E	ADVANCED MICROWAVE SCANNING RADIOMETER FOR EOS (NASA/JAXA)
AMSU	ADVANCED MICROWAVE SOUNDING UNIT (NOAA)
AOPC	ATMOSPHERIC OBSERVATION PANEL FOR CLIMATE (GCOS/WCRP)
AQUA	NASA EARTH SCIENCE SATELLITE MISSION ON EARTH's WATER CYCLE
AQUASTAT	INFORMATION SYSTEM ON WATER AND AGRICULTURE (FAO)
AR4	IPCC FOURTH ASSESSMENT REPORT
Argo	GLOBAL ARRAY OF PROFILING FLOATS
ARM	ATMOSPHERIC RADIATION MEASUREMENT (US DEPARTMENT OF ENERGY)
ASCAT	ADVANCED SCATTEROMETER (EUMETSAT)
ASTER	ADVANCED SPACEBORNE THERMAL EMISSION AND REFLECTION RADIOMETER
ATMS	ADVANCED TECHNOLOGY MICROWAVE SOUNDER
ATSR	ALONG TRACK SCANNING RADIOMETER
AURA	NASA EARTH SCIENCE SATELLITE MISSION ON ATMOSPHERIC CHEMISTRY
AVHRR	ADVANCED VERY HIGH-RESOLUTION RADIOMETER (NOAA)
AWI	ALFRED WEGENER INSTITUTE (GERMANY)
BAMS	BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY
BIO-ARGO	BIO-OPTICAL SENSORS ON ARGO FLOATS
BSRN	BASELINE SURFACE RADIATION NETWORK
CALIPSO	CLOUD-AEROSOL LIDAR AND INFRARED PATHFINDER SATELLITE OBSERVATIONS
CALM	CIRCUMPOLAR ACTIVE-LAYER MONITORING
CAS	COMMISSION FOR ATMOSPHERIC SCIENCES (WMO)
CBERS	CHINA-BRAZIL EARTH RESOURCES SATELLITE
CBS	COMMISSION FOR BASIC SYSTEMS (WMO)
CCl	COMMISSION FOR CLIMATOLOGY (WMO)
CEB	CHIEF EXECUTIVE BOARD (UN)
CEOS	COMMITTEE ON EARTH OBSERVATION SATELLITES
CERES	CLOUDS AND EARTH'S RADIANT ENERGY SYSTEM (NASA)
CFC	CHLOROFLUOROCARBON
CGMS	COORDINATION GROUP FOR METEOROLOGICAL SATELLITES
CHAMP	CHALLENGING MINISATELLITE PAYLOAD (GERMANY)
CHy	COMMISSION FOR HYDROLOGY (WMO)
CIMO	COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION (WMO)
CliC	CLIMATE AND CRYOSPHERE PROJECT (WCRP)
CLIMAP	CLIMATE: LONG-RANGE INVESTIGATION, MAPPING AND PREDICTION PROJECT
CLIVAR	CLIMATE VARIABILITY AND PREDICTABILITY PROJECT (WCRP)
CLOUDNET	PILOT NETWORK OF STATIONS FOR OBSERVING CLOUD PROFILES (EC FP5)
CMSAF	CLIMATE MONITORING SATELLITE APPLICATION FACILITY (EUMETSAT)
CNES	CENTRE NATIONAL D'ETUDES SPATIALES (FRANCE)
CNSA	CHINA NATIONAL SPACE ADMINISTRATION
CONAE	COMISION NACIONAL DE ACTIVIDADES ESPACIALES (ARGENTINA)
COP	CONFERENCE OF THE PARTIES (TO UNFCCC)
COSMIC	CONSTELLATION OBSERVING SYSTEM FOR METEOROLOGY, IONOSPHERE AND CLIMATE
COSMO-SKYMED	CONSTELLATION OF SMALL SATELLITES FOR THE MEDITERRANEAN BASIN OBSERVATION
CrIS	CROSS-TRACK INFRARED SOUNDER (NOAA)
CRU	CLIMATE RESEARCH UNIT (UNIVERSITY OF EAST ANGLIA, NORWICH, UK)
CryoSat	CRYOSPHERE SATELLITE (ESA)
CSIRO	COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (AUSTRALIA)
CTD	CONDUCTIVITY, TEMPERATURE AND DEPTH DEVICE
CYCLOPES	SATELLITE PRODUCTS FOR CHANGE DETECTION AND CARBON CYCLE ASSESSMENT AT THE REGIONAL AND GLOBAL SCALES (EU)
DBCP	DATA BUOY COOPERATION PANEL
DLR	DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT (GERMAN AEROSPACE CENTRE)
DMC	
DODS	DISTRIBUTED OCEANOGRAPHIC DATA SYSTEM
DWD	DEUTSCHER WETTERDIENST (GERMANY)
EARLINET	EUROPEAN AEROSOL RESEARCH LIDAR NETWORK
EARTHCARE	EARTH CLOUDS, AEROSOLS AND RADIATION EXPLORER (ESA/JAXA)

EASE-GRID	EQUAL-AREA SCALABLE EARTH GRID
ECMWF	EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
ECV	ESSENTIAL CLIMATE VARIABLE (AS DEFINED BY IP-04 (GCOS-92))
E-GVAP	EUMETNET GPS WATER VAPOUR PROGRAMME
ENVISAT	ENVIRONMENTAL SATELLITE (ESA)
EO	EARTH OBSERVATION
EPS	EUMETSAT POLAR SYSTEM
ERB	EARTH RADIATION BUDGET
ERS	EUROPEAN REMOTE SENSING SATELLITE (ESA)
ESA	EUROPEAN SPACE AGENCY
ESRL	EARTH SYSTEM RESEARCH LABORATORY (NOAA)
ETHZ	EIDGENÖSSISCHE TECHNISCHE HOCHSCHULE ZÜRICH (SWISS FEDERAL INSTITUTE OF TECHNOLOGY ZURICH)
ETM+	ENHANCED THEMATIC MAPPER PLUS (LANDSAT)
ETWS	EXPERT TEAM ON WIND WAVES AND STORM SURGES (JCOMM)
EUMETNET	NETWORK OF EUROPEAN METEOROLOGICAL SERVICES
EUMETSAT	EUROPEAN ORGANISATION FOR THE EXPLOITATION OF METEOROLOGICAL SATELLITES
EUROGOOS	EUROPEAN CONSORTIUM FOR GOOS
FAGS	FEDERATION OF ASTRONOMICAL AND GEOPHYSICAL DATA ANALYSIS SERVICES
FAO	FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
FAPAR	FRACTION OF ABSORBED PHOTOSYNTHETICALLY ACTIVE RADIATION
FCDR	FUNDAMENTAL CLIMATE DATA RECORD
FIRMS	FIRE INFORMATION AND MANAGEMENT SYSTEM (FAO)
FRA	FOREST RESOURCES ASSESSMENT PROJECT (FAO)
FRP	FIRE RADIATIVE POWER
FLUXNET	FLUX AND ENERGY EXCHANGE NETWORK
FSA	FEDERAL SPACE AGENCY (RUSSIAN FEDERATION)
FY	FENGYUN SATELLITE (CNSA)
GALION	GAW ATMOSPHERIC LIDAR OBSERVATION NETWORK
GAW	GLOBAL ATMOSPHERE WATCH (WMO)
GCM	GCOS COOPERATION MECHANISM
GCMD	GLOBAL CHANGE MASTER DIRECTORY
GCMP	GCOS CLIMATE MONITORING PRINCIPLES
GCOM	GLOBAL CHANGE OBSERVATION MISSION (JAXA)
GCOS	GLOBAL CLIMATE OBSERVING SYSTEM
GDPFS	GLOBAL DATA PROCESSING AND FORECASTING SYSTEMS
GDPS	GLOBAL DATA PROCESSING SYSTEM (WWW)
GEO	GROUP ON EARTH OBSERVATIONS
GEOSS	GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS
GERB	GEOSTATIONARY EARTH RADIATION BUDGET EXPERIMENT (EUMETSAT)
GEMS	GLOBAL AND REGIONAL EARTH-SYSTEM MONITORING USING SATELLITE AND *IN SITU* DATA
GEWEX	GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (WCRP)
GFMC	GLOBAL FIRE MONITORING CENTER
GFO	GEOSAT FOLLOW-ON (USA)
GHCN	GLOBAL HISTORICAL CLIMATOLOGY NETWORK
GHG	GREENHOUSE GAS
GHRSST	GLOBAL HIGH-RESOLUTION SST PROJECT
GIAM	GLOBAL IRRIGATED AREA MAP
GLCN	GLOBAL LAND COVER NETWORK
GLIMS	GLOBAL LAND ICE MEASUREMENTS FROM SPACE
GLOSS	GLOBAL SEA LEVEL OBSERVING SYSTEM
GMES	GLOBAL MONITORING FOR ENVIRONMENT AND SECURITY
GNSS	GLOBAL NAVIGATION SATELLITE SYSTEM
GODAE	GLOBAL OCEAN DATA ASSIMILATION EXPERIMENT
GODAR	GLOBAL OCEANOGRAPHIC DATA ARCHAEOLOGY AND RESCUE
GOFC-GOLD	GLOBAL OBSERVATION OF FOREST AND LAND COVER DYNAMICS (GTOS)
GOHS	GEODESY, OCEANOGRAPHY AND HYDROLOGY FROM SPACE (LEGOS)
GOME	GLOBAL OZONE MONITORING EXPERIMENT
GOOS	GLOBAL OCEAN OBSERVING SYSTEM
GOS	GLOBAL OBSERVING SYSTEM (WMO)
GOSAT	GREENHOUSE GASES OBSERVING SATELLITE (JAXA)
GOSHIP	GLOBAL OCEAN SHIP-BASED HYDROGRAPHIC INVESTIGATIONS PANEL
GOSIC	GLOBAL OBSERVING SYSTEMS INFORMATION CENTER
GOSUD	GLOBAL OCEAN SURFACE UNDERWAY DATA PILOT PROJECT
GPCC	GLOBAL PRECIPITATION CLIMATOLOGY CENTRE
GPCP	GLOBAL PRECIPITATION CLIMATOLOGY PROJECT
GPM	GLOBAL PRECIPITATION MISSION (NASA/JAXA)
GPS	GLOBAL POSITIONING SYSTEM
GRA	GOOS REGIONAL ALLIANCE

GRAS	GLOBAL NAVIGATION SATELLITE SYSTEM RECEIVER FOR ATMOSPHERIC SOUNDING (EUMETSAT)
GRDC	GLOBAL RUNOFF DATA CENTRE
GRUAN	GCOS REFERENCE UPPER AIR NETWORK
GSN	GCOS SURFACE NETWORK
GSICS	GLOBAL SPACE-BASED INTERCALIBRATION SYSTEM
GSOP	GLOBAL SYNTHESIS AND OBSERVATIONS PANEL (CLIVAR)
GTN	GLOBAL TERRESTRIAL NETWORK
GTN-G	GLOBAL TERRESTRIAL NETWORK FOR GLACIERS
GTN-H	GLOBAL TERRESTRIAL NETWORK FOR HYDROLOGY
GTN-L	GLOBAL TERRESTRIAL NETWORK – LAKES
GTN-P	GLOBAL TERRESTRIAL NETWORK FOR PERMAFROST
GTN-R	GLOBAL TERRESTRIAL NETWORK – RIVERS
GTOS	GLOBAL TERRESTRIAL OBSERVING SYSTEM
GTS	GLOBAL TELECOMMUNICATION SYSTEM (WMO WWW)
GTSPP	GLOBAL TEMPERATURE-SALINITY PROFILE PROGRAM
GUAN	GCOS UPPER-AIR NETWORK
HIRS	HIGH-RESOLUTION INFRA-RED SOUNDER
HOAPS	HAMBURG OCEAN ATMOSPHERE PARAMETERS AND FLUXES FROM SATELLITE DATA
HY	HAIYANG SATELLITE (CNSA)
HYDROLARE	INTERNATIONAL DATA CENTRE ON THE HYDROLOGY OF LAKES AND RESERVOIRS
I-GOOS	INTERGOVERNMENTAL IOC-WMO-UNEP COMMITTEE FOR GOOS
IAEA	INTERNATIONAL ATOMIC ENERGY AGENCY
IAGOS	INTEGRATION OF ROUTINE AIRCRAFT MEASUREMENTS INTO A GLOBAL OBSERVING SYSTEM
IASI	INFRARED ATMOSPHERIC SOUNDING INTERFEROMETER
ICESat	ICE, CLOUD AND LAND ELEVATION SATELLITE (NASA)
ICOADS	INTERNATIONAL COMPREHENSIVE OCEAN-ATMOSPHERIC DATASET PROJECT
ICOS	INTEGRATED CARBON OBSERVING SYSTEM
ICSU	INTERNATIONAL COUNCIL FOR SCIENCE
IGACO	INTEGRATED GLOBAL ATMOSPHERIC CHEMISTRY OBSERVATIONS
IGBP	INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME
IGOL	IGOS LAND THEME
IGOS	INTEGRATED GLOBAL OBSERVING STRATEGY
IGOS-P	INTEGRATED GLOBAL OBSERVING STRATEGY PARTNERSHIP
IGRA	INTEGRATED GLOBAL RADIOSONDE ARCHIVE (NCDC)
IGS	INTERNATIONAL GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) SERVICE
IGWCO	INTEGRATED GLOBAL WATER CYCLE OBSERVATIONS
IHALACE	INTERNATIONAL HALOCARBONS IN AIR COMPARISON EXPERIMENT
IMD	INDIAN METEOROLOGICAL DEPARTMENT
IO3C	INTERNATIONAL OZONE COMMISSION
IOC	INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)
IOCCG	INTERNATIONAL OCEAN COLOUR COORDINATING GROUP
IOCCP	INTERNATIONAL OCEAN CARBON COORDINATION PROJECT
IODE	INTERNATIONAL OCEANOGRAPHIC DATA AND INFORMATION EXCHANGE
IP-04	IMPLEMENTATION PLAN FOR THE GLOBAL OBSERVING SYSTEM FOR CLIMATE IN SUPPORT OF THE UNFCCC (GCOS-92, 2004)
IPA	INTERNATIONAL PERMAFROST ASSOCIATION
IPCC	INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
IPY	INTERNATIONAL POLAR YEAR
IR	INFRARED
ISCCP	INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT
ISD	INTEGRATED SURFACE DATASET (NCDC)
ISO	INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
ISRO	INDIAN SPACE RESEARCH ORGANISATION
JASON	ALTIMETRY SATELLITE (CNES/NASA)
JAXA	JAPAN AEROSPACE EXPLORATION AGENCY
JCOMM	JOINT TECHNICAL COMMISSION FOR OCEANOGRAPHY AND MARINE METEOROLOGY (WMO/IOC)
JMA	JAPAN METEOROLOGICAL AGENCY
LAI	LEAF AREA INDEX
LANDSAF	LAND SATELLITE APPLICATION FACILITY (EUMETSAT)
LANDSAT	EARTH OBSERVING SATELLITE FOR LAND APPLICATIONS (USGS/NASA)
LCCS	LAND COVER CLASSIFICATION SYSTEM
LDCM	LANDSAT DATA CONTINUITY MISSION
LEGOS	LABORATOIRE D'ETUDES EN GÉOPHYSIQUE ET OCÉANOGRAPHIE SPATIALES
LIDAR	LIGHT DETECTION AND RANGING SYSTEM
LPV	LAND PRODUCT VALIDATION SUBGROUP OF CEOS WGCV
LTER	LONG-TERM ECOLOGICAL RESEARCH NETWORK
MDG	MILLENNIUM DEVELOPMENT GOAL
MEGHA TROPIQUES	EARTH OBSERVING SATELLITE FOR WATER CYCLE IN TROPICS (CNES/ISRO)

MERIS	MEDIUM-RESOLUTION IMAGING SPECTROMETER (ESA)
METOP	METEOROLOGICAL OPERATIONAL POLAR SATELLITE (EUMETSAT)
MHS	MICROWAVE HUMIDITY SOUNDER (EUMETSAT)
MIPAS	MICHELSON INTERFEROMETER FOR PASSIVE ATMOSPHERIC SOUNDING
MISR	MULTIANGLE IMAGING SPECTRORADIOMETER (NASA)
MODIS	MODERATE-RESOLUTION IMAGING SPECTRORADIOMETER (NASA)
MODLAND	MODIS LAND GROUP
MOL	METEOROLOGICAL OBSERVATORY LINDENBERG (DWD)
MOPITT	MEASUREMENTS OF POLLUTION IN THE TROPOSPHERE
MOZAIC	MEASUREMENTS OF OZONE AND WATER VAPOUR BY IN-SERVICE AIRBUS AIRCRAFT
MSC	METEOROLOGICAL SERVICE OF CANADA
MSU	MICROWAVE SOUNDING UNIT (NOAA)
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (USA)
NCAR	NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (USA)
NCDC	NATIONAL CLIMATIC DATA CENTER (NOAA)
NDACC	NETWORK FOR THE DETECTION OF ATMOSPHERIC COMPOSITION CHANGE
NDBC	NATIONAL DATA BUOY CENTER (USA)
NDSC	NETWORK FOR DETECTION OF STRATOSPHERIC CHANGE
NEON	NATIONAL ECOLOGICAL OBSERVATORY NETWORK
NESDIS	NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE (NOAA)
NFMA	NATIONAL FOREST MONITORING AND ASSESSMENT
NIES	NATIONAL INSTITUTE FOR ENVIRONMENTAL STUDY (JAPAN)
NHS	NATIONAL HYDROLOGICAL SERVICE
NMS	NATIONAL METEOROLOGICAL SERVICE
NOAA	NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (USA)
NPP	NPOESS PREPARATORY PROJECT (USA)
NPOESS	NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (USA)
NSIDC	NATIONAL SNOW AND ICE DATA CENTER (USA)
NWP	NUMERICAL WEATHER PREDICTION
OCO	ORBITING CARBON OBSERVATIONS SATELLITE (NASA)
OCEANSITES	WORLDWIDE SYSTEM OF DEEPWATER REFERENCE STATIONS
OOPC	OCEAN OBSERVATIONS PANEL FOR CLIMATE (GCOS/GOOS/WCRP)
OPENDAP	OPEN-SOURCE DATA ACCESS PROTOCOL
OPERA	EUROPEAN OPERATIONAL WEATHER RADAR NETWORK
PAR	PHOTOSYTHETIC ACTIVE RADIATION
PCA	PLANT CANOPY ANALYZER (PCA-LICOR / LAI)
PEHRPP	PROGRAM TO EVALUATE HIGH-RESOLUTION PRECIPITATION PRODUCTS
PICO	PANEL FOR INTEGRATED COASTAL OBSERVATIONS (GOOS)
POGO	PARTNERSHIP FOR OBSERVATION OF THE GLOBAL OCEANS
PSMSL	PERMANENT SERVICE FOR MEAN SEA LEVEL (UK)
QUIKSCAT	QUICK SCATTEROMETER (NASA)
R/SSC-CM	REGIONAL/SPECIALIZED SATELLITE CENTRES FOR CLIMATE MONITORING
RA	REGIONAL ASSOCIATION (WMO)
RAPIDEYE	HIGH-RESOLUTION MULTISPECTRAL EARTH OBSERVING SATELLITE
RBSN	REGIONAL BASIC SYNOPTIC NETWORK (WWW/GOS)
REDD	REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION IN DEVELOPING COUNTRIES
RO	RADIO OCCULTATION
ROOS	EUROGOOS REGIONAL OPERATIONAL OCEANOGRAPHIC SYSTEM (GOOS)
ROSHYDROMET	RUSSIAN FEDERAL SERVICE FOR HYDROMETEOROLOGY AND ENVIRONMENTAL MONITORING
SAC-C	ARGENTINE SATELITE DE APLICACIONES CIENTIFICAS-C (ARGENTINA)
SAF	SATELLITE APPLICATION FACILITY (EUMETSAT SEA ICE SAF / LANDSAT SAF)
SAGE	STRATOSPHERIC AEROSOL AND GAS EXPERIMENT
SAHFOS	SIR ALISTER HARDY FOUNDATION FOR OCEAN SCIENCE
SAON	SUSTAINED ARCTIC OBSERVING SYSTEM
SAR	SYNTHETIC APERTURE RADAR
SARAL	HIGH-ACCURATE OCEANOGRAPHY ALTIMETER (CNES/ISRO)
SBA	SOCIETAL BENEFIT AREA (GEO)
SBI	SUBSIDIARY BODY FOR IMPLEMENTATION (UNFCCC)
SBSTA	SUBSIDIARY BODY FOR SCIENTIFIC AND TECHNOLOGICAL ADVICE (UNFCCC/COP)
SBUV	SOLAR BACKSCATTER ULTRAVIOLET RADIOMETER
SCARAB	SCANNER FOR RADIATION BUDGET (CNES/ISRO)
SCIAMACHY	SCANNING IMAGING ABSORPTION SPECTROMETER FOR ATMOSPHERIC CARTOGRAPHY (ESA)
SCOPE-CM	SUSTAINED COORDINATED PROCESSING OF ENVIRONMENTAL SATELLITE DATA FOR CLIMATE MONITORING (WMO)
SCOR	SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH
SEAWIFS	SEA-VIEWING WIDE FIELD-OF-VIEW SENSOR (NASA)
SEVIRI	SPINNING ENHANCED VISIBLE AND INFRA RED IMAGER

SGLI	SECOND GENERATION GLOBAL IMAGER (JAXA)
SHADOZ	SOUTHERN HEMISPHERE ADDITIONAL OZONESONDES
SLP	SEA-LEVEL PRESSURE
SMM	SPECIAL MAIN TELECOMMUNICATION NETWORK MONITORING EXERCISE (WMO)
SMMR	SCANNING MULTICHANNEL MICROWAVE RADIOMETER
SMOS	SOIL MOISTURE AND OCEAN SALINITY MISSION (ESA)
SOCAT	SURFACE OCEAN CO_2 ATLAS
SOGE	SYSTEM FOR OBSERVATION OF HALOGENATED GREENHOUSE GASES IN EUROPE
SOHO	SOLAR AND HELIOSPHERIC OBSERVATORY (NASA)
SOOP	SHIP OF OPPORTUNITY PROGRAMME
SORCE	SOLAR RADIATION AND CLIMATE EXPERIMENT (NASA)
SOT	SHIP OBSERVATIONS TEAM (JCOMM)
SPOT HRV	SATELLITE PROBATOIRE D'OBSERVATION DE LA TERRE HIGH-RESOLUTION
SRTM	SHUTTLE RADAR TOPOGRAPHY MISSION
SSM/I	SPECIAL SENSOR MICROWAVE/IMAGER
SSS	SEA-SURFACE SALINITY
SST	SEA-SURFACE TEMPERATURE
SURFA	SURFACE FLUX ANALYSIS PROJECT
SWE	SNOW WATER EQUIVALENT
TAO	TROPICAL ATMOSPHERE OCEAN PROJECT
TAR	THIRD ASSESSMENT REPORT (IPCC)
TEMS	TERRESTRIAL ECOSYSTEM MONITORING SYSTEM
TERRASAR	X-BAND SAR MISSION
TIM	TOTAL IRRADIANCE MONITOR (NASA)
TIP	TROPICAL MOORED BUOY IMPLEMENTATION PANEL
TOMS	TOTAL OZONE MAPPING SPECTROMETER (NASA)
TOPC	TERRESTRIAL OBSERVATION PANEL FOR CLIMATE (GCOS/GTOS)
TOPEX/POSEIDON	OCEAN SURFACE TOPOGRAPHY ALTIMETER EXPERIMENT (NASA/CNES)
TRMM	TROPICAL RAINFALL MEASURING MISSION (JAXA/NASA)
TSIS	TOTAL SOLAR IRRADIANCE SENSOR (NOAA/NASA)
ULS	UPWARD LOOKING SONAR
UN	UNITED NATIONS
UNEP	UNITED NATIONS ENVIRONMENT PROGRAMME
UNESCO	UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
UNFCCC	UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE
USGS	US GEOLOGICAL SURVEY
UTC	UNIVERSAL TIME COORDINATED
UV	ULTRAVIOLET
VGT	SPOT VEGETATION SENSOR
VIIRS	VISIBLE INFRARED IMAGING RADIOMETER SUITE (NPOESS)
VOS	VOLUNTARY OBSERVING SHIP
VOSCLIM	VOLUNTARY OBSERVING SHIP CLIMATE PROJECT
WCRP	WORLD CLIMATE RESEARCH PROGRAMME
WDC	WORLD DATA CENTRE
WDC ASHEVILLE	WORLD DATA CENTRE FOR METEOROLOGY, ASHEVILLE (NCDC)
WDC-GG	WORLD DATA CENTRE FOR GREENHOUSE GASES (JMA)
WDC-RSAT	WORLD DATA CENTRE FOR REMOTE SENSING OF THE ATMOSPHERE
WG-ARO	WORKING GROUP ON ATMOSPHERIC REFERENCE OBSERVATIONS (AOPC)
WGCV	WORKING GROUP ON CALIBRATION AND VALIDATION (CEOS)
WGMS	WORLD GLACIER MONITORING SERVICE
WIDAC	WORLD INTEGRATED DATA ARCHIVE CENTRE
WIGOS	WMO INTEGRATED GLOBAL OBSERVING SYSTEM
WIS	WMO INFORMATION SYSTEM
WMO	WORLD METEOROLOGICAL ORGANIZATION
WOUDC	WORLD OZONE AND ULTRAVIOLET RADIATION DATA CENTRE
WRDC	WORLD RADIATION DATA CENTRE
WWW	WORLD WEATHER WATCH (WMO)
XBT	EXPENDABLE BATHYTHERMOGRAPH
XCTD	EXPENDABLE CONDUCTIVITY, TEMPERATURE AND DEPTH SYSTEM

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