GLOBAL CLIMATE OBSERVING SYSTEM

GLOBAL TERRESTRIAL OBSERVING SYSTEM

REPORT OF THE GCOS/GTOS TERRESTRIAL OBSERVATION PANEL

Second Session

(London, UK, April 19-21, 1995)

August 1995

GCOS-18

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Intergovernmental Oceanographic Commission

United Nations Education, Scientific and Cultural Organization

Food and Agriculture Organization

United Nations Environment Programme

International Council of Scientific Unions

World Meteorological Organization

TABLE OF CONTENTS

ANNEXES

APPENDICES

REPORT OF THE SECOND SESSION OF THE GCOS/GTOS TERRESTRIAL OBSERVATION PANEL

1. OPENING OF THE SESSION

1.1 Dr John Townshend, Chairman of the joint Global Climate Observing System (GCOS)/Global Terrestrial Observing System (GTOS) Terrestrial Observation Panel (TOP) opened the meeting on 19 April at the Department of Geography, University College, London, UK. He welcomed the participants (Annex 1).

1.2 The Chairman briefly reviewed the overall progress of the TOP to date, and gave a brief review of the results from TOP I. He reminded people that this was a joint project between GCOS and GTOS, but that the purpose of this meeting was to develop the TOP Plan that would serve as the climate plan for GTOS and the terrestrial plan for GCOS.

1.3 The Chairman reviewed the provisional agenda (Annex II), and the draft outline of the TOP Plan. There were modifications to the Plan outline, which was then accepted. The working arrangements were accepted and the Panel divided into three working groups, hydrosphere, cryosphere, and biosphere. The hydrosphere working group considered all freshwater, including lakes, rivers, evaporation and soil moisture. The cryosphere working group considered all frozen waters, including sea ice. The biosphere working group considered all terrestrial organisms, land cover and land use.

2. INTRODUCTION AND BACKGROUND ON GTOS AND GCOS

2.1 Dr David Norse, Chairman of the ad hoc Scientific and Technical Planning Group for GTOS, gave a progress report on the GTOS planning activities. He explained that the second meeting of the GTOS Scientific and Technical Planning Group had met in Rabat, Morocco, in January 1995. As a result of that meeting, it was recommended that Working Group II be reorganized. Sub-groups have been established to develop the requirements for anthropogenic impacts on natural systems, sustainability of managed ecosystems, competition for water resources, loss of biodiversity, climate change and land use planning and land degradation.

2.2 Dr Norse explained that GTOS was planning on developing a distributed management structure. There would be a limited number of staff in a central secretariat. It is anticipated that the regional centres would play a central role in the establishment of the GTOS system and in developing national monitoring programmes. Operation would remain flexible so that a range of national preferences could be accommodated.

2.3 Dr Norse reported on an initial meeting about the World Hydrological Cycle Observing System (WHYCOS) that was held in Geneva in February 1995. The critical elements of WHYCOS that are relevant to the TOP include the following:

- There will be approximately 1200 runoff stations world wide;
- There will be a need selectively, to upgrade some existing stations so they can perform within accepted international standards;
- Current plans are to start in Africa and then expand from there;
- Ancillary data collected at hydrological sites will be of benefit to GCOS and GTOS.

2.4 Dr Harold Kibby from the GCOS Joint Planning Office (JPO) updated the group on the progress of GCOS. He stated that the GCOS Plan was in the final stages of review and would be published shortly. He reviewed the structure of GCOS showing a diagram of the relationship between the JSTC, the JPO and the planning panels.

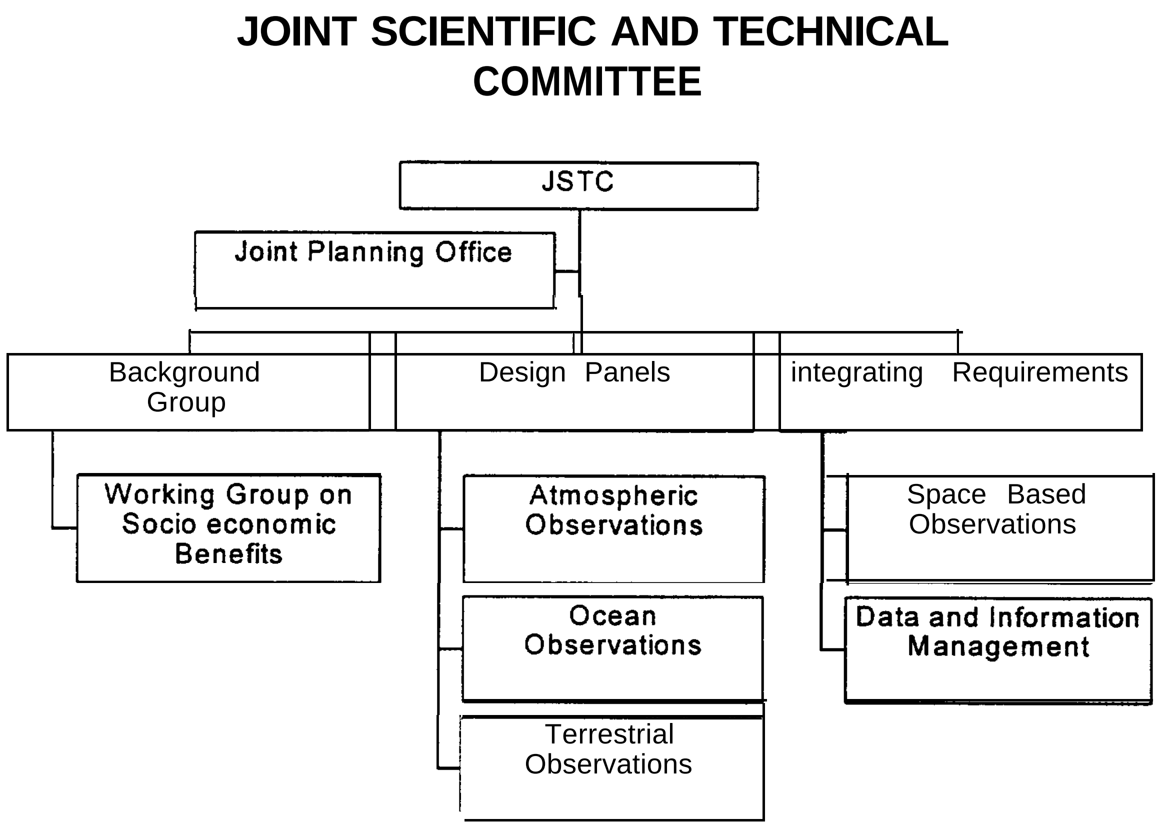

Figure 1. Structure of the JSTC. The Ocean Observation Panel for Climate is joint with GOOS and WCRP; the Terrestrial Observation Panel, with GTOS.

2.5 The GCOS objectives are to provide the data required to meet the needs for:

- Climate monitoring, climate change detection and response monitoring, especially in terrestrial ecosystems and mean sea level;
- Application to national economic development;
- Research towards improved understanding, modelling and prediction of the climate system.

2.6 Dr Kibby explained that from a GCOS perspective, it is desirable for the TOP to develop a single plan which should cover all of the terrestrial needs for climate information and all of the climate needs for terrestrial information. In other words, one TOP Plan should serve the needs for both terrestrial needs of GCOS and climate needs of GTOS. GCOS also feels that a common data and information management plan, and space plan, need to be developed for all three Global Observing Systems, as proposed by the GTOS and GOOS representatives to the 1994 JSTC meeting (See GCOS-4).

RELATIONSHIP BETWEEN OBSERVING SYSTEMS

	ATMOSPHERE		LAND	OCEANS
	WWW	**GAW**	**GTOS**	**GOOS**
GCOS	***CLIMATE***		***CLIMATE***	***CL/MATE***
	Weather	Pollution Ozone	Land degradation Pollution and toxicity Biodiversity Sustainability of managed systems Anthropogenic impacts on natural systems Freshwater	Marine services Coastal zone management Ocean health Living marine resources

Figure 2. Relationship between major Global Observing Systems

3. OPENING STATEMENT OF THE CHAIRMAN

3.1 The Chairman explained that this was really a drafting meeting and that it was critical that the draft of the TOP Plan be finalized. He pointed out that as a result of several GTOS meetings, some modifications to the original TOP design had been made. He urged the biosphere group to finalize a design and asked the hydrosphere and cryosphere groups to make a beginning on designs for those respective systems. He further stated that it was critical that each group draft sections on the initial operating system, data and information management, necessary tasks to be undertaken to move forward, and longer-term research needs. It was stated that if the TOP Plan was to gain widespread scientific acceptability it was necessary to do a good job, referencing statements. He encouraged the group to provide references even after they went home.

4. INVITED REPORTS

4.1 Most of the time at the workshop was spent in working groups. However, the following reports were given on the morning of the first day.

4.2 Report on the GCOS Space-based Observatton Panel and Plan (See GCOS-15)

4.2.1 The GCOS Space-based Observation Panel must have an on-going capability to keep under review the implications for space-based observation systems as the requirements for long-term global climate observations are progressively refined and further quantified. The Panel must also be well equipped to interact both individually and via the Committee on Earth Observation Satellites (CEOS), with the various agencies responsible for promoting and funding space programmes. The Panel must be cognizant of the requirements and priorities of other non-climate user bodies, with which it will have not only large areas of common ground, but also at times areas of conflicting priorities.

4.2.2 Dr Peter Ryder said the Plan for Space-based Observations was undergoing final review and was to be finalized at the meeting of the Space-based Observation Panel that was going to meet May 9 through May 13. Conventional surface-based observations cannot provide all of the data required for investigating the climate, and for many areas (e.g., the southern oceans, polar regions, desert areas, and other large parts of the continents) they provide very little data at all. Many GCOS requirements can only be met in a practical and cost-effective manner by the use of space-based observations; only space-based observations can provide the continuous and consistent observational data coverage over the entire globe which is required. Obviously, they are a practical source for measurements which cannot be made any other way (e.g., ocean topography, polar ice sheets extent, etc.).

4.2.3 It is also important to ensure that space-based data are widely available if their value is to be realized. This demands a data policy which facilitates the free and open exchange of data and the technical means to implement the policy. This is nowhere more important than in developing countries where the absence of the means to access, exchange and use data and products limits the collection and the exploitation of both surface and space-based data for sustainable development.

4.2.4 The GCOS Space Plan (GCOS-15) recognizes the importance of collaboration with major research programmes, such as those of the World Climate Research Programme (WCRP) and the International Geosphere-Biosphere Programme (IGBP). Their accomplishments will assist efforts to define requirements. The implementation of the Plan will in mm lead to a continuous supply of data for their programmes.

4.2.5 The production of the GCOS Space Plan is a first step to identifying which current or planned space observation systems should be considered as contributors to the GCOS, what gaps could be filled by minor modifications to existing programmes, and where there are more major gaps requiring longer-term attention.

4.2.6 The task is an iterative one which will continuously develop in time both as scientific advances better define the observational requirements, and/or as space programmes develop their programmes and funding policies. Those responsible for GCOS have to be prepared to respond quickly to such factors in a manner which continually optimizes the contribution relevant space-based observations can make in relation to available resources.

4.2.7 Finally, Dr Ryder stated he would welcome comments from the TOP regarding the Space Plan, but since the Space Panel was meeting in two weeks that he needed them by the end of the meeting. He suggested that the TOP should consider their needs in detail and that any that could not be included in this draft would be included in future versions of the Space-based Observation Plan. Dr Ryder invited the TOP to select a person to become a member of the GCOS Space-based Observation Panel. Dr Joseph Cihlar was nominated and accepted the position.

4.3 Report on Cryosphere Needs

4.3.1 Dr Roger Barry gave a report on the need for cryospheric observations for climate purposes. The complete text of his recommendations will be included in the TOP Plan. The following is a summary of his remarks.

4.3.2 The cryosphere includes components that respond to daily time-scale forcing and others that respond only to long-term (century or longer) effects. In the former category is snow cover, while in the latter are continental ice sheets. Here, we focus on components of the cryosphere that offer useful information in monitoring the climate system and in detecting natural trends or changes due to human activities on decadal time scales. The requirements for monitoring cryospheric variables have recently been reviewed and documented in two workshop reports (See the TOP Plan).

4.3.3 Monitoring of the cryosphere is of importance for improved understanding of global climate, hydrologic systems and sea-level change, as well as for impact assessments and earth system modelling. The complex nature of most cryospheric variables has necessitated that observations be made using a variety of methods involving surface and remote-sensing measurements and a range of sensors. Currently, efforts are underway to try and combine the preferred features of each method in order to obtain optimal representations of the important parameters. Hence, there is unlikely to be a unique observational solution in many areas of cryospheric monitoring. In several instances (permafrost conditions, ice sheet mass balance), there are currently no routine observations, while other remote sensing measurements (snow water equivalent, sea ice thickness) are still in a research mode. In the case of surface observations of snow cover and freshwater ice thickness, major efforts are still needed to assemble and quality-check archival records. The type and quantity of data on frozen ground conditions and their whereabouts are only just beginning to be inventoried. The availability of data sets for use in monitoring assessments has also been discussed in a number of papers by a number of different authors. A particularly focused survey has been made of cryospheric data for Canada in the context of climate system data requirements.

4.3.4 Dr Barry recommended that the TOP consider a number of parameters and necessary frequency of observations for snow cover, sea ice, glaciers and ice sheets and permafrost. (The final set of recommended parameters is included in the TOP Plan. For a simple listing of the recommended variables see Appendix 1. For a complete discussion of each variable the reader is referred to the upcoming TOP Plan.)

4.4 Report on Soil Carbon

4.4.1 Dr Keith W .T. Goulding reported on the need for soil carbon measurements. Soil carbon is the largest terrestrial carbon pool and the largest biospheric carbon pool subject to anthropogenic impact at the time scale of decades to centuries. Knowledge of the size of the soil carbon pool and its dynamics is therefore essential for conducting a national carbon dioxide flux inventory and for modelling the global carbon cycle. Soil carbon is also a controlling variable for many other soil variables; e.g., water holding capacity, cation exchange capacity and erodability. Soil carbon stocks are one index of sustainable agriculture. Total soil carbon consists of a number of components with different turnover times. At centres and stations, the carbon should be fractionated into at least microbial carbon and particulate organic matter. The particulate organic matter should be measured at least every 10 years. The microbial biomass carbon should be measured more frequently; perhaps annually. Most of the changes in soil carbon take place in the top 30 cm, but significant amounts of carbon lie at greater depths. Measurements at centres and stations should be O-30 cm and 30 cm-l m. It was therefore suggested that the TOP Panel consider microbial carbon as a variable to be observed.

5. WORKING GROUP PROGRESS

5.1 The meeting then broke into working groups to produce the TOP Plan. As previously stated, the TOP Plan has been developed to meet the terrestrial requirements for the Global Climate Observing System (GCOS) and the climate requirements of the Global Terrestrial Observing System (GTOS). The strategy for implementing the Plan will be through GTOS in co-operation with the GCOS, WHYCOS, the World Climate Research Programme (WCRP), and the International Geosphere-Biosphere Programme (IGBP).

5.2 The objective of the TOP Plan is to provide a rationale for the structure and implementation of the initial observing system. It describes the **minimum** set of land-based variables that are required to assess the impacts of, predict, and detect, climate change. The Plan recognizes that a comprehensive observing system must address the critical parameters by making measurements with sufficient and adequate precision, spatial and temporal resolution, and with long-term continuity. The data must be compiled and collated in a fashion that is useful to the users. Ultimately, the products that are produced by GTOS and others must include ones that are in a form that can be easily utilized by policy and decision makers. For much of the land and climate system, such comprehensive observations, data bases and associated products are not available.

5.3 The Plan consists of seven parts:

- An introduction:
- A rationale for selection of specific variables;
- A design for sampling sites, including a rationale for site selection;
- A short description of the GCOS data and information system;
- Specific tasks to be completed to implement the system;
- A literature cited section;
- Appendices, including a detailed description of the individual variables.

5.4 The following steps were agreed to complete the Plan:

• Draft Plan to TOP	Mid-May
• Comments from TOP	Early June
• Draft Plan to TOP, JSTC and sponsors	Early July
• Draft Plan to scientific community	Mid-July
• Review comments due	Early August
• Revised Plan to TOP	Late August
• Publish	Mid-September

Editorial note: Developments subsequent to the meeting have modified the above schedule slightly. The TOP Plan will be in final form and presented for JSTC approval at the October meeting and published in final form after that meeting. It is intended to have a draft final report ready by mid-September for distribution to JSTC members.

5.5 All of the working groups completed the identification of a number of key variables that should be included in the observing system, (Appendix 1) provided good justifications for the selected variables, and identified a series of tasks that need to be completed to begin to implement the required observations (Appendix 2). The biosphere group completed work on the design for a system that was begun at TOP I and modified by working groups of GTOS (Appendix 3). The hydrosphere and cryosphere groups began work on design for their respective sampling sites, but concluded additional work would be needed before it could be finalized. In addition to the draft summary of the Plan the working groups provided some comments on the Space Plan and made recommendations on several observations (Table 1).

6. CLOSURE OF THE MEETING

The Chairman thanked the panel for the participation in the meeting. No formal date was set for the next meeting, though it was agreed that the next meeting should be in the spring of 1996. The meeting was adjourned at 3.30 p.m. on 21 April, 1995.

Parameter	Scale	Resolution	Frequenc	Accuracy	Comments
SURFACE ALBEDO [1]	Global Global	30 km 30 m	10 days seasonal	2% 2%	GCM forcing Energy balance
MULTISPECTRAL RADIANCES [1]	Global Global	1 km 30 m	10 days seasonal	10 w/m^2 10 w/m^2	Derivation of surface fluxes
MULTISPECTRAL REFLECTANCE [1]	Global	1 km 30 m	10 days seasonal	1 % 1 %	Derivation of surface properties
VEGETATION INDEX	Global	1 km	10 days	5%	Biospheric dynamics
LEAF AREA INDEX	Global Global	30 km 1 km	10 days 10 days	10% 5%	GCM boundary condit. Vegetation productivity
FPAR	Global Global	30 km 1 km	10 days 10 days	2% 2%	GCM forcing Vegetation productivity
PAR	Global	30 km	hourly	2%	GCM boundary condit.
LAND COVER LAND USE	Global Global	1 km 30 m	5 years 5 years	-	GCM boundary condit. Impact assessment
FIRE EXTENT	Global	1 km	10 days	1 km	Trace gases/aerosols
FIRE TEMPERATURE	Global	1 km	10 days	50 K	Trace gases/aerosols
SURFACE TEMPERATURE	Global	1 km	10 days	0.5 K	Global surface temperature trends
LAND TOPOGRAPHY	Global	10 m vert 100 m hor	once	2 m 30 m	Correction of remote-sensing data/energy balance
SNOW EXTENT [3]	Regional Local	3okm 100 m	7 days 7 days	3okm 30 m	Regional temperature trends; Hydrology
ICE SHEET and GLACIER EXTENT [3]	Regional	100 m	amlually	100 m	Ice sheet and glacier advance and retreat
ICE SHEET ELEVATION 3)	> 60 N	100 m	10 years	5 cm	Ice sheet, stream and shelf dynamics, ice sheet mass balance [2]

1) Atmospheric correction requires global fields of aerosol optical thickness, water vapour and ozone;
2) For ice sheet mass balance, resolution of 10^3 km^2 is sufficient;
3) Cryospheric needs were considered by the GCOS/GTOS TOP; sea ice by the OOSDP

Table 1. Terrestrial Requirements from the GCOS/GTOS Terrestrial Observation Panel. (This version of the table is the version that was slightly modified by the Space-based Observation Panel.)

Annex I

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Annex II

AGENDA

1. Welcome and opening of the meeting
2. Welcome and update on GTOS
3. Welcome and update on GCOS
4. Statement of the Chairman and objectives of meeting
5. Plenary session

   Report on space-based observations and GCOS Space Plan

   Report on cryosphere observations

   Report on need for soil carbon observations
6. Working groups meet

   Hydrosphere

   Cryosphere

   Biosphere
7. Working group reports
8. Future business
9. Closure of the session

Annex III

TERMS OF REFERENCE FOR THE GCOS/GTOS TERRESTRIAL OBSERVATION PANEL

Recognizing the need for specific and technical input concerning terrestrial observations for climate purposes, the Joint Scientific and Technical Committee (JSTC) for the Global Climate Observing System (GCOS) and the ***Ad hoc*** Scientific and Technical Planning Group (STPG) for the Global Terrestrial Observing System (GTOS) have jointly established a Terrestrial Observation Panel (TOP) with the following terms of reference.

Terms of Reference:

- In accordance with the GCOS Plan (GCOS-14), and in co-operation with the GTOS STPG, to plan, formulate and design a long-term systematic observing system for those terrestrial properties and attributes which control the physical, biological and chemical processes affecting climate, are affected by climate change or serve as indicators of climate change, and which are essential to provide information concerning the impact of climate and climate change;
- To review the needs of the user communities for climate related data and to ensure timely provision of data sets at appropriate space and time scales and in suitable forms, paying particular attention to the needs of developing countries;
- To develop a strategy based on the concept of the Initial Operational System (IOS) which includes the assessment of existing systems, the determination of deficiencies and the recommendation of necessary enhancements, and a comprehensive data system;
- To seek review and support for the implementation from other relevant research or operational programmes (e.g., WCRP, IGBP, WWW, GAW, WHYCOS, GEMS, GRID, etc.) and to collate, review publish and prioritize data requirements and observing system specifications;
- To co-ordinate activities with other GCOS and GTOS panels and task groups to ensure consistency of requirements with the overall programmes;
- To recommend actions to address the gaps in present and planned systems;
- To report regularly to the JSTC and STPG.

In order to accomplish their above objectives the Panel will:

- Determine and document significant user/participant needs;
- Review existing reports and studies concerning requirements for the terrestrial/ecosystem measurements to meet climate objectives of GCOS/GTOS;
- Review the current and planned observational activities of:

  i) the relevant core projects and activities of WCRP (e.g., GEWEX, ISLSCP, ISCCP, etc.) and IGBP (e.g., GCTE, BAHC, DIS, GAIM, etc.),

  ii) the Human Dimensions of Global Change Programme (HDP) (especially those on land use and land cover change),

  iii) relevant programmes of international agencies (e.g., ICSU, WMO, UNESCO, FAO, UNEP);

- Identify major gaps in current and planned observing systems; propose prioritized options to address these gaps;
- Review existing information systems, particularly regarding their capability to provide the climate community with the terrestrial/ecosystem data needed;
- Review existing mechanisms to implement measurements and data management, assess their ability to meet existing and foreseen needs for terrestrial/ecosystem data and recommend mechanisms as appropriate;
- Publish and update GCOS/GTOS studies as planning documents;
- Make recommendations as appropriate.

Chairman: Dr John Townshend, USA.

Appendix 1
List of Recommended Terrestrial Variables

Detailed specifications for these variables were developed during the meeting and will be reported in the TOP Plan.

RADIATION (AND RELATED VARIABLES)
Radiation incoming
Radiation reflected - short-wave
Radiation - Fraction of Photosynthetically Active Radiation (FPAR)
Radiation - Outgoing Long-Wave
Aerosols
Cloud cover
Temperature-air

TRACE GASES
Methane (CH_4)
Carbon dioxide (CO,)

LAND COVER/LAND USE
Land cover
Land use

BIOPHYSICAL PROPERTIES OF VEGETATION
Leaf area index (LAI)
Net primary productivity (NPP)
Net ecosystem productivity (NEP)
Biomass - above-ground
Biomass - below-ground
Necromass
Roughness - Surface
Vegetation structure

SOIL PROPERTIES
Soil moisture
Soil carbon
Soil total nitrogen
Soil phosphorus
Soil bulk density
Soil particle size distribution
Soil surface state
Rooting depth

HYDROLOGY
Atmospheric Water Content Near the Surface (Relative humidity)
Evapotranspiration
Ground water storage fluxes
Precipitation
Runoff - River
Runoff land/ocean - transport of biogeochemicals

CRYOSPHERIC PROPERTIES
Sea ice
Sea ice motion
Snow and ice cover area
Snow cover area and snow water equivalent
Ice sheet mass balance
Ice sheet surface balance
Ice sheet extent and topography
Glaciers and ice caps
Lake freeze up and break up (timing)
Permafrost - active layer
Permafrost - thermal state

ANCILLARY VARIABLES
Topography
Wind Speed

Appendix 2
Framework for Implementing Necessary Observations

This appendix describes the major tasks that need to be completed to implement the initial observing system (For additional details see the upcoming TOP Plan). There are selected tasks that are required by all groups those are listed first, followed by a listing of specific tasks required by individual groups.

(Editorial Note: The responsible organizations are recommendations from TOP as to appropriate places to begin the tasks. The GTOS secretariat and the JPO of GCOS will need to make the contacts to request specific organisations participate in the implementation of the task. The completion of the tasks below is dependent upon availability of adequate resources.)

Identify and evaluate existing components

Description

The GCOS/GTOS Terrestrial Observation System will primarily be built from existing components. As a first step it is essential to build a comprehensive and systematic data base of potential contributing elements. The data base must include: location, history and future, research focus and variables collected, responsible institutions, contact persons and addresses, data management, and networks to which they belong. For the hydrosphere and cryosphere, this task will follow the development of a detailed sampling scheme. The biosphere portion of this task was initiated in 1995.

Time Frame

Hydrosphere: Summer 1996.
Cryosphere: Spring 1996.
Biosphere: Spring 1996.

Responsible Agencies/Organizations:

Hydrosphere: WMO/UNESCO/GTOS.
Cryosphere: TOP Workshops.
Biosphere: Secretariat of GTOS and JPO of GCOS.

Select existing sites in network

Description

Following the identification and evaluation of existing sites and based on the generic and specific criteria described in the TOP Plan, an initial list as to those providing the most useful climate data would be made. The list will be circulated and under the aegis of the TOP, a group of experts representative of all regions of the world will meet to make the final selection of stations for the IOS.

<u>Time Frame</u>:

Hydrosphere:	Autumn 1996.
Cryosphere:	spring 1997.
Biosphere:	Summer 1996.

<u>Responsible Agencies/Organizations:</u>

Hydrosphere:	WMO/ WHYCOS/ GTOS.
Cryosphere:	TOP Workshops.
Biosphere:	Secretariat of GTOS and JPO of GCOS.

Definition of methods for ground data collection

<u>Description:</u>

The preparation of global data sets for specific parameters demands consistent protocols. It is proposed to prepare a document specifying acceptable methods for individual measurements to be made, and to circulate this document to centres, stations and research groups that participate (or potentially may participate) in GCOS/GTOS. The document should be prepared by a small task group that includes representatives of existing centres or research groups collecting such data in different parts of the world.

<u>Time Frame</u>

Hydrosphere:	December 1995.
Cryosphere:	Summer 1996.
Biosphere:	Spring 1996.

<u>Responsible Agencies/Organizations</u>:

Hydrosphere:	WMO/ WHYCOSI GTOS.
Cryosphere:	TBD.
Biosphere:	Secretariat of GTOS and JPO of GCOS.

Establish data management system for terrestrial variables

Description:

To the fullest extent possible, the GCOS data and information system will rely upon existing national and international programmes. Systems operated by these programmes, such as the ICSU World Data Centres, World Weather Watch (WWW) of the WMO, Global Ocean Observing System (GOOS) and many others, will be enhanced as necessary to meet GCOS requirements. To make best use of existing facilities and expertise, the GCOS data and information system will be based on a hierarchy of local, national, regional, and global institutions. The first step will be to solicit proposals from major data centres to act as the initial focal points for storing and archiving GCOS data. Following a year's evaluation of progress, further centres will be selected and added to the system.

Time Frame:

Select centre by April 1996.

Responsible Agencies/Organizations:

Secretariat GTOS and JPO of GCOS.

Data access

Description:

Many existing data are not accessible, either within-country or internationally. There are three components to this task: promoting political commitment to data sharing; removing practical barriers by enhancing electronic interconnectivity and metadata; and data rescue and digitization.

Time frame

1996-2000.

Responsible Agencies/Organizations:

JSTC/Sponsoring Agencies/UN system for political commitment; GCOS-DIS for connectivity and metadata; sectoral interest groups for data rescue and digitization.

Hydrosphere

From a climate perspective, develop a long-term strategy and sampling design for monitoring key hydrological parameters (runoff, aerial extent of lakes etc.)

Description:

Currently, there is no overall strategy for detecting climatic change through hydrological variables; for understanding how changes in the hydrosphere feed back to climate; or for determining the impacts of climate on the hydrosphere. However, there are a number of stations collecting relevant information, but there is no scheme to assure that all of the information needed for climate purposes is being collected. This scheme will provide the framework to make judgements as to the adequacy of existing data sources.

When the work of WMO (comparing evapotranspiration ***in situ*** monitoring methods) and BAHC (water flux tower-based network) is concluded, the TOP, in co-operation with BAHC should organize a small group to review the work and determine how the observation system needs to be amended to reflect the conclusions of this effort.

Time Frame:

Initial workshop Autumn/Winter 1995.

Responsible Agencies/Organizations:

TBD.

Brochure on why it is relevant for providers to contribute precipitation, runoff, ground water, surface storage to GCOS/GTOS

Description:

First approach to (mainly) Hydrological Services explaining why they are asked to contribute to global data sets. At least it should explain what the relevance of this data is for global climate change research.

Completion Date:

Early 1996.

Responsible Agencies/Organizations

WMO, or Secretariat of GTOS and JPO of GCOS.

Surface water storage catalogue

Description:

Develop an inventory of global information currently available for surface water storage bodies (lakes, reservoirs, watersheds). The survey would include name and location of water body, nature (lake, reservoir, watershed) where dynamic data are available, how they are available (e.g., paper vs. digitized), if it is available in real time, and whether a volumetric transfer function has been developed. The work would take approximately one year and should provide GTOS/GCOS with a historical data base so that assessments of future change can be made.

Completion Date:

December 1996.

Responsibility

WMO.

Expand the number of stations contributing to GPCC

Description:

The aim is to reach a number of 30,000 stations regularly (i.e. twice a year) contributing data to GPCC. There is considerable work involved in this, such as contacting national focal points, obtaining metadata, evaluating the stations to see if they comply with WMO standards for instruments and methods of observation.

Time Frame:

1999 to 2001.

Responsible Agencies/Organizations:

WMO.

Cryosphere

Develop a long-term strategy and sampling design for monitoring key cryospheric parameters (glacier mass balance, permafrost borehole temperatures, etc.)

Description:

There are a number of efforts under way to monitor components of the hydrosphere, such as glaciers, permafrost, etc. However, currently there is no overall strategy for detecting climatic change through cryosphere variables, for understanding how changes in the cryosphere feed back to climate, or for determining the impacts of climate on the cryosphere. Currently, there are a number of stations collecting relevant information, but there is no scheme to assure that all of the information needed for climate purposes is being collected. This scheme will provide the framework to make judgements as to the adequacy of existing data sources.

Time Frame

Autumn 1995.

Responsible Agencies/Organizations:

TOP to organize a workshop.

Snow Cover

Description:

Efforts should be made to persuade national agencies to release snow records to a designated GCOS archive. Documentation, quality control and distribution of these data should be by the central archive.

Time Frame

Start 1995; possible completion 1998.

Responsible Agencies/ O r - -

WMO if possible; JPO of GCOS to ask WDC Centre to act as central archive.

Determination of Greenland and Antarctic ice sheet accumulation and surface balance and their dependence on surface meteorology

Description

The accumulation and surface balance at selected sites encompassing the Greenland and Antarctic ice sheets should be determined. The accumulation rate should be determined over the past 200 years. A comprehensive effort to intercompare modelled meteorological fields against observed surface accumulation and ablation. Modelling efforts should also concentrate on determining the controlling influences on the surface balance of the Greenland ice sheet.

Time Frame:

1995-2000.

Responsible Agencies/Organizations:

TBD

Characterization of the stress, temperature and basal conditions of the Western Antarctic Ice Sheet

Description:

A co-ordinated approach to the determination of the physics and state of the Western Antarctic Ice Sheet and shelf system is required. The elements of an observation system should include: determination of mass fluxes from the underside of ice shelves, collection of geological deposits attesting to the shrinkage of the system since the last glacial maximum, and the implementation of a GPS-tied tide gauge network. The observation work should be complemented by a strong effort in the modelling of the western Antarctic system.

Time Frame

1995-2000.

Responsible Agencies/Organizations:

TBD

Biosphere

Pilot global survey: Land cover and use

Description:

It is necessary to establish the operational capacity of GCOS/GTOS to provide integrated data sets at the global scale, and in this way build the credibility and networking for undertaking tier IV sampling in the future. An opportunity exists to enrich the global land cover product of IGBP-DIS with information which can only be collected on the ground; for instance, species composition, vegetation structure and land use. These data would form a validation and attribute data sets for the remotely-sensed cover classes, which in turn would provide the global extrapolation. As many nations as are willing to participate would be encouraged to provide geo-referenced point data (10 - 1,000 points per country, depending on size) of a few standard attributes.

Time frame:

1996-1999.

Responsible Agencies/Organizations:

GCOS/GTOS, in collaboration with IGBP-DIS.

Sensitivity analysis

Description:

Scenarios of change need to be developed to identify and focus attention on priority areas in which change is most readily and rapidly detectable (and identify which variables are the most sensitive indicators). These scenarios can be based on existing work using GCMs and impact models; they can also use existing observational data. The exercise will identify both areas of high change and areas of low change to act as 'controls'.

Time frame

1996-1999.

Responsib e Agencies/Organizations:

TOP sponsored workshop with representatives from existing research groups.

Survey Exercise

Description:

Through the approach combining ground observation and remote sensing to survey the features of land surface and find the correlation of land surface change and climate change, and human activities. The key issue of this task is to use field stations and sample points as the ground stations for calibrating remote-sensing images. Survey of land cover could be treated as a pilot project. Enhance existing remotely-sensed products and begin a land cover/land use global data base.

Time Frame:

1996-1998.

Responsible Agencies/Organizations:

Secretariats of GTOS and JPO of GCOS.

Appendix 3
Framework for the Design for Biosphere
(For additional details see the TOP Plan)

Many hundreds of variables are potential candidates for global monitoring of the biosphere and there are many thousands of potential sample locations. However, it is neither feasible nor desirable to measure everything, everywhere, all the time. Most variables have characteristic time-and-space domains in which they should be monitored. This reality leads naturally to a hierarchical sampling scheme in which at the one extreme a few variables are measured infrequently at many locations and at the other extreme a large number of variables are measured frequently at a few locations. Five logical tiers have been identified in this hierarchy (Tables 1 and 2). Scale, time resolution and detail are the main organizing principles of the hierarchy. The hierarchy is partially nested; in other words, some of the locations at one tier are components of a location at the next tier up, but not all are. An important feature of the hierarchy is its vertical and horizontal integration. Horizontal integration means that the data at one tier are sufficiently complete both spatially and topically to make useful products at that level; they are mutually supporting within a conceptual model operating at that level. Vertical integration means that the tiers are not independent. Each major theme is covered at all tiers by interrelated and compatible variables; allowing the detail and mechanistic insight obtained at higher tiers to be spatially elaborated and validated at lower tiers. For example, global wall-to-wall land cover is mapped in broad classes using remote sensing at tier V; this is enriched with ground observations of vegetation cover and land use at tier IV; further enriched with temporal detail (the seasonal progression of intercepted radiation) at tier III; supported with mechanisms at tier II (the landscape-scale dynamics of leaf area and architecture) and elaborated with spatial processes at tier I (for instance the 'green wave' which travels seasonally down a regional moisture gradient). This integrative logic has been applied to all variables.

The five tiers are characterized as follows:

Tier I: The objective is both to characterize processes that involve difficult or expensive measurements and to monitor changes in large-scale processes such as the wind- and water-borne transport of soils, latitudinal shifts in biomes, and the movement of biota. Tier I experimental facilities will be a small number of international, regional scale experiments, such as the IGBP transects, WCRP land-surface parameterization experiments and large catchment studies. Facilities at this tier add measurements of processes not quantified at lower tiers (e.g., trace gas exchange), and they address mechanisms of spatial integration.

The proposed IGBP transects, plus the existing or proposed large-scale surface experiments (e.g., HAPEX, BOREAS, Lambada) already total the appropriate order of magnitude. The spatial scale for these sites should include a core area of approximately 10 km2, and studied surroundings of 10^4 km2 or more. In principle, it is not essential that all of the members of this tier have a permanent existence, though it would be beneficial if at least some did.

Tier II: The objective at this tier is to understand the processes and the way processes respond to global change. To provide access to mechanisms, they will involve manipulative experiments in addition to monitoring. Tier II consists of major research centres, usually with a biome, regional or crop focus. There will be at least one (preferably two or three) centre in each of the major biome types (about 20) and a centre for each major crop and plantation forest type for a global total in the order of 100. Sites at this tier will be well equipped and staffed, with satellite stations or experiments. Hallmark measurements added at this tier will include diurnal resolved weather, soil moisture flux, isotopic studies of soil nitrogen and carbon, and continuous monitoring of fluxes of C02, water, and energy. For larger countries, there will be one or a few sites per country. For smaller countries, the tier II sites will be regional centres. The Consultative Group on International Agricultural Research (CGIAR) crop centres would fit into this tier, as would some of the better- developed ecological research sites in the US (such as some of the larger Long Term Ecological Research (LTER) sites), European, and Chinese networks. Together, these already total well over 100 sites. Extrapolation of measured data is made via periodically-updated inventory information. Some centres may need to be promoted (or sustained) in the less-developed parts of the world.

Tier III: The objective is to provide dynamic data at the sub-annual time scale (e.g., phenology, net primary production) as well as a spatial context. Tier III includes many of the existing national ecological and agricultural research stations. Tier III sites will be in the order of 1000 facilities that each cover areas of up to approximately 10 km2. It is also the tier of direct linkage to weather stations and calibration of remote sensing. They will usually have small permanent staff and modest facilities (e.g., a weather station, balances, drying ovens, communications). Because an approximate balance across biomes, agro-ecological regions, and farming systems is a high priority, these sites will need to be selected with care. At this tier, however, it is not necessary that all ecosystems be represented in proportion to their extent. Probably at least 80% of these stations already exist. Where gaps occur, especially in the developing world, international efforts may be needed to develop new stations.

Tier IV: The objective is to demonstrate the representativeness of the data obtained in tiers I, II, III, and to provide additional ground truthing for satellite observations. Tier III points will be systematically placed in approximately 10,000 locations in an unbiased fashion. This means that at least a portion of them will be in difficult-to-access locations. It is therefore important that they do not require permanent staff, and that the data can be quickly and cheaply obtained through a combination of occasional visits (once a year to once every few years) and remote sensing. The measurements, which will include assays of total soil C and N, management system, and species identities, must have low equipment and technical demands. Tier IV points will consist of precisely geo-referenced sample points possibly as small as 1 ha in extent. These will mostly be new, although some countries already have networks in place or in the planning stage.

Tier V: The objective is to provide spatially continuous fields at the global scale. Tier V will require satellite observations. In general, it is expected that resolution will be 1 square kilometer, though for specialized observations resolution will be provided for small areas at 30 meters. The measurements will include radiation, extent of snow fields, land cover, etc.

Measurement strategy

The proposed measurements are intended to capture elements of the status and dynamics of terrestrial ecosystems essential for climate purposes. The hierarchical system of proposed measurements acknowledges the fact that essential measurements span a range of spatial scales and that measuring some of the essential parameters is too expensive or difficult to be replicated everywhere.

Issues of data management will require careful planning. Maintenance of national data systems may provide a way to utilize existing structures, though these will need to be upgraded in some cases and transferred to second countries in others. The tier II centres could also serve as national or regional data centres.

An initial description is provided of the requirements for surface observations to support the use of satellite data. The system of ground sites described in the present section can also in principle provide much of the support needed for satellite observations.

Site selection

The objective is to take maximum advantage of existing facilities while still ensuring an appropriate global distribution of measurement sites. It is essential that the sites be carefully selected so as to meet the climate objectives of GTOS and GCOS. The different objectives associated with the tier I through IV facilities impose different criteria for site selection.

For the IOS, it is necessary to establish a skeletal network based on the criterion of minimal representation of the environments and biospheric systems (both natural and managed) of the world; identify practical issues; and develop a community of experienced personnel. Many options are open to select a sample of sites. A practical procedure is to make a primary selection of sites to cover the main climatic conditions around the globe, and screen these to determine sites representing main soil types, biomes and agroclimatic zones or agroecosystems. This multi-axis stratification scheme will allow establishment of the initial network. It will identify gaps and the need for replication, and assess the distribution of sites in relation to the scenarios of expected change.

Establishment of tier III should be given priority over other tiers. The tier III network will eventually be in the order of 1,000 sites world-wide but an initial network of 100-200 sites can be readily mobilized. Many potential sites have been identified for initial consideration. These sites broadly fulfil the criteria of an existing base of long-term observations, reasonable security of tenure, basic field facilities and staffing, and a degree of long-term institutional support.

Tier I: These major, intensive experimental sites should be located with a primary emphasis on feasibility, on the spatial diversity of regional ecosystems and land-use patterns, and on the availability of regional process integrators like appropriate watersheds. Capturing the entire range of the Earth's major biome types is a critical priority, but the location of the installation within biomes should be opportunistic. At present, there are probably no sites that function regularly as tier I installations, but the upgrade from existing facilities to tier I will only involve modest changes in the programmes at some sites. Measurements at the tier I sites will be a subset of the measurements of the major land-surface experiments though the transition from intensive field campaigns to continuous monitoring will require careful planning. Several of the tier I sites will probably be drawn from the sites of past or present experiments, including perhaps BOREAS (boreal forest - Canada), ABRACOS (tropical evergreen forest - Brazil), ARCS LAII (Arctic tundra - US), Harvard Forest (temperate mixed forest - US), and Oasis (dry land agriculture - Australia). The actual sites will probably consist of core areas of 100 km2 or less, plus a surrounding region. It is critical to select tier I sites so that they include a range of tier II, III, and IV sites.

Tier II: The 100 or so tier II centres will be chosen to include the Earth's major climate zones, ecosystem types, and land management practices. The actual siting will depend more on existing infrastructure and feasibility than on strict spatial guidelines, but the priority on capturing the broad range of ecosystem types may require developing some new sites, though not more than about 20% of the total. Since the proposed measurements emphasize a mix of point measurements and spatial studies, the spatial context for each site will be a priority. The best spatial contexts will include large enough regions of relatively homogeneous ecosystems to allow careful assessments against remote sensing, but enough diversity to allow access to a broad range of ecosystem structure and dynamics.

Tier III: These are the sites that are most congruent with the existing networks of agricultural and ecological research stations in China, Europe, the US, and other countries. The requirement for permanent staffing and frequent measurements will necessitate locating the sites where there is reasonable access, funding, and interest. Though there will be a need for some sites in under-represented areas, the number of new sites at this tier should be a small fraction of the total. Since these sites will provide a primary link with remote-sensing observations, selection criteria will include an emphasis on reasonable spatial homogeneity over the scale of a few kilometers, but this emphasis should not preclude the selection of sites in mountainous zones or in regions with heterogeneous land use or disturbance.

Tier IV: For these points, spatial representativeness is the highest priority. Because the measurement site is limited and access is infrequent, they can be sited wherever necessary to ensure representativeness. With approximately 10,000 sites globally, the question of whether the best sampling design is strictly regular will require a careful assessment of the statistical issues. A few of these points may be established research stations, but all should be subjected to the prevailing local management. In fact, it may be best to guard the locations, to the extent possible, so that the land management is not altered during the monitoring period. It may also be appropriate to continuously add sites so that impacts of the GCOS/GTOS designation can be estimated. If each of the tier III stations services a number of tier IV points, the tier IV monitoring will have minimal impacts on personnel and equipment requirements.

Tier V: These continuous fields are monitored from space. The frequency of measurement will be variable, depending on the parameter, particularly for reflected visible radiation and vegetation index.

Capacity building

In order to implement GCOS/GTOS, there will be a need for capacity building. This will range from collaborative research programmes in **relatively-**developed areas to basic courses, student exchanges, and structured field experiences in lesser-developed countries. The training potential represented by the tier II sites will be an important component of capacity building and should make a contribution towards the establishment of self-sufficient tier III and IV sites in developing regions. Much of the emphasis will be on training the scientists who will manage the tier III and IV sites. Some of the siting decisions will be adjusted to reflect the training needs and access in developing regions. Establishing the relevance of the proposed measurements for local and regional issues can make major contributions toward motivating the establishment of sites in developing regions.

Tier	Number of sites (Order of magnitude)	Space & time resolution	Rationale
I. Large area experiments	10	1000 km Hourly to monthly depending on variable	Specifically address the problem of spatial processes and scaling; change detection on key gradients.
II. Centres	100	1 km - 10 km; Flux variables hourly others daily to monthly depending on variable	Provide mechanistic insights for model development through detailed measurements of many supporting variables and manipulative experiments. One or two per main biome and farming system type. Substantial analytical and technical capacity.
III. Stations	1000	1 km -10 km Monthly	Permanently staffed, therefore able to provide temporal detail. Sufficient in number to quantify the variability within each main biome and farming system type. Modest technical capacity.
Iv. Points	10 000	100 m- 1 km Once per Decade	Unbiased, statistically valid sample.
V. Fields	100000000 (spatially continuous coverage)	30 m -1 km fundamentally 1 day - 30 day; high res composited decadally , med res 10-daily	

Table 1: Characteristics of the five-tiered hierarchy.

Tier	Emphasis	Examples of variables
I	A) Spatial integration	i) dynamics of landscape units
		ii) transport of soils and nutrients
		iii) airborne flux measurements
		iv) planetary boundary layer flux methods
	B) Point measurements	i) trace gases
II	A) Spatial integration	i) population structure
		ii) continuous tower fluxes of C02, H20, and energy
		iii) soil moisture
	B) Point measurements	i) diurnally resolved weather
		ii) complete radiometry
		iii) isotopic soil and plant studies
	C) Capacity building	i) serving as regional training centre
III	A) Stocks and fluxes	i) NPP
		ii) biomass
		iii) soil C and N by depth
		iv) atmospheric deposition
	B) Land use	i) management system (cropping, tillage)
		ii) fertilizer and irrigation
	C) Spatial integration	i) b and g diversity
		ii) habitat spatial structure
	D) Point measurements	i) leaf chemistry
		ii) phenology
	E) Daily weather	i) precipitation
		ii) temperature
		iii) wind
		iv) short-wave radiation and PAR
IV	A) Point measurements	i) decadal soil C, N, depth, bulk density
	B) Land use	i) land cover type
		ii) disturbance
		iii) land use type
	C) Biodiversity	i) decadal enumeration of vertebrates, higher plants
		ii) decadal status of invading species
	D) Weather	i) interpolated monthly climate from nearest stations
V	A) Continuous fields	i) land cover type
		ii) land use type

Table 2. Examples of variables collected at different tiers.

LIST OF GCOS PUBLICATIONS

GCOS-1 (WMO/TD-No. 493)	Report of the first session of the Joint Scientific and Technical Committee for GCOS (Geneva, Switzerland, April 13-15, 1992)
GCOS-2 (WMO/TD-No. 55 1)	Report of the second session of the Joint Scientific and Technical Committee for GCOS (Washington DC, USA, January 11-14, 1993)
GCOS-3 (WMO/TD-No. 590)	Report of the third session of the Joint Scientific and Technical Committee for GCOS (Abingdon, UK, November l-3,1993) **[ftp://www.wmo.ch/Documents/gcos/jstc-3.txt]**
GCOS-4 (WMO/TD-No. 637)	Report of the fourth session of the Joint Scientific and Technical Committee for GCOS (Hamburg, Germany, September 19-22, 1994) **[ftp://www.wmo.ch/Documents/gcos/jstc-4.txt** or **/jstc-4.wp5]**
GCOSJ **(WMO/TD-No.** 639)	Report of the GCOS Data System Task Group (Offenbach, Germany, March 22-25, 1994) **[ftp://www.wmo.ch/Documents/gcos/dstg.txt** or **/dstg.wp5]**
GCOS-6 (WMO/TD-No. 640)	Report of the GCOS Atmospheric Observation Panel, first session (Hamburg, Germany, April 25-28, 1994) **[ftp://www.wmo.ch/Documents/gcos/aop-1.txt** or **/aop-1.wp5]**
GCOS-7 (WMO/TD No. 641)	Report of the GCOS Space-based Observation Task Group (Darmstadt, Germany, May 3-6, 1994) **[ftp://www.wmo.ch/Documents/gcos/sotg.txt** or **/sotg.wp5]**
GCOS-8 (WMO/TD No. 642)	Report of the GCOS/GTOS Terrestrial Observation Panel, first session (Arlington, VA, USA, June 28-30, 1994) **[ftp://www.wmo.ch/Documents/gcos/top-1.txt** or **/top-1.wp5]**
GCOS-9 (WMO/TD-No. 643)	Report of the GCOS Working Group on Socioeconomic Benefits, first session (Washington DC, USA, August l-3, 1994) **[ftp://www.wmo.ch/Documents/gcos/wgsb-1.txt** or **/wgsb-1.wp5]**
GCOS-10 (WMO/TD-No. 666)	Summary of the GCOS Plan, Version 1.0, April 1995 **[ftp://www. wmo.ch/Documents/gcos/gps-ver1**.bct or **/gps-ver1.wp5]**
GCOS-11 (WMO/TD-No. 673)	Report of the GCOS Data and Information Management Panel, first session (Washington DC, USA, February 7-10, 1995) **[ftp://www.wmo.ch/Documents/gcos/dimp-1.txt** or **/dimp-1.wp5]**
GCOS-12 (WMO/TD-No. 674)	The Socioeconomic Benefits of Climate Forecasts: Literature Review and Recommendations (Report prepared by the GCOS Working Group on Socioeconomic Benefits), April 1995 **[ftp://www.wmo.ch/Documents/gcos/wgsb-1rr.txt or/wgsb-1rr.wp5]**

GCOS-13 (WMO/TD-No. 677)	GCOS Data and Information Management Plan, Version 1.0, April 1995 [ftp://www.wmo.ch/Documents/gcos/dp-ver1 .txt or /dp-ver1.wp5]
GCOS-14 (WMO/TD-No. 68 1)	Plan for the Global Climate Observing System (GCOS), Version 1.0, May 1995 [ftp://www.wmo.ch/Documents/gcos/gp-ver1.txt or /gp-ver1.wp5]
GCOS-15 (WMO/TD-No. 684)	GCOS Plan for Space-based Observations, Version 1.0, June 1995 [ftp://www.wmo.ch/Documents/gcos/sp-ver1.wp5] (wp version only)
GCOS-16 (WMO/TD-No. 685)	GCOS Guide to Satellite Instruments for Climate, June 1995 (will not be on FTP Server)
GCOS-17 (WMO/TD-No. 696)	Report of the GCOS Atmospheric Observation Panel, second session (Tokyo, Japan, March 20-23, 1995) [ftp://www.wmo.ch/Documents/gcos/aop-2.txt or aop-2.wp5]
GCOS-18 (WMO/TD-No. 697)	Report of the GCOS/GTOS Terrestrial Observation Panel, second session (London, UK, April 19-21, 1995) [ftp://www.wmo.ch/Documents/gcos/top-2.txt or top-2.wp5]