Global Terrestrial Observing System

Report of the GTOS/GCOS Terrestrial Observation Panel for Climate

Fifth Session

27-30 July 1999, Birmingham, the United Kingdom

August 1999

GTOS 22
GCOS 59

Table of Contents

1. Organization of the Meeting

1.1 Opening and Conduct of the Meeting

Dr Josef Cihlar opened the meeting by welcoming the participants, both members and those invited to discuss specific items. He emphasised the working nature of the meeting and the need for dealing with a number of issues. He identified the following broad objectives for the meeting:

- advance the implementation (and improvement) of *terrestrial networks;*
- facilitate progress and coordination of *demonstration projects;*
- lay the foundations for *terrestrial C cycle theme* definition: strategy, initial draft;
- advance the definition of *GTOS non-climate observation requirements;*
- develop *guidelines for national reporting* on terrestrial climate-related observations;
- understand and review *health-related* observation requirements;
- begin to write the meeting report.

1.2 Approval of the Agenda

Dr Cihlar reviewed the draft agenda distributed prior to the meeting. In view of the many issues to cover, it became necessary to have parallel breakout groups dealing with more than one topic. Thus, the agenda was re-organised to cover presentations relevant to the subsequent breakout discussions. Dr Cihlar also explained that further changes may be necessary depending on the travel schedule of some participants and other commitments, including presentations at the IUGG Conference that took place in parallel. With these changes the participants adopted the agenda (see Appendix 2).

2. IGOS, GCOS, GTOS and GOSSP: Reports on Current Status and Updates

2.1 IGOS-Related Activities

Dr Thomas, Executive Director of GCOS, reported on recent developments involving the three global observing systems (G3OS) and the Integrated Global Observation Strategy Partnership (IGOS-P):

The G3OS met in Rome on 6 June 1999 to review activities over the past year, to discuss mutual issues and to prepare for the IGOS-P meeting on 7 June 1999. Highlights from GOOS included the approval of a Joint Commission for Oceanography and Marine Meteorology by the WMO Congress and the IOC Assembly, and the organisation of a Conference on the Ocean Observing System for Climate.

Issues discussed at the G3OS meeting included (1) how can the G3OS best address the needs of the Conventions (Biodiversity, Desertification, etc.); (2) need to define products, not just data; and (3) cooperation among the G3OS in approaching the governing bodies, nations and international funding agencies, e.g., GEF.

IGOS-P met in Rome on 7 June 1999 to discuss the use of a theme approach to the development of joint activities. IGOS-P has in preparation several outputs: a brochure (now available); a bulletin (available in October), and new web site (igospartners.org) that can be accessed through the UNEP Earthwatch web site (**http://www.unep.ch/earthw/igos.htm**).

Discussion regarding proposals to organise a lecture and an exhibit at COP-5 on “IGOS and climate”, and to publish the first issue of the bulletin prior to COP-5. IGOS-P was interested in how it might become involved with the GEF and UNFIP.

IGOS-P endorsed the “theme” approach suggested by CEOS members and the use of criteria developed by Dr Asrar (NASA) to select themes. There was some concern the themes might be too broad to effectively develop mutually beneficial activities between the users and space agencies but they can be adjusted if necessary. The first theme will be “Oceans” led by NASA and developed around the data needs of GODAE.

The Global Observing Systems Space Panel will function as the interface and analysis mechanism between the user needs and the space agency capabilities.

On 8 June 1999 the CEOS SIT met to consider the “Ocean Theme” and the interactions with GOSSP.

2.2 GCOS Activities

Dr Thomas reported on recent developments in GCOS:

The GCOS objective from its MoU between WMO, IOC of UNESCO, UNEP and ICSU is to provide data for:

- climate system monitoring;
- climate change detection and attribution;
- response monitoring (e.g., terrestrial systems);
- national economic applications;
- research, modelling and prediction of climate system.

Implementation of a global observing system for climate requires the full participation of the climate components of the five partner observing systems: GOOS, GTOS, WWW, GAW, and WHYCOS.

Current priorities for GCOS are to follow up the decisions from COP-4 and provide input to the UNFCCC secretariat prior to COP-5 in November, 1999. Attention must also be given to the work of the panels on key scientific issues related to the implementation and improvement in the observing networks, and on input to the COP process. The key areas for GCOS in response to COP include:

- *Guidance for reporting on systematic observations.* GCOS Secretariat is seeking TOPC review and recommendatioss of draft guidance prepared for submission to the UNFCCC Secretariat prior to COP-5. In particular, GCOS needs input on the specific questions to ask the parties on the support for GTN-G, GTN-P and Fluxnet and for other comments on what questions to ask the parties on areas such as ecosystems and hydrology.

- *Intergovernmental process to address priorities for action on systematic observations*. GCOS and WCRP recognise the need for an intergovernmental process to implement climate research and observations that encompasses all domains, and that has active participation by appropriate agencies within countries. The existing mechanisms are too narrow in their currently defined missions. A proposal to have an informal meeting of governmental representatives to consider an appropriate mechanism for implementing climate observations and research was discussed at SBSTA in June.

- *Funding for the participation of developing countries and international coordination.* The COP decisions on support for capacity building in developing countries, including the GEF was discussed, as was the issue of funding for GTOS and GCOS Secretariats and the GT-Net.

- *Regional workshops.* GCOS implementation will require strong regional interactions to define issues and to develop country and regional support based on contributions of GCOS to the national needs of the countries is becoming clearer.

2.3 GTOS Activities

Prof. James Gosz, Chair of the GTOS Steering Committee, reported on the recent activities of GTOS:

- GTOS implementation plan. The plan has been widely circulated and has received positive comments from a variety of sources.

- Global network of terrestrial observing systems (GT-Net). Efforts are continuing in the development of GT-Net (see Section 7.4). Networks on glaciers and permafrost are already established; efforts are under way to address the important area of hydrology.

Regional activities

- *Europe.* A European-wide NoLimits workshop was organised (Oxford, April 1999) and was attended by nearly 90 scientists. GTOS was represented by the Chairman and the Programme Director. As a result of this workshop, five additional countries expressed interest in participating in the GTOS NPP project.

- *Central and Eastern Europe*
    - Katalin Török, of the Institute of Ecology and Botany at the Hungarian Academy of Sciences, is leading this project over a nine-month period (ending in September) with Alexandre Borde of FAO/GTOS, in collaboration with Terry Parr and Ian Simpson of the UK environmental change network. The countries of concentration are the Czech Republic, Hungary, Poland, and Slovakia. Visits are being conducted to each of these countries. Experts have been contracted to prepare studies and facilitate visits in each of the four primary countries. The project will end in October 1999.
    - Two workshops in Budapest focused on this region (June and September 1999). Participants come from the major countries in the region. The June workshop was in association with an International LTER (ILTER) meeting and the World Science Congress. The main output of the two workshops will be an implementation plan for initiating a regional programme in the Central and Eastern Europe. In the process of drafting the implementation plan, we will identify regional and national environmental priorities; review and evaluate observing sites; assess country terrestrial data and information; and carry out a desk study for 15 other CEE countries. The work is being carried out through the UK Institute of Terrestrial Ecology. The overall coordinators are Terry Parr and Ian Simpson, who are also responsible for the EU funded No-Limits project of which GTOS is a partner. In addition to NoLimits, the initiative is closely linked with the International Long-term Ecological Research Network (ILTER) which has a Central European initiative under way.

- *Southern and Eastern Africa*
  - Robert Scholes of CSIR, South Africa will be carrying out work in conjunction with colleagues in his institute during 1999. The countries of concentration are Botswana, Namibia, South Africa, and Zimbabwe. Subject to the availability of funds, four additional countries will be assessed in 2000. Additional financing for extending the work to other countries is likely.
  - A workshop, planned for February 2000, in Pretoria, will focus on developing a GTOS regional implementation plan. The initiative is closely linked with ILTER which has an initiative under way in the region. The project leader (Robert Scholes) is closely associated with the IGBP, offering an opportunity for further links.

Terrestrial observations

- *Core observations.* An important bottleneck in developing a number of GTOS applications such as TEMS and in the evolution of GT-Net has been the lack of a set of core terrestrial observation variables. These exist for climate change issues but are lacking for land quality, freshwater, biological diversity and toxic chemicals. Working with a variety of scientists, Paul Reichert has developed a list of variables that is presently under review. A revised list will be finalised in October 1999. A list of socio-economic variables that would be relevant to each of the five GTOS priority areas has also been developed. Discussions have also taken place with the Secretariat of the Basel Convention (Transboundary transport of hazardous wastes) to initiate a similar exercise for issues relating to toxic chemicals, one of GTOS priority areas.

Data and information

- *Management plan.* The GTOS Data and Information Management plan has been published and circulated widely.
- *Collaboration*
  - Coastal GOOS. Robert Christian of East Carolina University, United States, represented GTOS at the C-GOOS meeting in Accra and has suggested several areas of follow-up.
  - J-DIMP, GOSSP. GTOS continues to send representatives to these panel meetings. There may be a need for broadening the representation on terrestrial issues such as land quality, freshwater and biological diversity.
  - ILTER. Close collaboration is ongoing in both GTOS regional projects and in the NPP demonstration project.
  - IGBP. Contacts are ongoing but at a low level. Will Steffen may attend the IGOS Partners meeting and discussions will take place about possible collaboration on a terrestrial carbon initiative. GCOS has written to IGBP inviting them to cosponsor the TOPC. GTOS will make a keynote presentation at the GTCE conference on Food and Forestry: Global Change and Global Challenges in September 1999.

GTOS Steering Committee

- A five-person Executive Committee has been identified. This has been functioning informally since the beginning of 1999. The Steering Committee has been re-sized to about 12 members, including sponsors. Several additional members will be added. The GTOS Steering Committee (GTSC) was scheduled to meet in France during the first half of 1999. However, the sponsor was unable to provide the expected support. Efforts are under way to organise a self-funded meeting, possibly of the Executive Committee, toward the end of 1999. Due to the delay in organising the GTSC meeting, formal notification of the changes in membership have not yet been made.

2.4 GOSSP Activities

Prof. Bretherton, Chair of GOSSP, presented a perspective from the Global Observing Space Panel:

GOSSP was reconstituted in October 1998, and is now sponsored by the three Global Observing Systems (G3OS). Two members are nominated by each of GCOS, GOOS, and GTOS, and three members are nominated by the Committee on Earth Observing Satellites (CEOS). The GOSSP Chair is nominated jointly by the chairs of the G3OS steering committees. The principal GOSSP role is to facilitate the 2-way communication between the space agencies in CEOS and the user community for sustained measurements of the environment on a global scale, as represented by G3OS. GOSSP meets primarily in association with other gaps and invited experts.

Prof. Bretherton described recent developments in the Integrated Global Observing Strategy (IGOS) Partnership, in particular the meeting June 8, 1999 in Rome. There, the international organisations concerned with environmental measurements agreed:

- to an outline management structure based upon themes;
- to guidelines for proposals of such themes by cooperating partners or by others; and,
- to a prototype Oceans theme on a fast track, with a report due by September 30, 1999.

A draft list of IGOS themes was considered. However, the actual list will be determined by successful proposals. FAO and the Canadian Space Agency (CSA) indicated their intention to sponsor a theme on Terrestrial Carbon. Existing IGOS projects will continue, but it is expected that these activities will transition in due course to become part of broader themes which define a path to sustained operations.

Prof. Bretherton reviewed the and principles of IGOS, emphasising the importance of building incrementally on existing capabilities, with short term benefits to identifiable end users as well as to longer term goals of scientific understanding. In this context “end user” may be defined as “an organisation with substantial financial resources, and/or political influence”. It is important also to take an integrated view of both space-based and in situ techniques of observation, and across a range of end-use applications, including national and regional needs as well as the global ones. IGOS presents an opportunity strengthen observational capabilities, through articulation of a consensus framework for national decisions.

It is essential that user groups identify a clear and stable set of requirements, around which data providers can attempt to optimise the system within available resources. For satellite-based measurements, the CEOS/WMO database is the official repository for statements of requirements, as well as corresponding space agency statements of instrument capabilities and plans for implementing missions. A key function of GOSSP is to assist in periodic review of these statements and in mutual understanding of their significance. Ways must be found to extend this database or its equivalent to include in situ measurements. A database is also needed, including at least a sample of users of measurement products at all levels of synthesis up to the end users. This would enable systematic, user driven assessments of system performance. In the long-term, these assessments are essential for maintenance of or improvements to the observational system. Figure 1 illustrates the process of establishing an effective observation capability at the global level. This approach is now being pursued by IGOS-P.

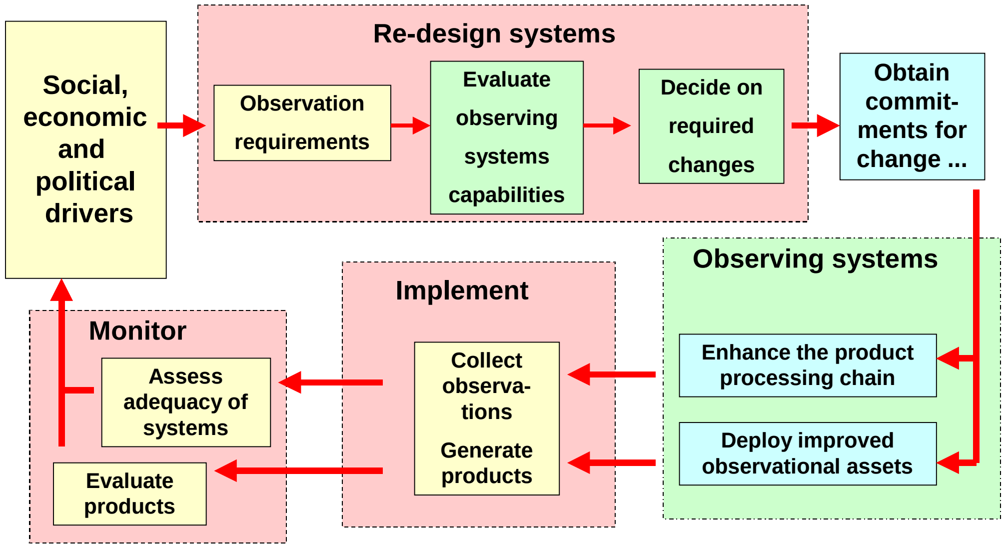

Figure 1. Approach to the Implementation of Systematic Global Observation Capabilities

3. Review of TOPC Goals and Progress Since TOPC-IV

3.1 Five-Year Goals of TOPC

Dr Cihlar reviewed TOPC five-year goals accepted at the previous meeting and endorsed by the steering committees of GCOS and GTOS:

- Assist in the establishment of networks, ensure their longer-term viability including necessary ongoing support of GCOS/GTOS. Functional networks will be established for ecology, glaciers, permafrost, and hydrology.
- Stimulate completion or near-completion of two demonstration projects, Net Primary Productivity NPP) and Global Observation of Forest Cover (GOFC).
- Stimulate compilation of critical data sets for use in IPCC or for other important users.
- Demonstrate continuing responsiveness to (changing) requirements, including those flowing from IGBP, IPCC, convention secretariats, WCRP.

Dr Cihlar stated that TOPC actions during the past year, adopted at the previous meeting or newly undertaken during the year, are consistent with these goals and have advanced progress towards them. He briefly reviewed the actions decided on at the TOPC-IV meeting in Corvallis, Oregon, and noted that since most were also concerned with items to be discussed during the meeting, they would be addressed at that time, except for the progress made by the Global Observing Systems Information Center (GOSIC) in making accessible data sets identified by TOPC.

3.2 GOSIC Report Provided by Dr Wilson, Summarized by Dr Cihlar.

GOSIC examined various metadata possibilities and accepted the NASA Global Change Master Directory format. The data sets identified by TOPC-IV were entered, and linkages and a search strategy to locate data sets were developed. A link has also been provided between the TOPC data requirements and the registered data sets (http://www.gos.udel.edu/)

Satellite observation requirements. GOSIC obtained the WMO/CEOS database and constructed a very preliminary interface. It allows different views of the database: one can view the parameters, instruments and missions for an application area, or the instruments and missions for a parameter. TOPC is listed as an application area.

GOSIC also produced a trial data flow diagram, using the Canadian forest fire detection and mapping project based on satellite data. The data flow is presented in the form of a diagram that was discussed at TOPC-IV, meeting with the addition of an “interpreter” box for a final high level decision support function. All the elements are to be linked to textual explanations of who the users actually are and where the models are run, the products generated, and who is responsible for these.

4. Global Observation of Forest Cover and Net Primary Productivity Pilot Projects

4.1 Global Observation of Forest Cover

Dr Frank Ahern, Coordinator of the Global Observation of Forest Cover (GOFC) project, presented a report on the current status and plansGOFC began as one of six pilot projects selected by the Committee on Earth Observation Satellites (CEOS) to test the concept of an Integrated Global Observing Strategy (IGOS).

Following two years of project development, CEOS has expanded IGOS to become the IGOS Partnership (IGOS-P) in order to increase the involvement of the major international organisations which make use of earth observation data (WMO, FAO, IGBP, UNEP, etc.), and to try to increase the degree of integration, as well as relevance to major emerging requirements such as the Framework Convention on Climate Change. To accomplish the latter, IGOS-P decided to encourage the development of broader themes. The pilot projects will eventually be incorporated into one of the themes. There is broad interest in the development of a theme for terrestrial carbon, and it is expected that GOFC will become a project under this theme.

In 1998 GOFC carried out its design phase, which resulted in a 104-page strategic design document (Ahern *et al.*, 1998). It describes how a programme for global observations of forests could be implemented, based primarily on data from existing and planned satellites. Because of differing degrees of technical and administrative complexity, the implementation is divided into three components:

- Forest Fire Monitoring and Mapping;
- Forest Cover Characteristics and Changes;
- Forest Biophysical Processes.

The implementation of each of these components would represent a significant advance in itself, but the strategic design shows how the interconnections between components result in a whole which is significantly stronger that the sum of its parts.

At this time, GOFC is at an early stage of implementation. The strategic design has received strong support by CEOS members. Several CEOS agencies have pledged data sets as contributions to GOFC (including data from proposed future satellites), and a few organisations have identified programmes with substantial funding which will be used for efforts to achieve GOFC objectives. The CEOS working groups for information and systems services (WGISS) and calibration/validation (WGCV) have been instrumental in the development of the GOFC design, and continue to provide valuable support for GOFC implementation. A workshop to plan implementation for tropical regions in March, hosted by IGBP-START, has shown the need for the creation of regional networks of interested institutions and has begun that process. A workshop to advance the implementation of the Forest Fire Monitoring and Mapping component will be held at the European Commission Joint Research Centre in Ispra, Italy in November, 1999. A GOFC web site is in operation, and a GOFC DataSite, to be hosted by the Canada Centre for Remote Sensing, is under development.

The TOPC meeting represents an ideal opportunity to become more aware of the GTOS-affiliated in situ networks, in order to take greater advantage of these sources of ground data; to explore ways for greater cooperation between GOFC and the GTOS Net Primary Productivity (NPP) project; and contribute to the initial design leading to a proposal for the development of a terrestrial carbon theme for IGOS-P. The presentation and subsequent discussions clearly demonstrated that the GTOS-sponsored networks represent an essential resource for GOFC which could provide critical in situ data and, in addition, could serve as professional contact points for international collaboration.

4.2 Net Primary Productivity Project

Prof. Gosz reported on the progress of the NPP demonstration project.

The project is organised and awaiting the launch of NASA's Terra satellite. Links are currently being encouraged in order to reinforce the project through FAO efforts; these efforts have led to obtaining access to the SPOT 4 VEGETATION data set and to other NASA images. Currently, 45 sites representing 12 countries have been identified with initial validation studies: China, Costa Rica, Czech Republic, Hungary, Israel South Korea, Poland, South Africa, Ukraine, the United Kingdom, the United States, and Venezuela. Among the networks attending the Guernica meeting, only LTER and ILTER were involved in the preparations for the project. This slow progress is mainly due to the delays in the launch of EOS Terra and does not provide a true perspective on the interest in the project by other networks.

For the above sites selected from the two networks, a mechanism has been set up to allow a two-way data flow via the Internet. These sites were also included in the second version of TEMS (see Section 11). The set-up has been tested with sample data. The initially specified methodology has been tested at several sites, and problems regarding details of the measurement methods (e.g., LAI measurement and scaling) have been considered.

TOPC was pleased to note the progress in both projects. It confirmed the continuing relevance of the projects, particularly given the increasing interest in the terrestrial carbon cycle. It also supported the implementation strategies being pursued which take advantage of related developments and build on these where possible.

TOPC noted the need to examine the match between the project objectives and the requirements for terrestrial carbon observations once these become firmly established (discussed separately, see Section 5.). Nevertheless, some reorientation is warranted at this time. For example, in view of the growing interest in the terrestrial carbon cycle, estimating net ecosystem productivity (NEP) should be included as an objective in both projects.

TOPC also considered the linkages and areas of common interest between the two projects: land cover, NPP, and NEP. For land cover, the intent is to take advantage of products being developed elsewhere, most notably as part of the EOS Terra programme; thus, it is desirable to establish closer linkages with groups developing these products. The NPP project can provide NPP and NEP for the Forest Biophysical Processes theme of GOFC. The local contacts and collaboration available through GTN-E will be of great benefit to GOFC. GOFC can aid in the provision of data and products from additional satellites, including Landsat, SPOT, and radar satellites to help cooperating sites with land cover assessments needed by the

NPP project. GOFC can also take on the responsibility for land cover and forest fire emissions needed for NEP estimation.

It was also agreed that it is important to emphasise the natural resource management benefits (rangeland, forestry, agriculture) as well as the research benefits of the collaboration to enable effective participation from many countries.

Regarding the two pilot projects, TOPC recommends:

Recommendation 4.1: It is recommended that mapping the spatial distribution of NEP be included as an explicit objective of the NPP project, and that the project be re-named accordingly ("NPP/NEP" is a possibility, used below).

Recommendation 4.2: It is recommended that all GTN-E sites interested in participating in the NPP/NEP project be included in the initial phase of testing the satellite-derived products (see also Section 11).

Recommendation 4.3: It is recommended that GOFC work with NPP/NEP to meet its Forest Biophysical Processes theme objectives and that it provide biomass burning emission estimates for that purpose.

Recommendation 4.4: It is recommended that GOFC broaden its Land Cover theme to include all terrestrial ecosystems, and that it establish close linkages with global land cover mapping activities under EOS Terra.

Recommendation 4.5: It is recommended that GOFC establish access and linkages to national forestry agencies on behalf of both NPP/NEP and GOFC projects.

5. Terrestrial Carbon Cycle Observation Theme

5.1 Background Information for Terrestrial Carbon Cycle Observation

Dr Cihlar explained the background for this topic with reference to Prof. Bretherton's and Dr Thomas' reports on IGOS-P (see Section 2.). Following IGOS-P meeting in June, 1999 in Rome, TOPC was requested to lead the definition of the terrestrial carbon observation theme on behalf of GTOS and with the agreement and support of GCOS (refer to Appendix 3 for terms of reference). Dr Cihlar described the approach to this task, which was intended to produce useful initial results within a short period of time. This meeting was the first opportunity to consider this subject. Thus, preliminary inputs were solicited by e-mail, and special presentations prepared as a background for discussion.

Dr Steve Running discussed issues to be considered in designing a global observing system for terrestrial carbon.

Optimum terrestrial carbon cycle monitoring would entail sites distributed across the full climatic range of vegetation, roughly a water balance range from - 3,000 to + 3,000mm/yr and annual temperature ranges from - 20 to + 30^{o}C. In addition, all biome types, including those with perennial vegetation and a chronosequence, should be sampled within their bioclimatic subspace (Churkina and Running, 1997).

The current 80 Fluxnet sites are concentrated mostly in temperate forests, with both cold and warm low precipitation zones being particularly underrepresented. The optimum number of Fluxnet sites is probably on the order of 500, but currently there are an insufficient number of trained scientists and technicians to operate that many.

Vegetation structural sampling for LAI and NPP is not as technologically difficult as NEP from a flux tower, and need not be done continuously. Rather, it is a GHOST Tier 4 activity where sample plots can be located, measured and vacated. Again, the complete array of bioclimates, biome types and major crops need to be sampled, with a temporal frequency ranging from annual in forests to monthly in croplands. Because of the simpler and less frequent sampling requirement, a much larger number of samples should be possible than those available with flux towers. With a global vegetated area of about 1.5 x 10^8 km^2, 1500 sites would yield a sampling density of one site for each area of approximately 300 x 300 km. The representativeness of those sample sites to the larger region to which they are to correspond, is a key question that the satellite mapping of NPP should be able to evaluate. Technical training of workers is less rigorous for vegetation structural data, although uniform methodologies are essential if measurement error is to be held below 20 percent (BigFoot web site).

The extreme microheterogeneity of soil carbon makes a global monitoring design seem unrealistic. However, in the context of the vegetation sampling suggested above, it would be highly efficient to take limited soil carbon samples. It is suggested that a measure of fast (<5 years) and medium (five to 50 years) turnover time litter/soil carbon be taken, and if possible, the tissue nitrogen. Since land use history of the previous century also impacts current soil carbon, the history of the sample site would aid significantly in interpreting the measurements attained. The litter/soil carbon data collected would still be invaluable for extrapolating the Fluxnet NEP measurements spatially.

The benefits of global NEP and NPP terrestrial monitoring networks are obvious for global science. There is no way a small number of global scientists could ever measure thousands of sites around the world themselves to test their global models and satellite algorithms. The benefit to field scientists in cooperating with this globally coordinated carbon sampling may initially be less clear, but ultimately equally valuable. The most legitimate way for field scientists to extrapolate their plot measures to overall estimates of vegetation productivity throughout their region is with satellite-derived computations of spatially georeferenced NPP. However, these satellite products cannot be offered as credible options for general use until rigorous field validation is completed. In the end, global scientists gain by having trustworthy estimates for carbon cycle research, and local land managers benefit by having a previously unavailable data stream of NPP that are continuous across the landscape, not merely plot samples, and are repeated frequently. Furthermore, local scientists have the option of enhancing these global satellite products with local weather data and crop yield factors for more specialised local products.

5.2 Kyoto Protocol

Dr Allen Solomon reviewed the Kyoto Protocol on forest sinks and its relation to the global terrestrial carbon cycle issues:

The Intergovernmental Panel on Climate Change (IPCC) is an international body of scientists convened to synthesise current information on the known characteristics of climate change and its impacts, for application by policy-makers. Since its credibility is critical to its mission, IPCC uses only scientific results published in the peer-reviewed literature. It does not commission collections of scientific or monitoring data, hence it is quite complementary to GTOS and TOPC, which address the gathering and/or organisation of the collection and the assembly of such measurements into data sets. The most likely relationship between GTOS and IPCC is through the Conference of Parties (COP) to the Framework Convention on Climate Change (FCCC). COP sponsored the Kyoto meeting in 1998 in order to operationalise the FCCC, generating the Kyoto Accords for that purpose. The scientific information for COP is provided by the Subsidiary Body for Scientific and Technical Advice (SBSTA). SBSTA has requested IPCC to produce a special report which describes how to define the carbon amounts associated with three specific types of land use: afforestation, reforestation, and deforestation (ARD). The Special Report on Land Use, Land Use Change, and Forestry, is being written by IPCC to meet this need, and is expected to be published in May 2000. The recommendations of that report, in turn, will be reviewed by SBSTA. They will form the basis for its recommendations to the COP concerning subsequent efforts to include the carbon sequestered and released by land use and forestry within the carbon abatement commitments by Annex I countries.

The Kyoto Accords contain three Articles of critical importance to efforts aimed at providing data in support of the accords:

Article 3.3. *The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period shall be used to meet the commitments in this Article of each Party included in Annex I. The greenhouse gas emissions from sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8.*

Note that the subject is land use change induced by direct human activity, that is, it probably does not include indirectly human-induced land use change, such as intense forest fires induced by fire suppression activities. Note also that the article is limited to forests and their appearance or disappearance, not to other land cover types. The article also specifies that forests of interest are only those undergoing a land use change since 1990; these are referred to hereafter as Kyoto Forests. Finally, note in this article that reporting requirements demand verifiable estimates of carbon fluxes; however, the values must be spatially explicit, otherwise, specific changes of land use cannot be measured and verified.

Article 3.4. *Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide for consideration by the Subsidiary Body for Scientific and Technological Advice data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how and which additional human-induced activities related to changes in greenhouse gas emissions and removals in the agricultural soil and land use change and forestry categories, shall be added to, or subtracted from, the assigned amount for Parties included in Annex I, taking into account uncertainties, transparency in reporting, verifiability, the methodological work of the Intergovernmental Panel on Climate Change, the advice provided by the Subsidiary Body for Scientific and Technological Advice in accordance with Article 5 and the decisions of the Conference of the Parties. Such a decision shall apply in the second and subsequent commitment periods.*

Article 3.4 specifies that only Annex I countries (essentially, the developed countries) must keep track of carbon storage and emission from land use and forestry because only Annex I countries are required to provide information on their carbon stocks. However, Article 6 of the Kyoto Accords permits trading of carbon credits between Annex I and Annex II countries and with countries in transition (primarily, Eastern Europe and Russia). Hence, land use-induced carbon sequestration in those countries also must be measured if it occurs after 1990, and if it is involved with carbon offset projects claimed by Annex I countries. Note in this regard that data are required to establish spatially explicit carbon density in 1990 (because of its application to later measurements), and spatially explicit changes in carbon density in succeeding years. Finally, the article demonstrates that other land use activities which are not ARD will only apply in the second commitment period and later ones. Hence, for simplicity those changes are excluded from this discussion. This point, however, brings up the question of what commitment periods are, and which is the first one.

Article 3.7. *In the first quantified emission limitation and reduction commitment period, from 2008 to 2012, the assigned amount for each Party included in Annex I shall be equal to the percentage inscribed for it in Annex B of its aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A in 1990, or the base year or period determined in accordance with paragraph 5 above, multiplied by five. Those Parties included in Annex I for whom land use change and forestry constituted a net source of greenhouse gas emissions in 1990 shall include in their 1990 emissions base year or period the aggregate anthropogenic carbon dioxide equivalent emissions minus removals in 1990 from land use change for the purposes of calculating their assigned amount …..*

Article 3.7 prescribes the first commitment period to be 2008 to 2012. While Kyoto Forests are those which undergo a change in land uses associated with ARD activities from 1990 onward, only the carbon losses or gains measured between 2008 and 2012 are to be included in the accounting of a country's carbon sum. To date, ARD has been considered by the Special Report authors to mean that a change in land use has occurred - either between deforestation and reforestation, or following deforestation or preceding afforestation or reforestation. As a result, a forest harvested for its lumber or pulp can only be defined as "deforested" when it undergoes some other intermediate land use, such as farming or pasturing. If instead the harvested land is immediately replanted, or if it continues to be carried as forest in national land classification schemes, then it would not be Kyoto Forest, but merely land subject to forest management. However, note that the decision on whether forest harvests are deforestation or are part of forest management is a decision COP will make in the future with advice from SBSTA.

Given the above, precise definitions in the application of the Kyoto Accords will be critical in determining the nature of the monitoring variables and measuring programmes which are of value in defining the Kyoto Accords requirements. Yet, the framers of the Kyoto Accords did not define such keystone terms as "forest," "direct human-induced land use change," "afforestation," "reforestation," and "deforestation." Instead, the authors of the IPCC special report are expected to review the more common definitions of these terms and to discuss the implications to carbon credits that each carries. This lack of definitions makes it difficult to estimate carbon amounts and especially, to avoid unintended consequences of the definitions. Examples of the complexities include:

Definition of "forest." If by forest density, say a minimum of 50 Mt/ha of woody biomass combined with some minimum height (5 m), then countries can remove trees from their dense forests down to that value, emitting large amounts of carbon but not requiring reclassification of the decimated forests as Kyoto Forests. If one defines forest by cover values, say the 10 percent of possible canopy area and 5 m height which FAO uses, then again forests can be thinned throughout the 22 years leading to the conclusion of the first commitment period without contravening a Kyoto Forest definition.

Definition of afforestation, reforestation and deforestation. Do they require a land use change? If so, how does one detect a change from say, pasture for cows and natural regeneration after removal of the cows? Do the definitions truly exclude forest harvest and regeneration? After all, the exact words in Article 3.3 refer to changes in greenhouse gas emissions due to direct-human induced land use and forestry activities - what can be more clearly described as forestry activities than the harvest and regeneration of forests?

The need for identifying the mechanism of change. This induces the requirement for land-surface observations in addition to any remotely sensed data since the latter do not necessarily permit attribution of causes for changes in surface characteristics. Hence, despite the unavoidable emphasis on remotely sensed data, reliance on those data either available now or from instruments on upcoming satellites, will not fully meet the requirements of COP for including carbon derived from land use change and forestry.

How "direct" must human-induced changes be? Do they include only plantation forest regeneration, or, can they also include natural regeneration where that is the standard approach to replant forests, as in the Pacific Northwest of North America? Do they include carbon releases from insect infestations and wildfire, where those losses derive from forest management policies (and if so, how is such causal source proven?), or, are these to be considered natural changes and hence, of no relevance to Kyoto Forest? If the latter, are wildfires caused by the careless use of campfires by humans also irrelevant to Kyoto Forest accounting? What about fires purposely started by humans?

Other complications arise from the definition of Kyoto Forest area. Only ARD is used in carbon accounting, but the activity can occur any time from 1990 to the end of 2012. Changes which first occur in 2010 may represent the first designation of land as Kyoto Forest, which then requires carbon density measures from 1990 as well as the changes which have occurred thereafter. A related consideration is the lags built into forest changes. Deforestation can take place during a single year, but carbon emissions from associated forest soils can continue for decades. Equally, planted forests gain very little carbon during their first decade or so, but continue to gain carbon for 50, 100 or even 200 years thereafter. How does one credit the carbon resulting from these activities if the commitment period ends and the accounting occurs in e.g. 2012? Does a country take the carbon losses associated with removal of an entire mature forest with e.g. 200 Mt/ha above ground biomass, and take the credits from its newly growing replacement a few years later which may amount to only e.g. 5 or 10 Mt/ha? Or, does the expected growth of replacement forests over subsequent decades add to the credit, while loss of carbon from soils in subsequent decades reduce that credit? If the latter, does one calculate the expected future growth in the absence of effects by ongoing climate change, or does one somehow calculate the expected change in growth from climate change during the several decades of lagged carbon storage and release?

There are also complications due to the need for a continued monitoring of land parcels once they become identified as Kyoto Forest. Obviously, a country cannot accept the carbon credits derived from a parcel on which reforestation takes place in one commitment period, then remove that parcel from consideration during the next commitment period, when it can be harvested without an accounting. Hence, continuous monitoring is required once a land is declared Kyoto Forest. This appellation applies as well to land involved in carbon trading in less developed countries; once the land is defined as Kyoto Forest, it cannot be removed and used for some other purpose, such as farming, urbanisation or the like, without incurring a carbon debt to the country in which it is located (i.e., the country under whose control the used land resides). This may severely limit the amount of land less developed countries will be willing to include in trading carbon credits with Annex I countries.

The above issues address some of the complications arising from the attempt to operationalise the Kyoto Accords. The IPCC special report is designed to highlight these difficulties and unintended consequences for SBSTA, a body which will use the report as the basis for their recommendations to COP following presentation of the IPCC special report in May 2000. There is also some question as to whether GTOS remit includes provision of carbon density and forest distribution data which the Accords require and, if so, how to facilitate their generation. These data do not involve climate change; rather, they are focused entirely on carbon sources and sinks resulting from land use and forestry activities, which only indirectly relate to climate change, especially during the few years involved in the current Kyoto Accord initiation of measures, and during subsequent commitment periods.

5.3 Perspectives and Requirements for Terrestrial Carbon Observation

Dr Wolfgang Cramer discussed IGBP perspective and requirements for terrestrial carbon observation:

The IGBP Carbon Project represents an initiative by a large part of the IGBP community, across core project and other programme elements, and in cooperation with the World Climate Research Programme (WCRP) and the International Human Dimensions Programme (IHDP) to provide a synthesis of current understanding of the entire global carbon cycle (not just the biospheric component of it) on two time frames: as a fast-track synthesis report (to be completed during 1999, targeted to the needs of scientific input to the IPCC), and a more comprehensive synthesis of present knowledge (to be completed during 2000).

Part of the comprehensive synthesis will be a reassessment of currently available data sets, as well as the definition of requirements for a better assessment of the observational basis. In Appendix IV, some elements of past discussions on the data requirements for the IGBP Carbon Project are listed, but this list is preliminary and has not yet been discussed by IGBP. Many data requirements in the list are clearly not directly available from observing systems - therefore, methodologies to derive quantitative estimates from observed data sets are a separate and critical topic for further work.

Dr Cihlar presented an overview of the evolving requirements for information on terrestrial carbon cycle: from information on land use changes (mainly in the tropics) in the 1980s, to vegetation (mainly forest) inventories and their biomass and age characteristics in the 1990s (carbon pools-based approach), to data on flux exchange between the ecosystem (plants and soil) in the late 1990s (flux-based approach). While the current IPCC-specified approach to estimating national trace gas emissions is based on the inventory/pools approach as the only feasible one at the national level for many countries, the research frontier is addressing the flux-based approach and has already produced validated regional results. From the GCOS/GTOS perspective, an additional advantage of this approach is its compatibility with the GHOST observation strategy.

Dr Cihlar summarised the expectations of IGOS-P in the development of the terrestrial carbon theme, based on recent documents. Briefly, the proposed theme should have well-articulated, synthesised high level requirements, separately supported with more details; should take account of international, national, and regional requirements; should be sensitive to major issues connected with international conventions; could include operational, research requirements but aim for operational; should include the definition and inclusion of in situ requirements as a vital component; should identify requirements beyond data and products that can be met/provided from existing systems and those currently under development; and should have clearly defined objectives, roles and responsibilities of space and user agencies, milestones, outputs, success criteria, and resources required for execution.

5.6 In a breakout group, meeting participants discussed the vision, scope and content of a terrestrial carbon theme. They agreed to put forth the concept for a Terrestrial Carbon Initiative (TCI), based on the following vision:

> TCI is envisioned as a functioning network of frequent observations and computer models, targeted for documenting and understanding the present state of the terrestrial

component of the global carbon cycle. The input data will be provided by an optimised combination of remotely sensed and ground-based observing systems. The carbon cycling models must be sensitive to natural and human - induced changes in the environment; operate at a relatively high resolution to use optimally the input data; and produce maps of the terrestrial C sources and sinks on a seasonal, annual, interannual, and decadal basis. The resulting products must be sufficiently detailed to be useful for international conventions, policy decisions, and climate or environmental change assessments at global, regional and national levels.

TOPC also defined the objectives, scope, intended products, essential components of TCI; identified existing observation requirements identified by various groups, including TOPC (Global Climate Observing System, 1997) and IGBP (Appendix IV); discussed technical approach, gaps and problem areas; and prepared an outline of the prospectus and an initial version (Appendix V). It decided that regarding the forest biome, given the complexities and the present state of implementation of the Kyoto Accords (see Section 5.4), TCI would provide contributing information but should not endeavour to meet all the information requirements.

In response to the charge from GTOS/GCOS, TOPC agreed to carry out the following actions and schedule:

- Complete the first version of the prospectus by the end of August, 1999
- Distribute the prospectus for comments among scientists in G3OSs, IGBP, IPCC, and in other forums to ensure the soundness of the overall goals and strategy
- Revise the prospectus, using email and/or additional meeting if necessary
- Prepare a presentation for the November 1999 meeting of IGOS-P, along with a plan for the completion of the theme document (with a full meeting in the spring of 2000 as a key step)
- Present to IGOS-P and obtain comments
- Modify approach based on comments, carry out the rest of the plan.

Regarding the terrestrial carbon theme, TOPC made the following recommendation:

Recommendation 5.1: TOPC recommends that GCOS/GTOS support the development of the TCI concept along the lines described Appendix V, including interactions with key agencies and interest groups as well as additional meetings as required.

6. Non-climatic Variables for Global Terrestrial Observations

To assist in the planning of GTOS, TOPC was requested to provide expertise in the development of specifications for observations needed for non-climate components of GTOS:

6.1 Development of Specifications for GTOS Terrestrial Observations

Dr Reichert described preparatory work done on the development of specifications for GTOS terrestrial observations in the following areas:

- changes in land quality;
- availability of freshwater resources;
- loss of biodiversity .

An initial list of variables related to above issues, starting with land quality and freshwater resources, was compiled within the Environment and Natural Resources Service (SDRN) of FAO, by reviewing and taking into account lists of variables developed by TOPC, the GTOS Steering Committee, the United States Environmental Protection Agency, and lists of other institutions and individuals identified through Internet search and literature review. These variables were entered into spreadsheets (separately for freshwater resources and land quality), and sorted into:

- baseline information, containing variables considered to be stable over a longer period (>10y), for instance the variable <Soil Class>;
- physical variables;
- chemical variables;
- biological variables.

In the case of land quality change variables, a distinction was made between soil parameters and other land quality-related variables. The following attributes were given to each of the variables, following the format developed for the climate-related variables:

- Priority (1=essential, 2=desirable, 3= optional). The rating was to be undertaken by FAO-internal and external experts with the aim of identifying a core set of essential parameters.
- Data Type (Target, Input, Ancillary, Measured), as specified in the TOPC IV report.
- Horizontal Resolution, Cycle, Timeliness and Accuracy at optimised and threshold level as defined in the TOPC IV report.
- Applications (as specified in the TOPC IV report).
- Method (variables measured in situ or derived or obtainable from remote sensing data, GIS-data, or modelling).

In the second step, the variable lists and their attributes were reviewed and revised by FAO-internal experts. Variables considered unimportant for the given subject under consideration were removed and other variables added. The revised variable lists were then sent to external experts and to GTSC for their review in preparation for discussions at the TOPC V meeting. Comments on these lists were received prior to the meeting in Birmingham, but the review by external experts is to continue afterwards.

Regarding variables to monitor loss of biodiversity, a specific working group will be set up in the framework of Convention of Biological Diversity (CBD) to define the key variables and will meet in September/October this year. In the meantime, a review paper ‘Suggestions for Biodiversity Loss Indicators for GTOS’ was prepared and distributed for review and comments. In addition, a literature and Internet search was undertaken and some 300 indicators were found which now have to be reviewed, sorted and short-listed in preparation for the forthcoming working group meeting.

6.6 Socio-Economic Variables

A preliminary list regarding socio-economic variables has been compiled by A. Borde, GTOS Secretariat, which should be relevant for all the GTOS issues:

TOPC meeting participants reviewed the specifications of variables for land quality and freshwater resources in a breakout group. Changes and modifications were proposed regarding the priority/importance of individual variables or for other attributes, and specific variables were proposed for addition or deletion. A ‘measurement units’ column was also added. In addition, the theme ‘health’ was added to the list of applications. The revised version of the tables is attached (Appendix VI).

There is a strong need to examine the specifications for individual variables from the perspective of applications and the models/other purposes within which these variables are to be employed. This important step will help ensure that the list is complete and that, once obtained, the list of variables will meet the intended purpose.

There is a requirement for further reviews of the specifications by other groups, as well as for similar reviews of variables beyond the expertise of TOPC members (e.g., health, and socioeconomic issues). Exact definitions of individual variables (other than those already defined by TOPC in the report of the Corvallis meeting; Terrestrial Observation Panel for Climate, 1998) should be developed. Once these specifications are finalised, the process and the result should be documented in a GTOS report, to provide traceability of the requirements to uses and a basis for making future adjustments. The resulting specifications should then be entered into the WMO database of specifications for global observations.

Recommendation 6.1: It is recommended that GTOS consider the following steps to finalise the variables for GTOS non-climate requirements:

- examination of the variables and specifications from the perspective of models/intended uses of the variables;
- additional reviews of the freshwater and land quality variables by other experts;
- preparation of exact definitions for individual variables and terms where required;
- preparation of a GTOS report containing a description of the process used, the definitions of the various terms and criteria used, and the final specifications.

7. Status of Glaciers, Permafrost, Hydrology and Ecology Networks

In addition to discussing specific issues regarding the further development of individual networks (see Sections 7.1. through 7.4), participants also prepared input to a concise description of each network as required for the SBSTA/COP process. These descriptions were subsequently finalised and are attached as VIII.

7.1 Glaciers

Dr Roger Barry reported on the status and progress of the glacier network:

During the past year, the glacier network (GTN-G) was formally established following preparations at TOPC-IV and subsequent actions which included contacts with national agencies, definition of observation and reporting guidelines, and organisation of the invitations sent to individual countries.

Twenty-eight countries have so far agreed to participate in GTN-G (Argentina, Australia, Austria, Bolivia, Canada, Chile, China, CIS, Colombia, Ecuador, France, Germany, Greenland/Denmark, Iceland, Italy, Japan, Mexico, Mongolia, Nepal, New Zealand, Norway, Pakistan, Poland, Spain, Sweden, Switzerland, the United States, Uzbekistan. GTN-G includes annual glacier length measurements at about 500 sites, and annual mass balance measurements on a subset of about 60 glaciers. The observations will be published on the web at the World Glacier Monitoring Service (WGMS) and the mirror site at the World Data Center-A for Glaciology: WGMS web: **http://www.geo.unizh.ch/wgms**. WDC-A/NSIDC web: http://www-nsidc.colorado.edu/NOAA/wgms_ inventory/.

During the year, TOPC members have been exploring various possibilities for an enhancement of global glacier observations and for further development of GTN-G: closer association of the Global Land Ice Measurements from Space (GLIMS) project with GTN-G (see 7.1.4); identification of gaps in the surface networks and ways of filling these; and streamlining of reporting and quality control procedures for glacier information.

Dr Kargel described the GLIMS project’s objectives, current status, the planning of an international collaboration involving regional GLIMS coordinating centres, the status of products development and validation, and the possibilities for an integration of GLIMS into GTN-G (GLIMS web: **http://www.flag.wr.usgs.gov/GLIMS**). The project addresses a major limitation of the present GTN-G, namely lack of spatially representative information. Subject to funding, the GLIMS project aims to produce an inventory of up to 95 percent of the world's estimated 160,000 glaciers by 2005 (currently only about 67,000 glaciers are in the World Glacier Inventory), assuming that the needed Terra-ASTER satellite data start becoming available in 2000. Three glacier parameters will be measured every one to five years, depending on data availability: total length, total area, and ablation area (displacement). The use of new technologies will also be explored to obtain displacement, glacier motion tracking, and elevation information using active satellite optical and microwave sensors. The information obtained from the satellite-derived products and related field data will be placed in the WDC-A for Glaciology.

TOPC discussed the status of GTN-G, link with GLIMS, and the need for national inputs regarding glacier observations. It highlighted the importance of GTN-G and GLIMS for a comprehensive global monitoring of glaciers. Given the relevance of glacier observations to climate as well as freshwater supply, glacier monitoring should be an important part of an eventual IGOS-P terrestrial theme. For this reason and given the progress made by both GTN-G and GLIMS, GTOS should consider developing plans for long-term, sustained glacier observations.

Glacier observations would logically form a part of the ‘terrestrial’ theme proposed for IGOS-P (refer also to Section 2). However, other terrestrial issues are not as advanced, and the definition of the entire terrestrial theme appears premature. This suggests that sustained glacier observations might best be developed as a component in its own right, to be incorporated in the terrestrial theme in due course, as the latter develops.

The following recommendations are made:

Recommendation 7.1: Given the potential of GLIMS to provide a fundamental enhancement to the global capability for glacier monitoring, the following actions should be taken:

- GTOS and GCOS should continue supporting GLIMS as an important component of systematic global observations of glaciers.
- GLIMS should be endorsed as a pilot project in the TOPC framework, with the goal of integrating GLIMS-developed capabilities into GTN-G.
- TOPC/GCOS/GTOS should support GLIMS in securing resources needed to carry out its plans in the various glacier regions of the world. In particular, a letter should be prepared to highlight the importance (both short-term and long-term) of GLIMS for the funding process.
- GLIMS should strive to ensure that regional gaps are filled where possible and should use existing GTN-G contacts/sites for this purpose.

Recommendation 7.2: That the process initiated by COP-4 be used to increase the comprehensiveness of GTN-G coverage (refer to Section 7.1).

Recommendation 7.3: It is recommended that based on the results and experience from GLIMS, glacier monitoring be incorporated in the terrestrial theme of IGOS-P when the latter is being defined.

7.2 Permafrost

Over the past year, TOPC has been working with the International Permafrost Association (IPA) to establish a global network for permafrost observations, GTN-P. Dr Jerry Brown, Member of the IPA Executive Committee, reported on the progress made and the current status.Two frozen ground variables were identified as part of the cryosphere component (Global Climate Observing System, 1997):

- Active layer: the thickness, and if possible the temperatures, of the seasonally freezing and thawing zone overlying permafrost; thickness to be determined at a minimum by soundings in late summer at the time of maximum thaw depth, through the installation of thaw tubes, or through temperature profiling.
- Permafrost thermal state: the temperature profile within perennially frozen ground at frequencies ranging from weekly to monthly in the upper permafrost and increasing to annually or every five to 10 years for greater depths.

In 1998, IPA established an ad hoc steering committee to develop a strategy for the organisation, implementation and management of a global monitoring network and service for active layer and borehole temperature monitoring. Membership included: Jerry Brown (IPA), Wilfried Haeberli (World Glacier Monitoring Service), Roger Barry (World Data Center-A for Glaciology), Frederick E. Nelson (University of Delaware), and Margo Burgess (Geological Survey of Canada). The group prepared and submitted to GCOS a strategy and implementation report. Based on the report GCOS Steering Committee endorsed the Global Terrestrial Network-Permafrost (GTN-P) in February, 1999 and requested that IPA implement the GTN-P to serve the needs of GCOS and GTOS.

Important uses and users of permafrost data include: research and modelling (e.g. carbon cycle, gas hydrate, paleoclimate, GCM input); IPCC assessments; GCM validation; engineering/geotechnical uses (e.g. roads, pipelines); government agencies and organisations (e.g. transport, energy, mines, hydropower, municipal planning); hydrocarbon/mineral industries (e.g. exploration and development); land management; water resources; water supply and treatment; and the handling of contaminants.

Parts of the GTN-P are already in place through national and regionally funded projects. Under the coordination of IPA, active layer measurements are being obtained at about 80 sites in the Northern Hemisphere as part of the Circumpolar Active-Layer Monitoring (CALM) network. The United States National Science Foundation (NSF)-funded CALM web site developed at the University of Cincinnati contains site descriptions, data summaries, and sampling protocols. The European Community project Permafrost and Climate Change in Europe (PACE) has begun to instrument a series of nine permafrost boreholes in mountains from Spain and Italy to Svalbard. A PACE renewal proposal under the Global Observation Systems Key Action of the 5th Framework is in preparation for a January 2000 submission. Web sites support each programme or recently designated subnetworks (see table in Appendix VII):

- IPA web: http://www.geodata.soton.ac.uk/ipa
- CALM web: http://www.geography.uc.edu/CALM
- PACE web: http://www.cf.ac.uk/iwcc/EARTH/PACE
- Borehole web: http://sts.gsc.nrcan.gc.ca/permafrost/

What remains to be accomplished is the development of a globally comprehensive network of permafrost borehole temperature measurements, building on past and current programmes. An action plan has been developed (Appendix VII) to put in place for the 21st century a standardised set of site measurements that will conform to the requirements defined by TOPC (Global Climate Observing System, 1997).

In order to gain national commitments for continued site measurements, GCOS is requested to send letters of invitation to individual countries. Although the GCOS criteria require commitments to ensure sustained observations, this will not always be possible in all countries, particularly for sites where standard equipment is unavailable and/or support is required for site visits. For this reason it is also proposed to assist in starting up a limited number of representative sites in Argentina, China, Kazakhstan, Mongolia and Russia.

Recent related IPA activities include compilation and publication of a new permafrost map (1:10,000,000), preparation of a CD-Rom (refer to the GOSIC web site under GTOS - Cryosphere), publication of the news bulletin Frozen Ground, establishment of several web sites, coordination among the eight IPA working groups and the 23 national members, preparation for the 7th International Conference on Permafrost held in Yellowknife, Canada, June 1998, and liaison with numerous international organisations. A resolution was passed in Yellowknife supporting the GCOS/GTOS terrestrial networks and its inclusion in the IPA CALM network as well as in the Permafrost and Climate in Europe (PACE) projects. Appendix VII provides further information on the GTN-P background.

TOPC discussed the progress report and the need for reporting on national activities. It commended IPA and Dr Brown on the progress achieved over the last year and the formulation of ambitious future plans, and made the following specific recommendations.

Recommendation 7.4: TOPC recommends that GCOS/GTOS send out invitations to countries to participate in GTN-P, based on the plans developed by IPA.

Recommendation 7.5: TOPC recommends that the borehole sites be identified in GTN-P as part of the measurement of the thermal state parameter.

Recommendation 7.6: TOPC recommends that once initial sets of sites (active layer and boreholes) are identified they be entered into the GTN database (refer to Section 11).

Recommendation 7.7: TOPC encourages GTN-P to continue improving the network, the comprehensiveness of its geographic and temporal coverage (with priority emphasis on mountain and plateau regions of Eurasia and South America), and its long-term viability and functioning, along the lines of the action plan developed (refer to Appendix VII).

Recommendation 7.8: TOPC endorsed IPA and GTN-P initiatives in recovery of data in digital form, including soil temperature observations in Asia and historical permafrost borehole data.

7.3 Hydrology

Dr Landwehr reported on the progress in establishing mechanisms for acquiring and accessing global hydrological data sets for GCOS/GTOS purposes:

As a follow-up to TOPC-IV item 12.6.1. (Information Dissemination), Dr Landwehr made a presentation at the IUGG99 conference taking place at Birmingham University, in the IAHS workshop HW1 "Global Data Bases" (cosponsored by WMO, IGBP-BAHC, ICASVR, ICWQ, ICSW, ICCE, and the IAHS/WMO Joint Working Group). The talk was entitled "A

Review of Global Hydrologic Data Sets in Relation to the GCOS/GTOS Plan for Terrestrial Climate-Related Observations. This was accompanied by a posting of GTOS and GCOS materials and reports for the duration of this workshop. The presentation highlighted the work of TOPC and its interest in developing a global hydrologic multivariable data set that meets needs of both researchers and managers. During the IUGG and IAHS meetings contacts were made with members of other groups attempting to develop global hydrologic data systems for their respective purposes, including GRDC, WHYCOS, FRIENDS, and the newly evolving HELP.

The limited progress that has been made toward the development of a TOPC hydrologic network following the initial identification of variables of interest (Global Climate Observing System, 1997) reflects the nature of hydrologic information availability. Although there is an increasing call for global information by many groups with a climate change focus, such as IPCC, as well as groups with global change concerns such as IGBP and various UN agencies, the global availability of hydrologic information is diminishing. Hydrologic measurements are made primarily to address the operational concerns of regional and national hydrologic services. These observational networks have not been established primarily to satisfy climate or research objectives, but rather are funded for purposes of water resources assessment. Thus, global hydrological data are highly heterogeneous in quality, with a diverse pedigree, and from a multiplicity of sources.

The number of hydrological data sources is decreasing. Although the cost relative to satellite systems may seem small, the staffing and sustained funding of the in situ networks is difficult to maintain. Presentations at the 1999 IUGG meetings have highlighted reductions of the observational systems, in developed as well as developing countries and in countries with rapidly changing economic conditions, such as those of the former Soviet Union. Furthermore, the access to existing hydrological data is diminishing for several reasons. First, many countries view information about water resources to be a matter of national security and do not wish to share this information. Secondly, as governments are searching for new sources of revenue to finance activities historically considered to be “for the common good”, many regional and national authorities treat hydrological data in particular as a commercial commodity. A reflection of the severity of the problem of access is attested to by the passage of Resolution 25 by WMO Congress XIII in May, 1999, pertaining to the exchange of hydrological data and products. In addition, there is an overall concern regarding the privatisation of scientific information.

In the 1997 report (Global Climate Observing System, 1997), TOPC identified seven variables to be of primarily hydrologic concern: surface water discharge, surface water storage fluxes, groundwater storage fluxes, precipitation, evapotranspiration, relative humidity, and transport of biogeochemical materials from land to ocean. Two other variables identified, soil moisture and snow water equivalent, also have important hydrological dimensions. Furthermore, *water use* should be added to better assess the impact of climate change on water resources. Unlike the other nine above variables which are primarily of a physical nature, water use arises from socio-economic causes and is critical to assessing climate change and human activity as an agent of global change.

There is no single global entity that serves as a data center for the above variables, nor is there a single national or regional agency that monitors each of these variables within a region or a nation. Thus, the assembly of an adequate global information base will be a significant challenge.

HELP (Hydrology for Environment, Life and Policy) is a new global initiative currently being organised under the auspices of WMO and the UNESCO IHP (International Hydrological Programme), as a parallel effort to the IHP FRIEND programme. HELP is envisioned to be a field-oriented programme of research, addressing questions about hydrological catchment processes at the mesoscale, but the research questions will be specifically motivated by societal needs. HELP's intention is to formally bring together water policy specialists and water resources managers with members of the hydrological research community. HELP plans to develop strong ties with the modelling and remote sensing communities, and the initial terms of reference recommended that HELP should also be closely interfaced with other global programmes such as the WCRP/GEWEX, ICSU/IGBP, other UN agencies, non-governmental organisations, international programmes and the World Water Council's Vision on Water, Life and Environment in the 21st Century. Close ties between HELP and GTOS and GCOS are desirable because of the shared need to develop global information that will satisfy both scientific and policy management needs.

Dr Kuma discussed the case for improved land hydrological information. For climate prediction, ocean-atmosphere interaction has been recognised to be of primary importance as research-oriented ocean observation networks such as TOGA-TAO array come to an operational phase. It has also been shown by many studies that Eurasian snow amount before the monsoon season is important for the intensity of the Asian Monsoon. The Global Soil Wetness Project conducted under WCRP/GEWEX identified the impact of global soil moisture distribution upon the seasonal climate prediction. Given the recent progress in land surface data assimilation, it will be possible in the next several years to combine in situ observation and satellite passive microwave observation with models to produce the global analysis for soil moisture and snow water equivalent, thus substantially improving seasonal climate prediction. River discharge data provide a powerful validation tool for global analyses. The success in seasonal climate prediction will yield large national benefits for agricultural, water management, and other user communities. Since improved predictions depend on the availability of observations to the climate modelling institutions, it is in the interest of nations and agencies conducting such observations to make them available for climate analysis and prediction. It is important to note that the relevant in situ observations are already made in many countries and the major problem lies in the exchange of the data. The keys for a successful transition are 1) promotion of the international exchange of operational data and 2) the increased use of the satellite data for the operational land surface analysis.

TOPC noted with satisfaction the adoption of Resolution 25 of the XIIIth Congress of WMO on hydrological data which it regards as an important step in developing a viable global network for hydrological observations. TOPC also welcomed the agreement to put snow cover data on GTS. These are important steps in improving the availability and effectiveness of land hydrological observations for climate analysis and prediction.

TOPC discussed the above issues and made the following recommendations.

Recommendation 7.9: Water use should be added to the list of hydrologic variables to be obtained globally. The USGS model of reporting WATER USE both by political and hydrologic spatial units, for various economic/industrial sectors, on a five-year time step, could be used as an appropriate format.

Recommendation 7.10: GTOS should develop contacts with HELP coordinators to see how programmes could be developed in a coordinated manner.

Recommendation 7.11: GTOS should continue exploring ways of improved availability of snow depth and other observations, and should consider the feasibility of proposing “water theme” in IGOS-P framework.

Dr Cihlar reported on the recommendation by GCOS SC for TOPC to organise, in collaboration with WMO and other organisations as appropriate, an experts meeting on a global hydrological observing system. In establishing such a system, the basic issue is a mechanism that provides hydrological data for a community of users interested in climate change/hydrological processes. This can most effectively be provided by agencies that are in the business of collecting, archiving and making available hydrological data on an operational basis. These include:

- Collecting: national agencies, WHYCOS, research programmes
- Archiving and access: the main two integration centres are GRDC and GPCC, and also several related WMO programmes. It should be noted that these centres and programmes routinely establish contacts with other groups/agencies that provide hydrological data, including the scientific community.

Consequently, a suitable initial strategy for GCOS/GTOS could be to ensure that such centres also provide data and products that are needed by GCOS/GTOS, and then assist them in this task in appropriate ways. In practice this means: a) familiarisation with the current programmes of the two centres; b) identification of gaps, problems in collection, etc.; c) agreement on the role of these in GCOS and GTOS,....; d) assistance in the collection and access to original data (including support in establishing new networks, filing gaps, etc. Dr Cihlar noted that this approach met with a broad support within GCOS and GTOS when initially proposed.

Based on the above, TOPC discussed the possible scope and format of such a meeting, and proposed the following:

Meeting objectives

- Develop a vision and a strategy for establishing an initial, end-to-end global hydrology observing 'system' consisting of observing network and sites, data assembly and quality assessment 'sites', and data archiving and distribution 'sites', focusing on the 10 hydrological variables identified by TOPC (see 7.3.1.4 above).
- Identify existing networks, centres and mechanisms that could contribute to achieving the vision.
- Develop a progressive action plan, starting with an initial, limited-scope observing system to be operational within two years and capable of expanding and taking advantage of new opportunities. The plan should identify specific actions that can realistically be implemented, propose implementing/responsible groups/agencies, and specify coordination mechanisms that would be required to facilitate such implementation.

Participants

In principle, two interests need to be represented, hydrological data 'sources' and 'users':

- 'Users': to include global observing systems (G3OS); WCRP (GEWEX, MOPEX); IGBP; UN Council for Sustainable Development.
- 'Sources': global data assembly centres (e.g. GRDC); representatives of national hydrologic services (e.g. WMO Commission for Hydrology); World Data Centers (e.g. NSIDC); national research institutes and programmes that collect hydrological observations; regional cooperative networks (e.g. FRIEND, WHYCOS, ILTER, HELP).

Format

- Background materials should be prepared to document hydrology data requirements with regard to the 10 variables, to clearly understand the spatial, temporal and accuracy requirements as well as other characteristics of these data as seen by the users. These should be based on, but not necessarily limited to, the information developed by previous meetings and expert groups (refer to reports GCOS-27, GCOS-32). The materials should be circulated before the meting and revised based on the comments received.
- Similarly, background materials should be prepared to document the status of global observations and data sets for each of the 10 variables, if feasible.
- The thrust of the meeting should be on using the information in the background materials to achieve the objectives defined above. This would be carried out primarily through plenary and discussion groups.
- A written document would be prepared from the meeting, in a format suitable for circulation among the main stakeholders and proposed contributors. Given the existing programmes and the differences in specific variables, the document should describe the overall framework and then outline the end-to-end ‘system’ for each variable, with appropriate action plan and identification of issues and problems to be dealt with.

Venue

TOPC noted with appreciation the offer of the Global Precipitation Climatology Center to host such a meeting, and it felt that the meeting should be held as soon as the preparations can be completed. Realistically, this would likely be in the spring of 2000.

Regarding the experts meeting on hydrological observations, the following recommendation is made.

Recommendation 7.12: TOPC recommends that the meeting on hydrological observations be prepared according to the outline in Section 7.3.6, and an organising committee should be established representing both ‘source’ and ‘use’ agencies.

7.4 Ecology

Prof. Gosz reported on the status of the ecosystems network, GTN-E:

The initial efforts at identifying global sites that could be involved in GTOS resulted in a large database of sites surveyed and entered into the original TEMS database. That list is now outdated and a renewed effort at locating ecological networks was initiated at the meeting of network experts in Guernica, Spain. That meeting reinforced the need for a Global Terrestrial Network (GT-Net) and the 12 networks represented at that meeting became the initial set in the network. Since that time three of those networks have continued their active involvement in GTOS; CERN (China), ECN (the United Kingdom) and LTER (United States). Renewed efforts will be made to contact the other networks (e.g., Fluxnet) to encourage their continued participation.

The Guernica meeting also determined that demonstration projects were critical in developing interest and demonstrating the capabilities of the network. The first demonstration project was identified to be the Net Primary and Ecosystem Productivity (NPP/NEP, refer to Section 4.2) project that will use data from the MODIS instrument on the Terra satellite to be launched later this year. It was apparent from that meeting that projects must demonstrate a value to the sites to encourage their participation. In this case, free satellite imagery that can be used to estimate local to regional productivity was the key. Since that meeting, the NPP demonstration project has been promoted at many international meetings with the result that other sites from national and international networks have been added to GT-Net. The International LTER Network (ILTER) which represents 17 countries and over 200 sites voted to participate in GTOS. Other countries are expected to join this network in the near future.

TOPC discussed the progress in the GTN-E development. It supported the addition of the existing ILTER sites to GTN-E and encouraged their involvement in the NPP/NEP and GOFC projects to the maximum extent possible. TOPC acknowledged that the addition of sites to the two demonstration projects will increase the level of effort needed for the two-way communications between the sites and satellite data providers, but considered this a critical element of closer cooperation between the satellite and ground-based components in the global observation scheme and essential for a proper validation of the satellite-derived products.

There is a need to examine the adequacy of the coverage by existing flux networks to meet the needs of the two projects. Data shown by Dr Running indicate that the present networks may not adequately sample the precipitation/temperature space occupied by the various ecosystems; this is consistent with an analysis by Dr Leemans presented at the TOPC-IV meeting (Terrestrial Observation Panel for Climate, 1998). A first-order answer to this question might be obtained from modellers who use Fluxnet measurements.

Following the discussion, TOPC made these recommendations:

Recommendation 7.12: TOPC recommends that GTN-E be expanded if possible to include all ILTER sites and that these be engaged in the demonstration projects to the maximum extent feasible.

Recommendation 7.13: TOPC recommends that GTN-E serve as the focal point for the involvement of the long-term ecological sites in the NPP/NEP and the GOFC projects.

Recommendation 7.14: TOPC recommends that NPP/NEP and GOFC projects further examine the adequacy of the existing flux networks for the two projects, and make appropriate recommendations for further action.

8. GCOS and National Reporting

8.1 National Reporting on the Status of Climate-related Observations

Dr Cihlar introduced the subject by reviewing the developments leading to SBSTA/COP-4 request to GCOS to develop guidelines for national reporting on the status of climate-related observations. An initial input to GCOS was reviewed and was found to require more focus, simplification and more emphasis on quantitative, tabular information. A second version was prepared by the GCOS Programme Office and made available prior to the TOPC-V meeting.

In breakout groups, meeting participants considered specific questions that would be appropriate to obtain the inputs from individual countries. Based on the results of the discussion, the following approach is proposed for the terrestrial networks:

For each thematic global network, GT-Net should prepare a web-accessible database with information in the three parts:

Part 1: Sites presently reporting to the global observing systems
GT-Net: For each site, list: site name, geographic location, country, variables measured, period of operation (years)

Candidate questions to be asked:
Does your country intend to support the operation of these sites during the next six years (2000-2005)?

Part 2: Sites taking measurements but not presently reporting to the global observing systems
GT-Net: For each site, list: site name, geographic location, country, variables measured, period of operation (years)
(as available)

Candidate questions to be asked:

Are there other sites where your country supports making similar observations?
Do you intend to support the operation of these sites during the next six years (2000-2005)?
Are the data a) quality controlled and b) archived, and where?
Are you willing to make these data available to GCOS/GTOS for climate-related purposes?

Part 3:GT-Net: Itemise major gaps in spatial coverage that hamper making global or regional assessment in climate trends and impacts; prepare a list of regions and/or countries, and explain the nature and consequence of the gap.

Candidate questions to be asked:
Are you willing to consider establishing observation sites in your country to reduce these gaps?

It is important to note that a country may be supporting sites in another country/region; the questions need to allow for this case. Note also that a different approach will be needed for hydrological information, given that the global network is still evolving (refer to Section 7.3).

TOPC made the following recommendations:

Recommendation 8.1: TOPC recommends that the above approach be considered in obtaining national inputs on climate-related observing networks

Recommendation 8.2: TOPC recommends that the member GT-NET networks develop the required information on the present networks, with the support of GCOS and GTOS secretariats.

9. Climate and Health

Dr Menne and Dr Haines presented an overview of the relationship between health issues and climate, from the perspective of terrestrial climate-related observations:

It is anticipated that climate change will have a range of health impacts. Some will result from direct effects (e.g. heatwave-related deaths and skin cancer induced by ultraviolet radiation); others will result from disturbances to complex physical and ecological processes (e.g. changes in patterns of infectious disease, drinking-water supplies and agricultural yields). Some health effects may become evident within the coming decade; others will take longer.

Literature reviews have shown that:

Changes in the frequency and duration of temperature extremes would entail increases in thermal stress and their well-documented impacts on mortality and morbidity, especially in the elderly.

- Less severe cold weather would reduce the excess winter mortality.
- The increased risk of coastal and riverine flooding has important implications for health (Menne *et al.*, 1999). Floods can cause deaths, injuries, outbreaks of infectious diseases and psychosocial problems.
- El Nino and ENSO events have caused droughts, which might cause famine. Famine has severe effects on the health of the population.
- Some vector-borne diseases have altered their range: a) within Europe: lead to tick-borne encephalitis, malaria - although it is unlikely that malaria would become re-established in Europe if control measures are maintained (however, the risk of localised (autochthonous) outbreaks of malaria may increase); within Africa (cases of highland malaria have been identified, although its causes have not been conclusively determined); and in the Americas (Hantavirus Pulmonary Syndrome was attributed to weather events in Central America).
- There is a correlation between food-borne diseases and air temperature. Increases in temperature may exacerbate the current trend of increases in cases of food-borne illness. There is also an increased risk of diseases associated with microbiological contamination of the water supply system.

Monitoring the potential impacts of climate change on health is important for a number of reasons. The provision of epidemiological data is needed to inform policy-makers about the magnitude of effects. Climate change is currently not seen as a priority within the health sector, although different international mechanisms have been set up to sensitise the public health community. As part of surveillance systems, data can help to determine the requirements for and the effectiveness of preventive and adaptive strategies. The monitoring of climate change impacts requires a more holistic approach to infection etiology, examining the possible influence of climate both on the environmental sources of pathogens and on humans (Stanwell-Smith, 1998).

Why monitor?

- To detect early effects
- To promote better research
- To assist in building integrated assessment models
- To improve and evaluate adaptation strategies
- To inform policy-makers and the public

What should be monitored?

- Climate sensitive diseases
- Potential confounders (migration, life-styles, land use, etc.)
- Adaptation strategies

Which criteria are used to select the climate sensitive diseases?

- Strength of evidence/climate sensitivity
- Potential magnitude of the effects (economic considerations)
- current availability of data including feasibility and cost of collection
- short term benefit of the monitoring process (for example, uses for other health activities and preventive work)

How should we monitor?

- Identify minimum data sets
- Arrangements for exchange/ coordination of data

During a recent consultation of the WHO Working Group on the early health effects of climate change a list of possible mechanisms for monitoring has been prepared (WHO-ECEH, 1998a, b). This list has been reviewed several times, however it still needs substantial rethinking.

Table 1: Issues in Monitoring the Health Effects of Climate Change

Health impacts of:	Where	Data needs: Health	Climate Environment Socio-economic data
Heat stress	Urban population	Daily mortality, by sex, age and cause	Air pollution parameters, others to be defined
Floods	Flood-risk areas	Mortality, morbidity, surveillance data on drowning, injuries, infectious diseases, psychosocial well-being	Early warning data, disaster impact data, meteorological data
Droughts	Vulnerable areas, population	Mortality- morbidity data, population, nutritional status	Early warning data, land use data, data on crops, socio-economic data, food supply, etc.
Other extreme weather events	Vulnerable areas, population	Mortality- morbidity data	Early warning data
Sea level rise	Vulnerable population, areas	Diarrhoeal diseases surveillance	Ground and surface water quality
Changes in marine ecosystems	Oceans, coastal populations	Surveillance data	Chlorophyll a, other indicators for algal bloom, water quality data

Particular Groups of Diseases to be Monitored:

Climate impact on:	Where	Health data	Other data
Water-borne diseases	Current areas of endemicity and sporadic diseases	Mortality and morbidity data; communicable disease surveillance	Essential nutrients and phosphorus levels; water surface temperature and other hydrological parameters; water quantity, etc.
Food-borne diseases	Current areas of endemicity and sporadic diseases	Mortality and morbidity data; communicable disease surveillance Outbreak investigations	HACCP data, etc.
Vector-borne diseases	Current areas of endemicity and sporadic diseases; margins of distribution	Mortality and morbidity data; communicable disease surveillance	Vegetation indices, climatic data, etc.

A number of infectious diseases are likely to be affected by climate change. Monitoring networks exist for some of these diseases. In Europe, WHO had identified *Campylobacter spp.*, *Cryptosporidium parvum*, malaria and tick-borne encephalitis (see Kovats *et al.*, 1999), as suitable for monitoring. For a worldwide, integrated environmental health monitoring a set of three diseases could be identified to begin with.

TOPC discussed the material presented above. It was agreed that TOPC mandate includes monitoring environmental characteristics that are important to health, and it noted the increasing interest in health issues in various regions of the world (e.g., North America, Europe). From the presentations it became evident that health issues are related to several aspects of GCOS and GTOS, including those that concern other panels (e.g., AOPC) and non-climate foci of GTOS. Further work and experimentation, including pilot projects, are required to identify focused strategies for environmental monitoring that would effectively support health monitoring.

TOPC noted the proposed collaboration in Europe between NoLimits and the European Centre forEnvironment and Health, and considered that this project is an appropriate next step in identifying the ways for collaboration between environmental monitoring and human health communities.

10. Land Cover Data Sets Production

10.1 Land Cover Change

Dr Cihlar introduced the subject by reviewing the status of land cover mapping. Land cover and cover change are important environmental variables identified by TOPC (Global Climate Observing System, 1997). In addition tot he general importance of land cover products, they are a critical input to the two pilot projects, NPP/NEP and GOFC.

In recent years, significant progress has been made in the development of global land cover products at the resolution of ~1000 m, and two global products have been completed from AVHRR composites (accessible through GOSIC). In addition, rapid progress may be expected over the next two years with the imminent launch of EOS Terra and research groups poised to use the ensuing data for land cover mapping.

Significant methodological development is required for the high resolution data (~25 m). Because of the mosaic-type coverage of large areas constituted by individual scenes, the data processing and classification procedures are not yet uniform and sufficiently automated to produce consistent regional or global products. Nevertheless, there are a variety of approaches and some convergence is developing towards a consensus strategy in this area. Several countries or research institutions have mapping programmes under way that cover fairly large areas and whose experience is highly relevant to the development of a globally applicable methodology.

TOPC discussed the above issues, with a view to defining a strategy for the production of quality land cover data sets for climate-related applications. It was agreed that, for the medium-resolution data (250-1000 m), TOPC and the two pilot projects should establish closer linkages with research teams involved in this area. For fine resolution data, there is a need to review the experience with various approaches with a view to defining a consensus approach(es), possibly regionally dependent. Given the special interest of GOFC in these products; and the planning and contacts already established, GOFC provides a suitable mechanism for attempting to obtain this consensus. It was also recalled that at the first GOFC workshop in Ottawa, a number of participants expressed interest in a community activity regarding land cover classification methodologies from high resolution data

Regarding land cover data sets, TOPC made the following recommendations:

Recommendation 10.1: TOPC recommends that close links be established with groups involved in the preparation of global or significant regional data sets, to facilitate early access to such data sets and to highlight their availability for G3OS purposes.

Recommendation 10.2: TOPC recommends that GOFC take the lead in organising a workshop on land cover classification and mapping methodologies involving high resolution data sets over large areas.

11. Terrestrial Ecosystems Monitoring Sites (TEMS)

11.1 Recent Developments in TEMS

Prof. Gosz described the recent developments in TEMS:

As per TOPC-IV recommendations, the original TEMS database was frozen. The approximately 45 GTN-E sites currently involved in the NPP/NEP demonstration project were incorporated into the next version of TEMS. This version is based on a web page format, and contains the description of the sites as well as links to the web pages of the individual GTN-E sites. It also allows the location of a site to be displayed on a raster map (such as land cover), along with zoom capability etc.

The current version is not interactive and does not offer a search capability among the sites based on user-specified criteria.

Meeting participants commended GTN-E for the progress in the development of the database. They emphasised the importance of this mechanism for communication among the sites as well as among the space and ground-based components of the global observing systems.

Several further enhancements were considered as essential for the next phase of development, and to facilitate a successful execution of the demonstration projects. They are listed below in the recommendations.

Recommendation 11.1: Regarding the next steps in the development of TEMS, TOPC recommends that:

- all sites that are participating in GTOS be added to GT-Net database (including national networks in ILTER, Central & Eastern Europe Regional Network, GTN-P, GTN-G, Fluxnet, South & Eastern Africa Regional Network, and NoLimits);
- the sites participating in the NPP/NEP, GOFC, GLIMS, and other demonstration projects as they develop, be flagged in the database;
- in collaboration with WMO (Dr Donald Hinsman), GOSIC (Dr Ron Wilson) and GOSSP (Dr Francis Bretherton), the necessary steps be taken to link TEMS with the WMO database of observation requirements and capabilities, thus enabling comprehensive overviews and analyses of requirements vs. capabilities (space- and ground-based);
- a template of all GTOS variables be added (as they are confirmed), and variables for which sites have data be identified in the database;
- a search capability (initially central server-based) be developed to sort by GTOS variable(s), network, etc.;
- an interactive plotting capability be developed to map sites selected in a search, which will complement (or be an option to) the list of sites identified in any given search;
- additional resources be identified to facilitate the above changes.

12. TOPC Data Sets

Dr Cihlar explained that the purpose of this item was to update the list of data sets identified for GOSIC at the last meeting (refer to Terrestrial Observation Panel for Climate, 1998). The work was to be carried out as background work prior to the TOPC-V meeting.

TOPC members provided descriptions of several data sets that were not included in the previous survey (refer to Appendix VIII). No additional problems or lessons learned (beyond those in the 1998 TOPC report) were highlighted.

Recommendation 12.1: TOPC recommends that the above data sets be added to the GOSIC inventory of relevant data sets.

13. Cooperation with IGBP and WCRP

Dr Cramer, Chair of the IGBP DIS Committee, reviewed recent IGBP developments regarding global data sets:

The International Geosphere-Biosphere Programme (IGBP) is currently restructuring its task force on Data and Information Systems (DIS). Activities towards the development of global data sets on the state of the Earth System, as well as its history, will be coordinated under a new leader, assisted by a full-time senior staff member, as well as a committee of representatives from each core project within the IGBP.

As a coordinating body (under the International Council of Scientific Unions, ICSU), IGBP does not directly control or fund data gathering activities *per se*. However, IGBP, through DIS, has provided, and intends to continue to provide, a contact surface between "producers" of data, such as TOPC and the agencies supporting it, and "users" such as the scientists carrying out specific projects aiming at understanding the earth system. This contact may take a variety of forms:

- participation of IGBP members in strategic meetings of TOPC and related workshops;
- revisions and elaborations of IGBP documents (if necessary, on demand by TOPC) concerning data requirements of IGBP science projects;

- independent review and "IGBP Endorsement" of EO products or other data sets by IGBP scientists (to be organised through DIS);
- participation of IGBP scientists in the development of global data products (previous examples include the global 1 km AVHRR data set, and the global soils data set).

TOPC agreed that the already established contacts with IGBP and WCRP should continue in the areas of mutual interest, and effort should be made to identify new areas or topics where collaboration would be mutually beneficial, such as ensuring the continuation of research networks.

14. References

Ahern, F. J., A. Belward, P. Churchill, R. Davis, A. Janetos, C. Justice, T. Loveland, J.-P. Malingreau, M. Maiden, D. Skole, V. Taylor, Y. Yausuoka, and Z. Zhu. 1998. A Strategy for Global Observation of Forest Cover, published by the Canada Centre for Remote Sensing, Ottawa, Ontario, Canada. GOFC TP-2

Churkina, G., and S.W. Running. 1997. Contrasting climatic controls on the estimated productivity of different biomes. Ecosystems 1: 206-215.

Global Climate Observing System. 1997. GCOS/GTOS plan for terrestrial climate-related observations. Version 2.0. GCOS-11, GCOS-32, WMO/TD-Nr.796: **http://www.fao.org/GTOS/PAGES/DOCS.HTM.**

Kovats, R.S., B. Menne, A.J. McMichael, R. Bertollini and C. Soskolne. 1999. Early human health effects of climate change and stratospheric ozone depletion in Europe. World Health Organisation.

Menne B, R. Bertollini, and E.K. Noji. 1999. Floods and public health consequences, preparedness and response. MP.WAT/SEM.2/1999/22. Seminar for flood prevention, Berlin.

Stanwell-Smith, R. 1998. European infection surveillance prepares for climate change. Euro Surveillance Weekly. No.23.

Terrestrial Observation Panel for Climate. 1998. Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, Fourth session, 26- 29 May 1998, Corvallis, USA, GCOS-46/GTOS - 15.

WHO-ECEH. 1998a. Report of a WHO/EURO International Workshop on the Early Human Health Effects of Climate Change. 21-23 May, WHO-ECEH Rome division, Italy.

WHO-ECEH. 1998b. Report of a WHO/EURO International Workshop on the Early Human Health Effects of Climate Change 17-19 October, WHO-ECEH Rome division, Italy.

Appendix I: List of Participants

Josef CIHLAR (Chairman)
Canada Center for Remote Sensing
588 Booth Street
Ottawa, Ontario K1A 0Y7 Canada

Tel.: +1-613-947-1265
Fax: +1-613-947-1406
E-mail: **josef.cihlar@ccrs.nrcan.gc.ca**

Frank AHERN
Research Scientist
Canada Centre for Remote Sensing
588 Booth Street
Ottawa, Ontario K1A 0Y7
Canada

Tel: +1-613-947-1295
Fax:: +1-613-947-1385
E-mail: **Frank.Ahern@ccrs.nrcan.gc.ca**

Arthur J. ASKEW
Director, Hydrology & Water Resources Department
World Meteorological Organization
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel: +41-22-7308355
Fax: +41-22-7308043
E-mail: **askew_a@gateway.wmo.ch**

Roger BARRY
Director WDC-A for Glaciology
National Snow & Ice Data Center CIRES/WDC
Campus Box 449
University of Colorado
Boulder, CO 80309 USA

Tel: +1-303-492-5488
Fax: +1-303-492-2468
e-mail: **rbarry@kryos.colorado.edu**

(IAHS member, poster on hydrological databases)

Francis BRETHERTON
Space Science and Engineering Center
1225 West Dayton Street
Madison, Wisconsin 53706, USA

Tel: +1-608-262-7497
Fax: +1-608-262-5974
E-mail: **fbretherton@ssec.wisc.edu**

Jerry BROWN
International Permafrost Association (IPA)
P.O. Box 7
Woods Hole, MA 02543, USA

Tel: +1-508-457-4982
E-mail: **jerrybrown@igc.apc.org**

(point of contact - GTN-P for IPA, member IPA Executive Committee)

Wolfgang CRAMER
Potsdam Institute for Climate Impact Research
P.O. Box 60 12 03
D-14412 Potsdam, Germany

Tel.: +49-331-288-2637
Fax: +49-331-288-2600
E-mail: **Wolfgang.Cramer@pik-potsdam.de**

Jim GOSZ
Biology Department
University of New Mexico
Albuquerque
New Mexico 87131, USA

Tel: +1-505-277-2265
Fax: +1-5-5-277-5355
E-mail: **jgosz@Sevilleta.unm.edu**

Andy HAINES
Department of Primary Care and
Population Science
Royal Free & University College
Medical School
Rowland Hill St.
London, NW 32 PF, UK

Tel: +44-171-830-2391
E-mail: **a.haines@ucl.ac.uk**

Jeffrey S. KARGEL
Research Geologist
US Geological Survey
Astrogeology Team
2255 N. Gemini Drive
Flagstaff, AZ 86001, USA

Tel: +1-520-556-7034
Fax: +1-520-556-7014
E-mail: **jkargel@flagmail.wr.usgs.gov**

Ken-ichi KUMA
Numerical Prediction Division
Japan Meteorological Agency
1-3-4 Otemachi,Chiyoda ku
Tokyo, Japan

Tel: +81-3-3212-8341 Ext. 3315
Fax: +81-3-3211-8407
E-mail: **kumaken@naps.kishou.go.jp**

Jurate M. LANDWEHR
USGS Geological Survey
National Centre - MS431
12201 Sunrise Valley Drive
Reston, VA 20192 USA

Tel: +1-703-648-5893
Fax: +1-703-648-5274
E-mail: **jmlandwe@usgs.gov**

Bettina MENNE
WHO - European Centre for Environment and Health - Rome Division
Via Francesco Crispi, 10
00187 Rome, Italy

Tel: +39-06-4877546
Fax: +39-06-4877599
E-mail: **bme@who.it**

Terry PARR
Institute of Terrestrial Ecology

Merlewood Research Station
Grange-over-Sands
Cumbria LA11 6JU, UK

i) NoLimits
Ëuropean Networking of Long-term
Integrated Monitoring Sites

ii) GTOS Regional Project in Central and Eastern Europe
Tel: +44-15395-32264
Fax: +44-15395-34705
E-mail: **T.Parr@ite.ac.uk**

Paul REICHERT
Environment and Natural Resources Service
SDRN
Food and Agriculture Organization of the UN
Via delle Terme di Caracalla
00100 Rome, Italy

Tel: +39-06-57054173
Fax: +39-06-57053369
E-mail: **Paul.Reichert@FAO.org**

Steve RUNNING
EOS Land Panel Chair
School of Forestry
University of Montana
Missoula, MT 59812 USA

Tel: +1-406-243-6311
Fax: +1-406-243-4510
E-mail: **swr@ntsg.umt.edu**

Sharon SMITH
Geological Survey of Canada
601 Booth St.
Ottawa, Ontario K14 OE8

Tel: +1-613-9477066
Fax: +1-613-9920190
E-mail: **SSmith@nrcan.gc.ca**

Allen M. SOLOMON
Environmental Protection Agency
Western Ecology Division

200 SW 35th Street
Corvallis, OR 97333 USA

Tel: +1-541-754-4772
Fax: +1-541-754-4799
E-mail: **solomon@mail.cor.epa.gov**

Alan R. THOMAS
Director, GCOS Secretariat
GCOS Programme Office
c/o WMO
7 bis Avenue de la Paix
P.O. Box 2300
1211 Geneva 2, Switzerland

Tel: +41-22-730-8401
Fax: +41-22-730-8052
E-mail: **thomas_a@gateway.wmo.ch** or **gcosjpo@gateway.wmo.ch**

ZHAO Shidong
Commission for Integrated Survey of Natural
Resources, Chinese Academy of Sciences
P.O. Box 9717
Beijing 100101, China

Member of Steering Committee of ILTER
Member of Steering Committee of GTOS
Member of Steering Committee of DIWPA

Tel: +86-10-6488-9812
Fax: +86-10-6488-9599
E-mail: **zhaosd@cern.ac.cn**

Appendix II: Meeting Agenda

WMO/IOC/UNEP/FAO/UNESCO/ICSU TOPC-V/Doc. 1
GLOBAL OBSERVING SYSTEMS (12.3.1999)

Meeting of the Terrestrial Observation Panel for Climate
Birmingham, United Kingdom, 27-30 July 1999

Final agenda

Tuesday 27 July 1999

1. ORGANIZATION OF THE MEETING	Josef Cihlar
1.1 Opening and Conduct of the meeting	
1.2 Approval of the Agenda	
2. REPORTS ON CURRENT STATUS AND UPDATES	
2.1 IGOS and G3OS Sponsors Meetings	Alan Thomas
2.2 GCOS Activities	Alan Thomas
2.3 GTOS Activities	Jim Gosz
2.4 GOSSP Activities and satellite data specification	Francis Bretherton
3. REVIEW OF TOPC-IV ACTIONS, TOPC GOALS, PROGRESS, MEETING OBJECTIVES	Josef Cihlar
4. DEMONSTRATION PROJECTS: PRESENTATION AND DISCUSSION TOPC ACTIONS	
4.1 Global Observation of Forest Cover	Frank Ahern
4.2 Global Net Primary Productivity	Steve Running/Jim Gosz
5. TERRESTRIAL CARBON CYCLE observation strategy	Josef Cihlar
5.1Terrestrial observing strategy (‘top down’)	Steve Running
5.2 Kyoto and (IPCC) national reporting strategies	Al Solomon
5.3 Development of a consensus C cycle observation strategy	Josef Cihlar
6. NON-CLIMATE GTOS REQUIREMENTS DEFINITION	Paul Reichert
7. BREAKOUTS	
7.1 Terrestrial carbon cycle	
7.2 GTOS non-climate requirements and satellite data specifications	

Wednesday 28 July 1999

BREAKOUTS (cont’d, including summary at the plenary)

8. NETWORKS: REPORTS, DISCUSSION, ACTIONS	Josef Cihlar
8.1 Glaciers network and enhancements	Roger Barry, Jeff Kargel
8.2 Permafrost network and enhancements	Jerry Brown

8.2 Ecological network status and plans	Jim Gosz
8.4 Hydrology network: status, next steps	Jurate Landwehr

Thursday 29 July 1999

9. GCOS AND NATIONAL REPORTING	Josef Cihlar
10. CLIMATE AND HEALTH	Bettina Menne, Andrew Haines

11. BREAKOUTS (am, pm): Network enhancement and National reporting (including summary at the plenary)

11a: Glaciers and Permafrost
11b: Ecology
11c: Hydrology

12. LAND COVER DATA SETS PRODUCTION	Josef Cihlar
13. TERRESTRIAL ECOSYSTEMS MONITORING SITES	Jim Gosz
14. TOPC DATA SETS revision/updates	Josef Cihlar

Friday 30 July 1999

15. COOPERATION WITH IGBP AND WCRP	Josef Cihlar Alan Thomas Jurate Landwehr
16. FUTURE TOPC ACTIVITIES	Josef Cihlar
17. MEETING REPORT PREPARATION	All participants

Appendix III: Terrestrial Carbon Theme Terms of Reference

DEVELOPMENT OF AN IGOS THEME ON THE TERRESTRIAL CARBON CYCLE

Objective

To develop the elements of an IGOS Partners theme on the terrestrial carbon cycle that addresses observational requirement, identifies gaps in coverage and develops project activities that meet the requirements of global research and policy initiatives.

Coleaders

GTOS (through the GCOS/GTOS Terrestrial Observation Panel for Climate)
FAO/SDRN (as UN focal point)
Canadian Space Agency (as a CEOS focal point)

Key partners

ICSU:
IGBP International carbon research project

Observing systems and projects:
Global Climate Observing System (GCOS)
Global Ocean Observing System (GOOS)
World Climate Research Programme (WCRP)
Global Observation of Forest Cover (GOFC)

Space agencies:
BNSC/NERC - British national space centre/National environmental research council;
NASA - NASA HQ/GSFC Carbon research laboratory
EC/JRC/SAI - DG XII - Global vegetation monitoring unit (GMV)

UN/Intergovernmental agencies:
IPCC
UNEP
WMO

Universities and institutes:
U of Maryland, Geography Department
U of Virginia, Geography Department
CSIR, South Africa
RIVM/SC-DLO

Initial steps

Discussion and agreement on procedures, partners, key issues, initial scope and content of an IGOS Carbon Cycle Theme, outline for a programme document, identification of resource requirements and initial writing assignments (TOPC meeting; Birmingham, the United Kingdom; 27-30 July 1999);

Inventory of carbon-related activities, assessment of existing and required observational requirements, identification of gaps (Individual writers; August - September);

Review and consolidation of results of 1,2 above, agreement on content to be presented to IGOS-P (FAO HQ? ; early October).

Presentation of the initial work for review and discussion (4th IGOS Partners meeting, Stockholm, 10-12 November 1999).

GTOS contribution:

Coordination, facilitation of TOPC work.
Contacts with observing systems.

FAO contribution:

Coordination with UN partners (see above)
Internal coordination within FAO (see below):
SDRN (WG's on Climate change, Biodiversity; Artemis, AfriCover)
SDWP (Population databases)
FOD/FOR (FRA2000, Forest volume/biomass project, fire related activities)
AGL
AGP
ESCG (GIEWS)

CSA contribution:

Contacts with space agencies.
To be developed.

Appendix III: IGBP Terrestrial Carbon Information Needs (Preliminary)

Fluxes

- Anthropogenic carbon emissions (fossil fuel, cement etc., including their history)
- Ecosystem-related carbon fluxes (measured at flux measurement sites, or derived from inventories of forest or agricultural yields)

Stocks and spatially comprehensive observations

- Stocks of mobile carbon in the Earth System (for these, observations of present status is equally important as a comprehensive reconstruction of past changes)

- Atmospheric chemistry (pCO2, O2/N2, CH4, other trace gases)

- Terrestrial carbon pools, stratified by above- and belowground, and short-, medium- and long-lifespan pools (available from measurements at irregularly spaced points or inventory areas only, needs to include ancillary data such as present ecosystem structure, history of land use and natural disturbance, climate and soils)

- Land surface parameters (fPAR, LAI etc.) including phenology-dependent temporal dynamics

- Freshwater ecosystem and ocean biogeochemistry parameters

Forcings

- *Climate, ocean circulation fields, soils, topography etc. (at compatible spatial and temporal resolutions with the above)*
- *Land use*
- *Deposition of atmospheric pollutants.*

Appendix V: Terrestrial Carbon Initiative - Prospectus

Version 1

PREAMBLE
Recognizing the growing need for systematic observations of the Earth's environment and the need for earth observation to serve the needs of humankind, an Integrated Global Observing Strategy Partnership (IGOS-P) was established jointly by the Committee on Earth Observation Satellites (CEOS) and various international organisations concerned with global or regional environmental issues. Besides CEOS which represents national space agencies, IGOS-P membership includes the Global Observing Systems for atmosphere, oceans and land (G3OS); international research organisations (WCRP,IGBP); UN environmental agencies such as UNEP, WMO,FAO; and other agencies with interest in earth science and observations. To undertake the evolution of sustained global earth observations in a systematic manner, IGOS-P proposed the concept of observation 'themes', with the expectation that a relatively small number of themes can be defined which would serve as a framework for developing capabilities which integrate space and in situ observing. In June, 1999 IGOS-P agreed that it would be appropriate to define a theme on the terrestrial carbon cycle, and the Global Terrestrial Observing System (GTOS) agreed to lead its initial development in collaboration with the Canadian Space Agency.

This prospectus is an initial outline of a theme dealing with terrestrial carbon. Its foundation is a recognition that the observation of the terrestrial component of the global carbon cycle is important in its own right, in addition to being a part of the global carbon cycle. It is anticipated that linkages with the ocean and atmospheric components (beyond those identified here) will be developed as part of the planning process. It is envisioned that, in responding to this theme, the IGOS partners will also establish new capabilities for the acquisition, processing, and distribution of earth-observation data which will enable other applications, e.g. improved natural resource management and highlighting areas of rapid land cover change. The TCI concept described here was initially developed during the fifth meeting of the Terrestrial Observation Panel for Climate (TOPC), a joint panel of the Global Climate Observing System (GCOS) and GTOS, on 27-30 July 1999 in Birmingham, the United Kingdom. TOPC mandate includes ensuring effective implementation of global terrestrial observation requirements for climate-related purposes.

PART I: EXECUTIVE SUMMARY

The Global Terrestrial Carbon Cycle Initiative (TCI) is a coordinated international response to the requirement by the policy and scientific communities for improved knowledge of the role of the terrestrial carbon sources and sinks in the global carbon cycle and global warming. The new and unique contribution of TCI is information on the spatial and temporal distribution of carbon sources and sinks in the terrestrial biosphere.

Vision

TCI is envisioned as a functioning, continuously evolving network of frequent observations and computer models, targeted for documenting and understanding the present state of the terrestrial component of the global carbon cycle and for supporting policy formation at the national and inter-governmental levels. The input data will be provided by an optimised combination of remotely sensed and ground-based observing systems. The carbon cycling models must be sensitive to natural and human - induced changes in the environment; operate at a relatively high resolution to make optimum use of remote and in situ observations; and produce maps of terrestrial carbon sources and sinks (synonymously termed ‘C balance’ below) on a seasonal, annual, interannual, and decadal basis. The resulting products must be sufficiently detailed to be useful for international conventions, policy decisions, and climate or environmental change assessments at global, regional and national levels. Building on the synergy of integrated observing systems, additional products of value for the management of terrestrial resources will be added in due course.

Need

An accurate knowledge of the terrestrial component of the global carbon cycle has become policy imperative for this and the forthcoming decades, both globally and for individual countries. The underpinning reason is recognition that the increasing atmospheric CO2 concentration is an important causative factor for climate variability and change. This recognition led to fundamental policy decisions. For example, the Kyoto Protocol recognizes the role of terrestrial systems as carbon sinks and sources, and it provides a basis for developing future emission trading arrangements that involve forests and potentially other ecosystems. Although the specific information and reporting requirements are to be worked out, they are expected to include information on carbon sinks and sources at the national or sub-national levels. While such information is likely to be provided through various methods, there will be a need for a globally consistent source to serve as a reference and a basis for comparison. This is due to at least two factors: the need for compatibility among individual (national or project-based) reports, and the fact that all known methods contain uncertainties which can, however, be reduced by independent estimation methodologies. In addition to the reporting required by the Kyoto Protocol, the United Nations Framework Convention on Climate Change (UNFCCC) instituted inventories of the national greenhouse gas situation, including terrestrial sources and sinks.

The above policy steps were taken in spite of an incomplete understanding of the pathways through which the anthropogenic CO2 leaves the atmosphere, thus negating a portion of the human-caused emissions. For example, about 15-30 percent of the anthropogenic carbon emissions cannot presently be accounted for, and are presumed to be absorbed by terrestrial ecosystems in the Northern hemisphere. A more accurate knowledge of the sequestration of the carbon emissions is therefore critical to the effectiveness of the carbon - related policies. Of equal importance is the ability to predict the future evolution of the atmospheric CO2 concentration in order to optimize mitigation policies and measures. The amount of carbon uptake and release by terrestrial ecosystems is a major uncertainty in these regards, and its better knowledge is essential to making progress in dealing with the climate change issue. In addition to the environmental policy dimension, the distribution and quantification of biospheric carbon has important economic and resource management dimensions. In particular, the yield of forest, rangeland and agricultural resources is a strong function of carbon tied up in the above-ground biomass. It is expected that improved understanding of the terrestrial carbon cycle can provide insight for improved management of forest, rangeland, and agricultural resources.

There is no present capability to estimate the size of the terrestrial carbon sources and sinks frequently and over larger areas. Its importance was recognised in the early IPCC discussions but neither the techniques nor institutional arrangements were available. However, the rapid progress over the last 10 years in the methods for measuring and computing the pools and fluxes of terrestrial carbon makes it possible to propose a major new initiative in this area. In technical terms, the above information gaps translate primarily into the need to obtain the spatial distribution of net primary productivity (NPP) and net ecosystem productivity (NEP), both measured as mass of carbon per unit area per year. NPP is the carbon assimilated by vegetation through photosynthesis, minus the carbon lost because of respiration (i.e. 'breathing') by the living plant tissue. NEP is the difference between NPP and the loss through a decay of organic matter (above or below ground). In addition, fire and other disturbances, and land use (e.g. cropping, grazing and silviculture) are important in determining long-term carbon retention by ecosystems, i.e. their net biome productivity (NBP). Therefore, determining the spatial and temporal characteristics of NPP, NEP and NBP are priority issues for TCI.

Goals and scope

The scientific and organizational problems posed by the TCI vision are significant, very challenging yet solvable. They cannot realistically be achieved in one step over a few years. Instead, a phased approach based on a combination of research and operational activities is the most effective strategy. Thus, for the near future the following goals are identified:

By 2004, demonstrate the capability to map the global spatial distribution of the sources and sinks of the terrestrial biospheric carbon with a TBD (to be determined) accuracy for areas as small as TBD (e.g. $\pm 30\%$ over areas $\geq 4 km^2$), and generate the global and regional map products.

Starting in 2008, produce an annual digital database of the terrestrial carbon sources and sinks on an ongoing basis, with the above or better accuracies.

The scope of TCI is characterized by emphasis on the current (at the time of observation) spatial distribution of the sources and sinks in terrestrial and aquatic components of the biosphere; long-term, global observation; and products for seasonal, annual, interannual, and decadal periods. TCI thus encompasses the terrestrial and associated atmospheric parts of the carbon cycle. These bounds are motivated by the need to fill a gap and to maintain a focus so that the effort may be productive. Consequently, TCI must be linked to activities concerned with the oceanic component of the global carbon cycle, and with programmes addressing C-related issues in the socioeconomic sphere.

Benefits

Results of TCI will provide immeasurable benefits to many constituencies and at many levels, from global to national. Why? First, the knowledge of carbon sinks and sources is very important, as briefly discussed above and as evident from the wide attention given to this problem by the policy, international, scientific and business communities worldwide. Second, there is no feasible way for a single group or nation to obtain such information reliably and cost-effectively because of the complexity of the environmental processes involving CO_2 (which occur at many interconnected levels, from landscape to globe) and because of the need to obtain a range of measurements (both in area and in time). However, a combined effort that brings together organisations with space and ground-based observing capabilities, users, and the scientific community does make the problem tractable and offers a high probability of success. Decreasing the build-up of greenhouse gasses in the earth's atmosphere will require unprecedented international cooperation. This initiative will bring about substantial international cooperation in an important area of that effort, i.e. improved information upon which difficult decisions can be based. Its contribution includes, but is not limited to, the provision of complementary and globally consistent information for the Kyoto Protocol.

The way forward

To be successful, TCI must involve the participation of agencies and groups that would benefit from the outputs TCI aims to produce, and whose programmatic interests are compatible with the TCI vision. The steps listed below are intended to obtain initial consensus on TCI and to facilitate the involvement of the various communities:

- Solicit feedback on the TCI concept by distributing this prospectus in the scientific, observation (satellite, ground-based), and user (international, national, policy, business?) communities.
- Obtain consensus on TCI aims and framework.
- Analyze in detail the technical aspects of the observation, data processing, modelling and quality control, primarily through discussions in the scientific and observation communities.
- Develop a phased implementation plan, building on current pilot projects (Global Observation of Forest Cover, GTOS Net Primary and Ecosystem Productivity); national programmes and planned activities; international research projects; space agency mission plans; and other related activities.
- Identify agencies, research programmes and other groups interested in participating in TCI; develop suitable mechanisms; and obtain commitments for participation.
- Identify near-term and mid-term gaps that remain to be addressed to make TCI successful, and develop appropriate response by involving additional participants or by initiating new activities with additional resources.
- Develop a transition strategy to a long-term operation.
- Begin implementation.

PART II: TECHNICAL BACKGROUND

1. Principles of observation

In the terrestrial environment, carbon is present in three main pools: atmosphere, plants and soil. NPP and NEP express the net fluxes between these pools. In theory, it is conceivable to measure the sizes of the pools and to compute NPP and NEP for a parcel of an ecosystem from the changes in these. However, this is not feasible by traditional methods, first because these methods employ destructive sampling (cutting plants, digging soil pits), and secondly because they are very costly and cannot be applied over large areas. It is thus not surprising that actual NPP and NEP measurements obtained so far are extremely scarce. In recent years, practical alternatives have emerged which employ non-destructive measurement procedures, coupled with models that mimic the behaviour of carbon within the ecosystem or in the near-surface atmosphere. Such measurements are typically carried out from towers (to measure CO2 fluxes or concentrations) or from satellites (to quantify the spatial patterns of ecosystem characteristics that control CO2 exchange). While these measurement strategies also require some destructive sampling, its extent is limited to ensuring that the models perform satisfactorily. Great progress has been made in our understanding of the biospheric components of the carbon cycle, the construction of models of carbon-related processes within the ecosystem, and the ability to combine data from various sources to obtain quantitative estimates of carbon exchanges over specific areas and periods of time.

2. State-of-the-art

Fundamental advances have been made in the use of atmospheric CO2 measurements to define the size and the continental or regional distribution of biospheric sinks, using global atmospheric tracer models. Large experiments have been carried out in selected ecosystems (boreal, tropical, temperate) that have greatly advanced our ability to model carbon fluxes as well as to establish and improve the accuracy of products derived from remotely sensed data. Satellite data and derived products such as land cover, leaf area index, and burned biomass have been generated that allow application of ecosystem-specific carbon exchange models. A 15-year data series has been assembled and products generated for specific regions (tropical forests, boreal ecosystems) or the globe (e.g., land cover, biomass burning). Ground-based networks have been established that measure carbon fluxes between the ecosystem and the atmosphere on time scales of minutes to years, thus providing data essential to testing computer models and for validating the accuracy of the final products. Several flux networks have been established (in North America, Europe, Asia, Australia) and operated for various periods of time. The necessary supporting data sets (e.g., soil parameters) have been assembled for various regions and in some cases for the global landmass. Detailed (1 km^2 cells) spatial distributions of the annual carbon uptake by vegetation have been successfully mapped at the regional level, with techniques that can be applied globally. The main remaining issues regarding carbon cycle quantification have been identified, and corresponding research plans have been developed and translated into new international or national research initiatives (e.g., in the United States carbon cycle science plan). In addition, new satellite missions are under way that will yield products with a greatly improved sensitivity to terrestrial carbon dynamics, enabling scientists to quantify the distribution of sources and sinks more accurately.

So far, the above various activities have taken place over limited areas, at different times and for different reasons, as part of research agendas. However, given the progress achieved and the imperative for better knowledge of the terrestrial carbon cycle, it is now feasible to consider an integrated system which takes advantage of these developments to establish an initial observation strategy for the globe.

3. TCI framework

3.1 Overall description

Given the diversity of CO2-ecosystem interactions in the global biosphere and the measurement uncertainties in any single observation strategy, a two-prong observation strategy is necessary which consists of ‘top-down’ and ‘bottom-up’ elements. Since atmospheric CO2 concentrations can be determined accurately and the global distribution computed from relatively few measurements, the regional distribution of terrestrial sources and sinks can be effectively constrained ‘top down’, using these measurements and associated atmospheric circulation models. However, this approach alone does not provide sufficient information on the spatial distribution of CO2 balance at the regional or landscape levels. In addition, the top-down approach does not elucidate the underlying mechanisms responsible for carbon balance distribution. Thus, it cannot be used to predict future carbon balance distribution and thereby assist in forming C-related policies and management options. Consequently, a complementary ‘bottom-up’ approach is necessary in which the carbon balance is assessed individually for small parcels of the terrestrial ecosystems, the size of which is determined primarily by the resolving capabilities of the satellite sensors. The results of these assessments are then combined to ensure both global/regional consistency and geographic specificity.

3.2 Functional components and flow

Because of the great variability of the terrestrial biosphere and the sensitivity of biospheric processes to the atmospheric conditions, the realisation of the TCI vision requires an integrated approach based on several components (Figure 1,2):

Frequent and sustained satellite observations with various sensors
Previously, these observations have most often employed data from the United States. NOAA series of satellites. Approved and planned satellite launches by the United States, Japan , the European Space Agency and other CEOS members will provide significantly enhanced capabilities over the next several years. Beyond these, the continuity of observations as well as the feasibility of additional important measurements needs to be examined.

Ongoing ground-based measurements at locations selected across the range of biomes and climatic conditions
Three main types of networks have been devised for such measurements. First, periodic air sampling of CO_2 at the surface and its precise analysis is conducted by a CO_2 flask sampling network to provide the basis for continental/regional level analysis. Second, an initial network of tall towers has been built to measure CO_2 concentrations at higher altitudes (typically 100-500 m) as a basis for estimating the continental or regional distribution of CO_2 sources and sinks. Third, several regional networks of short towers (typically twice the height of the vegetation canopy) have been established to measure CO_2 exchange for various local ecosystem conditions, and to validate models of canopy-CO_2 interaction as well as models estimating the spatial distribution of CO_2 sources and sinks. The representativeness, comprehensiveness, and continuity of these networks are issues requiring attention.

Reliable procedures for translating the remotely sensed and ground-based measurements into environmental variables
For satellite data, these include corrections for atmospheric and other effects that distort the relationship between the variable of interest and the measured signal, followed by algorithms that transform the corrected signal into an ecosystem variable. For ground-based measurements, corrections are similarly required to account for the deficiencies of the measurement techniques and to translate the measurements into units of CO_2 exchange.

Quantitative models of the processes of carbon exchanges within ecosystems, within the atmosphere, and between ecosystems and the atmosphere
Two basic classes of models have been successfully developed. Atmospheric inversion models describe the dynamic behaviour of the atmosphere and the transport and mixing of CO_2 within it. On the other hand, ecosystem models mimic the processes that influence CO_2 uptake and release and their dependence on the atmospheric and local ecosystem conditions, typically on a daily basis.

Systems/organisations engaged in the acquisition, processing, output generation and quality control through which the resulting products will be generated and made available
So far, these have been carried out as research activities in various countries or international programmes.

4. Issues

To realize the above vision, a detailed plan needs to be developed. Such plan must consider a number of issues, including those briefly discussed below.

4.1 Readiness

The TCI concept is based on scientific and technical accomplishments in several different areas: ground-based and satellite instrumentation and measurement techniques; atmospheric and ecosystem modelling, including a much improved understanding of the processes involving CO_2; and the conduct of coordinated research campaigns, allowing to test components of the entire system. These achievements, the anticipated quantum improvements in satellite observing capabilities in the next few years, and the importance of the global carbon cycle provide ideal setting for TCI at the present time. However, successful implementation must take into account a number of issues, including those listed below.

4.2 Comprehensiveness of observations

At the present time, neither the present ground-based nor remotely sensed observing capabilities are sufficient to produce long-term, globally consistent observation of terrestrial carbon sinks and sources. The main challenges in the ground-based networks are representativeness, continuity, and cost. The geographic distribution is based mostly on previous research priorities and interests, without adequately considering the need for global coverage. The networks are operated as part of research programmes, typically of a limited duration, and no adequate provisions have been made for a long-term operation. Also, the equipment and measurements are relatively costly, although the unit costs have been decreasing rapidly due to technological development.

In the satellite domain, the quality and continuity of observations are of major concern. Satellite data used so far were not originally intended for this purpose, thus they are marginally suitable. In the near future, greatly enhanced capabilities will become available through several missions. However, the long-term continuity of measurements has not so far been assured. Furthermore, additional measurements are required which necessitate the development of new sensing technology (e.g., vegetation biomass, leaf biochemistry, canopy horizontal and vertical structure). The needs for high-spectral resolution (for leaf biochemistry) and multiple angle (for canopy structure) satellite sensors have not yet been adequately addressed for global applications. These issues can be resolved but they will require close attention within the IGOS-P framework as part of the TCI preparations.

4.3 Data analysis and modelling

The capabilities of atmospheric and ecosystem models for estimating the spatial distribution of CO_2 sources and sinks have been clearly demonstrated in numerous studies. Nevertheless, significant further research and demonstration are needed to ensure long-term success of TCI. The challenges include: developing a closer synergy between top-down and bottom-up approaches; further validation of CO_2 exchange models in various regions and ecosystems, both natural and managed; further improvements in and the validation of algorithms for transforming raw measurements (satellite or ground-based) into biophysical parameters; preparation of key, high quality ancillary data sets such as land use history and terrain elevation; and the establishment of quality control procedures to ensure the ongoing quality of TCI outputs in an operational setting.

4.4 Implementation process

In view of the large spatial variability of terrestrial carbon distribution, the policy and economic interest in the terrestrial biosphere and the need for ground data from various regions of the world, the basic mechanism for TCI implementation must be collaboration of countries and institutions in a mutually beneficial manner. The implementation framework must therefore facilitate the contributions of various participants as providers (of data, supporting financial resources, scientific expertise) or as users (of the data, output products, or results of analyses).

In the near future, TCI can be most rapidly advanced if undertaken as a research and demonstration programme, supported by an ongoing acquisition and processing of satellite data. This is because of the relative complexity of the process leading to CO_2 balance estimation as well as the present state of methodological development. It is important, however, that both users and agencies involved in data collection and processing be closely involved throughout, thus ensuring both the effectiveness of the TCI outputs and the viability of a long-term operation.

A number of activities are presently under way that are relevant to TCI. These include:

- Data collection and processing using satellites presently in orbit (e.g., NOAA, Landsat, SPOT, GOES/METEOSAT).
- Construction and planned launches of new missions, both research and operational (e.g., EOS, ADEOS, ENVISAT, EarthProbe, VCL, NPOESS) .
- Global Observation of Forest Cover (GOFC), a pilot project of IGOS-P which aims to provide a significant part of the information required by the TCI bottom-up approach and the GTOS Net Primary and Ecosystem Productivity Project .
- International research programmes focusing on carbon cycle questions (e.g., IGBP).
- Regional programmes aimed at terrestrial carbon assessment (e.g., the European initiative Global Monitoring for Environmental Security).
- Regional research campaigns (e.g., the LBA Study).
- National carbon cycle research or observation programmes (e.g., Canada, the United States).
- Others.

All above-mentioned activities are potential contributors to some aspect of TCI. A significant near-term challenge is therefore to encourage closer coordination of these efforts in order to minimize potential duplication of effort but more importantly, to harmonize these activities and identify gaps that need to be addressed through additional projects where necessary. The most important task is to identify actions that are necessary to obtain an initial version of the TCI, and to implement these.

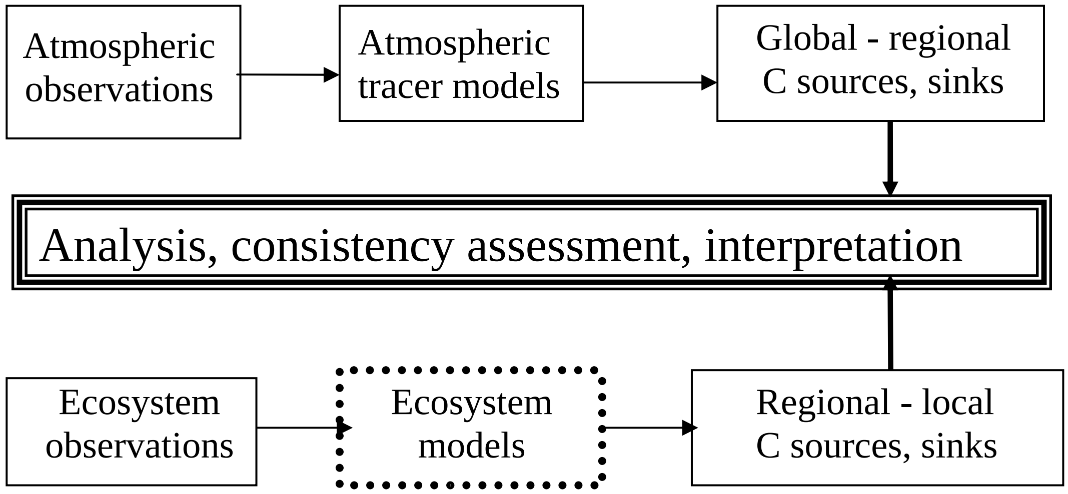

Figure 1

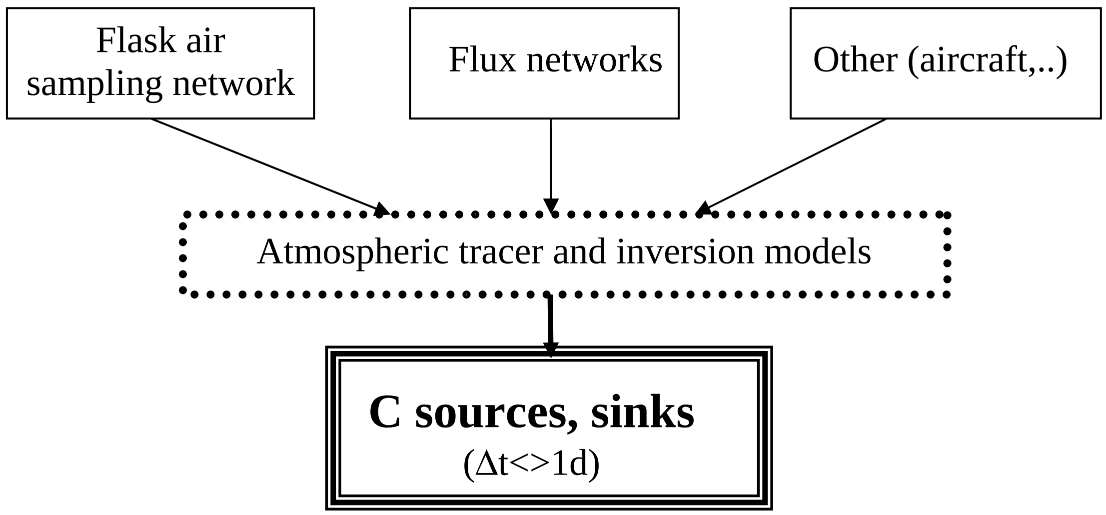

Figure 2a

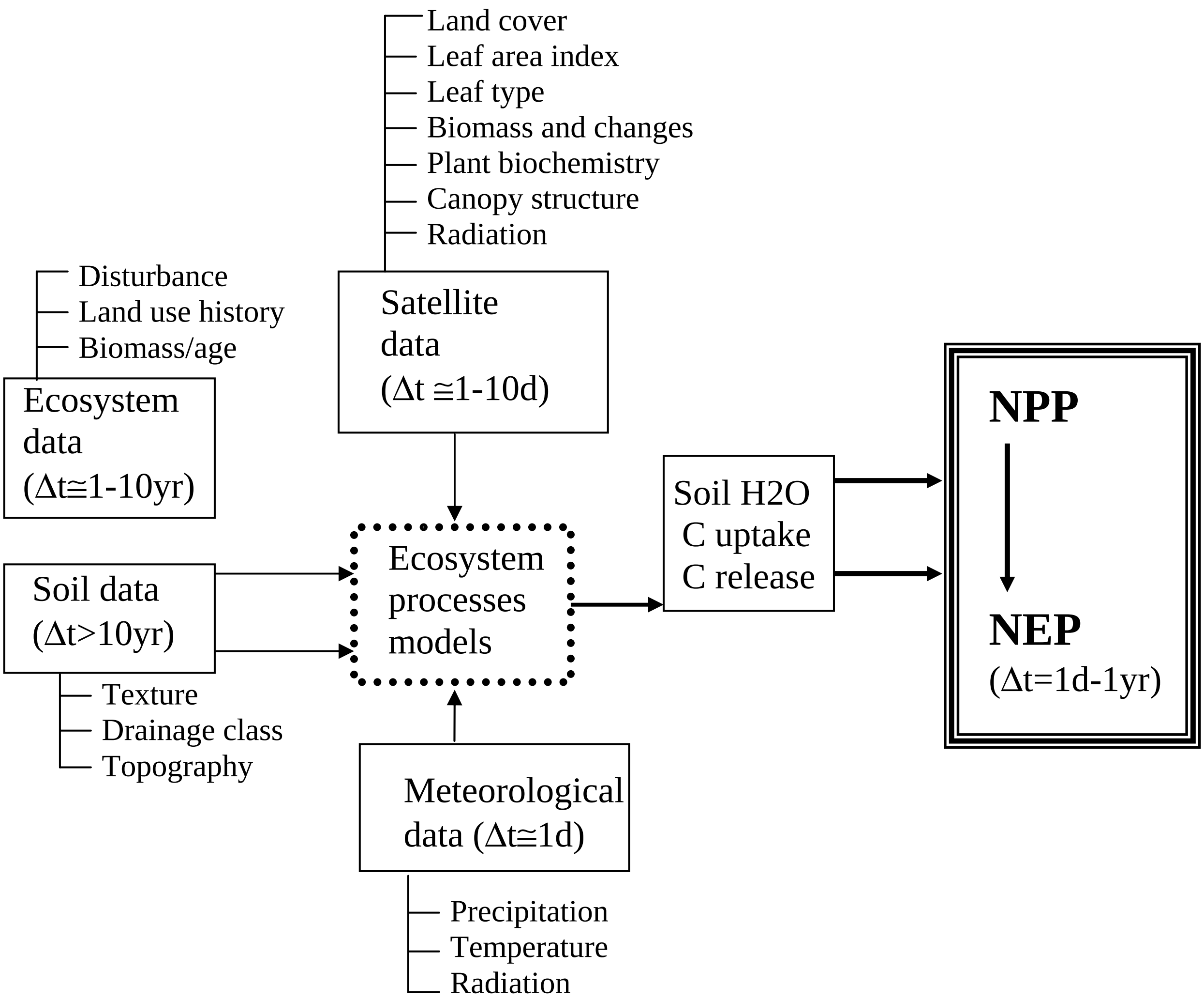
Land cover
Leaf area index
Leaf type
Biomass and changes
Plant biochemistry
Canopy structure
Radiation
Disturbance
Land use history
Biomass/age
Satellite data (Δt ≅1-10d)
Ecosystem data (Δt≅1-10yr)
NPP
Soil H2O
C uptake
C release
Soil data (Δt>10yr)
Ecosystem processes models
NEP
(Δt=1d-1yr)
Texture
Drainage class
Topography
Meteorological data (Δt≅1d)
Precipitation
Temperature
Radiation

Figure 2b

Appendix VI: Revised Non-climate Variable Observation Requirements

Variables/Indicators related to Freshwater resources												
Category/Variables			HOR RES.		Cycle d,m,y		Timeliness d,m,y		Accuracy		Applications other then freshwater resources	Methodology
	Type	Priority	Min	Opt	Min	Opt	Min	Opt	Min	Opt		
	Target	essential=1										in situ = 1
	Input	desirable=2										RS = 2
	Ancil	optional=3										GIS=3
	Meas											Model=4
3. Freshwater resources variables												
3.1 Physical												
3.1.1 Precipitation accum (solid and liquid)	I,M	1	10 km	1 km	1 d	1 hr	1 d	1 d	0	<+.1mm	1,2,5,6,7,8,10,12	1,2,4
3.1.2 Snow cover area	T,I	1	3 d	1 km	3 d	1 d	10%	2 d		5%	6,8,10,11	2
3.1.3 Snow depth	I	1		Tier 1,2,3+	10 d	1 d	5 d	1 d			1,5,7,12	1,2
3.1.4 Snow water equivalent (SWE)	T	1	25 km%	10 km	3 d	1 d	3 d	2 d	20%	5%	1.2.5.6.7.8.10	1,2,4
3.1.5 Glacier inventory	T	1	0.1 km	0.01	50 y	30 y	5 y	2 y			6,7,10	2
3.1.6 Glaciers mass balance	T	1	30 sitesgl.	50	5 y	1 y	6 m	3 m	0.1 m	0.01 m	2,6	1,3,4
3.1.7 Evapotranspiration	I	1	Tier 1,2	Tier 1,2	1 d	0.5 hr	1 y	1 m	20%	10%	1,2,5,10,13	1,2,4
3.1.8 Interception	I	1	Tier 1,2	Tier 1,2	1 d	0.5 hr	1 y	1 m	20%	10%	1,2,5,10	1,2,4
3.1.9 Water runoff	I	1	Tier 1,2,3	Tier1,2,3,4	1 d	1 hr	30 d	1 d	20%	10%	1,2,5,7,9,12,13	1,2,3,4
3.1.10 Surface water flow - discharge	T	1	Tier 1,2,3	Tier1,2,3,4	30 d	0.01 d	30 d	1 d	20%	5%	1,2,4,5,6,7,8,9,10,11,12	1(2,3,4)
3.1.11 Surface water storage fluxes	T	1	30	50	90 d	10 d	3 m	1 m	5%	2%	2,6	1,2,4
3.1.12 Sediment load	T	1		Tier 1,2,3		TBD						1
3.1.13 Light penetration	I	2			1 y	10 d	1 y	1 m	10%	5%	5,	1
3.1.14 Groundwater depth	T	1	Tier 1,2,3	Tier1,2,3,4	1 y	1 m	1 y	1 m	5% depth	1% depth	1,2,5,6,9,13	1
3.1.15 Groundwater storage fluxes	T	1	Tier 1,2,3	Tier1,2,3,4	1 y	1 y	1 y	1 y	10% depth	1% depth	2,6,9	1
3.1.16 Water surface temperature	I	1	Tier 1,2,3	Tier1,2,3,4	6 m	1 m	1 m	1 d	2 degrees	1 degree	1,5,6,10,13	1,2
3.1.16 Cloud cover/cold cloud c. duration	M	1	10 km	5 km	10 d	1 d	1 d	1 d			1,2,5,6,10	2,3,4
3.2 Chemical												
3.2.1 Electroconductivity	I	1	Tier 4	Tier1,2,3,4	6 m	1 m	10 d	1 d	5%	1%	salinity,1,2,5,7,13	1
3.2.2 pH	I	1	Tier 4	Tier1,2,3,4	1 y	3 m	10 d	1 d	5%	1%	2,5,12	1
3.2.3 Dissolved and particulate organic carbon	I	1	Tier 4	Tier1,2,3,4							TBD	1
3.2.4 Total dissolved solids (TDS)	I	1	Tier 4	Tier1,2,3,4	1 y	1 m	10 d	1 d	10%	5%	TBD,13	1
3.2.5 Sodium Adsorption Ratio (SAR)	I	1	Tier 4	Tier1,2,3,4	6 m	1 m	10 d	1 d	10%	5%	sodicity,1,2,5,7	1
3.2.6 Oxygen concentration	I	2	Tier 4	Tier1,2,3,4	6 m	1 m	10 d	1 d	10%	5%	fish prod., 5	1
3.2.7 Major cations e.g. Na, Ca, Mg, K	I	1	Tier 4	Tier1,2,3,4	6 m	1 m	10 d	1 d	10%	5%	1,2,5,12,13	1
3.2.8 Major anions e.g. CO, HCO,CL,SO	I	1	Tier 4	Tier1,2,3,4	6 m	1 m	10 d	1 d	10%	5%	1,2,5,12,13	1
3.2.9 Trace metals	I	2	Tier 4	Tier1,2,3,4	3 y	1 y	6 m	1 m	5%	2%	5,12,13	1
3.2.10 Potability	T	1	Tier 4	Tier1,2,3,4	6 m	1 m	10 d	5 d			5,	1
3.2.11 inorg. Nutrient content	I	1										
3.3 Biological												
3.3.1 Biological oxygen demand	I	1	Tier 3,4	Tier1,2,3,4	6 m	1 m	5 d	1 d	10%	5%	1,5,13	1
3.3.2 Chlorophyll concentration	I	1	Tier 3,4	Tier1,2,3,4	6 m	3 m	1 m	5 d	20%	10%	1,5,	1,2
3.3.3 Organic contaminants	I	1	Tier 3,4	Tier1,2,3,4	6 m	1 m	1 m	5 d	10%	5%	1,2,5	1
3.3.4 Nitrogen indicator species	A	2	Tier 3,4	Tier1,2,3,4	1 y	6 m	3 m	1 m	20%	10%	1,2,5	1
3.3.5 Phosphorous indicator species	A	2	Tier 3,4	Tier1,2,3,4	1 y	6 m	3 m	1 m	20%	10%	1,2,5,13	1
3.3.6 Fish population/production potential	T	1	Tier 3,4	Tier1,2,3,4	5 y	1 y	1 y	3 m	20%	10%	1,5	1,2,3,4
3.3.6 Potability (microoraganisms)	T	1	Tier 3,4	Tier1,2,3,4	5 y	1 y	1 y	3 m	20%	10%	5,13	1
3.3.6 Vegetation hydric stress index	T	1	5 km	1 km	1 m	10 d	5 d	1 d			1,2,5,6,7,13	1,2
3.3.7 Land cover	T	1	1 km	0.1 km	10 y	1 y	1 y	3 m	20 class	50 class	1,2,4,5,7,8,9,10,12,13	1,2,3
3.3.8 Land use	T	1	1 km	0.1 km	10 y	1 y	1 y	6 m	5 class	>100	1,2,4,5,6,7,8,9,12,13	1,2,3,4
3.3.8.x Wetland presence, type, area												
3.3.9 Primary productivity												
4. Socio-economic (separate table)												
1) 2cm up to 20cm,>20cm 10%/3cm,15%												

Variables/Indicators related to Socio-Economic													
Category/Variables			HOR RES.		Cycle d,m,y		Timeliness d,m,y		Accuracy		Sources	Status Data availability	Remarks
	Type	Priority	Min	Opt	Min	Opt	Min	Opt	Min	Opt			
	Target	essential=1										in situ = 1	
	Input	desirable=2										RS = 2	
	Ancil	optional=3										GIS=3	
	Meas											Model=4	
2. Socio economic variables													
2.1 Basic Eco.													
GNP per capita	M	1	national	province	y	m	6 m	1 m	5%	0	WDI, World Bank	Y	
GNP per capita, real annual growth rate	M	1	national	province	y	m	6 m	1 m	5%	0	WDI, World Bank	Y	
2.2 Environment													
public R&D expenditure, env. Protection	M	1	national	national	y	m	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
industry invest.in pollution control	M	1	national	province	y	y	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
expenditure on protective activities	M	1	national	province	y	y	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
pollution abatement/control expenditure	M	1	national	national	y	y	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
Human Development Index	T	2	national	province	y	y	6 m	1 m	na	na	UNDP, 1998	Y	
industrial production	T	2	national	district	y	m	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
Index of technological progress	T	2	national	national	y	y	6 m	1 m	na	na	LUCC, 1998	N	
Aid (% of GNP)	T	3	national	national	y	y	6 m	1 m	5%	0	WDI, World Bank	Y	
2.2 Institutional													
Ratified conventions (by regions and issues)	M	1	national	national	y	y	na	1 d	na	na	WRI, 1998	Y	
Political determinant: political regimes	M	2	national	national	y	y	na	1 d	na	na	LUCC, 1998	N	
National state of the environment reporting	M	2	national	national	y	y	na	1 d	na	na	WRI, 1998	Y	
Status of NEAP	M	2	national	national	y	y	na	1 d	na	na	WRI, 1998	Y	
2.3 Population													
Population Total	M	1	national	district	y	m	6 m	1 m	10%	5%	WDI, World Bank	Y	
Population density per square km	T	1	national	district	y	y	6 m	1 m	10%	5%	WDI, World Bank, WHO	Y	
Age/sex distribution (0-14 years/65+/male female)	T	2	national	district	y	y	6 m	1 m	10%	5%	LUCC, 1998, WHO	N	
population disturbed by noise	T	2	national	district	y	y	6 m	1 m	10%	5%	UNEP/RIVM, 1994	N	
Population Avg. annual growth rate (%)	T	2	national	district	y	y	6 m	1 m	10%	5%	WDI, World Bank	Y	
Urban population (% of total)	M	3	national	province	y	y	6 m	1 m	10%	5%	WDI, World Bank	Y	
Mortality rate	M	1	national	district	y	y	6 m	1 m	10%	5%	WHO	Y	
Infant mortality rate	M	2	national	district	y	y	6 m	1 m	10%	5%	WHO	Y	
2.4 Health													
% of total population with access to safe water	T	1	national	district	m	m	6 m	1 m	10%	5%	WDI, World Bank	Y	
% of total population with home connection to water	T	1	national	district	m	m	6 m	1 m	10%	5%	WHO	Y	
Number of hospitals per 100000 inhabitants	M	2	national	district	y	y	6 m	1 m	10%	5%	WHO	Y	
Number of doctors per 100000 inhabitants	M	2	national	district	y	y	6 m	1 m	10%	5%	WHO	Y	
Population disturbed by air pollution	M	1	national	district	m	m	6 m	1 m	20%	10%	UNEP/RIVM, 1994	N	
Life expectancy at birth	T	2	national	province	y	y	6 m	1 m	na	na	UNDP, 1998	Y	
% of total population with access to hygenic ?	T	2	national	district	m	m	6 m	1 m	10%	5%	WHO	Y	
% of total population with access to sanitation	T	2	national	district	m	m	6 m	1 m	10%	5%	WDI, World Bank	Y	
Prevalence of malnutrition (% under 5)	T	2	national	province	m	m	6 m	1 m	10%	5%	WDI, World Bank	Y	
Per capita average calories available	T	2	national	province	m	m	6 m	1 m	10%	5%	WRI, 1998	Y	
Rate of total central government expenditure for health	M	2	national	national	y	y	6 m	1 m	5%	0	WRI, 1998	Y	
% of total population with access to health care	T	3	national	district	m	m	6 m	1 m	10%	5%	WDI, World Bank	Y	
% of intoxication by microbiological food born disease	T	2	national	district	m	m	6 m	1 m	10%	5%	WHO	Y	
% of intoxication by microbiological water born disease	T	2	national	district	m	m	6 m	1 m	10%	5%	WHO	Y	
2.5 Lifestyle indicators													
% of daily smokers	T	2	national	province	m	m	6 m	1 m	10%	5%	WHO	Y	
consumption of cigarettes per capita	T	2	national	province	m	m	6 m	1 m	10%	5%	WHO	Y	
alcohool consumption per capita	T	2	national	province	m	m	6 m	1 m	10%	5%	WHO	Y	
Number of road accident	T	2	national	province	m	m	6 m	1 m	10%	5%	WHO	Y	
2.6 Education													
Environmental education	M	1	national	province	y	y	na	Na	na	na	UNEP/RIVM, 1994	N	
Adult illiteracy (%)	T	2	national	district	y	y	6 m	1 m	10%	5%	WDI, World Bank	Y	
2.7 Agriculture/land quality													
per caput food production	T	1	national	district	y	m	6 m	1 m	10%	5%	FAOSTAT	Y	
per caput agricultural production	T	1	national	district	y	m	6 m	1 m	10%	5%	FAOSTAT	Y	
total food production	I	1	national	district	y	m	6 m	1 m	5%	0	FAOSTAT	Y	
total agricultural production	I	1	national	district	y	m	6 m	1 m	5%	0	FAOSTAT	Y	
population living below poverty line in drylands	T	1	national	province	y	y	6 m	1 m	10%	5%	FAO/LQI, 1997	N	
total public research expenditures	M	2	national	national	y	y	6 m	1 m	5%	0	FAOSTAT	Y	
genebank status index	T	2	national	national	y	y	na	Na	na	na	UNEP/RIVM, 1994	N	

food consumption per capita	T	2	national	district	y	m	6 m	1 m	10%	5%	UNEP/RIVM, 1994	N	
level of subsidies	M	2	national	province	y	y	6 m	1 m	5%	0	FAO/LQI, 1997	N	
formation of farmer support groups	M	2	national	province	y	y	na	Na	na	na	FAO/LQI, 1997	N	
arable land per caput	T	2	national	district	y	y	6 m	1 d	10%	5%	FAO/LQI, 1997	N	
use of alternative methods for pest control	M	2	national	province	y	y	6 m	1 m	10%	5%	UNEP/RIVM, 1994	N	
manure production	M	2	national	province	y	y	6 m	1 m	10%	5%	UNEP/RIVM, 1994	N	
Labor Force in Agriculture (% from Total)	M	3	national	province	y	m	6 m	1 m	10%	5%	WDI, World Bank	Y	
Farm structure amd practices: fire management	M	3	national	district	y	y	na	Na	na	na	LUCC, 1998	N	
Infrastructure: time/distance to markets	M	3	national	province	y	y	na	Na	10%	5%	LUCC, 1998	N	
2.8 Water													
Annual freshwater withdrawal per capita (cu. m)	T	1	national	district	y	y	6 m	1 m	10%	5%	WDI, World Bank	Y	
Population connected to public waste water treatment plants	M	1	national	district	y	y	6 m	1 m	10%	5%	OECD, 1997	N	
Water balance	M	2	national	district	y	m	6 m	1 m	5%	0		N	
use of water resources	M	2	national	district	y	m	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
water withdrawal/consumption by economic sector (agriculture, industry, etc.)	M	2	national	district	y	m	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
daily household water con. per capita	T	3	national	district	y	m	6 m	1 m	10%	5%	UNEP/RIVM, 1994	N	
2.9 Energy - pollution - climate change													
Carbon dioxide emissions per capita (metric tons)	T	1	national	province	y	m	6 m	1 m	10%	5%	WDI, World Bank	Y	
Production/importation of CFCs	I	1	national	province	y	m	6 m	1 m	0%	0%	UNEP/RIVM, 1994	N	
primary (indigenous) energy production	M	2	national	province	y	m	6 m	1 m	20%	10%	UNEP/RIVM, 1994	N	
Cadmium consumption	I	2	national	province	y	y	6 m	1 m	0	0	UNEP/RIVM, 1994	N	
Mercury consumption	I	2	national	province	y	y	6 m	1 m	0	0	UNEP/RIVM, 1994	N	
chemical fertilizer used	M	2	national	province	y	m	6 m	1 m	0	0	UNEP/RIVM, 1994	N	
Energy use (oil equiv.) per capita (kg)	T	2	national	province	y	m	6 m	1 m	10%	5%	WDI, World Bank	Y	
Consumption of road fuel	M	2	national	province	y	m	6 m	1 m	0	0	OECD, 1997	N	
Selected environmentally significant industries	M	2	national	national	y	y	na	Na	na	na	OECD, 1997	N	
Consumption of ozone depleting subs	I		national	province	y	m	6 m	1 m	0	0	UNEP/RIVM, 1994	N	
2.10 Forest													
intensity of timber production	T	1	national	province	y	m	6 m	1 m	0	0	FAO/LQI, 1997	N	
total forest (ha)	M	1	national	district	y	y	6 m	1 d	0	0	FAOSTAT	Y	
fuelwood and charcoal production/consumption	M	2	national	district	y	m	6 m	1 m	0	0	FAOSTAT	Y	
industrial roundwood production/consumption	M	2	national	province	y	m	6 m	1 m	0	0	FAOSTAT	Y	
sawnwood production/consumption	M	2	national	province	y	m	6 m	1 m	0	0	FAOSTAT	Y	
wood-based panels productio/consumption	M	2	national	province	y	m	6 m	1 m	0	0	FAOSTAT	Y	
total fibre furnish production/consumption	M	2	national	province	y	m	6 m	1 m	0	0	FAOSTAT	Y	
timber consumption per capita	M	2	national	province	y	m	6 m	1 m	10%	5%	UNEP/RIVM, 1994	N	
Forest ownership	M	2	national	district	y	y	na	1 d	na	na	OECD, 1997	N	
2.11 Transports													
transport trends (road, train, air traffic)	T	3	national	province	y	y	na	Na	10%	5%	UNEP/RIVM, 1994	N	
% of "green"cars	M	1	national	province	y	y	6 m	1 m	10%	5%			
Measurement of traffic intensity	M	1	national	province	y	y	6 m	1 m	10%	5%			
2.12 Waste													
Costs of waste management	M	1	national	province	y	y	6 m	1 m	0	0	UNEP/RIVM, 1994	N	
Amounts of waste generated by sector	M	1	national	district	y	m	6 m	1 m	5%	0	OECD, 1997	N	
Waste treatment and disposal installations	M	1	national	district	y	y	6 m	1 m	5%	0	OECD, 1997	N	
Production, movement and disposal of hazardous waste	M	1	national	district	y	m	6 m	1 m	5%	0	OECD, 1997	N	
Public expenditures for pollution control of wastes	M	1	national	district	y	y	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
Generation of municipal/toxic waste	M	2	national	district	y	m	6 m	1 m	5%	0	OECD, 1997	N	
Collection and disposal of municipal/toxic waste	M	2	national	district	y	m	6 m	1 m	5%	0	OECD, 1997	N	
Nuclear waste production	M	2	national	national	y	y	6 m	1 m	5%	0	OECD, 1997	N	
import/export of hazardous waste	M	2	national	national	y	y	6 m	1 m	5%	0	UNEP/RIVM, 1994	N	
Waste recycling rates	T	3	national	province	y	y	6 m	1 m	5%	0	OECD, 1997	N	
2.13 Biodiversity													
Number of biospheres reserves	M	1	national	national	y	y	na	1 d	na	na	WRI, 1998	Y	
Number of world heritages sites	M	1	national	national	y	y	na	1 d	na	na	WRI, 1998	Y	
Net trade mammals/birds/reptiles/plants	M	1	national	national	y	y	6 m	1 m	20%	10%	WRI, 1998	Y	
Biodiversity profile	M	1	province	province	y	y	na	Na	na	na	WRI, 1998	Y	
export of ivory	M	2	national	national	y	y	6 m	1 m	20%	10%	UNEP/RIVM, 1994	N	
Number of wetlands of international importance	M	2	national	national	y	y	6 m	1 d	na	na	WRI, 1998	Y	
CITES reporting requirement met (%)	M	2	national	national	y	y	6 m	1 d	10%	5%	WRI, 1998	Y	

Variables/Indicators related to Soil and Land quality

Type	Category/Variables			HOR RES.		Cycle d,m,y		Timeliness d,m,y		Accuracy		Application	Methodology
		Type	Priority	Min	Opt	Min	Opt	Min	Opt	Min	Opt		in situ = 1
		Target	essential=1										RS = 2
		Input	desirable=2										GIS=3
		Ancil	optional=3										
		Meas											
	1 Soil and land quality variables												
	1.1 Baseline information (stable over long period)												
Target	Soil Type (FAO Classification)		1	1km	0.1 km	10y	5 y	5 y	1 y	TBD	FAO class	1,2,3,4,5,10,11,12	1,2,3
Target/Inp	Topography(relief,elev., slope, aspect, dig.elev.model(DEM))		1	1 km	30 m	30y	10 y	5 y	2 y	10%	3%	NPP,NEP,4,6,10,12	1,2,3
Target/Inp	Soil moisture storage capacity		1	Tier 1,2,3	Tier 1,2,3	10y	5 y	6 m	1 m	10%	5%	1-12 (all)	1
Input	Climate parameters		1	Tiers 1,2	Tiers 1,2,3,4	1 m-summaries	5y	6 m	1 m	10%	5%	1,2,3,4,5,6,7,9,10,12	1,2,3,4
Input	Soil Gravel, sand, silt, clay/soil texture		2	1 km	Tier 1,2,3,4	20 y	10 y	1 y	1 m	10%	5%	1,2,4,5,12	1,2,3
	1.2 Chemical												
Target/Inp	Dry and wet depositions of SO4, NO3, NO2+N2O+NH4+solids		2	50 km	1 km	1 y	1 m	1 y	7 d	30%	10%	1,2,3,4,5.12	1
Target	Biogeochemical transport from land to ocean		2	100 km	10 km	1 y	1 d	1 y	10 d	30%	10%	1,2,3,5,9,12	1,2,4,
Target/Inp	Fertilizer use (N,P,K; CACO3 if relevant)		1	national	sub-national	2 y	1 y	1 y	1 y	10%	5%	1,2,4,5,12	1,3,4
Input	Soil total Nitrogen		3	1 km	Tier 1,2,3,4	10 y	1 y	3 y	2 y	10%	5%	1,2,4,5,12	1
Input	Soil total phosporus		3	1 km	Tier 1,2,3,4	10 y	1 y	3 y	2 y	10%	5%	1,2,5,12	1
Input	Soil available phosphorus		2	1 km	Tier 1,2,3,4	10 y	1 y	1 y	6 m	10%	10%	1,2,5,12	1
Input	Exchangable Potassium		3	1 km	Tier 1,2,3,4	10 y	1 y	1 y	6 m	20%	10%	1,2,5,12	1
Input	Soil total carbon		1	1 km	Tier 1,2,3,4	10 y	1 y	3 y	2 y	10%	5%	1,2,4,5,6,12	1
Input	C, organic		1	1 km	Tier 1,2,3,4	5 y	1 y	6 m	3 m	10%	5%	1,2,4,5 10	1
Input	Calciumcarbonat CaCO3		1	1 km	Tier 1,2,3,4	10 y	5 y	6 m	3 m	10%	5%	1,2,4,5.10	1
Input	pH		1	1 km	Tier 1,2,3,4	5 y	1 y	3 m	1 m	10%	5%	1,2,5,12	1
Input	Acidity Exchangeable		2	1 km	Tier 1,2,3,4	10 y	5 y	6 m	3 m	20%	10%	12,3,5,12	1
Input	Soil Extractable bases		2	1 km	Tier 1,2,3,4	10 y	5 y	6 m	3 m	20%	10%	12,3,5,12	1
Input	Nitrogen mineralization/mineralization potential		3	1 km	Tier 1,2,3,4	10 y	5 y	1 y	6 m	20%	10%	1,2,5	1
Input	Exchangeable Aluminium (if pH <5.5)		3	1 km	Tier 1,2,3,4	10 y	5 y	6 m	3 m	20%	10%	TBD	1
Input	Trace Elements (if pH<5.5 or >6.5)		3	1 km	Tier 1,2,3,4	10 y	5 y	6 m	6 m	10%	5%	TBD	1
Input	Heavy metals		1,2	1 km	Tier 1,2,3,4	5 y	1 y	6 m	3 m	10%	5%	1,2,5	1
	Soil Water Chemistry (see variables for freshwater ressources)												
	1.3 Physical												
Input	Soil Bulk Density		2	1 km	Tier 1,2,3,4	20 y	10 y	1 y	1 m	10%	5%	1,2,3,4,5,12	1
Input	Soil moisture		1	Tier 1,2,3	Tier 1,2,3	5 d	1 d	3 d	3 d	10%	2%	1-12 (all)	1,2
Input	Soil depth		2	Tier 1,2,3	Tier 1,2,3	5 y	1y	6 m	6 m	10%	5%	1,2,3,4,5,12	1
Input	Soil temperature (-50 cm)		1	Tier 1,2,3	Tier 1,2,3	1m	1d	1y	1m	20%	10%	1,2,3,5,6,10,12	1
Input	Saturated hydraulic conductivity		2	Tier 1,2,3	Tier 1,2,3	10 y	5 y	TBD	TBD	10%	5%	TBD	1
Input	Soil surface state		2	Tier 1,2,3,4	Tier 1,2,3,4	10 y	1 y	6 m	3 m	10%	5%	1,5,12	1,2
Input	Surface-roughness coefficient		2	10 km	1 km	10 y	5 y	6 m	3 m	15%	5%	Surface/ground stor. fluxes	1.2
Input	Infiltration rate		2	Tier 1,2,3	Tier 1,2,3,4	10 y	5 y	6 m	1 m	20%	10%	1,2,3,5,12	1,4
Input	Evapotranspiration		1	Tier 1,2,3	Tier 1,2,3,4	1 day	1 hr	6 m	1 m	20%	10%	1,2,3,4,5,6,10,	
Input	Annual soil loss(meas. or predicted by model(USLE))		2	1 km	Tier 1,2,3,4	1 y	1 y	6 m	3 m	20%	10%	1,2,3.5.7,9,12	1,2,3,4
	1.4 Biological												
Input	Necromass		2	Tier 1,2,3	Tier 1,2,3	10 y	1 y	1 y	1 m	20%	5%	1,2,4,5,12	1,2
Input	Area occupied by indicator plants		3	Tier 1,2,3	Tier 1,2,3,4	5 y	1 y	1 y	3 m	10%	5%	1,2,5	1
Input	soil microfauna		1	Tier 1,2,3	Tier 1,2,3,4	5 y	1 y	6 m	3 m	10%	5%		1
Input	soil microflora		1	Tier 1,2,3	Tier 1,2,3,4	5 y	1 y	6 m	3 m	10%	5%	1,2,4,5,12	1
Input	Plant tissue nitrogen & phosphorus content		3	Tier 1,2,3	Tier 1,2,3	5 y	10 d	1 y	3 m	15%	5%	1,2,3,5,10,11,12	1
Target	Earthworms, termites, ants		1	Tier 1,2,3	Tier 1,2,3	5 y	1 y	3 m	1 m	15%	5%	1,2,3,5,12	1
Input	Rooting depth - 95%		2	1 km	Tier 1,2,3,4	10 y	5 y	2 y	1 y	10%	5%	1,2,3,5,10,11,12	1
Input	Decomposition rate		1	Tier 1,2,3	Tier 1,2,3	1y	30 d	30 d	30 d	15%	10%	1,2,4,12,NEP	1
Input	Soil respiration		3	Tier1,2,3	Tier 1,2,3	1y	20d	30d	30d	15%	10%	1,4,5,12,NEP	1
Input	Phenology (crop calendar)		2	Tiers 3,4	Tiers 1,2,3,4	1 month	1 week	1m	1m	major crops	major crops/nat.veg	1,2,4,5,6,10	1,2
Input	Spectral vegetation greenness index		1	4km	0.1 km	1 d	1 d	10 d	1 d	3%	1%	1,3,6,7,9,12	2
	1.5 Land quality change variables (except soils)												
Target	Land cover (FAO classification)		1	1 km	0.1 km	10 y	1 y	1 y	3 m	20 classes	50 classes	1,2,3,4,5,7,8,9,10,12,13	1,2,3,
Target	Land use (USGS)		1	1 km	0.1 km	10 y	1 y	1 y	6 m	5 classes	>100 classes	1,2,3,4,5,6,7,8,9,12,13	1,2,3

Target	Production Net Primary (NPP)	1	1 km	0.1 km	10 d	1 d	1 y	10 d	30%	10%	1,2,3,4,5,6,9,12,13	1,2,3,4
Target	Production Net Ecosystem (NEP)	1	1 km	1 km	1 y	1 d	3 y	1 y	30%	10%	1,4,5,6,12	1,2,3,4
Input	Biomass above ground	2	Tier 4	Tiers 1,2,3,4	1 y	0.5 y	6 m	3 m	10%	5%	1,2,4,5,6,10	1,2,4
input	Biomass below ground	2	Tier 4	Tiers 1,2,3,4	1 y	0.5 y	6 m	3 m	10%	5%	1,2,4,5,6,10	1,4
Meas/Inpu	Leaf Area Index	1	Tiers 3,4	Tiers 1,2,3,4	1 m	10 d	6 m	3 m	10%	5%	1,2,4,5.6,10,13	1,2
Target/Inp	Crown cover and heigth class	1	Tiers 1,2	Tiers 1,2,3	10 y	1 y	3 y	6 m	20%	10%	1,2,3,4,5,67,9,10,	1,2
Target	Species, density, yield	1	Tiers 1,2	Tier 1,2,3	1 y	0.5 y	6 m	3 m	10%	5%	1,2,4,5	1,2,3,4
Target	Cultivation input (agrochemicals, energy, manpower, cost)	1	Tiers 1,2	Tiers 1,2,3	1 y	0.5 y	6 m	3 m	10%	5%	1,2,4,5,12,13	1,4
Target	Residue management /green manure	1	Tiers 1,2,3	Tiers 1,2,3	5 y	1 y	1 y	6 m	20%	10%	1,2,3,4,5,6,10,12	1,4
Target	Herbivores (density/carrying capacity, amanagement system)	1	Tiers 1,2	Tiers 1,2	5 y	1 y	1 y	6 m	10%	5%	1,2,4,5,6,10,12	1,4
Target	Incidence of agric.drought,flooding,fire,other external events	1	Tiers 1,2	Tiers 1,2,3,4	annual summary	event	1 y	3 m			1,2,3,5,6,7,10,12,13	1,2,3,4
Input	Vegetation health/diseases	2	Tiers 3,4	Tiers 1,2,3,4	1 month	1 week	3 m	1 m			1,2,3,4,5,6,7,10	1,2
Target	Area under erosion in farming, pasture and forest land	1	Tiers 1,2	Tiers 1,2,3,4	5 y	1 y	1 y	6 m	20%	10%	1,2,3,5,7,9,12	1,2,3,4
Input	Incidence of gullying	3	Tier 1,2,3	Tier 1,2,3,4	10 y	5 y	1 y	6 m	20%	10%	1,2,3.5.7,9,12	1,2,3,4
Targ,Input	Sedimentation rates in rivers or behind dams	1	20 m	5 m	6 m	1 m	1 m	7 d	20%	10%	1,2,35,7,12	1,2,
Input	Deposit of sediment in coastal areas	2	1 km	0.1 km	1 y	6 m	3 m	1 m	20%	10%	1,5,9,12	1,2
Input	Amount of silt deposited on agricultural lands	2	0.5 km	0.1 km	1 y	6 m	3 m	1 m	20%	10%	1,2,3,5,12	1.2
Input	Aera of sealed surface	2	Tiers 1,2	Tiers 1,2	5 y	1 y	1 y	6 m	20%	10%	1,3,5,7,12	1,2,3,
Input	Area with soil depth reduced to less than 10 cm	3	1 km	Tiers 1,2,3,4	10 y	5 y	1 y	6 m	20%	10%	1,2,5,	1
	additional parameters (relevance to be discussed)											
	1.6 Pressure and response indicators											
	Cultivated area in zones of high erosion potential or impact	2							2			
	Pasture areas grazed in zones of high erosion potential	2							2			
	Forest understory exploited in zones of high erosion potential	2							2			
	Density of roads in zones of high erosion potential	2							2			
	Area deforested in zones of high erosion potential	1							1			
	Area without perennial soil cover during critical erosive periods	2							2			
	Area protected by conservation practices or landscape features	2							2			
	Change in land use to more or less erosive practices	1							1			
	Operational area under soil management plans	1							1			
	Area under nonconservation tillage practices	2							2			
	Area under poor crop residue management	2							2			
	Net nutrient extraction in cropland, pastures, and forests	1							1			
	Area covered by sustainable nutrient applications								2			
	Farmers or area participating in soil improvement programmes	1							1			
	Ratio of cultivated to cultivable land								2			
	Farmland abandoned	2							3			
	Change to crops with lower nutrient requirements	2							2			

Appendix 7: Five-year GTN-P Plan and Background Information

Action	Subnetwork CALM (Global, Active Layer)	Subnetwork Borehole Temperature (Global, Thermal)	Subnetwork PACE/mountains (Regional, Thermal)
Maintain web sites	Completed	Under construction	Completed
Site selection (Incl. WMO Letter)	80 sites (current) Expansion of network to include Southern Hemisphere; 1999-2001	Complete survey of initial sites 2000; Identify regional gaps Propose and develop future sites; 1999-2001	Implement Phase 2; 2001
Instrumentation: acquisition and distribution of standardised equipment	Ongoing	Contingent on funding	Ongoing
Meetings North America	AGU/annual	AGU /annual	
Europe/Russia	Pushchino/annual	Pushchino/annual International Permafrost Conference (Switzerland); 2003	Regional/European PACE/Annual
Asia	Tokyo, Mongolia; 2001	Tokyo, Mongolia; 2001	
Products			
Web	Univ. of Cincinatti **www.geography.uc.edu/CALM**	Geological Survey of Canada: sts.gsc.nrcan.gc.ca/permafrost/	Univ. of Cardiff **www.cf.ac.uk/uwcc/earth/pace**
Metadata forms	80 sites completed	Meta form completed	In progress
Observing protocol QA/QC	Completed - on web site	Complete in 2000	Completed - see web site
Site inventory	Annual update	Phase 1: 2000	Phase 1: completed
Data availability	See web site for annual updates	Adding past and current data to web site	See web site
Annual reports	X	X	X
First 5-year synthesis; Regional sections	Draft 2003; publish 2004	Draft 2003; publish 2004	Draft 2003; publish 2004
First decadal report	2008/2009	2008/2009	2008/2009

A proposal was prepared in June 1999 for the development of a long-term, well-coordinated international network of permafrost observatories that will document ground temperature changes, and thus provide the data for testing models and scenarios of cryospheric changes and resulting impacts.

Site selection. The basic objective of site selection is to obtain sound regional and global coverage while taking maximum advantage of existing facilities. The initial role of the permafrost network (GTN-P) is primarily to assess and detect long-term climate change through its impact on the permafrost, particularly on a regional basis. Although the network is not intended to monitor sites with human disturbances, including construction, some sites with minimal disturbances may be acceptable if long-term monitoring is guaranteed.

The first steps in site selection of permafrost boreholes were taken in 1998. The permafrost communities, both individuals and national IPA representatives, were requested by the IPA to identify existing boreholes that were available for future measurements. Over 250 locations were identified. Each site was assigned to one of four depth classes.

Additional sites were identified by Russian colleagues at the April 1999 cryosphere monitoring conference in Pushchino. In general, to detect and reconstruct climate history for the last several decades we will need information on the permafrost temperature regime at a minimum of 20 m, but depths of 40 to 60 m are preferable. Profiles of the permafrost temperature at depths of several hundred metres will be needed to investigate climate history during the post-Little Ice Age period.

The next step in site selection is to describe potential boreholes according to a standard set of descriptors. These site metadata descriptions were discussed and agreed to in Pushchino. We are in the process of gathering this information and it should be available by the end of 1999. Based on the metadata information, an initial set of sites will be identified in accordance with the following GCOS criteria:

- each participating country should identify sites representative of its own longitudinal, latitudinal and altitudinal permafrost zones;
- collection, documentation, and distribution of appropriate data should be ensured on a sustained and timely fashion;
- generally accepted, well-documented methodologies should be employed.

Sites in under-represented systems should have priority over those in already represented systems. Existing sites are preferred over sites without instrumental or observational records.

The formal selection process will start at the meeting of the AGU from 13 to 17 December1999, to be attended by North American GTN-P participants. We will review site information and refine selection criteria. The process will continue via email and be completed at the annual Pushchino permafrost conference scheduled for mid-May 2000. At this time it is difficult to say how many sites will be included in the network, but certainly most existing sites in North America and Europe (PACE) can be included.

The near-surface permafrost temperature regime (20 to 200 m) is a sensitive indicator of the interannual and decade-to-century climatic variability and long-term changes in the surface energy balance. Twenty-five percent of the land mass of the Northern Hemisphere is underlain by permafrost with over half of it at temperatures a few degrees below 0^oC. Global permafrost zones span many physiographic regions, including vast expanses of northern lowlands, high elevations in mountains, and plateaus from high to low latitudes. Predicted increases in mean annual air temperature of several degrees in northern latitudes will lead to thawing and destabilisation of perennially frozen ground. In the mountains, warming and thawing result in increased slope instability. Permafrost degradation has important implications for many landscape processes (terrain, slope and coastal stability), hydrology (surface and groundwater regimes), surface characteristics (vegetation, albedo), greenhouse gas sources and sinks (peatlands, soils, gas hydrates), as well as for ecosystems, engineering and infrastructure.

In order to understand the status and changes in the permafrost areas of the Earth, an effective international global monitoring strategy is required. It will provide field observations essential for the comprehensive detection of the terrestrial climate change signal and for the assessment of its lag and attenuation, as well as indications of the spatial variability of change across the high latitudes and mountains of both hemispheres. This information is critical not only for the improvement of predictive models and the reliability of impact assessments including that of the Intergovernmental Panel on Climate Change (IPCC), but also to further understand the sensitivity of permafrost conditions and processes to climate variability and change.

Standardise instrumentation and observations. There are two general methods for measuring temperatures in boreholes: (1) periodically lowering a calibrated thermistor into a liquid filled borehole and measuring temperature at descending intervals; and (2) recording temperatures over time with a permanently or semi-permanently installed multisensor thermistor cable. In either case the precision of the measurement can be from 0.1^{o}C to 0.01^{o}C, depending on the thermistor calibration. The second method involves greater initial cost for the cable. Both methods are used in North America. The PACE programme uses the recording cable system with provisions to retrieve and recalibrate the cable. The multisensor approach is generally workable for holes less than 100 m deep and allows for the installation of data logger systems. Although these systems introduce an additional cost, they often more than offset the costs associated with more frequent visits for data collections at remote sites.

A detailed measurement protocol, based on existing methodologies, will be developed in the first year. For GTN-P, the minimum requirement will be to use the calibrated single thermistor once a year, although monthly measurements accompanied by observations of snow conditions are optimal. This calibrated cable can be used in multiple holes by the same person or organisation. To ensure acquisition of standard data and quality, we propose to provide one calibrated thermistor cable and meter to each of approximately 15 sites or organisations in Argentina, China, Mongolia, Kazakhstan and Russia. Air and near-surface temperatures will be recorded at most sites using inexpensive data loggers as employed at many CALM sites. In return for the equipment and related support, we will require [expect] each site to report data annually.

The candidate organisations or sites requiring instruments are:

- Argentina - Geocryology Unit, (IANIGLA), Mendoza
- China - Institute of Cold and Arid Regions Environments and Engineering, Lanzhou
- Kazakhstan - Alpine Geocryological Laboratory, Alamty
- Mongolia - Institute of Geography and Geocryology, Ulanbator
- Russia - multiple sites by region: European North, Vorkuta, West Siberia, Sahka, Lower Kolyma, Magadan, Trans Baikal.

Temporal variability in the snow cover thickness and/or snow thermal properties can affect the permafrost temperature dynamics within decadal-to-century time scale. We propose that snow cover characteristics (depth and density) be observed in close proximity to the boreholes at sites that can have repeat winter observations. Alternatively we will rely on climate records (monthly mean) from the meteorological stations nearest the borehole. Analytical and numerical models allow the analysis of the separate air temperature and snow cover effects.

Data management. For a global observing system to be successful, all data from a site must be freely available to outside users. It is important that individual researchers who collect the data perform quality procedures before submission and follow standard accepted practices.

Information resulting from this process should accompany the data sets along with relevant instructions as to the proper use of data sets. To assist in fulfilling these policy statements, the Geological Survey of Canada (GSC) proposes to perform the data-management portion of the borehole temperature network as its contribution to GTN-P and as part of its national involvement in GCOS.

GSC will maintain the metadata information and receive the annual site data, in much the same way that the United States is performing the active layer component (CALM) and the Europeans are managing PACE. This GSC involvement recognizes Canada's important global role in permafrost research, its significant number of existing permafrost thermal observatories (more than 80 of the initial 250 sites identified), and its commitment to support the development and coordination of the international GTN-P programme. The proposed work also complements Canadian activities under way or proposed through Canada's Climate Change Action Fund -- a three-year federal programme established in response to the Kyoto protocol -- and extends these to the international level. In order to initiate these GTN-P activities and ensure continuity in the proposed five-year start-up phase, the GSC would perform the following activities:

- Develop a web site for the GTN-P. This site would be located on the permafrost home page of the GSC (http://sts.gsc.nrcan.gc.ca/permafrost).
- Maintain metadata forms on permafrost thermal state observatories contributing to the network, and make this metadata accessible on the web site.
- Receive and store thermal data reported from the borehole observatories, and make summary data available on the web, with annual updates.
- Contribute to reporting, in collaboration with the PI and co-investigators, including a short paper on the establishment and goals of the network (for publication in the Russian Journal Earth Cryosphere in 1999).
- Produce an initial summary report on the GTN-P programme (to be released as a GSC Open File in the end of year 2000). The report will officially release metadata and available data. Included will be a summary report on permafrost thermal conditions and recent changes for western arctic North America.
- Publish the first five-year summary report in year 2004 with a draft presented at the Eighth International Conference on Permafrost (VIII ICOP) in Switzerland in 2003.

This summary report will be organised by regions with regional editors: North America (see Burn 1998 as an example) and South America, Europe, Eurasia, China, Antarctica, etc. Details of the reporting plans will be develop by the International Permafrost Association. Periodically data will be archived in the IPA Global Geocryological Data (GGD) at one of the regional WDC data centres. Currently this is done in WDC-A for Glaciology in Boulder, Colorado, and periodically produced on a CD-Rom. See Table for the proposed work schedule.

Links to other programmes. Our primary responsibilities are to maintain close working relations with the IPA and GCOS organisations, and the CALM and PACE programmes. We will coordinate closely with the GCOS/GTOS Terrestrial Observation Panel on Climate and its Chair Josef Cihlar, Canada Centre for Remote Sensing. Two of the TOPC members hold positions in the IPA: Roger Barry and Wilfried Haeberli. We will keep all IPA committees, working groups and task forces informed (see Frozen Ground Number 22 and the IPA web site); particularly the working groups on Global Change and the Southern Hemisphere. The co-chairs of the Global Change working group are authors of the IPCC report Chapter 16, Arctic and Antarctic. We will also provide input to the WCRP programme on climate and the cryosphere (CLIC) and related activities. Within the United States, we will continue to maintain close contact with NSF programmes (Arctic Transitions in the Land-Atmosphere System [ATLAS], RAISE, and the new NSF Environmental Observatories), federal agencies (USGS, CRREL) and university programmes. Within Canada, we will maintain close contact with CRYSYS (use of the Cryospheric System to Monitor Global Change in Canada), a programme led by Environment Canada, and coordination with the Canadian GCOS Cryosphere contributions. We have recently established contact with several members of the International Heat Flow Commission (IHFC) of the International Association of Seismology and Physics of the Earth's Interior (IASPEI) and the International Geological Correlation Project #428: Past Climate Change Inferred from the Analysis of the Underground Temperature Field. The following web sites contain more information on GTN-P programmes and linkages:

- IPA web: **http://www.geodata.soton.ac.uk/ipa**
- CALM web: **http://www.geography.uc.edu/calm**
- PACE web: **http://www.cf.ac.uk/iwcc/earth/pace**
- GSC web: **http://sts.gsc.nrcan.gc.ca/permafrost/**

Appendix VIII: Descriptions of Existing GTOS/GCOS Networks

A. GCOS Terrestrial Network for Glaciers (GTN-G)

Overview
Changes over time that can be detected in the mass, volume, area and length of the world's glaciers provide some of the clearest signals in nature of climate change.[1] Unlike the permafrost network, which is only now being established, systematic observations of glacier fluctuations have been made in some parts of the world, notably in the Alps and Scandinavia, for over 100 years. The responsibility to collect and publish standardised data has been assumed since 1986 by the World Glacier Monitoring Service (WGMS), which is supported by the University of Zurich and the Swiss Federal Institute of Technology. WGMS now manages the recently created GCOS Terrestrial Network for Glaciers (GTN-G).

The mass balance of a glacier, which is a measure of the mass of water a glacier as a whole is gaining or losing, is a direct and undelayed signal of climate change. Some 60 glaciers throughout the world are currently monitored for mass balance as part of GTN-G. About 15 of these are being intensively studied with extensive stake/pit networks for improved process understanding and numerical modelling, while the remaining ones are monitored in a simpler way (index points and repeated mapping) to obtain information on regional changes. The changing length of a glacier also provides a key climate change signal. It is important both for enabling global coverage and for understanding the past evolution of a glacier. Although the climate change signal provided by glacier length is delayed and indirect, length is more easily measured than mass balance. The length of some 800 glaciers worldwide is measured approximately every five to 10 years.

Several publications document glacier data. The *Glacier Mass Balance Bulletin* is published by the WGMS every two years and reports measured values from selected reference glaciers.[2] The *Bulletin* complements the publication series *Fluctuations of Glaciers*, where the full collection of digital data, including the more numerous observations of glacier length variation can be found. The WGMS maintains data exchange with the ICSU World Data Center A (WDC-A) for Glaciology in Boulder, Colorado, and the UNEP Global Resource Information Database (GRID).

Network details

Subnetworks
None

Sites
60 glaciers monitored for mass balance, 15 intensively
Some 800 glaciers monitored for length
Inventory data (not complete) for some 67,000 glaciers
See **http://www.geo.unizh.ch/wgms/** for pdf files of Mass Balance Bulletins and **http://www-nsidc.colorado.edu/NOAA/wgms_inventory/**, a WGMS mirror site, for inventory information.

---

[1] W. Haeberli, "Climate Change Detection--Operational Elements of a Worldwide Monitoring Strategy," ….
[2] IAHS - UNEP - UNESCO, *Glacier Mass Balance Bulletin*, Bulletin No. 5 (1996-1997), 1999. This publication, which contains summary information for 64 glaciers and detailed information for 11 glaciers, can also be viewed as a pdf file from the WGMS web site (see footnote 2).

Measurements taken
Mass balance
Length
Distribution
Elevation
Areal extent

Best practices
See the WGMS web site (**http://www.geo.unizh.ch/wgms/**) for a description of the monitoring strategy for mass balance, length change and inventory data.

Data quality control
Collection of standardised glacier fluctuation data follows recommendations (and regularly updated instructions) first published by UNESCO in 1969.

The WGMS does not guarantee the correctness of *inventory* data. The accuracy of the data is the responsibility of the data collectors in the individual countries. All data are subjected to plausibility checks while being loading into the database

Data availability
Mass Balance Bulletins published every two years. See web site. Starting in 1999, mass balance measurements will be available for selected glaciers one year after the end of the measurement year. Length measured annually or every five to 10 years; report published every five years.

Data archiving
See the series *Fluctuations of Glaciers*, published by WGMS, for mass balance and length data. See **http://www-nsidc.colorado.edu/noaa/wgms_inventory/** for inventory information.

Other useful web sites
National Snow and Ice Data Center (**http://www-nsidc.colorado.edu/**). Also see links on WGMS web site.

Deficiencies
The total number and worldwide distribution of glaciers monitored for mass balance provides important information on general trends, but it is far from ideal. For example, almost one-third of the world's glaciers are in the Alps and Scandinavia, where practical applications with respect to landscape change, tourism or hydropower production are obvious. Other areas are either underrepresented or have no sites at all in the network. New or intensified observations are most urgently needed in New Zealand, with its Southern Alps. Chile and Argentina, with major glaciers in the Andes and Patagonia, have no observation sites. In the former Soviet Union, the number of glaciers monitored has declined in recent years. Even the United States and Canada, with many glaciers in Alaska, the Canadian Rockies and Canadian Arctic region, have been monitoring only a few glaciers on a long-term basis. Some regions/countries where needs are acute include: Kenya, where important measurements of a long-studied tropical glacier have recently been terminated; Argentina, where mass balance observations in Patagonia have started, but for which funding for continuing measurements must still be assured; Tajikistan, where an important research station at the Abramova glacier was recently destroyed in a war action; Peru, where funding, monitoring, and scientific activity is in danger of being completely lost; and Mongolia, where observations have only recently begun.

Continuity and amount of funds at the national level is a major problem for the operation of glacier observing sites. Mass balance measurements require a team of three to four people for only a few days each year. The funds required for drilling and surveying equipment and salaries are therefore modest but must be available on a long-term basis. Moreover, even such small amounts can be beyond the means of many developing countries, in which scarce resources are needed for higher priority purposes. In at least one case, an offer of assistance was unsuccessful because the assistance was deemed to be inadequate. More typically, however, the low priority of glacier observations as perceived at the national level has meant inadequate funds for long-term monitoring. This situation is as true in countries such as Canada and the United States, where budgets for survey work have been reduced, as it is in developing countries. In some developing countries, lack of scientific capacity is also a problem. Adequate training and provision of field equipment can remedy the problem, but this too requires funding. Tensions in remote mountainous border areas in certain parts of the world (e.g., Central Asia) have limited mass balance observations to some extent. Finally, some potentially valuable data (including survey records, maps and aerial photographs) exist in countries of the former Soviet Union that have not been recorded and are in danger of being lost. High staff turnover in many of these countries as a result of general instability, as well as lack of funds, is at the root of this problem.

In addition to mass balance and length observations of a representative subset of the world's glaciers, the WGMS collects inventory information on the distribution, elevation, and areal extent of glaciers.[3] Among others, such information is valuable for assessing climate change effects at the regional or national levels. However, detailed inventory information is currently not available for remote glaciated areas. A substantial number of aerial photographs exist for glaciers in the Alps, Scandinavia, and the former Soviet Union. Landsat satellite images are available for glaciers in other countries. However, Landsat images do not furnish elevation information. To provide global coverage of the world's glaciers, many of which are in remote areas, use of remote sensing techniques will be essential. New remote sensing technologies, such as synthetic aperture radar or laser altimetry used in connection with kinematic GPS and combined with digital terrain information, provide the basis for periodic detailed inventories.[4]

B. GCOS Terrestrial Network for Permafrost (GTN-P)

Overview

The GCOS Terrestrial Network for Permafrost (GTN-P) was established to organize and manage a global network of permafrost observations, most importantly of temperature changes in frozen ground. Some 25 percent of the landmass of the Northern Hemisphere is underlain by permafrost, with important permafrost zones in Canada, China, Russia and the United States, and with smaller permafrost areas in many other countries in both the Northern and Southern Hemispheres. Permafrost observations are an important element of the mission of GCOS because variations in permafrost temperature can be a sensitive indicator of climate change and climate variability. For these purposes, observations are required in both the ‘active layer’ -- the upper or surface layer which thaws and freezes seasonally -- and the lower permafrost layer of perennially frozen ground.

[3] The World Glacier Inventory of over 67,000 glaciers is provided at the WGMS mirror site at http://www-nsidc.colorado.edu/NOAA/wgms_inventory/. Outside the Alps and Scandinavia, many data gaps exist in the inventory.

[4] W. Haeberli, ed., *Into the Second Century of Worldwide Glacier Monitoring--Prospects and Strategies* (Paris: UNESCO Publishing, 1998). See "Conclusions and Recommendations," p. 216.

Important observations in the active layer include the maximum thickness of the seasonal thaw and, when possible, a record of ground temperature. In the underlying permafrost zone, temperature profiles are required, with the desired frequency of observations decreasing with depth. For example, monthly observations may be desirable in the upper 5-15 m, where ground temperatures follow the annual air temperature wave (although with a phase lag and amplitude attenuation). Annual observations are sufficient at greater depths in shallow boreholes (up to 50 m), while observations at five- to 10-year intervals are acceptable at the greatest depths (up to several hundred metres) where temperature changes very slowly.

The Circumpolar Active Layer Monitoring (CALM) network is part of the GTN-P that is already in place for obtaining active layer measurements at about 80 sites in the Northern Hemisphere. For the deeper permafrost layer, temperature measurements are obtained through boreholes, using one of several types of thermistor sensor and measurement systems. A survey of existing boreholes has indicated that at least several hundred locations throughout both hemispheres are candidate sites for future, long-term observations of permafrost temperatures and related climatic variables. Most of these boreholes were drilled for either research or hydrocarbon exploration purposes. A European Community project, the Permafrost and Climate Change in Europe project (PACE), is drilling and instrumenting a series of nine permafrost boreholes in mountains from Spain and Italy to Svalbard. However, a globally comprehensive network of permafrost borehole temperature measurements, using the candidate holes, has not yet been developed.

Network details

Subnetworks
Circumpolar Active Layer Monitoring (CALM)
Permafrost and Climate Change in Europe (PACE)
Borehole

Sites
CALM: About 80 stations in the Northern Hemisphere. See information at **http://www-nsidc.colorado.edu/nsidc/catalog/entries/g01175.html**. A CD-Rom containing data sets is available. See also **http://www.geography.uc.edu/~kenhinke/calm/**. Expansion of network to Southern Hemisphere by 2001.
PACE: Nine sites in Europe. See **http://www.cf.ac.uk/uwcc/earth/pace/fieldsites/index.html**.
Potential borehole sites: For inventory of accessible boreholes that are potentially eligible to GTN-P see **http://sts.gsc.nrcan.gc.ca/permafrost/gtn-p.htm**

Measurements taken
Active layer depth (maximum thickness of seasonal thaw)
Ground temperature
Borehole temperature

Best practices
See **http://www.geography.uc.edu/~kenhinke/calm/** for CALM.

Data quality control
See CALM and PACE web sites for metadata forms, observing protocol, and quality control. Same will be available for borehole temperatures in 2000.

Data availability
See web site for annual updates

Data archiving
Annual reports for CALM and PACE subnetworks and for borehole temperatures
Five-year synthesis for CALM
Final archiving in World Data Center A for Glaciology

Other useful web sites
International Permafrost Association (**http://www.geodata.soton.ac.uk/ipa/**)Deficiencies
Observation deficiencies are most prominent in permafrost areas of five countries -- Argentina, China, Kazakhstan and Russia -- although regional gaps exist elsewhere. Fundamentally, the problems have to do with lack of resources for installation and continuing operations. This is why the International Permafrost Association has requested funding from the United States National Science Foundation. The funding would assist in the development of observational programmes in these countries and be used to maintain a web site on which data could be regularly reported and subsequently archived. Lack of standardised instrumentation is a problem in all countries. Additional funds would thus be used in part to provide the thermistors and other equipment needed for temperature measurements at some 15 new sites in the five countries identified above. A second problem is that many existing boreholes are in remote and often inaccessible locations; hence, there may be logistical difficulties in reaching sites, leading to higher expenses. A major problem in Russia is that while a substantial amount of useful historical data already exist, they are dispersed throughout the country, generally not in usable digital form, and often are not subjected to quality control procedures. To avoid losing these valuable records, the data need to be located, processed and archived in an accessible form. Additional resources would also be required for data management.

Additional boreholes are desirable in some locations to ensure adequate coverage for a global observation network, but new holes are expensive to drill. It is estimated that 20 new holes are required initially in underrepresented regions to provide appropriate global coverage. High priority areas include Argentina, which currently has no boreholes, and in Antarctica, where there are existing boreholes, but data recovery and reporting will depend on coordination with the Scientific Committee on Antarctic Research.

An administrative problem that might be easily addressed is that the appropriate ministries in many permafrost countries are unaware of the existence of the Global Terrestrial Network for Permafrost or of the importance of permafrost data for the assessment of climate change and its impacts. In addition, national permafrost monitoring activities have not always been clearly incorporated into the mandate of government agencies. Recognition of the importance of these monitoring activities through SBSTA could lead to more direct involvement in GTN-P by these approximately 15 countries, and potentially also make available some internal funds for implementation and long-term monitoring. The deficiencies should also be addressed in the development of national GCOS plans.

C. Global Flux Tower Network (Fluxnet)

Overview
The Global Terrestrial Network - Carbon (GTN - Fluxnet) was established in 1997 to coordinate existing regional networks and independent sites monitoring long-term carbon and water vapour fluxes and the surface energy budget. Monitoring of these and associated variables, such as site vegetation and soil, hydrologic, and meteorological characteristics, enables researchers to assess

the annual net uptake of carbon dioxide from particular biomes, to quantify year-to-year differences in canopy carbon exchange, and to understand the environmental and biological factors controlling trace gas fluxes.[5] Such information is crucial for a better understanding the Earth's carbon cycle and human perturbations to this cycle, and thus has direct relevance to political decision-making on global climate change.[6] The creation of Fluxnet is intended to advance site-to-site comparability and coordination of enhancements to regional network plans.

At present, there are about 80 stations in the global Fluxnet network, but this number is expected to expand. Sites are heavily concentrated in North America and Western Europe. The AMERIFLUX network (including stations in Canada, Costa Rica and the United States) is the largest regional network with 35 sites. The EUROFLUX regional network has 18 sites in northwestern Europe, while MEDEFLU has seven sites bordering the northern Mediterranean Sea. JapanNet consists of some five sites, an expanding network in Brazil currently has two sites, and some 13 independent sites around the globe make up the rest of the network. A regional network is currently under development in Australia.

- Network details

Subnetworks
AmeriFlux
EUROFLUX
MEDEFLU
JapanNet

Sites
35 Ameriflux sites in the United States, Canada, and Costa Rica. See **http://cdiac.esd.ornl.gov/programs/ameriflux/**
18 EUROFLUX sites. See **http://www.unitus.it/eflux/euro.html**
Seven MEDEFLU sites. Posted site (**http://www.iata.fi.cnr.it/medeflu/minute.htm**) no longer active
Five JapanNet sites. See http://daacl.ESD.ORNL.Gov/Fluxnet/japan.txt for list of Japanese teams.

Measurements taken
Carbon dioxide, water vapour, sensible heat and momentum flux densities measured at a certain height above and within the canopy;
Air temperature and humidity measured above and within the canopy;
CO2 profiles measured above and within the canopy;
Soil temperature measured at certain distances above the soils;
Net radiation, PAR and solar radiation (direct and diffuse) measured above the canopy;
PAR measured below the canopy at 1m along a 20 m transect;
Precipitation and soil moisture.

Best practices
For Ameriflux see the science plan at **http://cdiac.esd.ornl.gov/programs/ameriflux/scif.htm**

---

[5] R. Valentini, D. Baldocchi, and R. Olson, "Fluxnet: A Challenge That Is Becoming Reality," **http://www.igbp.kva.se/newsletter37.pdf** March 1999.
[6] See the main Fluxnet web site at **http://daacl.esd.ornl.gov/fluxnet/**.

For EUROFLUX see **http://www.unitus.it/eflux/** for project methodology.

Data quality control
See Fluxnet Overview at **http://daacl.ESD.ORNL.Gov/Fluxnet/FLUX_Plan.html**
For Ameriflux, see appropriate section in science plan.

Data availability
In general, unrestricted within two years after the date of collection.
For Ameriflux, investigators required to submit fully documented data sets "shortly after acquisition," allowing for time needed to check and assure data quality.

Data archiving
Periodically, copies of finalised data in Fluxnet will be submitted to an archive (e.g., Oak Ridge National Laboratory Distributed Active Archive Center). For Ameriflux, data to be archived at the Carbon Dioxide Information Analysis Center. See **http://cdiac.esd.ornl.gov/**.

Other useful web sites
Oak Ridge National Laboratory Distributed Active Archive Center:
http://www-eosdis.ornl.gov/

Deficiencies

Many parts of the world are either not represented in Fluxnet or are poorly represented. Thus far, there are no Fluxnet sites in Africa, none in most of Asia (i.e., China, Siberia, India, the Near East, Indonesia, etc.), none in Eastern Europe, none in South America outside Brazil, and none in Mexico. Also, although Canada has seven sites, none are located in northern Canada. Gaps in the system are inevitable with an ad hoc volunteer network, and not all facilities have equal capabilities or levels of scientific activity.

Gaps in the Fluxnet network can also be characterized by biome type. The current network is concentrated on forests, particularly temperate broad-leaved forests, temperate conifer forests, and semi-arid woodlands. However, many important biomes, including tundra, peatlands, wetlands, deserts, and savannas are underrepresented. Tropical forests may be underrepresented as well. Additional sites are also needed over intensively cultivated areas, and disturbed systems, such as burned, grazed, and logged areas also need to be investigated (e.g., we do not know how NEP varies with time since disturbance). Finally, forest age class deserves greater attention: e.g., young forest stands are underrepresented in some regional networks. Mountain sites have not been considered due to their complexity, but focused studies are warranted in mountains to resolve thorny issues related to flux measurements in suboptimal terrain.

As with other global networks, funding can be an important constraint to establishing and operating a Fluxnet site. A typical costs would include the purchase of instruments to make core measurements, spare sensors, data telemetry, and data archiving hardware. The cost of site infrastructure is extra and will vary according to the remoteness of the site (e.g., if a road or power line is needed), the height of vegetation (i.e., whether or not a tall tower must be built), and the existence of other facilities.[7] Also, at minimum, a team of two individuals is required to operate a flux system. Day-to-day chores include calibration, instrument and computer maintenance, and data archiving. Such tasks require skilled operators, not readily available in

[7] S.W. Running, D.D. Baldocchi, et al, "A Global Terrestrial Monitoring Network Integrating Tower Fluxes, Flask Sampling, Ecosystem Modeling and EOS Satellite Data," *Remote Sensing of Environment*, Vol. 70, 1999. See also **http://www.forestry.umt.edu/ntsg/whatsnew/publications/bioval/**

many developing countries, to interpret data and detect subtle problems. Operations would be enhanced by measurement standardisation, as it would increase data quality and the ability to compare between sites and would also provide support and standards for emerging groups.

Appendix IX: Revision and Updates of Data Sets

This Appendix contains descriptions of only data sets for climate-related variables that have been made available or identified since the last TOPC meeting. This list and data set descriptions thus complement those provided to GOSIC in 1998, and should be used to revise the latter.

VARIABLE: FIRE AREA

DATA SET:	IGBP-DIS Global Fire Product
DATA ADDRESS:	**http://www.mtv.sai.jrc.it/projects/fire/home.html**
AUTHOR:	Simon Pinnock (World Fire Web), Ned Dwyer (Global Fire Product), Daniela Stroppiana (Burnt Area Mapping) Space Applications Institute, Joint Research Center, Ispra Italy
UNITS:	Global Fire Product, global fire position tables daily and raster fire counts at 0.5o X 0.5o latitude-longitude grids over both daily and 10-day periods. Burnt Area Mapping, in km2 per unit time, dependent on sensor (30 m LANDSAT-TM, 1.1 km and 5 km AVHRR resolutions have been experimented with). World Fire Web, detected active fires per unit area per day based on AVHRR 1.1 km imagery
SOURCE:	All from AVHRR 1.1 km imagery although Burnt Area Mapping continues to experiment with other sensors.
RESOLUTION:	Global Fire Product at 1.1-6.7 km (daily global fire position tables) and 0.5o X 0.5o latitude-longitude (daily, 10-day raster fire counts); Burnt Area Mapping, variable resolution depending on sensor, World Fire Web, 1.1-6.7 km
COVERAGE:	Global Fire Product (daily global fire position tables, daily, 10-day raster fire counts are global; Burnt Area Mapping, variable resolution depending on sensor, with one example available for the continent of Africa. Prototype implementation at two regional nodes expected by December 1999 with progressive enlargement thereafter. World Fire Web, 1.1 - 6.7 km, is currently available for Europe, Southeast Asia, Australia and much of South America, although "almost global" coverage is expected by the end of 1999.
METADATA:	Web site metadata are adequate for Global Fire Product. Burnt Area Mapping is still experimental and hence metadata are absent. World Fire Web metadata will require examination when it comes online.

VALIDATION: Global Fire Product has not clearly been validated, although publications may describe specific sites where ground observations have tested algorithm signatures. Burnt Area Mapping, variable resolution depending on sensor, World Fire Web which depends on the same methods as the Global Fire Product, has not been directly validated, based on information provided at the web site.

REVIEW: The methods have undergone review, and data to test validity of the algorithm's ability to discriminate fire and non-fire has been tested for limited locations and situations on all three products (Global Fire Product , Burnt Area Mapping, World Fire Web).

USE: Several refereed papers on the Global Fire Product have been published; papers describing methods used in Burnt Area Mapping, and the World Fire Web have been published.

APPLICATION: Global Fire Product has been applied in several publications to define global fire seasons, determine relationships between geography of fire occurrence and environmental variables; Burnt Area Mapping has been tested in Africa but not applied to its purpose of defining a record of areas burnt each year; World Fire Web has been tested on four main nodes but has not been applied yet to its function of providing coverage of currently burning wildland vegetation.

RECOMMENDATION: Global Fire Product should be accepted by GTOS; Burnt Area Mapping and World Fire Web should be reviewed regularly until they are running, and evaluated for acceptance at that time.

VARIABLE: LAND COVER

DATA SET: Several products:

- One Degree Global Land Cover
- One Kilometre Global Land Cover
- Eight Kilometre Global Land Cover Project
- Continuous Fields Tree Cover

DATA ADDRESS: http://glcf.umiacs.umd.edu/about/aboutwho.html

AUTHOR: Various

UNITS: Various

SOURCE: AVHRR data

RESOLUTION: Varies with product (1x1 degree, 8km, 1km)

COVERAGE: Global

METADATA:	Yes
VALIDATION:	Yes
REVIEW:	Yes (described in publications)
USE:	Yes
APPLICATION:	Yes
RECOMMENDATION:	Accept

Note: The products are available from the Global Land Cover Facility (GLCF) located at the University of Maryland, College Park, United States.

VARIABLE: SOIL MOISTURE

DATA SET:	Global soil moisture data bank
DATA ADDRESS:	http://climate.envsci.rutgers.edu/soil-moisture
AUTHOR:	Alan Robock
UNITS:	Various
SOURCE:	Russia, China, the United States, etc.
RESOLUTION:	100-500 km
COVERAGE:	Russia, China, the United States, etc.
METADATA:	Adequate - available on the web
VALIDATION:	available on the web
REVIEW (peer):	A paper by Robock *et al.*, 2000 (Bulletin of the American Meteorological Society)
USE in refereed papers:	
APPLICATION:	The data is used as the validation for satellite remote sensing and Global Soil Wetness Project.
RECOMMENDATION:	Qualified acceptance. These are scattered point measurements and are thus not globally comprehensive. It should be noted that soil moisture observation is strongly affected by the local heterogeneity of the land surface.

VARIABLE: EVAPOTRANSPIRATION

DATA SET:	Global Soil Wetness Project
DATA ADDRESS:	http://grads.iges.org/gswp/
AUTHOR:	CCSR/University of Tokyo
UNITS:	W/m2
SOURCE:	Land surface model output intercomparison
RESOLUTION:	1x1 degree, 10-day mean
COVERAGE:	Global, 1987 and 1988
METADATA:	Adequate - available on the web
VALIDATION:	Available on the web
REVIEW (peer):	Dirmeyer *et al.* (1999, Journal of the Meteorlogical Society of Japan 77 (1B).
USE in refereed papers:	Special issue of Journal of Meteorological Society of Japan, Vol. 77, No. 1B.
APPLICATION:	Used as the boundary condition for the GCM for seasonal prediction experiments.
RECOMMENDATION:	Qualified acceptance. The coverage is globally comprehensive, but all products are derived from SVAT models. The models are forced with realistic precipitation and radiation. There are significant differences among the models, leading to a degree of uncertainty. Soil moisture of the surface and the rooting layer, skin temperature, sensible heat flux, snow depth, run-off rate, net surface radiation are also available.

VARIABLE: PERMAFROST ACTIVE LAYER DEPTH

DATA SET:	Active layer depth
DATA ADDRESS:	http://www.geography.uc.edu/calm
AUTHOR:	37 observers from 15 countries
UNITS:	Depth in cm
SOURCE:	Circumpolar Active Layer Monitoring System (CALM); see web site

RESOLUTION:	Point measurement
COVERAGE:	Approximately 80 reporting sites mostly in Arctic and Subarctic
METADATA:	Adequate
VALIDATION:	Annually by observer
REVIEW (peer):	Funded NSF peer reviewed grant; various papers published on individual or groups of sites are peer reviewed. CALM web master and IPA coordinator review annual inputs.
USE in refereed papers:	Yes (bibliography being compiled)
APPLICATION:	Trace gas emission, climate index, soil nutrient availability, slope failures
RECOMMENDATION:	Full acceptance.

VARIABLE: PERMAFROST THERMAL STATE

DATA SET:	Borehole temperature
DATA ADDRESS:	Proposed host <http://sts.gsc.nrcan.gc.ca/permafrost/ >
AUTHOR:	35 observers from 14 countries
UNITS:	degree C
SOURCE:	Jerry Brown, International Permafrost Association, POB 7, Woods Hole, MA 02543
RESOLUTION:	Point measurement
COVERAGE:	Approximately 250 potential sites in the Arctic, Subarctic, Antarctic, and major mountain ranges and plateaus of both hemispheres.
METADATA:	Metadata form to be circulated in second half 1999.
VALIDATION:	By individual investigators.
REVIEW (peer):	Sites include peer reviewed funded proposal in the United States, Canada, and Europe (PACE); various papers published on individual or collective sites are peer reviewed.
USE in refereed papers:	Yes (current bibliography to be compiled based on metadata forms)

APPLICATION:	Decadal to secular climate changes, trace gas emission, slope failures
RECOMMENDATION:	Full acceptance.

Appendix X: IUGG Presentation

A REVIEW OF GLOBAL HYDROLOGIC DATA SETS IN RELATION TO THE GCOS/GTOS PLAN FOR TERRESTRIAL CLIMATE-RELATED OBSERVATIONS*

Jurate Landwehr (USGS, 431 National Center, Reston VA 20192, USA;
e-mail: **jmlandwe@usgs.gov**)
Josef Cihlar (Canada Centre for Remote Sensing, 588 Booth Street, Ottawa,Ontario,Canada K1A 0Y7; e-mail: **josef.cihlar@ccrs.nrcan.gc.ca**)

TOPC (Terrestrial Observation Panel for Climate) is a joint activity of the Global Climate Observing System (GCOS) and the Global Terrestrial Observing System(GTOS), both of which are initiatives of WMO, UNEP, and ICSU. IOC of UNESCO also sponsors GCOS, and UNESCO and the FAO, GTOS. The purpose of GCOS is to provide a forum for the development of a comprehensive long-term global observing system to improve our capability to detect, predict and assess climate change. GTOS was established to provide policy-makers, resource managers, and researchers data needed to detect, quantify, and give early warning of changes in the capacity of terrestrial ecosystems to support sustainable development and improvements in human welfare. TOPC has produced an analysis of data and actions needed to address these goals jointly. The GCOS/GTOS PLAN FOR TERRESTRIAL CLIMATE-RELATED OBSERVATIONS has been published and is available via the internet at **http://www.wmo.ch/web/gcos/pub/topv2_1.html** The TOPC plan not only identifies key hydrospheric, cryospheric and biospheric parameters but also compares their relative importance for their respective climate purposes and suggests methods and actions for obtaining this information. For example, for the hydrologic sector, the plan provides a detailed rationale for the following variables: atmospheric water content near the surface (relative humidity), biogeochemical transport from land to oceans, discharge (runoff), evapotranspiration, groundwater storage fluxes, precipitation, sediment load at large river mouths, snow cover area and snow water equivalent, soil moisture and surface water storage. TOPC is actively seeking to identify which data is available digitally to satisfy the above requirements. In this presentation, we will review which hydrologic data sources have been identified globally, and discuss the general availability and compatibility of this information, as well as gaps in the geographic or thematic coverage for the above variables.

*ABSTRACT submitted on behalf of TOPC to IAHS workshop on Global Hydrologic Databases during IUGG meetings in Birmingham, the United Kingdom, July 1999

Appendix X1: Summary of TOPC Recommendations

Pilot projects

Recommendation 4.1: It is recommended that mapping the spatial distribution of NEP be included as an explicit objective of the NPP project, and that the project be renamed accordingly ("NPP/NEP" is a possibility, used below).

Recommendation 4.2: It is recommended that all GTN-E sites interested in participating in the NPP/NEP project be included in the initial phase of testing the satellite-derived products (see also Section 11).

Recommendation 4.3: It is recommended that GOFC work with NPP/NEP to meet its Forest Biophysical Processes theme objectives and that it provide biomass burning emission estimates for that purpose.

Recommendation 4.4: It is recommended that GOFC broaden its Land Cover theme to include all terrestrial ecosystems, and that it establish close linkages with global land cover mapping activities under EOS Terra.

Recommendation 4.5: It is recommended that GOFC establish access and linkages to national forestry agencies on behalf of both NPP/NEP and GOFC projects.

Terrestrial carbon theme

Recommendation 5.1: TOPC recommends that GCOS/GTOS support the development of the TCI concept along the lines described Appendix V, including interactions with key agencies and interest groups as well as additional meetings as required.

GTOS non-climate observation requirements

Recommendation 6.1: It is recommended that GTOS consider the following steps to finalise the variables for GTOS non-climate requirements:

- examination of the variables and specifications from the perspective of models/intended uses of the variables;
- additional reviews of the freshwater and land quality variables by other experts;
- preparation of exact definitions for individual variables and terms where required; and
- preparation of a GTOS report containing a description of the process used, the definitions of the various terms and criteria used, and the final specifications.

Glacier network

Recommendation 7.1: Given the potential of GLIMS to provide a fundamental enhancement to the global capability for glacier monitoring, the following actions should be taken:

- GTOS and GCOS should continue supporting GLIMS as an important component of systematic global observations of glaciers
- GLIMS should be endorsed as a pilot project in the TOPC framework, with the goal of integrating GLIMS-developed capabilities into GTN-G

- TOPC/GCOS/GTOS should support GLIMS in securing resources needed to carry out its plans in the various glacier regions of the world. In particular, a letter should be prepared to highlight the importance (both short-term and long-term) of GLIMS for the funding process.
- GLIMS should strive to ensure that regional gaps are filled where possible and should use existing GTN-G contacts/sites for this purpose.

Recommendation 7.2: That the process initiated by COP-4 be used to increase the comprehensiveness of GTN-G coverage (refer to Section 7.1).

Recommendation 7.3: It is recommended that based on the results and experience from GLIMS, glacier monitoring be incorporated in the terrestrial theme of IGOS-P when the latter is being defined.

Permafrost network

Recommendation 7.4: TOPC recommends that GCOS/GTOS send out invitations to countries to participate in GTN-P, based on the plans developed by IPA.

Recommendation 7.5: TOPC recommends that the borehole sites be identified in GTN-P as part of the measurement of the thermal state parameter.

Recommendation 7.6: TOPC recommends that once initial sets of sites (active layer and boreholes) are identified they be entered into the GTN database (refer to Section 11).

Recommendation 7.7: TOPC encourages GTN-P to continue improving the network, the comprehensiveness of its geographic and temporal coverage (with priority emphasis on mountain and plateau regions of Eurasia and South America), and its long-term viability and functioning, along the lines of the action plan developed (refer to Appendix VII).

Recommendation 7.8: TOPC endorsed IPA and GTN-P initiatives in recovery of data in digital form, including soil temperature observations in Asia and historical permafrost borehole data.

Hydrology network

Recommendation 7.9: Water use should be added to the list of hydrologic variables to be obtained globally. The USGS model of reporting WATER USE both by political and hydrologic spatial units, for various economic/industrial sectors, on a five-year time step, could be used as an appropriate format.

Recommendation 7.10: GTOS should develop contacts with HELP coordinators to see how programmes could be developed in a coordinated manner.

Recommendation 7.11: GTOS should continue exploring ways of improved availability of snow depth and other observations, and should consider the feasibility of proposing “water theme” in IGOS-P framework.

Recommendation 7.12: TOPC recommends that the meeting on hydrological observations be prepared according to the outline in Section 7.3.6, and an organising committee should be established representing both ‘source’ and ‘use’ agencies.

Ecology network

Recommendation 7.12: TOPC recommends that GTN-E be expanded if possible to include all ILTER sites and that these be engaged in the demonstration projects to the maximum extent feasible.

Recommendation 7.13: TOPC recommends that GTN-E serve as the focal point for the involvement of the long-term ecological sites in the NPP/NEP and the GOFC projects.

Recommendation 7.14: TOPC recommends that NPP/NEP and GOFC projects further examine the adequacy of the existing flux networks for the two projects, and make appropriate recommendations for further action.

Reporting on national observation networks

Recommendation 8.1: TOPC recommends that the above approach be considered in obtaining national inputs on climate-related observing networks

Recommendation 8.2: TOPC recommends that the member GT-NET networks develop the required information on the present networks, with the support of GCOS and GTOS secretariats.

Land cover data sets

Recommendation 10.1: TOPC recommends that close links be established with groups involved in the preparation of global or significant regional data sets, to facilitate early access to such data sets and to highlight their availability for G3OS purposes.

Recommendation 10.2: TOPC recommends that GOFC take the lead in organising a workshop on land cover classification and mapping methodologies involving high resolution data sets over large areas.

TEMS development

Recommendation 11.1: Regarding the next steps in the development of TEMS, TOPC recommends that:

- All sites that are participating in GTOS be added to GT-Net database (including national networks in ILTER, Central & Eastern Europe Regional Network, GTN-P, GTN-G, Fluxnet, South & Eastern Africa Regional Network, and NoLimits)
- The sites participating in the NPP/NEP, GOFC, GLIMS and other demonstration projects as they develop, be flagged in the database
- In collaboration with WMO (Dr Donald Hinsman), GOSIC (Dr Ron Wilson) and GOSSP (Dr Francis Bretherton), the necessary steps be taken to link TEMS with the WMO database of observation requirements and capabilities, thus enabling comprehensive overviews and analyses of requirements vs. capabilities (space- and ground-based)
- A template of all GTOS variables be added (as they are confirmed), and variables for which sites have data be identified in the database
- A (initially central server-based) search capability be developed to sort by GTOS variable(s), network, etc.
- An interactive plotting capability be developed to map sites selected in a search. This will complement (or be an option to) the list of sites identified in any given search
- Additional resources be identified to facilitate the above changes.

TOPC data sets

Recommendation 12.1: The above data sets should be added to the GOSIC inventory of relevant data sets.

Appendix XII: List of Acronyms

AGU	American Geophysical Union
ARD	Afforestation, reforestation, deforestation
AVHRR	Advanced very high resolution radiometer
BNSC/NERC	British National Space Centre/National Environmental Research Council
CALM	Circumpolar Active Layer Monitoring
CCD	Convention to Combat Desertification
CEOS	Committee on Earth Observation Satellites
CERN	Chinese Ecological Research Network
CLIC	Climate and the cryosphere
COP	Conference Of Parties
CSA	Canadian Space Agency
DIS	Data ad Information Systems
ENSO	El Nino - Southern Oscillation
EO	Earth observation
EOS	Earth observing system
FAO	Food and Agriculture Organisation of the United Nations
FPAR	Fraction of photosynthetically active radiation
FRIENDS	Flow Regimes from International Experimental and Network Data
G3OS	Global Observing Systems
GAW	Global Atmospheric Watch
GCM	General circulation model
GCOS	Global Climate Observing System
GCTE	Global Change and Terrestrial Ecosystems
GEF	Global Environment Facility
GEWEX	Global Energy and Water Cycle Experiment
GGD	Global Geocryological Data
GHOST	Global Hierarchical Observing Strategy
GIS	Geographic information system
GLCF	Global Land Cover Facility
GLIMS	Global Land Ice Measurements from Space
GODAE	Global Ocean Data Assimilation Experiment
GOFC	Global Observation of Forest Cover
GOOS	Global Ocean Observing System
GOSIC	Global Observing Systems Information Center
GOSSP	Global Observing Systems Space Panel
GPCC	Global Precipitation Climatology Centre
GRDC	Global Runoff Data Centre
GSC	Geological Survey of Canada
GTN-E	Global Terrestrial Network for Ecology
GT-Net	Global Terrestrial Network
GTN-G	Global Terrestrial Network for Glaciers
GTN-P	Global Terrestrial Network for Permafrost
GTOS	Global Terrestrial Observing System
GTSC	GTOS Steering Committee
HELP	Hydrology for Environment, Life and Policy
IAHS	International Association of Hydrological Sciences
IASPEI	International Association of Seismology and Physics of the Earth's Interior
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
IGOS-P	Integrated Global Observing Strategy Partnership
IHDP	International Human Dimensions Programme
IHFC	International Heat Flow Commission

IHP	International Hydrological Programme
ILTER	International Long Term Ecological Research
IOC	Intergovernmental Oceanographic Commission
IPA	International Permafrost Association
IPCC	Intergovernmental Panel for Climate Change
IUGG	International Union for Geoscience & Geophysics
J-DIMP	Joint Data and Implementation Panel
LAI	Leaf area index
LTER	Long Term Ecological Research
MOPEX	Model Parameter Estimation Experiment
MOU	Memorandum of Understanding
NASA	National Aeronautics & Space Administration
NBP	Net biome productivity
NEP	Net ecosystem productivity
NOAA	National Oceanic & Atmospheric Administration
NPOESS	NOAA Polar-Orbiting Operational Environmental Satellite System
NPP	Net primary productivity
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
PACE	Permafrost and Climate Change in Europe
PAR	Photosynthetically active radiation
SBSTA	Subsidiary Body on Scientific and Technical Advice
SDRN	Environment & Natural Resources Service
SIT	Strategic Implementation Team
TBD	To be determined
TCO	Terrestrial Carbon Observation Initiative
TEMS	Terrestrial Ecological Monitoring Sites
TOPC	Terrestrial; Observation Panel for Climate
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific & Cultural Organisation
UNFCCC	United Nations Framework Convention for Climate Change
UNFIP	United Nations Fund for International Partnerships
WAICENT	World Agriculture Information Centre
WCRP	World Climate Research Programme
WDC	World Data Center
WGCV	Working Group on Calibration and Validation
WGISS	Working Group on Integrated Systems and Services
WGMS	World Glacier Monitoring Service
WHO	World Health Organisation
WHO-ECEH	European Centre for Environment & Health
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organisation
WWW	World Weather Watch