Global Terrestrial Observing System

Report of the GCOS/GTOS

Terrestrial Observation Panel for Climate

Third Session

Cape Town (Franschhoek), South Africa
19-22 March, 1996

June 1996

GCOS-23
GTOS-1

(WMO/TD No. 754)
(UNEP/DEIA/MR.96-6)

Contents

I. Welcome and Opening of the Meeting

Dr Robert Scholes opened the Global Climate Observing System (GCOS)/Global Terrestrial Observing System (GTOS) Terrestrial Observation Panel for Climate (TOPC) meeting on 19 March 1996 at the Franschhoek Mountain Manor, Franschhoek, South Africa. He welcomed the participants (Annex 1). The meeting was chaired by Dr Josef Cihlar.

II. Statement of the Chairman and Objectives of the Meeting

The Chairman, Dr Josef Cihlar, also welcomed the participants and in particular welcomed three new members of the Panel, Ing. G. Enrique Ortega Gil from Mexico, Mr Ken-ichi Kuma from Japan, and Dr Rik Leemans from the Netherlands. He thanked Dr Robert Scholes and Ms Dawn Middleton for making the local arrangements for the meeting. He reminded people that this was a Panel sponsored by GCOS and GTOS and referred to the provisional Terms of Reference for the Panel (Annex 3). The purpose of this meeting was to develop the initial stages of a TOPC Implementation Plan for Climate. The Chairman reviewed the provisional agenda (Annex 2). He explained that he hoped the agenda would be flexible depending on the nature of the discussions. The agenda was approved.

III. Update on GTOS and GCOS

Prof. John Townshend and Dr Robert Scholes, members of the Scientific and Technical Planning Group for GTOS, were in attendance at the meeting. Prof. John Townshend reported on the GTOS sponsors meeting held in January in Rome. The sponsors accepted in principle the GTOS Planning Group Report and decided to proceed with GTOS. The report is available from the Executive Secretary, ad interim, Mr Jelle U. Hielkema (Jelle.Hielkema@FAO.Org). The Food and Agricultural Organization of the United Nations (FAO) offered to house the Secretariat of GTOS with Dr Stein Bie having overall responsibility for the Secretariat.

Prof. Townshend also reported on the progress of GCOS since the last TOP meeting. Version 1.0 of all GCOS Plans have been completed. They utilize a strategy which is to define an Initial Operational System (IOS) based on existing observational programmes. The concept of the IOS acknowledges and encourages the continuation of those existing activities which significantly contribute to GCOS at the present time, and identifies those which, with modest enhancements, could make substantial additional contributions. With the initiation of the GCOS Upper Air Network, the implementation of GCOS has begun. The purpose of the network is to ensure a relatively homogeneous distribution of upper air stations to meet requirements of GCOS. The final list of sites was selected from the World Weather Watch (WWW) Global Observing System (GOS) on the basis of performance records, global distribution and quality of information coming from the stations. With the cooperation of the World Meteorological Organizations (WMO) Commission for Basic Systems (CBS), members have agreed to support the network.

Working with the WWW and the WMO Commission for Climatology (CCl), plans for the GCOS surface network of approximately 800 sites are underway. A joint CCl/CBS expert meeting on the GCOS permanent Land-based Surface Network, to be held in Norwich (U.K.) from 25 to 27 March 1996, will consider the designation of the proposed network and will make proposals for consideration by the CBS Working Group on Observations and subsequently for adoption by WMO Members. It is expected that this network will be in place by the end of 1996.

The fifth meeting of the GCOS Joint Scientific and Technical Committee (JSTC) recognized the increasing relevance of climate/land interactions and in particular acknowledged the need for the TOPC. The JSTC was pleased with the first version of the TOPC Plan, and recommended that it be published with some editorial changes.

The JSTC also suggested the following items for consideration by the TOPC for 1996. These include:

- The JSTC noted some apparent differences between the soil moisture requirements of the Atmospheric Observation Panel (AOP) and the TOPC and asked each Panel to review their requirements;

- To further develop hydrology needs and work more closely with the Global Energy and Water Cycle Experiment (GEWEX);

- Continue to extend the geographic coverage of biospheric sites, particularly for some developing countries;

- Determine the requirements for sites that are to be included within the GCOS network;

- Develop a sampling scheme for the hydrosphere and the cryosphere;

- Re-evaluate the need for tier IV;

- Develop a closer working relationship with the Global Runoff Data Centre (GRDC) and the Global Precipitation Climate Centre (GPCC); and

- Develop a brochure to explain the TOPC and to assist in obtaining support from organizations that can supply data from tiers II to IV.

Prof. Townshend stated there were a number of challenges facing the TOPC. These include:

- Prioritization and detailed specification of variables will be increasingly in demand;

- Few implementation structures for land exist and consequently the TOPC will have a major role in not only defining the implementation requirements, but also in assisting in the implementation of a network of land-based sites; and

- The TOPC must provide its requirements to the Space-based Observation Panel and the Data and Information Management Panel.

IV. Plenary Session

Introduction

Following lengthy discussions on the following topics, it was decided that the GCOS/GTOS Plan for Terrestrial Climate-related Observations (GCOS-21) should be revised to reflect the discussions. Each discussion was led by a different Panel member who provided the Panel with a working paper on the subject. Following the discussions, small working groups prepared a report summarizing the presentations and discussions. The following are those reports.

Tier Sampling Scheme

The GCOS JSTC requested that the TOPC carefully review the tier concept and in particular re-evaluate the need for tier IV. Dr Robert Scholes prepared an evaluation of the system and led the discussion. At this meeting, the tier system was still based primarily on ecosystem characteristics. Subsequent meetings of working groups on hydrosphere and cryosphere are expected to further clarify issues. The following is a summary of that Panel's discussion.

Rationale for the hierarchical system

The detailed description and rationale for the hierarchical system is given in GCOS-21 and the GTOS Planning Group Report. Briefly, it is not efficient to measure all variables at the same time interval, spatial scale or with the same accuracy. Since these three factors tend to be correlated, as a result of the characteristic space-time domains of key processes, an efficient sampling system naturally forms a hierarchy, with some variables measured continuously and intensively, but at a few locations, while others are measured simply, but at a large number of locations. When this continuum is matched against the types of observing systems which exist, the latter can be classified into five broad levels, identified as tiers. Some of the characteristic features of each tier are given in Table 1.

TIER	CHARACTERISTICS
I	Large-scale experiments, very intensive measurement of a large number of variables over a region of several hundred square kilometres or a transect of several thousand kilometre length, over a limited period of time. GCOS/GTOS does not fund or create these, it simply ensures that the data and understanding from them are captured for future use. Examples are the IGBP Megatransects, GEWEX large catchment studies, etc.
II	Research centres with a large staff (>10 participating scientists), sophisticated and expensive infrastructure (the necessary infrastructure varies with the research focus, but examples include laboratories, data loggers for continuous measurement, flux towers and gauging weirs). They tend to focus on one crop type in the case of agricultural centres (e.g., International Center for Tropical Agriculture (CIAT), International Rice Research Institute (IRRI) or one biome type (e.g., the US-LTERs). GCOS/GTOS relies on these sites to develop process-level understanding and to make continuous measurements of fluxes. There are thought to be about 100 globally. In principle, there should be one per major crop type, biome type and aquatic system type and cryospheric type.
III	Research stations with at least one permanent observer on site. Many hydrological observation sites fall into this category, as do ecological field stations and many agricultural research stations. The observations do not require very expensive, sophisticated or continuous measurements, but the annual cycle is important. A sufficient number of such stations are needed to cover the range of variability within each major ecosystem, crop system, aquatic system and ice system. This is thought to require about 500 - 1000 sites globally, the overwhelming majority of which already exist. GCOS/GTOS should assure that methods are compatible and data are stored in an-easy-to access system.
IV	Sites which are regularly but infrequently (once every 5-10 years) revisited. The purpose is to provide a statistically valid sample of variables which cannot be accurately obtained by remote sensing. GCOS/GTOS will need to assist countries in the development of a sampling scheme; assure that methods are compatible and data are stored in an easy-to-access system.
V	Remote sensing, which is usually quasi-continuous in both time and space, but limited in its capacity for direct observation of the variables of interest. GCOS/GTOS will need to assure that data are stored in an easy-to-access system.

Table 1. Characteristic Features of Each Tier.

Implementation

The tier structure is a classification system to aid implementation, not a rigid formula for implementation. All the tiers are necessary, but not all the variables are represented at all tiers. For example, the hydrosphere has few variables at tier IV, because the characteristic time scale of hydrological processes tends to be too fast to benefit from infrequent sampling. The key tiers for early implementation are II, III and V, because they are served by existing structures.

The tier IV issue

Tier IV was designed to consist of in the order of 10 000 land surface points, which would be visited regularly, but infrequently for the collection of surface parameter data. It was intended to bridge the gap between satellite observations, which are quasi-continuous in space and time (tier V), and the 500 or permanently-staffed but non-optimally distributed ground stations (tier III). The main problem with tier IV is that it is new, and cannot be assembled from pre-existing systems. This makes it apparently expensive and technically untested. The question addressed by the Panel at this meeting was: can tier IV be dispensed with, greatly reduced, or phased in without undermining the validity of the entire plan?

The unique role of tier IV

Tier IV has the unique function of providing accurate and spatially-resolved data on variables which at present cannot be remotely-sensed. An example is the soil carbon content, which is important because it is the largest biospheric carbon pool, is subject to change, and influences other factors such as the water-holding capacity. It cannot be observed from space. Tier IV serves two primary purposes, only the second of which is strictly speaking a monitoring function, but both of which are necessary for an operational system:

a) One-time measurements, for purposes assessing the state of the system and model parameterization; and

b) Repeated measurements, for purposes of change detection.

Tier IV can also act as the calibration and validation points for indirect remotely-sensed variables. Tier III can also provide these data, but may have insufficient sites to calibrate or validate all the ecosystem classes. It is important to separate the unique roles from the additional roles, because they have different sampling requirements.

Sampling pattern

One issue regarding tier IV is whether the location of sites should be systematic (e.g., gridded), stratified random, or targets of opportunity. Each scheme has implications in terms of cost, political feasibility and statistical analysis. Table 2 provides an analysis of the financial, political and statistical sensitivities of the issue.

	Systematic	Stratified random	Targets of opportunity
Financial	Expensive, because some sites will be hard to access.	Less expensive because more efficient and resampling can eliminate most expensive sites.	Marginal cost only.
Political	Issues of national sovereignty.	Resampling can eliminate sensitive sites.	No problem, but large parts of the world may be under-sampled.
Statistical	Simple and easy to interpret, unbiased now and in the future.	Statistically efficient if an information-rich stratifier is available. Can be unbiased but sensitive to changes in the stratification.	Biased and difficult to extrapolate.

Table 2. Implications of Different Sampling Patterns.

Tier IV need not have a single sample scheme for all variables and all places. For instance, where the purpose of the observation is calibration and validation of a remotely-sensed variable, the target-of-opportunity approach is acceptable. For statistical change detection of a variable not indirectly measurable, the scheme must be stratified or systematic. A systematic scheme in one country remains compatible with a stratified scheme in another, if they are designed to the same accuracy specifications.

What cannot be done without tier IV?

The following variables are unlikely to be available with useful accuracy and resolution in the foreseeable future without tier IV:

Necromass
Soil carbon
Soil total nitrogen
Soil phosphorus
Soil texture
Rooting depth
Ground water storage fluxes.

The accuracy of the following variables, which are indirectly measurable or potentially so, will be seriously compromised by an absence of tier IV:

Biomass - above ground
Biomass - below ground
Roughness - surface
Vegetation structure
Land use
Soil bulk density
Soil surface state
Precipitation
Ice sheet mass balance
Permafrost - active layer
Permafrost - thermal state.

GTOS also has several non-climatic requirements from tier IV. These include:

a) Land use inputs
b) Disturbance regime
c) Soil chemistry (pH, nitrate, phosphate, bases, acidity, CEC).

Options for implementation of tier IV

While there are costs associated with analyzing and storing any collected data, reducing the number of variables in tier IV is not a useful strategy, since the costs involved in sampling have largely to do with accessing the sites, not the time spent at an individual site. There may even be a case for increasing the at-site data collection in order to be able to share the sampling effort with a wider range of clients. For example, could GTOS geo-referenced socio-economic data be collected this way? The main cost-reducing options are:

d) Fewer points;

e) Use targets of opportunity; and

f) Phase the implementation gradually.

i) Fewer points

There are two issues: accuracy and spatial resolution. The debate on tier IV thus far has focused on the number of sites needed to validate a land cover product with a given number of classes, to a given level of precision and confidence for each class. This is a relatively trivial exercise in binomial probability. For instance, to validate the 17-class IGBP land cover scheme to within + 15% accuracy with 95% confidence would require 425 points. The accuracy requirements and number of classes for TOP purposes are likely to be more stringent. A + 5% accuracy would need approximately 4 000 points, and a + 0.5% accuracy would need about 22 500 points.

Most of the variables which depend on tier IV are continuous values, not categories. The determination of an adequate sample size for these is more complicated, since it requires a knowledge of their statistical distribution, which is largely lacking, and varies from variable to variable. For a completely unbiased and efficient sampling scheme (stratified random, for instance), and a normally-distributed variable with a coefficient of variation of 30%, an accuracy of + 10% with 95% confidence would need 36 samples, + 5 % would need 144 samples and + 0.5 % would need 14 400 samples. In practice, most of the variables in question are log normally distributed, and then only once they have been stratified, so the sample number needs to be multiplied by the number of strata if each is to meet the accuracy criteria, or by some area- or value-weighted number for a given global accuracy.

If only a global estimate is needed, the sample number is greatly reduced; perhaps by 75%. If regionalized estimates are needed, the requirement goes up in rough proportion to the number of regions.

Without doing a rigorous analysis, it seems that the original estimate of the order of 5 000 – 10 000 sites for tier IV is still valid. However, where the tier IV sites are simply required to calibrate or validate a remote-sensing algorithm, the required sample numbers are much smaller, and the sample location requirements are much less rigorous. Typically greater than 30 samples each are required for calibration and validation of a continuous, linear model if the errors are normally distributed, the model is reasonably predictive (accounting for >75% of the variance), and the sample points cover the full range of variation.

If the number of points needed can be reduced to 500 - 1 000, then tier IV can be substituted by tier III, but all the problems associated with a biased sample scheme remain.

ii) Targets of opportunity

By piggy-backing on other activities, the costs of sampling can in theory be reduced to the marginal costs of the additional effort needed to collect the TOP data. An example is the Soil and Terrain Data (SOTER) project to improve global soil data. If the vegetation component were slightly enhanced, and geo-location specifications were tightened to + 10 m, many TOPC requirements would be met.

There are two main drawbacks with using targets of opportunity: the sample locations are likely to be biased, biasing the values in an unknown way; and the chances of being able to revisit the point at the same low cost are small. This approach could be useful for calibration and validation of indirect algorithms and for one-time parameterizations, but is not suitable for change detection except in the sense of archiving a current state, which future generations may find useful. At a minimum, the TOPC data system should make provision for the recording of tier IV-type data from activities outside of GCOS/GTOS, and should actively pursue their acquisition from the original collectors.

iii) Phased implementation

All of the tier IV variables have relatively slow rates of change, which allows them to be infrequently collected. Thus, only 10-20% of the target sample needs to be collected in a given year. By concentrating the data collection in a given year regionally, logistic costs can be reduced. If it is assumed that on average one point can be collected per day by two observers, one of which is provided by the host country, a single GCOS/GTOS employee could collect about 200 points per year; five employees regionally deployed could cover the world at the desired density.

Alternatively, or additionally, each tier III station could be tasked with collecting one or two tier IV data points per year, in an a priori determined location.

Recommendations

If tier IV is not implemented, key variables which are directly or indirectly involved in the global climate system cannot be accurately collected. Most of these variables relate to below-ground processes with a high spatial variability and no obvious way of collecting via remote sensing. The sampling intensity cannot be greatly reduced without making the tier irrelevant. The real cost of tier IV is probably not as high as is thought, given the cost of activities which currently fill this role (such as satellite observations and their ground validation). The benefits of enriching the land surface data go beyond the needs of TOPC, or of GCOS and GTOS, into issues such as natural resource management at a regional or local scale. Tier IV can deliver national-level information and involvement. A specific action plan should:

1. Publish a brochure explaining and publicizing the Global Hierarchical Observation System for Terrestrial Ecosystems (GHOSTE);

2. Publish and distribute a methods handbook for tier IV data and actively encourage the placement of target-of-opportunity tier IV data in public domain databases; and

3. Phase in the implementation of tier IV by making it a tier III responsibility. Appoint one or two dedicated tier IV observers, who will simultaneously do in-field training of tier III personnel and collect tier IV data.

<u>Guidelines for Participation of Sites</u>

Prof. Shidong Zhao led a discussion of the requirements for participation of sites in the GCOS/GTOS network. He first presented the Chinese system and their requirements and made several suggestions for GCOS/GTOS. The following is a summary of the discussion.

Issues

All GCOS/GTOS sites have to satisfy the conditions of representativeness and sufficiency. Tier I sites are large experimental areas and do not fall within the scope of a long-term monitoring project. The responsibility for these sites rests solely with research programmes such as the International Geosphere-Biosphere Programme (IGBP), Global Energy and Water Cycle Experiment (GEWEX), etc. The responsibilities of GCOS and GTOS should be to assure that the data are available and that there are links to the data. Further lessons learned at these sites should be incorporated into monitoring programmes, where appropriate.

Tier II sites should be located near the centre of the range of environmental conditions (though not necessarily near the centre of the geographical range) of the system which they are representing. There are never likely to be so many tier II sites that choosing between them is likely to be a major problem.

Tier III sites are intended to sample the range of variation present in the system which they represent. This means that some of them will be close to the average of the various environmental factors which make up the environmental range of the system, while others will be closer to the extremes, and perhaps even at the ecotone of transition to a different system. There are very many potential tier III sites, but they are not optimally distributed. As a result, some ecosystem types may have more potential tier III sites than are needed for GCOS/GTOS purposes, particularly if a rough global balance is to be preserved. Other ecosystem types may have too few sites, or none at all, and thus GCOS/GTOS will need to work with funding organizations to enhance the network.

GCOS/GTOS must simultaneously have a top-down and bottom-up approach to site selection. The bottom-up approach is implemented by publicizing the existence and benefits of GCOS/GTOS, and inviting sites (and pre-existing networks of sites) to apply for membership. The GTOS Secretariat, acting on selection criteria defined by the Panel, would then screen the applicants for suitability. The criteria are spelled out in the GTOS Planning Group Report. Briefly, they are:

Each participating country should have at least one per biome;

They should be capable of collecting the appropriate data;

Sites in under-represented systems have priority over already-represented systems; and

Reasonable permanence is required.

All else being equal:

g) Sites where research is also carried out are preferred;

h) Long-established sites are preferred;

i) Existing sites are preferred over sites which need to be established;

j) National support for the site is preferred to sites dependent on external funding; and

k) Accessible, practical sites are preferred.

The bottom-up approach would not fill gaps where no or insufficient sites exist, or where the sites are not aware of the existence of GCOS/GTOS. A top-down approach, is needed to fill gaps in ecosystem types where no sites have applied for membership. This will first require a search of the Terrestrial Ecosystem Monitoring Sites (TEMS) (http://www.wsl.ch/services/services.html) database to determine site location. The GTOS Secretariat will then need to contact these sites asking if they would be willing to participate. If there are insufficient candidates in the database to sample some ecosystems adequately, then an active process needs to be followed to upgrade or establish sites in that type. ‘Adequacy’ is obviously relative - an initial target should be 10-30 tier III sites per system type. ‘System types’ are initially defined as:

l) The 11 IGBP natural land cover types for terrestrial systems (evergreen needleleaf forests, evergreen broadleafed forests, deciduous needleleaf forests, deciduous broadleafed forests, mixed trees and shrubs, closed shrublands, open shrublands, woody savannahs, savannahs, grasslands and permanent wetlands);

m) The most important foods, fibre crops and agricultural systems (rice, wheat, maize, potato, sorghum and millet, cassava, sugar cane, extensively-grazed livestock, vegetables, tropical fruits, temperate fruits, and cotton);

n) The aquatic systems are rivers, lakes and estuaries; and

o) The cryospheric systems are permafrost, ice sheets, ice caps and glaciers.

The site location of tier IV sites are based on an unbiased statistical representativeness. It is impractical to force a single statistical design on all countries. Hence, individual participating nations would be responsible for locating the sites, and may choose either a systematic or stratified-random approach (or both, for different variables or different systems). This requires an a priori location specification, but permits rejection of the site and resampling out of the same population if:

p) The site is inaccessible; and

q) Sampling at the site would compromize national interests.

Management

The general management structure outlined in the GTOS Planning Group Report is appropriate, but in its initial implementation it should focus on establishing an effective GTOS Secretariat and strong links to national implementing agencies and networks. The steps in an initial operating strategy for managing the system are:

1. Hold an international meeting of site and network managers. Its purpose would be to establish and ratify the rules and methods of data collection, data sharing and quality control;

2. Charge the GTOS Secretariat, in conjunction with discipline and system experts, to develop a “methods’ manual”, reporting procedures and a training programme. Training exercises should be in-field (not central), and should double as data-collection exercises; and

3. At the same time, the communication and distributed database functions of GCOS/GTOS need to be established so that they are ready to handle data flows.

Standardization and quality control

For each variable, standardization should be primarily achieved by specifying the necessary accuracy, frequency, and spatial footprint. Standard methods can be encouraged by publishing manuals and providing training, but are not obligatory. Full descriptions of the methods used at the site should be provided by the site to the

GTOS Secretariat at the time that a site joins the network, and updated when necessary. Variables where there is a significant bias due to the method used should be subject to expert review and cross-calibration exercises.

The first and most important line of quality control is the point of data collection. Data items not accompanied by time, exact location (+ 100 m) and method should be rejected. On entering a GCOS/GTOS data system, data should be passed through a "smart" filter to detect gross errors and inconsistencies, and then be checked for reasonableness by a discipline expert.

Data management

The general principles of data management outlined in the GCOS and the GTOS Planning Group Report and their accompanying documents must provide the guide.

Briefly:

All data entered into the system are public domain information. Data providers should exercise their prior publication rights within a reasonable time (two years) before entering the data into the system;

Data users should be charged costs of filling the user request only;

The GCOS/GTOS data system will be distributed. The GTOS Secretariat should be responsible for maintaining meta data, pointers to other data sets, and data sets which have no other home; and

Special efforts must be made to accommodate the data access needs of countries which are not well-connected to the electronic network. The strategies should include: establishment of regional mirror sites with regional data sets; the placement of key data sets on CD-ROM; use of email, fax and postal services for the input and export of small quantities of data where necessary and feasible.

Recommendations

1. Begin a dialogue with existing site networks (either international or national) to produce a draft of workable data exchange rules and procedures and to refine the potential site database;

2. Make the TEMS database more comprehensive by asking regional and national experts to check and populate it;

3. Conduct an initial tier III selection according to the procedures described above;

4. Identify under-sampled regions and ecosystem types; and

5. Invite site and network managers of the identified sites, plus representatives of organizations which could establish or upgrade sites in under-sampled regions, to a conference to agree on their participation in a network.

Cryosphere Needs - the Next Steps

Dr Haeberli provided a review of the cryosphere section of GCOS-21. The following is a summary of the recommended updates to GCOS-21.

Issues

There is now high confidence that many components of the cryosphere react sensitively to changes in atmospheric temperature because of their thermal proximity to melting conditions. The varying extent of glaciers has often been used as an indicator of past global temperatures. In fact, obvious thinning, mass loss and retreat of mountain glaciers have taken place during the 20th century. The areal extent of the Northern Hemisphere continental snow cover has decreased since 1987 even though there is much variability from year to year, and no definitive long-term trends can be defined. Climate projections into the coming century indicate that there could be pronounced reductions in seasonal snow, permafrost and glaciers with a corresponding shift in landscape processes. Such reductions would have significant impacts on related ecosystems and socio-economic factors. The thickness of the active layer of permafrost could increase and extensive areas of discontinuous permafrost could disappear in both continental and mountain areas. More water would be released from regions with extensive glaciers, and both engineering and agricultural practices would need to adjust to changes in snow, ice and permafrost distributions.

Priorities

Priorities with respect to initial implementation of monitoring cryosphere variables are based on: 1) climate relevance, 2) feasibility of measurement, and 3) the existence of suitable sites and programmes. The variables listed below are described in GCOS-21.

Sea ice
Sea ice concentration
Sea ice motion

The variable sea ice concentration includes sea ice extent. Operational elements exist (SSMI data stream, Arctic buoy network) for initial implementation for both of these variables. Priority for initial implementation is mainly related to climate feed-back (albedo) and practical implications (shipping).

Snow
Snow cover area and snow water equivalent.

Operational structures exist (weekly product from AVHRR) for initial implementation. Priority for initial implementation is mainly related to climate feed-back, to intense interactions with all other systems (glacier mass balance, permafrost thermal state, surface water, soil humidity, etc.) and to practical implications (hydrology, tourism, etc.).

Ice sheets
Ice sheet geometry
Ice sheet surface balance

Ice sheet geometry (elevation, margins) combines the former variables (GCOS-21) ice sheet extent/topography and ice sheet mass balance, whereas ice sheet surface balance includes firm density profiles as mentioned in the GCOS Plan for Space-based Observations (GCOS-15). Ongoing activities include studies of possible errors in altimeter measurements to monitor mass balance, at least in those areas where the slope is not so steep that the altimeter loses focus. It will be important to measure ice sheet velocity at points distributed over the whole of a satellite image to ensure the most accurate calibration.

Glaciers and ice caps

This variable includes information on mass/volume, length and area. Glacier fluctuation is one of 27 internationally selected geo-indicators of rapid environmental change. Glacier shrinkage at decadal to century time scales is a worldwide phenomenon, influences the water cycle and natural hazards in cold mountain areas, reflects an additional energy flux roughly comparable to the estimated radiative forcing, and, hence, constitutes a key indicator of ongoing climate change. Measurements should continue on glacier mass balance as a direct climate change signal, glacier length change as a delayed but also enhanced and more easily determined climate signal; and glacier spatial distribution patterns (glacier inventories) for assessing regional effects. Priority relates to the exceptionally clear and easily understood climate signal presented by glacier changes, to the practical impacts at local, regional and global scales. Problems mainly relate to reaching global coverage and to monitoring large glaciers especially with respect to sea level change.

Lake and river freeze-up and break-up (timing)

There are no recommended changes to GCOS-21 or updates regarding this variable. Priority for initial implementation is based on the characteristics of the variable as an integrated long-term signal that is easy to measure.

Permafrost
Permafrost active layer
Permafrost thermal state

Frozen ground activity and sub-surface temperature regimes are two out of 27 internationally selected geo-indicators of rapid environmental change. Efforts of the International Permafrost Association with respect to long-term monitoring concentrate on the rescue of borehole temperature data, on Circumpolar Active Layer Monitoring and on mountain permafrost monitoring. Standard International Tundra Experiment (ITEX) procedures recommend landscape-level observations at or near the end of the thaw season on a standard-size grid. Seven sites are presently being observed in the US Arctic, 7 in the Russian Arctic, 1 in Canada, 1 in Sweden and 1 in Norway. Inter-annual comparisons of thaw from within a site and among different sites within a region show significant season-to-season variations. As more sites from different programmes are added to the CALM network and longer-term records are accumulated, the significance of climate fluctuations on regional patterns of thaw and on plant and soil relationships and processes should be better understood.

Argentina, Canada, Norway, France, Germany, Switzerland, Austria, Italy, Kazakstan

(Central Asia) and China are participating in an effort to monitor mountain permafrost. Data input to the Global Geocryological Database (GGD of IPA) is planned for 1997/98. Permafrost temperatures at about 15 m depth in the few presently existing boreholes appear to have increased in the European Alps, the Kazak Tien Shan, the Kirghize Tien Shan and in the Qinghai-Tibet area.

Priority for initial implementation is based on the importance of the feed-backs involved with changes in active layer depth (CH4 emission, soil moisture, growth conditions), practical applications (stability of foundations for roads, pipelines, buildings, etc.) and the existence of monitoring structures (CALM).

Sampling strategy

A sampling strategy for the cryosphere still has to be developed. Sea ice concentration and snow cover area would fit into tier V of the presently existing system; ice sheet surface balance, glaciers and ice caps (extent), permafrost active layer and permafrost thermal state at depths greater than about 15 m into tier IV; and permafrost thermal state at depths shallower than about 15 m, snow water equivalent and extensive glacier mass balance measurements into tier III. Uncertainties continue to exist, for example, with measurements of elevation of ice sheets and large glaciers or with the mapping of ice sheet margins. The corresponding questions could best be treated by a short meeting which could take place in connection with the Symposium of the International Glaciological Society on the Representation of the Cryosphere in Climate and Hydrological Models, Victoria, B.C., Canada, 12-15 August 1996. This meeting could profit from the results of a joint International Arctic Science Committee (IASC)/Scientific Committee on Antarctic Research (SCAR)/World Climate Research Programme (WCRP)/International Commission on Snow and Ice (ICSI) Workshop on Ice Sheets, Glaciers and Related Sea Level Change, Fjaerland, Norway, 21-22 June 1996. Cooperation between ICSI(IAHS) and IPA for developing a coordinated sampling strategy and for guiding the implementation of the present cryosphere observation plan could probably be established during such a meeting.

Recommendations

1. Continuation of existing monitoring programmes for snow, sea ice, glaciers and permafrost active layer;
2. Further development of monitoring programmes for ice sheets, permafrost thermal state and lake/river ice;
3. Coordination of an integrated cryosphere monitoring programme under the guidance of the International Commission on Snow and Ice (ICSI/IAHS) and the International Permafrost Association (IPA);
4. Assess the utility of the tier sampling concept for the cryosphere and develop an overall sampling strategy; and
5. Modify GCOS-21 to reflect the above discussions.

<u>Precipitation</u>

Issue

The JSTC of GCOS asked the TOPC to better clarify why there is a need for many kinds of time series of precipitation for terrestrial purposes, in contrast to relatively few that are needed to address atmospheric purposes. Also, the TOPC was asked to comment specifically on whether the precipitation data product proposed by the Global Precipitation Climatology Project, consisting of a data set of aggregated precipitation on a 1 d x 1 d spatial grid and at a 3-hour temporal resolution would meet the needs of the various terrestrial process communities. Dr Jurate Landwehr prepared the initial working paper and led the discussion.

Discussion

It is difficult to generically characterize what precipitation data are needed for hydrologic modelling/analysis regarding climate. The hydrologic cycle operates at many scales and levels of temporal and spatial resolution. Requirements for precipitation information are specific to the problem one is addressing. Macro-scale questions, such as delineation of continental or large regional water balances, may indeed find the proposed 2.5 d by 2.5 d product to be sufficient. But if one moves to a meso- or micro-scale, for example, to do catchment or watershed modelling, one needs to characterize the small scale variation of precipitation over the watershed. This calls for time series with higher temporal and spatial resolution which can only be obtained with in situ measurements aligned with watershed or catchment boundaries.

Furthermore, in situ measurements are necessary to provide a check on any satellite-derived precipitation product, as well as forming the basis for aggregated regional climate products such as the National Oceanic and Atmospheric Administration (NOAA)/National Climatic Data Center (NCDC)'s Historical Climatology Network (HCN) for temperature and precipitation data aggregated on the basis of the USA's climatological divisions.

Dr Landwehr proposed a three-level structure (macro-, meso-, and micro-scales) for the exchange of global precipitation observations for the purposes of hydrological modelling directed to questions of climate variation:

For macro-level analyses, the future 1 d by 1 d GPCP product might be sufficient initially, although the 0.5 d x 0.5 d resolution being called for by SVAT modellers would be more flexible in fitting to hydrological drainages and route modelling; and

For meso- and micro-scale analysis, develop initially a set of as many long-term stations as available that are of good (measurement) quality and preferably hourly resolution (although daily and even monthly might be accepted).

The spatial resolution requirements are difficult to generalize and need to be set depending on the terrain -- they could range from 1 per sq. km in a mountainous areas with small watersheds to 1 per 104 sq. km in terrain with low or no orographic features and homogeneous soil and drainage characteristics that allow aggregation to larger watersheds. The stations should be organized or identified with respect to watersheds or water-divides, and a single major climate zone.

Recommendations

GCOS/GTOS/TOPC would have to provide some minimal criteria for what constitutes a "good quality precipitation station";

2. For all other purposes, maintain a meta data with pointers:

(i) to in-situ data centres that are holders of information that would be made available at the cost of filling the user request only; or

(ii) to specialized data sets already developed for climatic purposes, such as the HCN developed at NOAA/NCDC; and

3. The TOPC should further study the need for a .5 by .5 degree precipitation product, and if necessary and feasible, urge the GPCC to produce such a product rather than the 1 degree by 1 degree product that is planned.

Soil Moisture

The JSTC asked the TOPC to review the need for soil moisture data and whether or not it felt any soil moisture measurement was feasible to be observed from space. Dr Josef Cihlar and Mr Ken-ichi Kuma both prepared background documents. Mr Kuma led the discussion on the review of the need for soil moisture data, and Dr Cihlar led the discussion on the feasibility of observing soil moisture from satellites.

Issues

For climate prediction by fully coupled atmosphere-ocean-land models, sea surface temperature (SST) and soil moisture are the most important factors. The temporal changes of these two variables are large even for the short-term (seasonal) climate prediction so that their variation must be specified properly. As to the ocean, the current data assimilation techniques which have been implemented operationally, give the initial condition for coupled ocean-atmosphere models. These models can predict the evolution of the ocean and the atmospheric parameters in the climate time scale (from seasonal to decadal). Since SST is successfully observed by ships and satellites, the results of the model can be validated with these observed data.

A similar problem arises for the terrestrial environment and its role in climate prediction. With a coupled soil-atmosphere model, we need to predict the evolution of atmospheric as well as surface hydrological fields, e.g., soil moisture and run-off. Compared with the current ocean-atmosphere models, the development and validation of sound soil-atmosphere models has two problems to solve.

How to obtain the initial conditions for the soil moisture?

How to validate the soil moisture predicted by the model?

One of the difficulties in the first issue is that the initial condition must be well balanced with the coupled model. For this requirement, it is recommended that the initial conditions are obtained from the data assimilation using the same coupled model. To deal with the second problem, data sets obtained independently of the model are required. Thus, global soil moisture data sets are an essential requirement for the validation of the coupled models and thus successful climate prediction.

Apart from the climate model validation issue, soil moisture information is very important for hydrosphere and biosphere. It is a key determinant of primary productivity and vegetation structure, composition and density. From the hydrological view, soil moisture affects the partitioning of precipitation into soil moisture available for plant growth, ground water, and run-off.

Discussion

The soil moisture budget is determined by the balance of input (precipitation) and outputs (evapotranspiration, run-off, ground water storage). These components can be determined from the atmospheric forcing (radiation, temperature, moisture and precipitation) by means of a numerical soil model. Given proper atmospheric forcing to a sufficiently sophisticated soil model, one can obtain good estimates of soil moisture, run-off and the ground water storage terms. This simple soil moisture model-based method, which does not require the intensive computing (integration over time) of the coupled atmospheric model, has the advantage of low cost. A centre without massive computing power can apply this method to estimate soil moisture reserves and their temporal changes. On the other hand, soil moisture forced by the atmosphere may not be applicable to the initial condition for the soil-atmosphere model, where two-way interaction between soil moisture and atmosphere is important.

For the climate prediction by the coupled soil-atmosphere model, time integration should start with the soil moisture derived in the 4-dimensional data assimilation (4DDA). In 4DDA, both in-situ and space observations are integrated into global gridded data using a numerical model. Developed initially for numerical weather prediction, the 4DDA analysis is now regarded to be a very powerful way for climate monitoring. The feasibility of estimating soil moisture in 4DDA has been demonstrated.

Since soil moisture can vary rapidly in both space (metres) and time scales (hours, days), its direct or continuous measurement is not practically feasible at the global level. This has prompted interest in the development of remote sensing methods based on satellite sensors. Prior to this TOPC meeting, a survey of experts from several countries has been carried out to establish consensus on the state-of-the-art and prospects of remote sensing of soil moisture. Results of the survey are given in Annex 5 and can be briefly summarized as follows:
Remote sensing methods are capable of providing estimates of soil moisture for the near-surface layer only (5 cm or so), provided that vegetation is absent or the above-ground biomass is low. This would limit acquisition of useful data to arid, semi-arid and cultivated regions and exclude most forested regions;

The most accurate and robust technique at present is based on low-frequency passive microwave radiation measurements. Optimum sensors for soil moisture remote sensing have been proposed but not approved for satellite missions.

Since the remote sensing approach represents the only viable option for collecting global data sets, its thorough evaluation is necessary. This could include the possible use of soil moisture measurements from lower tiers as part of a combined validation/monitoring approach.

Recommendations

1. Establish the usefulness of near-surface soil information for climate monitoring purposes and the required spatial resolution should be established (as absolute quantities or in relative units). This implies the need for 4DDA tests to determine how the near-surface information would be used as initial or boundary condition in the models, assuming that it is available daily or every few days;

2. Based on the requirements, undertake a comprehensive evaluation of an end-to-end system (raw data to global data sets), and identify critical elements; and

3. Employ coordinated national initiatives to pursue further work on the critical elements.

<u>Biomass Data Set</u>

The need for biomass data was discussed at the meeting. Dr Rik Leemans led the discussion. There was considerable discussion over the need for biomass data. The topic needed further development so a small working group has been tasked with reviewing and rewriting this section of GCOS-21.

Requirements for Biogeochemical Cycle Models

It was noted that the biogeochemical cycling section of GCOS-21 was inadequate. Dr Robert Scholes prepared a discussion paper on the topic and led the discussion. The following is a summary of the discussion.

Why is biogeochemical data important to the climate?

Biogeochemistry studies the cycling of the elements essential to life. These cycles are strongly influenced by living organisms, and by interactions between the biosphere, atmosphere, hydrosphere and geosphere. Biogeochemistry focuses on the carbon nitrogen, phosphorus and sulphur cycles, and underlies all primary production and trace gas emission models. The impact on the climate is via the emissions of radiatively-active trace gases which occur as a result of biogeochemical cycling (CO2, CH4, N2O, ozone precursors and aerosols) and via the land surface characteristics such as biomass and leaf area which are constrained by biogeochemical considerations. Since biogeochemical cycling is strongly influenced by climate, this constitutes one of the major avenues for both impacts and feedbacks.

To understand, model or monitor any cycle requires three types of information:

r) The size of the pools;

s) The magnitude of the fluxes; and

t) The factors which control the fluxes.

In practice, all cycles can be simplified to some degree by considering only the major fluxes and pools. Generally, one flux will be 'rate-limiting', and its controlling factors need to be known in detail. For example, carbon assimilation by plants is a rate-limiting step in the carbon cycle, while nitrogen mineralization is limiting in the nitrogen cycle.

The crucial importance of the carbon cycle is well established, but why are the other elements included?

N Nitrogen is the principal limitation for the operation of the carbon cycle in most terrestrial ecosystems, including agroecosystems. N_2O and NO are climatically-important trace gases.

P Phosphorus is the principal limitation for the operation of the carbon cycle in many tropical terrestrial ecosystems and most aquatic ecosystems. Phosphorus also controls the input of nitrogen to ecosystems via biological nitrogen fixation.

S Sulphur cycles in tandem with nitrogen and carbon. Sulphur aerosols are very important to the radiative balance of the earth and are the main component of acid rain.

Table 3 contains a list of the key variables needed for biogeochemical modelling and monitoring. Only the principal pools and fluxes have been considered. What follows is a list of the key variables that are needed in addition to those already listed in GCOS-21.

1. Plant tissue N [and P and S if possible] content, (mg/kg) and specific leaf area (m^2/kg) on recent leaf litterfall, once a decade on the dominant species at tier III terrestrial sites. These are crucial variables for the modelling of NPP via biogeochemical models, and are subject to change under an elevated CO_2 world. Accuracy + 5%.

2. Maximum stomatal conductance (mmol/s/m^2), carbon assimilation rate (mmol/s/m^2) and dark respiration rate (mmol/s/m^2) of recently fully-expanded leaves of the dominant species, once a decade at terrestrial tier II sites. Irradiance, leaf temperature and vapour pressure deficit and nitrogen content to be specified at the time of measurement. These are crucial variables for both carbon models and hydrological models, and are subject to change in an elevated CO_2 world. Accuracy + 5%.

3. Total N and Total S content of rainfall (mol/litre), accumulated daily and analysed monthly at tier II terrestrial sites. These are the major constituents of 'acid rain', which can be of either anthropogenic or biospheric origin, and constitutes a major input to the N and S cycles of ecosystems. Accuracy + 5%.

4. Tropospheric ozone is needed to validate the emission fields of ozone-forming gases. Daily data at a resolution of 50 x 50 km are desired, with an accuracy of + 20%.

5. Emissions of sulphur and other aerosols from volcanic sources and the height at

which they are injected to the atmosphere, by major location and month. This may be achieved by a pointer to the appropriate data set.

6. Anthropogenic emissions of CO_2, CO, CH_4, NO_X, N_2O, NMVOC and SO_2 every 5 years per nation. These data (except SO_2) are reported under the Framework Convention on Climate Change. SO_2 is widely reported by the major emitting countries in the context of transboundary pollution, and can be inferred from energy statistics in non-reporting countries.

7. Use of N and P containing fertilizer, by year, by nation or district within nation. These data are reflected in FAO statistics.

Table 3: List of Key Variables Needed for Biogeochemical Modeling and Monitoring

Variable	Frequency	Comment
Precipitation amount and content of nitrate, ammonium, organic N and sulphate	Collected daily and frozen, accumulated and analysed monthly	To calculate fluxes of N and S in rain water and to drive mineralization models
Surface air temperature	Daily max. and min.	To drive process models
Soil sand & clay content, bulk density, water holding capacity, rooting depth, CEC	Once	Modelling of soil processes such as mineralization, run-off and leaching
Soil, tissue and litter C, N, P and S content, biomass, necromass, litter half-life	Decimally	Decomposition and primary production modeling
Tropospheric ozone and aerosol optical thickness	Daily, averaged monthly, 0.5 x 0.5°	Validation of NO and aerosol models
Atmospheric CO2 content and isotopic composition	Monthly, 50 sites	Inverse modelling of carbon sources and sinks
Surface roughness, maximum stomatal conductance, leaf area index	Monthly, 0.5 x 0.5°	Modelling of aerosol deposition
Streamflow, dissolved and particulate organic carbon, nitrogen and phosphorus, nitrate, phosphate	Daily, chemistry related to changes in flow conditions. On major and representative rivers	For calculation of the fluxes between the land, freshwater hydrosphere and oceans
Area burned, biomass, vegetation type	Monthly, 0.5 x 0.5°	Calculation of pyrodenitrification, elemental carbon formation, trace gas formation
Tropospheric wind fields	Hourly, 2 x 2°	Dispersion and transport models
Industrial, transport and domestic CO2, NOx and SOx emissions	Annually, 0.5 x 0.5°	Key flux from geosphere to atmosphere
Soil extractable P, pH, leaf biomass of BNF plants	Decadally, 0.5 x 0.5°	Modelling of biological nitrogen fixation
S and aerosol content of volcanic eruptions and height of ejecta	Monthly, by major source	Sulphate aerosols
Land cover	100 m - 1 km, decadally	Cover and cover change as drivers of N and C emissions
Use of N and P fertilizer	Annually, nationally or by district	Trace gas modelling, industrial fixation

Prioritization of Variables

The Chairman, Dr Josef Cihlar led a wide-ranging discussion on the best way to determine the highest priority variables for implementation. Appendix IV contains a complete list of variables as prioritized by the TOPC. The criteria that were finally selected for prioritizing the variables were:

- What is the impact of the variable in both depth and breadth?
- How well will the variable help meet a specific GCOS objective?
- What is the cost of implementing? and
- What is the existence of implementing structures?

Table 4 lists those variables that at least one group ranked with both Priority 1, to meet a GCOS objective, and Feasibility 1. There were no variables that all three groups ranked with Priority 1. There are several, however, e.g., snow cover area, that were ranked 1 by two groups and 2 by the third.

Table 4. Short List of Priority Variables.

VARIABLE	CRYOSPHERE	ECOSYSTEMS	HYDROSPHERE
CH4	P2 (c) F2	P1 (a,b,c) F1	
Cloud cover	P3 (a,b) F2	P1 (b,c,d) F1	P3 (a,c) F3
CO		P1 (a,b,c) F1	
CO2	P3 (b,c) F1	P1 (a,b,c,d) F1	P3 (a,b,c) F1
Glaciers and ice caps	P1 (a,b,d) F1		P2 (a,b,c,d) F2
Land cover	P2 (b,c) F2	P1 (a,b,c,d) F1	P2 (a,b,c,d) F1
Leaf area index (LAI)		P1 (a,b,c,d) F1	
Material transport from land to oceans via rivers	P2 (b) F2		P1(a,b,c,d) F1
N2O		P1 (a,c) F1	
Net ecosystem productivity (NEP)		P1 (a,b,c,d) F1	
Net primary productivity (NPP)		P1 (a,b,c,d) F1	
Permafrost - active layer	P1 (b,c,d) F1	P2 (a,b) F1	P2 (a,b,c,d) F3
Precipitation - areal	P1 (b,c,d) F2	P2 (a,b) F2	P1 (a.b.c.d) F1
Precipitation - point	P1 (b,c,d) F2	P2 (a,b) F2	P1 (a,b,c,d) F1
Radiation - fraction of photosynthetically active radiation (FPAR)		P1 (a,b,c,d) F1	
Radiation - outgoing long-wave	P1 (a,b,c,d) F1		P2 (c) F1
Radiation incoming	P1 (b,c,d) F1	P1 (a,b,c,d) F1	P2(c) F1
Radiation par		P1 (a,b,c,d) F1	
Radiation reflected - short-wave	P1 (a,b,c,d) F1	P1 (a,b,c,d) F1	P2 (c) F1
Rooting depth - depth to root impeding soil layer	P3 (b) F3	P1 (b,d) F1	P3 (c,d) F3
Salinity sea surface	P1 (a,d) F2	P1 (a,b,c,d) F1	
VARIABLE	CRYOSPHERE	ECOSYSTEMS	HYDROSPHERE
Sea ice concentration	P1 (b,c,d) F1		
Snow cover area	P1 (b,c,d) F1	P1 (a,b,c,d) F1	P2 (b,c,d) F1
Soil bulk density	P3 (b) F3	P1 (b,d) F1	P3 (c) F3
Soil moisture	P3 (b,c) F3	P1 (a,b,c,d) F1	P1 (b,c,d) F3
Soil moisture surface (0-5 cm)		P1 (a,b,c,d) F1	P1 (b,c,d) F2
Soil particle size distribution		P1 (b,c,d) F1	
Surface water flow – discharge	P2 (b,c,d) F2		P1 (a,b,c,d) F1
Surface water flow - run-off	P3 (b) F1		P1 (a,b,c,d) F1
Temperature surface - air	P1 (b,c) F1	P1 (a,b,c,d) F1	P2 (b,c,d) F1
Topography	P1 (a,b,c,d) F2	P1 (c) F1	P2 (c,d) F2
Vegetation structure	P3 (b,c) F2	P1 (a,b,d) F1	P3 (a,b,c) F3

Key to Table 4:

Priority:	P1 = high; P2 = medium; P3 = low.
Use:	a = climate detection; b = impact assessment; c = prediction and simulation; d = model validation.
Feasibility:	F1 = high; F2 = medium; F3 = low.

Data and Information Management

Prof. John Townshend made a presentation on the GCOS Data and Information Management System and led a short discussion on TOPC data and information management needs. The following is a summary of his presentation and the subsequent discussion.

Issue

Version 1.0 of the GCOS Data and Information Management Plan has been completed. This Plan describes a template for GCOS data management activities in broad terms. The information management strategy is based on the use of existing facilities and expertise. The system will be developed, implemented and operated by existing national and international organizations and programmes. The system relies on distributed centres sponsored by nations and institutions participating in GCOS. Participating data and information centres will be encouraged to develop data servers which can interact with clients according to agreed-upon guidelines. When fully implemented, the GCOS data and information management system will allow participating nations and programmes access to a wide variety of climate-related data. The GTOS proposal describes a similar approach.

There are a number of issues that have been identified by Prof. Townshend for the TOPC to consider. These include:

- .The terrestrial community in terms of data management is not well served for many observations. This community urgently needs the assistance of the Data and Information Management Panel to remedy these deficiencies. A related but separate problem is the ability of centres to acquire the data they need for the user communities and to have access to it in appropriate formats;

- .It is important that the needs of countries with inadequate access to the Internet have their needs met by the provision of data in other formats;

- .For the terrestrial community, there is a lack of adequate data handling capabilities especially within the ecological and hydrological areas. There are some nominated centres such as the GRDC and GPCC, but further capabilities are needed. A World Data Center (WDC) for Soils is in existence. UNEP's GRID holds several data sets collated from other sources;

- .For ecological observations, the situation is less satisfactory though there have been proposals within WDC-A to help rectify the situation;
- .There is a continuing problem in data being made available to centres in the appropriate format, such as long-term records collected for synoptic purposes which are in analogue format; and

•.It is important that the needs of countries with inadequate access to the Internet are satisfied by the provision of data in other formats. While Internet access is increasingly available, problems associated with bandwidth and charges are likely to inhibit its use by many users for several years.

Recommendations

1. TOPC should participate in the proposed IGBP-DIS/WDC workshop which will be evaluating the needs of the IGBP community for data management;

2. The TOPC, with the assistance of the Data and Information Management Panel (DIMP), should identify and assess existing data centres to determine if its needs can be met;

3. The possible benefits of archiving more of the data collected through the World Weather Watch GTS system should be explored, especially in view of the development and application of web technology; and

4. Currently the land community does not appear to be well represented on the DIMP and this representation should be improved. Each member of the Panel should suggest names to the JPO for consideration as DIMP members.

Review of Space-based Observations

The JSTC had noted some apparent inconsistencies between the GCOS Plan for Space-based Observations (GCOS-15) and GCOS-21, and asked the TOPC to review their needs. Prof. John Townshend updated the Panel on GCOS interactions with CEOS and led a discussion of TOPC needs.

The GCOS-15 was presented to the Committee on Earth Observation Satellites (CEOS) in Montreal in October 1995. As a result of the presentation, CEOS has begun to rethink its role. The importance of the global observation systems is being substantially raised. The meeting decided to begin to develop an overall Integrated Global Observing Strategy (IGOS). The first meeting of IGOS is in Seattle (USA), during the week of 25 March, 1996. The results of this meeting will be reported to the next CEOS plenary in Canberra, Australia, in November 1996.

Recommendations

As a result of the discussions, the Panel had the following set of recommendations:

1. The various incoming and outgoing short- and long-wave observational needs should be reconciled with those of the AOP in terms of terminology and requirements, and then a consolidated list be presented to the Space-based Observation Panel;

2. The fire product should be redefined to include:

i) Coarse resolution global sensing of the distribution and daily frequency of fires;

ii) Fine resolution spatial calibration of fire scar extent using fine resolution data from satellites such as SPOT and Landsat; and

iii) Land cover data to provide information on the character of the fuel to assist estimation of the properties of the resultant atmospheric fire products;

3. Albedo should be added as a variable indicating how it is derived;

4. Emissivity is required by at least one set of users for interpretation of remotely sensed data but it is unclear whether this needs to be estimated by space techniques. TOPC should review and clarify this issue;

5. Surface roughness. Unclear currently whether this is required with a precision higher than that obtainable by parameterization using land cover classes;

6. Sea ice motion. This key variable is currently not in the Space Plan and should be added;

7. Surface water storage fluxes is not in the Space Plan but can benefit from space observation in its estimation (through observing areal extent of water bodies);

8. The observational requirements, nomenclature and definitions of ice sheet mass balance, ice sheet elevation and topography need to be clarified; and

9. Land use needs to be modified to better reflect the relative contributions of space and other observations.

4.12 The Demonstration Project

Dr Hal Kibby made a short presentation of a proposed demonstration project. The following is a summary of the discussion.

Issue

The issue is how to best demonstrate the need for GCOS and GTOS data in developing countries of the world. A project to demonstrate the utility of such data was discussed. The objectives are: (1) to demonstrate the operational feasibility of implementing GTOS and the terrestrial aspects of GCOS; (2) to demonstrate the need for GCOS, GTOS, and GOOS global data sets in seasonal to interannual climate predictions (in cooperation with WMO’s Climate Prediction Services (CLIPS) programme); (3) to demonstrate the utility of GTOS, GCOS and GOOS data sets in a national assessment.

Recommendations

1. The Panel recommended that in addition to spending time and effort developing coordination among potential GCOS/GTOS sites in Southeast Asia, some time should be spent on the development of tier III sites globally;

2. Prior to contacting the sites, clear guidelines for criteria for participating sites need to be provided; and

3. Identification and coordination of tier III sites should proceed simultaneously with development of the demonstration project in Southeast Asia.

Implementation Issues

As Chairman of the JSTC, Prof. Townshend felt that the implementation of in situ measurements presented a far grater challenge than the implementation of space-based observations. He pointed out that there is no overall coordinating mechanism analogous to CEOS for in situ measurements. Even if there were, the complexities are far greater because we are dealing with many more institutions.

It is important for the TOPC to take the responsibility of beginning to implement the in situ aspects of terrestrial observations. It is clear that TOPC needs to develop a statement that clarifies the vested interest that in situ sites have in participating in the programme. It was pointed out that one such interest would be in exchange of in situ data for satellite data. The satellite programmes need in situ data as much as the in situ programmes need satellite data. There are three potential options:

1. Where existing programmes are operating use these programmes;

2. Persuade an international agency to do it; and

3. Where all else fails invent a system ourselves.

V. Recommendations

The following is a summary of those recommendations made in each section above.

1. Begin a dialogue with existing site networks (either international or national) to produce a draft of workable data exchange rules and procedures and to refine the potential site database (Action: GTOS Secretariat);

2. Make the potential site database more comprehensive by asking regional and national experts to check and populate it (Action: GTOS Secretariat/GCOS JPO);

3. Conduct an initial tier III selection according to the criteria (Action: GTOS Secretariat);

4. Invite site and network managers of the identified sites, plus representatives of organizations which could establish or upgrade sites in under-sampled regions to a workshop to agree on their participation in a network (Action: Prof. Townshend in situ meeting as start);

5. Use the combined motivation of GTOS and GCOS to enhance and accelerate a SOTER-like activity to collect an initial set of tier IV data in a stratified random pattern (with substitution of inaccessible sites) using geomorphology, geology and land cover as the stratifiers (Action: TBD);

6. Publish a brochure explaining and publicizing the GHOSTE (Action:

Dr Scholes, GCOS JPO);

7. Publish and distribute a methods handbook for tier IV data and actively encourage the placement of target-of-opportunity tier IV data in public domain databases (Action: TOPC);

8. Develop some minimal criteria for what constitutes a "good quality station" (TOPC);

9. Maintain a "meta-data" data set with pointers to relevant data (Action: GCOS JPO and GTOS Secretariat):

(i) to in situ data centres that are holders of information that would be made available at minimal cost under agreement with GCOS/GTOS; or

(ii) of specialized data sets already developed for climatic purposes, such as the HCN or Historical Climatology Network of Precipitation Data developed by NOAA/NCDC;

10. Study the need for a .5 by .5 degree precipitation product, and if necessary and feasible, urge the GPCC to produce such a product rather than the 1 by 1 degree product that is planned (Action: TOPC in consultation with GPCC); and

11. Revise Version 1.0 of the GCOS/GTOS Plan for Terrestrial Climate-related Observations to reflect the following (Action: TOPC):

- Add variables required for BGC models;
- Add flow chart showing how observations lead to derived products;
- Revise precipitation to reflect macro-, micro- and meso-scale requirements;
- Add run-off as a variable sheet;
- Add albedo as a requirement;
- Add carbon change as a variable and modify biomass accordingly;
- Add variable on C13/C12;
- Revise soil moisture variable sheet;
- Add tiers to variable sheets;
- Revise land-use variable sheet;
- Add definition of classes to land cover;
- Improve descriptions of uses of data (client needs) for all variables;
- Add schematic illustrations including tier diagram; and

- Revise hydrology section to reflect the HWR/GCOS Hydrology meeting and interactions with FRIEND and GEWEX. (This meeting takes place 29 April to 1 May, 1996. The results of that meeting will be available shortly.)

VI. Closure of the Meeting

The Chairman closed the meeting at 2.30 p.m. on 22 March, 1996. The date and venue of the next meeting of the TOPC was not set.

Annex 1: List of Participants

Dr Josef CIHLAR (Chairman)
Canada Center for Remote Sensing
588 Booth Street
OTTAWA, Ontario K1A 0Y7, Canada
Tel: +1 613 9471265
Fax: +1 613 9471406
Email: josef.cihlar@ccrs.nrcan.gc.ca

Dr Wilfried HAEBERLI
Department of Geography
University of Zurich-Irchel
Winterthurerstrasse 190
8057 ZURICH, Switzerland
Tel: +41 1 2575120
Fax: +41 1 3625227
Email: haeberli@geo.unizh.ch

Dr Jurate M. LANDWEHR (Ms)
U.S. Geological Survey
431 National Center
RESTON, VA 22092, U.S.A.
Tel: +1 703 6485893
Fax: +1 703 6485274
Email:jmlandwe@usgs.gov

Dr Rik LEEMANS
Department of Global Environmental Assessment
RIVM
P.O. Box 1
3720 BA BILTHOVEN, The Netherlands
Tel: +31 30 2743377
Fax: +31 30 2744435
Email: rik.leemans@rivm.nl

Mr Ken-ichi KUMA
Numerical Prediction Division
Japan Meteorological Agency
1-3-4 Otemachi, Chiyoda ku
TOKYO 100, Japan
Tel: +81 3 32128341
Fax: +81 3 32118407
Email: kenkuma@npd.kishou.go.jp

Ing. G. Enrique ORTEGA GIL
Servicio Meteorologico Nacional
Av. Observatorio No. 192
Col. Observatorio
11860 MEXICO D.F., Mexico
Tel: +52 5 6268650
Fax: +52 5 6268695

Dr Robert SCHOLES
Division of Environment, Water and Technology
CSIR
P.O. Box 395
PRETORIA 0001, South Africa
Tel: +27 12 8412045
Fax: +27 12 8412689
Email: bscholes@csir.co.za

Prof. John TOWNSHEND
Department of Geography
University of Maryland
1113 Lefrak Hall
COLLEGE PARK, MD 20742-8225, U.S.A.
Tel: +1 301 4054050
Fax: +1 301 3149299
Email: jt59@umail.umd.edu

Prof. ZHAO Shidong
Commission for Integrated Survey of Natural Resources, Chinese Academy of Sciences
P.O. Box 9717
BEIJING 100101, China
Tel: +86 10 4937576
Fax: +86 10 4931970 or 4914230
Email: zhaosd@bepc2.ihep.ac.cn

Secretariat

Dr Harold KIBBY
Joint Planning Office for GCOS
c/o WMO, Case Postale 2300
1211 GENEVA 2, Switzerland
Tel: +41 22 7308259
Fax: +41 22 7401439
Email: Kibby_H@gateway.wmo.ch

Members of the TOPC unable to attend:

Dr Roger BARRY, U.S.A.
Prof. David NORSE, United Kingdom
Dr Steve RUNNING, U.S.A.
Dr Allen M. SOLOMON, U.S.A.

Annex 2: Agenda

1. Welcome and Opening of the Meeting

2. Statement of Chairman and Objectives of the Meeting

3. Approval of Agenda

4. Update on GTOS Sponsors' Meeting and GCOS JSTC-V

5. Draft Terms of Reference

6. Plenary Session

   Guidelines for Participation of Sites
   Cryosphere Needs - the Next Steps
   Demonstration Project
   Review of Space-based Observations
   Tier Sampling Scheme
   Precipitation
   Need for a Biomass Data Set
   Soil Moisture
   Product Requirements from BGC Experiments
   GCOS Data and Information Management System
   Variable Prioritization
   Implementation Needs

7. Working Groups
   The results of the discussion on each topic was written by a small working group

8. Reports from Working Groups

9. Closure of the Meeting

Annex 3: Provisional Terms of Reference for the GCOS/GTOS Terrestrial Observation Panel for Climate

Recognizing the need for specific and technical input concerning terrestrial observations for climate purposes, the sponsoring organizations of GTOS and the Joint Scientific and Technical Committee of GCOS have jointly established a Terrestrial Observation Panel for Climate (TOPC) with the following terms of reference.

- In accordance with the overall plans of GCOS and GTOS, to plan, formulate and design a long-term systematic observing system for those terrestrial propertiesand attributes which control the physical, biological and chemical processes affecting climate, are affected by climate change or serve as indicators of climate change, and which are essential to provide information concerning the impact of climate and climate change;

- To review the needs of the user communities for climate-related data and select a set of core variables, both in situ and space-based, at appropriate space and time scales, paying particular attention to the needs of developing countries;

- To develop a strategy based on the concept of the Initial Operational System (IOS) which includes the assessment of existing in situ systems, the determination of deficiencies and the recommendation of necessary enhancements. (The Space-based Observation Panel will evaluate satellite programmes, determine deficiencies and recommend the necessary enhancements for those variables identified by this Panel that can be observed from space);

- To seek, review and support for, the implementation of the strategy from other relevant research or operational programmes (e.g., WCRP, IGBP, WWW, GAW, WHYCOS, GEMS, etc.);
- To support the Data and Information Management Panel and other organizations as appropriate in the development of data management systems;

- To coordinate activities with other global observing system panels and task groups to ensure consistency of requirements with the overall programmes;

- To recommend a schedule of actions to address the gaps in present and planned systems;

- Make other recommendations as appropriate;

- Publish and update appropriate GCOS/GTOS studies and planning documents; and

- To carry out agreed assignments from, and to report regularly to the JSTC and the Steering Committee for GTOS.

Annex 4: Prioritization of Variables

Priority: P1 = high; P2 = medium; P3 = low.
Use: climate detection; b = impact assessment; c = prediction and simulation; d = model validation.
Feasibility: F1 = high; F2 = medium; F3 = low.

VARIABLE	CRYOSPHERE	ECOSYSTEMS	HYDROSPHERE
Albedo	P1 (a,b,c,d) F2	P2 (c,d) F2	
Biomass		P2 (b,d) F2	
CH4	P2 (c) F2	P1 (a,b,c) F1	
Cloud cover	P3 (a,b) F2	P1 (b,c,d) F1	P3 (a,c) F3
CO		P1 (a,b,c) F1	
CO2	P3 (b,c) F1	P1 (a,b,c,d) F1	P3 (a,b,c) F1
13C/12C		P2 (a,b) F2	
Current – ocean	P1 (a,b,c,d) F2		
Evapotranspiration	P2 (b,c) F2	P2 (a,b,c,d) F2	P1 (a,b,c,d) F3
Fire extent		P2 (a,b) F1	
Freshwater flux (to ocean)	P1 (b,c,d) F2		P1 (a,b,c,d) F2
Glaciers and ice caps	P1 (a,b,d) F1		P2 (a,b,c,d) F2
Ground water storage fluxes	P2 (b,c) F3	P3 (b) F2	P1 (a,b) F2
Harvested phytomass		P2 (a,b,c,d) F1	
Ice sheet geometry	P1 (b,c,d) F2		P3 (a,b) F3
Ice sheet surface balance	P2 (b,c,d) F2		P3 (a,b) F3
Lake and river freeze-up and break-up (timing)	P2 (a,b) F2	P3 (a,b) F2	P2 (a,b) F2
Land cover	P2 (b,c) F2	P1 (a,b,c,d) F1	P2 (a,b,c,d) F1
Land use	P2 (b,c) F2	P2 (a,b) F2	P2 (a,b,c,d) F1
Leaf area index (LAI)		P1 (a,b,c,d) F1	
Material transport from land to oceans via rivers	P2 (b) F2		P1(a,b,c,d) F1
N2O		P1 (a,c) F1	
Necromass		P2 (b,d) F2	
Net ecosystem productivity (NEP)		P1 (a,b,c,d) F1	
Net primary productivity (NPP)		P1 (a,b,c,d) F1	
Ozone		P2 (a,b) F2	
OH		P3 (d) F2	
Permafrost - active layer	P1 (b,c,d) F1	P2 (a,b) F1	P2 (a,b,c,d) F3
Permafrost - thermal state	P1 (a,b,d) F2		P1 (b,c,d) F2
Precipitation - areal	P1 (b,c,d) F2	P2 (a,b) F2	P1 (a,b,c,d) F1
Precipitation - point	P1 (b,c,d) F2	P2 (a,b) F2	P1 (a,b,c,d) F1
Radiation - fraction of photosynthetically active radiation (FPAR)		P1 (a,b,c,d) F1	
Radiation - outgoing long-wave	P1 (a,b,c,d) F1		P2 (c) F1

Radiation incoming	P1 (b,c,d) F1	P1 (a,b,c,d) F1	P2(c) F1
Radiation par		P1 (a,b,c,d) F1	
Radiation reflected - short-wave	P1 (a,b,c,d) F1	P1 (a,b,c,d) F1	P2 (c) F1
Rooting depth - depth to root impeding soil layer	P3 (b) F3	P1 (b,d) F1	P3 (c,d) F3
Rooting depth - characteristic rooting depth (vegetation)		P2 (b,d) F1	
Roughness - surface	P2 (b,c,d) F1	P2 (b,d) F2	P2(c,d) F1
Salinity sea surface	P1 (a,d) F2	P1 (a,b,c,d) F1	
Sea ice concentration	P1 (b,c,d) F1		
Sea ice motion	P2 (c,d) F2		
Sea level	P2 (b,c) F1	P2 (a,b) F1	P3 (d) F1
Snow cover area	P1 (b,c,d) F1	P1 (a,b,c,d) F1	P2 (b,c,d) F1
Snow water equivalent	P1 (b,c) F2	P2 (a,d) F2	P1 (b,c,d) F2
Soil bulk density	P3 (b) F3	P1 (b,d) F1	P3 (c) F3
Soil carbon		P2 (b,d) F1	
Soil moisture	P3 (b,c) F3	P1 (a,b,c,d) F1	P1 (b,c,d) F3
Soil moisture surface (0-5 cm)		P1 (a,b,c,d) F1	P1 (b,c,d) F2
Soil particle size distribution		P1 (b,c,d) F1	
Soil phosphorus		P2 (b) F2	
Soil surface state		P3 (b) F2	P3 (c) F3
Soil total nitrogen		P2 (b,c) F2	
Surface water flow – discharge	P2 (b,c,d) F2		P1 (a,b,c,d) F1
Surface water flow - run-off	P3 (b) F1		P1 (a,b,c,d) F1
Surface water storage fluxes	P3 (c) F2	P2 (a,b) F2	P1 (a,b,c,d) F2
Temperature sea profiles	P2 (b,c) F2		
Temperature sea surface (SST)	P1 (b,c) F1		
Temperature surface - air	P1 (b,c) F1	P1 (a,b,c,d) F1	P2 (b,c,d) F1
Topography	P1 (a,b,c,d) F2	P1 (c) F1	P2 (c,d) F2
UV-B -- Surface, profile		P2 (a,b) F2	
Vegetation index	P3 (a,c) F2	P2 (a,d) F1	P3 (a,c) F2

VARIABLE	CRYOSPHERE	ECOSYSTEMS	HYDROSPHERE
Vegetation structure	P3 (b,c) F2	P1 (a,b,d) F1	P3 (a,b,c) F3
Water total liquid or solid	P2 (b,c) F2		P3 (b,c) F2
Water vapour surface - relative humidity	P2 (c) F3	P2 (a,b,c) F2	P1 (a,b,c,d) F3
Wave height	P2 (b,c) F2		
Wind direction	P1 (b,c) F2		
Wind speed	P1 (b,c) F2	P2 (b,c,d) F2	P3 (b,c,d) F3
Wind stress	P1 (b,c) F2		

Annex 5: Consensus Statement on the Estimation of Soil Moisture from Space Platforms

March/April, 1996

The question of the feasibility of extracting soil moisture information from satellite data came up in discussing monitoring requirements for the Global Climate Observing System (GCOS). Given the uncertainties in this field, it was suggested that an initial step should be to produce a consensus on the state-of-the-art and likely future prospects.

As a step in this direction, a list of statements/propositions was prepared attempting to capture what we are reasonably certain of; what we suspect/have fair evidence on; and what we do not know, with some suggested next steps. This statement was sent to leading active researchers or research programme managers in this field, including:

Evert Attema, ESA/ESTEC; Craig Dobson, University of Michigan; Ted Engman, NASA; Thomas Jackson, USDA; Terry Pultz, CCRS; Jon Ranson, NASA; Sasan Saatchi, JPL; Soroosh Sorooshian, University of Arizona; Thomas Schmugge, USDA; and Ying Ming Wei, NASA.

The six responses received were sorted out with minimal editing according to the individual questions, and reproduced below.

1. What we know:

1.1 Microwave techniques are the only remote sensing method for assured, frequent data acquisition on which soil moisture estimation from space could be based (others suffer from atmospheric interference in an unacceptable way).

1: Agree;
2: Agree;
3: Agree;
4: True, thermal infrared can give useful information but the atmosphere provided too many interruptions;
5: Uncertain - they are the most operational methods certainly;
6: Agree.

1.2 Any microwave technique practicable from space platforms will provide information on soil moisture only for depths 0-5 cm or so (because of the dielectric contrast between the air and soil, and the ionospheric interference at much lower wavelengths).

1: Agree;
2: Agree;
3: Using direct observations;
4: It is not believed that direct observations are obtained of 0-5 cm at C-Band. It is necessary to go to longer wavelengths, e.g., L-Band to get this;
5: Agree;
6: Agree. Deeper depths may be modelled.

1.3 The soil moisture signal is contaminated by surface soil roughness and vegetation (live or dead biomass).

1: Agree;
2: Agree;
3: Agree;
4: Roughness is more of a factor for radar and vegetation effect is stronger for radiometers;
5: Doesn't this depend on active or passive method? How about incidence angle and topography?
6: Agree.

1.4 Vegetation moisture content, total biomass and canopy structure are the key parameters affecting the degree of soil signal contamination.

1: Agree;
2: Agree;
3: Agree;
4: For radiometric observations moisture content is the dominant factor;
5: See above - what about roughness and incidence angle?
6: Agree.

1.5 Estimation of relative changes in soil moisture between subsequent measurements is more easily achievable than that of absolute moisture content (provided that surface soil moisture is the only variable changed).

1: Agree;
2: Agree;
3: This is not true for passive; for active (especially current satellites) it is agreed;
4: True;
5: How could one disagree?
6: Agree.

2. What we suspect/think:

2.1 Multipolarization/multifrequency radar data will be required to obtain satisfactory soil moisture information for various ecosystems/phenological conditions.

1: Agree;
2: Agree;

3: Is it assumed that radar is the best solution? For active approaches, it is agreed;

4: Not believed to be true. An L-Band radiometer has been shown to be very effective for soil moisture in a wider range of conditions than the synthetic aperture radar (SAR) and is much simpler to interpret and can provide the data at a spatial scale relevant to climate change studies;

5: Agree. Soil moisture cannot be sensed below wet canopies so don't even bother this is a method for semi-arid and arid regions where soil moisture varies with time;

6: True if one requires a very robust approach for various ecosystems/phenological conditions. Single Channel SAR, such as Radarsat, may be sufficient in some environments.

2.2 Semi-empirical or empirical models must be used to extract soil moisture from microwave data.

1: Agree;

2: Most probably true, though perhaps sometime in the future we can find the 'Holy Grail' of soil moisture through an elegant (but simple) inversion;

3: Not true, we have only a limited understanding and incomplete databases;

4: The basic dielectric models have given reasonable agreement with radiometric observations in HAPEX-Sahel, Washita 92 etc., so the level of empiricism is low for radiometric observations;

5: Agree - without fully specifying the physical properties of the land cover, we must improvise;

6: Agree.

2.3 The influence of vegetation with soil signals may be accounted for by a single parameter (related to optical thickness of the canopy).

1: Agreed;

2: Quite possible;

3: For passive (long wavelengths): yes. For active: some structural information is needed;
4: True;
5: Not known;
6: Unlikely.

2.4 DEM data with sufficient x/y and z resolution will be required if radar data are used for soil moisture estimation.

1: Agree;
2: Agree and suspect that 1:100,000 hypsography is adequate for most places;
3: There is some doubt that for satellite scale footprints and larger look angles that this is true;
4: Not necessary for the radiometer;
5: Agree - see 1.3;
6: Agree. Canadian Prairies may be an exception (flat).

3. What we do not know:

3.1 We do not know if soil moisture information for the top 5 cm of soil would be useful for climate and climate change purposes (can be determined by modellers); and if so, whether remote sensing offers the best means of obtaining this information.

1: Agree;
2: Agree;
3: There is enough evidence in the literature to support the utility of this observation. The most obvious applications are the least demanding in terms of spatial resolution;
4: The repetitive observations of the moisture state for the upper boundary layer of the soil has to be useful. For one thing it can give a clear indication of regions of recent rainfall and a qualitative estimate of how much;
5: Agree, but move to Section 2;
6: Agree.

3.2 We do not know if relative change information would be useful for climate and climate change purposes (can be determined by modellers).

1: Agree;
2: Agree;

3: It would be useful. Climate modellers need a direct observation of state and/or flux variables. They need to reduce the degrees of freedom, not increase the uncertainty;

4: See above;

5: Agree;

6: It is understood that modellers are interested in these data. However, this information comes to me second-hand and through the literature.

3.3 We do not know if soil moisture signals can be isolated and quantified with sufficient accuracy under the variety of vegetation cover on a global basis and for various phases of the phenological cycle (requires much experimentation, likely further model development and validation, operational trials).

1: By averaging over a large number of pixels (say to a resolution of 500 x 500 meters) the investigators could get high correlation of ERS-1 SAR data with soil moisture (accumulated rain) by averaging over the interfering roughness and canopy variations. This is clearly dependent on land use and will be a 'regional' algorithm, not global;

2: Agree;

3: Agree;

4: More studies are needed. This is what they say when they don't want to do anything. Radiometric observations with the PBMR and ESTAR over the past ten years have demonstrated its capabilities over a wide range of conditions from FIFE to HAPEX-Sahel;

5: This is what we know (soil moisture cannot be sensed below wet canopies so don't even bother - this is a method for semi-arid and arid regions where soil moisture varies with time);

6: Agree.

3.4 We do not know which technique (active or passive) is preferable for global climate applications (could be answered through a dialogue between earth observation and climate scientists but we may need to know more about the performance of each technique).

1: Agree;

2: Agree - also need to know the requirements of each application;

3: Depending upon the application objectives (spatial/temporal) the choice of a system is quite clear;

4: As was pointed out, the radiometer works best for soil moisture where it is needed most, i.e., in sparse vegetation conditions where direct evaporation from the soil is a major factor in the surface energy balance;

5: Active offers the best signal - but at multiple costs;
6: Agree;

3.5 We do not know which ancillary data would be required for operational inversion of the microwave data to obtain soil moisture information and whether these can be obtained in practice (requires better understanding of the two methods and their respective data needs).

1: Agree;
2: Agree;
3: 0;
4: I think Jackson et al recent papers (Remote Sensing of Environment 53: 27-37; IEEE Transactions on Geoscience and Remote Sensing 31 (4): 836-841; Hydrological Processes 7: 139-152) have laid out an algorithm which indicates the types of ancillary data that are needed;
5. Again, we know what the main parameters are but sensitivity is another issue;
6: Agree.

4. Conclusions

4.1 The usefulness of near-surface soil information for climate monitoring purposes and the required spatial resolution should be established (as absolute quantities or in relative units).

1: Agree;
2: Agree. This should be a focus for some of the modelling efforts. Sensitivity studies could also be done that feed into 4.2 below;
3: There are ongoing activities;
4: The spatial resolution should indicate the major changes in soil moisture, i.e., the rainfall variations. The studies we had done in the late 1970's showed that most of the variation could be accounted with resolutions in the order of 5 to 10 km;
5: Suggested action: support modellers;
6: Agree, is this being addressed in GEWEX?

4.2 Based on the requirements, a comprehensive evaluation of an end-to-end system (raw data to global data sets) should be undertaken, and critical elements identified.

1: Agree;
2: Agree. Effort should include a complete error analysis for each step (this would also be a good mechanism for comparison of competing techniques);

3: There are ongoing activities;
4: For the radiometer with 5 to 10 km, resolution this would seem to be a trivial problem;
5: Partially agree;
6: Agree.

4.3 Sponsorship for further work on the critical elements should be sought through coordinated national efforts.

1: Agree;
2: Agree. This could be done within existing programmes, but an emphasis really needs to be placed upon 'coordinated' (not fragmented) efforts on critical parts of 1 (or more) possible end-to-end systems;
3: Agree;
4: Push NASA to fly an L-Band radiometer;
5: Agree;
6: ?