GLOBAL CLIMATE OBSERVING SYSTEM

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

REPORT OF THE GCOS REGIONAL WORKSHOP FOR CENTRAL AMERICA AND THE CARIBBEAN

OBSERVING CLIMATE FROM WEATHER EXTREMES TO CORAL REEFS

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INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) has recognized the importance of using high-quality data to understand climate-related issues and has noted that oftentimes the geographic coverage, quantity, and quality of the data produced by global and regional observing systems are inadequate. Most of these problems are especially true in developing countries due to obsolete observing networks, insufficient funds for adequate network maintenance or upgrading, and, in some cases, lack of well-trained staff.

The Global Climate Observing System (GCOS) Secretariat launched the Regional Workshop Programme in 2000 in response to decisions made by the UNFCCC Conference of the Parties (COP). The Programme is designed to address the needs for capacity building and identify projects that address deficiencies in meteorological, atmospheric, oceanographic, and terrestrial climate observing systems.

The main goals of the GCOS Regional Workshop Programme are:

- To help developing countries identify regional deficiencies in global climate observing systems;
- To determine priority observing system needs and funding requirements to enable countries to overcome deficiencies and collect, exchange, and use data on a regular basis as established by the UNFCCC; and
- To initiate the development of Regional Action Plans to address observing system needs.

In each region, GCOS will assist in the development of a Regional Action Plan. However, regional partners are expected to take the lead in developing specific proposals based on the Action Plan.

The first workshop in the 10-workshop programme was held in Apia, Samoa for Pacific Island countries in August 2000. It was co-sponsored by the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), the Australian Bureau of Meteorology, and the United States National Weather Service. The second workshop was organized for the countries of Eastern and Southern Africa and was held in Kisumu, Kenya in October 2001.

This third workshop has been organized for the 25 countries of Central America and the Caribbean and, in accordance with the above, has been designed to help participants identify deficiencies in climate observing systems and to launch a process that will lead to the development of a regional strategy (a Regional Action Plan) for addressing deficiencies.

OPENING CEREMONY

Mr Carlos Fuller, Vice-President of the WMO RA-IV, emphasized the importance of high-quality climate information for optimal forecasting. He referred to the initiatives and actions currently developed in the region on this matter to improve understanding of climate variability and change. He also mentioned that this workshop was an opportunity to foster collaboration among regional climate-related communities to enhance climate management efforts.

Dr Alan Thomas, the Director of the GCOS Secretariat, noted that this was the third GCOS Regional Workshop on improving climate observations and data. He referred to a growing awareness of the impact and importance of high-quality information for an improved understanding of climate variability, climate change, and regional vulnerability and adaptation studies. He expected the region to be able to count on support and contribution from United Nations agencies and from different scientific and research centers in Canada and the United States to assist national efforts to improve observing systems.

The Honorable Elizabeth Odio, First Vice-President of Costa Rica and Minister of Environment and Energy, noted that the 1992 United Nations Framework Convention on Climate Change was probably adopted 20 years too late. However, she admitted that it was developed as a result of a worldwide awareness of environmental changes affecting the Earth. The idea is for observations to be improved under the Framework Convention to support sustainable development and the preservation of life. Exchanging information is vital for improving our knowledge of climate behaviour, which in turn is closely related to the vulnerability of the region. Ms Odio stated that we have been and will be affected by the impact of natural events. Hence, accurate weather forecasting will provide governments with information necessary for making informed decisions. She emphasized that every activity that enables people in the region to share information and make their needs known to the scientific community will help protect the countries in the area, the world, and, of course, life itself.

SUMMARY OF THE PRESENTATIONS AND DISCUSSION SESSIONS DEVELOPED DURING THE WORKSHOP

TOPIC 1

SETTING THE CONTEXT

Chairman: Mr Patrick Jeremiah

The Chairman introduced the topic and mentioned that each one of us, in one way or the other, has contributed to global warming. He referred to some of the issues in the agenda and emphasized the need to develop a Regional Action Plan to identify national and regional priorities for action and the need to prepare national observing system reports. He urged participants to become part of a volunteer group to assist on the writing of the Plan. He mentioned that, ideally, this group should include representatives from both Central America and the Caribbean, and he defined some general rules for the conduct of the workshop.

Overview of GCOS and its Mission and the Purpose and Expected Outcomes of the Workshop

Dr Alan Thomas stated that the mission of GCOS, established in 1992, is to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. GCOS is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), and the International Council for Science (ICSU).

GCOS is intended to be a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate change, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modelling, and prediction of the climate system.

Dr Thomas also noted the following goals of the workshop:

- To assess the contribution of the region to GCOS baseline networks;
- To help participants understand guidelines for reporting on observations to the UNFCCC;
- To identify national and regional needs and deficiencies for climate data (including needs for assessing climate impact and conducting vulnerability and adaptation studies); and
- To initiate the development of Regional Action Plans for improving climate observations.

Finally, he referred to the following expected outcomes:

- To identify deficiencies in regional climate observing systems;
- To develop a regional strategy (Regional Action Plan) to address priority needs for observing systems;
- To launch a search for funds to address the needs identified in the Regional Action Plan; and
- To circulate throughout the region a draft version of the Plan by June 2002.

A Regional Perspective on the Importance of Improved Climate Observations to Central America and the Caribbean

Dr Michael A. Taylor, Department of Physics of the University of the West Indies, presented an overview of the evolution, current status, and future trends of climate-related research, especially with respect to climate variability and climate change in the Central American and Caribbean Region (CAC). He focused his presentation on the improvement of data.

Dr Taylor referred to the growing interest in climate-related issues in the region and mentioned the emergence of a "CAC Culture of Climate-Related Thought." This "culture of thought" includes, among other aspects, the emergence of local expertise, more regional research on climate-related issues, new regional research groups and think tanks, and an increasing use of climate-related jargon. The result has been a growing awareness of climate variability and climate change issues.

However, with this change of attitude comes the challenge to those driving the "thought movement" to provide answers to local climate-related questions. Their ability to answer such questions depends greatly on the availability of regional datasets of climate-related variables, but these data sets are not always accessible or of good quality.

In this regard, he addressed four relevant questions:

1. Is there evidence of climate change in the CAC region?
2. Why is this year's climate so different from last year's?
3. What is the likelihood of a good rainfall season this year?
4. How can knowledge of climate variability benefit me?

Finally, he referred to the challenges for the region, which must be addressed within what he called "the first step in the way forward." These challenges are:

- Reinforcing the importance of climate data collection and ensuring the continuation of local records with government economic support;
- Reinforcing the importance of sharing data to develop regional outlooks on climate issues;
- Recovering and digitizing deteriorating historical data records;
- Maintaining and upgrading existing data observation sites, and increasing their number within the region; and
- Increasing the number of variables observed.

Dr Taylor also mentioned that several climate hazards exist, including hurricanes, droughts, and floods among others, that have an impact on the quality of life of people in the region. These climate extreme events affect the development of nations due to the vulnerability of the region. However, he pointed out several adaptation strategies that can be adopted to prevent or mitigate the impact of these factors, such as early warning systems.

United Nations Framework Convention on Climate Change Reporting Guidelines on Global Climate Observing Systems

Dr William Westermeyer, from the GCOS Secretariat, Switzerland, discussed the UNFCCC's national reporting guidelines for observations. The preparation of observing system reports is voluntary for most developing countries. However, GCOS encourages all countries to provide such reports.

The presentation of these reports is important for four reasons:

1. Reports will help raise the level of awareness among the delegates to the UNFCCC about needed improvements in observing systems;
2. Individually and collectively, these reports will provide essential information for upgrading climate-observing systems;
3. The quality of the final synthesis report will depend on the number and quality of the individual reports received; and
4. These reports will help form the basis for the development of national observing system plans.

Finally, Dr Westermeyer proposed that a formal request to urge nations to finish their reports as soon as possible be included in the Regional Action Plan to be developed for the region.

General Discussion

The most important issues brought up for discussion by the participants were:

- The major concern regarding the absence of appropriate education. The need for this component was clearly established as an essential capacity building element;
- The need to train properly those in charge of handling data;
- The common concern about the importance of defining the type of climate data needed;
- The need to know the type of monitoring being done in each country;
- The widespread concern regarding the frequency of report requests (participants noted that reports represent an additional workload and that the quality and usefulness of these reports is reduced due to the lack of coordination among sectors);
- The need for capacity building in the use of new technologies, an element that could be included in the Regional Action Plan; and
- Finally, the importance of developing easy-to-understand, clear and concise reports to help government decision-makers and decision-makers in other sectors.

TOPIC 2

ATMOSPHERE: STATUS, DEFICIENCIES, NEEDS

Chairman: Mr Carlos Fuller

The GCOS Surface and Upper-Air Networks in the Caribbean and Central America

Mr Howard Diamond, US GCOS Coordinator and NOAA/NESDIS Representative, presented a lecture on the GCOS Surface Network (GSN) and the GCOS Upper-Air Network (GUAN), looking at the following areas:

- What are they and why are they important?
- How were they developed?
- What do we mean in terms of "best practice" for their operation?
- How are they performing?
- What are the immediate challenges?

The National Climatic Data Center (NCDC), in Asheville, North Carolina, is responsible for building the database, and provides free and open user access to this information via the World Wide Web. Despite the fact that, in September 1999, the WMO Secretary-General issued a request for historical and metadata to all WMO member states, currently the Center manages a database with information from only 250 surface stations in 28 nations.

Finally, Mr Diamond discussed the practices, established by WMO, that states should follow in implementing the observing program at GSN stations. He reminded participants that there is a reference document where they can find the requirements and the observing parameters for all network stations. He urged participants to be concerned with network quality, improve spatial density, and understand the importance of data management.

The WMO-Finnish Project

Mr Steve Pollonais, Director of the Small Island Developing States (SIDS)-Caribbean Project, spoke about the project that the Government of Finland has initiated in the Caribbean in cooperation with the WMO. The project is designed to provide tools to promote sustainable development and to provide information necessary for planning purposes at both the national and regional levels through the strengthening of Caribbean National Meteorological Services.

The project employs strategic interventions in six areas :

- Improvement of the telecommunication systems on national and regional levels;
- Rehabilitation and upgrading of the observing networks;
- Renovation of the regional technical laboratory for the calibration and maintenance of instruments;
- Upgrading database management systems;
- Implementation of data rescue programmes; and
- Training and awareness building.

Mr Pollonais described the work that has been done so far in the region, the difficulties encountered, and the current status of the project.

The following are some of the recommendations made for the Regional Action Plan:

- To support the proposed telecommunications system for the Caribbean;
- To support the European Union Radar project for all Caribbean countries;
- To support and enable database management and database rescue activities in all countries; and
- To urge governments to pay attention to their respective Meteorological Services, both in terms of funding and in the use of meteorological information as a component in the planning process.

Rescuing Historical Data in the Region

Dr Russell Vose, from the National Climatic Data Center (NCDC), Asheville, referred to the importance of historical climate data, particularly for assessing climate variability and climate change. Unfortunately, a large amount of data is not available to the international community.

From this perspective, data rescue has six components:

1. Having a reason to rescue the data;
2. Locating repositories;
3. Acquiring the data;
4. Digitizing it;
5. Assuring its quality and;
6. Making it accessible, free of charge, to the international community.

He referred to the great potential for data rescue in the region and defined and explained some of the methods to achieve this rescue, such as: “from the desktop”, library searches, international workshops, and “field” methods. Once the data have been rescued, data quality must be assessed before distributing it.

General Discussion

- Some nations expressed their concern that not all GSN and GUAN stations submitted for consideration were included in the networks. Hence, they wanted to know how the selection was made and if it was possible to define the necessary parameters.
- Participants from the Caribbean asked about the percentage, in US dollars, that will be allocated to each of the tasks established in the SIDS-Caribbean Project. Even though no amount was disclosed, it was mentioned that there are certain aspects, such as telecommunications, that require more support.
- They also expressed their concern regarding the feasibility of collaboration with national or regional initiatives to meet different needs. In this regard, it was clarified that a survey of projects already running in the region was made to avoid redundancies in efforts. Moreover, other agencies have been sought for support, and the idea is to adopt similar technologies throughout the region. However, it was pointed out that some of the islands might be left behind because, even when it was not intended to exclude anyone, the Government of Finland chose a specific group of islands, probably by taking into account *per capita* income.
- Some participants referred to data property rights and to the fact that acquiring data through different means can "close off avenues" (and this situation was considered difficult to change at the present time).
- Participants were concerned about the lack of staff available for data rescue, and it was hoped that organizations like the WMO and NOAA could offer their support.

TOPIC 3

OCEANS: STATUS, DEFICIENCIES, NEEDS

Chairman: Dr George Maul

IOCARIBE-GOOS: Perspective on status, deficiencies, and needs for ocean observations

Dr Alejandro Gutiérrez, from the National University Oceanographic Laboratory, Costa Rica, explained that IOCARIBE-GOOS is a basic source of information, services and products to support sustainable social and economic development through systematic observations and research on the coasts and seas in the Caribbean region.

The strategic plan includes numerous terms of reference that complement GCOS objectives and provide an opportunity for integration and cooperation. The following are some of the many activities IOCARIBE-GOOS is planning:

- Develop an inventory of observing system capacity and existing structure capacity;
- Establish guidelines for national participation;
- Develop synergies for participation in existing projects;
- Encourage the development of the GCOS project nationally and coordinate with other existing groups;
- Develop marketing and financing plans for project sustainability;
- Evaluate the costs and benefits of implementing the project for discrete user sectors (e.g. tourism, offshore industry, fishing);

- Establish an integrated initial observing system, building on national systems; and
- Identify key gaps in existing observing systems and design plans to fill them.

Design and Operation of Air-Sea Monitoring Systems in Central America and the Caribbean

Dr J. Lee Chapin, Organization of American States (OAS) Regional Network Adviser, referred to the two regional air-sea monitoring systems designed between 1997 and 2001 for Central America and the Caribbean.

The Caribbean system is known as the Caribbean Planning for Adaptation to Global Climate Change (CPACC) and includes 12 countries. The CPACC was funded by the Global Environment Facility (GEF) through the World Bank and executed by the Organization of American States (OAS) Unit for Sustainable Development and Environment (USDE), in partnership with the Caribbean Institute for Meteorology and Hydrology (CIMH) and the University of the West Indies (UWI).

The Central American System, RONMAC (Red de Observacion del Nivel del Mar para America Central), includes four countries. It was funded under the US Agency for International Development (USAID) "Post Mitch" program through the National Oceanic and Atmospheric Administration (NOAA) and executed by the OAS-USDE, in partnership with the Regional Committee for Water Resources (CRRH). Both systems were designed and implemented using the same equipment and procedures.

Dr Chapin gave a review of the systems, methods and lessons learned in both systems. Finally, he talked about the future of these projects and mentioned that currently the CRRH is in charge of RONMAC. He also referred to the need for training, problems with satellite connections, and to other similar systems running in Panama, Cuba, the Yucatan Peninsula, and Venezuela.

Data Applications in the Caribbean – Needs Analysis

Ms Shelley-Ann Jules-Moore, from the CPACC/MACC Regional Archiving Centre, focused on the tidal data collection, including tidal constituents, relative and absolute sea-level rise, and sporadic events.

She referred to the current distribution and capabilities of the CPACC/MACC network, which currently incorporates 18 stations in 12 CARICOM countries. She described the key concerns and deficiencies in the network, such as interruptions in data transmissions resulting from problems with the assigned satellite window, and delays in maintenance and replacement of sensors and the resulting data gaps.

At the end, she mentioned several recommended strategies for overcoming these deficiencies. These included:

- Training and support for local meteorological officers;
- Financial support to improve maintenance efficiency in remote stations; and
- Upgrading the current station configuration.

Data Applications in Central America - RONMAC/LABCODAT Project: Sea-Level Observation in Central America

Mr Jim Navarro, from the Oceanographic Laboratory, Universidad Nacional, Costa Rica, summarized the institutional background and the installation of the sea-level observation system in the Central American region. He began with the 1940s, when the first sea-level records were developed in Costa Rica (for both the Pacific Ocean and the Caribbean Sea) to control geodesic levels in Central America and the Caribbean, and proceeded to the 1990s, when marine-meteorological stations were established in the region.

The RONMAC project was developed as a consequence of Hurricane Mitch. Its main objective is the construction of a marine-coastal network for Central America. Some of the activities mentioned were:

- Installation of stations to measure in each country the sea level and atmospheric and marine variables; and
- Establishment of a coastal meteorological system to send satellite data to ground stations or via radio waves to boats.

Dr Maul, Chairman of this topic, made a presentation on the status, needs and deficiencies related to ocean data. He discussed the way in which data are collected, showed a questionnaire developed to collect this information, and referred to the locations of stations.

Regarding status, Dr Maul mentioned the modernization of coastal marine stations, which have become more precise. On deficiencies, he discussed the urgent need to recover, digitize, distribute, and analyze both data and observations, as well as to establish education and technical training programs. He highlighted several variations between sea surface and atmospheric temperature data trends that do not always coincide. Some of the most urgent needs listed by Dr Maul include:

- Maintaining the existing infrastructure;
- Disseminating knowledge through the creation of a permanent group of international researchers; and
- Installing stations for use in storm surge and tsunami warning.

General Discussion

- The issue of the kind of training given thus far was raised, and the intellectual property right problem was highlighted.
- Some participants asked for clarification regarding the problem of the sporadic discontinuities between sea surface and atmospheric temperature data trends and their analysis for summer data, and whether these always occur at the same sites.

It was proposed to:

- Increase technical capability, particularly in those countries with weak networks, to help them operate more stations and improve their observations;

- Join efforts to achieve a better regional capability; and
- Enhance institutional capability and regional capacity building through training.

TOPIC 4

TERRESTRIAL: STATUS, DEFICIENCIES, NEEDS

Chairman: Mr Oscar Arango

Status and Needs of Hydrological Cycle Observing Systems in the Caribbean and Central America

Mr Kaylas Narayan, hydrologist from the Caribbean Institute for Meteorology and Hydrology (CIMH), referred to the need for hydrological cycle observing systems and pointed out the deficiencies in these networks, especially in the developing world. He observed that the distribution of observing stations is very irregular in the region and mentioned that some of the most important existing problems include:

- Lack of trained personnel;
- Improper and irregular maintenance of equipment; and
- Non-replacement of unserviceable equipment.

Mr Narayan summarized the particular problems in the islands, such as the concentration of population on the coastal belt and the concentration of activities in relatively small areas that impact coastal aquifers, affect water quality and domestic and commercial water supply, and have a general negative impact (in particular, on the tourist trade). He talked about the vulnerability of the islands to the impact of hydrometeorological events and pointed out the lack of national and regional institutional coordination or of integrated water management. Also, he referred to the very serious problem faced by most of the islands where fresh water demand exceeds supply.

He summarized the status of hydrological observing systems in Central America, mentioned some of the existing projects in the area, and discussed weaknesses. The following are some tentative recommendations:

- Develop a minimum set of requirements for hydrological observing systems;
- Formulate a programme to rectify deficiencies;
- Set up a mechanism for data and knowledge exchange within the region;
- Provide continuous assistance to countries; and
- Identify training possibilities.

Carbon Cycle Observations: Measuring Changes in the Carbon Stored in the Terrestrial Ecosystems of Central America and the Caribbean Region

Dr Deborah Clark, from the Department of Biology, University of St. Louis, Missouri, is carrying out research on carbon cycle at La Selva Biological Station, Costa Rica, in relation to the processes that determine the net carbon (C) balance of tropical regions and how this balance is changing. Recent evidence indicates that the terrestrial tropics are strongly influencing the rate of atmospheric carbon dioxide (CO_2) accumulation. She showed a study developed between 1984 and 2000, from the Arctic to the South Pole, that indicates that in certain years very large net CO_2 emissions were produced by the terrestrial tropics as a result of three factors:

1. Land-use change (large-scale deforestation, forest succession, reforestation/afforestation, agriculture and urbanization). These emissions are estimated through high-resolution satellite images. Moreover, it is necessary to know the changes in the amount of carbon stored in the soil under different types of forests and under other land-use types;
2. Variation in the respiration of soil microbes; and
3. Variation in plant net productivity.

Dr Clark mentioned that recent evidence suggests rising global temperatures are changing the balance between photosynthesis (carbon uptake) and respiration (carbon emission) by tropical forests. Moreover, she showed how in hotter years, usually El Niño years, trees grew substantially less and CO_2 emissions from terrestrial forests significantly increased according to atmospheric data. Also, tree mortality in this forest and elsewhere in the tropics, like in the Amazonian region, greatly increased in the 1997/1998 mega-Niño event.

The following are some of her recommendations:

- Measure tropical forest CO_2 flux in both the atmosphere and the soil;
- Join multidisciplinary efforts to study the dynamics of the carbon cycle;
- Increase the number of measurements;
- Upgrade controlling techniques;
- Use remote-sensing for monitoring; and
- Set up an appropriate long-term monitoring system of the carbon cycle in tropical forests.

General Discussion

- The Canadian representative informed participants that they have a complete hydrology-related training package available over the Internet and on CD.
- The inter-institutional coordination problem both at the national and at the regional levels was highlighted.
- The Chairman proposed making a list of the minimum operating requirements for hydrological systems and an inventory of stations needed to optimize network efficiency.
- It was proposed that observing systems undertake other measurements and that priorities of developing countries be taken into account as much as those of developed nations.
- The carbon issue aroused a strong interest among participants who asked many specific questions on the carbon cycle, research, results, impacts, etc. As a general recommendation, it was agreed to emphasize the need to develop concrete research and training programs in the region.

TOPIC 5

VULNERABILITY AND ADAPTATION

Chairman: Dr Max Campos

Observational and Related Requirements for Vulnerability and Adaptation Studies

Dr Max Campos, Secretary-General of the Regional Committee for Water Resources (CRRH) mentioned that the water issue prevails in the agenda of the CRRH and that, for this reason, observing networks are currently given a lot of support so climate variability and climate change studies can be conducted. The information obtained from these studies is used as a tool to estimate vulnerability in the different sectors. Such information helps identify regional trends and extreme events.

Dr Campos summarized the variability and climate-change-related activities developed in Central America, which also include economic and social aspects. As evidence of the vulnerability of the region, he referred to the economic impacts on Central America as a result of extreme events in the last 40 years. He discussed the importance of creating climate scenarios as tools for decision-makers and put emphasis on the development of models and their comparison with observations.

He referred to the status of Central American observing networks and discussed different projects being carried out.

Regional Trends in Extreme Events: The Recent Increase in Atlantic Hurricane Activity

Dr Stanley Goldenberg, from the Hurricane Research Division of NOAA, pointed out that compared with the activity of the previous 24 years, the years 1995-2001 showed the highest level of hurricane activity in the reliable record, as the overall activity for the whole basin was doubled. The greater activity results from simultaneous increases in sea-surface temperatures and decreases in vertical wind shear. He elaborated on some of the effects of the change in Atlantic hurricane activity and portrayed what could be expected in the future, like the increase in Atlantic cyclone activity, which means that more hurricanes are likely to impact the Caribbean, and that more major basin-wide hurricanes might occur.

Finally, he recommended that government officials and emergency managers be aware of the possible impacts and develop appropriate prevention and mitigation strategies. Likewise, he emphasized the need to increase observations through a rawinsonde network in the Caribbean region to provide sufficient input data for numerical models and to enable better forecasts.

CASE STUDIES

The Use of Meteorological Data in Vulnerability and Adaptation Studies in Mexico

Dr Julia Martínez, Climate Change Research Director of the National Institute of Ecology, Mexico, mentioned how important it is for Mexico to study vulnerability to climate change. She referred to the vulnerability studies developed in Mexico in sectors such as agriculture and food supply, health, coastal zones, and industry. She emphasized the need for priority actions related to vulnerability, including:

- Improving data distribution;
- Enhancing technical capabilities to develop preventive measures; and
- Finding financial resources to implement these measures.

Dr Martínez spoke about prevention, mitigation, and adaptation actions taken in Mexico to face climate change.

Impact of Sea-Level Rise on Grenada's Coastal Groundwater Resources

Mr Terrence Smith presented a case study on the impact of sea-level rise in Grenada and on the island of Carriacou, undertaken under CPACC. One of the main goals of the study was to determine the status of groundwater. To do this, a number of aquifer-related parameters were studied (hydro-geological characteristics, recharge, levels, etc.), and different scenarios, at different periods, were created to determine the impact in coastal aquifers. However, the study faced many limitations, such as the lack of bathymetry data and information on groundwater levels, tides, contour maps, etc.

The study, despite its limitations, led to conclude that both islands are highly vulnerable to the potential negative impacts of climate change-induced sea-level rise. The following are some of the recommendations:

- Implement a groundwater monitoring programme;
- Determine the ground level elevations of all boreholes;
- Acquire bathymetry data, increased resolution contour maps and updated software/hardware;
- Undertake biennial test pumping of production wells;
- Build capacity to enhance future vulnerability and adaptation studies; and
- Incorporate the results of the study into National Planning.

To conclude, Mr Smith stated that the GCOS project must not overlook the importance of technical training (skill enhancing) and urged those in charge to emphasize this aspect from the hydrological point of view.

The Use of Data in Climate Change Vulnerability and Adaptation Studies in Agriculture

Mr Carlos Fuller, Director of the National Meteorological Service of Belize, spoke about the project, funded in 1994, to assess the vulnerability in the Central American sectors of agriculture, coastal zones, and underwater resources. This assessment was done with the aid of four global circulation models that simulated future climate conditions. However, due to the physical characteristics and geographical location of Central America, the models could not adequately depict the regional climate conditions. The models predicted an increase in mean air temperature of 2°C, but it was not possible to obtain a definite signal for rainfall, and the group decided to use a +- 10% and 20% change.

With these estimates, eight scenarios were run for the three crops selected for study: rice, beans and corn. The models predicted a decline in yield for all.

The study recommended:

- Development of more heat resistant crop varieties;
- Enhancement of irrigation systems; and
- Expanding climate and hydrological observing networks and enhancing knowledge of soil and crop characteristics.

Scenarios of Climate Change for Vulnerability and Adaptation Studies

Dr Geoff Jenkins, from the Hadley Centre for Climate Prediction and Research, United Kingdom, referred to the climate change scenarios which are developed from global predictions. However, due to resolution problems, not all scenarios are appropriate for evaluating the impact of climate change. For this reason, it is important to develop regional climate models, that is, downscaling from the global to the regional scale, because regional models have a finer resolution and enable better predictions. Among other difficulties, he mentioned that some predictions may be contradictory depending on the scale used, and he gave several examples.

Dr Jenkins also discussed the PRECIS (Providing Regional Climates for Impacts Studies) climate model, designed to provide regional climate predictions for impact studies. It can be set up over any area of the globe, and it is intended to help developing countries undertake vulnerability and adaptation studies. (Afterwards he gave a hands-on demonstration of the model.)

General Discussion

- New technology enables biophysical and other sectoral impact assessments.
- Decision-makers need to handle short-term forecasts.
- It is necessary to make vulnerability assessments in the social, economic, health and water resource sectors, among others.
- National capacities to improve forecasts must be strengthened as a tool for decision-makers.
- Regional political will is reflected in governmental support to Climate Change units and in the introduction of vulnerability and adaptation issues in agendas.
- The subject of adaptation must be included within the Sustainable Development policies of every country.
- Joint efforts between Meteorological Services and other sectors, both at the national and regional levels, must be increased.
- Meteorological Services should consider Climate Change personnel as their customers.
- Information-users from different sectors should make their needs known to their Meteorological Services. In this way, Meteorological Services can adapt the information for each sector and provide them with useful data.
- Along with vulnerability, adaptation and mitigation should be included.
- Water is a top priority issue for the countries of the region.
- The hydrometeorological infrastructure must be improved.
- Education must be included within the Action Plan as a fundamental component in the use of meteorological information.

TOPIC 6

CORAL REEFS AND CLIMATE CHANGE MONITORING

Chairman: Dr Alan Strong

Introduction and Context of Session

Dr Alan Strong, from the National Oceanic and Atmospheric Administration (NOAA), listed the most important topics to be addressed regarding the effect of global climate on the health and development of coral reef ecosystems and, in particular, coral bleaching. He proposed to improve the observation of variables such as:

- Sea temperature;
- Salinity;
- Photosynthetically active radiation;
- Ultraviolet radiation; and
- Wind speeds.

He also recommended compiling information on all physical monitoring endeavours on or near coral reefs to identify gaps or redundancies in effort, as well as creating a bibliography of published work on this issue.

Coral Reef Monitoring – A Regional Perspective

Dr Pedro Alcolado, from the Oceanographic Institute of Cuba, emphasized that coral reef monitoring must be regional because coral reefs may be interconnected at quite large spatial scales. He mentioned the negative impact that climate change has on these ecosystems and that coral bleaching is the most evident impact of climate change on coral reefs. Among other reasons, reefs are very sensitive to increasing sea temperatures, higher CO_2 concentrations, and shallower sea levels. Other coral diseases, including infectious ones, can also be related to climate change. For a better understanding of these processes, Mr Alcolado made the following recommendations:

- Variables, such as sea-surface temperature, surface wind fields, cloud cover, current velocity, solar radiation and ultraviolet light radiation, should be observed more attentively;
- Interaction between oceanographers and meteorologists must be enhanced for a better understanding of sources of impact;
- Developed countries should strengthen the financial support of regional initiatives;
- Governments should be willing to support coral reef monitoring and develop regional partnerships to sustain a regional monitoring system;
- International specialists should collaborate with countries lacking full institutional capacity for coral reef monitoring and data analysis; and
- A periodical report on the status of coral reefs should be strongly supported.

Coral Reef Monitoring – A Satellite Perspective

Dr Strong also presented a new NOAA program for monitoring key indices in coral reefs from space, using Coral Reef Early Warning System (CREWS) towers/buoys. The program intends to provide both early warnings and extended time series of the impact of climate on coral reefs.

Comments and recommendations:

- There is a need to develop a Caribbean Coral Reef Indices page;
- Two Global Environment Facilities projects are underway, through CPACC, to help obtain better monitoring for the Mesoamerican Barrier Reef System, by satellite and *in situ* observations; and
- As demonstrated by 1985-2000 data, sea-surface temperatures are increasing at most sites in the Caribbean, and most notably in the South and East.

Coral Reef Monitoring – An *In Situ* Perspective

This topic was prepared by Dr James Hendee, from the Coral Health and Monitoring Program of the National Oceanic and Atmospheric Administration (NOAA), and presented by Alan Strong, from the same Division. It referred to the fact that the Coral Reef Watch program is installing *in situ* monitoring stations (CREWS), which transmit data hourly, at strategic coral reef areas for purposes of establishing long-term data sets and providing near real-time information products. Dr Strong emphasized the importance of the local maintenance of stations and the calibration of the sea temperature sensor to ensure quality data. These data can then be automatically compared with satellite-monitored temperatures. These stations will also measure wind speed and direction, air temperature, barometric pressure, sea temperature, and salinity.

These were his final recommendations:

- It is important to look for partners in the Caribbean region for monitoring new sites;
- More collaborators are needed to share costs;
- It is necessary to provide maintenance to delicate sensors twice monthly;
- Establishing coral reef monitoring stations fosters technology transfer; and
- Good internet connectivity is required.

Institutional Capacity and National Priorities in Coral Reef Monitoring in Barbados

Mr Andre Miller, from the Coastal Zone Management Unit (CZMU) of the Ministry of the Environment of Barbados, explained that the coral reefs of Barbados have been monitored since 1983 to study extreme events. At the beginning, the project concentrated on water quality because the most significant contributor to coral reef mortality is deterioration in coastal water quality.

Since 1982 to the present, there has been a 40% reduction in abundance and diversity of bank reefs, and over 25% of the coral reefs have been lost (80 million acres). Today, however, those observations are part of the program developed to study climate change effects and mitigation strategies. The most important studied variables are sea-surface temperatures and storm surge. Some of the mitigation actions discussed were coral restoration and transplantation to deeper waters.

Mr Miller emphasized that the program has worked due to the clear vision of its precursors and the support and the technical training it has received. Moreover, there has been an institutional strengthening, and the linkages with governmental and non-governmental agencies have improved.

The Caribbean Planning for Adaptation to Global Climate Change (CPACC)

Mr Ian King, Coordinator of the Information System Unit of the CPACC, Barbados, referred briefly to the CPACC program in relation to coral reef monitoring, as well as to some of the existing problems, including difficulties faced by some countries in undertaking observations and in finding financial support. However, he also mentioned that some institutions are offering their support and that there are potential collaborators who would like to expand monitoring to other islands.

General Discussion

- Participants were interested in the impact of hurricanes on coral reef ecosystems. Increasing sea-surface temperature have intensified hurricanes.
- Other coral reef projects currently being implemented were mentioned (projects related to selecting target sites, coral reef location maps, synoptical monitoring, integrated management of coral reef observations, etc.)
- Sharing experiences was recommended.
- Some efforts are being made to coordinate the availability of coral reef information.

TOPIC 7

PROMOTING COORDINATION

Chairman: Dr Eladio Zárate

Integrating *in situ* and Satellite Observations

Dr Vilma Castro, from the WMO Regional Meteorological Training Centre (RMTC), Costa Rica, spoke about the importance of validating satellite observations and data with *in situ* data. Unfortunately, many Latin-American countries do not receive digital satellite imagery. In the wake of Hurricane Mitch, several projects were developed to provide this technology to Central American countries. High-resolution satellite imagery complements and improves the information from climatological stations. Moreover, it can help in the detection and understanding of climate variability and its consequences.

Her final recommendations were to:

- Improve satellite-imagery products by comparing them with surface observations;
- Improve reception capacity and the use of images and image products in other countries;
- Develop data from satellite images;
- Organize international cooperation with product developing groups;
- Find financial support to repeat Mitch project results in other regions; and
- Establish alliances with research centers.

The Use of Automated Observations for Climate: Challenges and Opportunities

Dr Terry Allsopp, from the Meteorological Service of Canada, presented a chart on the background of observations in Canada, focusing on the automation of networks. Currently, one-third of the network has been automated, and this number increases every day. He mentioned the importance and benefits of automated networks, but also referred to the problems that must be faced, such as operation costs, lack of personnel in distant places, and on-site equipment calibration. He talked about metadata and how fundamental they are for the life cycle of networks.

He concluded that for managing an effective automated observing network it is necessary to:

- Ensure there is a complete understanding of requirements, including the need for real-time observations;
- Develop or adopt a formal change management process that includes a qualification of equipment, algorithms and procedures for the network, and related data management systems;
- Ensure the programme is sustainable, life-cycle managed, to defined standards, and operated by a well-trained, informed workforce;
- Adopt standard autostation configurations to the extent possible;
- Put in place quality assurance and quality control programs; and
- Develop metadata information systems tuned to the needs of those responsible for maintaining the observational programmes as well as the needs of data users.

PANEL DISCUSSION

Two issues were joined for discussion: "Regional Institutions and their Role in Promoting Greater Interaction among Climate Change Coordinators, research institutes, Meteorological and Hydrology Services, and others" and "Discussion of Integration Issues and Institutional Obstacles".

This panel was composed of Mr Selvin Burton (CIMH), Mr Fred Sambula (CMO), Mr Luc St. Pierre (UNEP), and Mr Oscar Arango (WMO).

The following were the most important points discussed:

- Meteorological and Hydrology Services should increase their participation in more actions, beyond the strictly scientific ones, establishing liaisons and working in coordination with other departments and institutions;
- Since GCOS operates under the sponsorship not only of WMO but also of other sponsors, it was suggested that reports should address not only meteorological elements but also include oceanographic and terrestrial observations and networks;
- It was suggested that national GCOS coordinators be established, who could reach out and inform decision-makers and the government, and also to negotiate with banks and other potential contributors;
- A need was identified to address the problem of national integration and interaction; (In this respect, CIMH considered.)
- It was noted that many organizations in the region coordinate activities, and it was suggested that GCOS also coordinate with these groups to help strengthen the institutional framework;
- UNEP recommended more training, information, and coordination meetings, and asked that this recommendation be included in the Regional Action Plan;
- It was suggested that diverse solutions were needed to achieve regional and intersectorial integration and cooperation, taking into account differences between countries;

- It was acknowledged that greater integration would be difficult to achieve;
- It was recommended to include in the Regional Action Plan a review of the functions and constraints of regional institutions;
- It was suggested that, as far as possible, only one institution should handle all the climate-related data in each country;
- It is important to review regional actions and to complement them with the national ones;
- It is important to strengthen the National Meteorological and Hydrological Services so that they can better address national and regional problems;
- It was requested that an education element (training and capacity building) be included in the Action Plan;
- Participants wanted to know more about how to automate networks; and
- It was suggested that Meteorological Services become more involved with standards to share high-quality data.

A Brief Introduction to the Way Forward (Goals for Day 3)

Dr Alan Thomas, GCOS Director, mentioned some important aspects for participants to take into account to carry through the third day of the meeting to a successful conclusion. He asked participants to:

1. Make recommendations and to reach agreement on some decisions;
2. Define regional requirements more specifically;
3. Address the problems of the region and propose solutions in top priority areas; and
4. Consider the makeup of a team to draft the Regional Action Plan.

He presented possible actions to take in different observing system domains based on the presentations and discussions of the first two days of the meeting:

- **Atmospheric Observations:**
  For surface and upper-air observations: upgrade, maintain, and give priority to regional networks; recover and digitize historical data; improve communications; define training, education, and capacity-building needs.

- **Oceanographic Observations:**
  Expand the network of tide gauge and sea-level stations within the region; improve infrastructure; increase observed variables; upgrade the current sea-level station configuration; provide support to improve maintenance efficiency in remote stations; improve data availability; improve communications; define training, education, and capacity building needs.

- **Terrestrial Observations – Hydrology:**
  Undertake an inventory of stations and then readjust networks to optimize them; set up mechanisms for exchange of hydrological data and for more effective coordination; determine a minimum set of requirements and guidelines for hydrological observing systems; define deficiencies in each country; recover and digitize data; define training, education, and capacity building needs.

- **Carbon Observations:**
  Undertake annual tropical forest growth measurements; expand observations with remote sensors; develop a program to monitor carbon in soil; define training, education, and capacity building needs.

- **Data Needs for Vulnerability and Adaptation:**
  Maintain an adequate rawinsonde network in the Caribbean; implement a groundwater monitoring programme; undertake capacity building to enhance future vulnerability and adaptation studies, including training in computer modelling.

- **Coral Reefs:**
  Support long-term integrated monitoring.

- **Satellites:**
  Improve products derived from satellite images;
  Improve the capacity of image reception; and
  Acquire equipment and training.

TOPIC 8

THE WAY FORWARD

Resource Mobilization Issues Panel

Participants: Dr Alan Thomas, GCOS Director, Dr Bruce Angle, Meteorological Service of Canada, Mr Alejandro Deeb, World Bank, and Mr Yamil Bonduki, UNEP.

The following is a summary of the important points raised in this panel:

- The World Bank, with its strategy to fight poverty, is willing to support certain climate change-related activities, but support of observations has not been a priority;
- It was noted how difficult it is to convince decision-makers and donors to support projects to improve networks;
- There are other organizations in the region, besides banks, that finance climate-change-related projects;
- It was recommended that the messages from this meeting be communicated to politicians and other decision-makers at the regional and global levels;
- Decision-makers must be sensitized to the importance of observations if adequate funding is to be mobilized for improving observing systems;
- The problem of data collection is not on the agendas of organizations that could provide funds; and
- It was suggested that a strategy to identify needed resources should be included in the Regional Action Plan.

Planning the Way Forward: Introducing a Framework Action Plan for the Region

Presented by Dr Desmond O'Neill

Summary

- A Regional Action Plan must include solid recommendations to meet the needs that were identified during the workshop sessions;
- Future results will depend on the details included and the quality of the document; and
- The Plan must reflect a high level of commitment to improving observations and participation at the regional level.

The following general outline is suggested for the draft:

- **Introduction:**
  GCOS Background
  The Regional Context

- **Presentation of the Plan:**
  1. Chapter explaining the current status of observational networks (atmospheric, oceanographic, terrestrial, and other networks and systems, such as remote sensors);
  2. Chapter detailing the current status of the regional GCOS infrastructure (including identification of needs); and
  3. Chapter including specific proposals to respond to both GCOS requirements and regional needs in relation to the different observing systems. Such proposals could complement existing initiatives or develop new ones in the region; support local and regional capabilities; address data accessibility and management, etc.

- **Concluding Remarks**

- **Appendices:**
  Maps, networks, etc.

WORKSHOP CONCLUSIONS

As is evident from the preceding sections of this report, the San José workshop contributed very substantially to the development of a regional GCOS Action Plan for Central America and the Caribbean. The workshop presentations and discussions not only highlighted important issues that need to be addressed if the region is to contribute effectively to GCOS but also drew forth concrete suggestions and recommendations for actions to rectify shortcomings in the region's observational, data management and data access capacity. The following paragraphs provide a condensed summary of the needs, suggestions and recommendations identified by workshop participants. These have been grouped under several broad categories or areas of focus.

Public and Political Profile

Workshop participants identified a need to enhance the profile of climate data and to broaden policy and decision-makers' appreciation of the importance of systematic observations of the climate system, highlighting the fact that high-quality observational data are fundamental to informed decision-making. Specific suggestions directed towards achieving these objectives were as follows:

- Demonstrate real uses of climate data as an effective means of sensitizing decision-makers to their importance;
- Utilize the mechanism provided by the UNEP Secretariat (with its three regional protocols) to increase the visibility of climate data with national governments;
- Take advantage of the 2003 WMO Day Theme "Our Future Climate" and of the WMO Voluntary Cooperation Program Theme "Systematic Observations" to demonstrate the fundamental importance of climate monitoring;
- National Climate Change Coordinators should highlight the importance of climate system observations across government agencies; and
- Climate Change Coordinators and Meteorological Services should work together and jointly approach their governments.

Capacity Building

Workshop participants considered that building technological and human capacity was a fundamental priority for the region. They identified the following specific needs and suggestions:

- There is a need to address and rectify the uneven state of technological development across the Central America-Caribbean region;
- There is a need to undertake coordinated regional action to address training/education needs, establishment of regional data centres and the challenge presented in mobilizing resources;
- Reliable telecommunications networks are needed to acquire and relay satellite data;
- There is a need to develop alliances with satellite research centres, acquire PC's and other equipment and train people in satellite data analysis and application;
- There is a need to address a key regional deficiency in expertise in operation and maintenance of equipment at sea-level observing stations;
- There is a need to train people to undertake the very demanding measurement and analysis of carbon in soils and vegetation;

- There is a need to develop regional expertise in vulnerability and adaptation work;

- Designing regional observational networks to capture regionally-important climatic features is a MUST;

- In developing the regional component of GCOS we should seek to collaborate with other regional and national initiatives;

- The region must build consortia, look for a consortium of donors; access GEF funds in developing plans and seek World Bank support;

- Advantage should be taken of the opportunity provided by the upcoming World Summit on the Information Society (sponsored by the International Telecommunication Union) to substantially enhance telecommunications capacity in the countries of the region.

Coordination

Improving coordination at both national and regional levels was seen by workshop participants as being critically important. Specific suggestions for achieving such improvement were as follows:

- Encourage the establishment of coordination mechanisms spanning all components of the climate system and all user groups;

- Establish a framework to coordinate across all three components of the climate system, starting at the national level. National-level coordination should be part of a Regional GCOS Action Plan;

- Regional archiving centres are needed for observations of the climate system and these should be established; and

- Meteorological Services should work closely with National Climate Change Coordinators in addressing climate issues. The Services should regard the Coordinators as customers and find out what they need to support negotiations.

Atmospheric Stations and Networks

As discussed earlier in this report, a number of issues and shortcomings exist with respect to atmospheric observations and networks. To address these, the following specific suggestions and recommendations were made:

- We must find out why individual GSN stations are not reporting regularly and correct these situations;

- We must ensure that GUAN stations undertake 2 flights per day and relay their data on the GTS in a timely manner;

- We must ensure the long-term continuity of GCOS observing stations;

- As a first priority, we must complete an inventory of observing stations in the region then assess the network and take action to fill network gaps by addition or relocation of stations;

- At least one Climate Reference Station should be established in each country in Central America;

- Maintenance of an adequate radiosonde network in the Caribbean is essential to support hurricane forecasting and this must be supplemented by satellite and aircraft observations and global SST data;

- Regional bulk buys of radiosondes should be implemented and cooperative maintenance and sparing systems established in order to achieve reduced costs and increased efficiency;

- It is essential to harden observing stations against hurricanes;

- Data rescue should be pursued, including seeking out observational records from private sector sources such as banana and railroad companies;

- Meteorological services should be involved in regional agricultural studies and meteorological stations established in farming areas;

- Satellite reception and application capacities in the region must be improved including improving algorithms by using surface observations;

- There is a need to develop satellite-based climatologies for the region;

- Application of weather radar for estimation of precipitation should be pursued in the region; and

- The vital importance of metadata must be emphasized as being essential to data quality assurance/quality control needed for climate change detection.

Ocean Stations and Networks

Ocean observation stations and networks in the region require increased emphasis. The following needs and suggestions were identified in relation to the oceans:

- Efforts must be made to heighten national interest in monitoring the oceans;

- Implementation of an Integrated Observing System (IOS) for IOCARIBE GOOS must be pursued aggressively;

- Additional, modern, tide gauges are needed in Belize, Guatemala, Honduras, Nicaragua;

- A small network of buoys should be installed in the Pacific Ocean to the east of the international observing network;

- A priority should be placed on reactivation of non-operational sea-level stations and on making the data available to users;

- Sea-level observing stations must be hardened against hurricanes;

- Spare parts and tools and trained technicians are needed to maintain automatic stations in the region;

- It is necessary to correct timing problems for satellite transmissions from automatic CPACC/RONMAC automatic sea-level stations;

- There is a need to acquire a portable Global Positioning System (GPS) for regional use and to train a regional GPS crew;

- A tsunami warning/monitoring capability must be established in the region;

- Development of country-driven observational programs for coral reefs is recommended;

- Cooperation should be enhanced between the atmospheric and oceanographic communities in addressing bleaching of coral reefs;

- Observational information on land movement is needed to determine sea-level rise;

- There is a need to process sea-level data at a regional centre and put it on-line; and

- There is a need to translate reliable high-quality oceanographic data into decision-making information.

Terrestrial Stations and Networks

Systematic observations of terrestrial parameters are clearly essential to understanding and predicting the behaviour of the climate system and its impacts. The following needs and suggestions were identified with respect to hydrology and the carbon cycle:

1. Hydrology

   - A development program must be pursued for hydrological monitoring in individual countries;

   - A requirements statement and guidelines for hydrological observing stations should be developed;

   - The WHYCOS program should be supported and specific CARIB-HYCOS recommendations included in a Regional GCOS Action Plan;

   - Coordination must be improved both between national agencies and between national and regional institutions where hydrology is concerned. To this end, we must establish national and regional mechanisms for coordination and information exchange with respect to hydrological stations and networks;

- Problems related to continuity and maintenance of hydrological stations must be resolved;

- Additional hydrological monitoring stations should be installed in the eastern part of Nicaragua where the greatest rainfall occurs;

- Data from hydrometeorological networks operated by power and energy companies in some countries should be acquired and made available;

- It is necessary to geo-reference wells, undertake groundwater measurement programs and model salt water intrusion in Caribbean nations (e.g. Grenada);

- Data rescue should be undertaken for hydrological data including seeking out records held by private companies;

- Hydrological gauging stations must be selected and protected over the long term in order to understand the basic hydrology of countries/regions; and

- Observations must be acquired of non-standard hydrological parameters related to aquifer characteristics and groundwater regimes.

2. Carbon Cycle

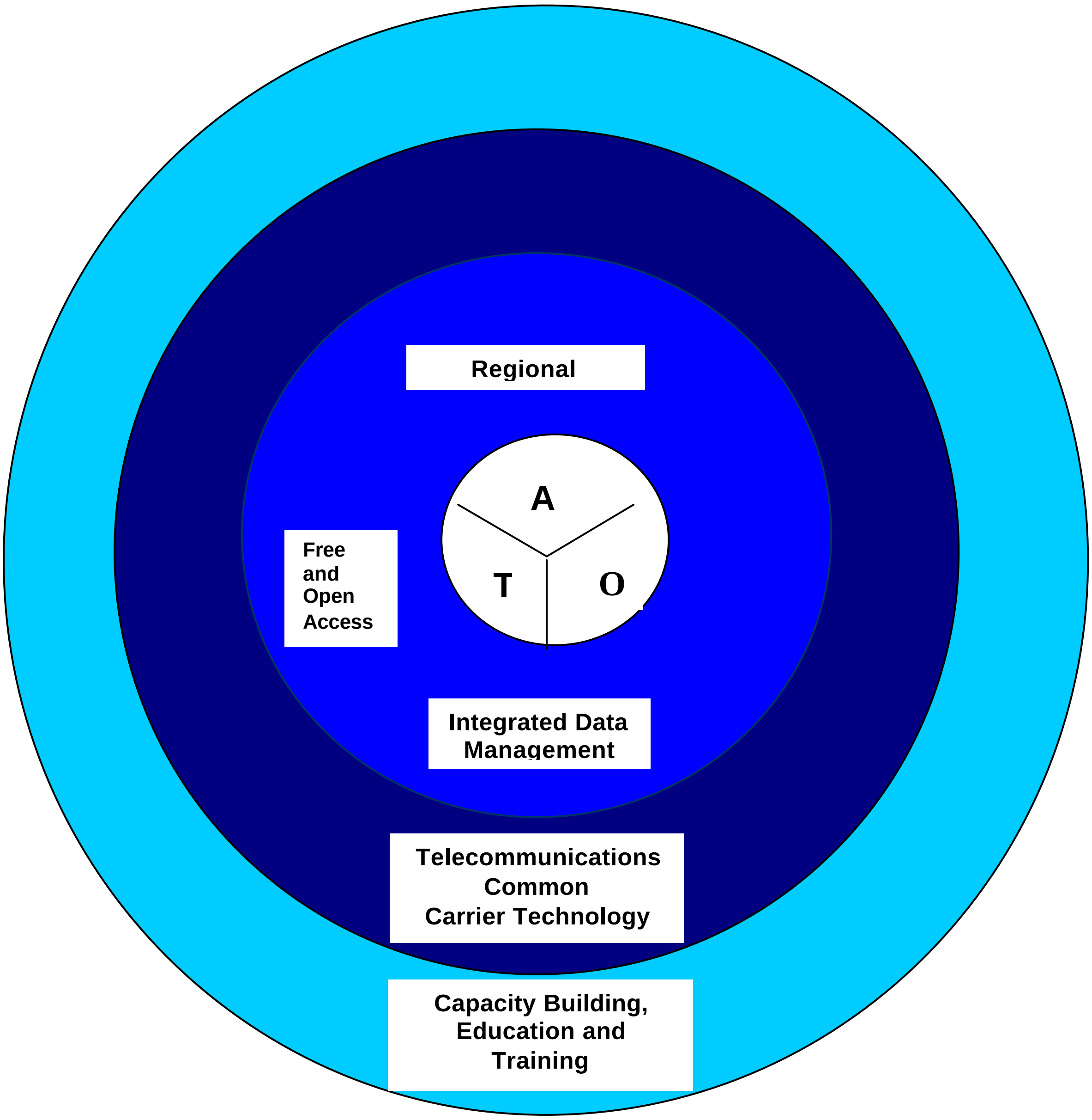
The vital importance of regional soils and forests in the global carbon cycle was emphasized during workshop presentations and discussions. In this context, specific recommendations were that:

- Land-use changes should be monitored over the long term by means of satellite observations;

- Annual measurements should be made of tree growth in old growth forests; and

- Soil carbon should be measured at a number of sites in the region and the long-term changes in soil carbon should be monitored.

In conclusion, the preceding observations and suggestions reflect a comprehensive understanding of regional realities, needs and requirements, representing the collective knowledge and insight of experts from the countries of the Central America/Caribbean region who participated in the San José workshop. They will unquestionably be of great assistance to members of the writing group engaged in drafting a Regional GCOS Action Plan. An effective, readily implemented, Regional GCOS Action Plan must, however, not only capture and address the identified needs and recommendations but do so within a coherent and easily-understandable framework. The diagram below illustrates a proposed conceptual framework discussed at the workshop. Against a backdrop of the atmospheric, oceanic and terrestrial components of the climate system, it groups issues and needs into broad categories within rings intended to represent the time frames (time increasing with increasing radius) within which substantial progress might be achieved in addressing the corresponding issues. This pictorial model may also be helpful in sequencing implementation actions and targeting achievement of specific goals within a Regional GCOS Action Plan.



At the end of the workshop, participants endorsed the drafting of an Action Plan for the Central America/Caribbean region. After the close, a writing team was selected to draft the Plan. Mr Carlos Fuller of Belize consented to chair this team. It is expected that the draft plan will be ready for circulation throughout the region for comment by July 2002 and that a regionally-approved plan will be in place by the end of the year.

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Annex I

THE GLOBAL CLIMATE OBSERVING SYSTEM IN CENTRAL AMERICA AND THE CARIBBEAN
--OBSERVING CLIMATE FROM WEATHER EXTREMES TO CORAL REEFS--

Costa Rica, March 19-21, 2002

Agenda

DAY 1

0900-0945	Opening Ceremony Carlos Fuller, Vice President WMO RA-IV Ligia Elizondo, UNDP Resident Representative Alan Thomas, Director, GCOS Elizabeth Odio Benito, Vice President, Costa Rica and Minister, Environment and Energy Ministry
Theme 1	**Setting the Context** **Chair: Patrick Jeremiah**
0945-1015	Overview of GCOS and its mission and the purpose and expected outcomes of the workshop - Alan Thomas
1015-1045	Break
1045-1115	A regional perspective on climate observations and user requirements: Why improved observations are needed in the region (extreme events, vulnerability & adaptation, sea-level rise, etc.) – Michael Taylor
1115-1135	National reporting on systematic observations to the UNFCCC – Bill Westermeyer
Theme 2	**Atmosphere: Status, Deficiencies, Needs** **Chair: Carlos Fuller**
1135-1205	The GCOS surface and upper-air networks in the Caribbean and Central America – Howard Diamond
1205-1230	The WMO-Finnish project -- Steve Pollonais
1230-1400	Lunch
1400-1430	Rescuing historical data in the region – Russell Vose
1430-1510	Discussion of atmosphere theme priorities; recommendations
Theme 3	**Oceans: Status, Deficiencies, Needs** **Chair: George Maul**
1510-1540	IOCARIBE GOOS perspective on status, deficiencies and needs for ocean observations – Alejandro Guttierez
1540-1600	Break

1600-1650	The CPACC/MACC and RONMAC observation programs and their integration into GCOS --Design and operation of stations -- Lee Chapin --Data applications in the Caribbean -- Shelley Anne Jules-Moore --Data applications in Central America -- Alejandro Guttierez --Recovery of Historic Central America Sea-Level Data -- Jim Navarro
1650-1730	Discussion of ocean theme priorities; recommendations
1730	Adjourn
1900-2000	Evening reception

DAY 2

Theme 4 Terrestrial: Status, Deficiencies, Needs Chair: Eladio Zarate

0830-0900	Status, Deficiencies and Needs of Hydrological Observations for Climate – Kailas Narayan
0900-0930	Discussion of hydrology priorities; recommendations
0930-1000	Carbon cycle observations – Deborah Clark
1000-1030	Discussion of carbon cycle priorities; recommendations
1030-1100	Break

Theme 5 Vulnerability and Adaptation Chair: Max Campos

1100-1120	Observational and related requirements for vulnerability and adaptation studies –- Max Campos
1120-1140	Regional Trends in Extreme Events – Stanley Goldenberg
1140-1200	Case studies on the uses of data in V&A studies --The Mexican experience -- Julia Martinez --Impact of Sea-Level Rise on Grenada's Coastal Groundwater Resources – T. Smith --Climate change and agriculture -- Carlos Fuller --Introduction to scenarios of climate change for V&A studies -- Geoff Jenkins
1200-1245	Discussion of needs for V&A studies; improving interaction between climate change coordinators and meteorological services
1245-1400	Lunch

Theme 6 Coral Reefs and Climate Change Monitoring Chair: Al Strong

1400-1410	Introduction and context of session -- Al Strong

1410-1430	Coral Reef Monitoring— A Regional Perspective -- Pedro Alcolado Menendez
1430-1450	Coral Reef Monitoring— A Satellite Perspective -- Al Strong
1450-1510	Coral Reef Monitoring--An *In Situ* Perspective -- Jim Hendee (presented by Al Strong)
1510-1530	GEF World Bank Program for Supporting Coral Reef Monitoring in the Region -- Marcia Creary
1530-1600	Panel Discussion of Coral Reef Monitoring Priorities for the Region (i.e., IGOS Sub-Theme Discussion)
1600-1615	Break
Theme 7	**Promoting Coordination** **Chair: Oscar Arango**
1615-1640	Integrating *in situ* and satellite observations – Vilma Castro
1640-1700	The use of automated observations for climate: challenges and opportunities -- Terry Allsopp
1700-1730	Regional institutions and their role in promoting greater interaction among NMHSs, climate change coordinators, research institutes, and others – panel composed of heads of institutions; beginning with brief (i.e., 5 minute) presentations
1730-1800	Discussion of integration issues and institutional obstacles
1800-1805	A brief introduction to the way forward (Goals of Day 3) – Alan Thomas
1805	Adjourn

DAY 3

Theme 8	**The Way Forward**
0830-1000	Resource mobilization issues panel -- Representatives of national and international organizations
1000-1030	Planning the way forward: Introducing a framework Action Plan for the region - Chair: Desmond O'Neill
1030-1100	Break
1100-1215	Sub-group discussions on framework Action Plan
1215-1400	Lunch
1400-1530	Plenary discussion of framework Action Plan
1530-1600	Break

1600-1630 Next steps and timetable

1630 Closing ceremony

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Within 6 weeks: Draft Action Plan by Working Group

A small group will convene to finalize the Action Plan for the region. The group should comprise about 10 people, with a balance of representation between meteorological service directors and climate change coordinators, among observing system domains, and between Central American and Caribbean countries. The chairman will guide the group in further developing the "framework" Action Plan introduced and revised at the workshop.

Annex II

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Annex III

GCOS ACTION PLAN OUTLINE

Foreword - "Implementing the Plan of Action"

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Why improved global observational networks are needed
- deterioration of networks - link to regional situation[1]
GCOS objectives
GCOS Climate Monitoring Principles
GCOS structure, sponsoring institutions and global networks
GCOS contribution to national/regional capacities

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Description of the region/unique aspects
Its climatic features
Their global significance
Regional climate needs/issues
Status of GCOS implementation in region
Other planned/current observational projects/initiatives
The need reinforce synergy between GCOS initiatives and other projects

1.3 The Purpose of the Plan

Address GCOS requirements
Respond to regional needs – be user driven
Encourage coordination/synergy between observational initiatives
Provide a rational framework for implementation actions

1.4 The Structure of the Plan

Brief overview of structure

2. THE CURRENT STATUS OF OBSERVATIONAL SYSTEMS IN THE REGION

Introductory overview comments – brief
General state of networks in region

[1] Ref. 1998 Report to UNFCCC re Adequacy of Global Climate Observing Systems.

Highlight various international capacity building efforts – completed, in progress or planned (WMO, GEF, OAS etc) drawing attention to synergies
Lead-in to subsequent sections

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The GSN
Status of network implementation – regional components
Performance monitoring - quality/timeliness
Sustainability of network
Data Management - hardware, software, QA/QC systems/procedures, archival systems, data access, data rescue activities (provision of historical GSN data and metadata)
Communications - existing systems/networks, performance, sustainability
Training/Education/Capacity building
Issues
Any initiatives underway to address issues(domestic/externally funded)

The GUAN
Status of network implementation – regional components
Performance monitoring - quality/timeliness
Sustainability of network
Data Management - hardware, software, QA/QC systems/procedures, archival systems, data access, data rescue activities
Communications - existing systems/networks, performance, sustainability
Training/Education/Capacity building
Issues
Any initiatives underway to address issues (domestic/externally funded)

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Sustainability of networks
Data Management - hardware, software, QA/QC systems/procedures, archival systems, data access, data rescue activities
Communications - existing systems/networks, performance, sustainability
Training/Education/Capacity building
Issues
Any initiatives underway to address issues (domestic/externally funded)

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GTOS
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Training/Education/Capacity building
Issues
Any initiatives underway to address issues (domestic/externally funded)

Overall Assessment
Prioritization of issues

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Issues
Any initiatives underway to address issues (domestic/externally funded)
Synergies

Overall assessment
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3. REGIONAL GCOS INFRASTRUCTURE

Current status
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Actions already underway (if any) to address needs

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Introductory remarks – brief

Plans - build on/complement initiatives already underway or planned
- respond to GCOS requirements and regional needs
- time-phased to facilitate implementation and optimize value
- costed (preliminary) – to facilitate access to funding mechanisms
- implementation will significantly enhance regional capacity

4.1 **GCOS Infrastructure**

Coordination
Opportunities for efficiencies
Regional capacity building

Time frames
Implementation Costs
Operating Costs

4.2 **The Atmosphere**
GSN
GUAN
Data management, communications
Synergies/complementarity with existing initiatives (domestic/external)
Time frames
Implementation Costs
Operating Costs

4.3 **The Oceans**
GOOS
Other systems
Coral reefs
Data management, communications
Synergies/complementarity with existing initiatives (domestic/external)
Time frames
Implementation Costs
Operating Costs

4.4 **Terrestrial Systems**
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Forestry networks
Soils networks
Ecosystem monitoring
Data management, communications
Synergies/complementarity with existing initiatives (domestic/external)
Time frames
Implementation Costs
Operating Costs

5. CONCLUDING REMARKS

Brief summary of what document contains
Next steps – seek funding, proceed with implementation

SELECTED REFERENCES

APPENDICES

- Map of region
- List of National GCOS Coordinators
- Members of Regional GCOS (Implementation) Committee
- Map of relevant atmospheric networks
- List of GSN, GUAN stations
- Map of relevant ocean networks

- List(s) of ocean stations
- Map of relevant terrestrial networks
- List(s) of terrestrial stations (e.g. Carbon Flux)

- Summary Tables for Individual Plan Elements – GCOS Infrastructure, Atmosphere, Oceans, Terrestrial

- Roll-up Summary Table with Costing and Timing.

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Annex IV

QUESTIONNAIRE ON OBSERVING SYSTEMS FOR CLIMATE

Purpose of the questionnaire

The Conference of the Parties to the UN Framework Convention on Climate Change has invited the Parties to the Convention to submit national reports on the status of their observing systems. Although voluntary for developing countries, GCOS considers these reports especially important for these countries and an opportunity to reach high-level policymakers. The following questionnaire has three purposes: first, to help workshop participants begin to focus on compiling the information that will be the basis for national reports to the UNFCCC; second, to prepare workshop participants to actively participate in the workshop; and third, to provide basic information that can be used after the workshop in the development of a regional observing system Action Plan.

Questions pertaining to the status of observing systems

Meteorological

1. If your country has already prepared a national report, could you bring this to the workshop? Otherwise, could you complete Table 1 in the UNFCCC Guidelines? How many GSN and GUAN stations are located in your country? What is the operating status of each of these stations?

2. If requested GSN and GUAN observations are not currently being received by monitoring centers, what is the nature of problems in making and/or transmitting these observations?

3. If your country has not already done so, what are the plans for furnishing historical GSN data and metadata to the National Climatic Data Center in line with the request from the WMO Secretariat in September 1999?

Oceanographic

4. How does your country contribute to oceanographic observations? For example, with respect to sea-surface temperature, sea level, temperature and salinity profiles, etc., what type and how many of each type of platform does your country operate? If you have completed Table 2 of the UNFCCC Guidelines, please bring it with you.

5. What problems, if any, do you have operating these platforms?

Terrestrial

6. What observations does your country contribute to terrestrial networks, and, in particular, to hydrology and carbon networks? If you have completed Table 3 in the UNFCCC Guidelines, please bring it with you. What other terrestrial programmes are in place or are being contemplated that contribute to observational needs for climate?

7. What problems do you have or foresee related to making terrestrial observations?

Space-based
8. In what ways are you participating in space-based observing programmes? Do you utilize observations from satellites? If so, in what ways? How are these observations received? In what other ways do you participate in space-based programmes?

General
9. If your organization does not have direct access to the information required to answer the above questions, which organizations in your country do have this access? How can we, and you, communicate with these organizations?

<u>Questions pertaining to needs of users</u>

1. What is your judgment of observational needs for monitoring local climate change, for example, in view of the issue that accurate predictions will be difficult without verification?

2. What observations would be valuable for your needs that are not now being made?

3. How useful is the available data for developing regional climate change scenarios? How could it be improved?

4. How useful is the available data for vulnerability and adaptation studies? What additional data are needed?

5. What capacity building needs do you have? What capacity building needs do you see elsewhere that need to be met?

6. What advice do you have for improving interaction between generators and users of climate data?

The UNFCCC Reporting Guidelines as well as explanatory notes on the Guidelines that GCOS has prepared can be found at http://www.wmo.ch/web/gcos/gcoshome.html. At the site, click on "GCOS and the UNFCCC" and then scroll to below the heading "GCOS Regional Workshops."

Annex V

THE GLOBAL CLIMATE OBSERVING SYSTEM AND THE GCOS REGIONAL WORKSHOP PROGRAMME

Alan Thomas
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Mission of GCOS

The Global Climate Observing System (GCOS) was established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. It is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU). GCOS is intended to be a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modelling and prediction of the climate system. It addresses the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, hydrologic, cryospheric and terrestrial processes. Although GCOS does not make observations or generate data products itself, it however stimulates, encourages, coordinates and otherwise facilitates the taking of the needed observations by national or international organizations in support of their own requirements as well as of common goals.

Purpose of the Workshop

The United Nations Framework Convention on Climate Change (UNFCCC) has recognized the importance of research and systematic observation. Further its Conference of the Parties (COP) has noted that high quality data for climate-related purposes is not available in many instances due to inadequate geographic coverage, quantity and quality of the data produced by current global and regional observing systems. Most of the problems occur in developing countries, where lack of funds for modern equipment and infrastructure, inadequate training of staff, and the high costs of continuing operations are often the major constraints. Decision 5/CP.5 in 1999 invited the Secretariat of the Global Climate Observing System, in consultation with relevant regional and international bodies, to organize regional workshops to facilitate improvements in observing systems for climate. The central goals of the GCOS Regional Workshop programme are:

- To assess the contribution of the region to GCOS baseline networks;
- To help participants understand guidelines for reporting on observations to the UNFCCC;
- To identify national and regional needs and deficiencies for climate data (including needs for assessing climate impact and conducting vulnerability and adaptation studies; and
- To initiate the development of Regional Action Plans for improving climate observations.

Expected Outcome

The GCOS Regional Workshop for Central American and the Caribbean is designed to help participants identify deficiencies in climate observing systems and to focus their attention on developing a regional strategy to address priority needs for observing systems. Given the strong recognition by the UNFCCC Conference of the Parties (COP), a substantial opportunity now exists to obtain the support of the Parties to make much needed improvements in observing networks that will benefit not only the global concerns of COP but also national and regional purposes. GCOS would like to see participants agree to develop a regional strategy—a Regional Action Plan—that identifies high priority observing system needs for the region and that can be used as the basis for seeking funding to address these needs. The first steps in developing such a plan can be taken at this workshop, and a draft version of the plan could be prepared for circulation throughout the region by May 2002. With resources limited both nationally and internationally, a regional plan for improving observing systems is practical, achievable, and we believe, fundable.

Annex VI

A REGIONAL PERSPECTIVE ON THE IMPORTANCE OF IMPROVED CLIMATE OBSERVATIONS TO THE CENTRAL AMERICAN AND CARIBBEAN REGION

DATA COLLECTION – A WAY FORWARD

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Climate and climate related research within and about the Central America and Caribbean (CAC) is arguably at a crossroads. Though the region for some time lagged behind the developed world with respect to interest in and knowledge about climate and climate related events, within the last two decades there has been the emergence of a vibrant "Central American and Caribbean culture of climate-related thought" rooted in the uncoordinated but persistent efforts of many to explore contextually relevant areas of climate variability and the climate change debate. Evidence of this culture of thought includes: (i) a burgeoning cadre of regional expertise (ii) expanding research on climate and climate related issues being done within and about the region (iii) the emergence within the CAC of scientific departments, schools, research groups, think tanks, and a myriad of acronymed governmental and non-governmental organizations with an environmental or climate focus, and (iv) the routine use of climate related jargon ("ENSO", etc.) in the parlance of CAC politicians, policy and decision-makers, and the average man.

The result has been a growing interest in and awareness of climate variability and climate change issues particularly beyond the scientific boundaries – an interest which has been further fuelled by the realisation that climate variability and change directly impacts people in all sectors of society. With this awareness however comes the challenge to those driving the thought-movement to provide answers to locally relevant and pertinent climate-related questions. The ability to answer such questions to a large extent hinges on the availability of regional datasets of climate related variables, with the absence of good quality, easily accessible, well distributed, long time series of station data proving a limitation to attempts to address many of the climate issues of the CAC region. In a real sense then, the maintenance and fostering of the CAC climate thought process is rooted in the unearthing, maintaining and improving of local data reserves - data representing an essential means for moving beyond the crossroads.

What then are some of the questions being asked and how would improved climate observations in the CAC region assist in answering them?

Question 1: Is there evidence of climate change in the CAC region?

Climate warming has resulted in the global mean surface temperature rising by 0.4-0.8^{o}C since the second half of the 19th century, and a global average sea-level rise between 0.1 and 0.2 metres during the 20th century. Analyses of mean daily maximum and minimum temperatures also suggest a reduction in the diurnal temperature range, with minimum temperatures increasing at about twice the rate of maximum temperatures over the second half of the 20th century. Utilising climate models under various emission scenarios, the consensus projections for the CAC region include average increases over much of Central America ranging from 0.8^{o}C for the year 2010 to 3.3^{o}C for the year 2100, with similar increases in temperature over the Caribbean region. Projected changes in precipitation vary widely over the CAC region with model choice and modelling scenarios.

The detection and confirmation of climate change within the CAC region requires the assembly of high quality local observations spanning appreciable time periods. In many cases such records currently exist but must be quickly salvaged from rapidly decaying sources, while maintenance of the current observation sites is essential for validating future projections. Analyses to date do provide evidence of climate change within the region: a noted 0.4^{o}C increase every 10 years for the continental central valley areas of Costa Rica (1957-1997); an increase in both maximum and minimum temperature over the last 40 years in the Caribbean. Since high quality climate data is also the underpinning of the climate models, satisfaction of the basic need for more observations with better coverage and higher accuracy will also ensure more realistic and accurate climate projections for the region.

Question 2: Why is this year's climate so different from last year's?

With the CAC region uniquely positioned, there is considerable influence by both the tropical Pacific and tropical Atlantic oceanic basins on the climate of the region. Observed regional climatic variations are therefore associated with variability ranging from interannual to decadal timescales in the two oceanic basins. Some evidence of this includes:

- The tendency toward drier conditions in the Caribbean during the latter half of the mature El Niño year, with wetter conditions in the early half of the year of El Niño decline.
- An alteration of rainy season onset and end dates for Central America due to an interplay between the tropical Pacific and tropical Atlantic.
- The link between the occurrence of more intense hurricanes plying the tropical Atlantic and a multi-decadal oscillation in the Atlantic sea-surface temperatures.

Local climate and oceanic records over the last half century were essential to the development of an understanding of the oceanic and atmospheric circulation patterns and oceanic-atmospheric interactions that cause regional climate variability. Local data reserves were also essential for confirming 'local intuition' about relationships between global climatic fluctuations and local climate. The challenge then is to ensure a continuous stream of climate data by maintaining and restoring disappearing monitoring sites, so as to increase further our understanding of the factors impacting local climate variability. In addition, general circulation models of global climate have proven useful tools for uncovering natural climate variability and providing dynamical linkages between them and local climates. The verification and validation of these models are dependent on well distributed accurate climate observations.

Question 3: What is the likelihood of a good rainfall season this year?

The analysis of observed data has to date provided the scientific underpinning for the development of seasonal outlooks for the Caribbean and Central American region. As suggested previously the records have been used to identify relationships between regional climate variability and major global climatic fluctuations (ENSO, etc.) which are then translated into statistical predictive models. As an example of their subsequent use it is noted that the results of such models have been the subject of annual regional Climate Fora (separate fora for the Caribbean and Central America), which are held to produce two to three month temperature and precipitation outlooks for the respective regions. In the Caribbean the seasonal outlooks are updated at two monthly intervals and posted on a web site for general viewing. The combination of real time climate monitoring, satellite global monitoring of sea-surface temperatures and other climate variables, and tethered ocean observations (e.g. PIRATA) provide critical input for the seasonal climate prediction models. Such seasonal climate forecasts enable policy makers to take effective action to mitigate climate hazards, and take advantage of climatic opportunities as they arise.

Question 4: How can knowledge of climate variability benefit me?

In the Caribbean islands, 50% of the population lives within 2 km of the coast, with much of the critical infrastructure (social services, airports, tourism facilities, vital utilities) also located near the shoreline. In the CAC region in general, many of the economies of the developing nations hinge on climate-impacted industries such as agriculture, fishing, or tourism; while there has been growing concern recently within the CAC about the higher incidences of vector and water borne diseases (e.g. dengue) which are seemingly attributable to changes in temperature and rainfall regimes. The vulnerability of the region to extremes in climate (floods/droughts, stronger hurricanes, storm surges, sea-level rise, etc.) arising from both shorter timescale fluctuations (ENSO, PDO, AMO) or the more gradual change in the climatic environment due to a global warming is undeniable.

The region however does not lack adaptive strategies (disaster preparedness plans, education and preventative programs, integrated models of climate and agriculture/aquatic life/economic viability and sustainability) as the growth of the "climate-thought movement" has directly facilitated the formation of numerous regional agencies and/or research-efforts aimed at mitigating hazardous climate extremes or taking advantage of favourable climatic opportunities. The effectiveness of many of these efforts however hinge on the ability to (i) establish relationships between local observations of climate variables and indices of social welfare (e.g. rainfall and dengue outbreaks) (ii) anticipate changes in the local climatic regime with sufficient lead time to act, and/or (iii) have real-time or historical climate data which can be fed directly into the coupled models. The continued effort at mitigation or adaptation is therefore in many ways directly dependent on the availability of quality datasets of regional climate and oceanic variables.

The First Step in the Way Forward

A reliable Central American and Caribbean climate observing system is essential a) for the region to better understand and document climate change, b) as the basis for monitoring and predicting climate variability in the region which occurs on an interannual or decadal timescale, and c) for the evaluation of the impacts of both climate change and extremes caused by ENSO and other global fluctuations and the assessment of mitigation strategies. By so doing a reliable observing system then also forms the underpinning for the progression of the "Caribbean climate-thought movement" beyond its current crossroads.

Even however with an appreciation of the importance of climate data some obvious related challenges exist for CAC countries which must be addressed. These include:

- Reinforcing the importance of climate data collection to existing site managers and government funding sources to ensure the continuation of site records.
- Reinforcing the importance of sharing the collected data (beyond political boundaries) as a means of developing regional outlooks on climate issues, and developing a protocol to do so.
- The recovery and digitising of historical data records from rapidly disappearing sources. In many territories century-scale data exist in paper form but only decadal scale data is digitised.
- The maintaining and upgrading of existing data observation sites.
- The expansion of the number of data observing sites within the region.
- The review and possible expansion of the number and type of climate variables observed at observing sites to ensure that current data observations satisfy the needs of the research and user community.

Though seemingly daunting at first glance, the task of moving forward has however already begun. Examples of efforts to address the challenges mentioned above include regionally sponsored data workshops e.g. that for the Caribbean held in Jamaica in January 2001, and the current effort represented by this workshop. On a more global scale, the GCOS model of making GCOS surface network data available from the beginning of record to the present day, is a tangible mechanism for addressing the data requirement issue. Both represent good starts to the movement to ensure the availability to all of high quality, regional data. Continuation of the movement however now hinges on the support and effort of all the member territories of the Central American and Caribbean region.

Annex VII

UNFCCC REPORTING GUIDELINES ON GLOBAL CLIMATE OBSERVING SYSTEMS

William Westermeyer
GCOS

The Conference of the Parties (COP) to the 1992 UN Framework Convention on Climate Change (UNFCCC) recognized the importance of systematic observations in Articles 4 and 5 of the Convention to further the understanding of climate change and to reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude, and timing of climate change. In a series of decisions related to systematic observation following the entry into force of the UNFCCC, the COP has reaffirmed the importance of systematic observation and noted the inadequate state of observing systems, particularly in developing countries.

Recognizing the inadequacy of climate observations in many parts of the world, the COP in 1998 urged nations to undertake programs of systematic observation and requested them to submit information on national plans and programs related to observations (Decision 14/CP.4). The issue was addressed again in 1999 when the COP urged Parties to address deficiencies in climate observing networks and adopted guidelines for reporting on systematic observations. The COP further invited Parties to provide detailed reports on systematic observation in accordance with the guidelines (Decision 5/CP.5).

The preparation of detailed national reports is voluntary for Parties not included in Annex I, that is, for most developing countries. However, GCOS is encouraging all countries to provide such reports. GCOS regards reports from developing countries as important for four reasons. First, the reports will help raise the level of awareness among the delegates to the UNFCCC about needed improvements in observing systems. Second, individually and collectively, the reports will provide essential information that can be used in making the case for upgrading climate observing systems. Third, the quality of the final synthesis report that will consolidate the information provided in individual reports will depend on the number and quality of the individual reports received. Finally, the reports will help form the basis for the development of national observing system plans.

The UNFCCC guidelines are a set of general instructions that outline the preferred approach for reporting to the COP on the national status of meteorological, atmospheric, oceanographic, and terrestrial observing systems. GCOS has also produced some notes on the guidelines that provide additional information on the preparation of national reports. Both the UNFCCC guidelines and the GCOS notes are available on the GCOS website (http://www.wmo.ch/web/gcos). They have also been placed on the special document web site created for this workshop.

There is no deadline for the preparation of national reports for non-Annex I countries. However, GCOS urges that reports be prepared as soon as feasible in order to be incorporated in the initial synthesis report. It would be useful to include a statement in the Regional Action Plan that will be developed at this workshop encouraging countries to complete their national reports as soon as possible, if they have not already done so.

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Annex VIII

THE GCOS SURFACE AND UPPER-AIR NETWORKS IN THE CARIBBEAN AND CENTRAL AMERICA FROM A DATA MANAGEMENT PERSPECTIVE

Howard Diamond
U.S. GCOS Coordinator, NOAA/NESDIS

This presentation will examine the GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN) in the region and look at the following key areas:

- What are they and why are they important?
- How were they developed?
- What do we mean in terms of "best practice" for their operation?
- How are they performing?
- What are the immediate challenges?

In a statement from the Conference on the World Climate Research Programme Geneva, Switzerland, 1997 regarding systematic observations of the Climate System, it was noted that " Without action to reverse this decline in conventional networks in some regions and develop the Global Climate Observation System, the ability to characterize climate change and variations over the next 25 years will be even less than during the past quarter century. " As pointed out in the Report on the Adequacy of GCOS (GCOS-48), "What is urgently needed is a commitment by nations to provide global coverage for the key variables, to halt and reverse the degradation of existing observing systems, and to exchange information more effectively."

The presentation will look at the overall GSN and GUAN world-wide as well as within the region, the performance of the stations, the timeliness of the receipt of data, and how well stations are operating. It will also go on to talk about some key data management issues involved with the provision of historical data and metadata as called for by the WMO in September 1999 and see how well the region is doing in providing that data. For example in regards to the global surface air temperature record there is an obvious need to maintain and reduce uncertainties in past and future data basic elements of a climate watch, in maintaining a quality network and seeing that if we do not follow best practices a reduced spatial density of high quality data will result in an overall poorer resolution of data required.

The National Climatic Data Center (NCDC) in Asheville, North Carolina, is responsible for building a permanent data base of GSN daily and monthly data submissions, along with the appropriate station metadata history, and for providing free and open user access to this information via the World Wide Web. This site contains all of the historical daily and monthly CLIMAT-formatted GSN data received (as of December 2001) at NCDC from 250 of these surface stations in 28 nations. As more data is received they will be integrated into the system and made available for use. The visitor may view data in both textual and graphical form, and, through the use of copy and paste, can download subsets of the database to their own system for later use and analysis. As new station information is made available to NCDC, the GSN database will be updated and this information will be noted on their web site at http://lwf.ncdc.noaa.gov/servlets/gsn.

The data format and supporting documentation for members to use when providing digital historical data for GSN sites for inclusion in the NCDC GSN historical database can be found at http://www.eis.noaa.gov/gcos/gsn_format/gcos_dfsd.pdf. The information can be submitted as an e-mail attachment (e.g., Word format) and should be sent to the U.S. GCOS Program Manager, Howard Diamond, at howard.diamond@noaa.gov. From there the data will be transmitted to the appropriate personnel at NCDC for processing.

The WMO Secretary-General issued a request for GSN historical data and metadata in September 1999 to all WMO member states. As of December 2001 only 28 member states have provided this information. It is imperative that these data be added to the holdings in the GSN historical database. A list of all GSN sites can be found on the GSN Monitoring Centre web page at http://www.dwd.de/research/klis/gsn_mc/ The compilation of the configuration of GSN sites was accomplished by the GCOS Atmospheric Observations Panel for Climate (Peterson, 1997). While a call for GUAN data has not yet been made, plans are in the works to address that at some time.

The need for monitoring the performance of the GSN was recognized and formulated by the Second Joint CCL/CBS Meeting on GSN in 1997 in GCOS Publication 35. The participants considered it essential that the operational exchange of the GSN temperature and pressure data via CLIMAT messages on the GTS be monitored routinely. At the third session of the Joint Data and Information Management Panel (JDIMP) (GCOS Publication 39) the Deutscher Wetterdienst (DWD) offered to monitor the GSN data flow, data availability, and data quality with special regard to precipitation. In August 1997 the CCL agreed that the availability and quality of CLIMAT messages being distributed over the GTS be globally monitored by monitoring centers, with the assistance of regionally-designated focal points (WMO, 1997). Following this agreement, Germany and Japan officially offered to serve as GSN Monitoring Centres.

In January 1999, the GSN Monitoring Centre Implementation Meeting was held in Offenbach, Germany (GCOS-53, 1999). This was the official start of the monitoring activities. The proposed tasks of the GSN Monitoring Centres (GSNMC) were documented in 1999 in GCOS Publication 53. The tasks of the GSNMCs are to: (1) monitor the availability, timeliness and completeness of the CLIMAT messages distributed via the Global Telecommunication System (GTS) to improve the performance of the GSN; and (2) to perform basic quality control and assurance procedures for GSN stations to obtain high quality and completeness of the data set. These GCOS publications can be found at http://www.wmo.ch/web/gcos/gcoshome.html.

In implementing the observing program at GSN stations, states should comply with the following best practices provided by the WMO:

(a) Long-term continuity should be provided for each GSN station. This requires the provision of the necessary resources, including well-trained staff, and keeping changes of location to a minimum. In the case of significant changes in sensor-devices or station location, Members should provide for a sufficiently long period of overlap (at least one but preferably two years) with dual operation of old and new systems to enable comparisons to be made and the identification of inhomogeneities and other measurement characteristics.

(b) CLIMAT data should be provided in an accurate and timely manner. CLIMAT reports should be transmitted by the fifth day of the month but not later than the eighth day of the month.

(c) Rigorous quality control should be exercised on the measurements and their message encoding; CLIMAT reports require quality control of the measurements themselves and their message encoding to ensure their accurate transmission to national, regional and world centres for their use. Quality-control checks should be made on site and at a central location designed to detect equipment faults at the earliest stage possible. The Guide to Instruments and Methods of Observation publication (WMO-No.8) provides the appropriate recommendations.

(d) The site layout should follow the recommended form; *the* layout of the site should follow the recommendations in the Guide on the Global Observing System WMO-No. 488).

(e) The site and instruments should be inspected regularly and maintained according to WMO recommended practices; to obtain homogeneous data sets, maintenance should be carried out as is documented in the Guide to Instruments and Methods of Observation (WMO-No. 8). The quality of the measured variables should be guaranteed by appropriate inspection of sites, instruments and exposure to be based on the procedures given in the Guide. As part of the maintenance, the necessary calibration practices should be traceable to the standards provided by the Guide.

(f) A national plan should be developed to archive daily data from GSN stations for climate and climate research purposes; the archive should include both observational data and metadata pertaining to each climate station. Metadata should include data concerning a station's establishment, subsequent maintenance, and changes in exposure, instrumentation and staff. The data and metadata should be in its original form as well as digital format.

(g) Detailed metadata and historical climate data for each GSN station should be provided; a GSN Data Center should have an up-to-date digital copy of the historical climate data and all types of metadata for GSN stations. A current copy of the long-term series of data and metadata from GSN stations should be made available.

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Annex IX

THE SIDS CARIBBEAN PROJECT – SUMMARY

Steve Pollonais

The Government of Finland in Cooperation with the WMO has initiated a project in the Caribbean for the purpose of providing tools for better planning towards sustainable development, and the provision of information necessary for planning purposes at both national and international levels. In so doing, it is expected that targeted countries would gain a better capacity for fulfilling their responsibilities to international conventions such as the UNFCCC, CBD and CCD, among others. These objectives are seen as achievable through the strengthening of National Meteorological Services in the area.

The project employs strategic interventions into six critical areas via six components:

(i) Improvement of the telecommunication systems on national and regional levels;
(ii) Rehabilitation and upgrading of the observing network;
(iii) Renovation of the regional technical laboratory for the calibration and maintenance of instruments;
(iv) Upgrading of the database management systems;
(v) Implementation of data rescue programmes; and
(vi) Training and awareness building.

In pursuance of the stated goals, visits have been made to all countries with a view towards the inspection of facilities and discussions with officials regarding needs. At present and with the help of contracted experts, recommendations for a re-engineered telecommunications system is currently before the WMO for evaluation. This will of necessity entail further discussions and agreements with NOAA before implementation. Meteorological instrumentation is also being examined critically in order to overcome the disadvantages of obsolescence and irrelevance; the Calibration facility is expected to play a significant role in the maintenance of regional standards.

As in all studies relating to Climate Change, the development of an accurate and easily accessible database is essential. The difficulties created by CLICOM are to be removed by the introduction of a standard database management system in the Caribbean. Work in this area has already begun with the aid of another expert attached to the project. In a similar vein, data rescue activities are being pursued which hopefully will add to the existing body of historical information and be especially useful in Climate Change studies.

Finally, our meteorologists need to be replaced. The existing cadre of professionals is about to exit the scene. This is seen as an urgent matter with the challenge being met through the development of training programmes to address traditional aeronautical needs, while offering areas of applied meteorology. This is necessary if we are to achieve success in our drive towards sustainable development.

The project is managed by a Team Leader; who reports to a Steering Committee. A Supervisory Board is responsible for the final approvals and policy decisions affecting the project. The project will establish a Trust Fund in the future, for the maintenance of recurrent activity such as equipment inventories, and calibration exercises, among others. A Public Awareness programme will be pursued to ensure that the greatest visibility is made available for meteorological services in the future.

Action Plan for the Region – Recommendations

1. The SIDS-Caribbean Project strongly recommends the support for the proposed Telecommunications Systems in the Caribbean as it has the potential to enhance and improve meteorological services in the region.

2. The European Union Radar project requires the active support of all Caribbean countries. Taken in conjunction with the proposed Telecommunications System, Radar images can be made available to all governments especially in times of severe weather.

3. All efforts should be made to support and enable Database Management and Data Rescue activities in all countries as this would set the platform for meaningful investigations in Climate Change and Climate Variability questions.

4. Regional Governments are asked to pay greater attention to the Meteorological Service of their respective countries both in terms of increased funding for development and the utilization of meteorological and climatological information in the planning process.

Annex X

IOCARIBE-GOOS PERSPECTIVE ON STATUS, DEFICIENCIES, AND NEEDS FOR OCEAN OBSERVATIONS

Doug Wilson

In response to regional user needs, a regional Ocean Observing System (GOOS) is being developed for the IOCARIBE (Wider Caribbean and Gulf of Mexico) region. A Strategic plan has been drafted, an inventory and assessment of resources has been undertaken, and a Steering Group has been formed by IOCARIBE to begin implementation. A short definition of the system is as follows:

IOCARIBE-GOOS is a basic source of information, services and products to support sustainable social and economic development, welfare, and safety, through systematic observations and associated research on coasts and seas in the IOCARIBE region. The system is operational in nature and designed to yield products and services that meet the needs of users. It provides information on the past, present and future state of the marine and coastal environment, on marine ecosystems and biodiversity, and on weather and climate variability. It is also a tool for integrated management of the coastal zone. International cooperation and capacity building are essential to the effective operation of the system and to enable potential users to benefit from it.

The Strategic Plan includes numerous terms of reference that complement GCOS objectives and provide opportunities for integration and cooperation, and provide a starting point for discussion of regional observational needs. These include *inter alia,*

- Carry out a survey among the marine-related communities of the participating IOCARIBE Member States (i) to construct an appropriate set of user scenarios, and (ii) to determine what end-products and services are required by the user community;

- Evaluate the costs and benefits of implementing IOCARIBE-GOOS for discrete user sectors (e.g. tourism, offshore industry, fishing);

- Develop an inventory of existing activities relevant to IOCARIBE-GOOS including: (i) operational systems and programs; (ii) organizations; (iii) scientific programs; (iv) services and products; (v) commercial interests; and (vi) training and capacity building;

- Devise an Implementation Plan that meets both the advice from the GOOS advisory panels and the needs of the region;

- Establish an integrated Initial Observing System building on existing national and sub-national level observing systems;

- Identify key gaps in the existing observing systems, and make plans to fill them;

- Prepare an engineering and design analysis to integrate the various existing and planned ocean observations and provide for the future adaptability of the system;

- Develop and implement concept-demonstration projects that will contribute to the long-term health and stability of IOCARIBE-GOOS, beginning by organising a regional workshop on concept-demonstration projects;

- Organize data management among the IOCARIBE-GOOS Initial Observing System elements, to improve data collection, storage, exchange and dissemination, building on existing structures, and exploiting the proposed Ocean Data and Information Network for the Caribbean and South America (ODINCARSA);

- Establish an appropriate capacity building programme, building initially on existing and planned capacity building activities;

- Work to ensure not only the effectiveness and efficiency of the observing system, but also its sustainability for the long term;

- Ensure that GOOS design principles and principles of involvement are maintained within IOCARIBE-GOOS activities;

- Encourage the development of National GOOS Coordinating Committees and appropriate national GOOS focal points in IOCARIBE Member States;

- Take full advantage of the creation of JCOMM to bring together meteorologists and oceanographers to design IOCARIBE-GOOS in such a way as to extract the maximum benefit from JCOMM as an implementation mechanism for GOOS;

- Develop appropriate synergies with global programs having activities in the region;

- Hold a regional applications-oriented science conference (like the biennial Operational Oceanography conferences of EuroGOOS or the science conferences of WESTPAC), to bring the community together behind the development of IOCARIBE-GOOS;

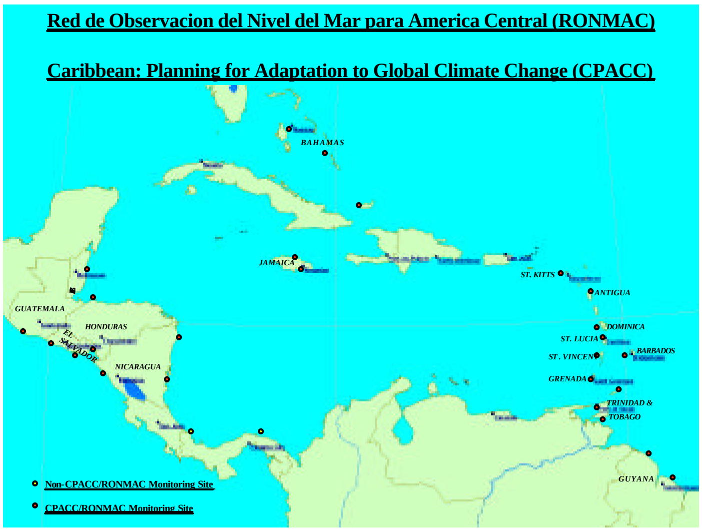
- Develop appropriate marketing and communications strategies including a web site and newsletter for IOCARIBE-GOOS.

Annex XI

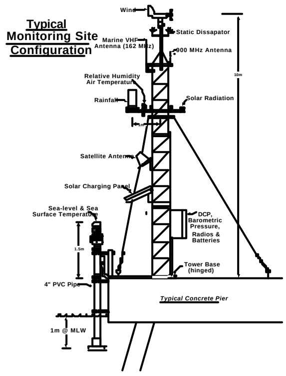
DESIGN AND OPERATION OF AIR-SEA MONITORING SYSTEMS IN CENTRAL AMERICA AND THE CARIBBEAN

J. Lee Chapin
OAS Regional Network Advisor

Between 1997 and 2001 two major monitoring systems were designed and placed into operation in Central America and the Caribbean. The Caribbean system; Caribbean Planning for Adaptation to Global Climate Change (CPACC) was funded by the Global Environment Facility (GEF) through the World Bank and executed by the Organization of American States (OAS) Unit for Sustainable Development & Environment (USDE), in partnership with the Caribbean Institute for Meteorology & Hydrology (CIMH) and the University of the West Indies (UWI). CPACC included 12 CARICOM countries; The Bahamas, Jamaica, Belize, Antigua, St. Christopher & Nevis, St. Lucia, Dominica, St. Lucia, St. Vincent & the Grenadines, Barbados, Trinidad & Tobago and Guyana. The Central America system RONMAC was funded under the USAID “Post Mitch” program through the National Ocean Service/NOAA executed by the OAS-USDE, in partnership with Comité Regional de Recursos Hidráulicos (CRRH). RONMAC included: El Salvador, Guatemala, Honduras and Nicaragua.



Both systems were designed and implemented using the same equipment and procedures. The typical station design included a Vitel VX1100 Data Collection Platform, with GOES satellite data communications. Data collected includes; sea level (air-acoustic), wind (speed, direction & gust), air temperature, sea-surface temperature, barometric pressure, relative humidity, solar radiation and rainfall. All monitoring sites were selected using sea-level monitoring criteria. The addition of the meteorological sensors was to look at the local factors effecting the sea surface.



This presentation will consist of a review of the systems, methods and lessons learned in both CPACC and RONMAC.

Annex XII

DATA APPLICATIONS IN THE CARIBBEAN – NEEDS ANALYSIS

Shelley-Ann Jules-Moore
CPACC/MACC Regional Archiving Centre

- **Sea-Level Processes**

The presentation initially focuses on the objectives of the tidal data collection. What are the sea-level processes and phenomena that the data is utilized to determine or model. Currently the focus is on tidal constituents, relative and absolute sea-level rise and sporadic events. The importance of obtaining good results for these processes and their current applications will be identified.

- **Data Collection requirements**

The particular data requirements to facilitate modelling of these processes and phenomena will be identified. The accuracy, time frame and the particular parameters required for good modelling of the different processes under study will be the focus. This will include an evaluation of time scale limitations on potential data analysis and facilitate the evaluation of network performance.

- **Current CPACC/MACC Capabilities**

The current distribution and capabilities of the CPACC/MACC network will be identified. The network currently incorporates eighteen (18) stations in twelve (12) CARICOM countries. The mode and sequence of data collection will be outlined and possible problem areas identified. This discussion will include the current status of height information available to the CPACC/NACC network and will identify areas where improvements need to be made to aid modelling.

- **Key Issues and Deficiencies**

Key concerns and deficiencies in the current CPACC/MACC network will be outlined. His issues include interruptions in data transmissions resulting from stations transmitting outside of their assigned satellite window, delays in maintenance and replacement of sensors and the resulting data gaps. The deficiencies in analysis capabilities associated with the data gaps will be identified. Access to stations and expertise remain the chief reason for a number of maintenance issues. Observational deficiencies also include the absence of continuous GPS observations to facilitate the analysis of absolute sea-level rise. The region needs to improve its data analysis capabilities to facilitate the translation of observations to decision-making needs.

- **Recommendations**

The strategies for overcoming these deficiencies will be outlined and discussed. These include:

- Training and support for local meteorological officers.
- Financial support to improved maintenance efficiency in remote stations.
- Upgrade of the current station configuration (initially the inclusion of GPS card to eliminate clock drift; ultimately to include continuous GPS observations at tide gauge locations).

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Annex XIII

RONMAC/LABCODAT PROJECT: SEA-LEVEL OBSERVATION NETWORK IN CENTRAL AMERICA

Alejandro Gutiérrez
Oceanography Laboratory
Universidad Nacional

In order to establish an administrative and operational reference for the future sea-level observation system in the region, it is necessary to discuss the institutional background prior to the network installation, its operational requirements, the general plan execution and the current operational structure of data exchange, as well as the sustainability of the installed project.

Introduction

Nowadays, both sea-level records as well as sea-surface temperature are fundamental to control climate and climate variability. These factors, though usually evaded, provoke enormous problems to the regional economy and at worst, affect the physical integrity of the population. For this reason, it is imperative to control them in time, and therefore avoid not only the aforementioned damages, but also to establish timely national development plans and thus have pertinent adaptation mechanisms. At last, this will empower those communities which otherwise have to resign themselves to the typical and insufficient mitigation plans that result from the impact of natural disasters over coastal zones.

The information that the RONMAC system registers in time is accordingly, a critical requirement to train those communities that are vulnerable to natural phenomena and the decision-makers that are related to them.

Background and network installation

Sea-level records in Costa Rica go back to the 40`s and 50`s when the first mareographs were granted by the Geodesic Surveillance Office of the United States Department of Commerce. These instruments were managed by the National Geography Institute in the harbors of Limon, Puntarenas and Quepos. Then, measurements were carried out to control geodesic levels in Central America and the Caribbean. However, this also served to determine tide maps for cadastre purposes.

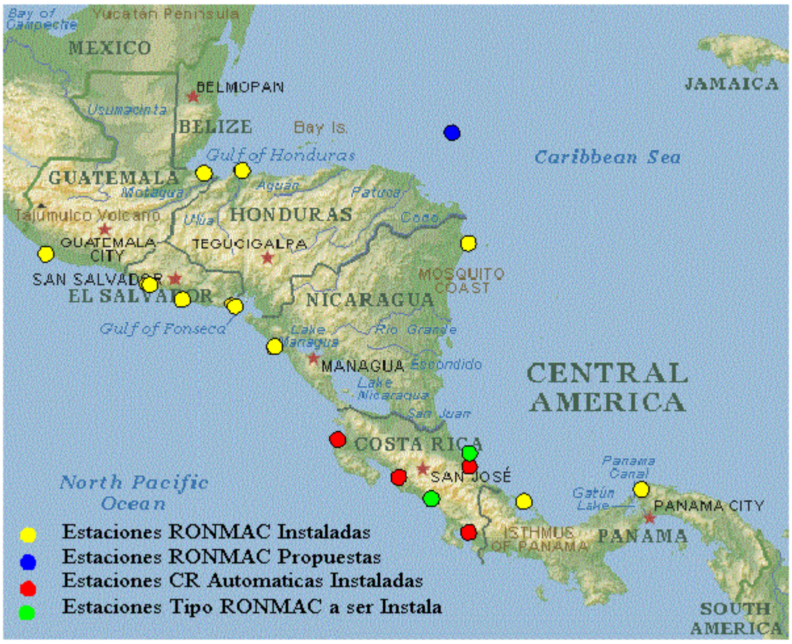
At the beginning of the 80´s, the national mareograph network is transferred to the "Servicio Mareográfico y de Estado del Mar" –SERMAR- of the Universidad Nacional –UNA-. This institution signs an agreement with the National Meteorological Institute at the end of the decade. The purpose of this agreement was to improve the maintenance of the stations and expand the national mareograph network to other coastal areas where marine climate control was relevant. As a result, during the 90`s, the network becomes automated and it is expanded to the harbors of Cuajiniquil –northern part of the country-, Golfito and Caldera. The current objective is to control marine climate and climate variability, including El Niño and La Niña phenomena.

At the end of the 90´s, and as a result of the impacts of hurricane Mitch over Central America, the United States government contributed, among other things, to the establishment of marine-meteorological stations in the so-called Mitch countries of the region. The National Oceanic and Atmospheric Administration (NOAA) is given such a task, and it is executed by the Sustainable Development and Environmental Unit of the Organization of American States (OAS) in Washington. The Regional Committee for Water Resources (CRRH), which is located in Costa Rica, was designated to guarantee the sustainability of this regional system. The CRRH made SERMAR responsible for the operational control of the system. Therefore, this institution created a new data and calibration quality control laboratory, called LABCODAT. Now, this new system registers the behavior of the most important atmospheric and marine variables, sends the satellite signal and allows the different regional stations to receive information in nearly real-time. At the same time, controlling stations have incorporated the automated record of seaquakes that may potentially affect Central America.

ABSTRACT: RECOVERY OF HISTORIC CENTRAL AMERICA SEA-LEVEL DATA

Jim A. Navarro
Comité Regional de Recursos Hídricos

In the last 100 years, three different campaigns for the establishment of Geodetic and Sea-level Monitoring Networks, have taken placed in Central America. The most recent of these networks was funded and executed by the Post-Mitch Project(USAID-NOAA-OEA-CRRH) uses state of the art technology with stations based in Honduras, Nicaragua, El Salvador and Guatemala with the data collection center based in Costa Rica. The selected sites follow Sea-Level Climate Control Criteria that requires stability of the monitoring station through a long data series as well as the continuity and frequent geodetic surveys to the historic benchmarks.



The first sites selected during the first two tidal monitoring campaigns, where placed in specific locations considered key for the geodetic control of the region. Due to the lack of resources during that time, operation and maintenance of the equipment was the responsibility of the national entities in each country where the station was located; while the United States Coast & Geodetic Survey(USC&GS) was in charge of the data analysis mareograms. The length of each monitoring period depended on a variety of limitations, both environmental and human.

Within the last campaign, all of these national entities show particular interest in the recovery of historic sea-level information, through modern methods of digitalization. It is intended not only to check the archived information in global climate change repositories, but have historic data about high temporal resolution events such as Tsumanis, local quakes, etc.

The paper will initially look at the historic sea-level data recovered by the national entities in each of the Central America countries and the USC&GS. It will examine the format and temporal resolution of the data. Finally, it will examine the methodology, tools, timeframe and data presentation format required to digitalize mareograms for better data analysis.

Annex XV

STATUS AND NEEDS OF HYDROLOGICAL CYCLE OBSERVING SYSTEMS IN THE CARIBBEAN AND CENTRAL AMERICA

Kailas Narayan
Hydrologist, CIMH

The presence of water as solid, liquid and gas is a feature that makes earth unique in the solar system, and that makes life possible as we know it. The transport of water through the hydrological cycle and the energy exchanged due to its conversion from one state to another are important drivers in our weather and climate , which in turn determine the conditions under which we survive on the planet. Some of these conditions, such as floods and droughts, can be extreme, resulting in major disruptions in societies – relocation of communities, epidemics, etc. The necessity therefore, for hydrological cycle observing systems cannot be over-emphasized.

The overall number of observing stations around the world seems to be quite large, about 478,000, including precipitation, evaporation, discharge, sediment, water quality and groundwater. However, the coverage of the network is seriously inadequate, especially so in the developing world, where the need for water data is the greatest. In the Caribbean and Central American region the distribution of observing systems is very irregular. In some cases the density of observing systems may be considered sufficient for specific purposes; however, in many areas the networks are totally inadequate, and in some cases observation stations are completely non-existent. Even in situations where the networks may be considered adequate there are deficiencies in the systems which result in loss of data for considerable periods of time. Some of the deficiencies presently existing include lack of trained personnel, improper and irregular maintenance of equipment, non-replacement of unserviceable equipment, etc. The results of such deficiencies are inadequate and discontinuous data, which are not of much use.

In this presentation an attempt is made to study the existing deficiencies and to develop a strategy to rectify these deficiencies.

Tentative Recommendations:

- A proposal for minimum requirements for hydrological observing systems capability to be distributed to countries.
- Determine deficiencies in individual countries.
- Formulate a programme for countries to acquire the minimum capability.
- Formulate a programme of assistance for countries requiring such.
- Set up mechanism for exchange of data and knowledge within the region.

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Annex XVI

REGIONAL TRENDS IN EXTREME EVENTS: THE RECENT INCREASE IN ATLANTIC HURRICANE ACTIVITY

Mr Stanley B. Goldenberg
Hurricane Research Division/National Oceanic and Atmospheric Administration
(Co-Authors: Christopher W. Landsea,
Alberto Mestas-Nuñez, and William M. Gray)

The years 1995-2001 experienced the highest level of North Atlantic hurricane activity in the reliable record. Compared with the generally low activity of the previous 24 years (1971-94), the last seven years have seen a doubling of overall activity for the whole basin, a 2.5-fold increase in major hurricanes (50 m s^{-1}) and a five-fold increase in hurricanes affecting the Caribbean region. The greater activity results from simultaneous increases in North Atlantic sea-surface temperatures and decreases in vertical wind shear. It has been hypothesized that multidecadal changes in these oceanic temperatures are related to fluctuations in the intensity of the thermohaline circulation in the North Atlantic.

Some have asked whether the increase in activity since 1995 is due to anthropogenic global warming. The historical multidecadal-scale variability in Atlantic hurricane activity is much greater than what would be expected from a gradual global temperature increase attributed to global warming, although it is possible that a small fraction of the increase in hurricane activity might be associated with the *gradual* SST increase.

An additional impact of the shift in Atlantic activity has been a dramatic increase in October hurricane (especially major hurricane) activity. During the years 1965-1994, there were only two major hurricanes that developed after the first couple of days of October – Joan (October, 1988) and Kate (November 1985), only one of which affected the Caribbean. Since the shift in activity in 1995, however, there have been six of these late season major hurricanes in only seven years, with most of these affecting the Caribbean.

Because of the multidecadal-scale nature of the Atlantic SST variability portrayed here, the shift since 1995 to an environment generally conducive to hurricane formation is not likely to change back soon. This means that during the next 10-40 years or so, most of the Atlantic hurricane seasons are likely to have above average activity with a continuation of significantly increased numbers of hurricanes (and major hurricanes) affecting the Caribbean Sea, and basin-wide numbers of major hurricanes. Tragic impacts of the heightened activity since have already been felt, especially in the Caribbean, where over two dozen killer hurricanes have occurred since 1995 -- the worst being Hurricanes Georges and Mitch.

Government officials, emergency managers, and residents of the Atlantic hurricane basin should be aware of the apparent shift in climate and evaluate preparedness and mitigation efforts in order to respond appropriately in a regime where the hurricane threat is much greater than it was in the 1970s through early 1990s. In light of this increased activity, the maintenance of an adequate rawinsonde network in the Caribbean region is imperative to provide sufficient input data for numerical models which in turn supply guidance for forecasting track and intensity of these deadly storms. In addition, it is important to support the collection of additional data through satellite, and from reconnaissance missions flown by U.S. Air Force reserve and NOAA aircraft.

Primary reference:

Goldenberg, S.B., C.W. Landsea, A.M. Mestas-Nuñez, and W.M. Gray, 2001: The recent increase in Atlantic hurricane activity : Causes and implications. *Science*, **293**, 474-479.

Annex XVII

IMPACT OF SEA-LEVEL RISE ON GRENADA'S COASTAL GROUNDWATER RESOURCES SUMMARY OF KEY ISSUES AND RECOMMENDATIONS

Terrence Smith

1. INTRODUCTION

This study was undertaken as a sub-component of Grenada's case study on Coastal Vulnerability and Risk Assessment under Component 6 of the Caribbean: Planning for Adaptation to Global Climate Change Project (CPACC). The fieldwork was carried out during the period July 2000 and September 2001.

For the purposes of the Study the coastal zone was demarcated at the 45m (150ft.) contour. The study area comprised the Southwest Peninsula of Grenada – which includes the major tourism belt and the capital city of St. George's – and the coastline of the island of Carriacou.

2. METHODOLOGY

The Study employed the UNEP V&A methodology, while the water resources sub-component included geo-referencing of wells and modelling of floods using a geographic information system (GIS); determination of groundwater levels; modelling of seawater intrusion using the Ghyben-Herzberg analysis; and administering of a coastal vulnerability survey questionnaire. *The primary limitation of the study was the lack of baseline data.*

3. COASTAL GROUNDWATER INVENTORY

The main public sources of domestic and commercial groundwater supply within the study area comprise for:

> *Grenada* – 6 production boreholes at Chemin Valley and Baillie's Bacolet (4,300 m^3/day); 7 private boreholes supplying brackish water for desalination at 4 hotels and a brewery (700 m^3/day).
> *Carriacou* – 1 production borehole (5.2 m^3/h) and 10 shallow dug wells used mainly for livestock.

4. SEAWATER INTRUSION, FLOODING AND INUNDATION IMPACTS

Scenarios used for sea-level rise (SLR) were 0.2m for 2020; 0.5m for 2050; and 1.0m for 2100; while flooding impact of storm surges combined with SLR were 1.72m by 2020 and 2.82m by 2100. The impacts follow:

Baseline scenario: 3 boreholes (BB-1, BB-2, Ch-4) threatened by seawater intrusion during production.
0.5m SLR by 2050: 5 dug wells in Carriacou encroached by seawater beyond use for livestock.
1.0m SLR by 2100: additional 3 dug wells in Carriacou encroached by seawater beyond use for livestock.
2020 Storm Surge (1.72m flooding): 1 dug well in Carriacou overtopped by waves.
2100 Storm Surge (2.82m flooding): 2 boreholes and 1 monitoring borehole in Grenada overtopped by waves.

5. RECOMMENDATIONS

The Study, despite its limitations, concluded that Grenada is very vulnerable to the potential negative impacts of climate change-induced sea-level rise. The principal recommendations on the data needs related to coastal groundwater resources follow:

- Implementation of a groundwater monitoring programme, *for which equipment should be procured*, and sharing of the resultant data with the Coastal Resource Information System (CRIS) at the PPU.

- Determination of the ground level elevations of all boreholes with survey-grade accuracy to facilitate accurate hydraulic computations.

- Acquisition of bathymetry data, increased resolution contour maps and computer modelling software/ hardware to enable more rigorous groundwater modelling and GIS-based inundation and flood modelling.

- Biennial test pumping of production wells to determine performance characteristics and aquifer hydraulic parameters, thereby enabling aquifer modelling and reducing the risk of wellfield overpumping.

- Capacity building to enhance future V&A studies, including training in the relevant areas of computer modelling.

- Incorporation of the results of the Study into National Planning, including the work of the National Emergency Relief Organization (NERO), the Physical Planning Unit (PPU) and the Economic Affairs Division of the Ministry of Finance.

Annex XVIII

THE USES OF DATA IN CLIMATE CHANGE VULNERABILITY AND ADAPTATION STUDIES IN AGRICULTURE

Carlos Fuller
Belize

In 1994 the US Country Studies Program funded vulnerability assessment studies in Central America. Vulnerability assessments were undertaken in three sectors: agriculture, coastal zone and water resources.

Climatologists and meteorologists from the region met in a series of national and regional workshops to assess the results of four General Circulation Models (GCMs) which simulated a future climate with a doubled carbon dioxide concentration in 75 years. The GCMs used were those of the Geophysical Fluid Dynamics Laboratory (GFDL), the Canadian Climate Center (CCC), the United Kingdom Meteorological Office (UKMO) and the Goddard Institute for Space Studies (GISS). The resolutions of the models could not adequately depict the regional climates of Central America, an area consisting of a narrow land mass with a considerable vertical profile surrounded by two extensive bodies of water. The models predicted an increase in mean air temperature of 2°C in the region. There was no definite signal noted for rainfall. The group decided to use a 1 to 2°C increase in temperature a ±10 to 20% change in rainfall.

The Department of Agriculture and the National Meteorological Service undertook the vulnerability assessments of agriculture in Belize. They used crop simulation models developed by Decision Support System for Agrotechnology Transfer. These models simulated physiological crop responses to climatic parameters, soil and crop management. The three main staples in the Belizean diet were selected for study: rice, beans and corn. The "DSSAT v3 CERES" crop simulation model was used for the "PIO X 304C" variety of maize and the "CICA8" variety of upland rice. The "DSSAT v3 CROPGRO" simulation model was used for the dry bean cultivar "CARIOCA".

Eight scenarios were run for the three crops. The temperature rise shortened the growing period of the crops, which lowered their yields. Changes in precipitation did not affect the growing season, but it did lower the yield. The models predicted a decline in yield of 14 to 19% for beans, a 10 to 14% reduction for rice and a 17 to 22 % decline for corn.

The study recommended the following adaptation measures:

- That research be conducted on maize, beans and rice to develop more heat resistant varieties that would perform better in a shorter growing season,
- That the infrastructure be developed for the establishment of appropriate irrigation systems,
- That crop management practices be improved, and
- That the climate change simulations be run again when better models with finer resolutions became available.

The team experienced several difficulties and constraints in undertaking the vulnerability studies.

- Data on crop yields were limited.
- Soil data was also limited.
- Meteorological data had to be extrapolated since there were no weather stations near the farms.
- Not all the weather stations had the full suite of instruments, so some data had to be generated or obtained indirectly.

These constraints naturally limited the data available to calibrate the models and therefore the results were not as representative as they could be.

The following recommendations should be considered for improving the availability of meteorological data for future climate change studies:

- Farmers should be encouraged to install weather stations in their fields.
- National Meteorological Services should increase the density of their observing networks to place stations in the agricultural productive zones.
- Modelers should collaborate with National Meteorological Services to ensure that the parameters they require are being measured.

HIGH-PRIORITY ACTIONS STATEMENT: CORAL REEF ECOSYSTEMS AND GCOS

James C. Hendee, Ph.D., and Alan E. Strong, Ph.D.
National Oceanic and Atmospheric Administration

The purpose of the Global Climate Observing System (GCOS) Workshop for Central America and the Caribbean is to discuss regional deficiencies and needs in atmospheric, oceanographic, and terrestrial observing systems for climate and to develop a strategy for overcoming these deficiencies.

As Co-Conveners of the Coral Reefs Session of the GCOS Workshop, we would like to list what we feel are important topics to be addressed regarding the effect of global climate on the health and development of coral reef ecosystems. The phenomenon of coral bleaching, for instance, has received widespread attention in recent years (e.g., see reviews by Glynn 1993, Brown 1997, Hoegh-Guldberg 1999). It is often regarded as a generalized stress response by zooxanthellate corals to high sea temperature, which is assumed to be due to global warming; or abnormal salinity, bacteriological or viral infection, high solar radiation, pollutants and a range of other stressors (Glynn 1993; Brown 1997; Kushmaro et al 1997; Jones 1997). In most reported incidences of mass coral bleaching, however, locally high sea temperature is in evidence and appears to be the chief environmental stressor (Brown & Ogden 1993). One other meteorological variable that is thought to be conducive to bleaching, in the presence of high sea temperatures, is the presence of low wind speed, as this is thought to favor localized heating and a greater penetration of solar radiation (Glynn 1993; Causey 1988; Jaap 1978, 1988; Lang 1988). Thus, regarding physical factors which influence coral bleaching, it would behoove us to observe sea temperature, salinity, photosynthetically active radiation, ultraviolet radiation and wind speeds at threatened and commercially important coral reef areas in the Caribbean. These factors would also influence coral and coral reef inhabitants' growth and reproductive characteristics, and in turn fisheries (and other) recruitment. Biological studies that elucidate changes in growth, reproduction, larval survival and migration in response to relevant severe physical stressors, such as high sea temperature and increased irradiance levels, would allow us to better gauge and predict the effects of global climate change on coral reef ecosystems.

Regarding the application of a stratagem to realize this goal, an accounting of all physical monitoring endeavors on or near coral reefs in the Caribbean might be compiled to identify gaps or redundancies in effort. Similarly, a bibliography of published work which pertains *directly* to the effects of the physical factors mentioned on coral reef growth, recruitment, reproduction and migration could give researchers and governmental policy makers a baseline status of the reefs and a standard against which to measure change.

Presentations for the Coral Session should focus on the status, deficiencies, and needs of coral reef monitoring as they pertain to climate change, at their site in the Caribbean, and provide recommendations for addressing the highest priority needs. Where possible, quantitative data should be used. The recommendations will be considered in developing the final report of the workshop.

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Annex XX

CORAL REEF MONITORING - A REGIONAL PERSPECTIVE

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Coral reefs are governed by physical and biological factors, as well as by processes that co-vary over a wide range of spatial and temporal scales. For that reason, a multi-scale approach to physical and biological environmental processes to understand coral reef structure and dynamics is vital. Coral reefs may be interconnected at quite large spatial scales (transport of larvae, nutrients and pollutants; migration). This wide scale spatial connectivity should be taken into account for management, monitoring and research of meta-populations and ecosystems.

Climate change is a global scale phenomenon that is threatening coral reefs worldwide, occupying a level of concern comparable or higher than local anthropogenic stressors. In the Wider Caribbean area, it induces or can induce direct and indirect effects on (1) atmosphere (e.g. higher CO_2 concentrations and air temperature; increased amount of suspended African dust in trade winds; possible increase of extreme and dangerous meteorological events such as torrential rains, more powerful cyclones and severe droughts; etc.), (2) sea (e.g. increasing temperature, CO_2 concentrations and sea level; coral bleaching; thermal stress and infectious diseases in marine organisms; changes in local circulation patterns, current velocity and wave parameters; more sedimentation, turbidity and toxics; habitat modifications and boundary shifts; etc.), (3) land (higher frequency of sudden strong runoff of water, nutrients and sediments; more coastal erosion and flooding; local desertification; modifications in coastal landscape, vegetation and land use; etc.), and (4) atmosphere-sea-land interactions.

Coral bleaching is recognized as the most evident outcome of climate change in coral reefs. In order to predict and mitigate the effect of coral bleaching, a better understanding of the spatial and temporal patterns of that event and the climatological and oceanographic factors causing such patterns is needed. Several significant infectious diseases affecting coral reefs as “white band” (causing huge damage to elk-horn corals), “White Plague”, “black band”, ”dark spot”, “yellow blotch”, “Aspergillosis” (attacking sea fans) and the lethal pandemic disease of the sea urchin Diadema antillarum can also be directly or indirectly related to climate change.

The most important climate change related event influencing coral reef health is increasing sea temperature. It can induce coral bleaching, lethal thermal stress in shallow areas, possible depression of coral immune response, higher physiological energy expenditures in corals that can conduct to starvation, etc. Recently, some authors are suggesting that higher amount of African dust transported by trade winds are probably importing pathogens (e.g. soil fungus Aspergillus sydowii) and increasing microbial growth and virulence due to higher concentration of dust iron (a limiting element in oceanic water).

Sea-surface temperature is a main factor to monitor for understanding causalities and trends in coral reef health. Monitoring sea-surface temperature (SST) and its statistics from satellite imagery is vital. SST NOAA/NESDIS Hotspots imagery supported by coral bleaching ground check is a very relevant tool for better understanding the causes and dynamics of coral bleaching. Temperature is widely recognized as trigger of massive coral bleaching, but this causality is often conditioned by other factors that deserve to be monitored and integrated in spatial and temporal analyses: (1) surface wind fields (influencing sea-surface roughness and consequently light penetration), (2) cloud cover (influencing on light irradiance), (3) current velocity (influencing on boundary layer width on coral surface and consequently on coral-water exchange rates), and (4) solar radiation and (5) ultraviolet light measurements.

More attention should be paid to the observation of dispersion pattern and amount of African dust on the Wider Caribbean, before definitively and prematurely discarding it as a real coral reef threat. A combination of satellite imagery information (NASA´s SeaWiFS, AVHRR, TOMS ozone mapping sensor, MODIS Ocean Color Sensor), observation from space stations, and field determinations are recommended. Continuing a sound deployment of the real time observation system of hydro-meteorological variables is also strongly recommended.

CARICOMP (Caribbean Coastal Marine Productivity), AGRRA (Atlantic & Gulf Rapid Reef Assessment), ReefCheck, GCRMN (Global Coral Reef Monitoring Network, now acting in Colombia), RECON (Reef Condition) and CPACC (Caribbean Planning for Adaptation to Climate Change-component 5) are outstanding regional coral reef monitoring and assessing ("snapshoting") initiatives that deserve permanent and generous funding. These initiatives rather tend to complement each other with regard to degree of necessary skill, rapidity, and iteration of sampling. Comparing them, one could surmise the existence of some degree of redundancy among them but, as in ecosystems, some degree of "diversity" seems to be advisable and precautionary to guarantee a more sustained regional monitoring.

Among most significant indicators for assessing and monitoring coral reef status it can be mentioned: coral and algal cover, coral condition, percent of recent an old coral mortality, coral size distribution, dominant algal morph types, fish abundance, fish size and trophic composition, abundance of herbivores (parrot fish, surgeon fish and the black long-spine sea-urchin Diadema antillarum), coral recruitment, indicator invertebrate species, chlorophyll from remote sensing, etc.). Not necessarily all of them are directly related with climate change issues, but the remaining provide information about other issues (pollution, over-fishing, sedimentation, turbidity, physical damage) that interact with climate factors and so deserve to be monitored for better more comprehensive understanding of the situation of coral reefs.

Interaction between oceanographers and meteorologists must be still enhanced and operationally supported for better understanding of local, regional, hemispheric and extra-hemispheric sources of impact on Wider Caribbean coral reefs (e.g. Northern Atlantic Oscillation, Atlantic Dipole, El Niño Southern Oscillation, etc.).

Developed countries should have the responsibility to strengthen the financial support of sound initiatives dealing with research, assessment and monitoring the coral reefs of the Wider Caribbean, to better understand the effect of climate change and other factors involved in the ongoing process of decline, trends and possible local, regional and global management solutions. Funding approaches must consider time scales in excess of budget cycles and political administration cycles to guarantee long term stable regionally integrated monitoring programs. With regard to the prejudiced research vs. monitoring dichotomy, taking into account the large temporal and spatial scales of climate change, financing sources should be aware that monitoring deserves the same priority as research, because in fact monitoring is a basic and crucial component of scientific research.

In agreement with CPACC, government willingness to support coral reef monitoring and develop regional partnership, in the extent of national possibilities, and within the context of Integrated Coastal Zone Management, is also vital for sustaining a regional coral reef monitoring system. Not less important is to guarantee the collaboration of foreign coral reef specialists to those countries lacking full institutional capacity for coral reef monitoring and data analysis, as recommended by CPACC.

Finally, the excellent GCRMN initiative of publishing a periodical report on the status of coral reefs of the world should be strongly supported.

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Annex XXI

CORAL REEF MONITORING – A SATELLITE PERSPECTIVE

Alan E. Strong

A new NOAA program for monitoring key indices at 15-20 prime domestic coral reef locations has been started with the first *in situ* installations, outside the Florida Keys, using coral reef early warning system (CREWS) towers/buoys. NOAA's first international CREWS station was recently inaugurated in the Bahamas at Lee Stockings' Rainbow Gardens Reef in 2001. A second site in the Caribbean has been placed at Salt River in St. Croix, US Virgin Islands just this month. Additional CREWS sites are now being planned at selected locations though out the Caribbean. Coral Reef Watch (CRW) combines both the overreaching view of the satellite and key *in situ* measurements from these CREWS buoys/towers. The program intends to provide both early warnings of anomalous and changing conditions (e.g. bleaching) in and around these key sites as well as an extended time series of these observations for shedding new insights into our changing climate throughout the entire coral reef community. Several experimental satellite products have already demonstrated their usefulness and are being adopted as operational products through CRW. These include SST anomaly charts, Bleaching HotSpot Charts, Degree Heating Week (DHW) Charts, and Coral reef Bleaching Indices.

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CORAL REEF MONITORING – AN *IN SITU* PERSPECTIVE

James C. Hendee

The National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Watch program is installing *in situ* monitoring stations at strategic coral reef areas for purposes of establishing long-term data sets, providing near real-time information products, and surface-truthing NOAA satellite sea-surface temperature (SST) products which are used for coral bleaching predictions ("HotSpots"). The suite of *in situ* instruments, which transmit data hourly, together with custom artificial intelligence software, are called Coral Reef Early Warning System (CREWS) stations. At each CREWS station a critical part of the effort is the local maintenance and calibration of the sea temperature sensor to ensure quality data; these data can then be automatically compared with satellite monitored temperatures and thus provide near real-time feedback on the accuracy of the satellite-monitored temperatures. The local maintainers also give critical feedback on the presence and progress of coral bleaching and thus validate coral bleaching predictions made by HotSpot and CREWS information products. The CREWS stations slated for deployment in the Caribbean will also measure wind speed and direction, air temperature, barometric pressure, sea temperature, and salinity, as well as photosynthetically active radiation and ultraviolet-B above and below the water. These environmental variables are important to local bleaching and other biological manifestations (e.g., spawning, migrations), but are also valuable in helping to assess the effect of global climate change on local reefs.

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Annex XXIII

INTEGRATING *IN SITU* AND SATELLITE OBSERVATIONS

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The facts

- There are many Caribbean and South American countries that still receive imagery in picture format at infrequent time intervals. Use of imagery is thus very limited.

- Funds for the reconstruction efforts for Meteorological Offices in Central America, in the wake of hurricane Mitch, were successfully used to provide digital, real time imagery at 30-minute intervals to Central American countries through the internet (see Annex).

- Requirements for implementing satellite capability to every country: low cost PCs and training. Countries are responsible for their internet connectivity.

- Products that can be obtained from digital imagery:
  - Presence of dust or smoke from fires, volcanic eruptions, etc.
  - Presence of fire
  - Estimation of rainfall
  - Climate statistics: frequencies, averages, extreme values

  All these products must be ground-truthed.

The possibilities

- High resolution satellite imagery complements and improves substantially the information from climatological stations, by providing an extended vs. a punctual point of view.

- **A misconception:** satellite imagery for the exclusive use of synoptic/forecasting purposes. The truth is that satellite data can help in the detection and understanding of climatic variability and its consequences. As an example, the dry season in Central America is drier than usual during an El Niño year. Fig. 1 shows cloud frequencies for the month of February 1998 (Niño event) vs. February 1997 (non-Niño). Fig. 2 shows fires were more extended in 1998 than in 1997.

The needs

- It is not possible to build a local climatology, less to integrate *in situ* and satellite observations, without continuous access to digital imagery, comparison of real time satellite data with observations through the window or a climatological station helps building an incredible understanding of the behaviour of the atmosphere.

- For the tropics, one of the most useful products is rainfall estimation, from which a climatology can also be derived. These estimations must be validated for every place and situation.

A proposal

- To extend the effort of providing satellite imagery capabilities to countries requiring it.

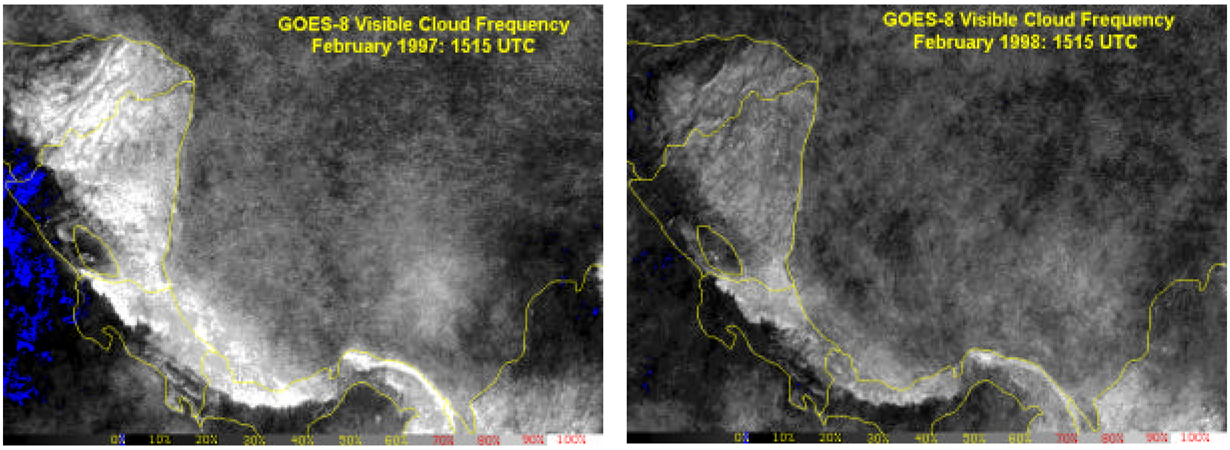

Fig. 1 Cloud frequency is lower in 1998, an El Niño year, than the previous year.

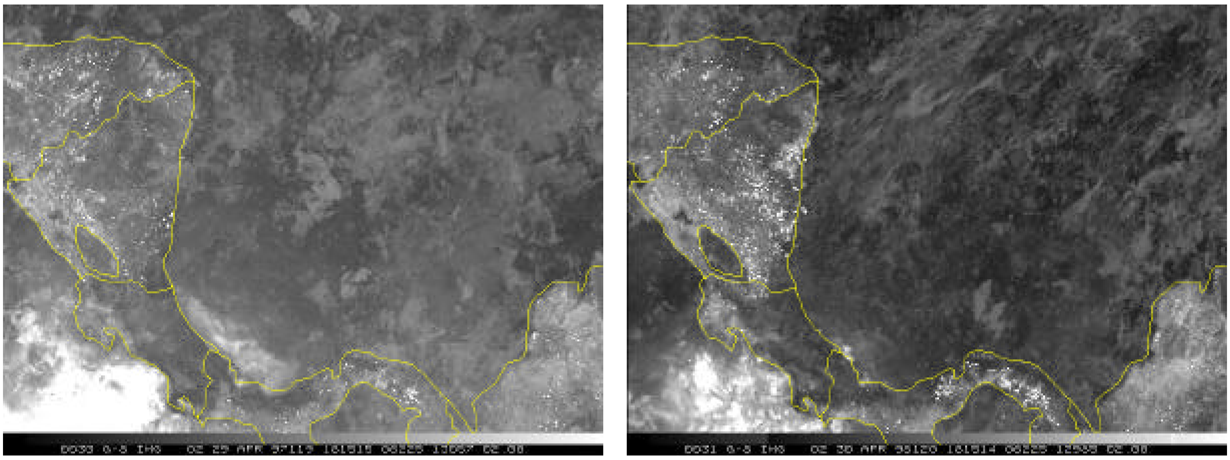

Fig. 2. The satellite fire product detected more fires (bright spots) in 1998 than in 1997.

Annex XXIV

THE USE OF AUTOMATED OBSERVATIONS FOR CLIMATE: CHALLENGES AND OPPORTUNITIES

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Background

The Meteorological Service of Canada (MSC) manages a national climate observation network through cooperative arrangements with government organizations at all levels, the private sector and volunteers. It is a tiered system consisting of Reference and Basic Climate Stations and incorporates climate data obtained from surface weather networks that support Canada's public, marine and aviation weather programmes. Canada's vast, remote and sparsely populated regions combined with budget constraints have compelled the MSC and its partners to rely heavily on autostations for collecting climate data. A major challenge is to ensure an orderly transition from human-based to automated programmes while preserving the integrity, reliability and quality of climate data for various applications and users. The purpose of this paper is to provide some 'best practices", using Canadian examples to illustrate specific challenges.

Managing Change

The transition from human-based to automated observations requires a formal and comprehensive change management process that is applied to all monitoring networks, the management of the data, and maintenance standards and procedures. As a supporting activity, sensors and systems must undergo a rigorous test and evaluation process before qualifying for operational use to reveal performance characteristics that are not necessarily identified in the manufacturer's description of specifications. Whenever possible, the MSC has conducted a two-year overlap of the existing observational programme with the autostation to quantify observing biases.

Operational Considerations

Managing networks involves applying standards suggested by WMO guidelines, user requirements, peculiarities of climatic zones and operational considerations. To illustrate, operational constraints in MSC limit scheduled inspections of autostations to between 2 and 4 times annually. In considering the deployment of all-weather precipitation weighing gauges, Canada identified the need for two types of gauges. The best performing gauge is employed as the primary gauge and, where annual precipitation amounts are high and frequent inspection visits are not possible, a slightly less accurate but higher capacity gauge is deployed.

Human-based observation programmes allow for manual correction of rate-of-rainfall data from tipping bucket rain gauges utilizing quantity measurements from co-located standard precipitation (Type "B") gauges. When initiating an automated programme, the MSC chose to replace gauges with a siphoning tipping bucket that has a flat error profile over a broad range of precipitation rates.

Life-Cycle Management

Managing networks requires consideration of the true costs of the system including, *inter alia*, purchase, installation, telecommunications, maintenance, human resource commitment. It begins with properly documented: siting, installation, inspection and maintenance programmes supported by a well-trained workforce. Far too often, data quality and reliability are compromised by deficiencies in these programmes regardless of the quality of the equipment selected for the network. Standardization of observations, reporting and collection programmes are also requisite. The MSC has initiated life-cycle management in all of its networks.

Real-time Quality Assurance

On-site routine inspection and maintenance are important preventative measures but do not fully overcome problems such as sensor failures or calibration drift. The MSC has established a real-time national monitoring procedure that routinely scans data, identifies problems and notifies regional inspectors of the need for corrective action.

Information Management

It is imperative to have good metadata for reasons ranging from life-cycle management of sensors and systems to documenting characteristics of the observational programme and data management procedures. There is ample evidence that lack of knowledge of observational programmes, past and present, have negatively influenced data interpretation. The MSC has digitized historical inspection records so that, for example, climatic trends can be properly interpreted from archived data sets.

Conclusions

The following serve as guiding principles for managing an effective automated observing network:

- Ensure there is a complete understanding of requirements, including the need for real-time observations.
- Develop or adopt a formal change management process that includes a qualification of equipment, algorithms and procedures for the network and related data management systems.
- Make sure the programme is sustainable, life-cycle managed, to defined standards and procedures within an assigned budget.
- Adopt standard autostation configurations to the extent possible.
- Establish a well-trained technical workforce equipped with documented standards and operational procedures.
- Put in place quality assurance and quality control programmes consistent with network strategies.
- Develop metadata information systems tuned to the needs of those responsible for maintaining the observational programmes as well as the needs of data users.

LIST OF ACRONYMS AND ABBREVIATIONS

CAC	Central America and the Caribbean
CARICOM	Caribbean Community
CARIB-HYCOS	Caribbean Hydrological Cycle Observing System
CIMH	Caribbean Institute for Meteorology and Hydrology
COP	Conference of the Parties (to the UNFCCC)
CPACC	Caribbean Planning for Adaptation to Global Climate Change
CREWS	Coral Reef Early Warning System
CRRH	Regional Committee for Water Resources
CZMU	Coastal Zone Management Unit
GCOS	Global Climate Observing System
GCM	General Circulation Model
GDSIDB	Global Digital Sea-Ice Data Bank
GEF	Global Environment Facility
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GSN	GCOS Surface Network
GUAN	GCOS Upper Air Network
IOC	Intergovernmental Oceanographic Commission
IOCARIBE	IOC Sub-Commission for the Caribbean and Adjacent Regions
LABCODAT	Data Quality Control Laboratory
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NESDIS	National Environmental Satellite, Data and Information Service
OAS	Organization of American States
PRECIS	Providing Regional Climates for Impacts Studies
RMTC	Regional Meteorological Training Centre
RONMAC	Water Level Observation Network for Central America
SIDS	Small Island Developing States
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAID	US Agency for International Development
USDE	Unit for Sustainable Development and Environment
UWI	University of the West Indies
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organization

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LIST OF GCOS PUBLICATIONS*

GCOS-1 (WMO/TD-No. 493)	Report of the first session of the Joint Scientific and Technical Committee for GCOS (Geneva, Switzerland, April 13-15, 1992)
GCOS-2 (WMO/TD-No. 551)	Report of the second session of the Joint Scientific and Technical Committee for GCOS (Washington DC, USA, January 11-14, 1993)
GCOS-3 (WMO/TD-No. 590)	Report of the third session of the Joint Scientific and Technical Committee for GCOS (Abingdon, UK, November 1-3,1993)
GCOS-4 (WMO/TD-No. 637)	Report of the fourth session of the Joint Scientific and Technical Committee for GCOS (Hamburg, Germany, September 19-22, 1994)
GCOS-5 (WMO/TD-No. 639)	Report of the GCOS Data System Task Group (Offenbach, Germany, March 22-25, 1994)
GCOS-6 (WMO/TD-No. 640)	Report of the GCOS Atmospheric Observation Panel, first session (Hamburg, Germany, April 25-28, 1994)
GCOS-7 (WMO/TD No. 641)	Report of the GCOS Space-based Observation Task Group (Darmstadt, Germany, May 3-6, 1994)
GCOS-8 (WMO/TD No. 642) (UNEP/EAP.MR/94-9)	Report of the GCOS/GTOS Terrestrial Observation Panel, first session (Arlington, VA, USA, June 28-30, 1994)
GCOS-9 (WMO/TD-No. 643)	Report of the GCOS Working Group on Socio-economic Benefits, first session (Washington DC, USA, August 1-3, 1994)
GCOS-10 (WMO/TD-No. 666)	Summary of the GCOS Plan, Version 1.0, April 1995
GCOS-11 (WMO/TD-No. 673)	Report of the GCOS Data and Information Management Panel, first session (Washington DC, USA, February 7-10, 1995)
GCOS-12 (WMO/TD-No. 674)	The Socio-economic Benefits of Climate Forecasts: Literature Review and Recommendations (Report prepared by the GCOS Working Group on Socio-economic Benefits), April 1995
GCOS-13 (WMO/TD-No. 677)	GCOS Data and Information Management Plan, Version 1.0, April 1995
GCOS-14 (WMO/TD-No. 681)	Plan for the Global Climate Observing System (GCOS), Version 1.0, May 1995
GCOS-15 (WMO/TD-No. 684)	GCOS Plan for Space-based Observations, Version 1.0, June 1995

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GCOS-16 (WMO/TD-No. 685)	GCOS Guide to Satellite Instruments for Climate, June 1995
GCOS-17 (WMO/TD-No. 696)	Report of the GCOS Atmospheric Observation Panel, second session (Tokyo, Japan, March 20-23, 1995)
GCOS-18 (WMO/TD-No. 697) (UNEP/EAP.MR/95-10)	Report of the GCOS/GTOS Terrestrial Observation Panel, second session (London, UK, April 19-21, 1995)
GCOS-19 (WMO/TD-No. 709)	Report of the GCOS Data Centre Implementation/Co-ordination Meeting (Offenbach, Germany, June 27-29, 1995)
GCOS-20 (WMO/TD-No. 720)	GCOS Observation Programme for Atmospheric Constituents: Background, Status and Action Plan, September 1995
GCOS-21 (WMO/TD-No. 721) (UNEP/EAP.TR/95-07)	GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 1.0, November 1995
GCOS-22 (WMO/TD-No. 722)	Report of the fifth session of the Joint Scientific and Technical Committee for GCOS (Hakone, Japan, October 16-19, 1995)
GCOS-23 (WMO/TD-No. 754) (UNEP/DEIA/MR.96-6) (FAO GTOS-1)	Report of the GCOS/GTOS Terrestrial Observation Panel for, Climate third session (Cape Town, South Africa, March 19-22, 1996)
GCOS-24 (WMO/TD-No. 768) (UNESCO/IOC)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate, first session (Miami, Florida, USA, March 25-27, 1996)
GCOS-25 (WMO/TD-No. 765) (UNEP/DEIA/MR.96-5)	Report of the GCOS Data and Information Management Panel, second session (Ottawa, Ontario, Canada, May 14-17, 1996)
GCOS-26 (WMO/TD-No. 766)	Report of the Joint CCl/CBS Expert Meeting on the GCOS Surface Network (Norwich, UK, March 25-27, 1996)
GCOS-27 (WMO/TD-No. 772) (UNEP/DEIA/MR.96-7)	Report of the Expert Meeting on Hydrological Data for Global Observing Systems (Geneva, Switzerland, April 29-May 1, 1996)
GCOS-28 (WMO/TD-No. 793) (UNEP/DEIA/MR.97-3)	*In Situ* Observations for the Global Observing Systems (Geneva, Switzerland, September 10-13, 1996)
GCOS-29 (WMO/TD-No. 794) (UNEP/DEIA/MR.97-4)	Report of the Global Observing Systems Space Panel, second session (Geneva, Switzerland, October 16-18, 1996)

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GCOS-30 (WMO/TD-No. 795)	Report of the sixth session of the Joint Scientific and Technical Committee for GCOS (Victoria, British Columbia, Canada, October 28-November 1, 1996)
GCOS-31 (WMO/TD-No. 803)	Proceedings of the fifth meeting of the TAO Implementation Panel (TIP-5) (Goa, India, November 18-21, 1996)
GCOS-32 (WMO/TD-No. 796)	GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 2.0, June 1997
GCOS-33 (WMO/TD-No. 798)	GHOST - Global Hierarchical Observing Strategy, March 1997
GCOS-34 (WMO/TD-No. 799)	Initial Selection of a GCOS Surface Network, February 1997
GCOS-35 (WMO/TD-No. 839)	Report of the second Joint CCl/CBS Meeting on the GCOS Surface Network (De Bilt, The Netherlands, June 25-27, 1997)
GCOS-36 (WMO/TD-No. 844) (UNESCO/IOC)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate, second session (Cape Town, South Africa, February 11-13, 1997)
GCOS-37 (WMO/TD-No. 845) (GOOS-10) & (GTOS-9)	Report of the Global Observing Systems Space Panel, third session (Paris, France, May 27-30, 1997)
GCOS-38 (WMO/TD-846) (GTOS-10)	Report of the Meeting of Experts on Ecological Networks (Guernica, Spain, June 17-20, 1997)
GCOS-39 (WMO/TD-No. 847) (GOOS-11) & (GTOS-11) (UNEP/DEIA/MR.97-8)	Report of the GCOS/GOOS/GTOS Joint Data and Information Management Panel, third session (Tokyo, Japan, July 15-18, 1997)
GCOS-40 (WMO/TD-No. 848)	Report of the GCOS/WCRP Atmospheric Observation Panel for Climate, third session (Reading, UK, August 19-22, 1997)
GCOS-41 (WMO/TD-No. 849) (GOOS-33)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC) Ocean Climate Time-Series Workshop, (Baltimore, MD, USA, March 18-20, 1997)
GCOS-42 (WMO/TD-No. 857)	Report of the seventh session of the Joint Scientific and Technical Committee for GCOS (Eindhoven, The Netherlands, September 22-26, 1997)
GCOS-43a (GOOS-36)	TAO Implementation Panel, sixth session (Reading, U.K., November 4-6, 1997)

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GCOS-43b (GOOS-55)	International Sea Level Workshop (Honolulu, Hawaii, USA, June 10-11, 1997)
GCOS-44 (GOOS-61)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC), third session (Grasse, France, April 6-8, 1998)
GCOS-45 (WMO/TD-No. 922) (GOOS-58) & (GTOS-16) (UNEP/DEIA/MR.98-6)	Report of the Joint Meeting of the GCOS/WCRP Atmospheric Observation Panel for Climate and the GCOS/GOOS/GTOS Joint Data and Information Management Panel, fourth session (Honolulu, Hawaii, USA, April 28-May 1, 1998)
GCOS-46 (GTOS-15)	Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, fourth session (Corvallis, USA, May 26-29, 1998)
GCOS-47 (WMO/TD-No. 941) (GOOS-67) (GTOS-20)	Report of the Global Observing Systems Space Panel, fourth session, (College Park, Maryland, USA, October 22-23, 1998)
GCOS-48	Report on the Adequacy of the Global Climate Observing Systems (United Nations Framework Convention on Climate Change, November 2-13 1998, Buenos Aires, Argentina)
GCOS-49 (GOOS-64)	Implementation of Global Ocean Observations for GOOS/GCOS, first session (Sydney, Australia, March 4-7, 1998)
GCOS-50 (GOOS-65)	Implementation of Global Ocean Observations for GOOS/GCOS, second session (Paris, France, November 30, 1998)
GCOS-51 (GOOS-66)	Global Ocean Observations for GOOS/GCOS: An Action Plan for Existing Bodies and Mechanisms
GCOS-52 (GOOS-68)	TAO Implementation Panel, 7th Session (Abidjan, Ivory Coast, November 11-13, 1998)
GCOS-53 (WMO/TD-No. 958)	GCOS Surface Network (GSN) Monitoring Centre Implementation Meeting (Offenbach, Germany, January 19-20, 1999)
GCOS-54 (WMO/TD-No. 953)	Report of the eighth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS (Geneva, Switzerland, February 9-12, 1999)
GCOS-55	Report of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), fifth session (Silver Spring, MD, USA, April 20-23, 1999)
GCOS-56 (GOOS-75)	Special Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC), fourth session (May 17, 1999); The CLIVAR Upper Ocean Panel (UOP), fourth session (May 21, 1999); A Joint Planning Meeting of the OOPC and the UOP for the OCEANOBS99 Conference (Woods Hole, MA, USA, May 18-20, 1999)

GCOS-57 (WMO/TD-No. 978) (GOOS-79)
Report of the OOPC/AOPC Workshop on Global Sea Surface Temperature Data Sets (Palisades, N.Y., USA, November 2-4, 1998)

GCOS-58 (GOOS-71)
Report of the 6th Session of the IOC Group of Experts on the Global Sea Level Climate Observing System (GLOSS)

GCOS-59 (GTOS-22)
Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, fifth session (Birmingham, UK, July 27-30, 1999)

GCOS-60 (WMO/TD-No. 1004) (GOOS-70)
GCOS/GOOS/GTOS Joint Data and Information Management Plan, Version 1.0, May 2000

GCOS-61 (WMO/TD-No. 1031)
Report of the ninth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS (Beijing, China, September 12-14, 2000)

GCOS-62 (WMO/TD-No. 1038)
Report of the Pacific Islands Regional Implementation Workshop on Improving Global Climate Observing Systems (Apia, Samoa, August 14-15, 2000)

GCOS-63 (WMO/TD-No. 1047) (GTOS-26)
Establishment of a Global Hydrological Observation Network for Climate. Report of the GCOS/GTOS/HWRP Expert Meeting (Geisenheim, Germany, June 26-30, 2000)

GCOS-64 (GOOS-107)
Report of the eighth session of the TAO Implementation Panel (TIP-8) (St. Raphael, France, October 15, 1999)

GCOS-65 (WMO/TD-No. 1055)
Report of the sixth session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC) (Geneva, Switzerland, April 10-13, 2000)

GCOS-66 (GOOS-108)
Report of the ninth session of the TAO Implementation Panel (TIP-9) (Perth, Australia, November 16-17, 2000)

GCOS-67 (WMO/TD-No. 1072)
GCOS Implementation Strategy: Implementing GCOS in the New Millennium

GCOS-68 (WMO/TD-No. 1093)
Report of the seventh session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC) (Geneva, Switzerland, April 30-3 May, 2001)

GCOS-69 (GOOS-98)
Report of the fifth session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), Bergen, Norway, June 20-23, 2000.

GCOS-70 (GOOS-113)
Report of the sixth session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), Melbourne, Australia, April 2-5, 2001

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GCOS-71 (WMO/TD-No. 1099) (GTOS-29)	Report of the GCOS/GTOS/HWRP Expert Meeting on the Implementation of a Global Terrestrial Network - Hydrology (GTN-H), Koblenz, Germany, June 21-22, 2001
GCOS-72 (GOOS-95)	Report of the 7th Session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, April 26-27, 2001
GCOS-73 (WMO/TD-No. 1106)	Manual on the GCOS Surface and Upper-Air Networks: GSN and GUAN, April 2002
GCOS-74 (WMO/TD-No. 1109)	Report of the GCOS Regional Workshop for Eastern and Southern Africa on Improving Observing Systems for Climate, Kisumu, Kenya, October 3-5, 2001
GCOS-75 (WMO/TD-No. 1124)	Report of the tenth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS, Farnham, UK, April 15-19, 2002
GCOS-76 (WMO/TD-No. 1125)	Report of the eighth session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), Bracknell, UK, May 20-24, 2002
GCOS-77 (GOOS-122)	International Workshop for Review of the Tropical Moored Buoy Network, September 10-12, 2001, Seattle, Washington, USA. Workshop Report
GCOS-78 (WMO/TD-No. 1126)	Report of the GCOS Regional Workshop for Central America and the Caribbean. "Observing Climate from Weather Extremes to Coral Reefs", San José, Costa Rica, March 19-21, 2002 (disponible también en español)

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