Climate Monitoring
Results of Oct. 11-12, 2001 CCAF Workshop

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Context

Systematic climate observations are fundamental, and vital. Without them, climate assessments and predictions on variability and trends, attributions to cause and effect, and economic and social policy decisions related to climate change will be without scientific justification. Climate has both national and international dimensions. Canada must contribute to, and take advantage of, global climate monitoring efforts.

Over the past decade, networks providing climate data have deteriorated significantly, primarily due to budget restrictions. An important step at rationalizing optimum climate networks from existing measurements initiatives, undertaking sensitivity analysis, and assessing gaps and needed enhancements has been undertaken by the CCAF. That is, the CCAF has funded a number of projects needed to provide an information base for decision making relative to Climate Monitoring.

In 1998/99 the CCAF funded a comprehensive benchmark project entitled the "Preparation of a Canadian Global Climate Observing System (GCOS) Plan". Subsequently, in 1999/00 and 2000/01, the CCAF funded eleven (11) climate monitoring assessment projects aimed at addressing some of the identified short-term (quick-start) issues. Finally, a workshop was held on October 11-12, 2001 to evaluate successes, program gaps and possible next steps. The following is a report of the CCAF Evaluation Team on the Climate Monitoring Workshop.

CCAF Funded Monitoring Projects in 1999/2000 – 2000/2001

Project S99-12-01 "Assessment of Requirements for the Supplementary Climate Networks" This was a thorough study and comprehensive report. The need for the Supplementary Climate Networks (SCN's) is well documented for a variety of users. Clearly defined strategies and priority assignments for future development of SCN's are presented. It is noted that none of the Canadian networks meet WMO requirements and SCN's have been neglected and severely eroded during the recent past. Funding is a critical requirement to redress this. The Meteorological Service of Canada (MSC) itself directly operates some of the SCNs (the best example is the Upper Air Network), partially operates others (e.g. radiation, wind, evaporation, etc.) and in all instances is the Canadian promoter of/motivator towards WMO standards of measurement, quality assurance, reporting formats, international exchange protocols, etc. for these networks. While MSC has the preceding responsibilities/roles, the Service is heavily reliant on the cooperation of partners in operating these networks but does not have direct control over the operations of these partners. A major outstanding issue from the perspective of the Evaluation Team is data management, distribution, and responsibility. In the report it is shown that there have been considerable cutbacks of observational systems due to fiscal restraints, or there is reliance on experimental data bases from a variety of sources. As a consequence, the SCN's are dependant upon partnerships between agencies, universities and individuals to provide

the data required. Related to this is the degree of ownership that each agency has for the data. Partnerships can be useful in times of fiscal restraint, but when the objective is a long term commitment to products, a distributed management structure can be only as useful as the least committed partner. Further aspects of data management relevant to this project are addressed elsewhere in this report under the Issues heading.

Project S99-12-02 “Digitalization and Accessibility of Climate Station History Metadata” The final Project Evaluation Report was provided to the Evaluation Team as a final report without any additional documentation. This is a notable and necessary program of converting hardcopy files of station metadata (inspector's reports) into a searchable digital database. Considerable progress was reported with some outstanding issues identified, such a re-filing of the original documents and converting the document text to a searchable format through OCR. The ability to search for the station files in the database and then read the image files of the associated text and photographic contents is an important interim step. There is also a plan to link the metadata files to the actual data. This will be important for studies assessing data integrity for change studies. The database is available on a CD and soon will be available on the web through a public URL. It was noted that Canada is at the forefront in this activity. A considerable expertise in digitalization of hardcopy has been developed and this group is becoming a knowledge resource within MSC.

Project S99-12-03 “Liaison between Canadian and International GCOS Programs” This project provided the funds for the services of Dr. Kirk Dawson, Chair of the Steering Committee for the International GCOS Program to:

(i) provide leadership, advice and guidance to the GCOS Secretariat located at the World Meteorological Organization in Geneva and to member nations of GCOS,
(ii) provide advice and guidance to Canadian officials on GCOS matters, e.g. reporting requirements for CoP-V,
(iii) provide input to relevant sections of the Science, Impacts and Adaptation Options Paper, to Canadian preparations and input for CoP-V, and to the Canadian position for a planned intergovernmental commitments meeting on GCOS, and
(iv) provide regular reports on developments in the international GCOS Program and other international climate initiatives for relevant Canadian programs.

Now that this project is completed, and Dr. Dawson is no longer with the International GCOS Program, it is recommended that Canada seek alternative methods to ensure direct access to, and influence of, the International GCOS office.

Project S99-12-04 “Enhancements to Moored Buoy Data and Metadata for GCOS” This project was highly successful in developing a sea surface temperature (SST) sensor accurate to ± 0.05°C. Existing state of the art buoy measurement accuracies is ± 1°C while needed GCOS accuracy is ± 0.1°C. The sensor development was an excellent collaborative effort amongst CCAF as a funder, and government (MSC, DFO) and the private sector (AXYS Technologies). The new sensor was determined to have no drift in its measurements. Future work being undertaken includes possible use of the sensor on buoys in other countries and possibly on other platforms such as ships-of-opportunity and/or ARGO floats, and comparison studies with the new and old sensor mounted on a buoy for a one year overlap period. As well as developing the SST sensor,

the project also completed a database for moored buoy metadata and identified how to integrate this data base into a compatible international standard.

Project S99-12-05 "Climate Monitoring and Canada's Water Resources" The hydrology document provided an assessment of trends but did not have time or resources to address the other GCOS hydrology tasks. Section 12.1.3 of the GCOS plan for hydrology includes trend analysis as an objective but also anomaly analysis, database issues, overlays with precipitation networks, studies of processes and relationships, application of models for identification of questions, etc. The Evaluation Team recommended documentation of a more detailed explanation of the conclusion that there was a general decrease in runoff. A large percentage of rivers showed no change and the report noted "an even split between increasing and decreasing trends" in mean annual flow according to two of the statistical techniques. Table 5.13 of the report shows 82% of watersheds with no trends in mean annual flow, 9.5% decreased and 8.4% increased. It is known from observations in small watersheds that El Niño years have a large affect on hydrology and this was not examined in the analysis. The data were stratified in several ways, but none considering El Niño years as possibly being different. The IPCC notes that the relatively small increases in global land areas that experienced severe drought or wetness over the 20th century are frequently associated with ENSOs. The Evaluation Team recommends implementation of efforts to bring the network up to WMO standards with respect to equipment, but also recognizes that the WMO spatial standards are not feasible for Canada.

Project S99-12-06 "Assessing the Utility of Coastal Sea Level and Hydrographic Data in the Estimation of North Atlantic Circulation Variability" This project focused on model assessment and improvement, using monitoring data from tide gauges on islands and boundaries of the North Atlantic and hydrographic data. The project developed improved methodologies (nudging techniques) and demonstrated the utility of using existing monitoring data to estimate the climate (circulation) of the North Atlantic. It identified the need for repeat (time series) measurements of hydrographic data along set lines, and that additional sea level data are required at high latitudes along the western boundary (a station at Nain, and a station on the east coast of Greenland) if improvements to North Atlantic circulation are to be possible using the model. Additional work that should be undertaken includes a reanalysis with better topography, adding a re-analyzed WOCE data set, including current metre data and a reconsideration of sea level data that had been eliminated from original consideration for various reasons. Assimilation of future ARGO data will be very useful. A sea level array design is an obvious next step.

Project S99-12-07 "Delineation of an Optimal Sea Level Network" This project successfully developed techniques, for both the east and west coast of Canada, to assimilate satellite altimeter data with coastal sea level data for use in modeling and mapping the spatial variations of sea level on seasonal and longer term time frames. A trend analysis of sea level changes along the east cost of North America was undertaken, including examination of various forcing functions. The project also resulted in the migration of over 330 station years of tide and water level data into the DFO national archive. Finally, an analysis was undertaken, using results from the altimeter studies as well as an examination of available data and trends from existing stations, that identified core stations needed for long-term sea level measurements on the Atlantic and Pacific coasts of Canada. A companion study is underway to identify the placement of 3-4 sea level monitoring stations in the Arctic.

Project S99-12-08 “Definition of a Core Canadian Cryospheric Network of *in situ* and Remotely Sensed Data for Monitoring the Canadian Cryosphere in Support of GCOS” This is a substantial project that engaged most of the scientists in Cryosphere research in Canada through direct contribution or consultation. The specific GCOS requirements were identified and the Canadian strategic requirements for GCOS cryospheric monitoring were articulated as six planning elements. For each cryosphere component (e.g. snow) the action items for the six planning elements were reviewed. A cost and time for resolution were estimated. The Evaluation Team suspects that the figures are first call estimates and that a thorough costing would be required for implementation. It would be a substantial program involving commitment from a variety of partners. This raises the issue of data management to be discussed elsewhere, but it is noted that there is a data management, archiving and distribution program in development for the cryosphere in Canada.

Project S99-12-09 “Wetlands Distribution and the Carbon Cycle” Prior to the Review Workshop, the Science Liaison Office had only provided the Evaluation Team with the report “Wetlands of Canada” by Charles Tarnocai. This report includes an inventory of wetlands and peatlands and rough estimates of the carbon content. There is no estimate of the accuracy of these numbers. The project summary states that “estimates were made of the effect of climate change on the carbon stored in these wetlands” but we were unable to find any such information in the report.

Subsequently, the Evaluation Team was provided with the report of the January 2000 Workshop on “Observational Strategy and Baseline Data,” the map of Canadian wetlands, and the data CD. The map is an outstanding presentation of the extent and nature of wetlands in Canada. The data base will be of great value in future wetland evaluations. Of particular note is the updated inventory of wetland areas indicating a 16% larger area for Canada. The workshop report paints a rather bleak prospect for wetland studies, with only five of 15 sites with historical continuous data sets still operating in 2000. There is a recommendation for setting up three stationary and two roving flux measurement sites. There is only one stationary site operating now. Given the expected changes in wetland dynamics from such factors as increased nitrogen deposition (terrestrial report) and altered water levels, that will vary across Canada, it seems essential that a more comprehensive monitoring network is needed. This is especially the case if wetland carbon budgets are included in the national carbon dioxide control program, although the report notes that present scientific knowledge does not warrant such a policy. The Evaluation Team recommends that the Federal Government give serious consideration to the importance of wetlands and establish correspondingly appropriate monitoring programs. Resumption of monitoring at some of the 10 sites with historical data could be the starting point.

Project S99-12-10 “Design of a Canadian Network for Terrestrial Climate Related Observations” The Evaluation Team felt that this report was too limited in scope. Its recommendations for a GCOS terrestrial program dealt mainly with measurement of the flux of greenhouse gases. Such fluxes and related information on carbon sinks and sources in forests are of critical importance for Canada in implementing the Kyoto Protocol. However there are many factors affecting forest growth, such as ozone, loss of base cations from soils and insect and disease outbreaks. These factors must be included in a meaningful terrestrial program. The report does make a strong case for the need for *in situ* data, but mainly from the standpoint of calibrating satellite algorithms.

There is a need to understand other terrestrial effects of climate change, such as regional climate anomalies and soil processes, in order to support adaptation and prediction. The report does not include some relevant recent publications on forest health. For example: the extensive review "Forest Health in North America: Some Perspectives on Actual and Potential Roles of Climate and Air Pollution" by McLaughlin and Percy, Water Air and Soil Pollution **116** 151 1999, "Reduced sensitivity of recent tree-growth to temperatures at high northern latitudes" Briffa et al, Nature **391**, p. 678, 1998, and the satellite based observations "Increased plant growth in northern high latitudes from 1981 to 1991" Myneni et al, Nature, **386,** 17 April 1997. Freshwater affects of climate have not been covered in much detail and there are no recommendations on such effects. Hydrology, wetlands and ice phenology are covered in other programs but the entire field of lake biology appears to be missing. The present plan is a good first step but needs to be more comprehensive.

Project S99-12-11 "Delineation of Temporal/Spatial Scales of Primary Productivity on Canadian Shelves" This project amply demonstrated the utility of *in situ* and remotely sensed monitoring data to describe variability, intra-seasonal and inter-annual, of phytoplankton biomass and primary production. These are important to be able to help understand and assess changes and trends in the fisheries, and in the oceanic role in the carbon cycle. Further work that needs to be undertaken includes improved algorithm development for the Scotian shelf to remove bias, combination of various indices that have been developed into fisheries recruitment models, encourage the development of needed surface radiation fields, and further studies into trends in primary production as an index of ecosystem performance.

Related Issues: Action Plan 2000, Canadian GCOS Plan, and Coordination

GCOS is an encouraging recognition of the vital role that monitoring plays in understanding and solving the climate change problem. In the IPCC Working Group 1 "Summary for Policy Makers", of the 43 "bullets" that deal with the present situation, about 37 report monitoring data.

It was noted that results from the monitoring programs are needed to support Canada's decision to ratify the Kyoto Protocol. Implementation of the Protocol raises many challenges, particularly for the terrestrial component, in defending our land based carbon sinks policy.

There were numerous monitoring needs identified in each of the five GCOS components. The workshop participants were informed that the Federal Government's Action Plan 2000 on Climate Change, announced in the fall of 2000, will contain a component specifically dealing with Climate Science, with two components: climate monitoring, to fill critical gaps in Canada's monitoring network, particularly in the North; and sinks, to enhance understanding of the potential of forests and agricultural soils to store carbon. The climate monitoring initiative offers the potential to help address some of the deficiencies noted in this report, although it was understood from the discussion that while the Action Plan 2000 was expected to be significant, only a small portion, perhaps of the order of 10%, of the monitoring needs identified in the 1999 Science, Impacts and Adaptation Options Paper (prepared by the Canadian Climate Program Board) may be met by Action Plan 2000. It is clear that the funding being made available though the Action Plan 2000 is welcome, but insufficient to meet many of Canada's monitoring programs priority requirements.

The Evaluation Team recommends a three-step process to address the situation:

1. Assemble all of the broad (including those beyond identified CCAF initiatives) monitoring program objectives into one document, with a rationale and brief description of the deliverables and status of implementation. This information is all available but scattered throughout a large number of reports.
2. Using the objectives document as a guide, the appropriate Federal Departments should set priorities for distributing the available funds to ensure continuation of the most critical data gathering.
3. Encourage all programs to renew efforts to combine resources with appropriate partners, including the Provinces and the other climate funding programs. For example, there are opportunities for the Canadian Foundation on Climate and Atmospheric Sciences (CFCAS) to support university scientists in analyzing monitoring data, given the priority the IPCC places on such information.

Current/Future Issues: Where do we go from here?

The workshop participants and the Evaluation Team discussed a number of issues related to possible next steps. The following observations and recommendations are provided for the consideration of the CCAF and other appropriate agencies:

- **Update of GCOS Plan:** The 1999 "Plan for Canadian Participation in the Global Climate Observing System" (S98-12-01) is considered by the Evaluation Team to be an important and comprehensive document of value for future research initiatives by government, university and other partners. It should move beyond the draft stage and should be updated to include progress since writing. In fact the present “draft” designation for the report should be dropped, it should be disseminated widely, and efforts should be made to provide a report on progress made since the 1999 Plan, including an update of GCOS activities beyond those represented solely by the CCAF group. Such a report would be very valuable as resource material for Canada’s international report on GCOS plans and accomplishments.
- **Agency response to GCOS Plan:** Several of the reports addressed only a subset of the Canadian GCOS plan activities that would be relevant to the author agency. An example, for illustration only, is the hydrology document which provided a very thorough assessment of trends. The group did not have time or resources to address the other GCOS hydrology tasks. We note that there was no report of upper atmosphere data, nor of climate data analysis that were not related to greenhouse gas studies. A fit-gap assessment is necessary and plans to address the missing components must be developed.
- **Data Management Issues:** In almost all GCOS reports many issues of data management need to be developed further. These issues often evolve from the need for several agencies to partner to ensure collection of adequate records under current funding constraints. In addition, we have several divergent approaches to data protocols, approaches that are not necessarily coherent with relevant international protocols. The following questions are relevant:
    - Who has the mandate to ensure continuity and to maintain GCOS requirements in future times of constraint?

- Will data be archived according to relevant international protocols?
- Has there been consideration of a binding agreement amongst partners for provision of the cited data to GCOS users in a transparent manner, i.e. is the warehouse software compliant with international data exchange protocols such as Z39.50?
- Is there a plan for data rescue?
- Are the data structures amenable to fusion with other data types?
- Are metadata databases linked to data files?
- Are the products appropriate for GCOS studies, i.e. is the scale and coverage amenable to upscaling to model resolution?
- Are access policies developed?

- **Relationship of Networks and Leadership:** The proposal for a "not for profit association" with an elected board to be established for coordinating GCOS was not supported by the Workshop as presented. It was noted that, in addition to national climate networks for precipitation, temperature, etc., there has been a proliferation of monitoring related initiatives set up with direct and indirect input to the climate issue. Seven examples are GCOS, EMAN, C-CIARN, Forest Indicators of Global Change Project, Ontario Boreal Shield Network, CCAF (Action Plan 2000) and the CFCAS. In addition the Federal Government is exploring issues such as the establishment of a CISE (Canadian Information System for the Environment), the Canadian Environmental Science Network and Indicators of Sustainable Development Reporting. These programs would have coordinators and boards that oversee and promote their activities. The 1999 GCOS plan apparently was not given wide circulation within the scientific community of expected partners, nor, was there an organized follow-up "sales" plan. The 1995 plan, "The Case for Canadian Contributions to the Global Climate Observing System", had a similar fate. In spite of the general success of coordination within programs, the Evaluation Team felt that there is a major shortcoming in linking the working level scientists within and between the programs. The Evaluation Team recommends that more direct leadership on GCOS should be mandated to MSC, without setting up yet another oversight committee such as a "not for profit association". MSC should ensure that working level scientists be involved in all five areas of the GCOS endeavors so as to ensure efficiencies and interdisciplinary needs are considered, within available resources. Existing mechanisms, such as the Canadian Climate Program Board, should be reconsidered as the necessary coordination body that could be utilized, likely through a dedicated Board sub-committee on systematic climate observations, to ensure the necessary coordination with partners.
- **Integration of Satellite and *in situ* data:** A great portion of the analysis presented is based upon *in situ* observations. There is limited discussion of the use of, or integration with, satellite data. The satellite data includes both image related data and profile or point data. This is important for upscaling analysis, coverage in inaccessible regions, and for ancillary data. This is a GCOS component that is important for Canada, for which there is considerable Canadian expertise, and must be examined.
- **Canadian GCOS Priority Monitoring Issues:**
  - **Atmosphere:** There are some required elements that we do not have, such as a soil moisture network. Others are rather sparse insofar as a climate network is concerned, such as soil temperature and pan evaporation. There must be continued

dialogue with provincial agency partners. Metadata archives need to be linked to the corporate station information system. The Metadata archive needs to be OCR'd to create a database searchable for content.

- **Ocean:** A surface and marine monitoring program in general must be developed. There must be complete field testing for the SST instrument program. The ocean productivity program has been developed to a critical stage where further effort will bring substantial results. The NASA chlorophyll algorithm needs to be refined for Eastern Canadian waters. There is need for a global solar radiation field for the same area. Model results should be used to develop an array design for where the sea level gauges should be located. Real time ARGO data assimilation must be developed.
- **Terrestrial:** The involvement of other agencies and universities is necessary. The workshop report must be updated as there has been substantial activity in the last year, such as through BIOCAP. There should be an effort to get the working scientists together to provide convergence of activities in a systematic manner. Time is required to build new initiatives.
- **Wetlands:** Consideration must be given to the important issues of links to international programs, relevance to the carbon cycle and flux measurements.
- **Hydrosphere:** The network analysis should be physically based; a comprehensive network plan based upon the Regional Hydrometric Basin Network should be completed. The GCOS hydrological recommendations need to be reviewed and items not addressed to date should be considered.
- **Cryosphere:** The current report needs to be finalized and published on CD. The issue of fusion of disparate data sets needs to be addressed. Archive gaps need to be filled, such as the glacier data base. There is a need for discussion amongst partners to ensure long-term data sets. The '95 CD-Rom on snowcover needs to be updated. The archives need to be more readily accessible by the public and more visible to the research community. There are issues of certification for observing protocols and instruments.

- **Other Issues:**
  - There must be continuity in resource allocation. There is a need to keep the process moving.
  - Placement of CCAF funds into suspense accounts should be encouraged to allow for orderly project development irrespective of when the funds arrive during the fiscal year.
  - Furthering public awareness of climate issues, through the web, will be well served by providing ready access to monitoring data, products and services.
  - Users of climate data must be vocal at senior government and political levels with respect to the need to maintain and continue existing networks, and add stations and missing networks where needed.

The Final Analysis

In spite of the shot-in-the-arm provided by resources for the monitoring component of the Action Plan 2000, major climate monitoring gaps remain, particularly in Canada's northern regions. Additional resources and agency commitments to climate monitoring are critically needed.