THE CLIMATE CHANGE ACTION FUND (CCAF) - ARCTIC CLIMATE RESEARCH AND MONITORING

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Introduction

Canada's concerns about climate change include our commitment to the Kyoto Protocol. Our support of this protocol led to the Climate Change Action Fund (CCAF). This Fund supports scientific activities related to climate change in Canada. Current scientific knowledge indicates that the high latitudes play a very important role in processes of global climate change. In Arctic Canada in particular, major questions relate to the state of knowledge concerning climate variability and change. There is a need to recognize and measure the evidence, or characteristics, of such change, to understand how that change is expressed, and the effect that such changes have on lower latitudes.

The CCAF-Arctic was initiated under a strategy developed from the Canadian Arctic Climate Science workshop held at Dunsmuir Lodge, Sidney, B. C., in February 1999. The aim of Phase 1 was to strengthen the knowledge base upon which a longer term (10 year duration) arctic climate change research program for Canada could be developed. The Call for Proposals in 1999 was for:

(1) up-to-date summaries of knowledge about the climate system,
(2) the maintenance and rescue of long-term time-series data of importance to determining variations in Arctic climate, and
(3) assessments of current climate model projections for Arctic Canada.

Because CCAF-Arctic Phase 1 was of short duration (24 months maximum), most of the CCAF-Arctic Phase 1 activities were directed towards data retrieval and monitoring, and the syntheses of already-existing data. There is need to re-establish momentum in Arctic climate science in the light of the fiscal cuts in federal government agencies and programs over the previous decade.

SCIENTIFIC SYNTHESIS

Evidence about rapid or 'unusual' climate change in the Arctic, or the effects of such change, must be assessed as deviations from an already dynamic situation. Only in a few cases will this evidence be clear and unequivocal. Field observation and measurement, and model simulations based upon simplifications of physical, chemical and biological processes, should complement each other. A common and frequent science problem is that the temporal and spatial scales of observation and data in different subject areas may differ, and model parameters, may not always be compatible.

Any science synthesis must consider the distinctive features of the northern high-latitude climate system, especially as it relates to Canada. There are some distinctive problems of Arctic climate science. These include (1) many key cryospheric processes (e.g. ice-water phase change; annual energy fluxes) are not characteristic of lower latitudes, and therefore require relatively distinct and/or unique methodologies, and (2) although the northern high latitudes provide a number of highly significant proxy data sets (e.g. glacier ice cores, permafrost temperatures, ground ice, pollen and lake sediments, tree rings), these data have not yet been assembled into an integrated and holistic description of past climate change. The Arctic climate system and its sensitivity to change needs to be clearly identified as distinct from, but importantly related to, lower latitudes and the southern polar region.

Priority issues in Arctic climate science

At the global level, climate in the Arctic is a result of the general circulation of the atmosphere and heat transfer by the oceans. It is generally agreed that fluctuations in the upper atmosphere control or influence surface conditions. The factors that influence high-latitude energy fluxes including the Arctic Oscillation (AO) are fundamental science questions that need to be addressed. At this scale, global climate modeling coupled with modeling of ocean dynamics seems the most fruitful line of attack. At a regional level, the role played by sea ice urgently needs clarification. Spatial variability of sea ice over time, at annual, decadal and longer time scales, is poorly documented. More specifically, the positive and negative energy feedbacks associated with sea-ice variability need clarification and understanding. Sea ice exerts a feedback that will strongly influence the magnitude of global climate change in the coming century.

The identification and quantification of the energy and chemical fluxes into and out of the Arctic, and the storage, release and feedback of moisture, in all its forms, is another area of general concern at the regional level. The sources and sinks of CO_2, CH_4 and other gases, as well as anthropogenetic pollutants such as CFCs, need attention. The complexities of land/ocean interactions, especially within the Canadian Arctic Archipelago, and the dynamic links between the terrestrial and the marine environments need to be understood better.

Several immediate science issues of high priority may be noted. For example, the magnitude, frequency, and causes of extreme events in Arctic weather, stream flow, lake and sea ice, snow cover and other climatic-related variables need careful study in order that trends in global climate change are correctly interpreted and understood. Understanding of the magnitude and speed of past and ongoing climate change in the Arctic also needs to be improved through continued monitoring and the analysis of already existing time-series data. There are also some quite specific and focused science issues. For example, what roles do polynyas and Arctic Archipelago water mass changes play in influencing regional climate; what is the significance of the north-flowing Arctic rivers in influencing the characteristics and dynamics of the water masses in the Canada Basin; what is the role of wetlands and changes in tree-line on patterns or rates of regional climate change; and do permafrost and glacier ice provide terrestrial proxies for the monitoring of ongoing climate change?

CCAF-Arctic Phase 1

The Call for Proposals identified two science 'knowledge deliverables' : (1) Improved knowledge of the arctic climate system, its influences, regional and global linkages, changes ranges and feedback timings, (2) Knowledge of the adequacy of time-series information, and strategies to remedy deficiencies. Fifteen (15) projects were funded; these are listed and classified as to their science focus and knowledge deliverables as set out in the Call for Proposals (see appendix 1). The CCAF numbers are used to identify projects in the following comments.

Achievements

Eight projects (13, 14, 16, 19, 21, 23, 25, 26) were directed specifically towards adding to, or improving, knowledge and understanding of the changing climate system in arctic and sub-arctic Canada. These could be subdivided, somewhat arbitrarily, into either 'archiving' (14, 16, 25, 26) or 'synthesis' (19, 21, 23), with project (13) falling into both categories. Two of the 'archiving' projects have significantly increased our understanding of the relatively poorly documented marine environments of the Arctic; one (16) allowed calculation of the carbon budget of the Labrador Sea and extended its study to the Arctic Ocean, the other (14) extracted information from assembled archival data that permits a better understanding of the physical and biological processes operating in the Beaufort Sea. Finally, one project (26) assembled important and useful data concerning two northern watersheds in the Mackenzie Delta area of the Western Canadian Arctic. This data set permits future refinement of the dynamic linkages that exist between the atmosphere, and the various terrestrial components, such as the snow and vegetation covers, permafrost, and river discharge.

Two projects (13, 21) make specific contributions to our understanding of extreme events and climate variability in the Arctic. One (21) was an integrated examination of the response of the Arctic cryosphere and hydrosphere to the unusually warm summer of 1998. The other (13) analyzed the recurrence interval of flood regimes on arctic rivers and compiled a database of 35 'index' rivers from across northern Canada. This involved the extraction of data from various government agencies in the territories and the provinces. Both projects involved highly 'visible' topics that are of importance to a wide range of socio-economic activities in high latitudes (e.g. stability of foundations; water levels; transportation).

A characteristic of many CCAF-Phase 1 activities is that twelve projects (13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26) were centrally concerned with the 'maintenance and rescue' of relevant time-series climatic data. In many cases, data have been converted to modern format, thereby making it available to future generations of researchers. These successful rescue missions must be regarded as one of the main achievements of the Phase 1 funding. In particular, permafrost (i.e. ground) temperature measurements at three High Arctic localities have now been re-established and previous data 'recovered' (18), a wide array of highly variable climate data time-series, much of it compiled by PCSP-supported field parties over the past 35 years, has been collated and normalized (22), and energy flux data for the Canadian Archipelago has been assembled and a Web site initiated (17). Two projects (19, 23) have assembled and compared data from large areas and from many different sources, in order to identify climate trends that may be relevant in the global context and to assist in the identification of any regional climate change differentiation within Arctic Canada. One (19) developed a model that accepts data from a range of proxy sources, the other (23) emphasizes the usefulness of paleo-proxy data as a means of providing information on past climate trends in the Canadian Arctic. The incorporation of climate-related Arctic data into the existing National Arctic Geoscience Database (20) within the Geological Survey of Canada is an important development. This will facilitate data retrieval and ensure future Arctic data will not be lost.

Owing in large part to the relatively short duration for the investigations, and the funding levels available, only modest modeling-related projects could be supported, and the achievements were understandably limited. Three projects (12, 19, 26) focused on models that might predict or explain aspects of climate change in Arctic Canada. One project (12) used a coupled atmosphere-ocean global circulation model enhanced greenhouse warming to analyze characteristic patterns of variability in the Arctic climate. A fundamental science question is: what are the factors that control the AO; how much is the natural environmental variability changed by, or the result of, greenhouse warming and long-term, human-driven climate change? The general conclusion suggested from this study is that the AO will certainly change under enhanced greenhouse forcing and this will imply climate changes in many parts of Canada.

Another modeling project (19) considered a range of proxy data in an attempt to make a more realistic interpretation of past climatic trends. The third project (26) used field data from two well-documented watersheds in the Mackenzie Delta region to validate numerical weather prediction against ground observations and also developed a model procedure that will permit prediction of the water balance of areas where ground observations are either sparse or absent.

A number of the projects funded under CCAF-Arctic Phase 1 involved observations to characterize or monitor Arctic climate, to identify variability and anomalies, to detect anthropogenic influences, and to provide data for models (13, 14, 16, 18, 21, 25, 26). An especially notable success was the comprehensive and integrated documentation of the anomalously warm summer of 1998 (21). Other successes were the characterization of water masses in the Arctic Ocean and Labrador Sea as regards CO_2 and CFC concentrations (16), and the identification of ground temperature (permafrost) warming in the High Arctic (18). One project (25) undertook the compilation of a bank for climate data for the Nunavik region that will prove useful in any future assessment of the impact of climate change upon the boreal forest ecosystem.

Because of the short time duration of Phase 1 (15-18 months in some instances) and the modest levels of funding that were allocated, relatively few projects were able to focus upon the various cryospheric process linkages. One examined the effect of the Arctic Oscillation upon the large-scale atmospheric circulation of the Arctic (12), a second the linkages between ice cover and ocean dynamics in the Beaufort Sea (14), and a third investigated the link between terrestrial and atmospheric variables within a northern watershed context (26). All make initial steps towards adding to the knowledge base concerning the dynamics of Arctic climate. Similarly, although several projects involved the use of mathematical models, only two (19, 26) were able to proceed towards the testing of their models.

Gaps remaining in Canadian arctic climate science knowledge

An area vital to our understanding of climate change is the documentation and modeling of upper atmospheric phenomena and behavior. Such research, which is global or hemispheric in nature, does not necessarily relate exclusively to the high latitudes. Yet, because the polar region exhibits special cryospheric and solar radiation flux processes that are thought to exert an influence upon world climate that is larger than its proportional spatial extent, Canada needs to give adequate attention to research in this general area. The Arctic Oscillation and its role in climate variability, change and extreme weather events in the Canadian Arctic needs major study. In this respect, the integration of Canadian efforts with other international climate science initiatives and programs, including those in the southern polar regions, should be stressed.

Sea ice influences climate on both the regional and local scales. There is a need to continue and increase the collation and interpretation of sea-ice data gathered both manually (i.e. in the field) and from satellites. Knowledge acquisition should involve its seasonal and decadal distribution, its age and thickness, the positive and negative feedbacks associated with the changing extent of sea ice, and the impact of snow cover on sea ice and snowfall on the sea. Ocean-terrestrial interactions are also critical, not only along Canada's long coastline where ice conditions influence erosion and sedimentation, but also in the Arctic Archipelago in general, where water mass dynamics, ice conditions, and polynyas are intimately linked. Our current strength in understanding the Beaufort Sea and its ice dynamics needs to be extended into the High Arctic Archipelago.

A third weakness lies in our understanding of ecosystem response to Arctic climate change, and of the ways and the degree by which changes in the ecosystems affect regional and local climates. Studies of the interaction between the land surface and climate must be undertaken at both the regional and circumpolar scales. Special attention should be paid to the subarctic regions of Canada since lakes, wetlands and organic terrain are important 'sinks' for CO_2 and CH_4, and under some conditions, become sources. There are many 'science' questions. For example: What will be the effect upon high-latitude climates of a changing tree-line and associated changes in arboreal species? Will the shrub tundra become more widespread and if so, what will its impact be upon Arctic climate? Will warmer winters with more snow cover and earlier spring thaw change the tundra and peatland ecosystems, thereby changing permafrost dynamics in the subarctic and the thickness of the active layer in the arctic? Will stored carbon be released? The whole area of impacts of Arctic climate change, upon the physical environment, on ecosystems, and on the socio-economic environment of the Arctic, must become more central in CCAF-Arctic Phase 2.

There are other important areas of study where CCAF-Arctic Phase 1 activities should be continued. For example, the continued development of multi-proxy palaeo-climate reconstructions at both decadal and millennium time scales is required in order to validate climate models, to assess climate change and to formulate climate change scenarios for the 21st century. The interpretation of 20th century trends in the context of climate change predictions is particularly critical. Linked to this general activity should be the continued study of glaciers, icecaps, ground temperatures, ground ice, lake and river ice, snow cover, runoff and glacier discharge, all within Canada but with co-operative and comparative studies of the climate response of the nearby Greenland ice-cap. Not only do such studies provide evidence of past climates and the effects of climate change upon terrestrial hydrology and the freshwater and nutrient supply, but ice in all these forms is uniquely sensitive to climate change. One of Canada's main science roles in international global climate change programs should be to provide cryospheric information and modeling initiatives that assist a general understanding of the role played by the high latitudes.

In summary, the next stage of CCAF-Arctic should include the development of better coupled atmospheric models, the validation of such models against both paleo- and current time-series data sets, and the identification and understanding of regional variability in Arctic climate change. The latter can be approached through the continued study of sea ice, the response of northern terrestrial ecosystems, and the monitoring of critical, climate-responsive, cryospheric variables.

EVALUATION OF CCAF - ARCTIC PHASE 1 ACTIVITIES

Purpose and objectives

The initial Call for Proposals made it clear that funding was for a two-year "science sub-component that would strengthen the knowledge base upon which to plan and justify a long-term (10 year) Arctic climate change research program for Canada". However, the two-year period of Phase 1 funding was too brief to allow a well-rounded assessment of present knowledge, or a thorough assessment of the adequacy of predictive models. The apparent separation of 'science' from 'impacts and adaptations', although practical for the first stage of CCAF, tended to work against a holistic and synthesized approach to climate change and its impacts. Because of the short time duration of Phase 1, there was little opportunity for investigators to assemble overall knowledge, or to assess gaps or weak areas.

The 'recovery and modernization' of past data, that would otherwise have been lost or not in a form available to current and future research, has extended the knowledge base upon which future climate change studies in Arctic Canada can be carried out. This information would not likely have been recovered through the 'normal' research process or via standard environmental monitoring activities, and was only possible through the exceptional flexibility and broad objectives of the CCAF.

Although most projects funded under Phase 1 met their stated objectives, few had completed the investigation of their topic by September 2001. About half lead directly to further or continuing work. Those that were completed within the two-year period have themselves set the stage for subsequent phases.

Scientific quality

As to be expected, the quality and thoroughness of the science varied between topics and between investigators. In general, our impression is that the overall quality of the science undertaken is good. Results from all but three projects have been included in submissions made to peer-reviewed journals, five have contributed to national data archives, and nearly all have produced new or up-graded data sets that are openly available. There was not much scope for scientific originality within the Call for Proposals and the short time frame of Phase 1. It is hoped that subsequent phases will encourage and support innovative approaches to climate change issues.

Interaction between projects

The Call for Proposals required that each project be evaluated independently, in competition with other projects submitted. However, the Canadian Arctic climate science community is small and there was a degree of overlap between co-investigators, many of whom were involved in more than one project. Thus, there was interaction between many of the projects and ‘networking’ was promoted. It would appear that the climate change issue, in all its ramifications, is an effective common thread between many different scientific communities.

Effectiveness of CCAF-Arctic as a strategic funder of climate change research

CCAF-Arctic has served an important and critical role in bringing together many members of the small Canadian community that is interested in arctic science. However, CCAF-Arctic cannot, by itself, be the principal funding source for continued development of Arctic climate science knowledge. In fact, we believe that several of the CCAF-Arctic funded activities rightly belong within the A-base budgets of the agencies concerned and should not normally be funded with ‘special’ monies such as the CCAF-Arctic. In this context, the CCAF has the role and responsibility to communicate, both nationally and internationally, with other agencies and organizations that support scientific investigations into global climate change and Arctic climate change in particular. During the last 20 years Canada’s capability in Arctic research has progressively declined. This has become a cause for embarrassment and has raised concerns that our knowledge of the Arctic climate is inadequate to support sound policy decisions, investments or socio-economic responses to future changes. The CCAF-Arctic Phase 1 has been successful in re-invigorating Canadian arctic climate science.

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 sub-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 component in particular offers the potential to help address some of the deficiencies noted in this report.

The workshop also heard about the program of the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) in a presentation given by Dr. Gordon McBean, Chair of the CFCAS Board of Directors. Dr. McBean indicated that the CFCAS, which is targeted at university based research, views the Arctic as a priority area for climate research. The CFCAS thus would appear to offer an excellent opportunity for the CCAF Phase 2 to develop complementary climate research initiatives in this area.

Canada's international commitments

The most recent IPCC report has reinforced concerns about impending climate changes and the possible severity of ecological and socio-economic effects. Now, the events of September 11, 2001, have diverted attention towards more immediate security issues. It is very important that CCAF be kept on a steady course in the current circumstances. Integrated sound knowledge of climate and its effects will be more than ever important as social and economic activities regain momentum.

Scientific capacity building

Scientific activity in the Canadian Arctic has declined during the past two decades when compared to the increased investment in Arctic science by other circumpolar countries. CCAF - Arctic, in a modest fashion, has 'rescued' and re-invigorated scientific activity in the Arctic and allowed a number of younger, less experienced scientists to enter the Arctic science domain. In this way, CCAF-Arctic Phase 1 has contributed directly to capacity building in arctic science in Canada. This stimulation to Canadian arctic science can only be maintained if this activity is followed with an adequate 10-year plan for CCAF-Arctic research. Two years of funding 15 projects is not enough to turn around the decline in Canadian arctic science. In order to undertake effective science in arctic Canada, it is also clear that there must be investments in new Arctic science infrastructure and facilities.

Satisfaction among those who contributed leverage funding

Leveraged support, in terms of in-kind support, intellectual support and policy support was considerable; however, this must be regarded as 'soft' support and it remains to be seen whether this support will grow into quantitative, dollar terms (i.e. hard currency or 'new' monies) with later phases of CCAF-Arctic.

RECOMMENDATIONS

In preparing for Phase 2, careful attention should be paid to statements in the current (2001) report of the Intergovernmental Panel on Climate Change (IPCC).

CCAF Phase 2 must be a supplement to, and not a substitute for, the on-going scientific studies of climate and its ramifications in Canada, both nationally and internationally. Phase 2 should not only address gaps in knowledge but also reinforce scientific strengths within Canada. The ultimate goal should be (i) a thorough and up-to-date knowledge of the climate system of the Arctic, (ii) adequate and balanced data, and (iii) a strong, vigorous, and continuing Canadian arctic climate research program, the value of which is recognized and supported both within Canada and internationally.

It is understood that CCAF Phase 2 program plans are incomplete. However, should there be a Call for Proposals with an Arctic theme or Arctic content, it should invite particular studies that relate to the 'gaps in knowledge' identified in the Scientific Synthesis above. Encouragement should be given to the following topics: large-scale and meso-scale atmospheric behavior in the Arctic; sea ice dynamics and climatic influences and responses; coastal areas and the specific climatic characteristics and influences of the Arctic Archipelago and the Hudson Bay system. More attention should also be given to the biological component of the Arctic as a factor in climate change. For example, this might include topics such as its role in changing albedo, greenhouse gas retention or release, the carbon balance, snow cover and the various impacts and adaptations that have socio-economic importance.

CCAF - Arctic Phase 2 must give attention to completing the collection and organizing of Arctic data that was supported in the earlier phase. Phase 1 investigators should be asked, as part of planning for Phase 2, to identify areas of data priority within their subject fields.

The special problems and needs for model development of high latitude climate, ocean and ecological phenomena need to be considered in Phase 2. The cryosphere itself presents special modeling problems. Modeling experts may be needed to assess proposals for future modeling work and thought should be given to the creation of an arctic modeling advisory group within CCAF-Arctic. A long-term goal of CCAF should be to ensure that Canada possesses a viable group of expert modelers who can adapt current model development to arctic conditions and problems that can then be applied to emerging environmental priorities.

The Phase 2 research plan should focus not only on distinct Arctic processes and relationships but also be developed within the context of climate change research in non-Arctic areas and in the context of impact and adaptation studies. Relevant non-Arctic climate-change topics might include: likely changes in south-north heat flow due to changes in the Gulf Stream and North Atlantic Drift; changes in the climate and radiation balance in South Polar regions that will have a reciprocal effect on the Canadian Arctic; and changes in the regime of north-flowing rivers of Eurasia and North America that will affect the hydrology of Arctic regions and the salinity and sea ice of the Arctic Ocean.

It is important that flexibility in funding, characteristic of CCAF-Arctic Phase 1, be maintained in Phase 2. There should be a mix of broad, multi-disciplinary and highly-focused cutting-edge studies. There should be a number of innovative, non-conventional scientific approaches. Holistic and/or synthesis type investigations should be increased. Traditional knowledge, and the expertise of northern indigenous people, should be utilized wherever possible. In these ways, scientific information will be obtained that would not readily be obtained through traditional granting agencies and government departments.

There should be periodic assessment and interchange between projects in Phase 2. Workshops should be an integral part of the program. Principal Investigators should be required to attend such workshops.

CONCLUSIONS

CCAF-Arctic Phase 1 was successful. It gave emphasis to and accelerated climate-related scientific activities into the Canadian Arctic regions. These are areas where present scientific knowledge is insufficient. Within the constraints of the funding available, it succeeded in meeting its stated objectives of ‘strengthening the knowledge base upon which to plan and justify a long-term (10-year) Arctic climate research program for Canada’. It is now more than ever necessary to proceed with this longer-term (10-year) program.