SCENARIOS OF CLIMATE CHANGE

Results of the January 31, 2005 CCAF Science Evaluation Workshop

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Context

There is general scientific consensus that the increase in levels of carbon dioxide in the atmosphere generated from anthropogenic activities is resulting in global climate change and climate variation, and that such activities, if they remain unchecked, will result in escalating impacts well into the future. Temperature change is predicted to be larger at northern latitudes, significantly larger than global averages, placing countries such as Canada at considerable risk in the coming years and decades. One means of assessing possible climate change impacts, and developing mitigation and/or adaptation options, is to apply research resources to develop future climate change scenarios.

The Science component of the Climate Change Action Fund (CCAF) recognized in its first funding phase (1998/99-2000/01) the importance of developing the tools and capacity for building climate change scenarios. In Phase 2 of the CCAF (2001/02-2003/04), the science program was narrowed to just 3 components, with climate scenarios remaining a priority along with research on climate processes and climate modelling. The results of the climate scenarios component of CCAF Phase 2 projects were the subject of a January 31, 2005 workshop. The workshop presentations by Principal Investigators were subject to the scrutiny of a CCAF Evaluation Team. Most, but not all, investigators submitted written interim and final reports in advance of the workshop to support the review process. CCAF funding for Phase 2 covered 4 projects extended in part from Phase 1, and 5 new projects. There was some allowance in a transition year (2004/05) to allow completion of a few of the Phase 2 projects.

The purpose of the Phase 2 evaluation workshop was to discuss achievements of CCAF scenarios projects, provide feedback on CCAF operations, provide a scientific assessment of CCAF climate scenario projects and discuss ideas for needed future work in the short and long term. A similar assessment was undertaken of the Phase 1 scenarios projects, the final report of which is published on the CCAF Science Web site at http://www.ec.gc.ca/climate/CCAF-FACC/Science/reports_e.htm

The Evaluation Team findings on the January 31, 2005 workshop on the Phase 2 CCAF climate change scenario projects are the subject of this report. The report reviews each project individually and then concludes with several overarching themes and observations.

S01-15-01: Canadian Climate Impacts Scenarios (CCIS) Facility.

More than half the funds available to the CCAF scenarios projects were targeted to this very important project. As well, each year, partners contributed about one third of the total funds available to the project. In accordance with the IPCC guidelines, the facility provides a domestic capability to produce and deliver climate scenarios applied to the identified needs of the impacts and adaptation community. The facility, originally established in 1999 with CCAF resources and subsequently extended through 2004/05 by the CCAF, provides a range of scenarios and outputs for many Canadian researchers and stakeholders. It has over 800 registered users. It has been well applauded internationally for its mandate, operations, focus, accomplishments and products. To date CCIS has provided:

- Climate change scenarios for Canada from Global Circulation Model (GCM) projections with IS92a and SRES forcing
- Predictors from the Canadian GCM1 (CGCM1) for use with statistical downscaling methods (SDSM)
- Bioclimate profiles under climate change
- Model intercomparisons
- Training on using scenarios

One of the main liaison tools of the facility was its comprehensive web site (www.cics.uvic.ca/scenarios), providing access to climate change scenarios from GCM projections, model inter-comparisons, scenario tools, links to recent accomplishments and presentations, workshop results, newsletters, etc. Due to the end of CCAF funding and the desire to engage undergraduate and graduate students in the facility, it was necessary to develop a new model for the facility that would be financially sustainable and to embed the facility within the adaptations and impacts research community, one of its largest user groups. A transition has recently occurred (2005) that includes the development of a new web site (www.ccsn.ca) and vehicle for delivering climate change scenarios and adaptation research -- the Climate Change Scenarios Network (CCSN). Distinct regional nodes in the CCSN are planned for the University of Regina, Ouranos Consortium, University of British Columbia (UBC), University of New Brunswick (UNB) and University of Toronto. This new network is planning to expand the content to include regional climate model scenarios, additional downscaling tools developed in Canada, and adaptation research tools. **It is important to make the Impacts and Adaptation community (current and future users of scenario data) aware that CCIS is now CCSN, and to inform on the sources of data, and the level of technical support available.** The Climate Scenarios workshop held on January 31, 2005 is one step in that direction. In fiscal year 2005/06, depending on man-power to provide knowledge and funding, the UNB and UBC nodes will be implemented. **Continued collaboration needs to occur with the wider climate change research community and other stakeholders working outside of the proposed nodes through regular meetings, consultations and the Adaptation newsletter.**

Developing and maintaining the core facility, particularly from a human resources perspective has been a challenge (the project leader, Dr. Elaine Barrow being on maternity leave in 2004/05). At the time of this workshop, the network had two full-time resource people (Drs. P. Gachon and B. Bass) and Elaine Barrow on a part-time basis to answer questions. Over the next few years, the CCSN plans to develop additional expertise at the University of Regina. The strong partnership with others in general, and MSC in particular, has allowed the facility to continue its development over the CCAF funding period. The facility has been widely recognized as being of significant benefit to the research user community. **There is a large demand for climate model scenarios as well as for the accompanying technical support from the Impacts and Adaptation community, and therefore it is recommended that the facility continue to operate to fill the much needed gap between the GCM and RCM modelling community and**

the climate change impacts research community. There are continuing and increased needs for access and improvements to Canadian GCM projections, scenarios, downscaling tools, and facilities for training in the development and analysis of climate scenarios tuned to the Canadian context. It was noted that, in the main, the facility had concentrated on terrestrial based climate scenarios and associated downscaling data, etc. **It was recommended that the facility broaden its attention to ensure that marine scenario issues are given more prominence in the future.**

Due to the nature of the network, this project did not provide specific training to post-graduate students until the transition to the CCSN, which has involved undergraduate and graduate students at the Universities of Regina and Toronto. Funding from CCAF through the scenarios facility has resulted in the highly visible 2004 peer-reviewed report on Climate Variability and Change in Canada: Past, Present and Future, by Elaine Barrow, Barrie Maxwell, and Philippe Gachon (Eds).

S01-15-02: Development of Weather Generators and Statistical Techniques for Downscaling Climate Extremes for Canada.

This project was a mix of applied and basic work. One task undertook the improvement of existing weather generators. Specifically, the authors tuned the WGEN weather generator for Canadian stations for the following variables: precipitation, temperature, wind speed, dewpoint temperature, and solar radiation. The results for most variables were quite satisfactory, but this weather generator does not accurately capture the variability of precipitation. The project addressed this issue by exploring the fundamental underpinnings of weather generators. Specifically, the researchers compared various mathematical/statistical approaches for the modelling of daily precipitation. They recommended specific approaches that appear to be suited to Canadian climate conditions. A manuscript describing the results has been accepted in Atmosphere-Ocean; a review by the evaluation team suggests that this work is methodologically sound and an original contribution to the state-of-the-art in weather generators. The authors state that FORTRAN software is available for simulating precipitation based on the results of their work. **The evaluation team did not review the software, but in order for the results of the weather generator work to yield dividends, it is important that the software be user-friendly for the I&A community, many of whom will not be familiar with the mathematical basis of these tools.**

Another component of this project investigated the downscaling of extremes. The researchers used sophisticated techniques to examine potential changes in extreme precipitation. Specifically, generalized extreme value functions are used to model the probability distributions of precipitation extremes. A unique feature is that atmospheric circulation measures are incorporated as co-variates in the parameters of the distribution. Changes in atmospheric circulation projected by GCMs were then input into the extremes model to estimate changes.

In another aspect of the extremes work, the researchers performed a study of methods for detecting trends. This study was published in the Journal of Climate. In the future, the team plans to study the uncertainty of scenarios and to tackle the special interpretation of weather generator parameters over data sparse regions.

The results of this project provide a sound mathematical/statistical basis for advancing the science of scenarios development in Canada. **However, it is important that interactions between this group and other scenarios development groups continue so that these advances can be rapidly incorporated into appropriate efforts by other groups.**

This project contributed to the training of graduate students and post-doctoral scientists.

S01-15-03: Development of Climate Change Scenarios for the Agriculture Sector.

The project developed much useful daily climate scenarios data for 30 years at a 0.5^{o} grid-scale for 2040-2069, using 1961-1990 as a baseline. The Agriculture and Agri-Food Canada (AAFC) WG stochastic weather generator was used, based on a modification of WGEN, which was further enhanced (by modifying the second-order Markov chain) for generating future scenarios. It was noted that recorded raw data from Environment Canada was used to feed into the AAFC-WG for the 1961-1990 baseline. **It should be ensured that homogenized data (Adjusted Historical Canadian Climate Data obtainable from the CCCma website or Environment Canada) be used for downscaling where it is available. This would also simplify any future linkages with related projects as the data sets would be comparable.**

The project generated two sets of multiple 30-year daily time series of maximum temperature, minimum temperature, precipitation and solar radiation data for the 2040-2069 period based on two climate change simulations, one based on CGCM1 (IS92a GHG+A) and the other based on HadCM3 (IPCC SRES A2). The multiple realizations provided a range of potential future climate outcomes that are useful for risk analysis and assessment in Canada's agriculture sector. Although the focus was on western Canada and the Prairies, all potential agricultural areas of Canada were looked at, using Canada's Land Inventory ratings (British Columbia was excluded due to topography). **As such, it is recommended that the findings be distributed to agricultural regions throughout Canada.**

The most outstanding part of the project was modifying AAFC-WG (weather generator) to capture changes or represent better the changes in wet spells. **Since there is no spatial connection between the output data from a weather generator, users must be cautioned when feeding this point information into their impacts model.** Data sets were all provided to the impact community on request, and data sets will be provided to CCIS (CCSN) to disseminate. The agroclimatic indices will be disseminated when available.

Other useful outcomes of the project for future users were climate station data (multiple 30 year daily time series of Tmax, Tmin, precipitation and solar radiation) interpolated for the baseline period (1961-1990) at a 0.5˚ scale for current and potential agricultural areas of Canada and climate statistics for the 1961-1990 and 2040-2069 periods for input into the weather generators.

Other benefits of the project included providing interpolated gridded data, based on ecodistricts, to generate the continuous time series of data from 1951-2020 for 4 variables. AAFC is currently preparing to put together an executable version of AAFC WG model to make it publicly available. One peer-reviewed paper has been published, and a few more are under preparation. Two PDFs were trained, and several AAFC staff gained experience with GCM scenario data.

S02-15-01: Downscaling of Global Climate Model Outputs for Flood Frequency Analysis in the Saguenay River System.

This highly leveraged project assessed the utility of using three different neural network models to generate high resolution precipitation and temperature data downscaled from GCM outputs, needed as input to hydrological models for the Saguenay River system. While other studies have assessed climate change impacts on annual and seasonal flow regimes, this study was targeted to determining changes in extreme events (floods/droughts). Meteorological and hydrometric data from the watershed were used to assess results. Both snowmelt and rainfall were included in the analysis. Climate change impacts could have significant impacts on extreme events in the watershed, and with over 300 reservoirs in the Saguenay system there could be implications for future water resource systems management and planning for such events in the region.

Results indicated that the time lagged feedforward neural network was the most efficient model for downscaling daily precipitation and temperature for the Saguenay watershed. Under the climate change “business as usual scenario” the hydrologic models resulted in an increase in river flows and reservoir inflows as well as earlier spring-peaks, except for the summer months where a reduction of flow was observed. Different downscaling methods resulted in significantly different (future) hydrologic regimes, indicating that one must choose with care any one particular downscaling technique over another.

Similar, and (possibly) different, neural network models, downscaling models and hydrological models would have to be evaluated in other regions of Canada if climate change impacts on water resource systems are to be properly understood for extreme events. For example, in this watershed snowmelt in alpine terrain was a very important factor. **It is recommended that research similar to that undertaken for the Saguenay be applied to a few other watersheds in physically different regions.**

S02-15-02: GCM Based High Resolution Spatial Temporal Precipitation Scenarios for Western Canada.

This project applied synoptic downscaling techniques to develop and evaluate western Canadian precipitation scenarios. Due to the layout of the water basins, all of western North America had to be used for the scenario development, a region greater than initially proposed. It was found that estimates of future synoptic circulation statistics from climate models (CGCM1 and CGCM2 using 2020-2050 12 hour 500 mb) can provide a means of estimating future fall, winter and spring precipitation. Over 370 meteorological stations across western N. America were used to determine precipitation for 2021-2050. An unexpected, yet successful, outcome was discovering that summer precipitation was driven by the unclassified patterns of the synoptic circulation. It was also found that the monthly values for 2020-2050 have variances that were greater than observed. This is unexpected as models normally underestimate variances. These scenarios have not as yet been compared to those produced by other researchers. However the synoptic downscaling does tend to fit better with historical data, and therefore one may assume that it would be closer on the future events/predictions. **It is recommended to hold regular forums to share and discuss scenarios amongst researchers, nationally and internationally.**

Outputs of the project were precipitation and variance ratio maps produced for the periods December through February, March through May, June through August and September through November on a 50 km grid for all of western North America. The results were published in one paper, and at least nine various conferences. Training was provided to three M.Sc. students, and three Research Associates.

So far, applications of the results of this project were to make the data available to users on the CCIS (CCSN) scenarios website, and to use results in an oil sands development court case.

The methodology has also been applied to microscale insect work, snow modelling, as well as to forestry cover work. Follow-up of this work is to continue the micro meteorological work and downscaling to larger geographical regions. **The Principal Investigator expressed a need for one data coordinating agency that can help to share downscaled and other data collected from these types of projects amongst Impacts and Adaptation researchers and users. This task should be allocated to an existing body, such as CCSN.**

S03-15-01: Developing Paleoclimatic Scenarios for Impact and Adaptation Research in Canada.

This low-budget one-year project made use of expert opinions and discussions between paleoclimatologists and the user community to achieve its first two objectives in relation to the value and limitations of paleoclimatic data for impact and adaptation research, and the development of a plan to address the identified gaps. The process was highly successful and identified considerable value and capabilities as well as a number of limitations or gaps in each of the long-term/ low resolution Holocene records, paleolacustrine and paleomarine intermediate records, and recent high resolution records from tree rings and ice cores. The main element of the plan to address the needs is a proposal to establish a counterpart to the CCIS/CCSN, fully linked with the GCM modellers and paleoclimatologists on the one part, and the Impact and Adaptation community on the other. The third objective was the establishment of a web site to present maps and databases of paleo-climatic and -environmental data. This site is now operational (http://rcvcc.nrcan.gc.ca/).

The nature of this project was not conducive to formal scientific publications or the training of personnel. Nevertheless, the interest in the work is indicated by the number of requests for the CD containing the workshop report and initial version of the web site. Also, the project leader is committed to an active promotion of the work and distribution of the data by the C-CIARN. Indeed, some users are hesitant in relying solely on modelled output for paleoclimate scenario information and prefer to rely on actual data, even if incomplete. The workshop has also generated interest in the paleo community itself for climatic I&A research, and NRCan has assured continuity of the work. The web site link with CCIS is appreciated by users. **A long**

term goal should be to establish continuity in the presentation of data from the past, the present and the future, but it is not clear how to achieve that. Some users interested in the recent past feel that paleoclimatologists place too much emphasis on the long term records, but the justification is that a long record is essential to capture adaptation to major climate changes; though even then, the temperature extremes observed in the Holocene are somewhat less than those projected for the near future by GCMs.

A Canadian problem with the availability of tree ring and ice core data was identified, in that the data collected by non-federal scientists is often held back for personal research and not always deposited in the international databases. **It is recommended that an effort be made to sensitise the paleo community to the importance of depositing their data in the international databases, or that funding agencies impose this practice as a requirement for funding.**

S03-15-02: Development of a Climate Change Geographical Information System (GIS) for Canada.

This small-budget one-year project hoped to capitalize and expand on a web-based GIS system already in operation in the Atlantic region to demonstrate the ability to download raw climate data, provide profiles or graphs of variables at points and contour variables in layers that can be superposed on existing geographic reference layers or layers of other variables. Whereas numerous ways to display climate data already exist, they are mainly suited to researchers and specialists with considerable knowledge and software capabilities. The main appeal of this project is that it can present climate change information in a manner that can be understood by non-specialised users, directly on the web. Also climate change information can be made available as GIS layers to a large sector of potential climate impact researchers (e.g. landscape, municipal and transportation planners) for whom GIS is the main tool of work. A final point of interest is that, being based on an official federal web site, all the help tools are available in both languages. Thus, part of the gap between researchers and Canadian users could be bridged by this technology.

The amount of effort, money and time required to adapt the system and assemble the proposed databases had been underestimated. Nevertheless, a good basic capability has been achieved, with a small dataset over the region. Although the system will display any data, the maps for certain discontinuous variables may not be meaningful. The hoped for data from Québec has not yet been integrated, but the system is ready, and meets the GeoConnexion standards required for expansion across Canada, to include other climate change scenario information from the past, present or modelled future. The Region is prepared to provide guidance to other regions that wish to use the system. CCAF funding has given this project an initial impetus to develop the prototype, and the Region is committed to maintain and expand the system for its own use. An application is already underway with NRCan in relation with their project Climate Smart. This CCAF project was not conducive to the training of highly qualified personnel and will not generate peer-reviewed publications, but more presentations are planned within Environment Canada and possibly at the CMOS Congress. **It is hoped that the value of the tool will be promoted through presentations at C-CIARN meetings and that it may be offered through the (virtual) nodes of the Climate Change Scenarios Network (CCSN).**

S03-15-03: A First Evaluation of the Strengths and Weaknesses of Statistical Downscaling Methods for Simulating Extremes over Various Regions of Eastern Canada.

This is a highly leveraged project with CCAF funds accounting for about 20% of the total cost. The downscaling methods tested included the Statistical Downscaling Model (SDSM) and the LARS weather generator. A set of 18 extremes and variability indices were defined and computed for evaluation. This project was undertaken in the context of a larger program on climate change within the Ouranos consortium.

One set of analyses compared observed frequency distributions with those estimated by SDSM and LARS-WG. Not unexpectedly, better results were obtained for temperature variables than precipitation variables. Also, in general SDSM produced superior results to LARS-WG. Another set of analyses compared distributions computed directly from GCM data (CGCM1 and HadCM3) with distributions computed from SDSM using GCM predictors. The SDSM distributions using GCM predictors compared much more favourably with observed data than the direct GCM distributions.

The basic research on improving precipitation weather generators in the S01-15-02 project provides an opportunity to explore the extent to which such model improvements would improve the results for the stations in this project. **If there are future opportunities for such work, collaboration between these groups to investigate this possibility is recommended.**

The achievements of this project generally meet the stated objectives. There is one inconsistency between the proposed deliverables and those given in the presentation at the evaluation workshop. The proposal mentions that a workshop was to be organized in the fall 2003, but no mention of this was made in the presentation. Subsequently, the CCAF Science Liaison Office contacted the project proponent and learned that a full-day session was organized for the Canadian Water Resources Association conference in Montreal in June 2004 (Water and Climate Change – scenarios and extremes).

At this point, the written results of the project are two conference proceedings papers. Six articles are listed as being in preparation or nearing submission. It appears that these articles will satisfy the promised report deliverables upon completion. Several graduate students and post-doctoral scientists were involved in the project.

S03-15-04: Production of Multiple High-Resolution Climate Change Scenarios.

This project produced a set of high resolution scenarios using a thin plate smoothing spline technique implemented in a tool called ANUSPLIN. Scenarios were produced for four GCMs (CGCM2, HadCM3, ECHAM4, and CSIRO Mk2) for the A2 and B2 SRES emissions scenarios. This is slightly different than proposed (2-3 GCMs and 6 emissions scenarios), but provides a quite satisfactory range of possible outcomes. Thirty-year mean fields were produced for a set of 19 bioclimatic variables for 3 future periods (2011-2040, 2041-2070, 2071-2100) and monthly or annual fields were produced for 12 other bioclimatic variables and 6 standard climatic variables. The process to produce scenarios is now relatively routine such that other scenarios can be produced with relatively little effort. The methodology appears to be fundamentally sound and straightforward, resulting in scenarios that are suitable for the targeted application of landscape modelling.

The sheer volume of scenario data produced by this project is impressive considering the minimal budget. Also, the availability of the tools to produce additional scenarios should continue the payoff from this project in the future. The authors were not able to fully automate the process, but that outcome is hardly surprising in view of the complexity of GCMs and the range of climatic conditions that are being modelled. **A large number of simulations by many modelling groups are now being completed for the IPCC Fourth Assessment Report. It is recommended that scenarios be produced for as many of these as practical if internal or external resources can be found.**

Although a promised short peer-reviewed article has not yet been prepared, a detailed preprint paper was prepared for the American Meteorological Society's Agricultural and Forest Meteorology Conference in August 2004. Also, two papers that use the scenarios have been accepted by peer-reviewed journals.

General Discussion

The workshop concluded with a plenary discussion on gaps, opportunities, and ongoing and future needs. That discussion is summarized as follows:

The Climate Change Scenarios Network (CCSN) and the User Community

There was strong agreement that the work of Elaine Barrow and her team in the Canadian Climate Impacts Scenarios (CCIS) Facility was exemplary in terms of accomplishments, service to Canadians and international leadership. The transition to a CCSN mode was supported by the workshop participants.

The future role and approach of the CCSN was a focal point of discussion. Delivery of climate scenario information to the user community must be sustained, with an appropriate balance of research, including development of tools (downscaling techniques, extraction methods, mapping methodology), and service to users. The importance of the CCSN working with the user community (identifying gaps for example) was stressed.

The CCSN plans to target three levels of users, namely novice, intermediate, and advanced in order to better serve the community. That approach could help to address a concern that there is still a need for simple-to-use material and user manuals. It was suggested that most users probably do not need many scenarios and sophisticated products. Given the uncertainties that exist, small variances in scenario outcomes may not be significant for some users. A discussion ensued on the number (and types) of scenarios to implement for any given research project. It was agreed that maximizing the required outcome with the minimum number of scenarios was desirable; however no consensus was reached on the subject of whether more or fewer scenarios ought to be used. The CCSN is essential to provide basic guidance needed for the use of RCM and GCM scenarios.

There is a need for synergy in the scenarios field in order to maximize the use of limited resources, including more targeted research. The CCSN could help with R&D needs as well as providing the three proposed levels of service. Given the inevitable limited resources that will ultimately be available, a CCSN should develop a strategic approach on how best to bring together various researchers across the nation to ensure efficient programs and information exchange, and to ensure ongoing international liaison with other agencies.

With the termination of funding from the CCAF, the concern over future funding for the CCSN was a major issue. One suggestion was that several departments could share some of the costs.

Research Priorities and Approaches

In plenary, several needs were identified for future research. The following cannot be considered an exhaustive list for future priorities, given the limited participation of experts at the workshop. Nevertheless the workshop did identify some critical gaps deserving of future attention and funding, including:

- the lack of marine-oriented scenarios research in general was cited as a serious gap that needs to be addressed.
- more research is needed on paleoclimate scenarios to link the past, present, and future.
- additional generic scenarios (those not tuned to specific sectors / regions) are needed in order to broaden the applicability to the wide range of Canadian interests and concerns.
- downscaling techniques for wind are required.
- GCM and RCM downscaling tools should continue to be a priority.
- further development and testing of applications of scenarios are needed.
- there is a need to produce simple-to-use material and user manuals.
- more frequent meetings of scenarios scientists would promote stronger connections among research projects.

The aspect of open versus targeted calls for proposals was discussed. There may not be enough critical mass (i.e., science capacity) to have only targeted calls for research. The need to maintain a high level of competition in awarding funding was encouraged.

Capacity for Climate Change Scenario Research

While not a primary mandate of the CCAF, all projects reported on training aspects of their work, and on partnerships generated in the conduct of the research. It is evident that over its lifetime the CCAF has generated a significant scientific capacity within Canada related to the development of climate change scenarios. Building scenarios has allowed, to some extent, experts from different institutions and with different expertise to work together. There is a body of expertise now, and a need to share ideas and continue developing partnerships in the form of some sort of network. There is a need to sustain the capacity that has been built, but the mechanism and funding to carry this into the future remains uncertain given the lack of identified resources at the conclusion of the CCAF program.

Building the capacity for the research and development of scenarios is just as important as ensuring that the needs of the impacts and adaptation community are met. As such, it is paramount to bridge the gap between the scientists who develop the scenarios, and the users who apply the scenarios.

Several projects commented on the paucity of climate stations in Canada; especially with respect to geography and topography. This makes it challenging to undertake the desired calibration of models, or model verification, for rigorous spatial coverage of scenarios in Canada. Sustained capacity for climate observations is paramount if one expects to develop and verify creditable scenarios based on real world data.

Communications

Communication of results, access to tools, information exchange, etc. is of vital necessity. Continued development and access to web sites such as that developed by the Canadian Climate Impacts Scenarios Facility is strongly encouraged. It was evident from the workshop that the scenarios R&D community needs to do more marketing of the value of what it produces, perhaps linking its research results to extreme events, taking care not to make a direct cause-effect link between climate change and any specific event. CCSN could help with respect to these needs as well as provide various levels of service to the community.

There is a need to deliver information to policy makers and managers in a way that they can best understand; that is, the delivery should include products and analyses, etc., not just the data itself.

CCAF Process / Procedures

At the workshop, Principal Investigators were encouraged to comment on how well the CCAF process worked with respect to the process and funding priorities of the climate change scenarios component of the program. All were very positive in their remarks concerning the usefulness of the CCAF funding mechanism; in particular, they were very complimentary of the Science Liaison Office for providing useful and prompt feedback to all of their concerns throughout the lifetime of their projects. However, a longer life-span of the program would have been welcomed by the researchers to enable a higher level of technology transfer. The point was made on one project that the funds were not disbursed on time, which led to temporary difficulty funding and keeping the graduate student on the project.

Concluding Comments

The post-workshop review of all materials by the evaluation panel resulted in a number of general observations and recommendations. The following overall observations emerge as a result of the workshop:

- The CCAF Science program has filled a critical gap in Canadian climate change research by funding high quality priority projects in the area of scenario development and access tools, allowing high resolution impact assessments of important climate-change sensitive issues. From a program perspective, the range of activities funded under the scenarios theme was quite diverse. Under constraints of limited funding this was probably the optimum strategy to best meet the diverse needs of the Impacts and Adaptation community. The projects were generally successful in making substantive contributions to the program objectives. Most of the research results appear to represent significant advances to the fundamental science of scenarios development.

- Sustained funding must be a priority for future climate change scenario research in Canada.

- A focus is needed, likely through the Climate Change Scenarios Network (CCSN), to ensure sustained collaboration within the impacts and adaptation community, and to ensure delivery of common services such as delivery of generic scenarios from GCMs and RCMs as well as associated downscaling tools and models.

- A number of the projects indicate that there are manuscripts in preparation and/or nearing submission to peer-reviewed journals. The effort to publish should be continued in order to subject the results to expert peer review and ensure the highest quality of the resulting scenarios.

- To foster a high level of interaction among projects, any future program should consider some formal forum, such as workshops, that could be held at intermediate stages during the course of the program. These would include both scenarios developers and representatives of the Impacts and Adaptation community.

Future directions in support of climate change scenarios would seem to be in the development of tools, methodologies, data services, provision of expertise and construction of scenarios. The overall message is that resources for research, and delivery of climate change scenarios and research tools to the user community, need to be assured. Two specific areas for future effort are worth noting:

1. Ongoing work by modelling groups worldwide for inclusion in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change affords an opportunity to significantly enhance the value of scenarios available to the Impacts and Adaptation community. Participating modelling groups are producing a number of new simulations with their latest model versions. These new model simulations will represent the state-of-the-art in global climate modelling. Simulations are already available from 18 different GCMs produced by 12 different modelling centers (Feb. 2005), with more expected. Future scenarios development projects should be encouraged to examine simulations from these modelling groups and make strategic selections of GCMs in order to represent the range of future projections. A very useful early contribution would be to quickly select and develop a set of generic scenarios for Canada from these new model simulations.

2. There remains much work to be done in creating realistic and defensible scenarios of extreme events. Probably the most difficult, and most important problem is that of precipitation extremes, which was investigated by several of the projects. For instance the sensitivity of future projections of flooding to the choice of downscaling method and hydrology model reflects a continuing high level of uncertainty in the present scenarios of such extremes. It is important to continue reducing the uncertainty related to extreme events.