Climate/Weather Extremes
Results of the Oct 26, 2001 CCAF Workshop

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Context

Climate change is often expressed simply in terms of increases in globally averaged temperature. However, extreme regional consequences of climatic change, such as droughts, heat waves, forest fire occurrence, floods, shifts in ecosystem boundaries, etc, could be more significant than changes in mean temperature. Furthermore, the high latitudes are expected to experience greater changes than global averages in some key climatic variables such as air temperature, and, changes in extreme conditions in northern regions may differ from much of the rest of the world.

The CCAF undertook an initial analysis, through a North American Climate Extremes Workshop held in October 1999 in Atlanta, to assess current capabilities and understandings, and to identify needed steps to advance modelling and assessment of climate extremes. Subsequently, the CCAF called for proposals in two main areas, namely:

(i) defining and identifying extreme events from existing records, and
(ii) projecting changes in climate/weather extremes.

As a result of the Call for Proposals, the CCAF funded six (6) climate extremes research projects in 2000/01. Finally, a Climate Extremes Workshop was held on October 26, 2001 in Bromont, Québec to evaluate successes, program gaps and possible next steps. The following is a report of the CCAF Evaluation Team on this workshop.

Overview of Projects and Specific Recommendations

S98-14-01 Tri-National Workshop on Extremes and Climate Change – Canadian Support and Participation. CCAF funding allowed Canadian scientists and managers to participate in the international workshop in Atlanta, Georgia, October 6-8, 1999. The workshop was very successful in bringing together the expert community in North America to address issues of climate change and weather extremes. The resulting research agenda was authoritative and comprehensive, and resulted in a targeted CCAF call for proposals. However, because of budget considerations, the CCAF was only able to fund six research projects emanating from its call for proposals in this very important topic. All had short term objectives, but only a few of the topics identified in the research agenda were addressed**. It is recommended that the research agenda be revisited with respect to extremes to identify priority topics that need attention. One issue that needs short term attention is to make readily available to researchers the paleo-climate records that have already been identified. Also needed is a mechanism(s) to facilitate a continuing dialogue between scientists and managers to ensure the longer term issues are identified and addressed.**

Project S00-15-06 Evaluation of the Canadian Regional Climate Model (CRCM) Ability to Simulate Current and Future Extreme Weather Event Climatology. This project is related to scenario development project S99-15-02. Here the deliverables were

1) a high-resolution data set for the current climate using the CRCM driven at the boundaries by observations from a re-analysis, i.e. a 15 year simulation at a resolution of 45 km;
2) the statistical distributions of observed temperature, precipitation and wind extremes for a number of regions of the country;
3) comparison of the modelled extremes with the observed ones; and
4) evaluation of the uncertainties in the CRCM-generated extremes.

Deliverables 1, 3 and 4 turned out to be overly ambitious, given the amount of time available, since the CRCM had not yet been expanded from the initial runs over the western half of Canada to the whole country. Therefore, most of the time and resources were expended in resolving numerous model operations problems. Nevertheless, the CRCM and the appropriate diagnostic programs are now available for climate simulation over the whole of Canada.

An additional problem was encountered with the NCEP re-analysis that had been selected to drive the simulation. It was found to be missing data, and needed to be repaired and validated. As of September 2001, two and a half years of simulations of the current climate over Canada have been completed, and analysis is in progress. Preliminary comparisons with observations indicate, among others, that winter precipitation is well simulated by the CRCM, but not summer precipitation, which shows an overestimate over most of the domain. Thus it would appear that **the model's convective parameterisation is incapable of simulating the hydrological reality, a very important consideration for extreme summer weather events.** Therefore, studies of summer precipitation extremes will need to be done at a still higher resolution, using numerical or statistical methods.

Some progress was made with the second deliverable, namely a gridded data set from the national observation network suitable for CRCM validation; identification of a test region with an optimal station density; and methodology for characterizing extremes of temperature, precipitation and wind in the observations or in the model simulations.

Project S00-15-04 Severe Weather Climatology and its Planetary-scale Precursors. Working with a Doppler radar it is possible to identify mesocyclones (intense rotating cells of a few kilometres in diameter) from which most extreme local weather events result, e.g. heavy precipitation (rain and/or hail) accompanied by strong winds over a very small area or path. Tornadoes constitute the worst such events. Other definitions of severe weather events could have been chosen, such as extreme daily precipitation or number of thunderstorms in an area over a period of time, but in the absence of a given definition, mesocyclones were chosen as a good indicator. There is a tendency for reported severe weather statistics to show an increase with time, some of which is simply related to the presence of more population and other non-climatological causes. The project has produced an objective and more unbiased statistic, continuous in spatial and temporal extent, at least over the first 80 km around the radar. Mesocyclone statistics were calculated and analysed for the 8 year period for which archived data exist at McGill, and some hitherto suspected small scale geographic features of the Montreal climate could be confirmed quantitatively. **The methodology developed has been transferred to MSC, and it is recommended that it be applied at all the sites of the new Canadian Doppler radar network**. In a collaborative study, a connection between mesocyclones and the large scale weather was identified. **This connection needs to be studied further, particularly at other sites (Toronto, Edmonton), to determine its universality,** in which case it could become a very powerful tool for downscaling past and simulated future extreme weather climatologies from large scale features.

S00-15-05 A Probabilistic Study of Major Hydrological Events Recorded in the Saguenay Fjord and Lower Estuary of St. Lawrence. The Saguenay Fjord and the lower estuary of the St. Lawrence, because of their very high sedimentation rates, are able to provide a unique data set that can be used to identify major hydrological and climate events over the past millennia. Cores from the International Marine Global Studies (IMAGES) program of July 1999 were examined to reconstruct a time series of climate/hydrological events over the last six millennia, with decadal resolution. The time-series was then analysed relative to the occurrence of extreme events, and for natural variations or other forcing (landslides, earthquakes) of these events, and anthropogenic effects (deforestation, paper mills). ^{210}Pb measurements were used for a chronology of the last 100 years, ^{14}C for the 1000 year chronology, and grain size analysis to distinguish flooding and earthquake events.

The sediment core analysis with respect to variability, trends and extreme events was very successful. Exceptional events (floods) have been documented in the Saguenay Fjord core. **Additional research (already underway through thesis work) needs to be undertaken to define the frequency of hydrological and seismic events**. Trends recorded in the lower Estuary identify increases in anthropogenic fluxes and decreases in salinity (indicator of precipitation variations in the drainage basin). **While oscillations have been identified in the surface waters, these observations need to be extended to bottom water measurements. Additional analysis needs to be undertaken to better understand the nature of the climate and hydrological variability that can be identified in this very important sediment record.**

S00-15-08 Climatic Extremes in Southern Manitoba during the Past Millennium. This project was able to exploit and extend results from a related ongoing project. The first component involves the determination of the annual ambient moisture conditions from the analysis of a continuous record of tree growth rings going back 700 years. The trees used are bur oaks living or having grown in the narrow forested margin of the Red River and Assiniboine valleys. Growth rings of living trees were first correlated with the historical weather records, and cross-dating techniques were used to extend the tree ring data back in time. **Temperature changes, clear-cutting and insect infestations may be**

significant, secondary factors affecting tree growth - it is recommended that these be investigated in the future. The analysis was able to identify, among others, a period of 75 consecutive dry years around the 1700's, which is much longer that any drought observed since colonisation. Between 1661 and 1774, the frequency of below-normal annual precipitation seems to have been as high as 2 out of 3 years, while annual precipitation was at its highest around 1600.

The second component is a study of silt deposits in Lake Winnipeg using bottom mud cores reaching back to more than 1000 years. Dating of lake bottom cores cannot be as accurate as for tree rings (tens of years near the top, 100's of years at the bottom), but the analysis nevertheless reveals significant past excursions of some of the parameters from the conditions prevailing in more recent times. **More accurate dating and analysis should be completed within the next year. Also, it is recommended that the mud core analysis be related to the tree ring analysis.**

S00-15-07 Climate Indices – A View of Changing Living Conditions. The Climate Severity Index (CSI) was developed in 1984 to measure and compare climate comfort/discomfort on humans across the full range of Canadian climatic zones. Other impacts on such climate sensitive areas as ecologies and economies (tourism, industry) are not included in the index. This present CCAF study examined the variability of the CSI during the period of 1953-1995, and examined CSI trends in the future using data and outputs of a Canadian Global Circulation Model (CGCM1). The CSI combines winter and summer discomfort factors (half the weight), and includes psychological, hazard and mobility factors (the other half weight). Some components of the CSI are not amenable to analysis for future trends since they are not available as GCM model outputs; "fog" for example.

The CSI is very sensitive to temperature. So, with measured increases in past mean temperature, and predicted increases in future mean temperature, the project confirms that, not surprisingly, the CSI "improves" with time, both in the past and future, for specific locations in Canada. Examples are: the Ottawa CSI for 2025 would approach that of the 1955 CSI for Toronto; the Whitehorse CSI for 2025 would approach that of the 1955 CSI for Calgary; etc. The CSI, because of its aggregation of winter discomfort with summer discomfort, does not discriminate seasonal effects very well (e.g. winter temperatures rise, improving the Index, while summer temperatures also rise giving a deterioration of the Index at any one site). **It is recommended that, if readers wish to better appreciate winter/summer trends, they should visit the website (www.cics.uvic.ca/severity) where the various winter and summer sub-indices of the CSI are provided in detail.**

One participant reported that he had undertaken a similar index analysis of climate change for North America with tourism being the main driver of this Index, and he offered to share the results of the study with other researchers.

S00-15-09 Prairie Drought and Surface Winds from Eolian Deposits. When broad scale droughts persist over long periods, the vegetative soil cover is lost and wind erosion occurs, forming sand dunes that can become permanent features of the landscape. The prevailing wind circulation during these periods can be inferred from the orientation of the dunes, and the timing of droughts can be inferred by analysing the organic material incorporated in the dune and other geological techniques. This project produced a map of present-day dunes in the Prairies (more than 170 dune fields), accompanied by a map of potential sediment transport based on the historical wind data.

By dating past dune activity, several periods of dune building were identified, going back 4000 years or more, indicating significant drought periods in many parts of the Prairies. In particular, many areas show evidence of droughts within the last 500 years which would have been more severe than those recorded in historical times. **Detailed studies of correlation between sand dune activity and the paleo-environmental record are in progress**.

(Note: This project was not presented to the evaluation Workshop; this project summary is included in this report for the sake of covering all CCAF funded projects under the “extremes” theme.)

Related Discussion and Recommendations

What is a climatic extreme? There is currently no consensus on indicators of extreme climate, and each one makes their own definition. For example, an event viewed as a climate extreme for tourism may not be similarly viewed by the agriculture sector. **It is recommended that Canada approach the IPCC to develop international standards for the definition of a climatic extreme.**

Workshop participants were generally well satisfied with CCAF procedures and reporting requirements. One aspect that could be improved upon in the future is the timely delivery of finances for approved projects, and improved carry over provisions from one year to the next of approved funds, so that workloads, hiring, etc could be efficiently managed. Additionally, participants and the Evaluation Team observed the following generic issues:

- Of the six research projects funded so far, three dealt exclusively with paleo-climate extremes: major floods and droughts in the Prairies and in the St-Lawrence basin, whereas the others looked at extremes in the more immediate past and considered the future to a limited extent.

- Results of paleo-climatic research projects are necessarily informative only about large spatial and temporal scale climatic extremes, more or less the same scales that are represented by GCM/RCM’s. Instructive as they may be by themselves by placing the past climate in the current context (there are many applications, such as event recurrence statistics), they should also be used to attempt to validate models operating under the current or pre-industrial greenhouse gas emission scenarios. **To this effect, it is recommended that reconstructions of past large scale climate extremes be developed by the international science community, and made available for all GCM modellers to use.** Long GCM integrations from validated models could then be analysed for the occurrence of similar extremes under different greenhouse gas emission scenarios. **It is recommended that the three Canadian CCAF funded paleo-climate projects be linked, thus contributing to a much broader Canadian picture. Similar projects based on "exotic data" in other regions should also be considered for funding, with the view of describing the nature of past climate extremes experienced over all of Canada.**

- Concerning the smaller scale climate extremes (frequency of weather extremes), once some definitions have been agreed, it would be appropriate to develop the observed climatology for Canada, based on the actual data and not on gridded or analysed data (which cannot represent small scale extremes well). Some work has already been done. **It is recommended that research on the Arctic and with coastal phenomena be considered in the near future.**

- Extrapolating small scale event climatology is well outside the capabilities of the GCM/RCM's, and so the best approach is probably the establishment of statistical/dynamical relations with features of the synoptic scale. Concerning the dynamical approach, some of the very high-resolution work with the Mesoscale Compressible Community model (MC2) of CMC/RPN related to wind climatology should be considered by users. Stochastic weather generator methods also need to be improved to handle extremes, particularly as few variables can be expected to be normally distributed. **The mesocyclone radar detection project provides an excellent example of a relation between extreme events and the synoptic scale. It is recommended that other similar projects be supported.** These could address extreme surface winds, out-of-season frosts, storm surges and the like.

- **It is recommended that more research, testing and inter-comparisons be funded relative to downscaling methods from GCM and RCM scenarios so that suitable, credible scenarios of extreme events can be made available to the impacts community.**

- **Latest Model Predictions.** Model runs are the best source of predictions of future climates. A presentation by the CCCma provided Workshop participants with an overview of their latest findings. **It is recommended that results such as this be provided to the broader research community through the web on a regular basis (along with all the necessary caveats).** Communication of (initial) findings is recognized to be a pressing issue if the public, senior officials and researchers are to be kept informed in a timely fashion.

- **Public awareness.** Outputs of general interest should be made available more widely than at present. Cases in point are the results of the Climate Severity Index, and companion studies to which the public may readily relate. The CSI is a relatively simple concept which, when accompanied by appropriate interpretative notes, can be used effectively to facilitate understanding of complex and uncertain future climatic changes and impacts, and to generate support for individual mitigation actions. **It is recommended that the CCAF ensure the wide dissemination, on the web directly or through pointers to other sites, of results of public interest initiatives emanating from CCAF funded research.**

- The CCAF Workshop on Climate Extremes was welcomed and appreciated by participants. There was wide acceptance as to its usefulness in exchanging research results in a timely fashion, and in addressing generic concerns such as the use of techniques to better make use of model scenarios to understand and predict possible future weather extremes in a changing climate**. It is recommended that CCAF encourage and foster mechanisms to ensure a regular and continuing dialogue amongst active researchers in the area of "extremes".** The CCAF is not alone in supporting climate oriented research. It should continue to work closely with in-house government programs, the CFCAS, and others to focus its efforts on the most promising and needed areas of research, following the guidance obtained through workshops and other means of determining action consensus.

The continuation of the CCAF, into its second phase, includes measures on Climate Science, and Impacts and Adaptation, particularly in the areas of modelling, processes, and scenarios. While "extremes" are not identified in particular in any of these three areas, some elements of climate/weather extreme research must inevitably be addressed since the issues are so closely linked.