CLIMATE SECTOR REPORT

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OVERVIEW

The Climate breakout group included participants from various universities and research facilities from around the Upper Great Lakes region. The overall strength of the group was its knowledge of climate modeling and regional climatology. Participants with expertise in paleoclimate reconstruction, mesoscale modeling, and hydrology further extended the knowledge base of the group. This diverse and comprehensive background of the participants made for very insightful and productive discussions concerning the monitoring of climate variability, assessing potential climatic change, and evaluating the resulting environmental impacts for the Upper Great Lakes region.

Because the set of questions that most of the other sectors addressed was not applicable, a different set of overarching questions (listed in the next section) was devised to guide the breakout discussions. Each of the four breakout sessions was further guided with specific questions (also listed below) that related to the general overarching themes. In addition, each session began with a short presentation by one of the group participants. These presentations provided a "jumping off" point for the discussion.

A major theme of the breakout discussions was the assessment of the natural variability of the regional climate. Understanding the short-term and long-term natural variability is important both for understanding the behavior of the regional climate and for assessing the performance of General Circulation Model (GCM) simulations for the region. The breakout group emphasized the importance of a quality observational record for evaluating climate variability and discussed the many limitations of the available historical climatological record. Alternative means for enhancing and extending the climatological record, such as the use of proxy data, were also discussed.

A second major theme was the role of GCMs in impacts analysis. The breakout group acknowledged that the limitations of the current family of models make assessing regional climate change difficult. Regional climate models and statistical downscaling were advocated as ways to provide greater spatial detail and richness to climate scenarios. The breakout group emphasized that the unique meteorology of the Great Lakes region needs to be carefully considered in model simulations and in any impacts analysis.

General recommendations of the breakout group were that more research is needed to better understand past and current climate variability in the Upper Great Lakes region. More research is needed to evaluate the behavior of GCMs at different levels of greenhouse gas forcing. Also, a better understanding of the interaction between the large water bodies of the Great Lakes and the regional climate is necessary before long term climate impacts can be adequately assessed. More specific recommendations, along with the background for these recommendations, are provided below.

DISCUSSION QUESTIONS FOR THE CLIMATE BREAKOUT GROUP

Overarching Questions

The following overarching questions were addressed by the Climate Breakout Group:

1. ***Scenarios.*** What are the important characteristics that climate change scenarios should possess if they are to be used for impacts assessment in the Upper Great Lakes region?

2. ***GCMs.*** How can the important climate and weather characteristics be incorporated into GCM-based scenarios?

3. ***Research.*** What new directions of research should be pursued to reduce uncertainties in scenarios?

4. ***Uncertainties.*** What uncertainties exist regarding current and past climate of the Upper Great Lakes region?

5. ***Baseline data.*** What research still remains to be conducted to provide an adequate baseline climatology for the region?

6. ***Monitoring.*** What (e.g. tools, knowledge, data) is required for adequate climate monitoring in the future?

Specific Questions

The specific questions discussed in the breakout sessions were as follows:

- ***Scenario development.*** What is the nature of historical variability of climate in this region, particularly with regard to impacts-relevant characteristics, such as water supplies and extreme events? What range of conditions should be incorporated into scenarios? What are the limitations in using GCM-based scenarios? Will GCM-based scenarios provide unrealistic ranges of future conditions?

- ***Spatial Variability.*** How do climate fluctuations and trends vary spatially across this region? Will GCM-based scenarios produce unrealistic spatial patterns? What methods are available to produce realistic spatial patterns?

- ***Local influences.*** How are local and regional features of the climate (e.g., lake effect snowstorms, lake breezes and near-shore modification of temperature) related to large-scale variability and change? How can such features be incorporated into GCM-based scenarios? Will such scenarios provide a realistic range of future conditions?

- ***Land Surface.*** How important are land-surface feedbacks in modifying the climate of the region? How likely is it that these feedbacks will change in response to anthropogenic influences? Is it important that GCM-based scenarios incorporate a range of land-surface feedbacks?

- ***Future research.*** What are the major recommendations of the group related to the overarching questions? What new research should be pursued to reduce uncertainties in scenarios of future change?

RECOMMENDATIONS

- ***Scenario length.*** The historical climate record exhibits temporal variability over a range of time scales. Of particular interest are multi-decadal periods with climate conditions significantly different than the long-term mean. Such long-term variability is likely to be a feature of any future climate regime. Some impacts will be sensitive to variability on long time scales. In order to accurately assess such impacts, it is necessary to have scenarios of great length.

Recommendation #1:

We recommend that scenarios used for climate assessments be of an appropriate length. A minimum length of 100 years is recommended for examining important long-term variability within the Upper Great Lakes region.

- ***Scenario detail.*** Many impacts are directly caused by short-term and/or extreme weather events. In order to assess such impacts, scenarios rich in detail are required. Weather events that need to be specified in order to assess certain impacts of climate change include: thunderstorm (wind, hail, tornadoes, etc.) frequency, winter storms (wind, snow, etc.), critical temperature threshold exceedances, freeze dates, clouds/fog, length of wet/dry periods, and heavy precipitation amounts and intensities.

Recommendation #2:

We recommend that scenarios have, at a minimum, a daily resolution in order to assess event-influenced impacts and be rich in climatic detail, including the variables listed above to the extent practical.

• ***Derived climate variables.*** Related to *Recommendation #2* is the use of "integrative" or "derived" variables rather than "standard" climate variables in impacts analysis. Integrative and/or derived variables may include ice-on and ice-off dates, bore-hole temperatures, evapotranspiration, soil moisture balance, and length of time above a threshold temperature, among other possibilities. An advantage of employing integrative and/or derived variables is that these variables represent more closely the concerns of stakeholders. Another advantage is that some of the integrative variables (ice on/ice off, for example) have long records and can be used to supplement standard climatological records. Disadvantages of integrative and/or derived variables are that they often require careful interpretation and that they may be hard to produce from model output.

Recommendation #3:

We recommend that analysts consider integrative and/or derived climate variables when developing climate impacts assessments. However, they should bear in mind that the choice of an integrative or derived variable is likely specific to the impact under investigation. Climatologists, impact analysts, and stakeholders should work jointly in defining appropriate integrative and/or derived variables.

• ***Model assessment.*** General circulation models incorporate a variety of simple parameterizations to simulate boundary layer processes, convection, and radiation, to name a few. These parameterizations lead to uncertainties in certain aspects of the GCM-based climate projections. Some aspects, such as mean annual temperature, may be associated with a relatively smaller level of uncertainty than others. Also, these uncertainties may vary from one region to another. For example, uncertainties may be greater for high-latitude locations compared to low-latitude locations. An excellent starting point for assessing the uncertainty of a future climate projection is to evaluate how well GCMs simulate the current or control climate. This type of evaluation can be useful for identifying "uncertainty boundaries" for perturbed simulations.

Recommendation #4:

We recommend that uncertainties in model climatologies of impacts-relevant variables be assessed and documented at the regional scale. This assessment should encompass not only mean temperature and precipitation, but also other impacts-relevant variables, such as those listed in the "scenario detail" section under Recommendation #1.

• ***Downscaling.*** We recognize that many of the weather phenomena listed in the "scenario detail" item are not resolvable in the current generation of GCMs. Thus, the richness called for in Recommendation #2 is often not directly achievable from GCM output. However, there are downscaling methods that can contribute to the desired richness.

Recommendation #5:

We recommend that available contemporary downscaling techniques be applied to GCM scenarios in order to maximize the climate detail available for impacts assessment, to the extent that the current state of science allows.

• ***Mesoscale features.*** A unique feature of the Upper Great Lakes region is the modification of the climate by the Great Lakes. Features such as lake-effect snow and near-shore modification of temperature have a multitude of impacts. These are mesoscale features, unresolved by most GCMs. Accurate estimates of future changes in these features will require downscaling. This is a problem that is ideally suited to the use of Regional Climate Models (RCMs) embedded within GCMs. A possible short-term solution, as regional models are developed further, is the use of statistical downscaling and analogue models.

Recommendation #6.1:

We recommend that statistical downscaling and analogue techniques be developed specifically for the assessment of near-shore lake modification features.

Recommendation #6.2:

We recommend the continued support for the development of RCMs with a resolution that is capable of simulating lake effects. It is important that they eventually incorporate a lake model in order to assess the timing of any overturning of the lakes in a perturbed climate. It is not sufficient for them to incorporate the lakes as a simple water surface.

• ***Multiple scenarios.*** It is important that impacts researchers appropriately convey the uncertainty of climate scenarios to stakeholders. One method of conveying uncertainty is to employ an ensemble of climate scenarios that span a range of plausible outcomes. However, in order for this to be possible, impacts analysts must have ready access to simulations from a large number of GCMs and RCMs.

Recommendation # 7:

We recommend that analysts routinely employ an ensemble of scenarios for impacts research. In order to facilitate analysts' access to climate simulations, we recommend that a central "clearing house", perhaps at the National Center for Atmospheric Research, be established where model developers can archive detailed output from recent model simulations.

• ***Spatial variability.*** The spatial variability of severe climatic anomalies plays a key role in the management of Great Lakes water supplies. Specifically, Lake Superior is used as a storage basin to minimize fluctuations in the levels of the lower lakes. This management strategy is of limited effectiveness when anomalies are in phase between Lake Superior and the rest of the basin. The outcome of an impacts assessment will depend on the nature of this spatial variability.

Recommendation #8:

We recommend that the spatial variability of climatic anomalies simulated in GCM and RCM scenarios be documented to assist in the interpretation of the outcomes of impacts assessments. Of particular interest is the frequency of in-phase and out-of-phase patterns of anomalous temperature and precipitation conditions, both in control and perturbed climate simulations.

• ***Proxy data.*** As stated under Recommendation #1, large variability at low frequencies (periods of years to several decades) is evident in the Upper Great Lakes region. Such variability can both ameliorate and exacerbate greenhouse gas-induced change. Our understanding of the magnitude and nature of this variability is incomplete, particularly with regard to very long period variations. Proxy data (e.g., sediment analysis, isotope analysis, ice on/ice off and tree ring data) may allow us to extend the climate record back several hundred years in this area. In addition, the joint use of proxy data and paleoclimatic simulations helps to validate GCMs and RCMs.

Recommendation #9:

We recommend further support for the collection and examination of proxy data to extend the climatic record and for the validation of climate models.

- ***Vegetation.*** The synergistic effects of climate on vegetation are of great interest to climatologists and ecologists. The human-induced deforestation of the Upper Great Lakes region in the mid-to-late 1800s and the subsequent reforestation in the early 1900s is likely more extreme than land cover changes expected under climate change. The impacts of this deforestation/reforestation on the climate record, however, is unclear.

Recommendation #10:

We recommend that long-term climate records, including proxy records, be carefully examined to determine whether a signal reflecting past large-scale changes in vegetation can be identified.

- ***Land-surface interactions.*** Land-surface feedbacks are important when examining impacts at fine spatial and temporal scales. These feedbacks include both natural surface changes (e.g., changes in lake ice cover) and anthropogenic changes (e.g., increased urbanization/suburbanization, or wetland removal).

Recommendation #11:

We recommend that developers of GCMs and RCMs continue to work toward the inclusion of land-surface feedbacks in climate models, such as the inclusion of interactive biosphere models.

- ***Monitoring.*** A quality observational network with fine temporal and spatial resolution is absolutely essential to: 1) understand the current baseline climatology, and 2) to identify and evaluate changes in short and long term climate variability. Recent changes in climate observing practices in the United States raise concerns about the long-term health of our current network. In addition, recent improvements in remotely-sensed observations of atmospheric variables provide unprecedented opportunities for a more detailed and sophisticated monitoring of our climate.

Recommendation #12:

We recommend that, at a minimum, the current observational record be retained and, preferably, that the observational network be improved. In addition, we support the improvement and use of remotely-sensed observations of atmospheric variables.