PROPOSAL
Climate Modeling in Support of 'Preparing Coastal Communities for Climate Change'
Submitted to the Program Managers of SARP

Principal Investigator:
Brent M. Lofgren
NOAA/Great Lakes Environmental Research Laboratory
2205 Commonwealth Blvd.
Ann Arbor, MI 48105
Brent.Lofgren@noaa.gov
(734) 741-2383

In collaboration with the principal investigator and co-investigators of the proposal "Preparing Coastal Communities for Climate Change: Translating Model Results to Prepare Ports, Harbors and Stormwater Management Facilities in an Era of Climate Variability and Scientific Uncertainty", submitted to the Coastal Resource Management component of NOAA's Sectoral Applications Research Program.

Approximate dates of work: January 1, 2008-December 31, 2009
Total funds requested: $14,000

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Brent Lofgren, Principal Investigator	Sandra Salyers, Administrative Officer
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Doran Mason, Science Branch Chief	Stephen B. Brandt, Director

Relation to other proposal

This request is being submitted in conjunction and cooperation with the group that are submitting "Preparing Coastal Communities for Climate Change: Translating Model Results to Prepare Ports, Harbors and Stormwater Management Facilities in an Era of Climate Variability and Scientific Uncertainty" to the NOAA SARP Program, Coastal Resource Management component. The Principal Investigator of this proposal, a NOAA federal employee, will exchange collaboration and assistance with the participants in the related proposal. In particular, he will work most closely with Dr. Carlo DeMarchi, and one of the summer fellows requested in the other proposal will primarily be tasked with assisting Dr. Lofgren.

Previous work

Climate variability and change are major drivers of lake levels in the Laurentian Great Lakes. There are apparent major cycles of variability at periods of about 30 years and 160 years (Baedke and Thompson 2000). At the same time, secular changes in climate can have an effect (e.g. Lofgren et al. 2002, Croley 2003).

Climate change due to increased greenhouse gas concentration has been shown to have various effects on the water quantity in the Great Lakes. Most results from general circulation models (GCMs) show an increase in both precipitation and air temperature, which in turn is associated with increased evaporation from both lakes and the land of their drainage basin. A balance between basin-wide changes in precipitation and evaporation determines the change in net basin supply. In Lofgren et al. (2002), using a hydrologic model with one-way coupling to GCMs, two different GCMs that predicted different quantities of change in precipitation and air temperature resulted in changes in net basin supply and hence lake level of opposite sign. Other studies using similar methodology (e.g. Croley 2003) have more often shown decreases in net basin supply and drops in lake level, although of varying magnitude. Results from a two-way coupled model of the lake-atmosphere system (Lofgren 2004a,b) show much smaller increases in evaporation and significant increases in net basin supply in the Great Lakes. In Milly et al. (2002), the runoff calculated by a GCM is spatially accumulated to infer the mean outflow from the St. Lawrence River drainage basin. The resulting increase in outflow directly implies a rise in the lake level of Lake Ontario, and more indirectly implies a rise in the levels of other lakes.

Each of these methodologies suffers from its unique set of biases, but nevertheless gives insight into the system and its sensitivities. The method used in Lofgren et al. (2002) and Croley (2003) lacks interaction between the surface (both lake and land) and the atmosphere, and thus not all of the factors that affect evaporation can be accounted for. Previous versions of the Coupled Hydrosphere-Atmosphere Research Model (CHARM, Lofgren 2004a,b) had temperature biases that led to unrealistically high water temperatures in the lakes and a lack of ice even in the 20^{th}-century base runs. The model used by Milly et al. (2002), although it has greater self-consistency by having the Great Lakes region fully interactive with the rest of its global domain, is deficient in that the energy and moisture exchange with the surface were calculated as if the entire Great Lakes basin had a land surface (i.e. no lakes).

Objectives

This proposal deals primarily with objectives 1A through 1C of the related proposal. Outcome (1) and Objectives 1A-1C are reproduced here:

Outcome (1): Improved regional scale models of the impacts of climate change to the Great Lakes region that address factors most relevant to stakeholders.

Objective (1A): GLERL and CILER researchers [note: this refers primarily to Brent Lofgren of GLERL and Carlo DeMarchi of the Cooperative Institute for Limnology and Ecosystems Research, along with summer fellows assigned to this project] will gain a better understanding of and appreciation for the forecasting needs of the key stakeholders so that they can identify priority stakeholder forecasting needs which can be met by their models.

Objective (1B): GLERL and CILER researchers will run 3 regional model scenarios relating to lake water levels on the existing platforms (CHARM and LBRM, with additional prescribed scenarios for LBRM) to address specific priority concerns identified by stakeholders.

Objective (1C): Where capability to run scenarios important to stakeholders is not within the current modeling capacity, GLERL and CILER researchers will use this project to identify future directions for research in developing their models and the products resulting from them.

Statement of work

The Coupled Hydrosphere-Atmosphere Research Model (CHARM, Lofgren 2004a, with subsequent improvements) is a model of climate with a domain encompassing the Great Lakes drainage basin. It simulates the dynamics of the atmosphere, the state variables of the land surface, including soil moisture and temperature, and a vertical diffusion-based simulation of lake temperatures, as well as energy and moisture exchanges between the atmosphere and the land and water surfaces. Its emphasis on sensitivity of time-mean values of state variables and fluxes to changes in greenhouse gas concentrations means that it is best to run it for time slices of at least ten years. At present, CHARM has a horizontal grid spacing of 40 km.

Simulation runs of CHARM with different concentrations of greenhouse gases and corresponding atmospheric lateral boundary conditions will provide improved assessment of the likely changes in climate and hydrology of the Great Lakes basin. Relative to the previous version of CHARM, the temperature bias will be reduced. Relative to the one-way coupled hydrologic models, improvement will be gained by full coupling of the atmosphere and lake and land surfaces, rather than using a passive atmosphere. Relative to the GCM-based hydrologic accounting method of Milly et al. (2002), CHARM's advantages are finer spatial resolution and inclusion of the effects of the presence of the lakes on the hydrologic budget.

CHARM will initially be executed as a series of three time slices of twenty years. The first of these will have CO_2-equivalent concentrations of greenhouse gases appropriate to the period 1981 to 2000, and boundary condition data taken from the National Center for Atmospheric Research's (NCAR) Community Climate System Model (CCSM) from a simulation of that time period. The second time slice will be for approximately the period 2031 to 2050, with CO_2-equivalent concentrations and lateral boundary conditions taken from the A1B scenario of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES). The third time slice will likewise simulate 2081 to 2100. This work will be performed with assistance from a summer fellow funded through the related proposal at the Cooperative Institute for Limnology and Ecosystems Research.

In cooperation with Carlo DeMarchi (see "Relation to Other Proposals"), further refinement of hydrologically-related output from CHARM can be accomplished by using the Large Basin Runoff Model (LBRM, Croley 1983). Use of CHARM to drive LBRM will add the dimension of lake-related forcing to the atmospheric conditions used to force LBRM. Furthermore, methods will be developed to couple the LBRM more closely to the energetics of CHARM, rather than simply air temperature.

While it is important to convey the level of uncertainty in the results to stakeholders, this is usually accomplished through the use of ensembles of model runs and the use of multiple models. This is a level to which the presently proposed project will be unable to ascend, due to limitations in human resources, computing power for this project, and the availability of the large volumes of input data required to drive ensembles of these simulations on a regional domain. Anticipated developments in the future will be GCMs that include simulation of the Great Lakes at spatial resolution similar to that of the present version of CHARM. These will be run in ensembles by multiple modeling centers.

References

Baedke, S. J., and T. A. Thompson, 2000. A 4,700-year record of lake level and isostasy for Lake Michigan. *J. Great Lakes Res.*, 26, 416-426.

Croley, T. E., II, 1983. Great Lake basins (U.S.A.-Canada) runoff modeling. *J. Hydrology*, 64, 135-158.

Croley, T. E., II, 2003. Great Lakes Climate Change Hydrologic Impact Assessment: I.J.C. Lake Ontario-St. Lawrence River Regulation Study. NOAA Tech. Memo. GLERL-126. 77 pp. ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-126/tm-126.pdf

Lofgren, B. M., 2004a. A model for simulation of the climate and hydrology of the Great Lakes basin. *J. Geophys. Res*., 109, D18108, doi:10.1029/2004JD004602.

Lofgren, B. M., 2004b. Global warming effects on Great Lakes water: More precipitation but less water? Proceedings, 18th Conference on Hydrology, 84th Annual Meeting of the American Meteorological Society, Seattle, WA, January 11-15, 2004, 3 pp. http://www.glerl.noaa.gov/pubs/fulltext/2004/20040002.pdf.

Lofgren, B. M., F. H. Quinn, A. H. Clites, R. A. Assel, A. J. Eberhardt, and C. L. Luukkonen, 2002. Evaluation of potential impacts on Great Lakes water resources based on climate scenarios of two GCMs. *J. Great Lakes Res.*, 28, 537-554.

Milly, P. C. D., R. T. Wetherald, K. A. Dunne, and T. L. Delworth, 2002. Increasing risk of great floods in a changing climate. *Nature*, 415, 514-517.

Budget

The following funds are requested:

Year 1:
Scientific travel--$3,000
Administrative travel--$1,500
Computer--$2,000
Page Charges--$1,500
Year 1 total--$8,000

Year 2:
Scientific travel--$3,000
Administrative travel--$1,500
Page Charges--$1,500
Year 2 total--$6,000

Grand total--$14,000

Budget justification

Scientific travel will cover travel, registration fees, and abstract fees for Dr. Lofgren to attend and present at one scientific conference per year. Likely venues will be the American Meteorological Society Annual Meeting or the American Meteorological Society Meeting on Applied Climatology. Administrative travel will cover Dr. Lofgren's attendance at group meetings of the project "Preparing Coastal Communities for Climate Change: Translating Model Results to Prepare Ports, Harbors and Stormwater Management Facilities in an Era of Climate Variability and Scientific Uncertainty." The money requested for a computer will provide necessary equipment for data analysis to be used both by Dr. Lofgren and by a student assistant (summer fellow) who will work with him. Page charges will be necessary for publication of the results of this study.

CURRICULUM VITAE
Brent M. Lofgren
Physical Scientist
Great Lakes Environmental Research Laboratory, 2205 Commonwealth Blvd.,
Ann Arbor, MI 48105-2945
(734) 741-2383
Brent.Lofgren@noaa.gov
Citizenship: USA

Educational background:
B.S., May 1988, Physics and Mathematics, Augsburg College, Minneapolis, MN
M.A., May 1990, Atmospheric and Oceanic Sciences, Princeton University
Ph.D., January 1993, Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ.
Ph.D. dissertation title: "Sensitivity and Feedbacks Associated with Vegetation-Related Surface Parameters in a General Circulation Model"

Work experience:
Undergraduate Research Assistant, Augsburg College/University of Minnesota, Minneapolis, MN, September 1985-August 1988.
Graduate Teaching Assistant, Princeton University, Princeton, NJ, September 1990-January 1991.
Graduate Research Fellow, NOAA Geophysical Fluid Dynamics Laboratory/Princeton University, Princeton, NJ, September 1988-November 1992.
Cooperative Institute for Limnology and Ecosystems Research, Post-doctoral Research Fellow, University of Michigan, Ann Arbor, MI, December 1992-January 1995, assigned to the Great Lakes Environmental Research Laboratory.
Cooperative Institute for Limnology and Ecosystems Research, Visiting Assistant Research Scientist, University of Michigan, Ann Arbor, MI, February 1995-June 1996, assigned to the Great Lakes Environmental Research Laboratory.
Physical Scientist GS-1301-12, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, June 1996-May 2004.
Physical Scientist GS-1301-13, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, May 2004-present.
Detail assignment: Research Program Analyst/Physical Scientist ZP-IV, Earth System Research Laboratory, Boulder, CO, on detail January 2006-January 2007.

Selected peer-reviewed publications:
Lofgren, B. M., 1995: Sensitivity of land-ocean circulations, precipitation, and soil moisture to perturbed land surface albedo. *J. Climate*, **8**, 2521-2542.
Lofgren, B. M., 1995: Surface albedo-climate feedback simulated using two-way coupling. *J. Climate*, **8**, 2543-2562.
Lofgren, B. M., 1997: Simulated effects of idealized Laurentian Great Lakes on regional and large-scale climate. *J. Climate*, **10**, 2847-2858.

Lofgren, B. M., and Y. Zhu, 2000: Surface energy fluxes on the Great Lakes based on satellite-observed surface temperatures 1992 to 1995. *J. Great Lakes Res.,* **26,** 305-314.

Lofgren, B. M., 2001: Global warming influences on lake levels, ice, and chemical and biological cycles: Some examples. In *Fisheries in a Changing Climate*, N. A. McGinn, Ed., American Fisheries Society, 15-21.

Brandt, S., D. M. Mason, M. McCormick, B. Lofgren, T. Hunter, and J. Tyler, 2001: Climate change: Implications for habitat quality and fish growth performance in the Great Lakes. In *Fisheries in a Changing Climate*, N. A. McGinn, Ed., American Fisheries Society, 61-75.

Lofgren, B. M., F. H. Quinn, A. H. Clites, R. A. Assel, A. J. Eberhardt, and C. L. Luukkonen, 2002: Evaluation of potential impacts on Great Lakes water resources based on climate scenarios of two GCMs. *J. Great Lakes Res*., **28**, 537-554.

Lofgren, B. M., 2004: A model for simulation of the climate and hydrology of the Great Lakes Basin. *J. Geophys. Res*., **109**, D18108, doi:10.1029/2004JD004602.

Lofgren, B. M., 2006: Land Surface Roughness Effects on Lake Effect Precipitation. *J. Great Lakes Res.,* **32**, 839-851.

Ge, J., J. Qi, B. M. Lofgren, N. J. Moore, N. Torbick, and J. M. Olson, 2007: Impacts of Land Use/Cover Classification Accuracy on Regional Climate Simulations. *J. Geophys. Res.,* 112, doi:10.1029/2006JD007404.