Lake Level Modeling under Climate Change

Background

The Laurentian Great Lakes began to form about 20,000 years ago during the Last Glacial Maximum. As the earth's climate warmed, the glacial continental ice sheets that covered the region retreated. The glacier, up to 2 miles thick, was so heavy and powerful it gouged out the earth's surface to create the lake basins. Meltwater from the retreating glacier filled the newly created basins. Approximately 3,500-4,000 years ago, the Great Lakes attained their modern levels and area.

The Great Lakes are a valuable resource. They contain the largest supply of freshwater in the world, holding about 18% of the world's total surface freshwater and about 90% of the United States' total surface freshwater. The Lakes provide drinking water to 40 million U.S. and Canadian citizens. Combined, the lakes cover an area of over 94,000 square miles and contain 5,400 cubic miles of water.

Global warming is anticipated to have an influence on the water budget of the Great Lakes—the runoff of the drainage basin, direct precipitation onto the lakes, and evaporation from the lake surfaces.

Global Climate Models generally show increased precipitation due to global warming, but the warming itself leads to increased evaporation from both land and lake. Whether increased precipitation or increased evaporation dominates determines the net effect on lake water supply and lake levels.

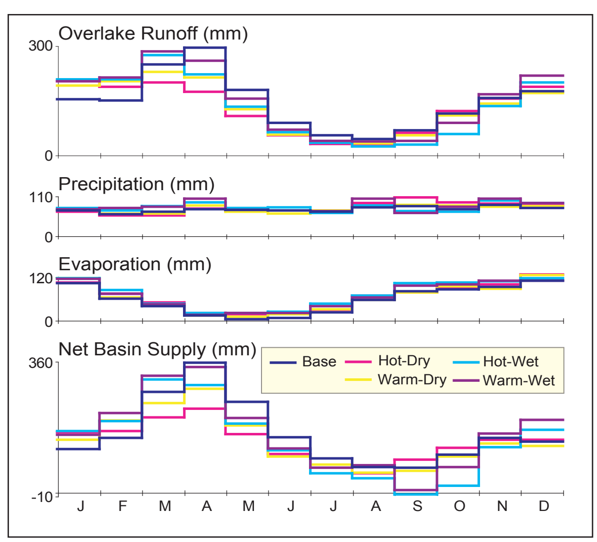
There are two different modeling approaches that have been used by GLERL scientists for determining this net effect.

Method #1 - Hydrologic Modeling With One-Way Coupling to GCMs

GLERL scientists employ General Circulation Models to make predictions about future climate change. The results of model predictions of the effects of climate change from the Canadian Centre for Climate Modeling and Analysis (model CGCM1) and the United Kingdom Meteorological Office's Hadley Centre (model HadCM2) have been used to make such predictions. On one hand,

a Great Lakes water system model using CGCM1 data predicts large drops in lake levels, up to a maximum of 1.38 m on Lakes Michigan and Huron by 2090. This is due to a combination of a decrease in precipitation and an increase in evaporation. On the other hand, using data from HadCM2, rises in lake levels are predicted, up to a maximum of 0.35 m in Lakes Michigan and Huron by 2090, due to increased precipitation and a lesser increase in air temperature (Lofgren et al. 2002).

The figure below shows results from Croley (2003) for the Lake Ontario net basin supply and its components, which result from newer updates of the GCMs relative to Lofgren et al. The four projections are intended to bracket the range of possibilities of changes in precipitation and temperature. They come from the Canadian Centre for Climate Modeling and Analysis (CCCma) Coupled General Circulation Model version two (CGCM2) emission scenario A (hot-dry), CGCM2 emission scenario B (warm-dry), Hadley Centre Climate Model version 3 (HadCM3)



emission scenario A (hot-wet), and HadCM3 emission scenario B (warm-wet). These cases show an increase in net basin supply (precipitation + runoff – evaporation) during the winter, but a decrease throughout the rest of the year, yielding an overall decrease in net basin supply. These models are being used to consider options for future regulation of Lake Ontario.

Method #2 - Regional Dynamical Modeling

GLERL scientists have devised a regional dynamical climate model for the Great Lakes basin, known as the Coupled Hydrosphere-Atmosphere Research Model (CHARM). In contrast to Global Climate Models, CHARM effectively zooms in on the Great Lakes region. This allows complete interaction between the atmosphere and both the lakes and land surface of the Great Lakes drainage basin.

These panels show the Lake Ontario net basin supply and its components as simulated by CHARM for the time periods centered at 1989, 2030, and 2095. Increases in precipitation and runoff in the late winter-early spring and late summer-early fall time periods lead to increased annual mean net basin supply especially in the 2095 case but also in the 2030 case relative to 1989. Changes in overlake evaporation play a secondary role.

Future Plans

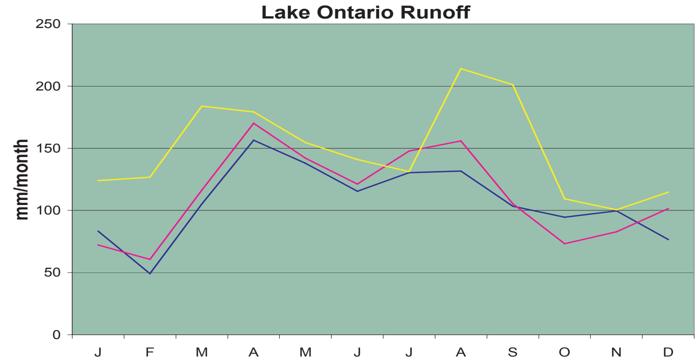
CHARM will be further developed with a concentration on eliminating bias. One approach will be making inland lakes (other than the Great Lakes) fully interactive with the atmosphere.

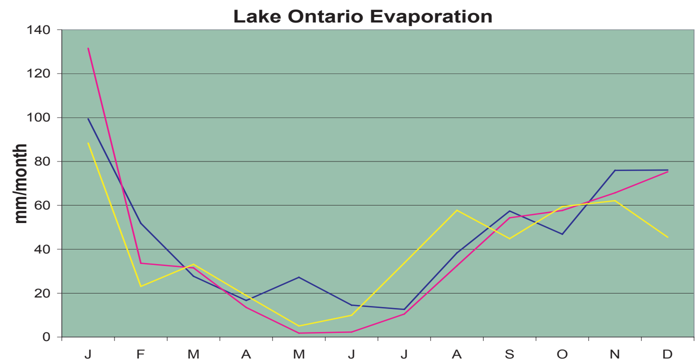
Plans are also being made to modify the Global Climate Modeling method so that it takes some account of the anticipated trend that precipitation will be concentrated in heavy storms. This will be done by using daily data from the Global Climate Models rather than monthly averages.

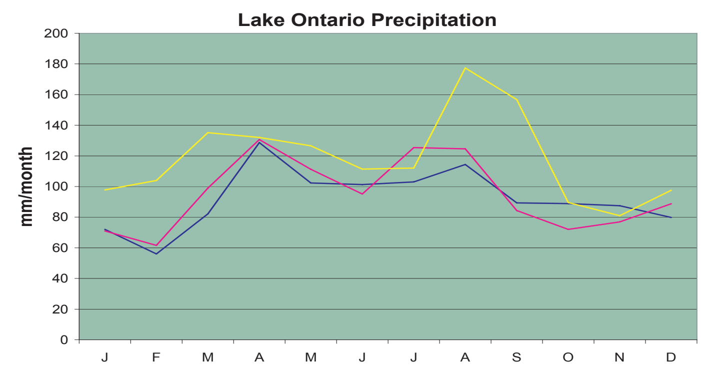
References

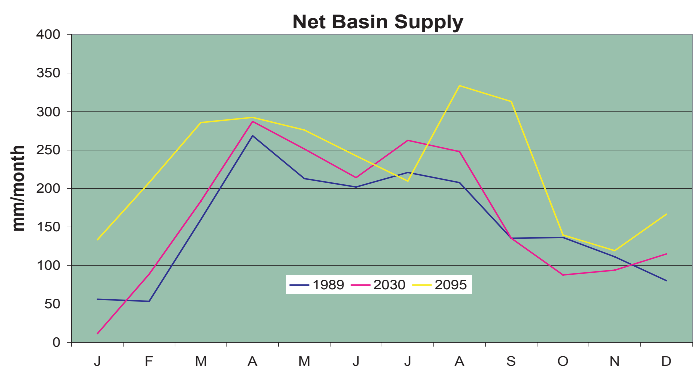
Croley, T.E., II. Great Lakes climate change hydrologic impact assessment: IJC Lake Ontario-St. Lawrence River regulation study. NOAA Technical Memorandum GLERL-126, Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan, 77 pp. (2003).

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









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