Improving Ice Cover and Evaporation Estimates

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This project was completed in 2002

Overview

A sensitivity analysis of the evaporation model to input parameters will lead to a better assessment of the importance of projected changes in these parameters under climate change scenarios and thus on the projected future water resources of the Great Lakes. For example, ice cover is projected to be significantly less under global warming, air temperature higher, and precipitation greater (Lofgren, et al, in press). Improved long-range ice forecasts would be of interest to the National Ice Center while improved evaporation forecasts is of interest to the US Army Corps of Engineers for operational applications in regulation of the Great Lakes. The ability to provide improved estimates (modeled) of historical monthly ice cover data prior to 1973 will be useful in retrospective studies of climate and the lake ecosystem, in which ice cover is an important consideration.

The lake evaporation model is a lumped-parameter (point) model of evaporation and thermodynamic fluxes for the Great Lakes. It is based on an energy balance at the lake's surface and on a one-dimensional (vertical) superposition of lake heat storage. Ice formation and loss is coupled also to lake thermodynamics and heat storage. Ice cover concentration is calculated from two GLERL digital ice cover data sets. Daily lake averaged ice cover was calculated for each Great Lake from daily grids of ice cover developed for computer animations that portray the seasonal and spatial progression of ice cover on the Great Lakes for each winter season from 1973 to 2000. These data will be used here to calculate monthly ice cover for use in this project. Two calibrations are involved in applying the model in a particular setting. The first determines values of the first eight model parameters that minimize daily water surface temperature root mean square error (RMSE). The second determines values of the last two parameters that minimize daily ice cover RMSE with these same calibration techniques. Model concepts have been carefully chosen so that the parameters have physical significance; this allows them to be interpreted in terms of the thermodynamics they represent. Initialization of the model corresponds to identifying values from field conditions, which may be measured; interpretations of a lake's thermodynamics then can aid in setting both initial and boundary conditions. Turnovers (convective mixing of deep lower-density waters with surface waters as surface temperature passes through that at maximum density) occur as a fundamental behavior of GLERL's thermodynamic and heat storage model. Hysteresis between heat in storage and surface temperature, observed during the heating and cooling cycles on the lakes, is preserved. The model also correctly depicts lake-wide seasonal heating and cooling cycles, vertical temperature distributions, and other mixed-layer developments. Last year, recalibrations of the lake thermodynamic model were completed using meteorological and satellite water temperature and ice coverage data through 1995. The recalibrations will be added to both the forecasting (AHPS) and simulation model suites at GLERL.

2002 Accomplishments

GLERL investigated sensitivity of their lake thermodynamics and evaporation model on Lake Superior. They considered changes in model parameters and boundary conditions (meteorology time series) and analyzed calibration statistic changes. These included the mean ratio, variance ratio, correlation, and RMSE between model and observed water surface temperatures and ice cover. They also analyzed changes in model outputs for water temperature, heat in storage, evaporation, and ice cover. They found that model outputs were most sensitive to a cloudiness parameter; this parameter affects both short-wave and long-wave radiation exchange between the lake and the atmosphere. They also found that model sensitivity is approximately linear to changes in meteorology.

2002 Plans

We will use GLERL's historical Great Lakes ice cover data and GLERL's Lake Evaporation and Thermodynamics model in a joint program to improve both. In program "A" (to improve ice cover estimates), we will use antecedent and concurrent historical monthly average whole-lake ice cover data, observed meteorology, and evaporation model "indices" (e.g., heat content of the lake, ice cover, surface temperature, lake-averaged over-water air temperature) as inputs into statistical multivariate studies (including analogue methods, lag correlation studies, and ensemble scenario prediction) to estimate the relationship of ice cover to observable meteorology and calculable thermodynamics quantities. We will also conduct sensitivity analyses, as part of program A, of the evaporation model to all input parameters (both initial conditions and meteorology during a simulation run). A later expansion of program A will relate 1-D evaporation model ice cover (and other model outputs) to 2-D ice observations to predict 2-D ice cover. In program "B" (to evaluate and improve the evaporation model), we will insert ice observations as boundary conditions into model simulation runs. By using half of the observations this way and the other half for comparison, we should be able to evaluate model improvements and utility in simulating or forecasting ice cover. A later expansion of program B will investigate if the use of historical ice cover data as boundary conditions in evaporation modeling improves forecasting of other quantities, including lake levels. The results of both programs will allow us to extend the ice cover record back to 1948 and to fill in missing segments in the record. It will also allow us to improve ice forecasts (both 1-D and possibly 2-D forecasts) and evaporation forecasts in operations.

Products

Publication

Croley, T. E. II, and R. A. Assel. 2002. Great Lakes evaporation model sensitivities and errors. *Proceedings, Second Federal Interagency Hydrologic Modeling Conference*, Subcommittee on Hydrology of the Interagency Advisory Committee on Water Data, Las Vegas, NV, July 28-August 1, 2002. 12 pp.

Presentation

Assel, R. A. and Croley, T. *Great Lakes Evaporation Model Sensitivities and Errors*. Second Federal Interagency Hydrologic Modeling Conference. July 28 - August 1, 2002. Las Vegas, Nevada.