GLERL WATER RESOURCES RESEARCH PROGRAM

PURPOSE. Regarding NOAA's goal of ***promoting global environmental stewardship***, the availability of adequate water resources to support the nation's continuing growth and infrastructure will be one of the major issues of the 21st century. Water demand will increase as the arid southwestern states and the midwestern states deplete their groundwater resources and look to the Great Lakes water supply in the 21st century. Atmospheric deposition of pollutants is a continuing problem also for the 21st century. We must continue in our assessment of atmospheric-hydrologic pathways. We need the capacity to plan and to assess the impacts of management and climate variations.

Regarding NOAA's goal of ***describing, monitoring, and predicting environmental change***, the nation must have systems for anticipating and managing water supply crises to avoid simply reacting to each one after the fact. The provision of both deterministic and probabilistic outlooks will be of paramount importance to water resources planners and managers, to commercial and private interests, and to the general public, in the temporal use of our water resources.

BACKGROUND. GLERL's current water resources research program is summarized below. GLERL developed, calibrated, and verified conceptual lumped-parameter models for simulating hydrological processes in the Laurentian Great Lakes (including Georgian Bay and Lake St. Clair as separate entities) as well as Lake Champlain. These include: 138 daily watershed models for rainfall-runoff, evapotranspiration, and moisture storage, 7 daily over-lake precipitation models, 7 daily one-dimensional (depth) models for lake thermodynamics, lake surface flux, thermal structure, and heat storage, 4 daily models of channel routing for connecting channel flow and level, outlet works, and lake levels, a monthly lake regulation plan balancing Lakes Superior, Michigan, and Huron, a quarter-monthly plan balancing Lake Ontario and the St. Lawrence Seaway, and historical diversions and consumptions.

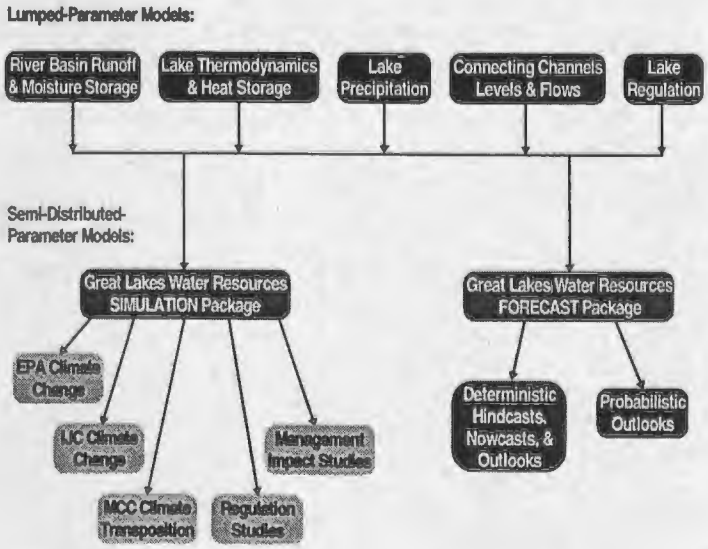

Figure 1. GLERL's Water Resource Models & Applications

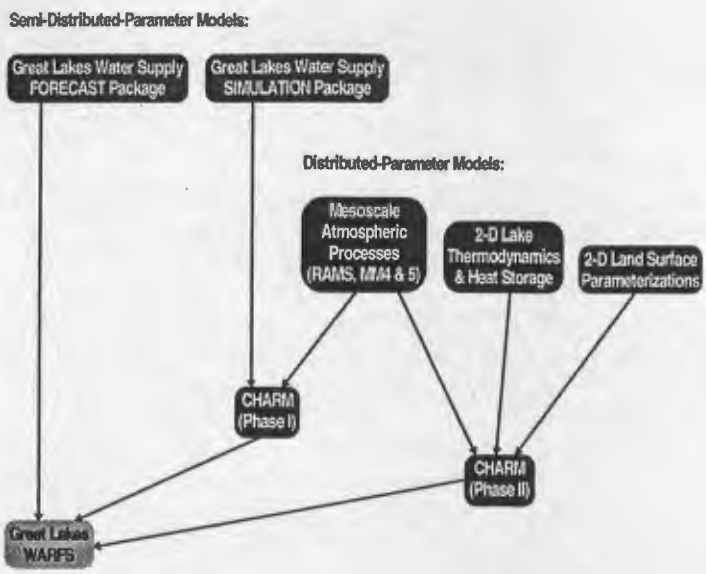

Figure 2. GLERL's Water Resources Research Program

As shown in Fig. 1, GLERL integrated the models into 2 systems to estimate lake levels, whole-lake heat storage, and water and energy balances for forecasts and for assessment of impacts associated with climate change. The first system, used for ***water resources simulation***, models hydrology across the entire Great Lakes basin and has been used in early climate change assessments that proceeded from General Circulation Model (GCM) output provided by the Environmental Protection Agency. It was also used in similar impact studies for the IJC, which used a Canadian GCM, and for the Midwest Climate Center, which transferred existing southern and western US climates to the Great Lakes basin (including the Mississippi flood of 1993). Also various studies were performed to examine regulations and management impacts for various agencies. The second system, used for ***water supply forecasting***, allows estimation of current initial conditions (nowcasting) and interpretation of meteorological outlooks into hydrological outlooks. GLERL has supported a variety of users including the US Army Corps of Engineers, the New York Power Authority, the Midwest Climate Center at the Illinois State Water Survey, Ontario Hydro, and the National Weather Service (NWS) Northeast River Forecast Center on Lake Champlain. Both deterministic and probabilistic outlooks exist for all variables.

RESEARCH PROGRAM. Largely as a result of its climate impact research, GLERL determined needs for building improved two-dimensional (2-D) parameterizations of land and lake surfaces to replace its present lumped-parameter models, and for integrating surface models with atmospheric models at the mesoscale. Figure 2 depicts these developments in sequence. The present water supply forecasting package is GLERL's precursor to a new Water Resources Forecasting System (WARFS) and will be used to begin WARFS developments. Meanwhile, existing models are to be integrated with an atmospheric model into a first version of a Coupled Hydrologic Atmospheric Research Model ("CHARM Phase I" in Fig. 2). As distributed-parameter models for the atmosphere, lake thermodynamics, and land surface progress, they will be integrated into a second version ("CHARM Phase II" in Fig. 2). Both of the coupled models will then be available for WARFS.

OBJECTIVES.

- ***Find models for prediction & simulation.***
  lake thermodynamics
  land surface processes
- ***Couple hydrology to atmospheric models.***
  develop prediction/simulation capabilities
  use long-range issues as regional supply
  start with existing process models
  implement hydrology models as ready
- ***Generate probabilistic outlooks for all variables.***
- ***Integrate prediction into management & operations.***

FORECASTING. GLERL now has forecasts of meteorology, floods, and water levels for several hours to several days but needs them over larger areas and time periods. Also needed are nowcasts and 1-day to 3-month probabilistic outlooks. GLERL developed a semiautomatic software package for making forecasts of many hydrological variables by integrating modeling and near real-time data handling. It is implemented in FORTRAN for MS-DOS and several UNIX systems. Current plans include interface development, in which we consider the motif and look and feel of the user interface, build the user interface into the existing package, consider additional forecast products, and incorporate a Geographic Information System (GIS) and relational data base managers. Current plans also include incorporating new climate outlooks from NWS. The National Weather Service is switching to climate outlooks and we must redefine our probabilistic outlooks to use them. Future plans include GLERL cooperating with NWS in NOAA's WARFS program on the Great Lakes.

SIMULATION. Simulation activities are broken into two areas: climate change studies and water level statistics. Climate change studies comprise work with general circulation models (GCMs) for the Environmental Protection Agency and the International Joint Commission and climate transposition studies done with MCC. Water level statistics were considered to help alleviate water level fluctuation impacts on the Great Lakes community. They must reflect existing conditions, long-term lake response, secular changes in climate, and the needs of Great Lakes decision makers.

LAKE THERMODYNAMICS. GLERL built lumped-parameter 1-D thermodynamic models on all lakes representing point (surface) thermodynamic fluxes, 1-D (depth) superposition heat storage, and point ice cover. They allow limited insight to spatial distributions and exploration of long-term lake responses. GLERL developed a 2-D spatial model from their 1-D model for use in a near real time mode and a simulation mode. Refinements are needed to: study 2-D surface temperature and ice cover processes, compare CoastWatch data to the 2-D model, build empirical models of surface temperature and ice cover, augment meteorological interpolations, augment NOAA AVHRR data, and incorporate the 2-D thermodynamic model into CHARM.

RUNOFF HYDROLOGY. GLERL's runoff models comprise two efforts: the lumped-parameter hydrology model and two-dimensional land surface parameterizations. GLERL's lumped-parameter model is a conceptual model for moisture storage and runoff consisting of a tank-

cascade concept for application to spatial scales of 30-100 km (irregular-shaped areas) and time scales of 1-30 days. The lumped-parameter model has been successfully used for simulation, forecasting, and estimating impacts of climate change. GLERL's 2nd generation land surface hydrology model research currently involves: developing a geographic information system (GIS) lab, assessing and acquiring Great Lakes basin spatial data, and assessing the state-of-the-art in spatial hydrology modeling. Planned research includes: consideration of land surface parameterizations, developing and testing a prototype model, evaluating surface parameterizations in the Great Lakes, and incorporating them into CHARM, WARFS, and simulations.

CHARM. GLERL is linking hydrologic and mesoscale atmospheric models in cooperation with the University of Michigan (UM) through the Cooperative Institute for Limnological and Ecological Research (CILER), the Air Resources Laboratory, and the Savannah River Laboratories. Two efforts are now underway at GLERL. For the present (phase I), we are coupling existing irregular-area surface models and mesoscale atmospheric models by using grid-box irregular-area overlaps and synchronization. For the future (phase II), we will couple gridded surface models allowing consideration of finer scales. There are two fine-scale approaches possible now. The first uses joint models from phase I with external hydrology models and the second develops fine-scale hydrology models.

WARFS. Large spatial and temporal scales are necessary in water resource forecasting. NWS addresses hours to days in meteorological outlooks and hours to days and river basin scales in riverine forecasts. GLERL's Great Lakes Forecast System addresses hours to days in Lake Erie level fluctuation outlooks. GLERL-WARFS addresses weeks to months and basin-wide scales. NOAA's program to build WARFS provides for NWS to apply meteorological and riverine forecasting throughout the US and for NWS to apply water resource forecasting in the Colorado Basin and possibly the Pacific Northwest. It provides for GLERL to apply water resource forecasting in the Great Lakes, with possibilities on other large lakes. GLERL's goal is to build an operational WARFS for the Great Lakes by improving methodologies, updating models, better collecting data, and better communicating information. GLERL is cooperating with NWS in building WARFS on the Great Lakes, beginning with their present forecasting effort and doing parallel process model development, data stream incorporation, and integrated data management.