Integration of Great Lakes Water Resources into National and Continental Systems for Weather and Climate Prediction

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Abstract

The Laurentian Great Lakes contain over 20% of the world's surface fresh water and provide drinking water, recreation, shipping access, ecosystems, and other services to impact the lives of a large fraction of the population of the United States and Canada. While weather and climate outside of the immediate drainage basin affects the water budget within the basin, this can also work in reverse, with the lakes affecting the weather, sometimes on a large spatial scale. The advent of the variant of the Weather Research and Forecasting Model with enhanced hydrologic capability (WRF-Hydro) provides an opportunity to put Great Lakes water resources within a standardized framework for cooperation in weather and climate prediction at the scale of the conterminous United States and North America as a whole. Hindrances to this in the past have included a lack of modeling systems sufficiently standardized to talk across the larger-scale forecasting systems and the Great Lakes-specific water resource system, and the international data stream needed for elements such as radar-based precipitation products, seasonal-scale climate outlooks, and detailed land elevation data for stream routing. We will discuss plans for work using WRF-Hydro at various time scales, incorporating all of the Laurentian Great Lakes into continental-scale forecasts, with special attention to water resources.

The Challenge

NOAA's Great Lakes Environmental Research Laboratory has collective experience and modeling systems in the areas of atmospheric dynamics and hydrologic systems, as well as lake hydrodynamics. However, these models have been applied in the past mostly to discrete sub-systems of the larger regional physical system on different time scales: weather (< 5 days), multi-seasonal, and multi-decadal. There has been little coupling among the sub-systems for mutual exchange of moisture and energy.

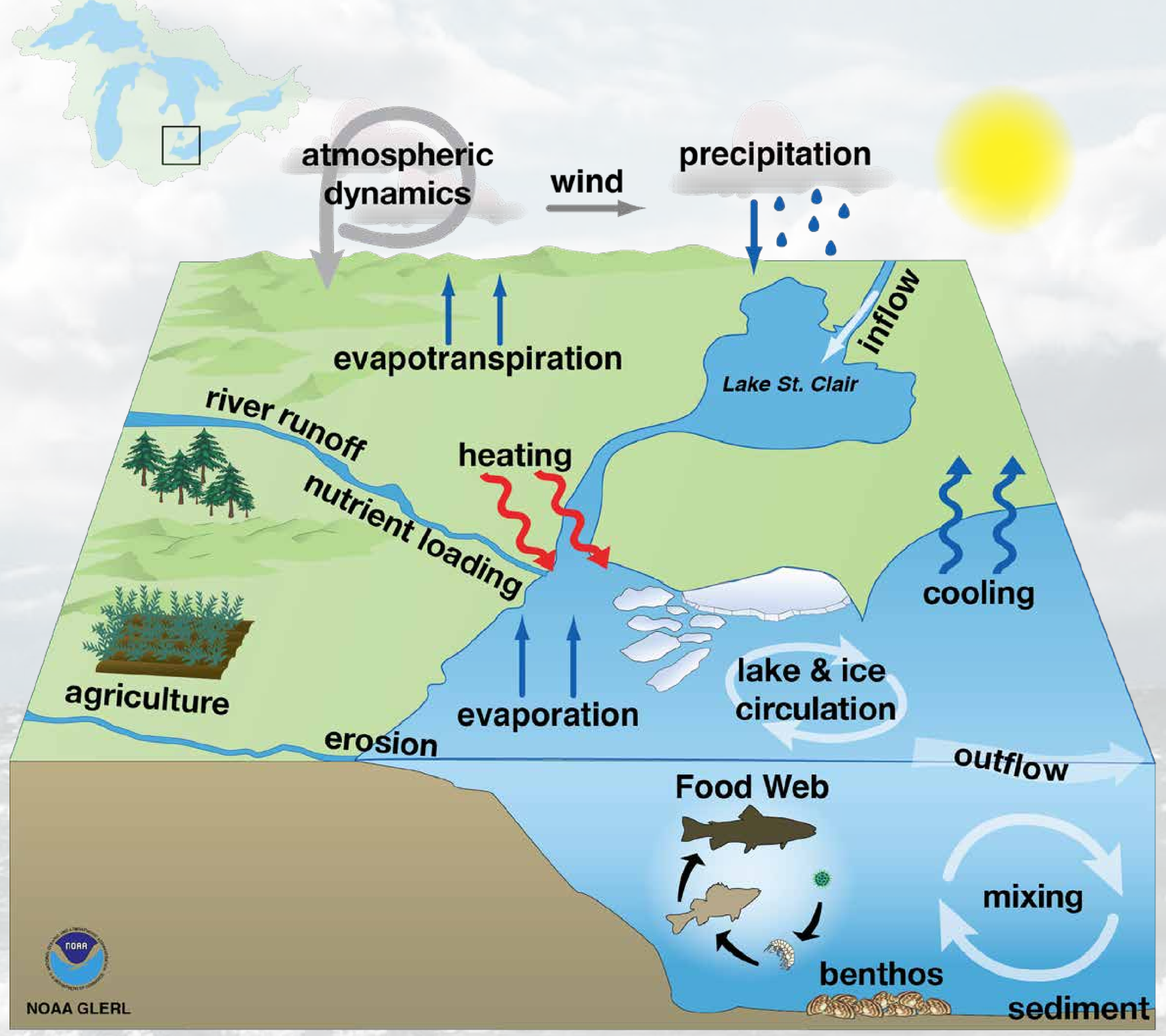
Time Scales and Processes

Weather	Dynamic water levels, waves, currents, up/downwelling, tributary river flows and levels, ice cover
Seasonal/multi-seasonal	Monthly mean lake levels, ice cover, lake temperature and stratification
Multi-decadal	Long-term lake levels, trends in seasonal ice cover, precipitation, evapotranspiration, water temperature, and stratification

Water Levels—A Key Endpoint

A very important metric for many Great Lakes stakeholders is lake water level, influenced by the balance between precipitation and evaporation in the basin. Water level fluctuations at time scales less than about a week can be strongly influenced by lake hydrodynamics, including phenomena such as currents, storm surge, and seiches.

Great Lakes Basin Conceptual Model



Physical Characteristics of Great Lakes vs. Oceans

	Ocean	Great Lakes
Water level mechanism	Thermal expansion	Net water budget
Thermocline	Permanent with seasonal enhancement	Seasonal only
Density	Salt (maximum density below freezing point) leads to stratified estuaries	Fresh (maximum density at 4° C); estuaries defined by chemical content, not density
Wind-driven upwelling	Nearly permanent in places (e.g. equatorial Pacific)	Frequent but not permanent
Thermally-driven atmospheric circulation	Sea and land breeze (ageostrophic), monsoon and basin-scale standing waves (quasi-geostrophic)	Lake and land breeze with lake effect precip (ageostrophic), lake aggregate effect circulation (near geostrophic)
Water wave modes	Surface gravity, internal gravity and Poincaré, Kelvin (edge and Equatorial), Rossby	Surface gravity, resonant external seiche, internal gravity and Poincaré, Kelvin edge
Ice cover	Almost none at latitudes < 60°	Frequent except in deepest areas

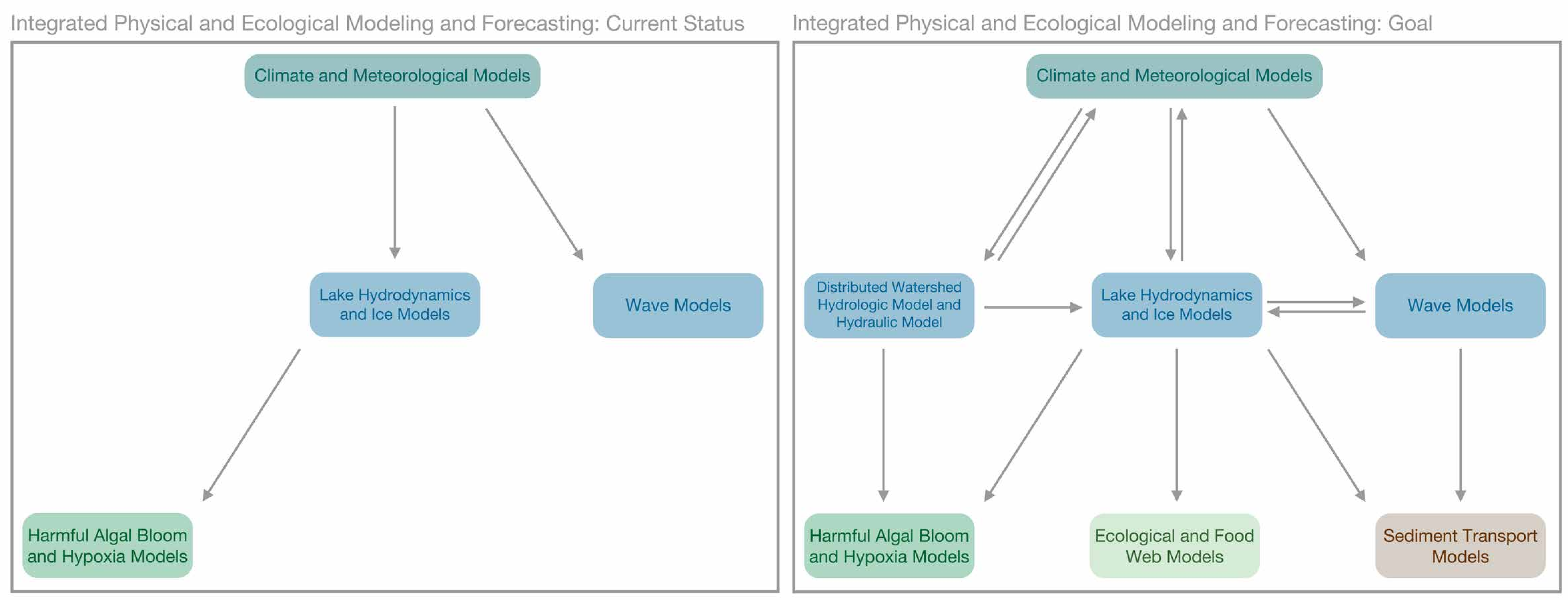


Figure 1. (left) Flow chart of existing coupling scheme of physical and ecological models at NOAA/GLERL. (right) Planned concept with more complete coupling and additional ecological components.

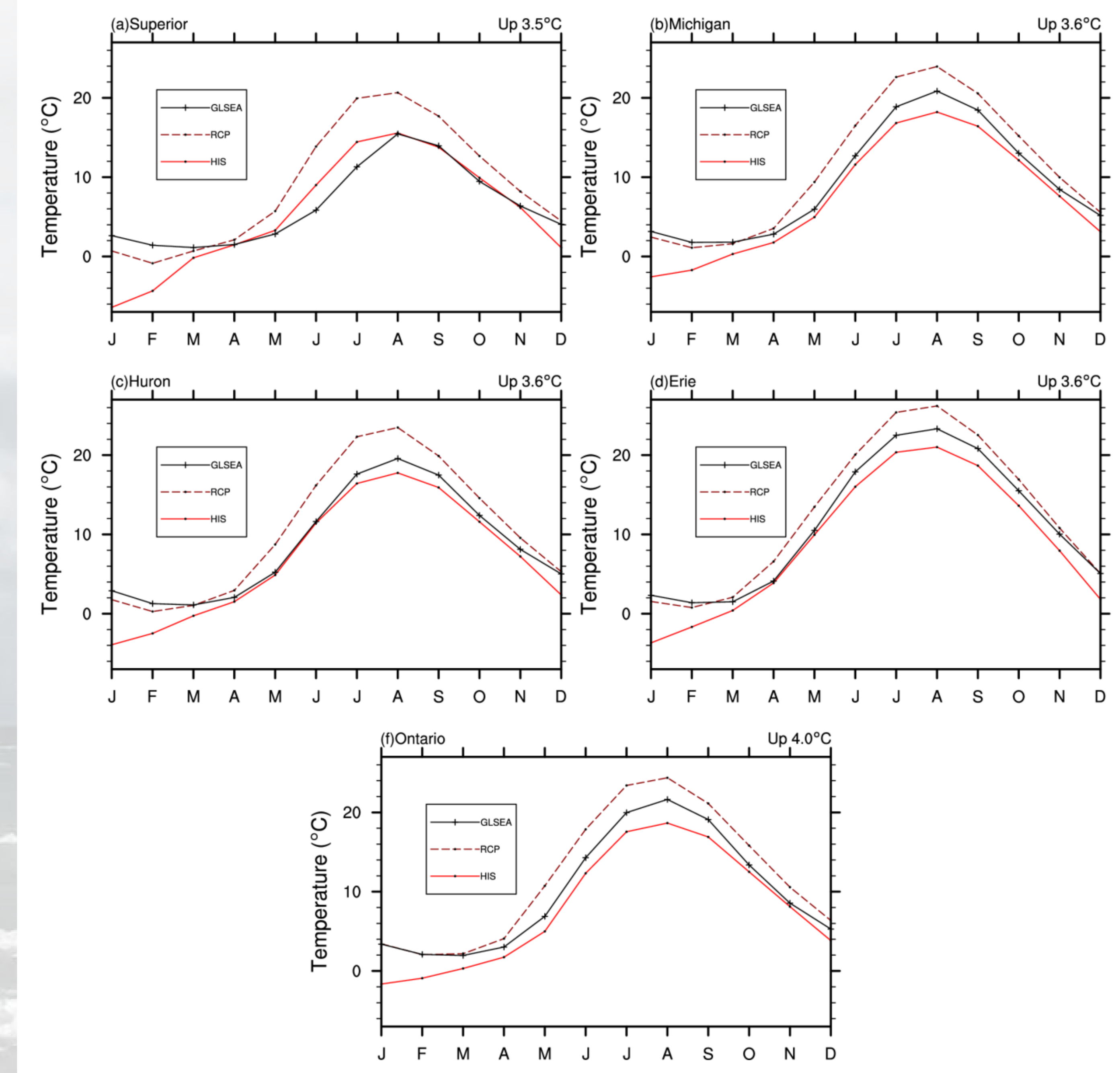


Figure 2. Observed (GLSEA satellite product) and simulated mean annual cycles of lake surface temperature using WRF coupled to a 1-dimensional lake diffusion model (the WRF-Lake module) driven by the GFDL CM3.0 under the RCP 4.5 concentration scenario. The HIS (historical) data are climatological means from 1980-2010, and the RCP (future) data are from 2070-2100. (a) Lake Superior, (b) Lake Michigan, (c) Lake Huron, (d) Lake Erie, and (e) Lake Ontario.

Summary

NOAA's Great Lakes Environmental Research Laboratory will be working toward comprehensive modeling systems for the physical aspects of the atmosphere, land surface, and lake water and ice for the Great Lakes region, in addition to incorporating the lower trophic levels of the ecosystem. The physical aspects are also intended for inclusion in models of larger spatial domain.

Key Partners

- Additional personnel internal to NOAA GLERL and CILER
- NOAA Earth System Research Laboratory
- Inter-agency National Water Center
- Environment Canada
- National Center for Atmospheric Research