Customizing WRF-Hydro for the Laurentian Great Lakes Basin

Lisi Pei1, Andrew Gronewold2, David Gočis1, Lacey Mason1, Kevin Sampson1, Aubrey Dugger1, Laura Read1, James McCreight1, Chuliang Xiao1, Brent Lofgren2, Eric Anderson1, Philip Chu1

1University Corporation for Atmospheric Research, 2NOAA Great Lakes Environmental Research Laboratory, 3National Center for Atmospheric Research, 4University of Michigan, 5Cooperative Institute for Great Lakes Research

Abstract

To advance the state of the art in regional hydrological forecasting, and to align with operational deployment of the National Water Model, a team of scientists has been customizing WRF-Hydro (the Weather Research and Forecasting model Hydrological modeling extension package) across the binational land and lakescapes of the Laurentian Great Lakes and St. Lawrence River basin. Objectives of this customization project include operational hydrography simulation and forecasting of the Great Lakes water balance and development of research-oriented insights into modeling one- and two-way coupled lake-atmosphere and nearshore processes. Initial steps in this project have focused on overcoming inconsistencies in land surface hydrographic datasets and meteorological forcings along the international border between the United States and Canada. Improvements in the model’s current representation of lake physics and stream routing are also critical components of this effort.

Development of new hydrography

In initial configurations of the National Water Model, WRF-Hydro was built on the medium resolution (1:100,000 scale) National Hydrography Dataset Plus Version 2 (NHDPlus V2). To date, however, NHDPlus V2 has not been extended across the Canadian land surface of the Great Lakes and St. Lawrence River basin. Through a partnership with the NOAA Great Lakes Environmental Research Laboratory (GLERL), the University of Michigan Cooperative Institute for Great Lakes Research (CIGLR), and the National Center for Atmospheric Research (NCAR), a new hydrography dataset has been developed for this region (Figs. 1 and 2) that combines NHDPlusV2 and the Great Lakes Hydrography Dataset (GLHD). This new product leverages previous efforts to resolve the binational watersheds of the Great Lakes in the GLHD, while also employing features of NHDPlusV2 that facilitate expansion of WRF-Hydro across the Canadian land surfaces of the basin.

Evaluating meteorological forcings

Developing spatially and temporally consistent meteorological forcings along the Laurentian Great Lakes basin is a major challenge. Our research indicates that conventional meteorological data products, such as the North American Land Data Assimilation System (NLDAS), have severe biases along the US-Canada border (Fig. 3). At present, members of this research team are evaluating the skill of a suite of operational and experimental products over the land surfaces of the basin, and over the vast surfaces of the Great Lakes as well.

Runoff simulation—calibration and testing

Routine protocols for calibrating and testing WRF-Hydro across the entire United States have been developed by NCAR, and are being leveraged in our ongoing regional application of WRF-Hydro to the Laurentian Great Lakes. Preliminary results (Figs. 5 and 6), based on initial testing in watersheds in Michigan’s lower peninsula, indicate reasonable model performance, including a noticeable improvement in skill after calibration.

Coastal coupling and related future work

The next phases of this work will include continued model calibration and verification across the US and Canadian land surfaces of the Great Lakes basin, and intercomparison of different meteorological forcings. Preliminary tests indicate that lake circulation and pollutant fate and transport processes in existing operational lake physics models are sensitive to lateral tributary flow inputs, and underscore the importance of implementing a coastal coupling scheme between WRF-Hydro and the lake models. We expect the capabilities of the new National Water Model to include improved ability to forecast and understand Great Lakes basin flooding events, including the recent historical flooding across much of the Lake Ontario basin.

Acknowledgements

Funding for this research was provided by NOAA through the Office of Water Prediction, the Great Lakes Environmental Research Laboratory, and the Joint Technology Transfer Initiative (JTTI). Kaye LaFond and Nicole Rice provided graphical and editorial support.

For additional reading


FIGURE 1. Evolution of new Great Lakes hydrography data sets including detailed perspective of the original NHDPlus (top panel) with noticeable discontinuities across the US-Canada border, and new combined product (bottom panel) with discontinuities resolved.

FIGURE 2. Complete new hydrography dataset for the Laurentian Great Lakes basin based on combination of NHDPlus V2 and Great Lakes Hydrography Dataset (GLHD). This new hydrography serves as a cornerstone for supporting WRF-Hydro across the entire land surface of the Laurentian Great Lakes basin. Data indicate locations of points for modeling Canadian (black) and US (red) streamflow data. One of the challenges of implementing WRF-Hydro across the Great Lakes basin is customization of operational protocols for assimilating Canadian streamflow data.

FIGURE 3. One of the biggest challenges facing Great Lakes regional hydrological modeling is development of consistent hydrometeorological forcings along the international border. Covariant, North American Land Data Assimilation System (NLDAS) cumulative precipitation for a) 2012, and b) 2012 both indicate unrealistically gradients along the US-Canadian border (Fig. 3). At present, members of this research team are evaluating the skill of a suite of operational and experimental products over the land surfaces of the basin, and over the vast surfaces of the Great Lakes as well.

FIGURE 4. Development and testing of a coupled WRF-Lake model

Representing lake physical processes, including seasonal fluctuations in heat content, ice formation, and latent and sensible heat fluxes, is critical to simulating and forecasting the short- and long-term water balance of the Great Lakes system. Recent research (Fig. 4) indicates potential improvements in the WRF-Lake model based largely on sophisticated treatment of lake surface albedo, and underscores the importance of accurately representing ice melt and snow accumulation across the lake surfaces. This research also serves as a foundation for improving the lake scheme within the WRF-Hydro system for other smaller lakes across the continental United States.

For additional reading