Improving Great Lakes Regional Operational Water Budget and Water Level Forecasting

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Background

Accurately forecasting monthly average water levels of the North American Great Lakes is an important priority for regional research-oriented and operational institutions. Both historical and projected water level information is a critical component of regional water resource management planning; the shipping industry, the hydropower industry, recreational boaters, and shoreline property owners all depend on robust water level projections to assess future potential financial and human health risks. Historical basin-scale hydrological phenomena, including a rapid water level decline in the late 1990s (Figure 1) coincident with one of the strongest El Niño events in history [Assel, 1998; Van Cleave et al., 2014], a 15-year period of persistent low water levels [Gronewold and Stow, 2014], and a recent water level surge that overlapped with the arctic polar vortex anomaly (Figure 2) in early 2014 [Clites et al., 2014a] all underscore the challenges of understanding seasonal drivers of regional hydrologic conditions, and propagating that understanding into water budget and water level projections.

To address this challenge, NOAA (through its Great Lakes Environmental Research Laboratory) conducts research on water budget and water level forecasting in partnership with the US Army Corps of Engineers (USACE, Detroit District). The USACE (in partnership with colleagues from Environment Canada) is responsible for developing and distributing official operational forecasts of six-month water supplies and lake levels for each lake every month, while NOAA-GLERL (in partnership with other NOAA line offices and research laboratories) focuses on recommending and implementing improvements to models, monitoring infrastructure, and forecasting protocol.

Recent evolutions in the NOAA-USACE regional research-to-operations partnership have focused on improving both historical estimates, as well as projections, of regional air temperature (T) and precipitation (P) across the Great Lakes basin (as well as for the sub-basins of each individual lake).

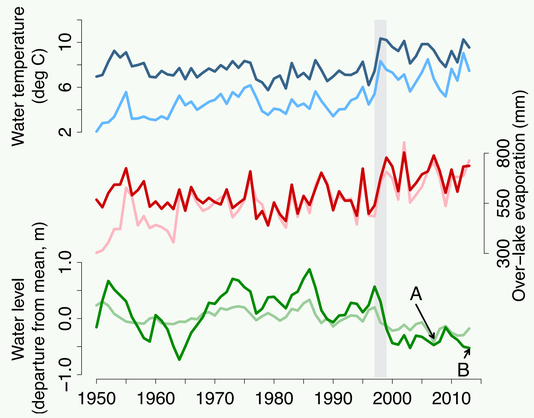


Figure 1. Time series of annual-average climate and hydrological variables for Lake Superior (light colors) and Lake Michigan-Huron (dark colors) reflecting long-term trends and abrupt shifts in surface water temperature (blue lines) and over-lake evaporation (red lines). These factors, combined with human intervention (including dredging of channels connecting the Great Lakes) contribute to recent record low water levels on both lake systems (green lines). Vertical gray band indicates approximate period of 1997-1998 El Niño. Adapted from Gronewold and Stow [2014].

Forecasting Skill Assessment

Recent assessments of regional seasonal water level forecasting skill [see, for example, Gronewold et al., 2011], indicate that the existing protocols provide a reasonable projection of seasonal water levels along a 3 to 6-month time horizon. However, recent assessments also indicate that forecasts have a tendency to underestimate extremes and, more recently, has tended to underestimate both the rate of water level increases as well as the rate of water level declines (Figure 7).

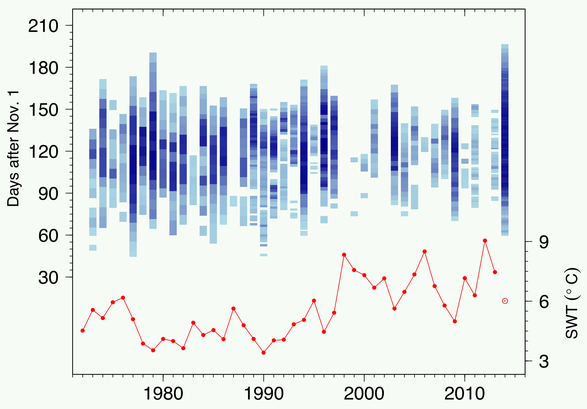


Figure 2. Areal extent of daily ice cover (blue columns) and average annual lake-wide surface water temperature (SWT; red line) on Lake Superior from 1972 through 2014. Each column corresponds to the 'ice season' for given year. The darkest shades of blue across all columns indicate ice cover near 100%, while the lightest shades of blue indicate ice cover near 10%. Ice cover and SWT data are from the NOAA Great Lakes ice atlas project [Assel , 2005; Wang et al., 2012] and the NOAA Lake Thermodynamics Model.

Existing Forecasting Protocol

The USACE (Detroit District) develops operational water level projections for the Great Lakes using qualitative criteria to select from a suite of models including trend models, empirical regression-based models, and a simple one-dimensional process-based model [see, for example Gronewold et al., 2011]. Model selection is typically based on expected future hydrological conditions (and which models might best represent those conditions) in light of expected future climatology based on National Weather Service Climate Prediction Center seasonal outlooks (as shown in Figure 3). Information on existing hydrologic conditions throughout the Great Lakes basin is available through a limited set of sources including NOAA's National Operational Hydrologic Remote Sensing Center (Figure 4) and regional meteorological monitoring stations (Figure 5). The USACE distributes forecasts to the general public both through the "Monthly Bulletin of Great Lakes Water Levels" (Figure 6) and, more recently, through the multi-agency web-based Great Lakes Water Levels Dashboard [for further reading, see Gronewold et al., 2013; Clites et al., 2014b]

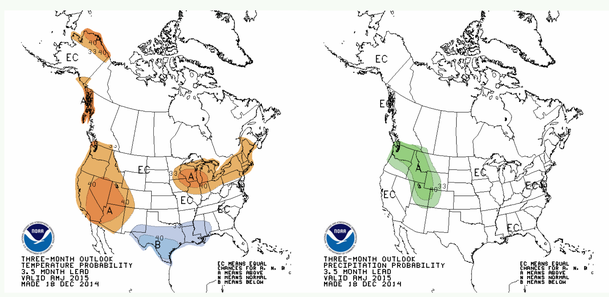


Figure 3. NOAA National Weather Service (NWS) Climate Prediction Center (CPC) three-month national outlook maps for temperature and precipitation probabilities for AMJ 2015. Understanding the skill of these outlooks (and alternative outlooks based on different models or model ensembles) specifically for the Great Lakes region is an important stepping stone towards improving regional water budget and water level projections, particularly in light of complex lake-atmosphere interactions and data discontinuities along the US-Canadian international border.

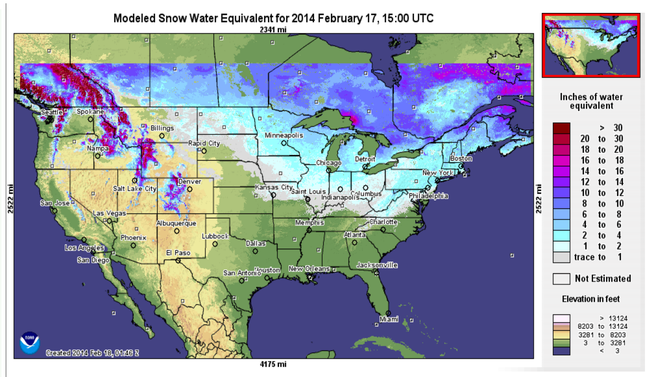
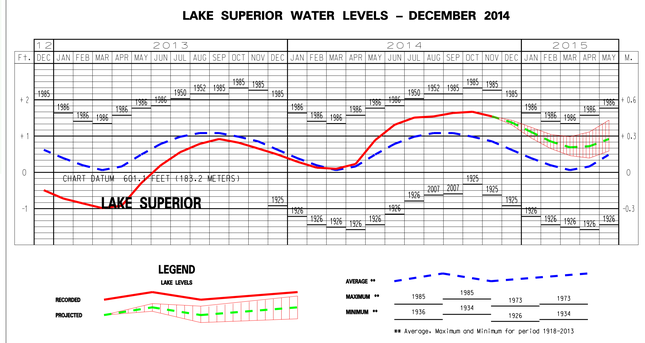


Figure 4. NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC) national snow analysis. Modeled snow water equivalent for Feb. 27, 2014.



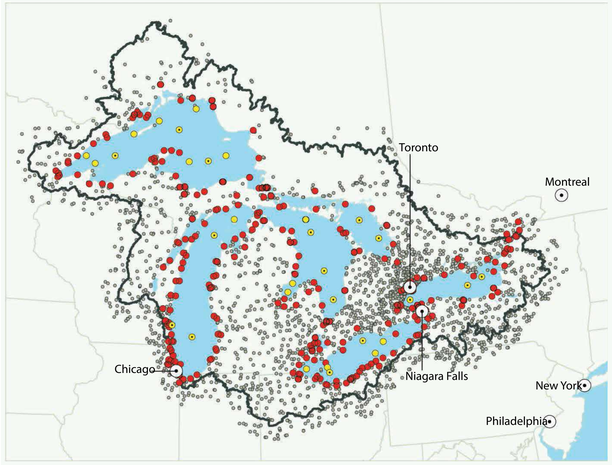


Figure 5. Great Lakes regional long-term hydrometeorological monitoring network including terrestrial stations for watershed hydrology (gray circles), near-shore monitoring stations for over-lake processes (red dots), and off-shore monitoring stations and buoys (yellow dots), also for over-lake processes.

Figure 6. Operational projections (along with recent trends and historical highs and lows) of monthly-average Great Lakes water levels as presented in the US Army Corps of Engineers "Monthly Bulletin of Great Lakes Water Levels". Image shown is for Lake Superior only. The Bulletin is a conventional platform for distributing observed and projected water level information; in the future, this information will be increasingly distributed through interactive web-based platforms (see, for example, Figure 7).

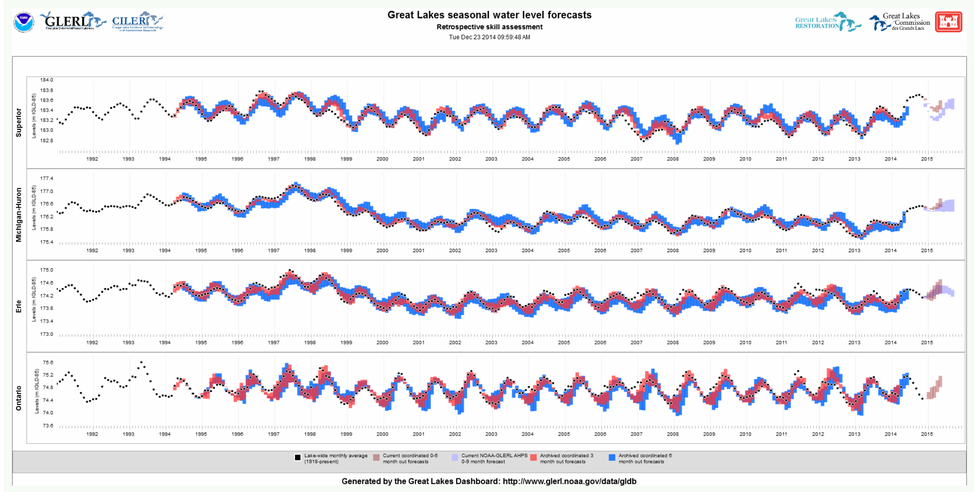


Figure 7. Retrospective assessment of internationally-coordinated monthly-average water level forecasts. 3-month 95% prediction intervals are colored red, and 6-month 95% prediction intervals are colored blue. Observed monthly-average water levels are represented by black dots. Internationally-coordinated projections (95% prediction intervals) for the next 6 months (far right-hand side of figure) are shaded in light red, and experimental projections from NOAA's AHPS are shaded in very light blue.

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Acknowledgements

This study was funded by NOAA through the Great Lakes Environmental Research Laboratory (GLERL), by the University Corporation for Atmospheric Research PACE (postdoctoral applications in climate expertise) Program, and by the USACE. This study was also funded by the Great Lakes Restoration Initiative (administered by the USEPA). Cathy Darnell provided graphical and editorial support.