Recent Water Level Changes across Earth's Largest Lake System and Implications for Future Variability

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Abstract:

Water levels on Lake Ontario, the most downstream of the Laurentian Great Lakes, reached a record high in the spring of 2017. This event was accompanied by widespread flooding and displacement of families. Water levels across all of the Great Lakes have risen over the past several years following a period of record low levels. When levels were low, public and expert discussion focused on the possibility that low levels would continue into the future due to climate change, diversions of water from the lakes, and dredging. During the current high water period, variability is being attributed to water management, despite evidence of unusually high precipitation and river flows across the region. Understanding and communicating the drivers behind water level variability, particularly in light of recent extremes, is a fundamental step towards improving regional water resources management and policy.

Comment:

The Laurentian Great Lakes in the United States and Canada are the largest system of lakes on Earth and represent 20% of all fresh surface water. In May 2017, water levels on Lake Ontario (the most downstream of the lakes) rose to a record high. In the preceding months, water accumulated rapidly across the region, leading to unusually high flows through the Niagara River (into Lake Ontario) and Ottawa River (downstream of Lake Ontario), and resulting in widespread flooding. This crisis followed a record-setting rise on the two most upstream Great Lakes (Superior and Michigan-Huron) and coincided with a period when all of the Great Lakes were above their long-term average levels (Figure 1).

The transition to high water level conditions began in 2013 when Lakes Superior and Michigan-Huron were at or near record lows (Gronewold & Stow, 2014). At that time, there was a common perception that diversions and dredging had led to chronic water loss, and that increasing temperatures and evapotranspiration rates (Desai, et al. 2009; Pekel, et al. 2016) would further exacerbate the problem. The public demanded controls to offset low water conditions.

Interestingly, the high water levels on Lake Ontario in 2017 have also been attributed to water management; outflows from Lake Ontario have been regulated via the Moses-Saunders dam since 1960 (Lee, et al. 1994). There is, however, no plausible lake level control scenario that could have significantly altered the recent rapid rate of water accumulation across the Lake Ontario basin and surrounding areas.

The notion that recent extremes in Great Lakes water levels are dominated by regulation is not realistic. Likewise, the notion that future water levels will be predominantly lower due to rising temperatures and increased evapotranspiration (Lofgren, et al. 2013) is facile – such arguments do not honor the conservation of energy in the hydrometerological cycle. The global climate models (GCMs) that often serve as a basis for these arguments have low fidelity in their representation of the weather-scale processes that are responsible for precipitation across the Great Lakes basin (Briley, et al. 2017). The spatial scales of most GCMs are not nearly fine enough to adequately represent the hydrologic cycle of the Great Lakes.

Therefore, GCMs are perhaps most useful for offering guidance to frame analyses of future Great Lakes water level variability scenarios, but not for making explicit predictions. Generally, GCMs suggest an increase in both temperature and precipitation across the Great lakes region. We posit that the most meaningful guidance that can be extracted from these results is that two of the most important factors influencing future lake levels are of opposite sign.

Given the uncertainty associated with climate models, it is important to first consider how they align with emerging observations, and then frame scenarios for potential future behavior. Increased precipitation rates have already been observed across the Great Lakes region (Melillo, et al. 2014)*;* indeed, across the United States and Canada there are strong trends of increasing precipitation and, especially, extreme precipitation events along with flooding on local and regional scales. These observations align with recent model simulations that also indicate potential periods of extended drought to collectively suggest a future of continued and potentially increasingly variable water levels (Notaro, et al. 2015).

Profound changes in Arctic snow and ice cover further complicate scenarios for future lake level variability. There is growing evidence, for example, that changes in Arctic ice are influencing the propagation of weather systems important to precipitation in the Great Lakes basin (Francis & Vavrus, 2012). The evidence suggests that weather-scale precipitation events are moving more slowly and thereby increasing regional accumulated precipitation. Changes in the Arctic may also be influencing major modes of weather-climate variability, such as the Arctic

Oscillation (Hassanzadeh & Kuang, 2015). These processes will continue to compete with others to influence Great Lakes ice cover, lake effect snow events, seasonal freeze-thaw dynamics, as well as lake levels.

Recent lake level fluctuations induced by weather extremes and climate variability, including the Lake Ontario flood of 2017 and the preceding extended period of low water levels, have been outside of the range that are reasonably attributed to water management. The possibility of a future with increased variability is supported by current observations and is in contradiction to the wide-held public perception that lake levels will necessarily decline as the climate warms (Frank, et al. 2015). This suggests that lake level management should consider variability in scenarios of future water supply, rather than decreasing water supplies alone. Aside from impacts to coastal residents, industry, and commerce, a future characterized by Great Lakes water supply and water level variability has important consequences for international water resources management and policy development (Annin, 2018).

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Figure Caption:

Figure 1. Monthly average water levels (black dots) for each of the Great Lakes from 2011 through 2018. Historical record low (red dots) and high (blue dots) monthly average water levels for each calendar month are aligned, for clarity, with the calendar months of 2011 and 2018, respectively.

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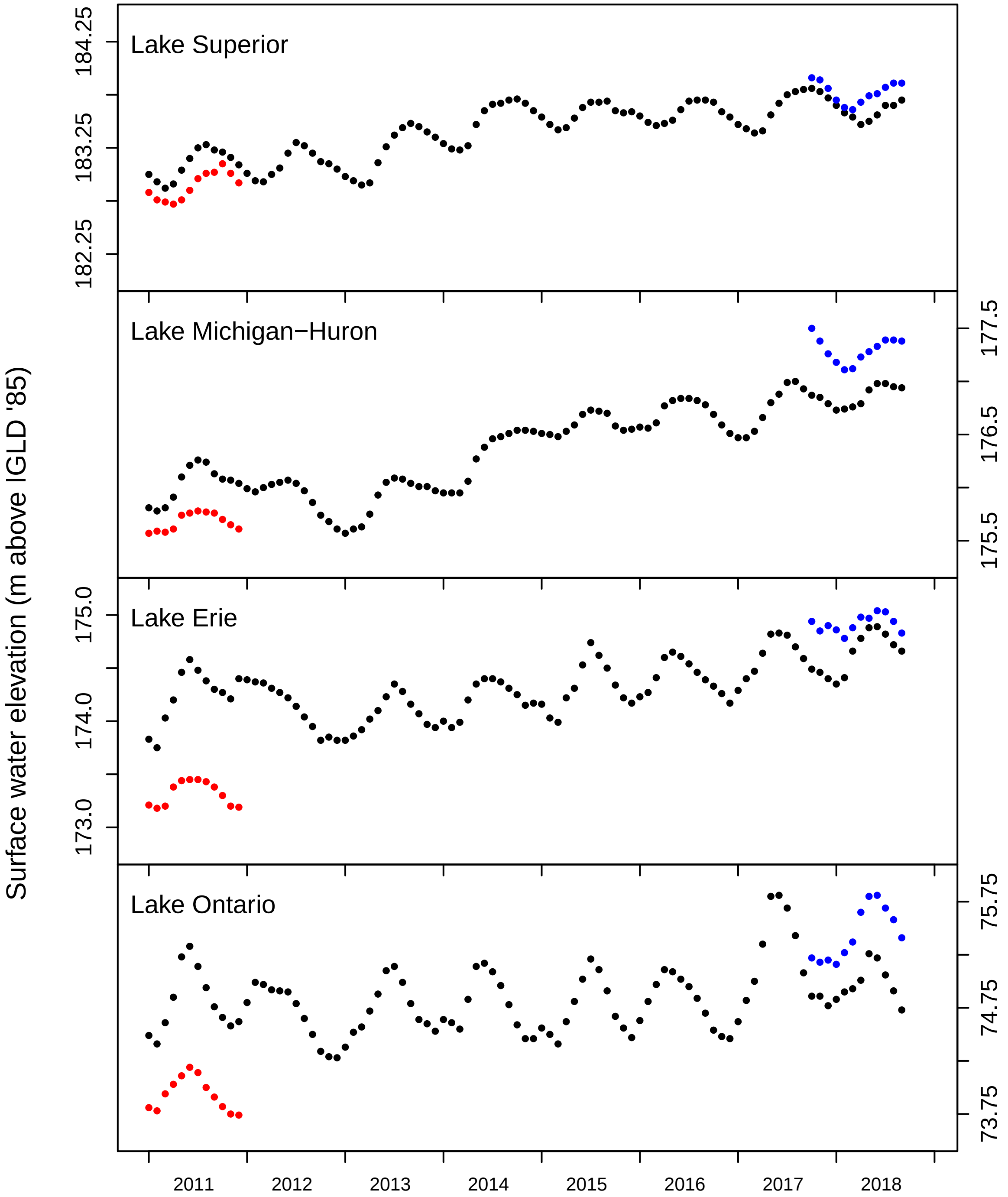

Surface water elevation (m above IGLD '85)
Lake Superior
184.25
183.25
182.25
Lake Michigan−Huron
177.5
176.5
175.5
Lake Erie
175.0
174.0
173.0
Lake Ontario
75.75
74.75
73.75
2011
2012
2013
2014
2015
2016
2017
2018