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Linking Watershed Hydrology and Coastal Hydrodynamic Models for Improved Water Level and Inundation Prediction in the Great Lakes

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Gap Between Existing Operational Models

- A gap exists between operational hydrodynamic models and watershed hydrology models along the coastline.
- The **National Water Model (NWM)**, which provides streamflow forecasts for the continental United Status at 250-meter resolution, extends to the coastline, or even upstream of the coast to avoid backwater effects, but has no information or linkage to hydrodynamic conditions (e.g. sea or lake level, currents, waves, storm surge) in the ocean or Great Lakes.

Figure 1. Next-Generation Great Lakes Operational Forecast System (GLOFS) on FVCOM grids

- The **Great Lakes Operational Forecast System (GLOFS)** provides 3D hydrodynamic forecast guidance at a resolution of 50m to 500m in the nearshore, and is based on the Finite Volume Community Ocean Model (**FVCOM**; Fig. 1). However, the grid does not extend into the land watershed.
- Because of this gap between watershed and coastal models, we are unable to provide flood forecast guidance for most events in the Great Lakes.

Figure 2. Example of coastal flooding event during period of high lake level on Lake Ontario in 2017

Approach

- In order to address extreme weather driven storm surge events and high lake level induced coastal flooding, we are developing a linkage between the NWM and FVCOM using the following approach:
- **Extend GLOFS-FVCOM grid into watershed**
  i. Evaluate FVCOM flooding capability
- **Link NWM+FVCOM (Fig. 3)**
  i. Input NWM streamflow into FVCOM for accurate lake-level and coastal flood simulation
  ii. Develop model infrastructure to exchange water across overlapping grids (e.g. hydrodynamic surge -> NWM ponded water)
- **Case study**
  i. Storm Surge event:
  - Ludington, MI 2018 meteotsunami (Fig. 4,5)
  - Wave run-up and coastal inundation driven by overlake wind and pressure
  - Representative of flooding event due to extreme coastal storm

Figure 4. 2018 Ludington, MI meteotsunami, photos of breakwall before (top) and during (bottom) event

Coastal Coupling | NWM+FVCOM

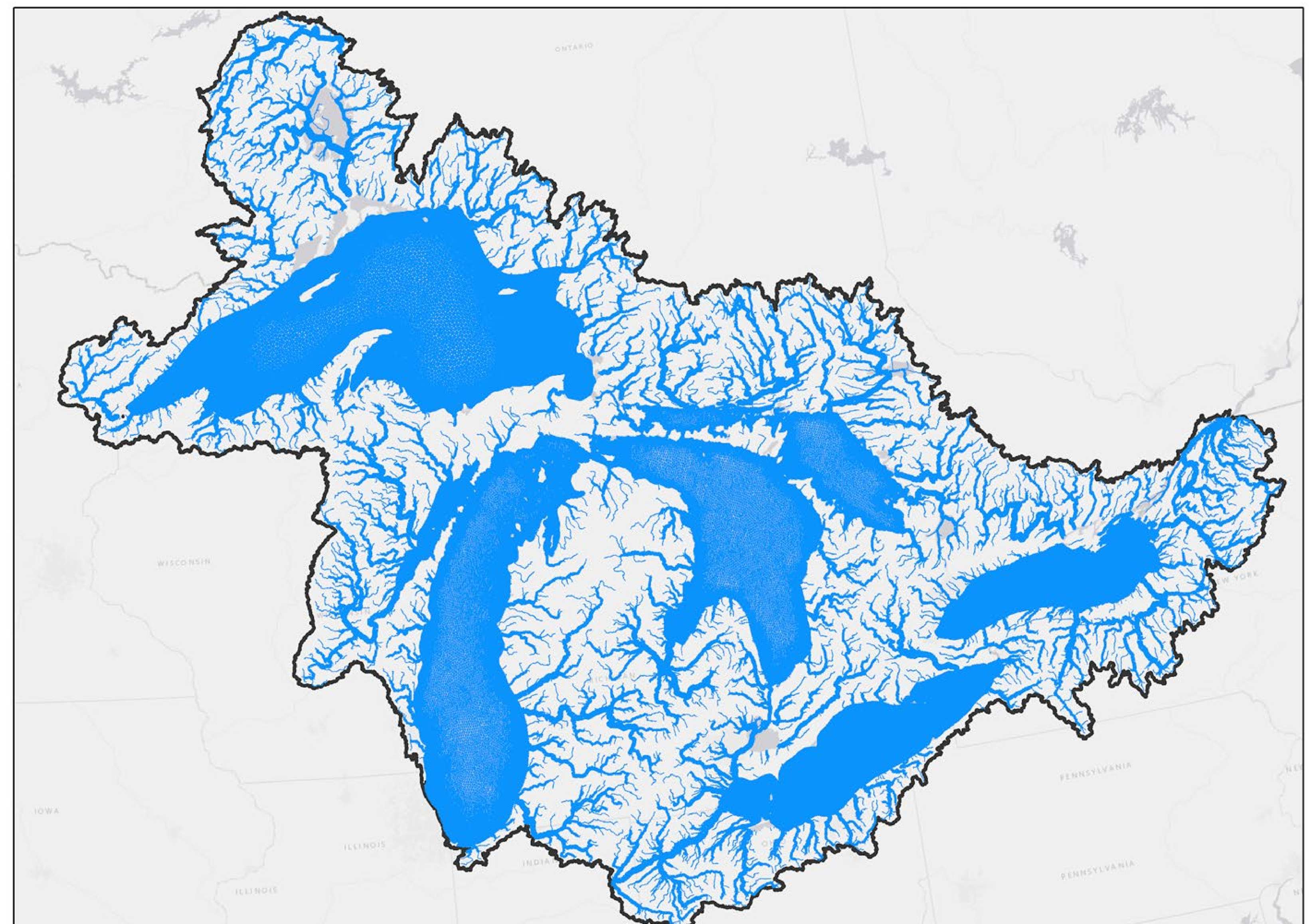

Figure 3. Linked NWM and FVCOM (GLOFS)

Storm Surge Coastal Flooding

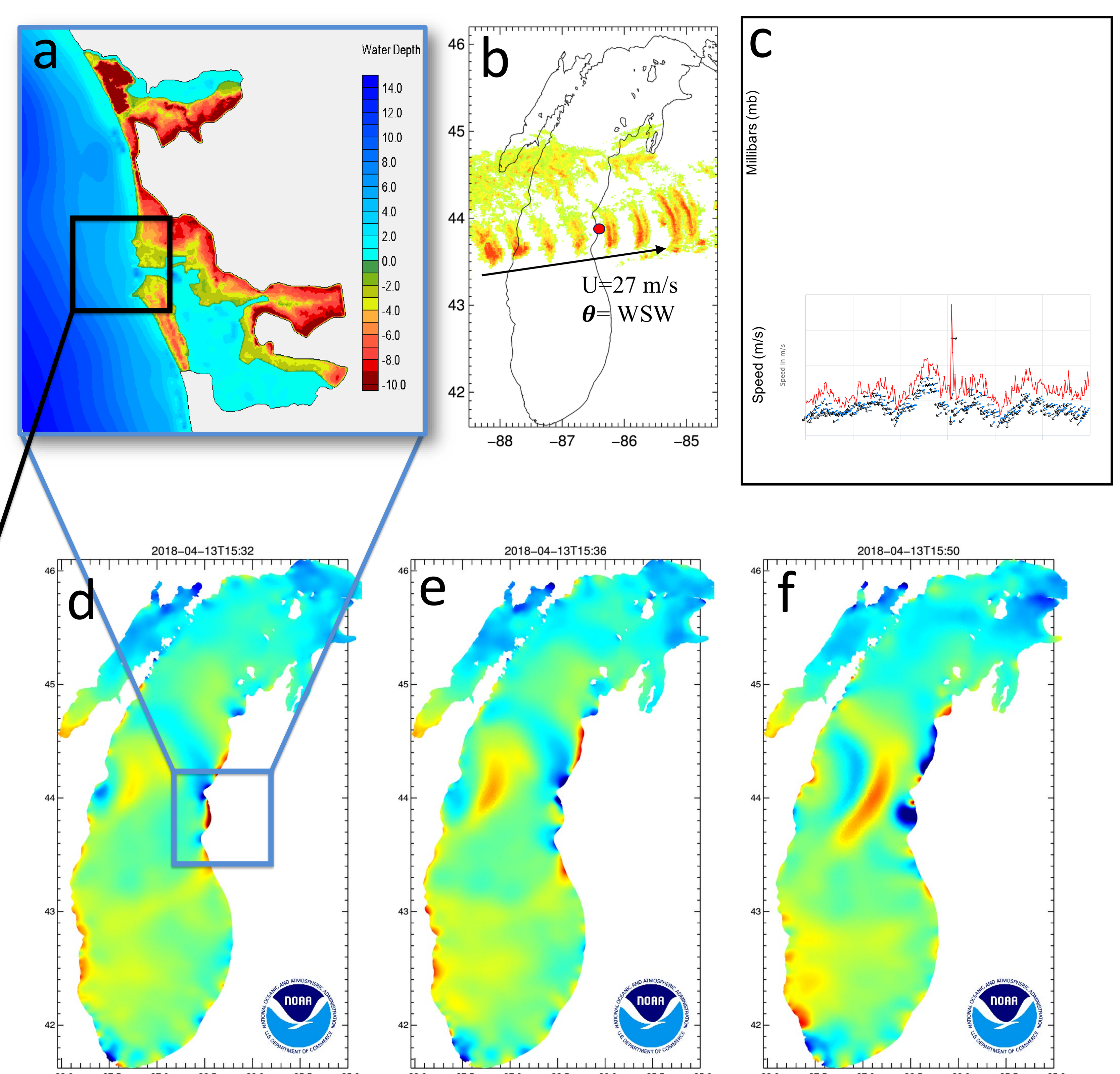

Figure 5. Case study of coastal flooding event due to storm surge during the April 13, 2018 meteotsunami. (a) Flooded area and extended FVCOM grid domain, (b) radar signature and pathway of atmospheric gravity wave, (c) observed jump in pressure and wind speed in Ludington, MI from atmospheric gravity waves, (d-f)meteotsunami wave response to storm (yellow and red colors highlight increases in water level, and blue represents decreases in water level).

Results – Storm Surge Coastal Flooding

Figure 6. Photographs near Ludington, MI on April 13, 2018 showing the (a,b) onset of meteotsunami inundation and (c) water level withdrawal.

- An atmospheric gravity wave (Δ10mb in 12 mins) produced 0.5 m rise in water level in the harbor near Ludington, MI (NOS 9087023; Fig. 6,7)
- Model simulation reveals a 1-meter fluctuation in water level along the open coast as a result of the meteotsunami wave that is not captured by the available water level gauges
- The wave resulted in overtopping of the breakwall, coastal flooding of shoreline homes, damage to cottages and docks

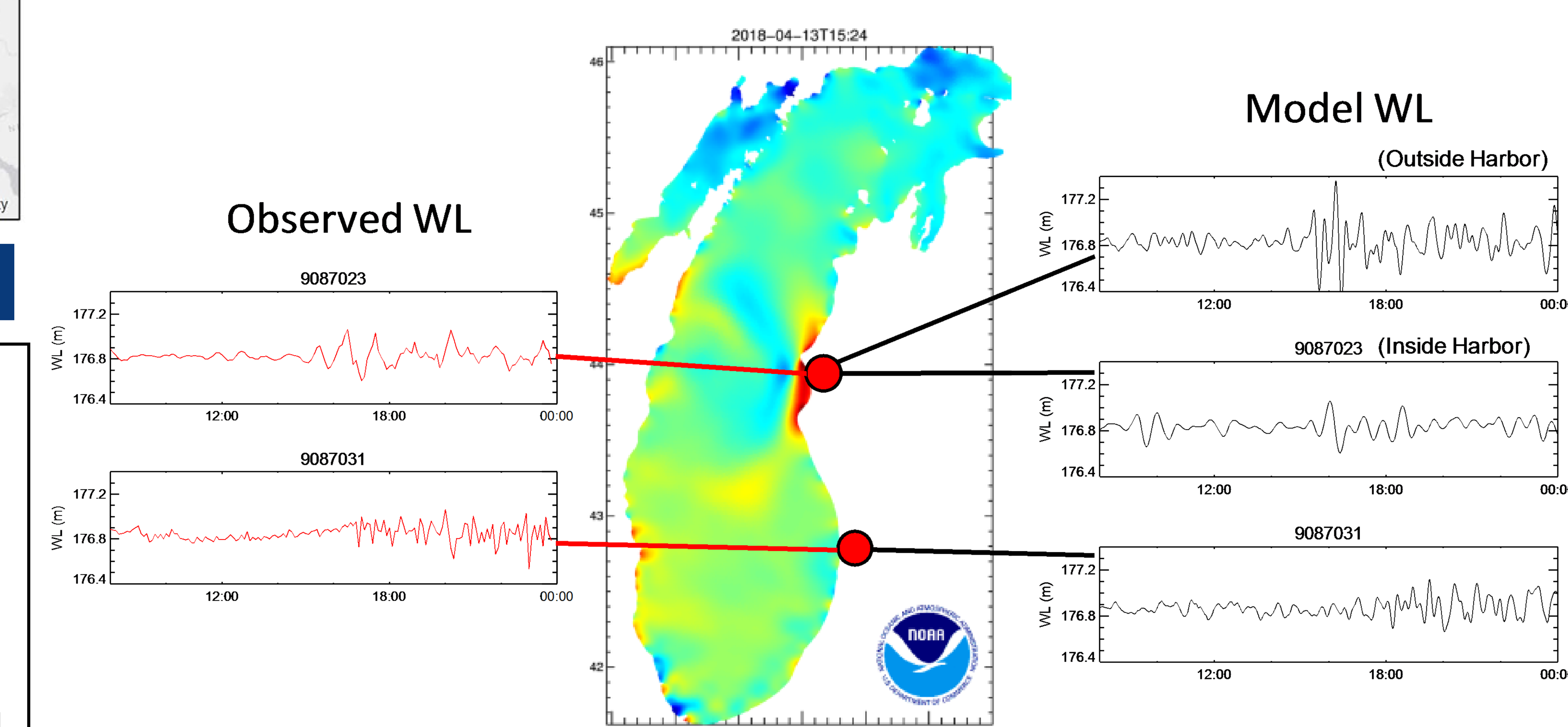

Figure 7. Observed and modeled coastal water level response during April 18, 2018 meteotsunami.

Conclusions

- FVCOM grid extension into watershed and wetting/drying tests prove ability to resolve coastal flooding
- Test case of a storm surge event due to a meteotsunami shows FVCOM is able to recreate the meteotsunami wave as a result of atmospheric forcing
- Wave arrival time and amplitude in agreement with observations from coastal water level gauges
- NWM inputs into FVCOM improve water level tracking
- Next Steps: (i) evaluate inundation extent for storm surge event and (ii) investigate sustained high water level flooding events

Acknowledgements & References

Acknowledgements

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References

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