Climate Change Impacts on Coastal Storms and Ice Cover for Lakes Erie and Ontario

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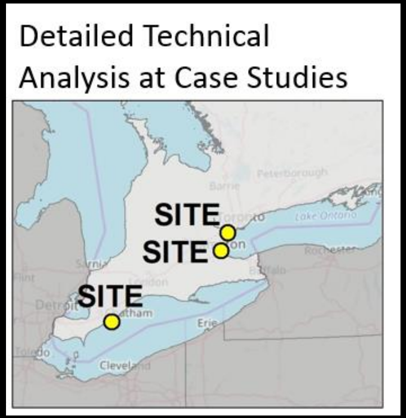
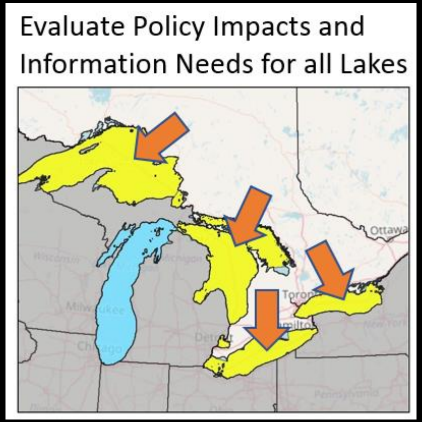
September 17, 2019





Study Partners

- Supported by Natural Resources Canada’s Climate Change Adaptation Program
- 20+ Members of the Conservation Authorities Coastal Working Group
- Municipality of Chatham-Kent (C-K)
- Lower Thames Valley Conservation Authority (LTVCA)
- Credit Valley Conservation Authority (CVC)
- Halton Region
- A Steering Committee with representation from all levels of government, including the US Army Corps of Engineers and the IJC

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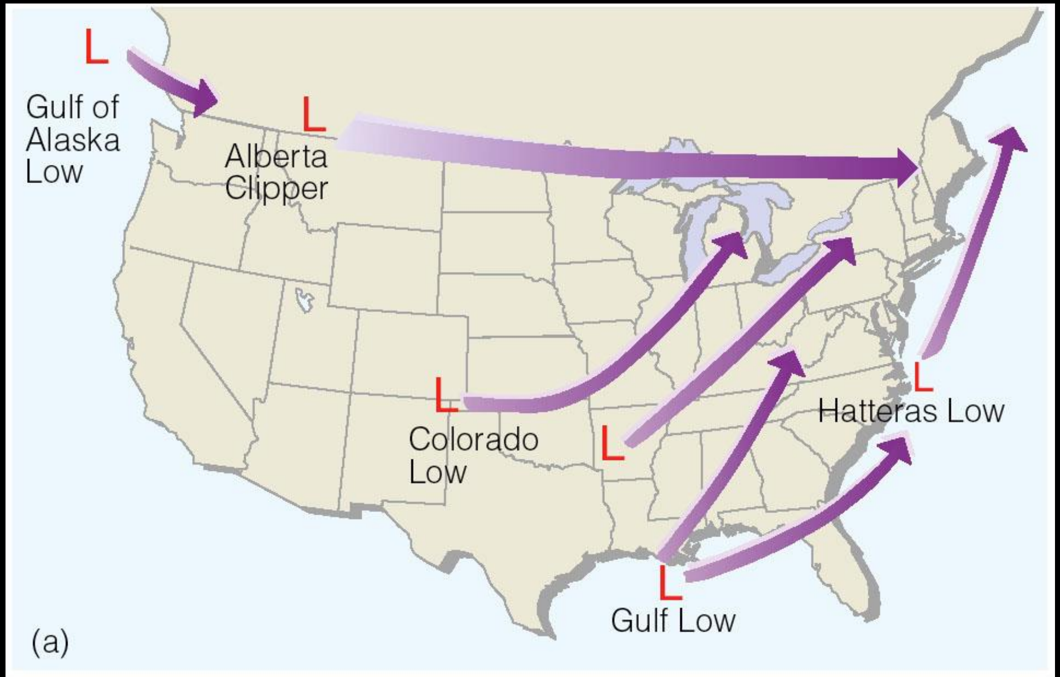
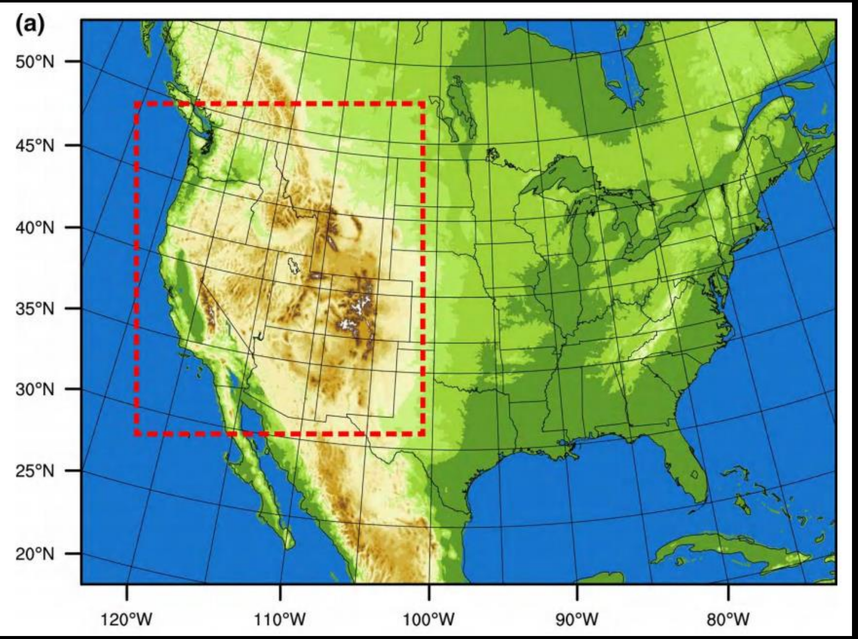
I – STREAM ONE RESULTS CLIMATE CHANGE IMPACTS ON COASTAL STORMS



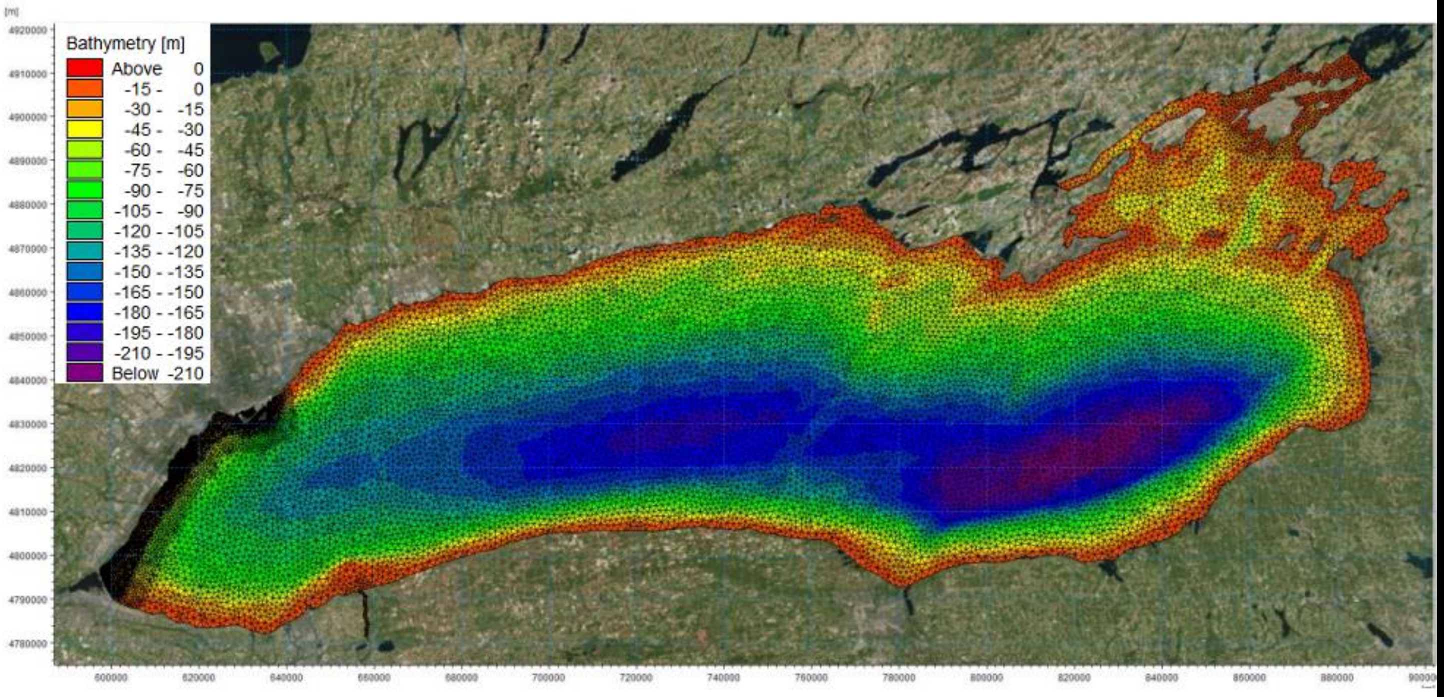
Weather Research and Forecasting (WRF) Model

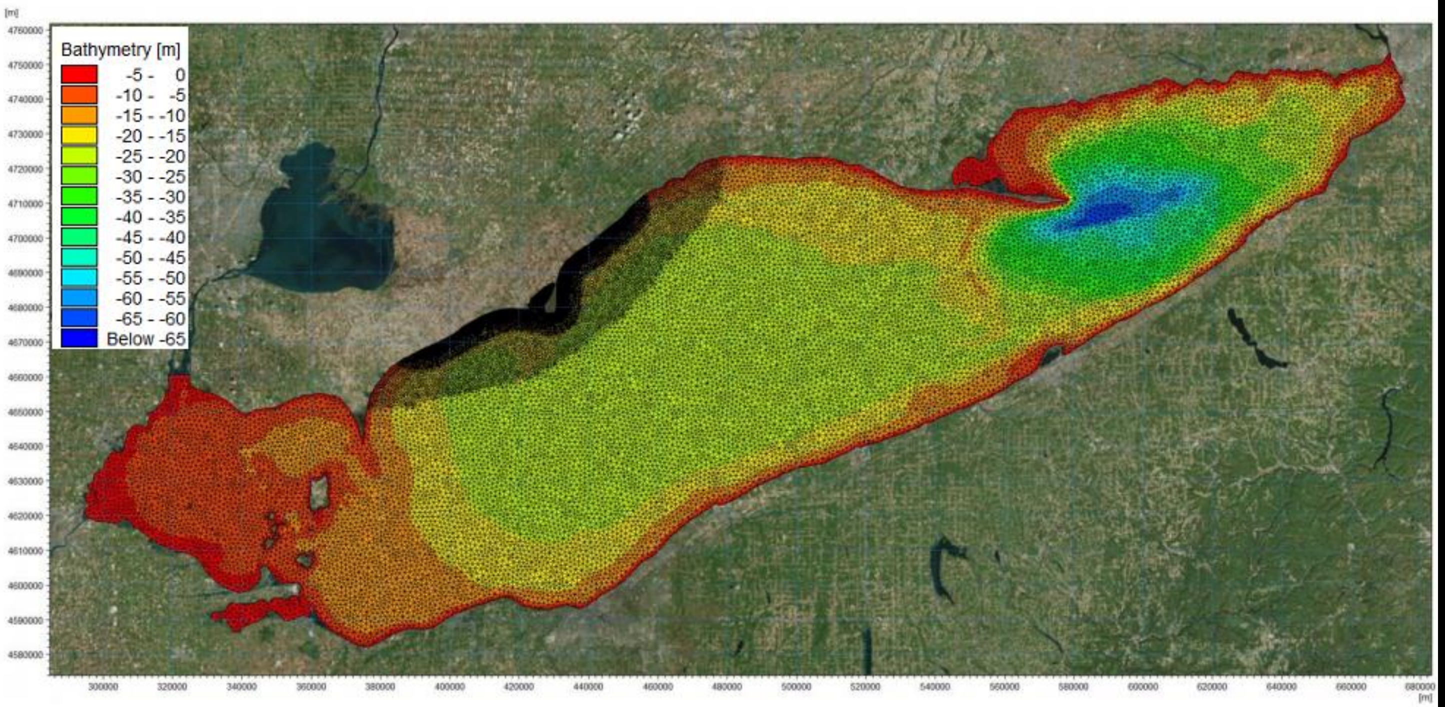
- National Center for Atmospheric Research (NCAR) applied the WRF model for a North America domain using a 4 km grid
- Baseline period was October 2000 to September 2013
- For the future late-century (2071-2100) scenario, the boundary condition were perturbed based on the ensemble average of the RCP8.5 GCM simulations from CMIP5
- Gridded wind and pressure data for models



MIKE21 Model Domains

Spectral Wave Model / Surge Model





Focused on Largest Events

Storm Selection 2000 to 2013 from WIS Wave Hindcast

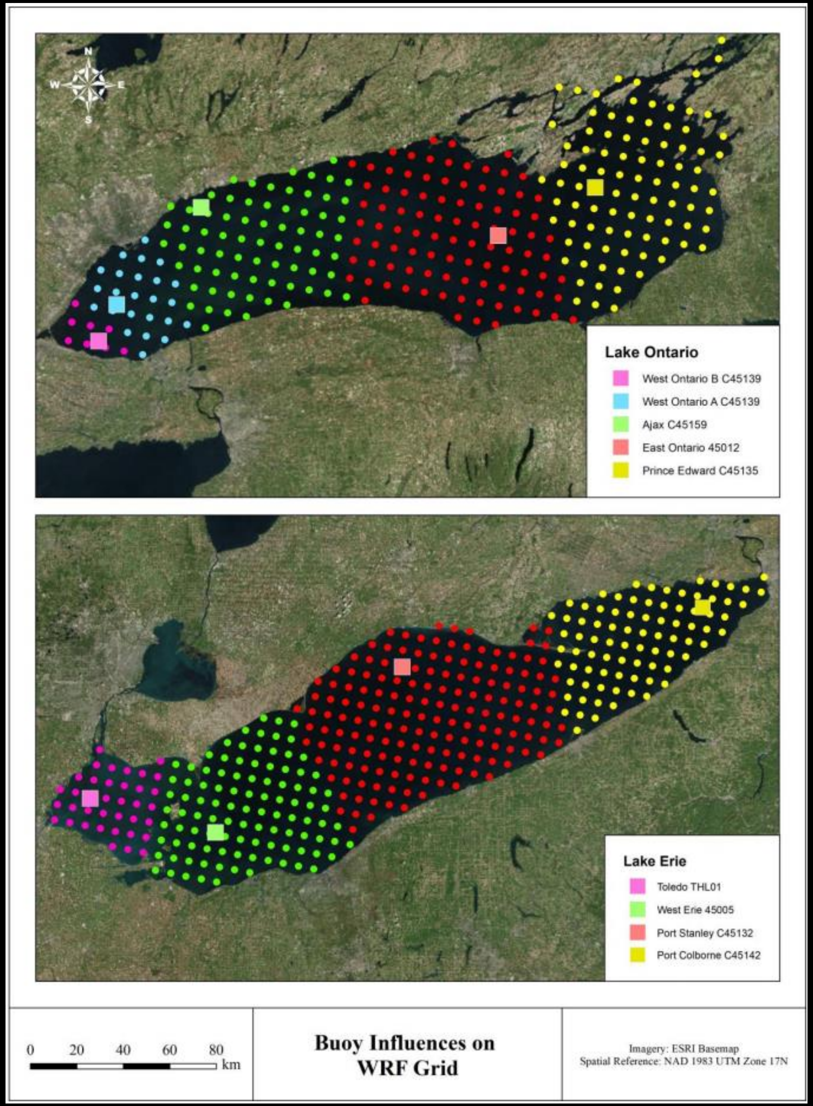
Table 3.2: Storm listing for Lake Ontario (WIS Station 91150).

Storm	Peak Storm Date	Hm0 (m)	Tp (s)	Dir (deg)
1	2013/04/12	5.10	9.4	90
2 (Ice)	2011/02/02	4.92	9.1	90
3	2011/10/20	4.85	9.3	89
4	2007/03/02	4.41	8.6	88
5	2011/04/20	3.93	8.3	88
6	2007/12/16	3.89	8.8	88
7	2005/01/22	3.87	8.2	83
8	2006/12/01	3.86	7.6	88
9	2012/10/30	3.85	10.6	84
10	2008/12/19	3.84	8.2	82
11	2012/03/03	3.77	7.4	193
12	2012/02/29	3.63	7.9	91
13	2011/11/23	3.61	8.2	87
14	2010/03/14	3.51	8.4	84
15	2009/12/09	3.47	8.0	88

Table 3.3: Storm listing for Lake Erie (WIS Station 92154).

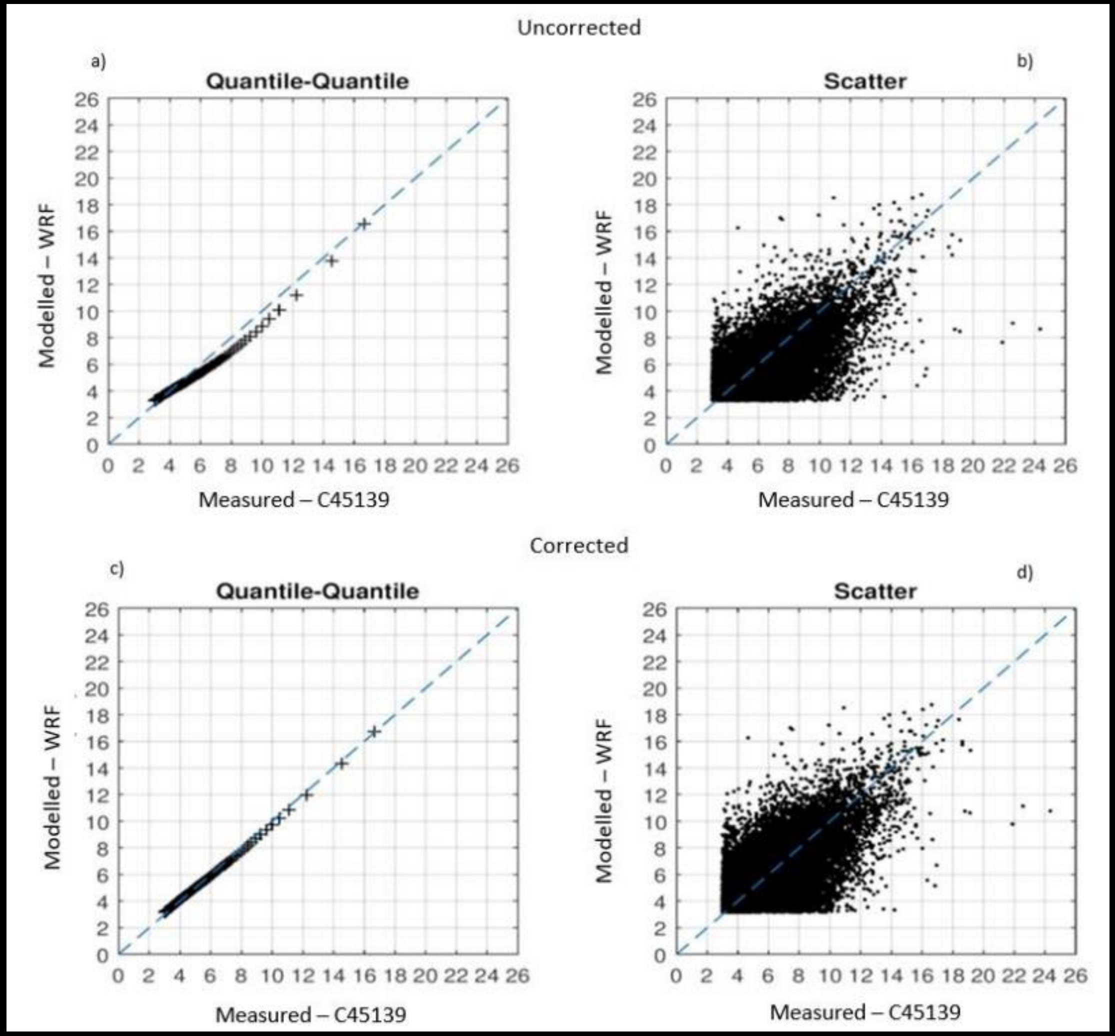
Storm	Peak Storm Date	Hm0 (m)	Tp (s)	Dir (deg)
1	2009/12/10	5.67	9.1	225
2	2002/03/10	4.69	8.4	230
3	2011/04/15	4.56	8.4	77
4	2011/11/23	4.53	8.4	77
5	2012/12/26	4.45	8.4	76
6	2002/11/29	4.45	7.9	215
7	2012/03/03	4.43	8.0	227
8	2007/12/24	4.35	7.8	228
9	2011/11/10	4.32	7.8	231
10	2009/09/28	4.23	7.8	228
11	2003/11/13	4.20	7.7	242
12	2006/12/01	4.19	7.7	236
13	2008/12/22	4.18	7.7	232
14	2011/04/28	4.11	7.6	226
15	2011/10/20	3.96	7.6	67

Bias Correction of 2000-2013 WRF Winds (m/s) Using Measured Winds from the Lake Buoys



WRF Grid Points Assigned to Wave Buoys

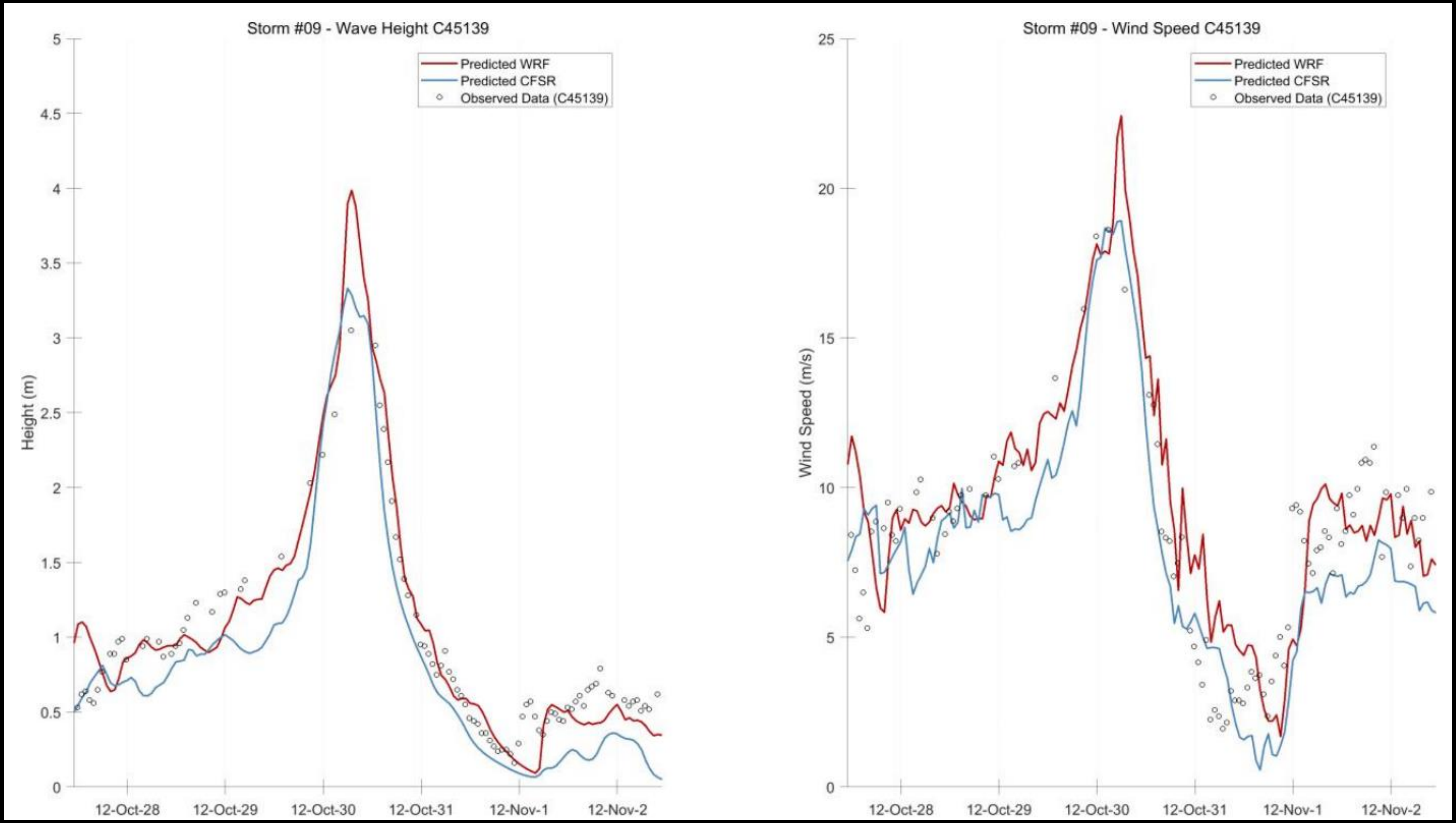
Q-Q Regression for C45139



Comparison of Corrected WRF Winds and MIKE21 Wave Heights for Storm 9 (late Oct. 2012)

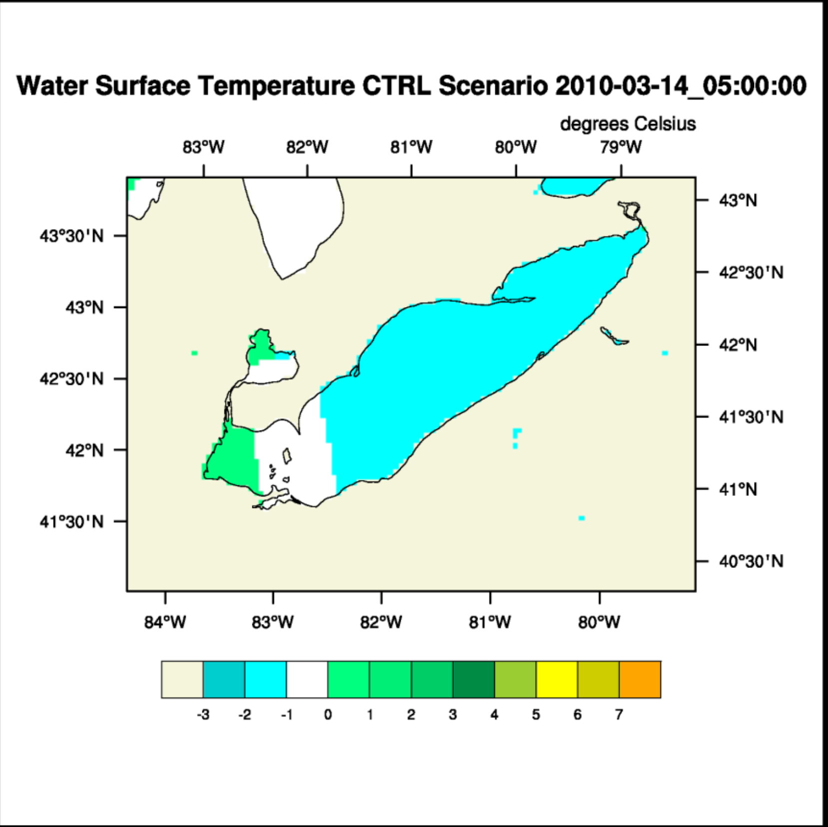
- Winds from WRF over-estimated the peak wave height by ~20%

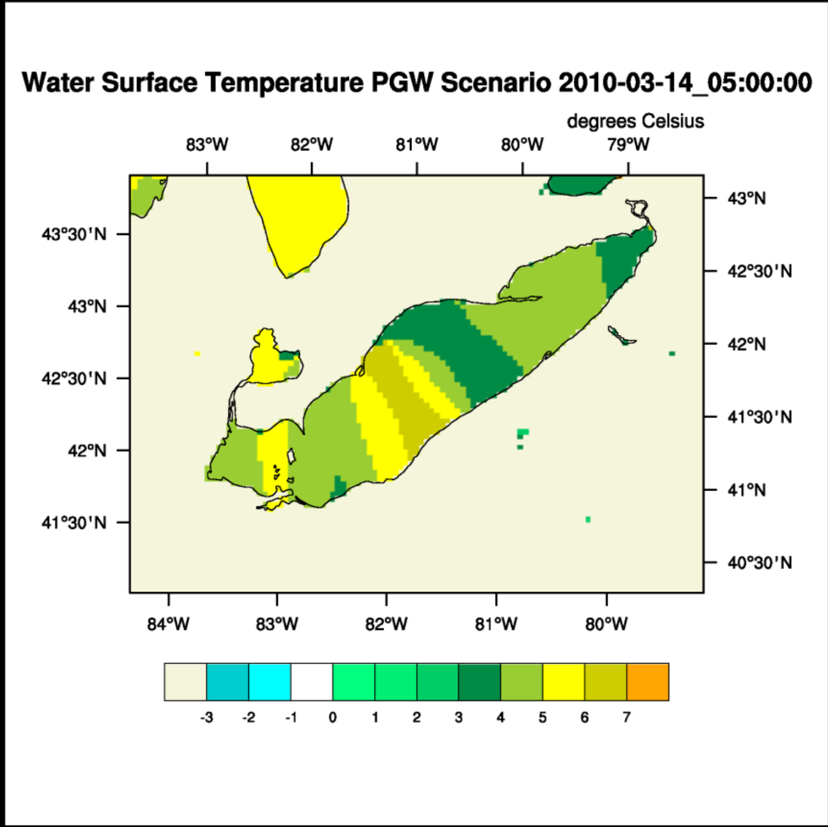
- For comparison, NCAR's Climate Forecast System Reanalysis (CFSR) winds also analyzed



WRF Estimates Water Surface Temperature

- Mar. 14, 2010
- Baseline, WRF predicts surface temperatures of 0 C to -2 C
- Future, WRF surface temps. 3 C to 7 C

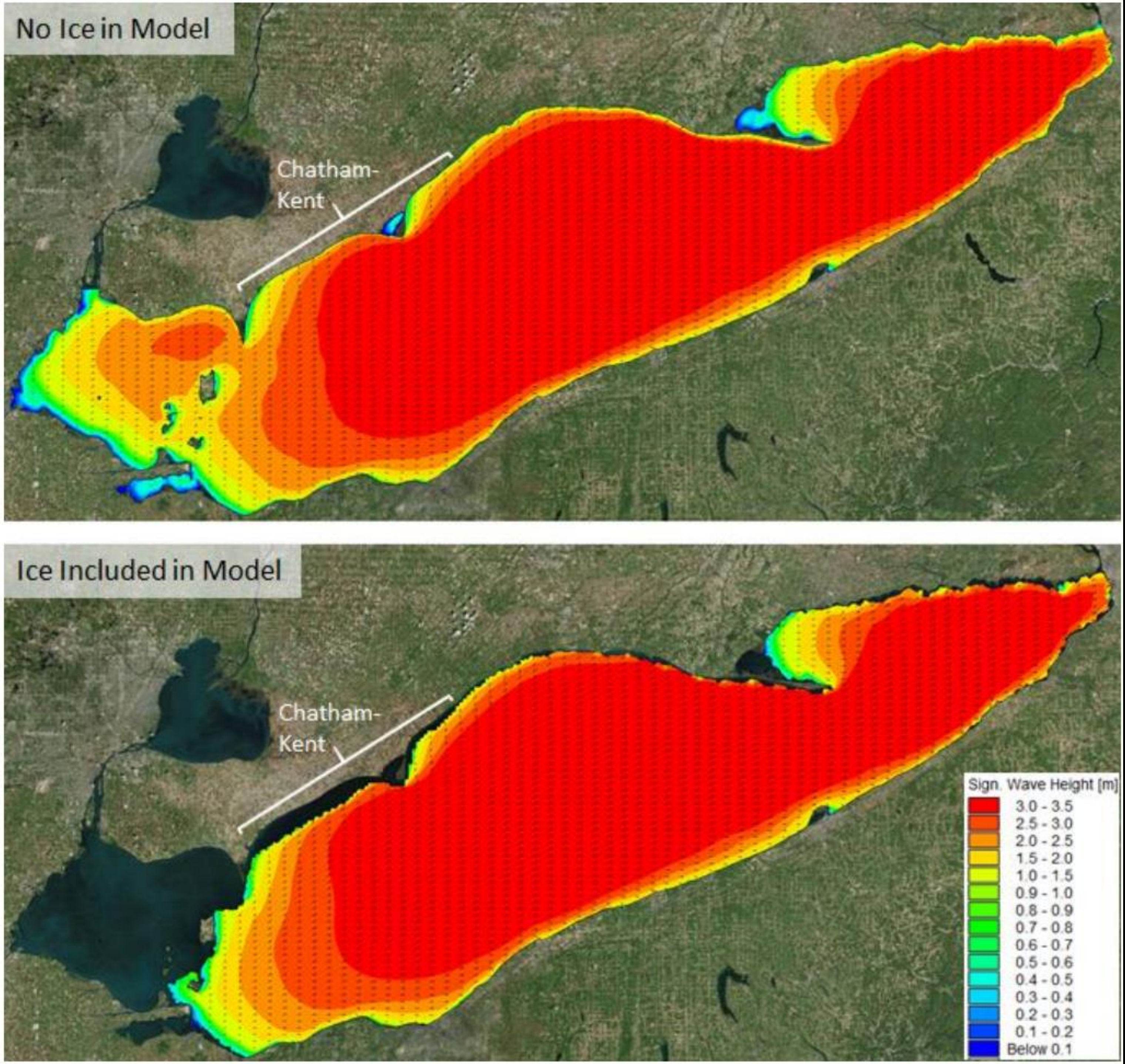




- Lake temperatures support ice cover
- Future, no ice

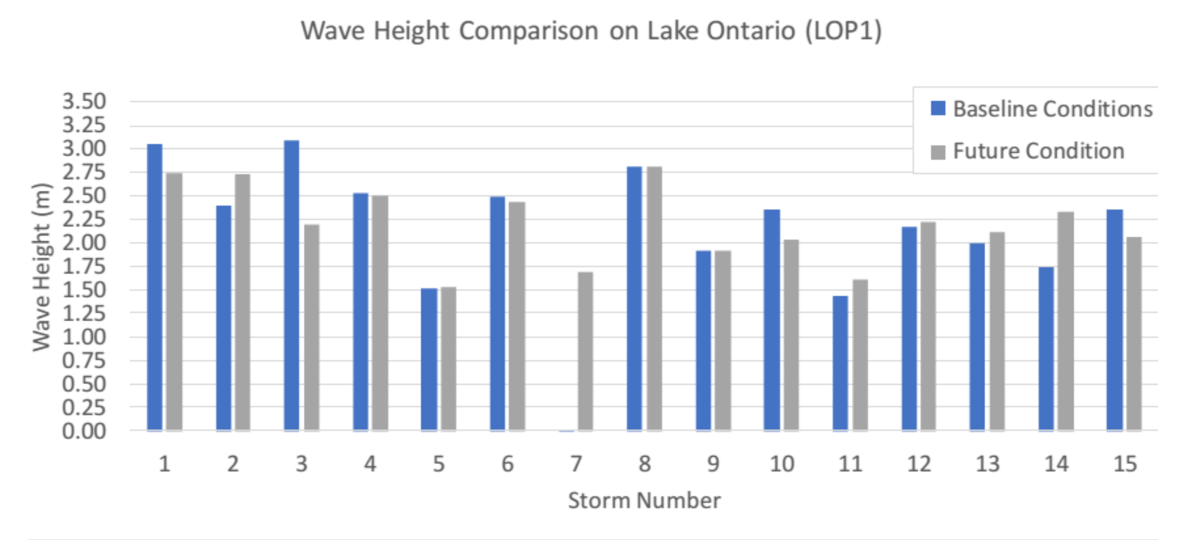
Treatment of Ice in the MIKE21 Model

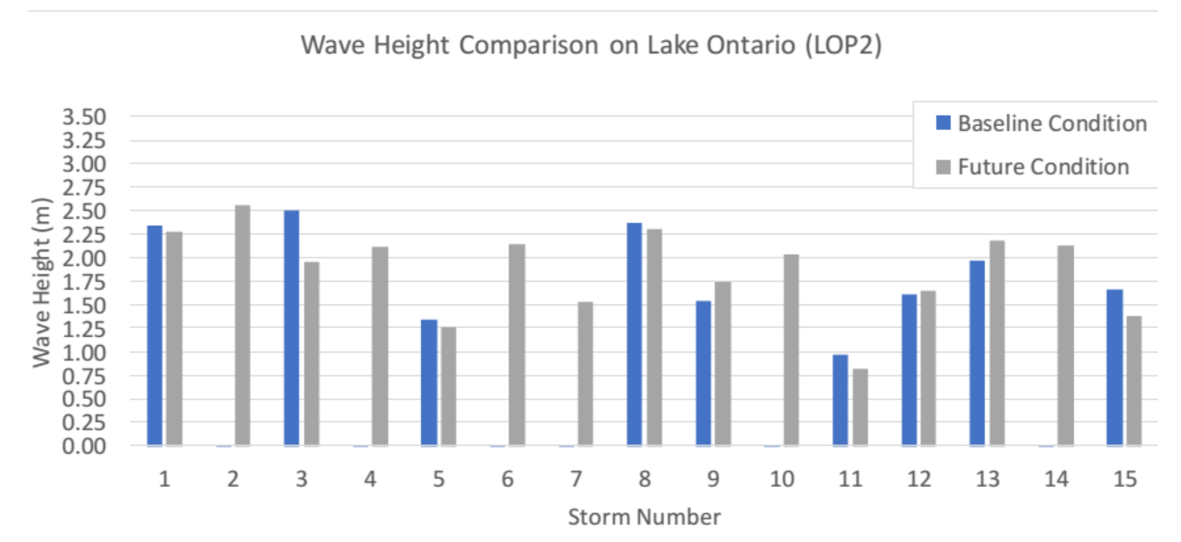
Dec. 22, 2008 Storm

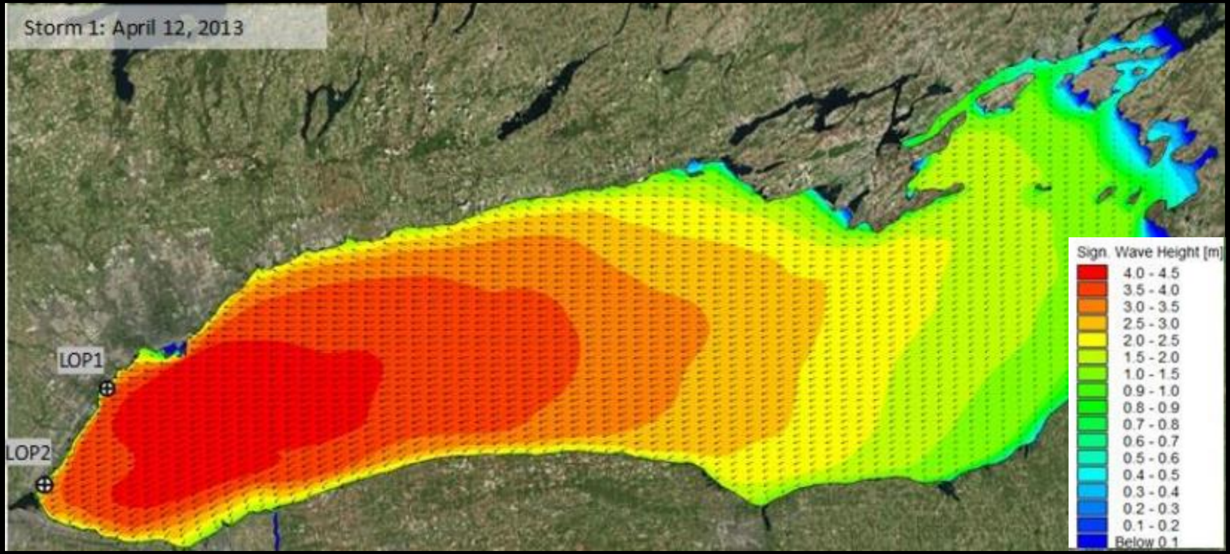


Lake Ontario Wave Height Predictions for the 15 Storms with Baseline and Projected Future Winds

- No clear trend for peak wave heights
- For the baseline, NOAA ice-charts
- For the future, <u>no ice</u> in the model
- LOP2, Burlington Beach, more sensitive to loss of ice cover

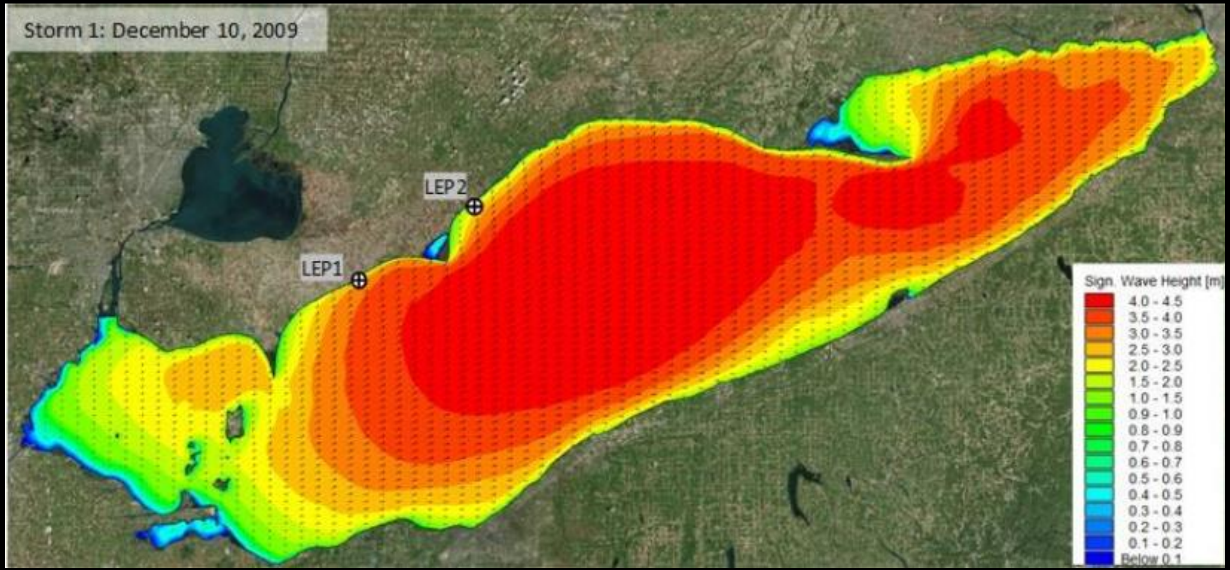


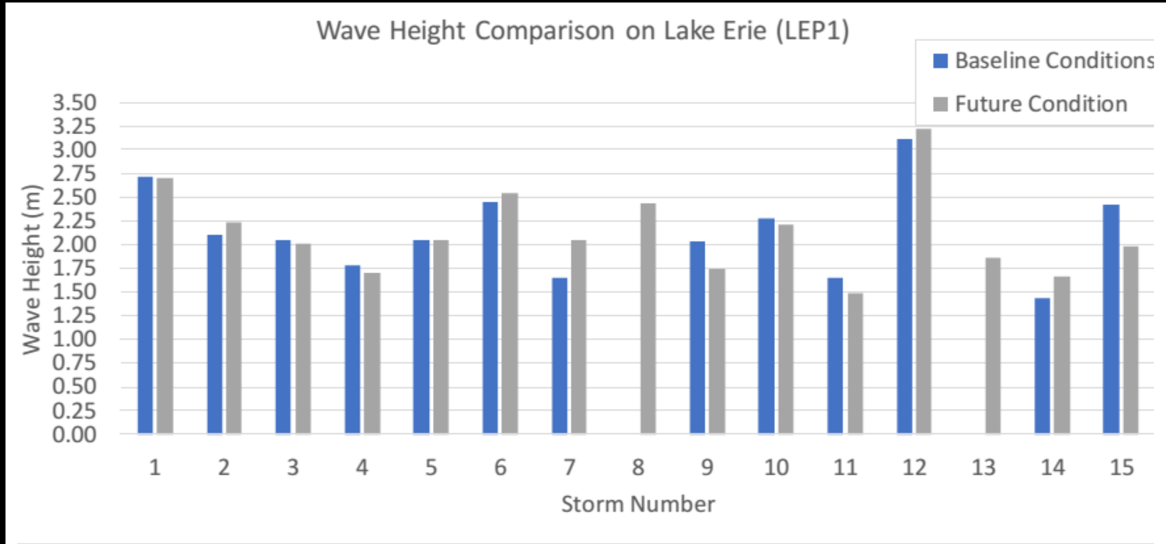


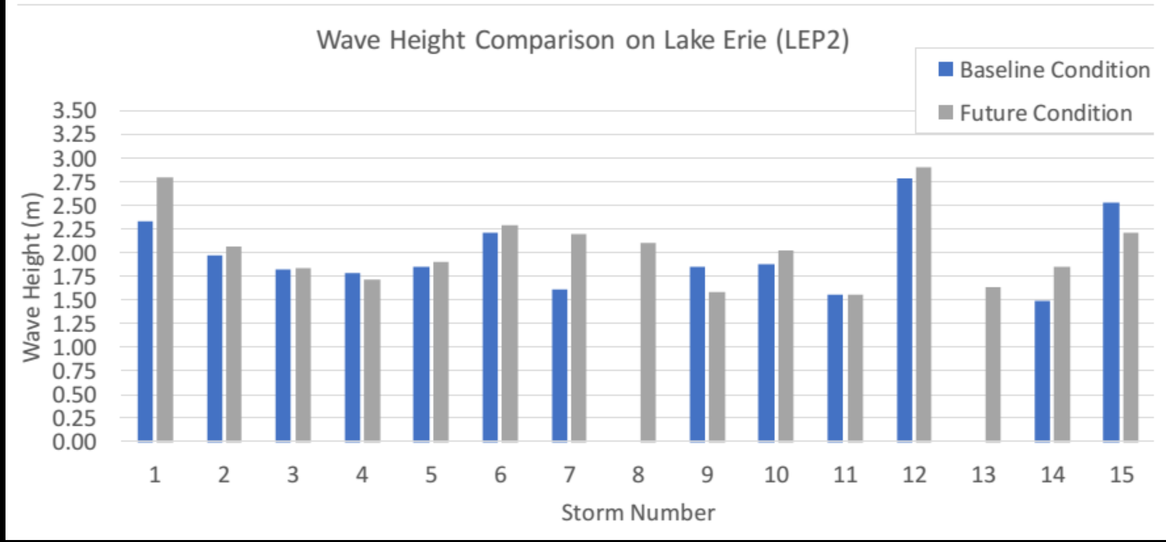


Lake Erie Wave Height Predictions for the 15 Storms with Baseline and Projected Future Winds

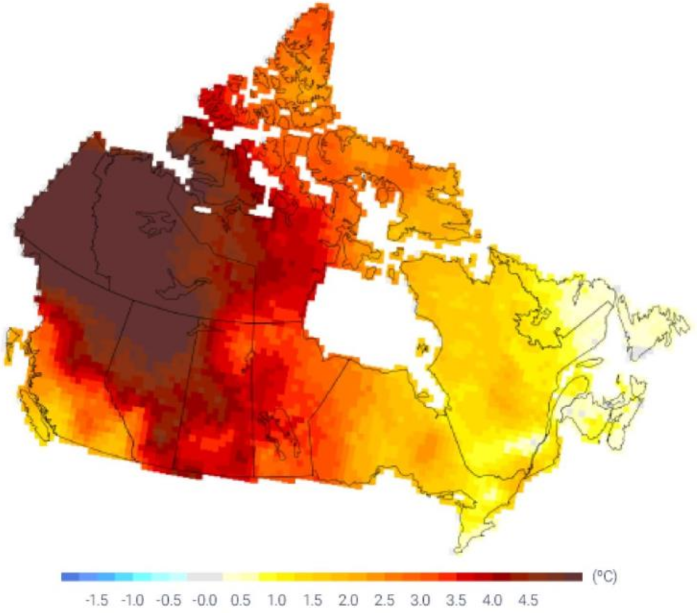
- No clear trend for peak wave heights
- For the baseline, NOAA ice-charts
- For the future, no ice in the model
- The influence of zero ice on results was more significant than wave height differences for baseline vs future





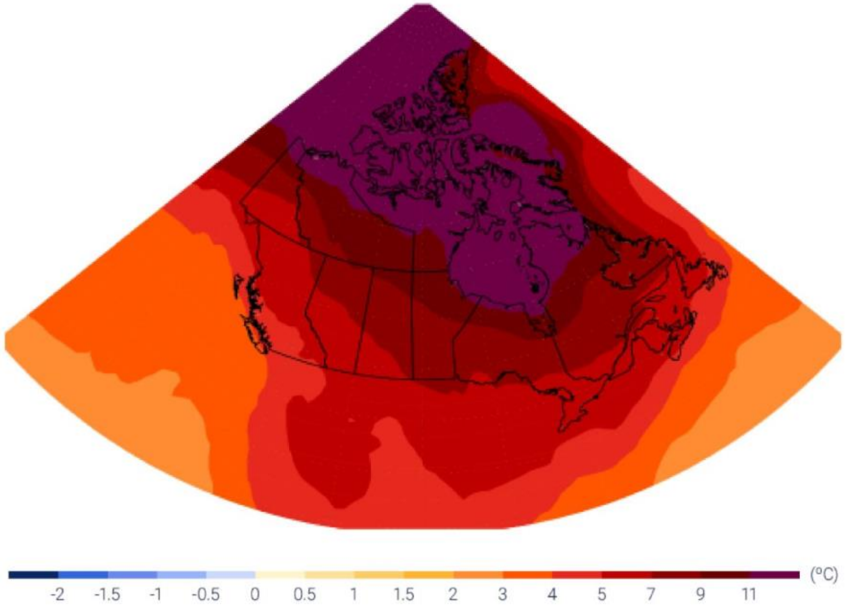


1948 to 2016 Winter Air Temperature Increase



Source: Vincent et al, 2015. In 'Zhang, X., Flato, G., Kirchmeier-Young, M., Vincent, L., Wan, H., Wang, X., Rong, R., Fyfe, J., Li, G., Kharin, V.V. (2019): Changes in Temperature and Precipitation Across Canada; Chapter 4 in Bush, E. and Lemmen, D.S. (Eds.) Canada's Changing Climate Report. Government of Canada, Ottawa, Ontario, pp 112-193'.

2081-2100 Winter Warming Projection for RCP8.5



Source: Climate Research Division, Environment and Climate Change Canada. In 'Zhang, X., Flato, G., Kirchmeier-Young, M., Vincent, L., Wan, H., Wang, X., Rong, R., Fyfe, J., Li, G., Kharin, V.V. (2019): Changes in Temperature and Precipitation Across Canada; Chapter 4 in Bush, E. and Lemmen, D.S. (Eds.) Canada's Changing Climate Report. Government of Canada, Ottawa, Ontario, pp 112-193'.

Warming has already decreased the extent and duration of Lake Erie ice cover. In the future, the lake could be ice-free in the winter.

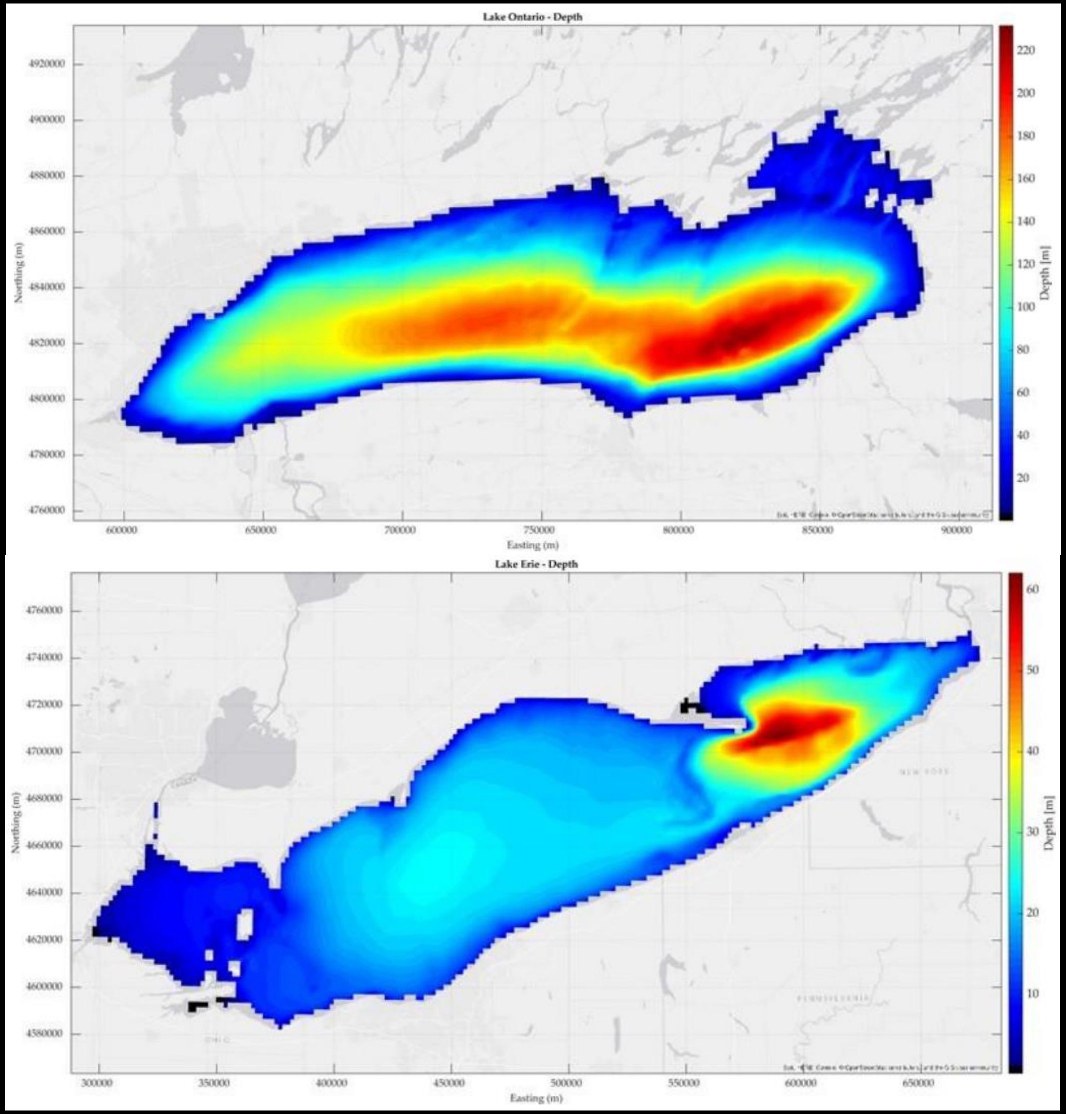
Lake Ice Cover Near 100%

Partial Ice Cover on the Lake

Ice Cover Limited to the Eastern Basin

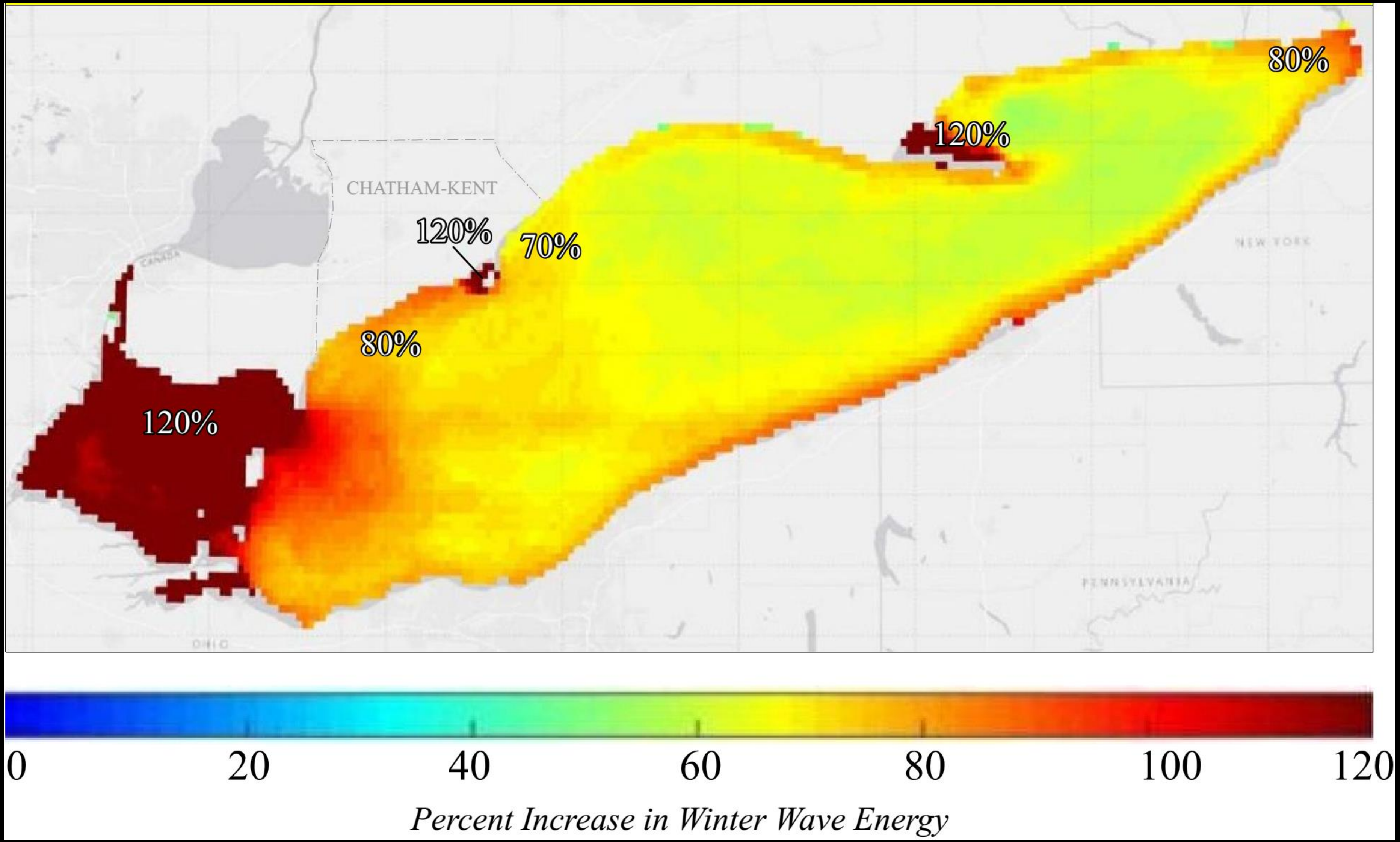
Switched to the WAVAD Model to Complete an Hourly Hindcast for the Baseline and Future

- WAVAD is a 2nd generation spectral wave model (Dr. D. Resio, USACE)
- Used for deep water hindcasts (10 – 15 m depths in the Great Lakes)
- Does not simulate shallow water wave processes such as refraction, diffraction, shoaling, and breaking
- Computationally efficient
- Modelled 13 years of hourly data for the baseline and future



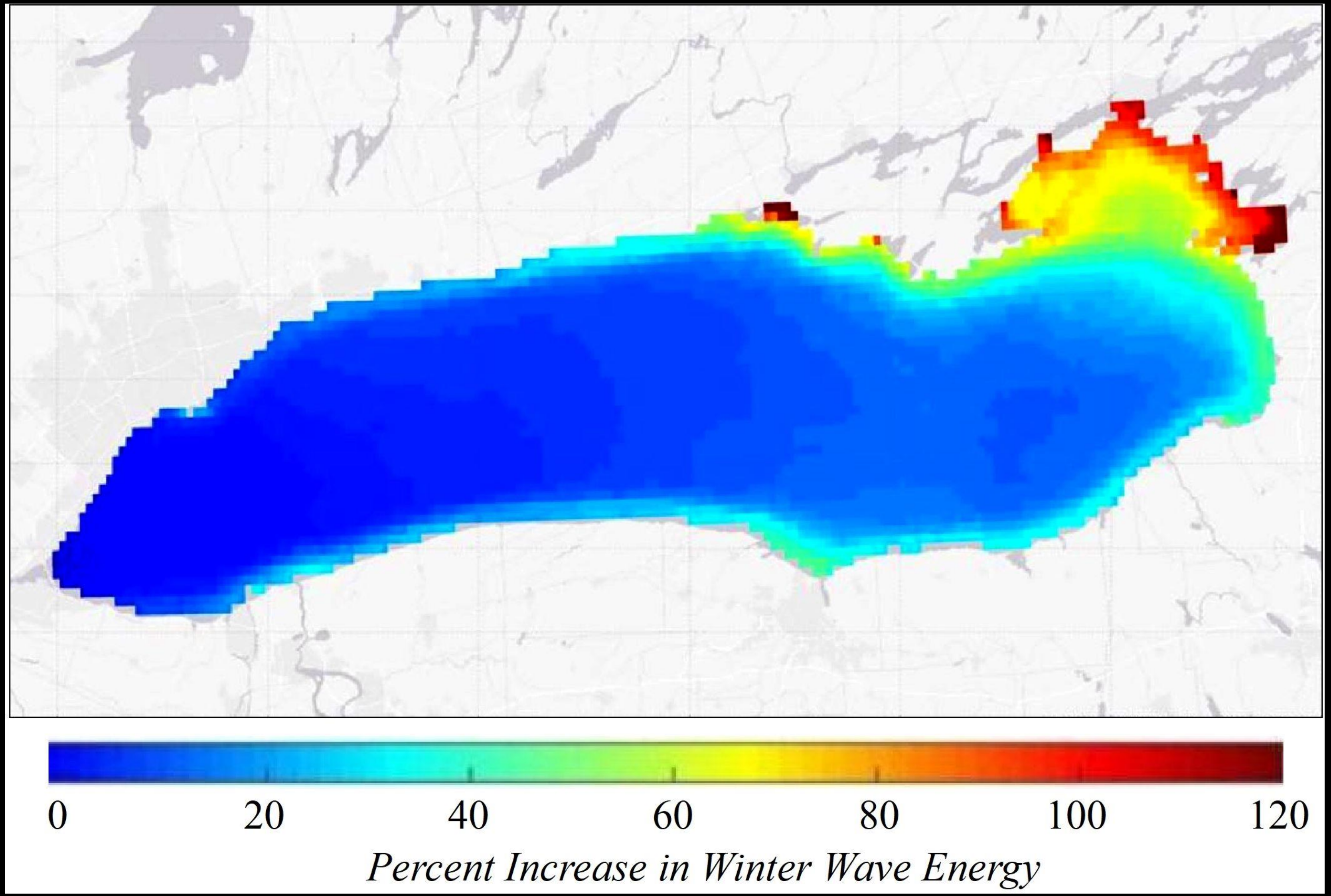
Projected Lake Erie Increase in Winter Wave Energy due to Reduced Ice Cover (late-century RCP8.5)

- 70% to 120% increase in wave energy
- Wave energy can be used for a surrogate of erosion rate
- Potential for significant increases in erosion rates in the future



Projected Lake Erie Increase in Winter Wave Energy due to Reduced Ice Cover (late-century RCP8.5)

- 10% to 120% increase in wave energy
- Kingston Basin is the most sensitive
- GLERL ice charts don’t capture narrow bands of shore-fast ice which can protect shorelines from wave exposure
- Interpret western basin carefully …



KEY FINDINGS

- No statistically significant change in peak wind speeds and pressure gradients for the RCP8.5 WRF outputs (late century). These results suggest storm intensity will not increase (*further research should be completed*)
- This finding is consistent with recent findings on measured storm surges on Lake Ontario and Lake Erie. No changes in the pre-1989 storm surge levels (MNRF, 1989) versus post-1989 storm surges (*using measured data*)
- Potential changes in water supply and static lake levels due to CC will be more important for coastal management than potential changes in storm surge
- Due to projections for reduced ice cover, wave energy reaching the shoreline will increase dramatically (non-events become storms in the future)
- When talking about potential changes in storm intensity and frequency in the Great Lakes due to climate change, we need to make the distinction between rainfall events and wave/storm surge events on the lakes

WAVE DATA WILL BE AVAILABLE FROM:
http://www.zuzekinc.ca/waves

LAKE ERIE AND LAKE ONTARIO WIND-WAVE HINDCASTS

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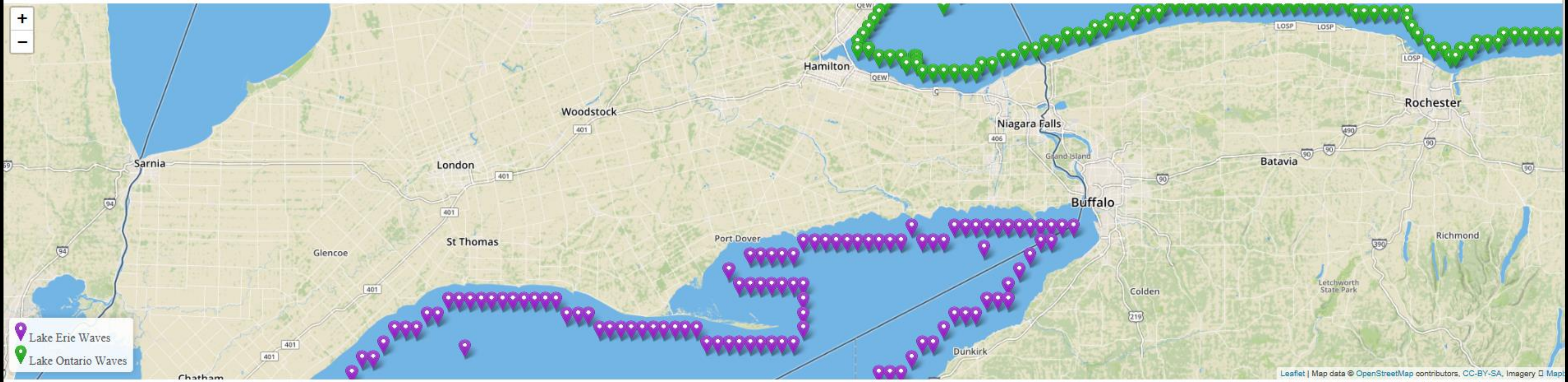

Modeled wave time series data can be downloaded by station using the map above.
Use your mouse (or the map '+' and '-' control) to zoom in and click on a Station Marker for download options.

This study was supported by Natural Resources Canada's Climate Change Adaptation Platform.

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About

An hourly wind-wave hindcast was completed for Lake Erie and Lake Ontario using historical spatially varying winds from 2000 to 2013. The WAVAD numerical model produced hourly predictions of wave height, period, and direction for the grid covering each lake. This historical hindcast was completed twice, using two concentration thresholds for ice, 10% and 30%. When the NOAA ice polygons exceeded the threshold in a polygon (e.g., greater than 30% cover), the model domain was reduced in size to account for ice effects.

QUESTIONS

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