



Oct 13: Major Consequences of Climate Change: Lakes

Update
Quiz #3

Foci of the Day

- Great Lakes in a changing climate: algal blooms, frozen surface, snow fall, ET, etc.
- Shift of Water Level Global Lakes

Reading

Liu, Y., Chen, J., Sun, G., Zhang, G., Feng, J., & Fan, X. 2025. Catastrophic shifts in large lake levels. *Fundamental Research*, [5\(5\)](#):2084-2087



Take-Home-Messages

- 1) Warming has increased evapotranspiration (ET), but this trend has been constrained by reduced soil moisture since 1998.
- 2) Ecosystem water use efficiency (WUE) exhibited a noticeable shift after 2001.
- 3) The Aral Sea experienced both shrinkage and expansion due to land-use changes.

A Thirsty Globe!

Field Impressions



Field Impressions



Field Impressions





Field Impressions





Field Impressions





Field Impressions





Field Impressions





Field Impressions



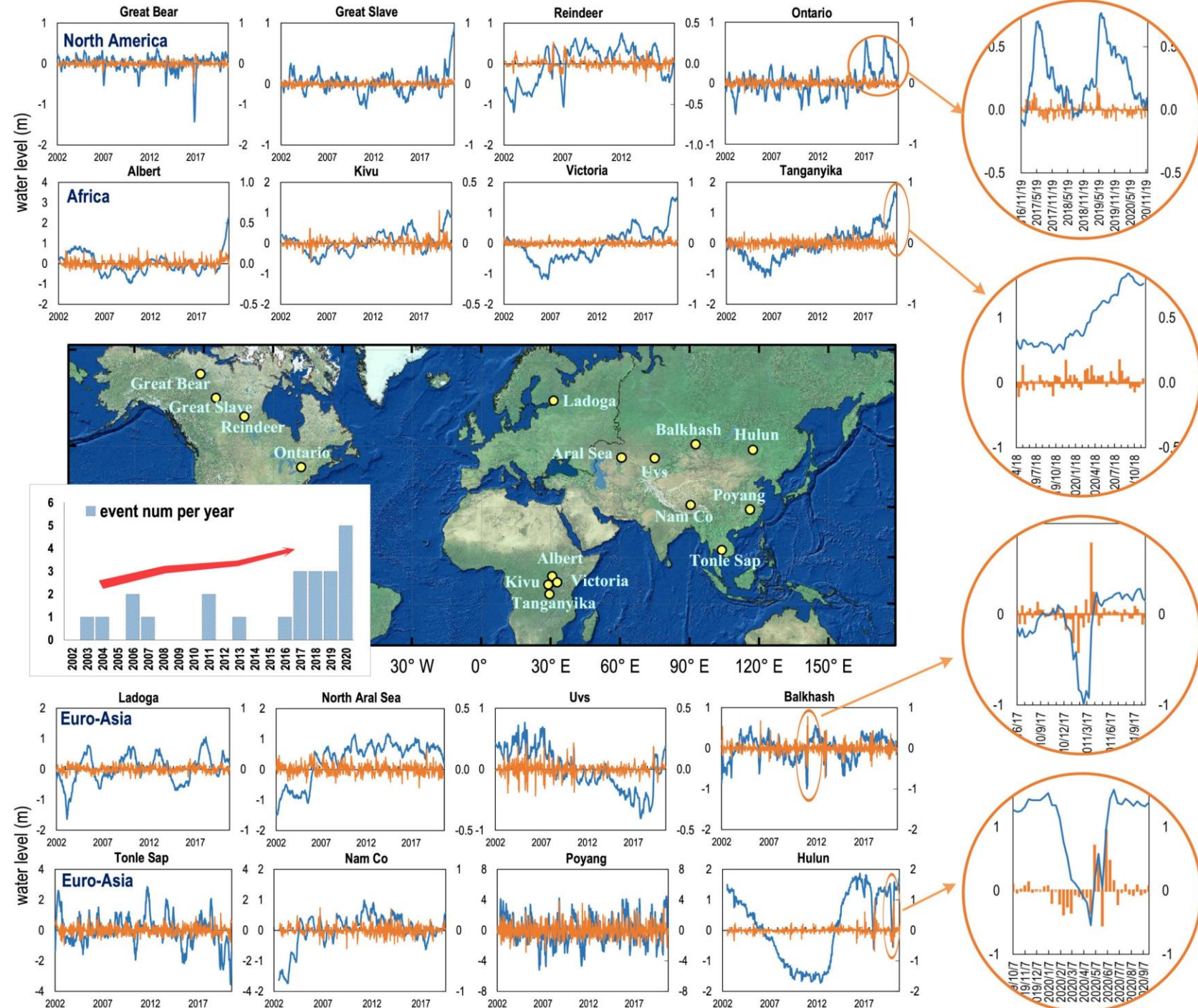


Field Impressions





Water level fluctuations for large lakes on the N. American, African, and Eurasian continents during 2002-2020.



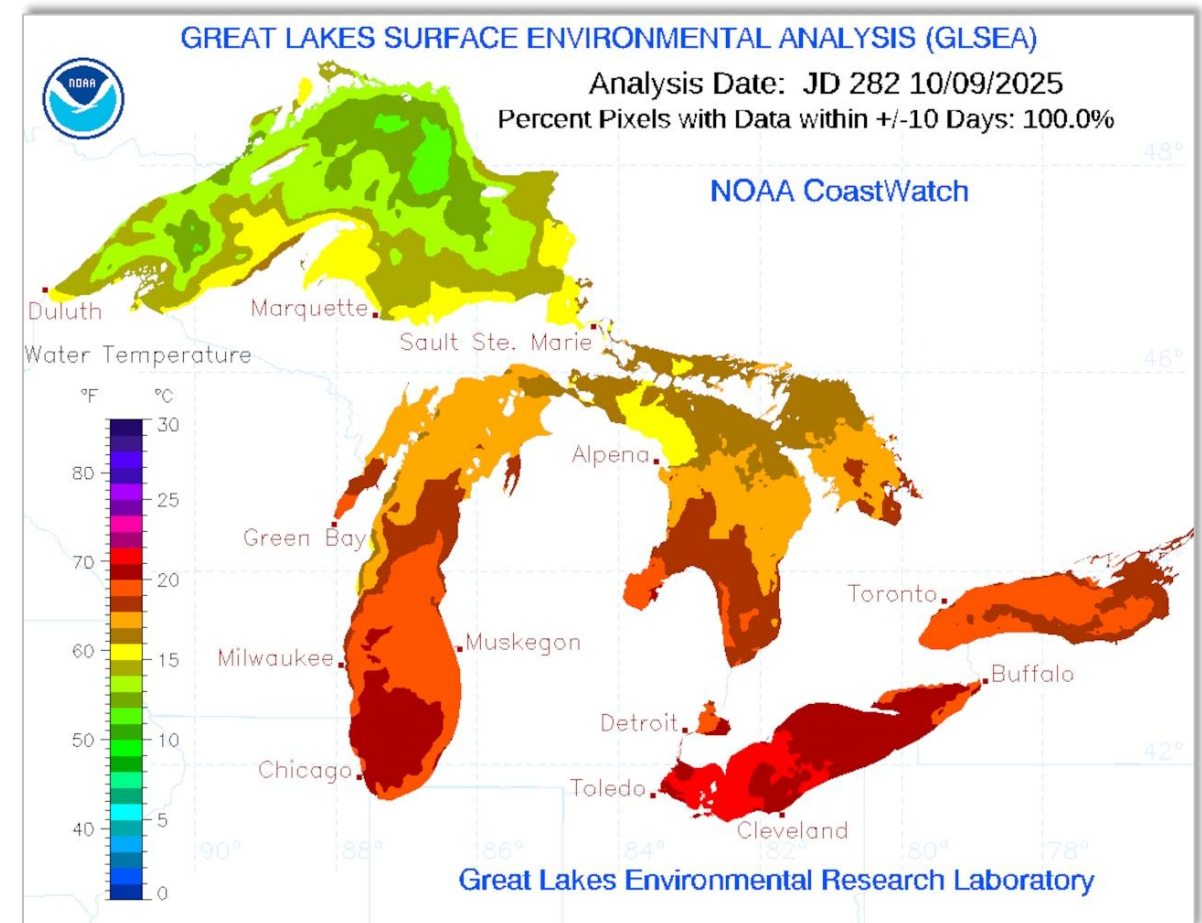
Liu, Y., Chen, J., Sun, G., Zhang, G., Feng, J., & Fan, X. 2023. Catastrophic shifts in large lake levels. *Fundamental Research*, [5\(5\)](#):2084-2087



Lake Michigan water temperature: Record warmth could impact winter weather

(<https://www.mlive.com/weather/2025/10/lake-michigan-water-temperature-record-warmth-could-impact-winter-weather.html>)

- Lake Michigan right now has an overall surface temperature of 65.6 °F. The long-term average surface water temperature for Oct. 9 is 59.4 °F.
- This means Lake Michigan is now 6.2 °F warmer than the long-term average.

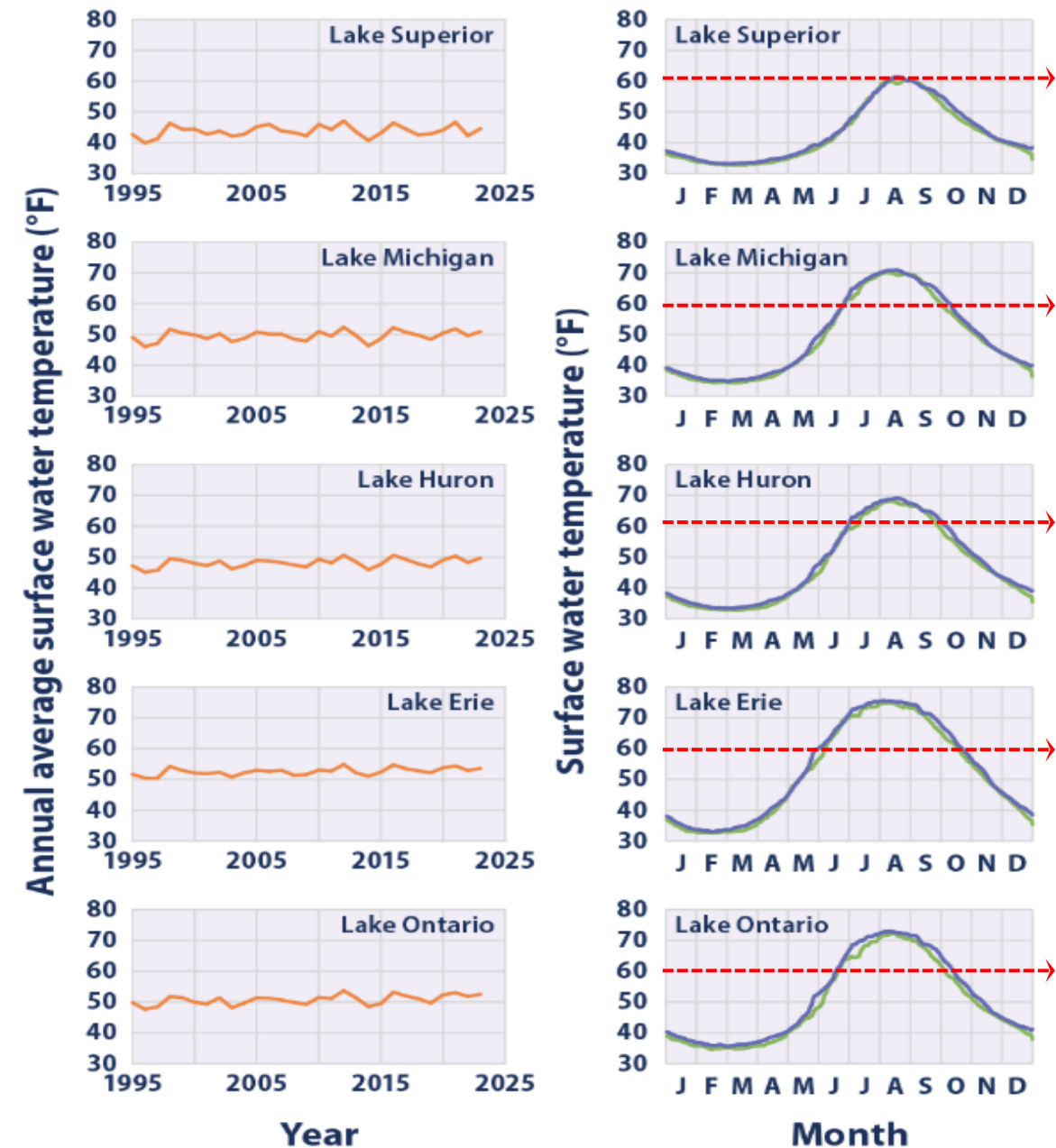




Climate Change Indicators: Great Lakes Water Temperatures

(<https://www.epa.gov/climate-indicators/great-lakes>)

- Stable compared with terrestrial land surface temperature, with **slight** warming trend
- Lake Erie has the highest temperature due to:
 - 1) low latitude;
 - 2) shallow water



Climate Change Indicators: Great Lakes Water Level

(<https://www.epa.gov/climate-indicators/great-lakes>)

Highly variable lake level over year and by lake

Lake Michigan

-3 m to +3.5 m

Low during 2000-2012

Lake Erie

Lowest in 2014 after a decade

Lowest in the mid-1930s

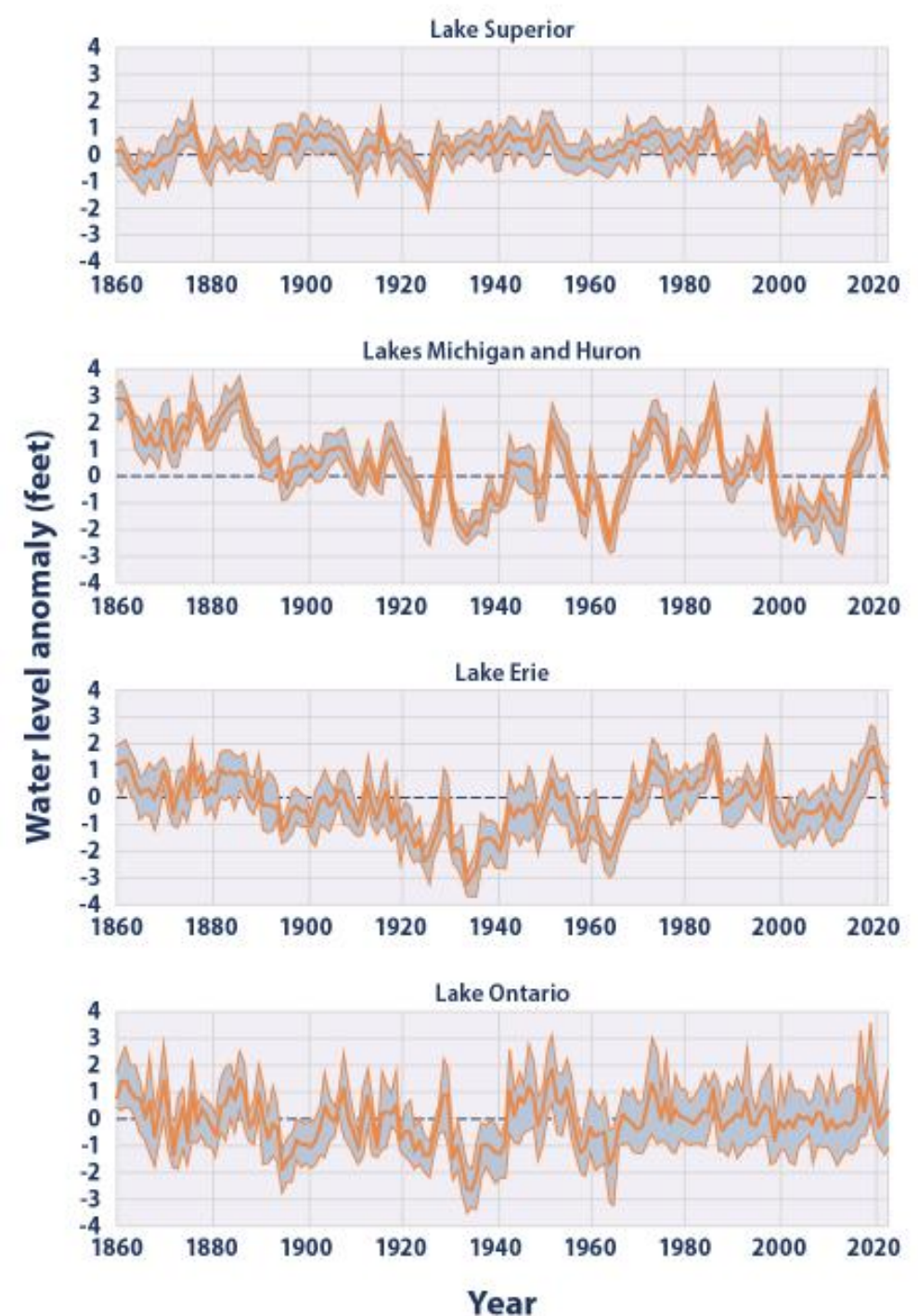
Lake Superior

Ver stable

Lake Ontario

Stable since 1960

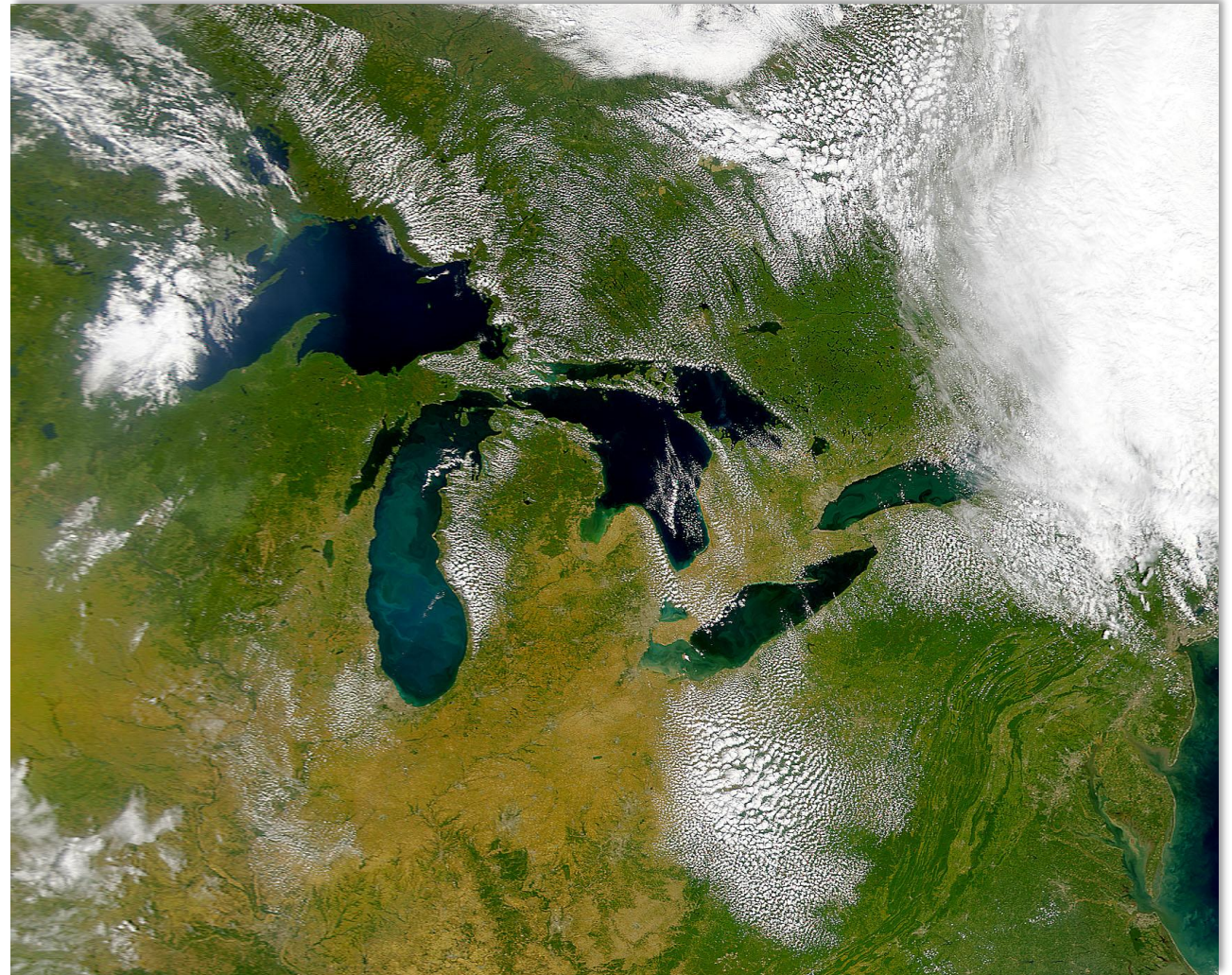
Reference: <https://seagull.glos.org/map?coords=-83.6466995%2C44.3707460%2C5>





Three Stories from the Great Lakes Region

- **Wolves and moose on Isle Royale National Park**
- **Algal blooms in Lake Erie**
- **Lake-effect snowfall (LES) in Buffalo, NY**

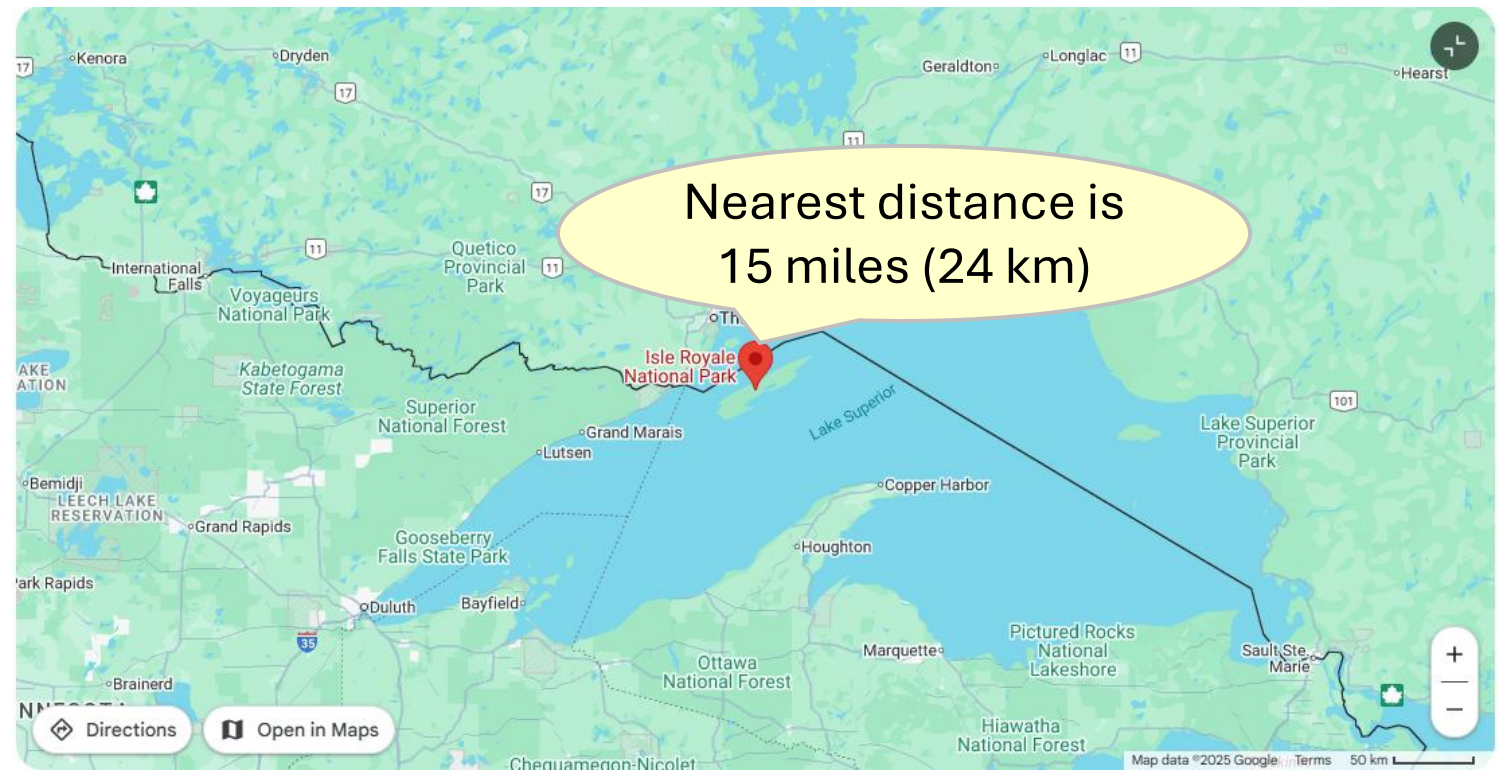




According to a 2024 report, there are ~30 wolves on the island in several packs and new pups.

How did they get on the Island?

Wolves got to the park by crossing a temporary ice bridge over Lake Superior from the mainland, which is believed to have happened in the late 1940s.





Lake Superior has frozen over completely, though it is rare, with the last complete freeze being in 1996





Climate Change Indicators: Great Lakes Ice Cover

(<https://www.epa.gov/climate-indicators/climate-change-indicators-great-lakes-ice-cover>)

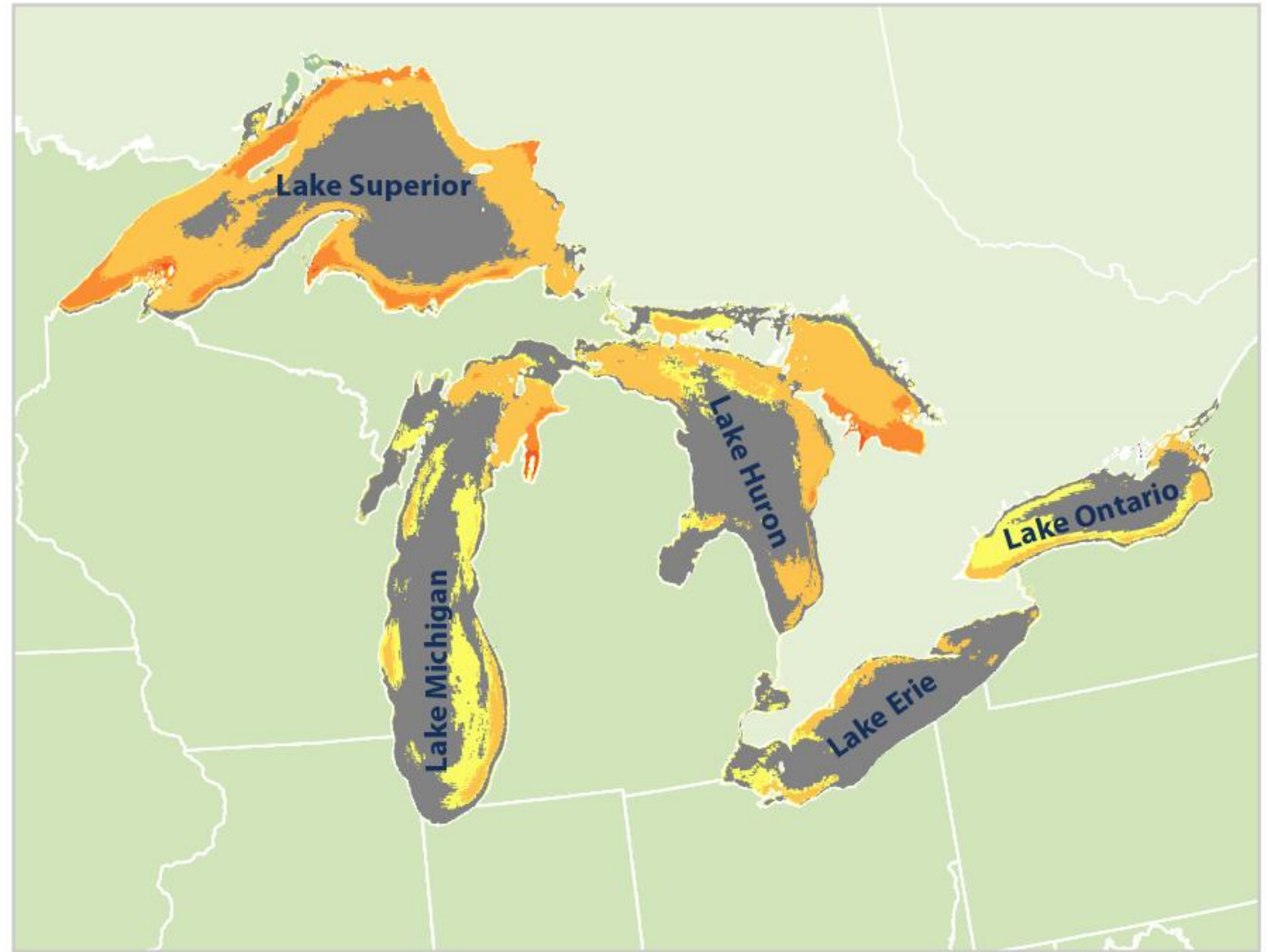
Key Points

- Since 1973, the maximum area covered in ice on the Great Lakes has **varied considerably from year to year**. Adding the five Great Lakes together, maximum frozen area has ranged from less than 20 percent in some years to more than 90 percent in others. All five lakes have experienced some degree of long-term decrease, but **the decrease is only statistically significant in one lake (Superior)**. Years with much-lower-than-normal ice cover appear to have become more frequent during the past two decades, especially in lakes like Erie and Superior that have a history of freezing almost completely.
- Since 1973, the number of frozen days (duration) on all five Great Lakes has declined. Ice duration on these lakes has decreased at rates ranging from approximately one-fifth of a day per year in Lake Huron to almost a full day per year in Lakes Ontario and Superior. Overall, this means the **Great Lakes are frozen for 8-46 fewer days now** than they were in the early 1970s. The decreases in Lakes Ontario and Superior are statistically significant.
- A detailed map (see Figure 3) shows that many areas of the Great Lakes have experienced significant decreases in ice cover duration, but other parts of the lakes have not changed significantly. Duration has decreased the most in areas near the shore.

The average annual rate of change in the duration of ice cover in the Great Lakes from 1973 to 2019. Duration is

measured as the number of days in which each pixel on the map was at least 10 percent covered by ice.

Gray areas are labeled “no trend” because the change over time is not statistically significant (using a 90-percent confidence level).



Trend in days per year:





Algal bloom in Lake Erie

What happened?

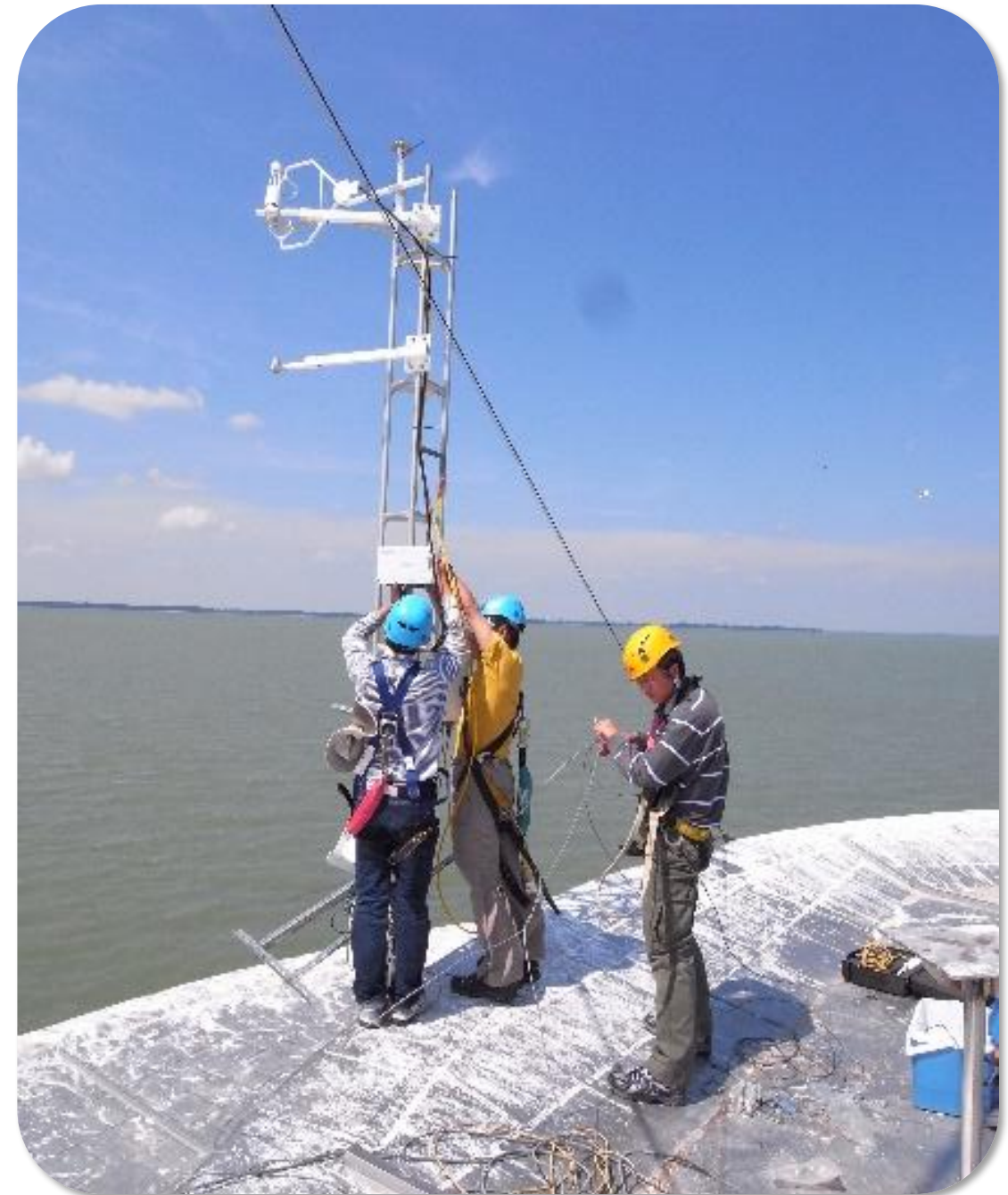
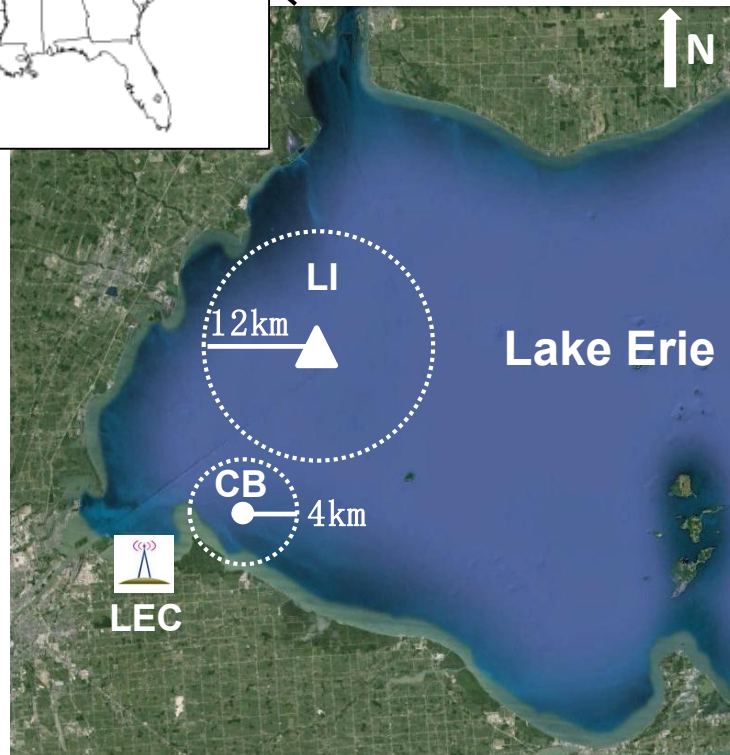
August 2014: Harmful algal blooms (HABs) affected the Toledo water intake.

Do Not Drink Advisory:

Even after treatment, the toxin levels in the processed water exceeded safe limits, leading Toledo officials to issue a "do not drink" advisory for residents.



Eddy-covariance flux measurements over Lake Erie



What were the causes?

1) Nutrient Pollution: Phosphorus from sources like agricultural fertilizer, urban runoff, and leaky septic systems fuels the rapid growth of algae.

2) Lake Erie

Environment: Calm, warm conditions and the shallow western basin of Lake Erie are ideal for algal blooms to form and become a persistent problem.

<https://abcnews.go.com/US/caused-toledos-water-contamination/story?id=24825275>



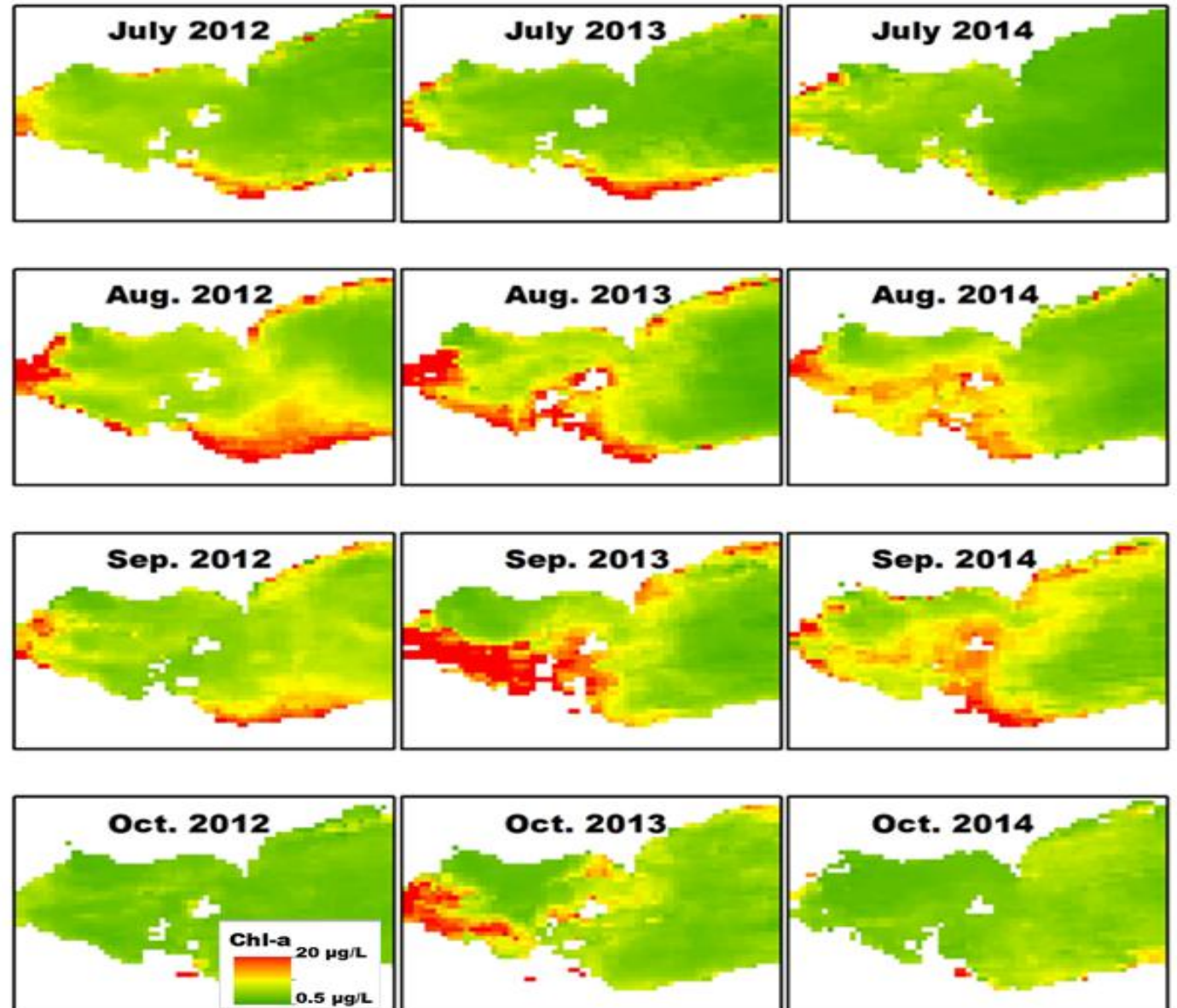
Photo credit: NOAA



Mean chlorophyll-a concentration (algal biomass) estimated from MODIS imagery for April–November during 2012–2014 in western Lake Erie.

Ouyang, Z., Shao, C., Chu, H., Becker, R., Bridgeman, T., Stepien, C.A., John, R. and Chen, J., 2017. The effect of algal blooms on carbon emissions in western Lake Erie: An integration of remote sensing and eddy covariance measurements. *Remote Sensing*, 9(1), p.44.

Algal bloom at Lake Erie during 2012-2014



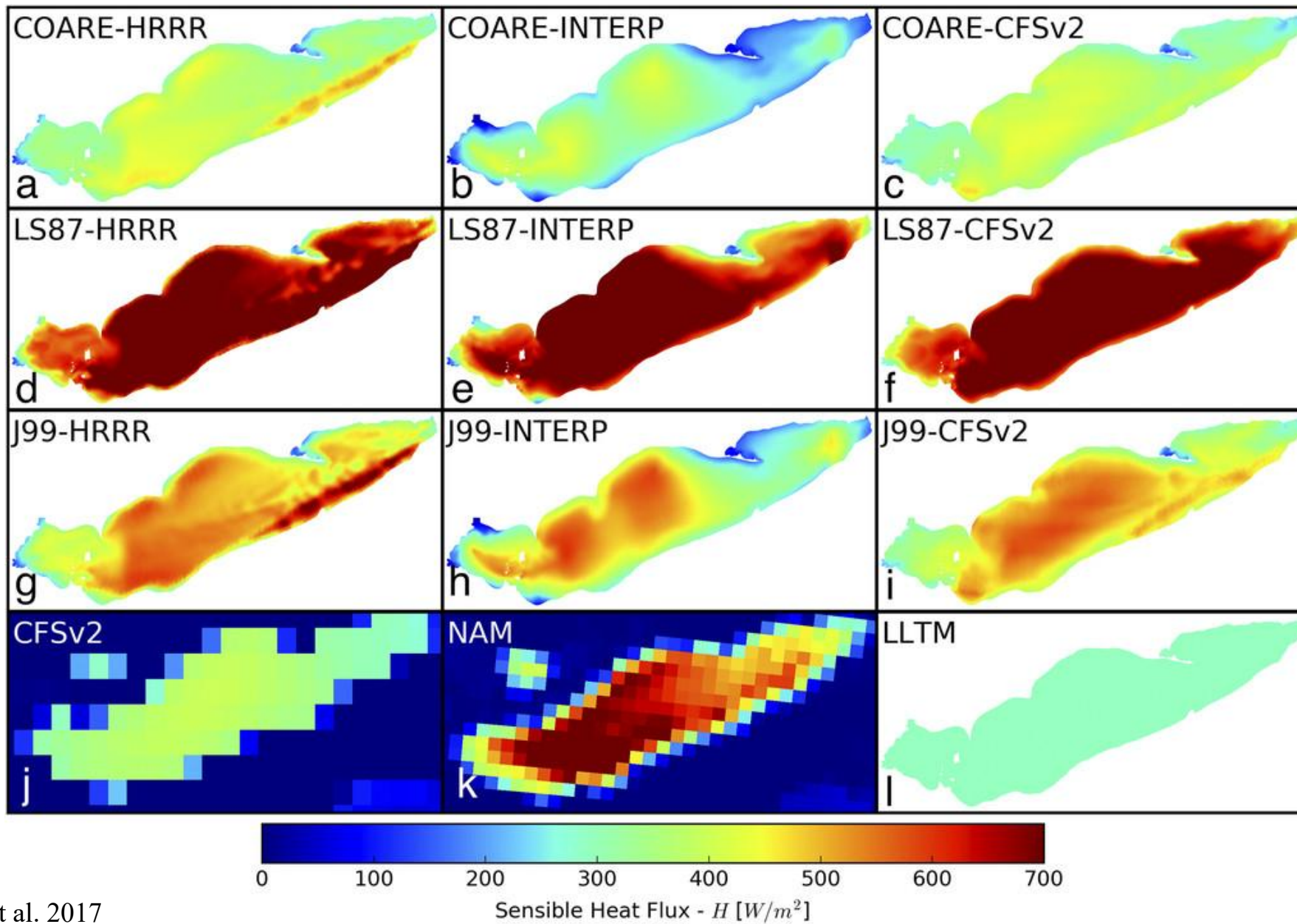
Record snow fall in Buffalo, NY

Lake-effect snow (LES) forms when cold, below-freezing air passes over a lake's warmer waters. This causes some lake water to evaporate and warm the air. Then, the moist air moves away from the lake. After cooling, the air dumps its moisture on the ground, potentially becoming snow.

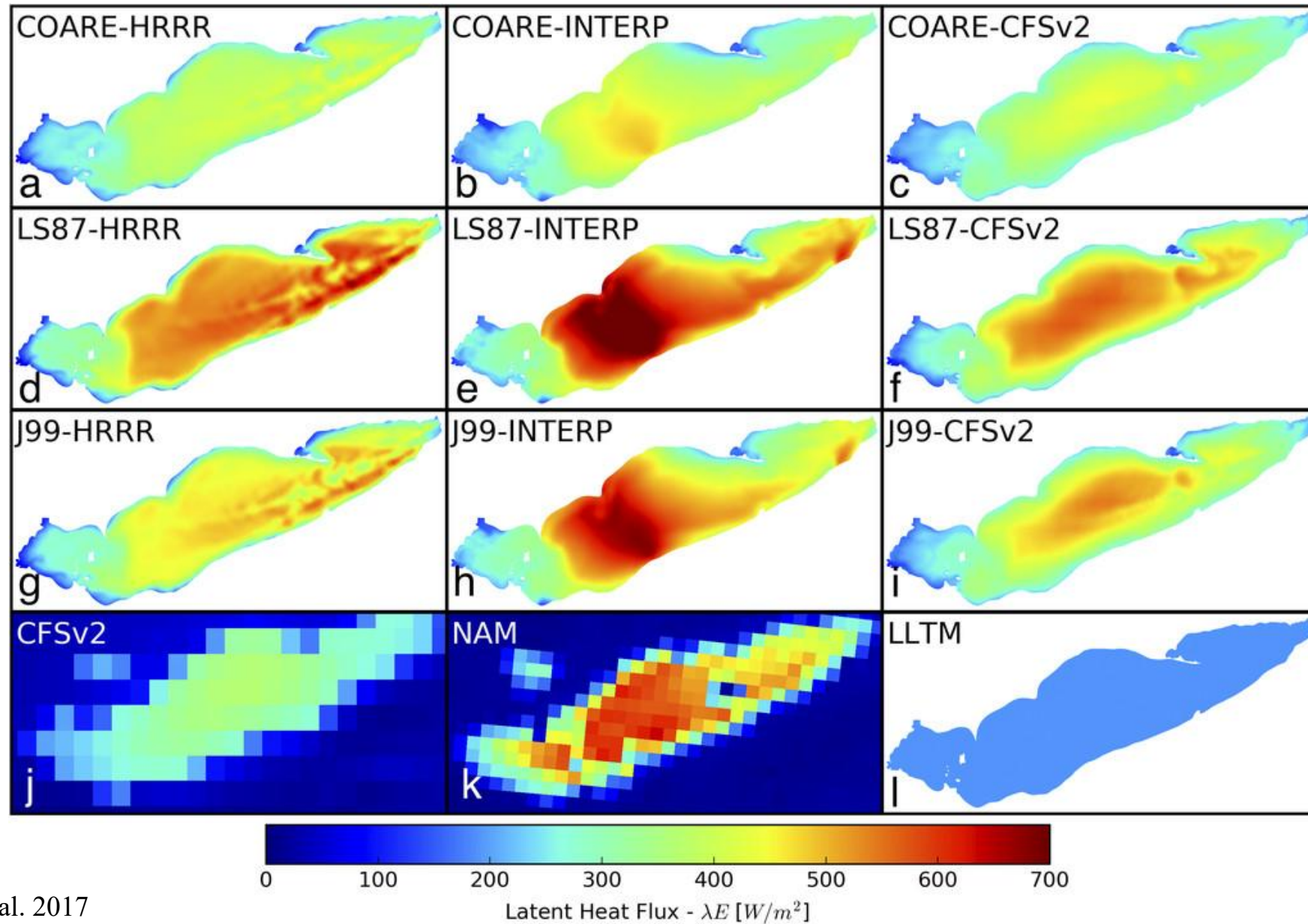


A record LES event was triggered by an extreme North American cold wave in November 2014. The regional snowfall severely impacted the local community: there were at least 13 fatalities, thousands of stranded motorists, power outages, and food and supply shortages. The LES event included two storms. The first storm started on the evening of Nov 17 2014 at 1800 EST, during which time ~ 1 m of snow fell within the first 12 h, and an additional 1.5 m fell over the remaining 36 h to the east of Buffalo. The second storm arrived on the evening of Nov 19 at 2300 EST with an additional 1 m of snow.

LES: Warm lake water

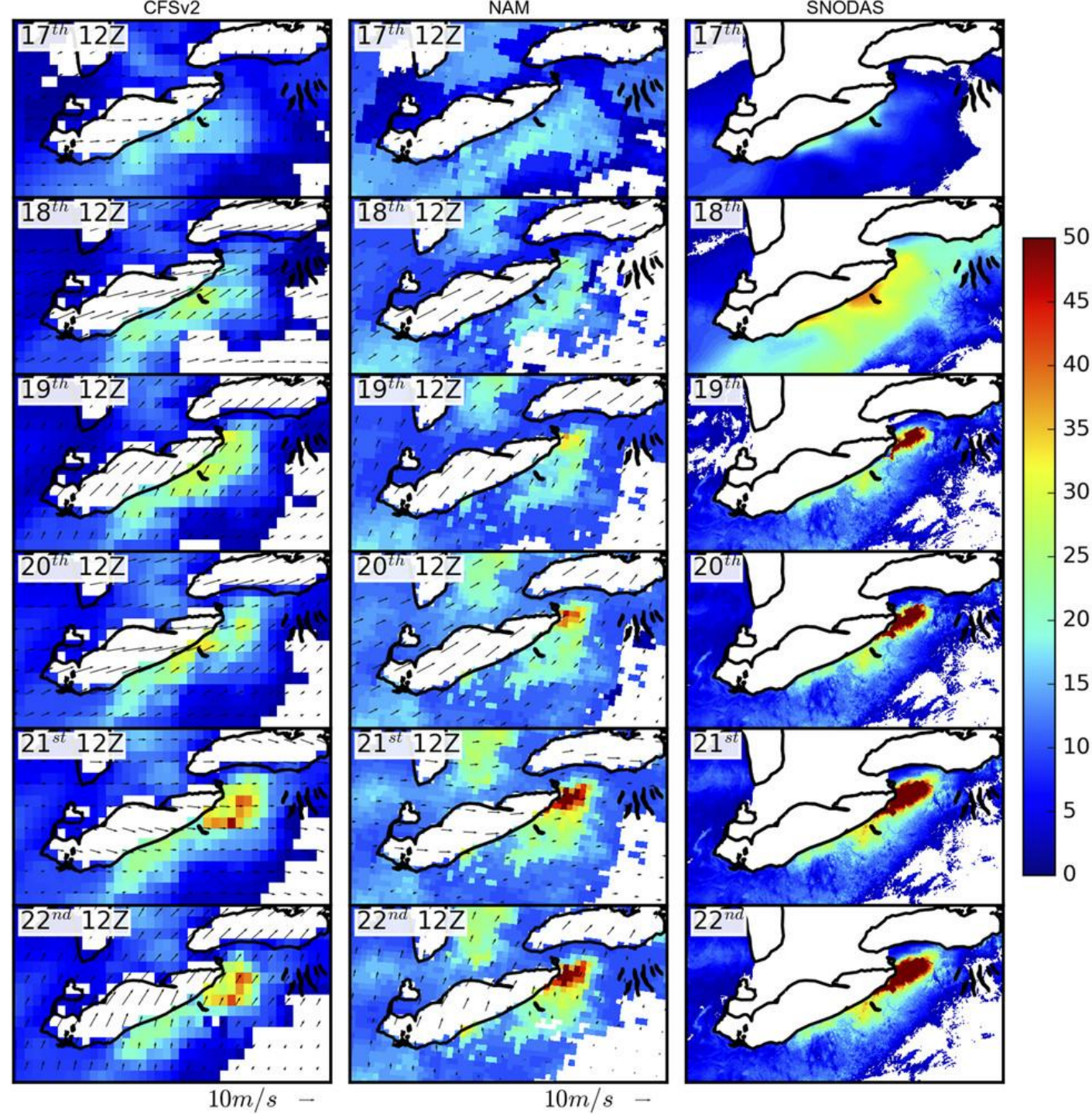


LES: High evaporation



LES: Right wind directions

SWE from the model results of NAM and CFSv2, as well as the analyses of SNODAS from 17 to 22 Nov 2014. The NAM and CFSv2 data show snapshots at 1200 UTC on each day, while the SNODAS data show a daily field. Vectors on the NAM and CFSv2 fields show daily averaged winds at 10-m height from the two models.





In sum

A combination of warm temperatures, high evaporation, and favorable wind directions contributed to the record snowfall in Buffalo, NY.



Take-Home-Messages

- 1) Warming (rising global temperatures) directly affects lake water by reducing volume and water levels, and increasing temperature.
- 2) These changes are often accompanied by greater extremes, including both high and low variations.
- 3) Indirect effects are also common, such as lake-effect snowfall, algal blooms in Lake Erie, the salinization of the soil (Aral Sea), and others (wolf-moose on the Isle Royal National Park).



Oct 15: Recap & Midterm Exam

- Review since Week 1 (20 min)
- Midterm Exam (1 hour)
- Reminder: Field Excursion on **October 22 at 3:00 PM** sharp