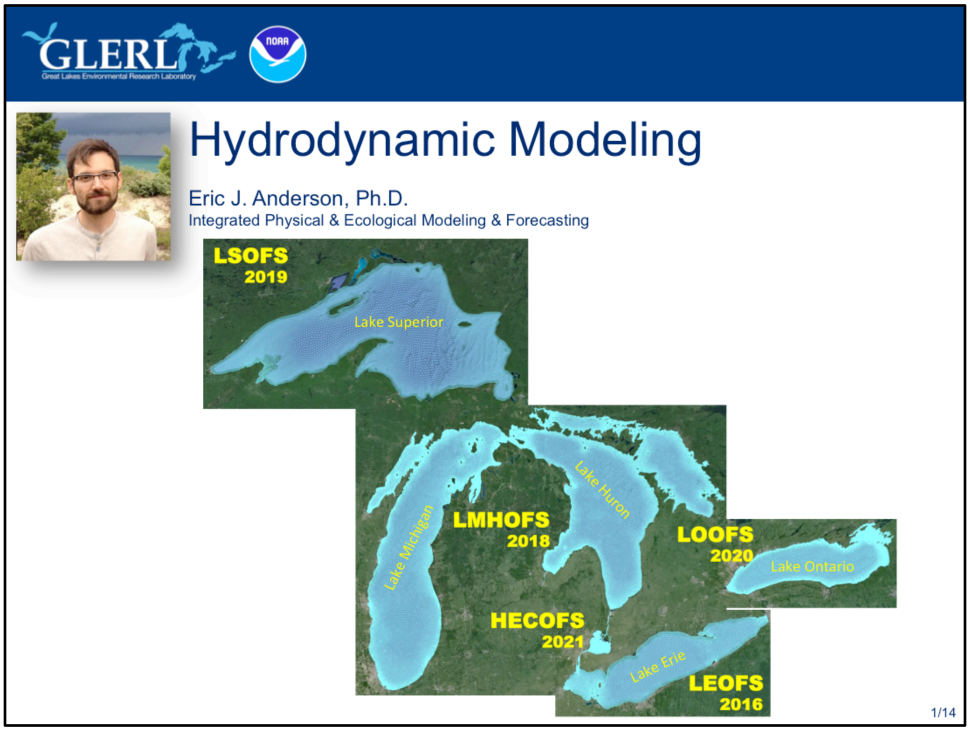


The domain of the next-generation Great Lakes Operational Forecast System (GLOFS) and approximate timeline for transition (Research-to-Operations; R2O) to NOS/CO-OPS. The new FVCOM-based GLOFS improves coastal resolution, expands the model domain into critical areas, and includes the connecting channels between the lakes, a gap in the current GLOFS implementation.

Lake Erie Operational Forecast System (LEOFS), transitioning to CO-OPS in end of March, 2016
Lake Michigan-Huron Operational Forecast System (LMHOFS), transitioning to CO-OPS in 2018. Slated to include the FVCOM-Ice model

Lake Superior Operational Forecast System (LSOFS), transitioning to CO-OPS in 2019
Lake Ontario Operational Forecast System (LOOFS), transitioning to CO-OPS in 2020
Huron-Erie Corridor Operational Forecast System (HECOFS), transition to CO-OPS in 2021. First transition of a connecting channel hydrodynamic model.

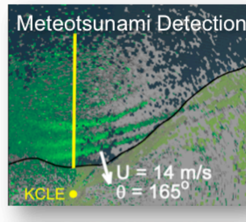
This work aligns with the following NOAA Goals:
Science: Climate Adaptation and Mitigation
Improved scientific understanding of the changing climate system and its impacts
Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions
Mitigation and adaptation efforts supported by sustained, reliable, and timely climate services
A climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions
Science: Weather-Ready Nation
Reduced loss of life, property, and disruption from high-impact events
Improve freshwater resource management
Improve transportation efficiency and safety
Healthy people and communities due to improved air and water quality services
A more productive and efficient economy through information relevant to key sectors of the U.S. economy
Science: Healthy Oceans
Improved understanding of ecosystems to inform resource management decisions
Recovered and healthy marine and coastal species
Healthy habitats that sustain resilient and thriving marine resources and communities
Science: Resilient Coastal Communities and Economies
Resilient coastal communities that can adapt to the impacts of hazards and climate change
Comprehensive ocean and coastal planning and management
Safe, efficient and environmentally sound marine transportation
Improved coastal water quality supporting human health and coastal ecosystem services
Safe, environmentally sound Arctic access and resource management
Education: Science-Informed Society
Youth and adults from all backgrounds improve their understanding of NOAA-related sciences by participating in education and outreach opportunities
Formal and informal educators integrate NOAA-related sciences into their curricula, practices, and programs
Formal and informal education organizations integrate NOAA-related science content and collaborate with NOAA scientists on the development of exhibits, media, materials, and programs that support NOAA's mission
Education: Safety and Preparedness
Youth and adults from all backgrounds are aware of, prepare for, and appropriately respond to environmental hazards that impact health, safety, and the economy in their communities
Formal and informal educators use and produce education materials and programs that integrate and promote consistent science-based messaging on hazards, impacts, and societal challenges related to water, weather, and climate

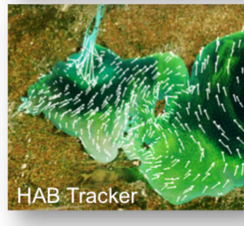
Research Questions

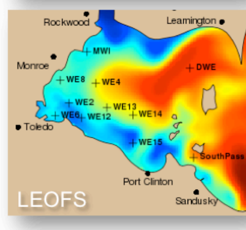
- How do we improve our ability to forecast extreme conditions?

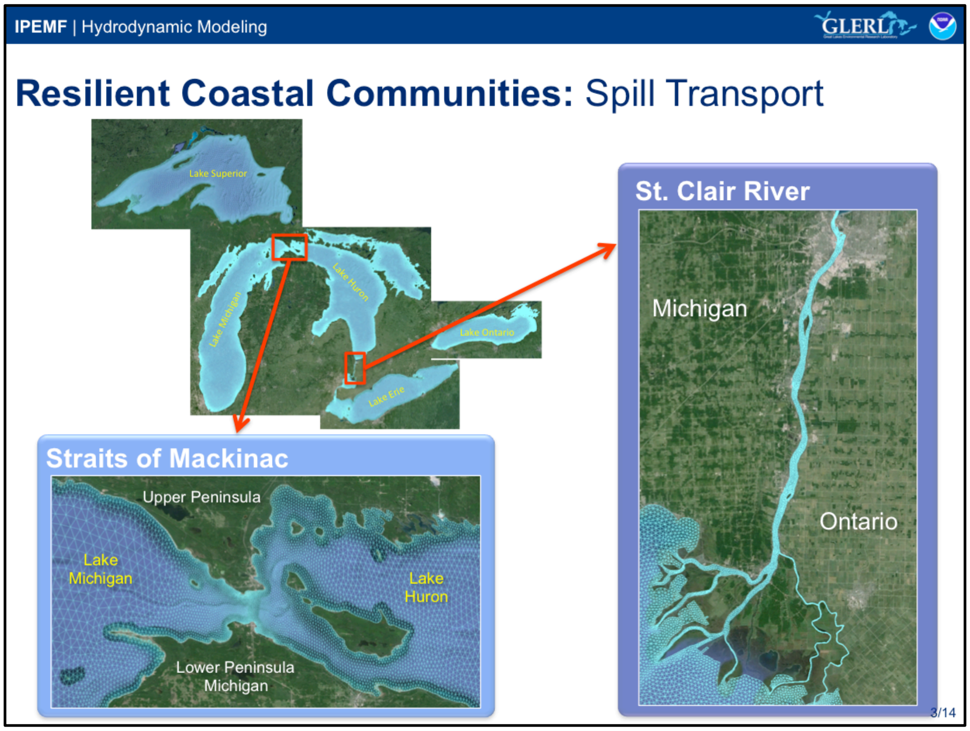
- How do we improve our understanding of physical processes to support coastal resiliency and ecological forecasting?

- How do we translate innovative research into useful products for the public?

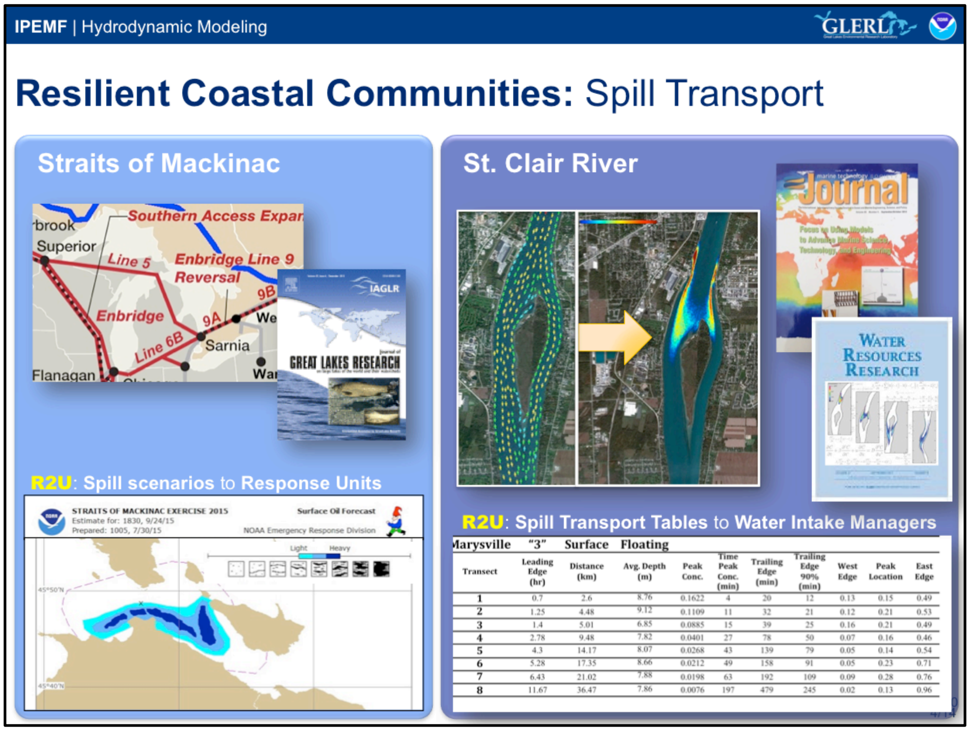








Examples of support for resilient coastal communities are contaminant tracking (or toxic spill transport) in areas such as the Straits of Mackinac or the St. Clair River.



Transect	Leading Edge (hr)	Distance (km)	Avg. Depth (m)	Peak Conc.	Time Peak Conc. (min)	Trailing Edge (min)	Trailing Edge 90% (min)	West Edge	Peak Location	East Edge
1	0.7	2.6	8.76	0.1622	4	20	12	0.13	0.15	0.49
2	1.25	4.48	9.12	0.1109	11	32	21	0.12	0.21	0.53
3	1.4	5.01	6.85	0.0885	15	39	25	0.16	0.21	0.49
4	2.78	9.48	7.82	0.0401	27	78	50	0.07	0.16	0.46
5	4.3	14.17	8.07	0.0268	43	139	79	0.05	0.14	0.54
6	5.28	17.35	8.66	0.0212	49	158	91	0.05	0.23	0.71
7	6.43	21.02	7.88	0.0198	63	192	109	0.09	0.28	0.76
8	11.67	36.47	7.86	0.0076	197	479	245	0.02	0.13	0.96

In both cases, understanding the science resulted in tangible Research-to-Application (R2A) products for key stakeholders such as:

- Water intake managers
- State and local health departments (e.g. South East Michigan Council of Governments; SEMCOG)
- EPA
- United State Coast Guard (USCG)
- Department of Environmental Quality
- Department of Natural Resources
- other Line Offices (LO) in NOAA (e.g. NOS/ORR)
- Industry (e.g. Enbridge. RPS-ASA)

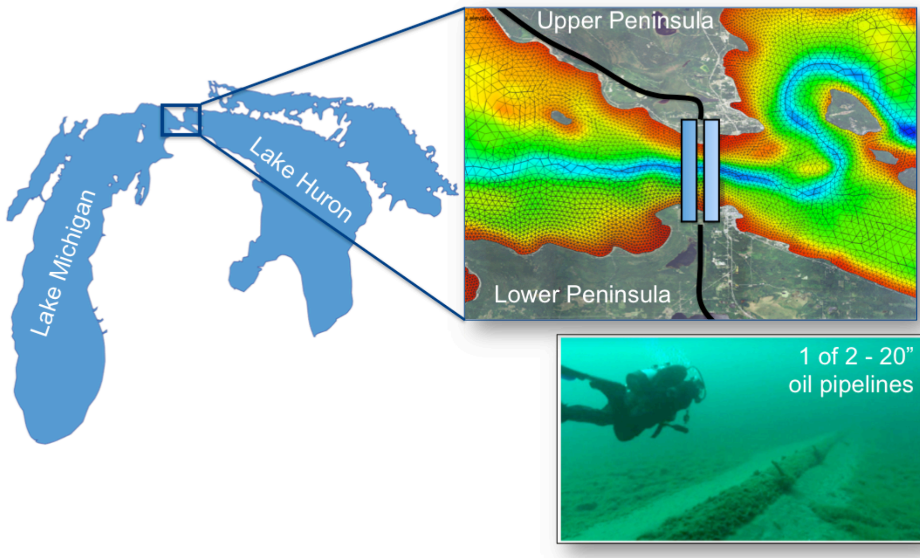
ANDERSON, E.J., and M.S. Phanikumar. Surface storage dynamics in large rivers: Comparing three-dimensional particle transport, one-dimensional fractional derivative, and multirate transient storage models. Water Resources Research 47(W09511): 15 pp. (DOI:10.1029/2010WR010228) (2011)

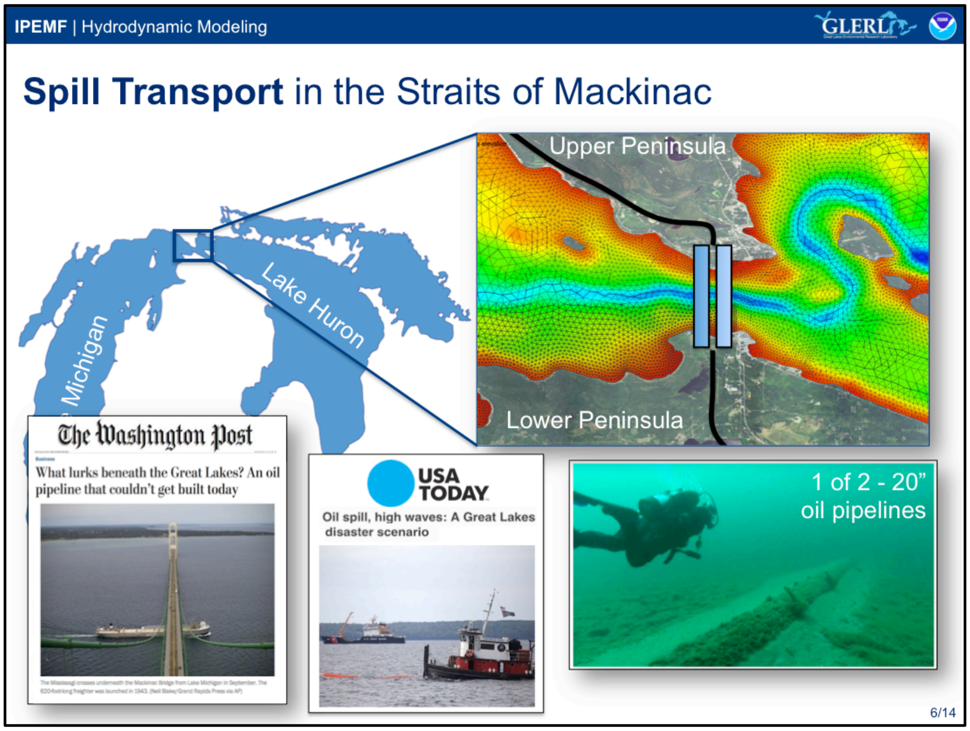
Sun, Y., M.G. Wells, S.A. Bailey, and E.J. ANDERSON. Physical dispersion and dilution of ballast water discharge in the St. Clair River: Implications for biological invasions. Water Resources Research 49:1-13 (DOI:10.1002/wrcr.20201) (2013)

ANDERSON, E.J., and D.J. SCHWAB. Contaminant transport and spill reference tables for the St. Clair River. Marine Technology Society Journal 46(5):34-47 (2012). http://www.glerl.noaa.gov/pubs/fulltext/2012/20120035.pdf

ANDERSON, E.J., and D.J. SCHWAB. Predicting the oscillating bi-directional exchange flow in the Straits of Mackinac. Journal of Great Lakes Research 39(4):66671 pp. (DOI:10.1016/j.jglr.2013.09.001) (2013)

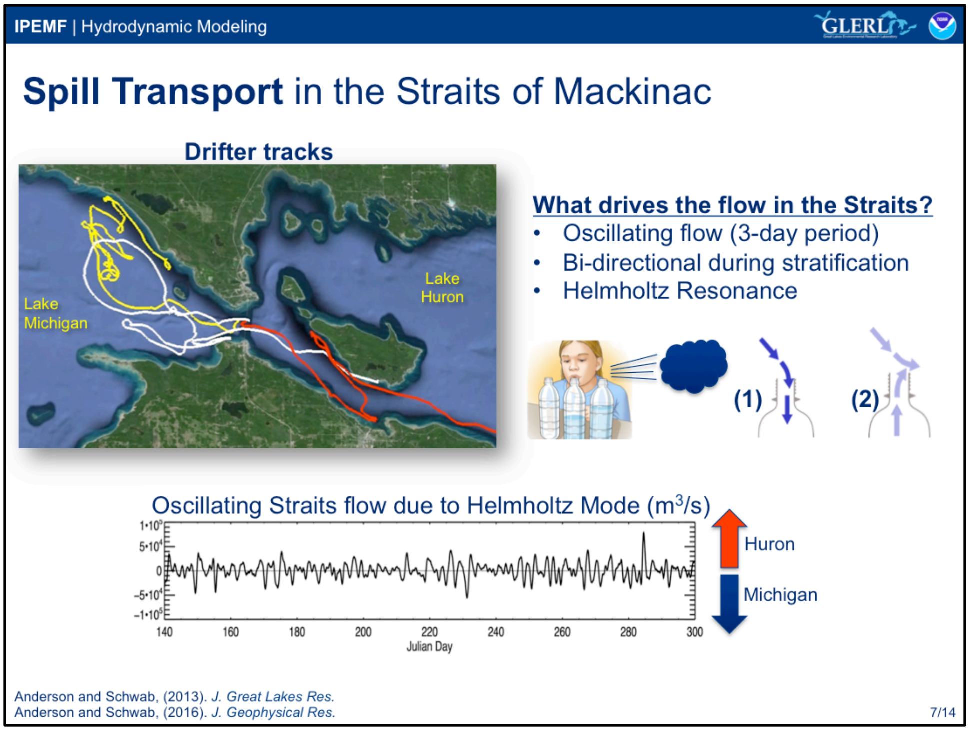
Spill Transport in the Straits of Mackinac





3 important factors in the Straits of Mackinac:
- One of the most dynamic places in the Great Lakes (currents up to 1 m/s, oscillating exchange flow, bi-directional flow in summer)
- Don't have a clear understanding of what drives flow in the straits
- NOAA has no operational models of Straits (gap in forecast capability)

In the event of a release, contaminants could spread rapidly into both lakes within a few hours/days (up to 150 km, with heavy shoreline impact).



Goals:
- understand the science
- get information to stakeholders (R2A – NOAA/ORD/ERR, USCG, EPA, etc.)
- transition understand to operations (R2O – Lake Michigan-Huron Operational Forecast System (LMHOFS))

Partners:
- NOS/ORD/ERR
- U. Michigan
- Michigan Tech. University
- USCG

ANDERSON, E.J., and D.J. SCHWAB. Predicting the oscillating bi-directional exchange flow in the Straits of Mackinac. Journal of Great Lakes Research 39(4):66671 pp. (DOI:10.1016/j.jglr.2013.09.001) (2013)
ANDERSON, E.J., and D.J. SCHWAB. Geostrophic control of exchange flow in the world's largest lake. Journal of Geophysical Research Oceans (*submitted*)

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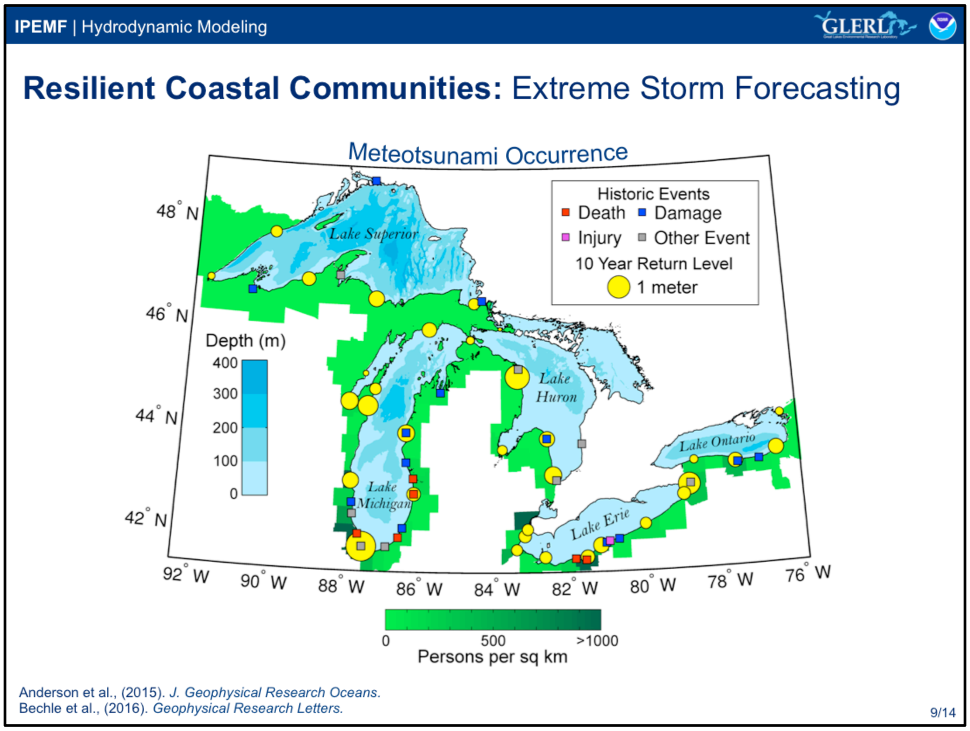
- Michigan Tech. University
- USCG

Federal collaboration:
http://www.regions.noaa.gov/great-lakes/index.php/highlights/prep-oil-spill-drill-in-the-straits-of-mackinac/

- Photo credit in right column: Neil Blake (Mlive.com)

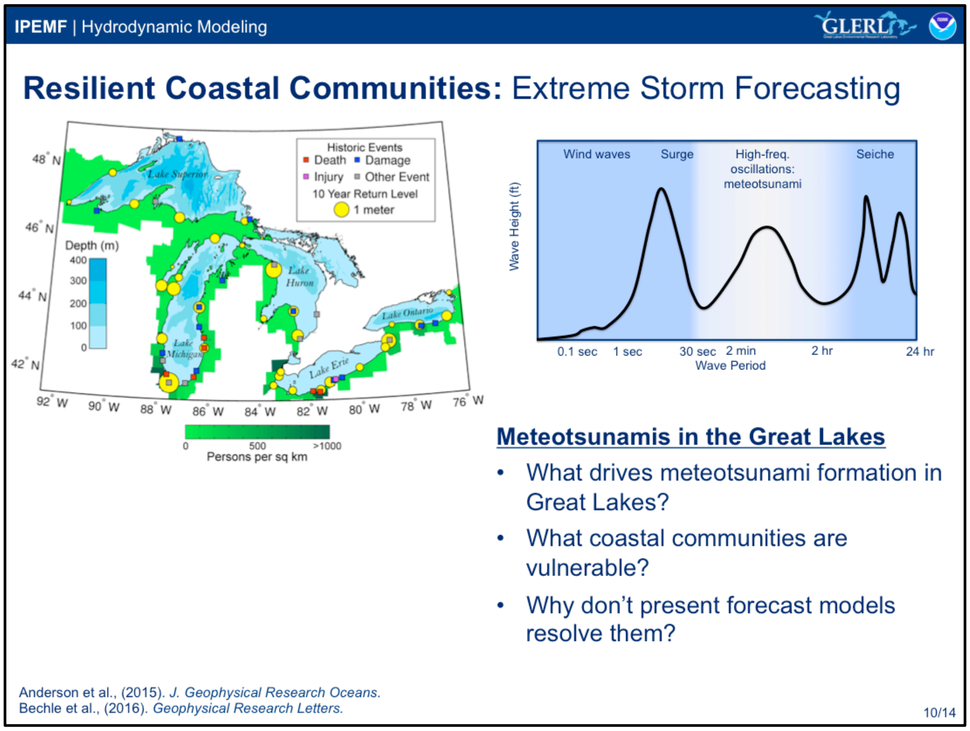
- Surface Oil Forecast courtesy of NOS/ORR/ERD



- Experimental “high-risk” research: meteotsunami forecasting (meteorological tsunami = meteo-tsunami)
- Meteotsunamis are waves with periods between 2 minutes and 2 hours, similar to seismic tsunami waves, but driven by atmospheric disturbance (e.g. squall line, derecho)
- current gap in our ability to predict waves-hydrodynamics in coastal zones (Great Lakes & ocean coasts)
- source of several historic events (fatalities, injury, damage) along Great Lakes coasts
- may often be the cause of rip current incidents in the Great Lakes

Partners:
- NWS WFO Cleveland and Detroit
- University of Wisconsin-Madison
- University of Michigan
- University of Illinois

Anderson E.J., et al., 2015. Reconstruction of a meteotsunami in Lake Erie on May 27, 2012: roles of atmospheric conditions on hydrodynamic response in enclosed basins, J. Geophys. Res. Oceans, 120, 8020–8038, doi: 10.1002/2015JC010883
Bechle et al., 2016. Regional characteristics of meteotsunamis in the Laurentian Great Lakes, Geophysical Research Letters, (*submitted*)



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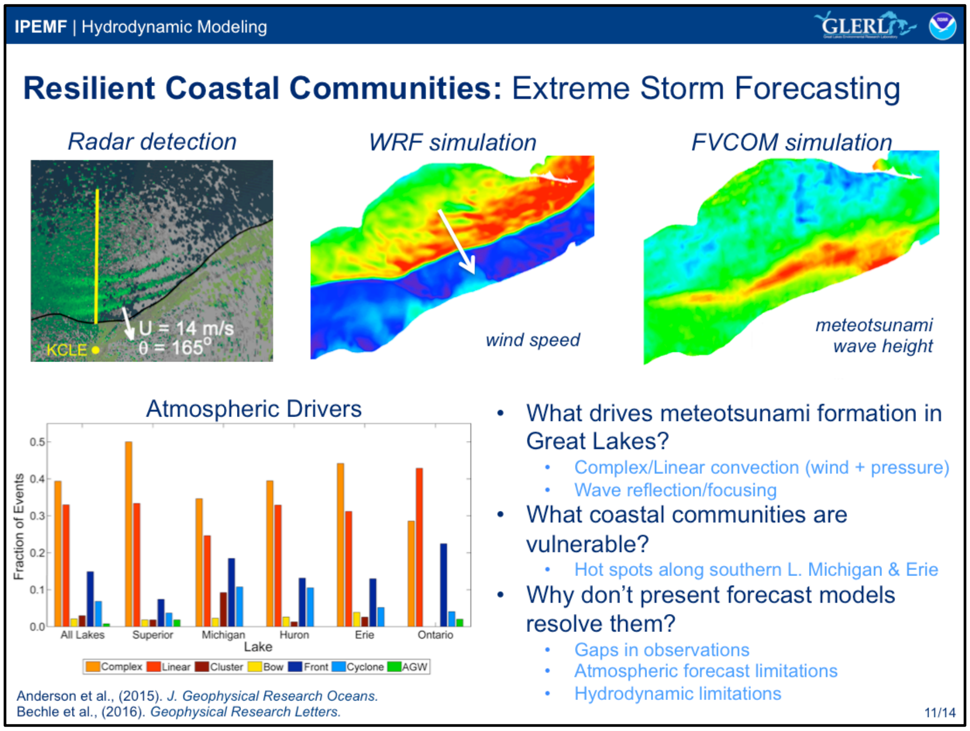

- Great Lakes pose a unique threat given that they are enclosed basins, which enables reflection and focusing of meteotsunami waves to increase coastal danger. Presents a new paradigm in meteotsunami formation.

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Transitioning Research to Products & Services

Research-to-Operations (R2O)

- Operational Forecast Systems (OFS) to NOS/CO-OPS
  - Lake Erie Operational Forecast System (LEOFS) [***April 2016***]
  - Lake Michigan-Huron OFS [*2018*]
  - Lake Superior OFS [*2019*]
  - Lake Ontario OFS [*2020*]
  - Huron-Erie Corridor OFS [*2021*]
- Ecological Forecast System to NOS/CO-OPS
  - Lake Erie HAB particle model ("HAB Tracker") [*2019*]

Research-to-Application (R2A)

- St. Clair River Contaminant Spill Transport Tables to Drinking Water Intake Operators, IOOS/GLOS, local health departments [*2014*]
- Niagara River Short-Term Flow Forecasting to NYPA/OPG [*July 2016*]
- Water level and seiche forecast guidance to NRC [*ongoing*]

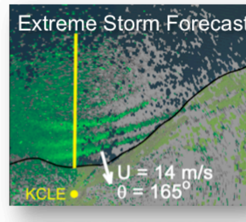
- Upgrade to the Great Lakes Operational Forecast System (GLOFS) models (LEOFS, LMHOFS, LSOFS, LOOFS, HECOFS) is a collaboration between OAR/GLERL, NOS/CO-OPS, and NOS/OCS/CSDL.
- Development of the Lake Erie HAB particle model (in FVCOM; aka HAB Tracker) is a collaboration between OAR/GLERL, CILER, and NOS/NCCOS.
- Niagara River Short-Term flow forecasting model is a collaboration between OAR/GLERL, USACE Detroit and Buffalo Districts, and NWS/NERFC, with transition to industry partners New York Power Authority (NYPA) and Ontario Power Generation (OPG).
- Water level and seiche forecast products for the Nuclear Regulatory Commission (NRC) is a collaboration between OAR/GLERL, NRC, and USACE Detroit District.

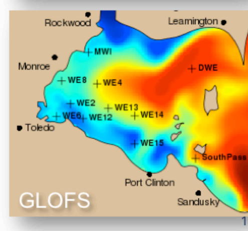
Research Directions

- Further our understanding of over-water meteorology and hydrodynamic processes
  - Extreme storm conditions (weather & water)
  - Mixing processes and thermal structure

- Integrate physical & ecological models
  - Improve ecological forecasting by reducing error in physical predictions

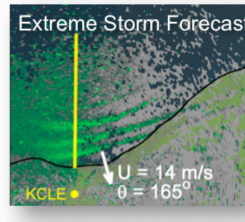
- Transition cutting-edge science to application and operations
  - Foster partnerships within Great Lakes basin and across NOAA, Federal Agencies



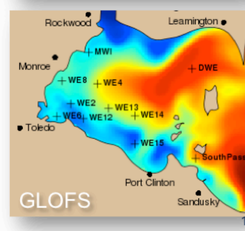


Questions?

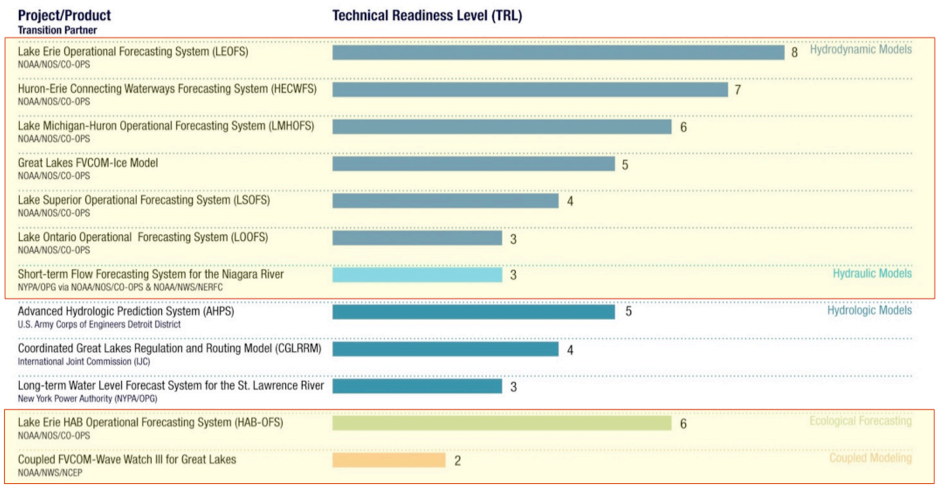

LSOFS
2019
Lake Superior
LMHOFS
2018
Lake Michigan
Lake Huron
LOOFS
2020
Lake Ontario
HECOFS
2021
Lake Erie
LEOFS
2016


Extreme Storm Forecast
KCLE
U = 14 m/s
θ = 165°


HAB Tracker


Rockwood
Leamington
Monroe
MWI
WE8
WE4
DWE
WE2
WE13
WE14
WE6
WE12
Toledo
WE15
SouthPass
Port Clinton
Sandusky
GLOFS

Technical readiness level of IPEMF research to operation (R2O) products



Additional Information