CILER
Cooperative Institute for Limnology and Ecosystems Research

# Lake Erie FVCOM-Ice

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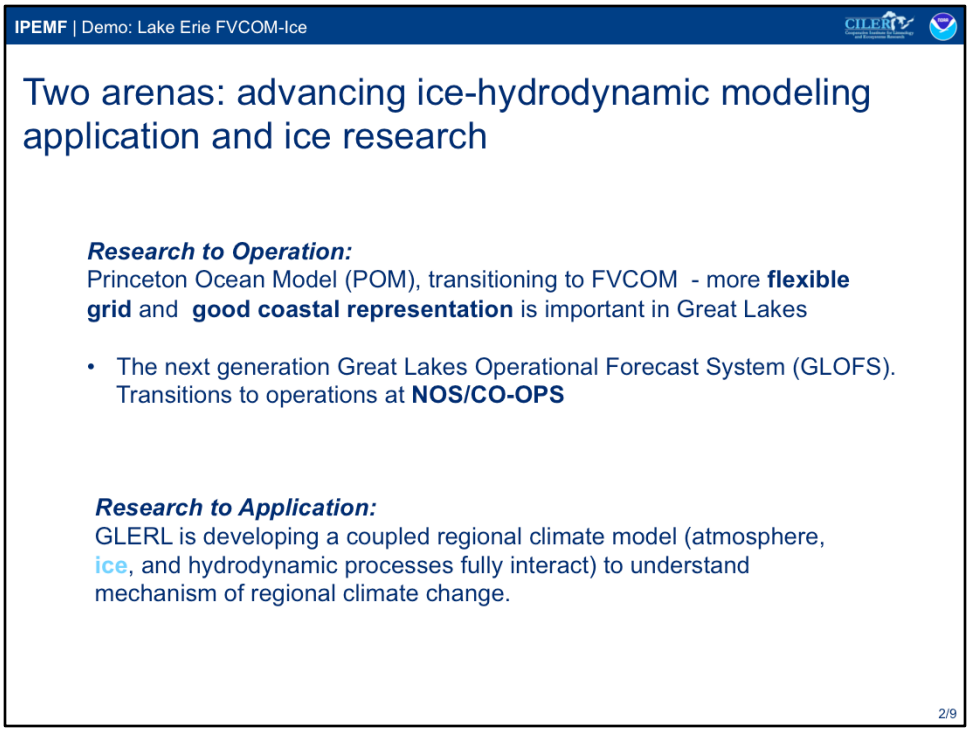
1/9

**NOAA Goal - Climate Adaptation and Mitigation:**
Improved scientific understanding of the changing climate system and its impacts
Assessment of current and future states of the climate systems that identify potential impacts and inform science, service and stewardship decisions
Mitigation and adaptation efforts supported by sustained, reliable and timely climate services




R2O
- In the current operational forecasts at NOS/CO-OPS, ice processes are not taken into account.
- In connection with E. Anderson's talk, GLOFS is in transition to a new new system. Incorporating ice processes is important addition.
- Tied to "Great Lakes FVCOM-Ice Model" in IPEMF Research to Operation Products of the technical readiness level (TRL) chart in the strategic plan.

R2A
- On the science side: GLERL is developing a regional climate model. A coupled model is important to understand mechanisms of regional climate change.
- Also important to make sure each component of models has a solid performance in a coupled regional climate model
- Tied to "WRF-FVCOM Coupled Regional Model" in IPEMF Research to Application Products of the technical readiness level (TRL) chart in the strategic plan.

- Introduce latest results from ice hydrodynamic model with application to Lake Erie

* Definition
POM: Princeton Ocean Model

## Background: FVCOM

- Unstructured Grid Finite Volume Community Ocean Model (FVCOM)
- Triangular grids (200m-3km)
- Los Alamos sea ice model (CICE) as a sub module
- Next generation GLOFS.


3/9

- FVCOM is based on the unstructured grid framework, which allows local grid refinement in the nearshore and estuaries.
- An ice model comes with FVCOM as a sub-module. The ice model is based on CICE, but adapted to the unstructured grid framework.
- FVCOM-Ice is to be the physical core of the next generation GLOFS.
- Animation shows the unstructured grid for Lake Erie used in the FVCOM simulations.

*Definition
GLOFS: Great Lakes Operational Forecast System
CICE: Los Alamos Sea Ice Model

## Research: Adding ice to FVCOM

- No published application to freshwater lakes
- Extensive testing and tuning for Lake Erie application
- Compared with
  - Observations
  - Older model results with the Princeton Ocean Model (ICEPOM, Fujisaki et al. 2013).

***Ice model comparison***

| | CICE | ICEPOM |
|---|---|---|
| Rheology | Elastic-Viscous-Plastic | |
| Thickness distribution | Multi categories | Single category |
| Ridging | Yes | No |
| Albedo | Function of surface temperature and thickness | Constant 0.7 (0.5 when melting) |
| Thermodynamics | Multi layer | 0 layer |

4/9

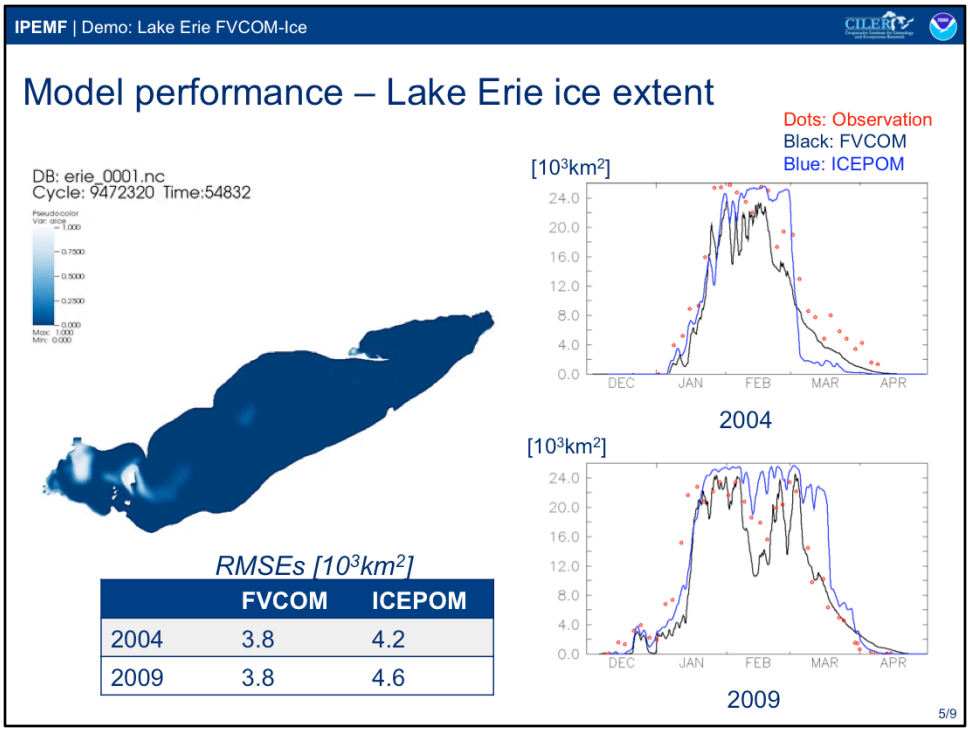
- FVCOM-Ice is relatively new. There is no published application to freshwater lakes.
- Extensive testing and tuning for Lake Erie application have been done in comparison with observations and the older model results with the POM.
- The table compares each component of the two ice models, CICE and ICEPOM.

• Definition

ICEPOM: Princeton Ocean Model coupled with ice processes. The ice model uses the elastic-viscous-plastic rheology, similarly to CICE, but ICEPOM uses simpler single category ice thickness and the 0-layer thermodynamics.

* Reference

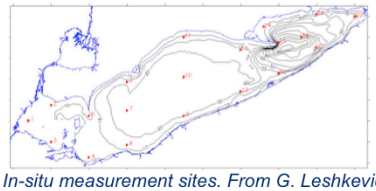
Fujisaki (Manome), A., J. Wang., X. Bai, G. Leshkevich, and B. Lofgren (2013), Model-simulated interannual variability of Lake Erie ice cover, circulation, and thermal structure in response to atmospheric forcing, 2003–2012, J. Geophys. Res. Oceans, 118, doi:10.1002/jgrc.20312.



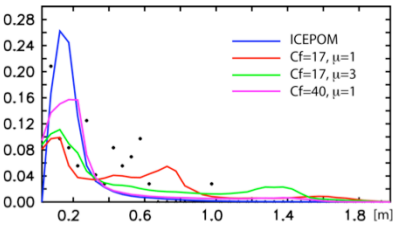

- First example of the results: Ice extent time series from the winters of 2003-2004 and 2008-2009.
- Y axis is area in [$10^3 km^2$] and X axis is time. Red is FVCOM and blue is ICEPOM
- Performance: Two models perform similarly. Succeeded in reproducing the annual maxima.
- Quality: ICEPOM tends to simulate overshooting after the peaks and too fast melting in spring, while FVCOM-Ice's results are closer to the observation.

* Animation: Ice concentration in the winter of 2009.

## Model performance – Lake Erie ice thickness



*In-situ measurement sites. From G. Leshkevich (GLERL) and U.S. Coast Guard, since 2008.*



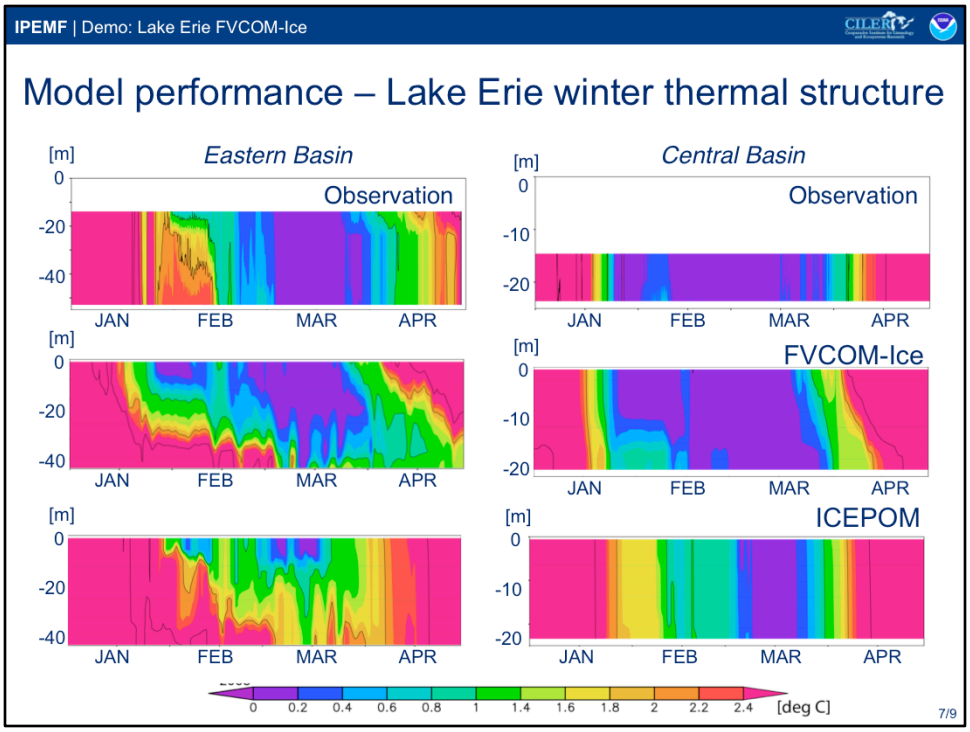

*Probability density function of ice thickness (Dots: Observation)*



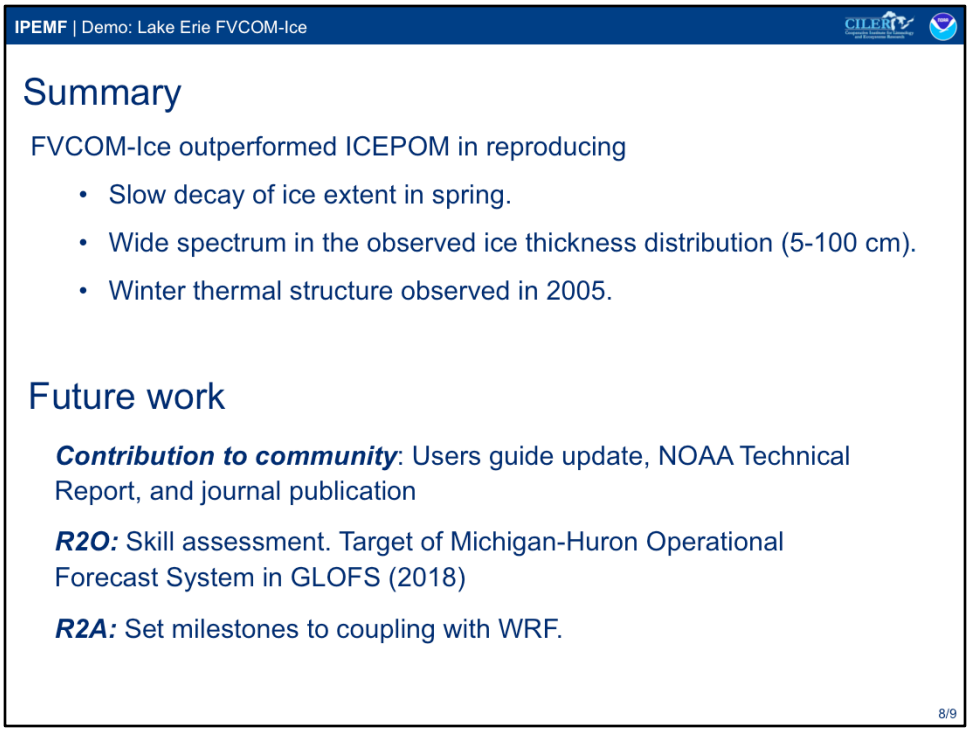
- Second example: Ice thickness comparison with the in-situ measurements since 2008. The measurements were conducted in collaboration between GLERL (G. Leshkevich) and U.S. Coast Guard.
- Picture: Sampling ice in Green Bay (not in Lake Erie).
- Probability density function (right)
    - Y-axis is the probability density of ice thickness and X-axis is ice thickness. Only the period of Feb. 20-Mar.5 is extracted from the models for consistency with the observations.
    - The sensitivity study of μ, a tunable parameter of the ice ridging process, and the empirical parameter Cf for ice strength P was conducted
    - Quality: FVCOM-Ice succeeded in reproducing the observed wide spectrum (5-100cm) of ice thickness with adequate setting of m and Cf, while ICEPOM has one narrow peak in ~20cm.

• Reference

Lipscomb, W. H., E. C. Hunke, W. Maslowski, and J. Jakacki (2007), Ridging, strength, and stability in high-resolution sea ice models, J. Geophys. Res., 112, C03S91, doi:10.1029/2005JC003355.




- Final example: Water temperature in winter.
- Y-axis is depth and X-axis is time. Top: observation, middle: FVCOM-Ice, and bottom: ICEPOM.
- The in-situ measurements in the top panel are from the thermistor measurements in 2005, during the International Field Year on Lake Erie (IFYLE).
- Quality: FVCOM is closer to the observation in deep cooling during February and March, as well as vertical temperature gradient in April.




Summary

- FVCOM-Ice outperformed ICEPOM in reproducing
  - Slow decay of ice extent in spring.
  - Wide spectrum in the observed ice thickness distribution (5-100 cm).
  - Winter thermal structure observed in 2005.

Future work

- Contribution to community will be done by updating users guide in collaboration with Dr. C. Chen U. Massachusetts Dartmouth (FVCOM developer), compiling a NOAA Technical Report, and journal publication.
- R2O: Skill assessment will be conducted with a primary target of Michigan-Huron Operational Forecast System in GLOFS (2018).
- R2A: Set milestones to coupling with WRF.

# Questions?