Reconstructing Evaporation over Lake Erie During the Historic November 2014 Lake Effect Snow Event

Lindsay Fitzpatrick[1], Ayumi Fujisaki-Manome[1,3], Andrew Gronewold[2], Eric Anderson[2], Chris Spence[5], Jiquan Chen[4], Changliang Shao[4], David Wright[3], Brent Lofgren[2], David Schwab[3]

[1]Cooperative Institute for Great Lakes Research, [2]Great Lakes Environmental Research Laboratory, [3]University of Michigan, [4]Michigan State University, [5]Environment and Climate Change Canada

Cooperative Institute for Great Lakes Research
CIGLR
Great Lakes Science for Society
GLERL
Great Lakes Environmental Research Laboratory

Introduction

- The purpose of this study was to assess how state-of-the-art numerical models perform in simulating turbulent heat fluxes over the Great Lakes, which is tied to evaporation.

Method

Water vapor budget equation:

$$P = E - F_v - dQ/dt \quad (1)$$

where P is precipitation, E is evaporation, F_v is divergence of water vapor and dQ/dt is the change is water vapor mass over time.

Figure 1	Model	Flux Algorithms	Meteorological Forcings	Resolution / Interval
FVCOM	The unstructured-grid, Finite-Volume Community Ocean Model	CICE (Los Alamos Sea Ice Model)	CFSv2 (Climate Forecast System version 2 Operational Analysis)	200 m – 3 km / half hourly
		SOLAR (NOAA's Great Lakes Environmental Research Lab)	Interp (Interpolated Observations)	
		COARE (Met Flux Algorithm)	HRRR (High Resolution Rapid Refresh)	
CFSv2	Climate Forecast System version 2			0.2 degrees / hourly
NAM	North American Mesoscale Forecast System			12 km / 6-hourly
LLTM	Large Lake Thermodynamic Model			Basin Average / daily

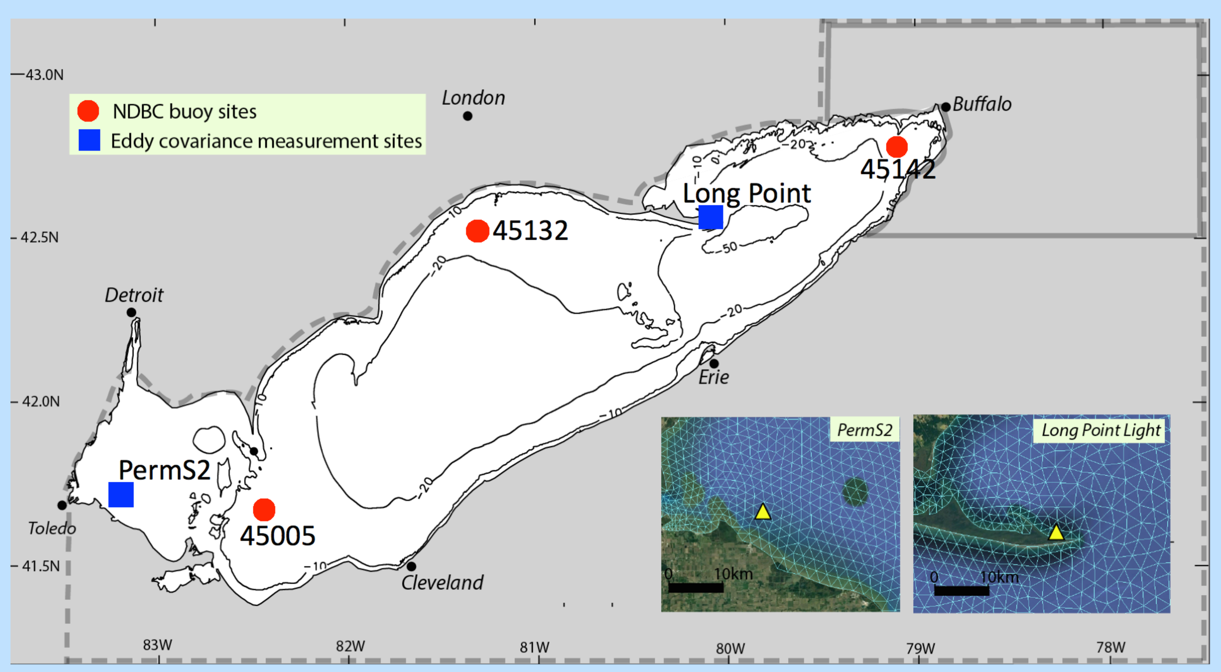

Figure 2 shows a map of Lake Erie. The red dots indicate locations of the three different NDBC buoys. The blue squares indicate the locations of the two eddy covariance measurement sites.

- Heat fluxes were reconstructed using nine FVCOM model runs.
- Simulated heat fluxes were validated at two eddy covariance stations: Long Point Lighthouse and the Toledo crib intake (PermS2).

- Meteorological forcing elements were validated using observational data from three buoy sites (Fig. 3a-c).
- 3D mean water temperature was calculated to show corresponding lake heat content (Fig. 3d).

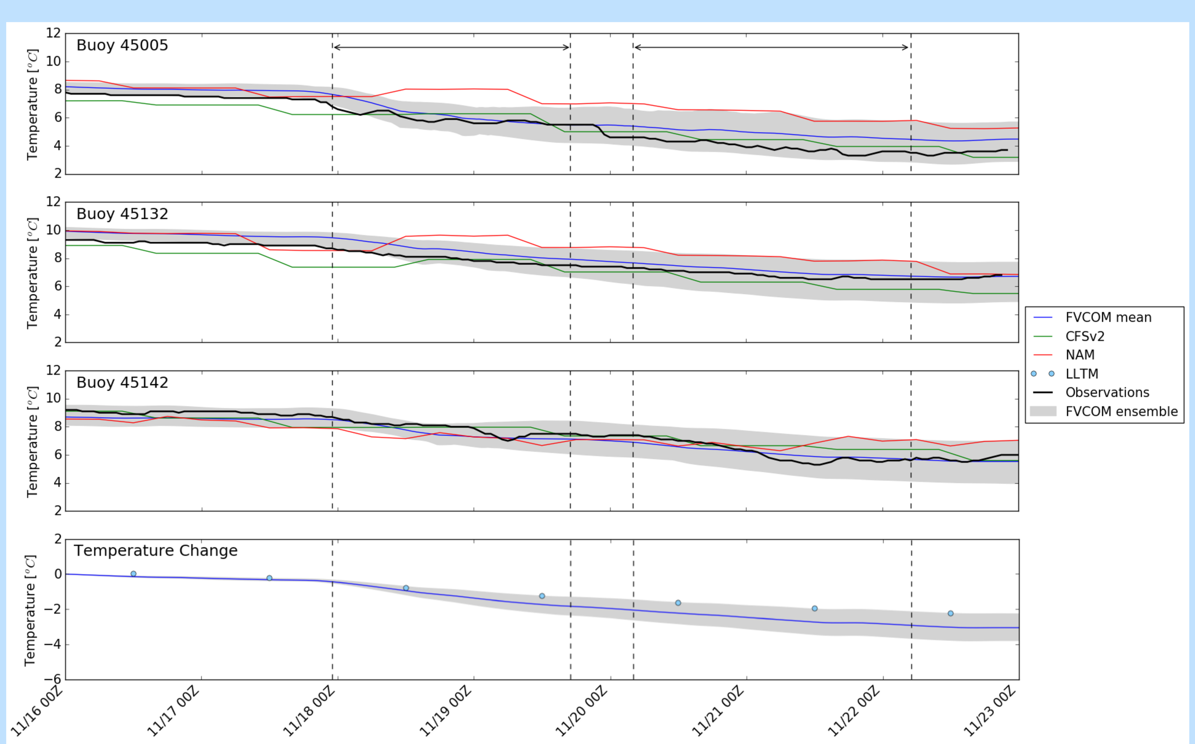

Figure 3 shows lake surface temperature at (a) 45005, (b) 45132, and (c) 45142, as well as change of 3-D mean water temperature (d). The grey region represents the max and min of the nine FVCOM model runs.

Analysis

- All the model runs captured the sharp rise in LE and H on the 17th.
- NAM and CFSv2 significantly overestimated, likely due to their coarser spatial resolution.

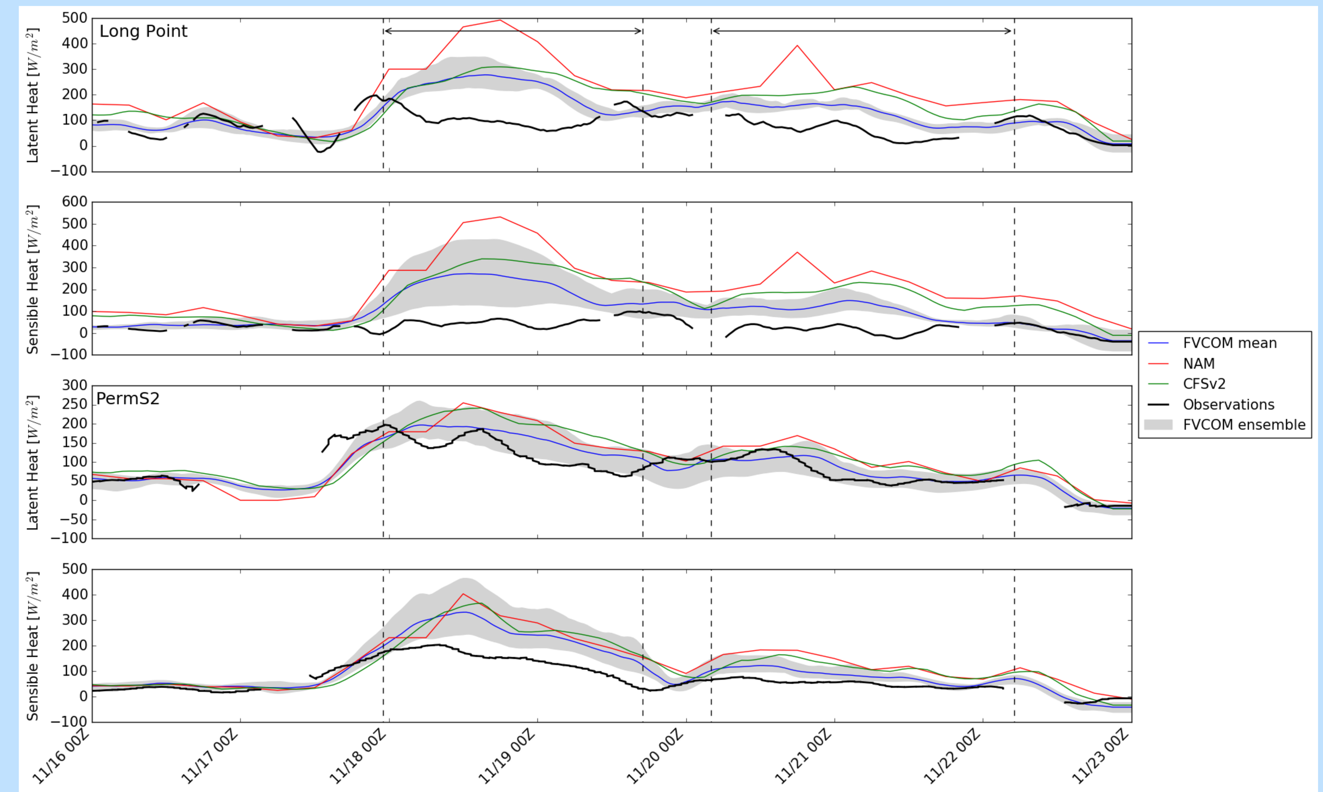

Figure 4 shows the comparison between the simulated and observed latent heat and sensible heat flux at Long Point (a,b) and PermS2 (c,d). The grey region represents the max and min of the nine FVCOM model runs.

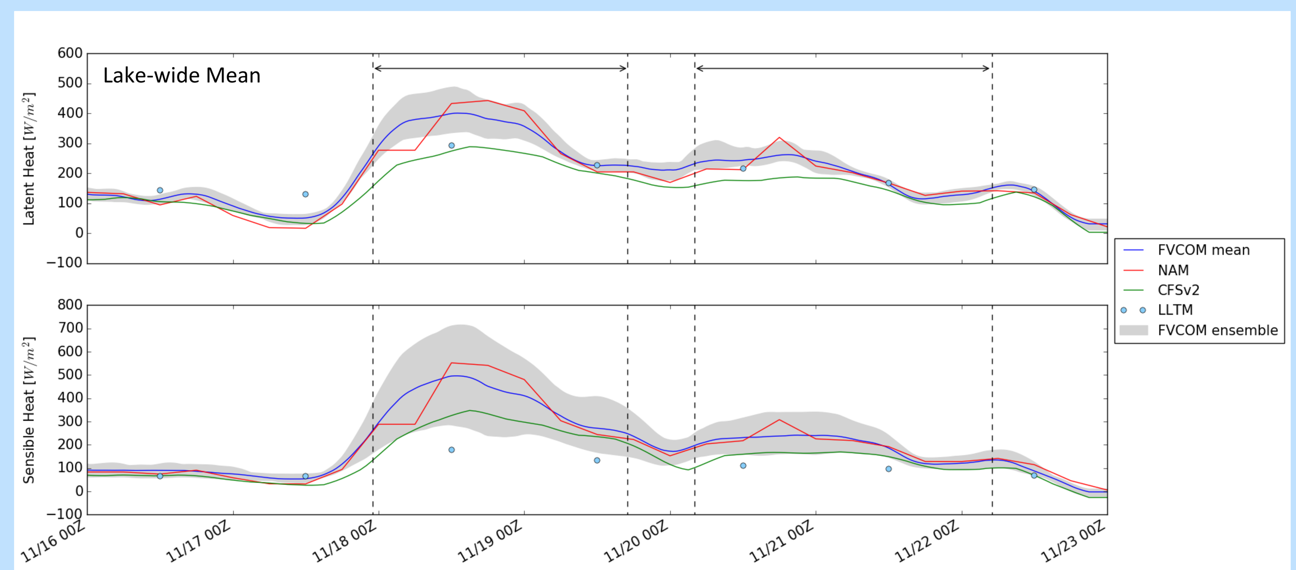

Figure 5 shows time series of the lake-wide mean (a) latent heat and (b) sensible heat fluxes from the model results. The grey region represents the max and min of the nine FVCOM model runs.

- Lake-wide LE and H averages were calculated across Lake Erie and translated into cumulative evaporation.

- Cumulative SWE was added to Fig 6.
- The water vapor budget equation shows majority of the moisture came from Lake Erie and not a larger synoptic system.

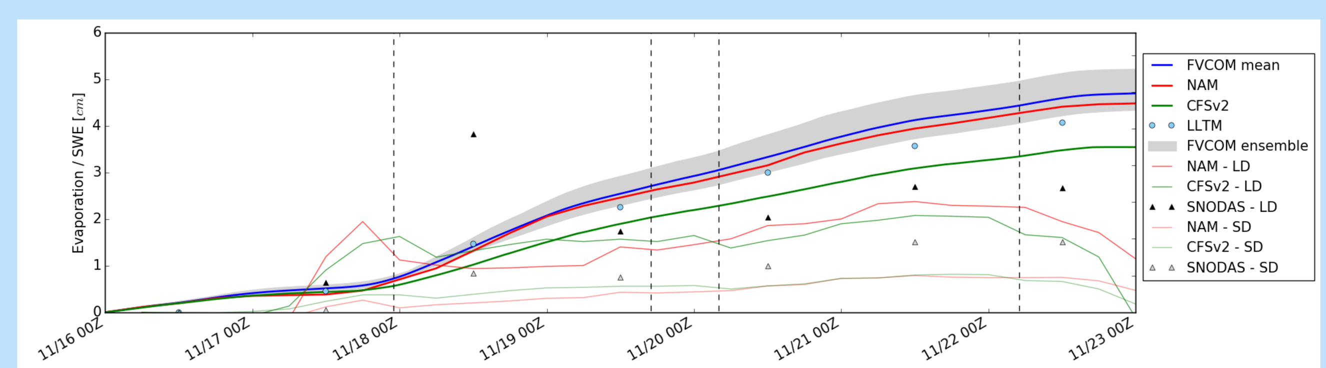

Figure 6 shows simulated lake-wide cumulative evaporation (primary y-axis) and snow water equivalent (SWE, secondary y-axis). "LD" and "SD" denotes values over the large and small domain.

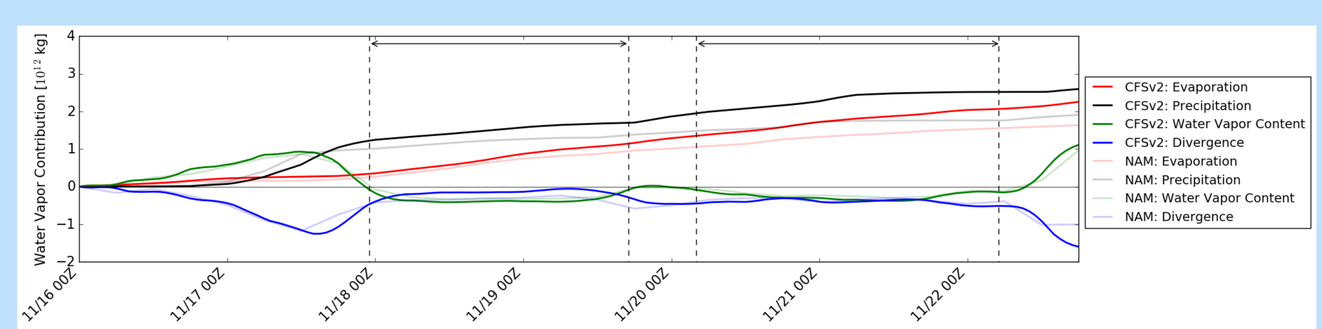

Figure 7 shows the contribution of water vapor to the control volume integrated over time. Black lines show the amount of precipitation, P, red lines show the amount of evaporation, E, the green lines show the water vapor content, and the blue lines show the horizontal divergence, F_v.

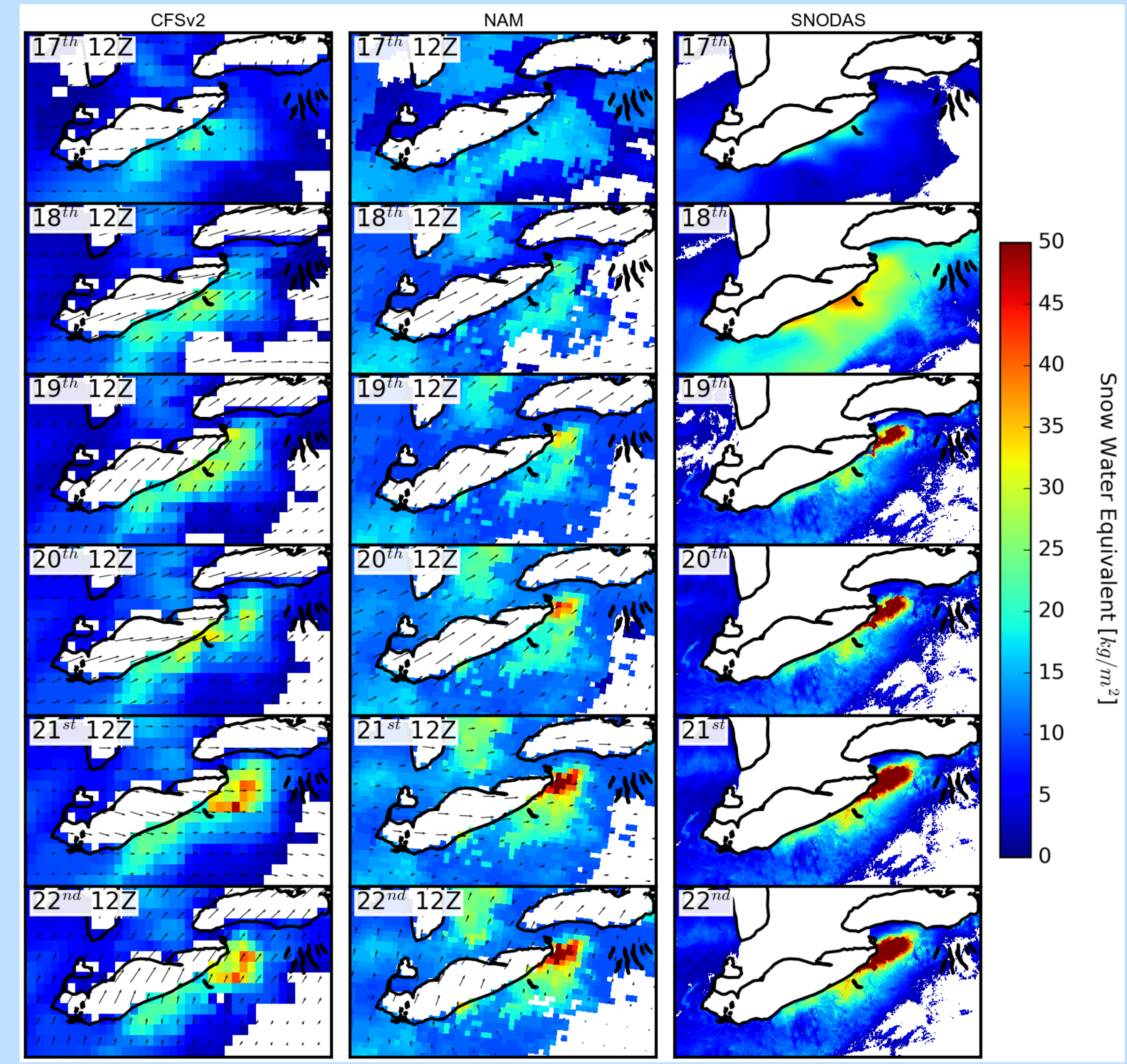

Figure 8 shows the modeled spatial snow water equivalent from CFSv2, NAM, and the observational analyses from SNODAS.

- Observational data from SNODAS shows an increase of SWE along the east of Lake Erie during the duration of the LES event.
- These increases were somewhat captured by the CFSv2 and NAM but both missed the intensity observed in the Buffalo area.

Conclusion

- The FVCOM-simulated LE and H agreed with direct flux measurements better than other models.
- This study emphasized the importance of accurate simulation of turbulent heat fluxes to better predict these intense LES events in the Great Lakes region.

Acknowledgements & References

This work is supported by the National Oceanic and Atmospheric Administration (NOAA) Costal Storms Program (CSP).

Fujisaki-Manome, A., L. Fitzpatrick, A. Gronewold, E.J. Anderson, C. Spence, J. Chen, C. Shao, D. Wright, C. Xiao, and B. Lofgren, Turbulent Heat Fluxes during an Extreme Lake Effect Snow Event: Direct Measurements and Model Ensemble, in preparation.

Lenters, J. D., B. Anderson, John, P. D. Blanken, C. Spence, and A. E. Suyker, 2013: Great Lakes Evaporation : Implications for Water Levels Assessing the Impacts of Climate Variability and Change on Great Lakes Evaporation : Implications for water levels and the need for a coordinated observation network. 2011 Proj. Reports. D. Brown, D. Bidwell, L. Briley, eds. Available from Gt. Lakes Integr. Sci. Assessments Cent.

Shao, C., and Coauthors, 2015: Diurnal to annual changes in latent, sensible heat, and CO2 fluxes over a Laurentian Great Lake: A case study in Western Lake Erie. J. Geophys. Res.