Reconstructing Evaporation over the Great Lakes

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Overview

* Water Balance
  * Observations
* Great Lakes Evaporation Network (GLEN)
* Lake Effect Snow
  * November 2014 Case Study
* Future Work
* Questions/References/Acknowledgements

Water Balance

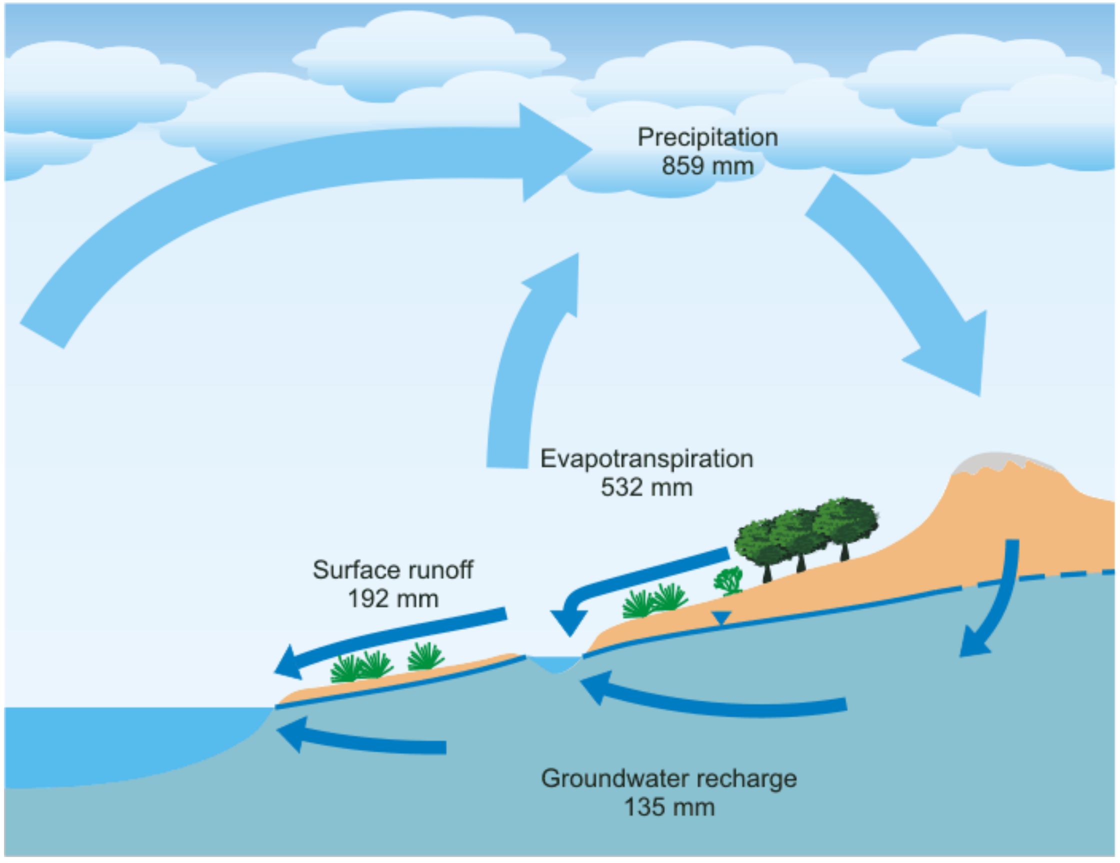
P = E – Fv - dQ/dt

P = Precipitation

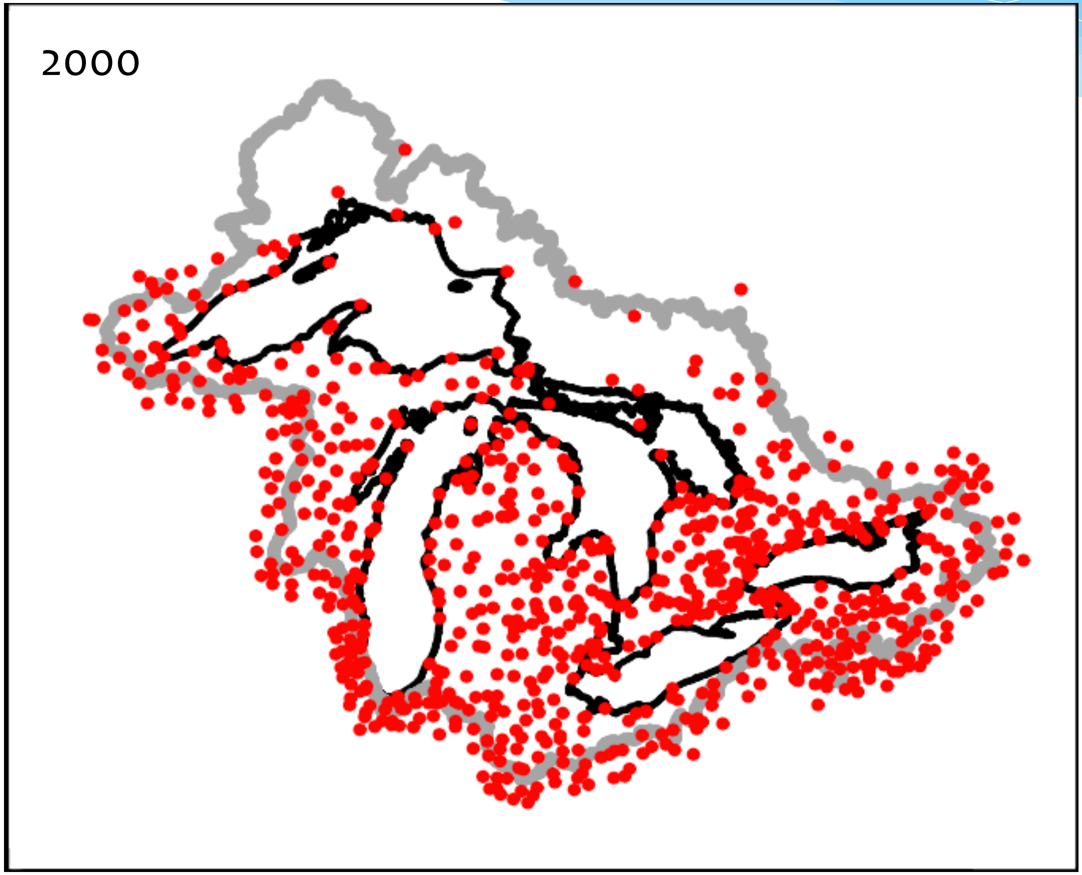
E = Evaporation

Fv = Horizontal Divergence

dQ/dt = change with time

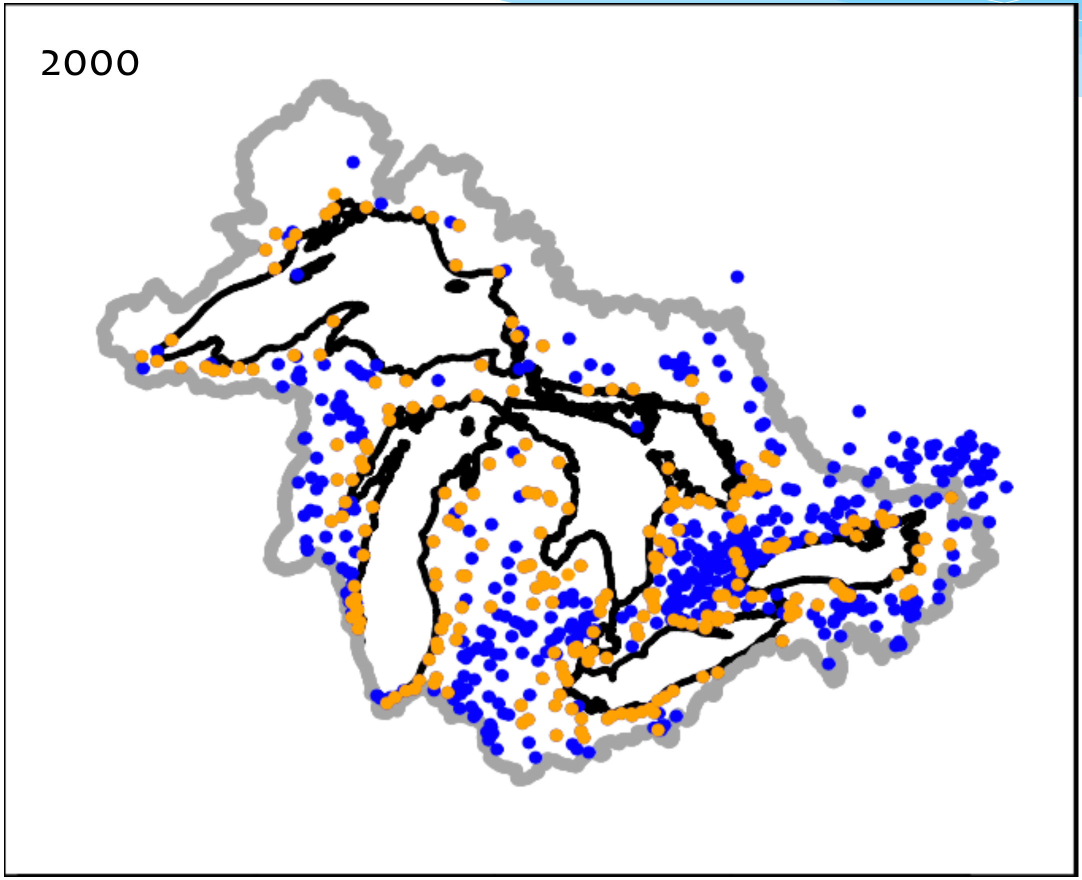


Precipitation



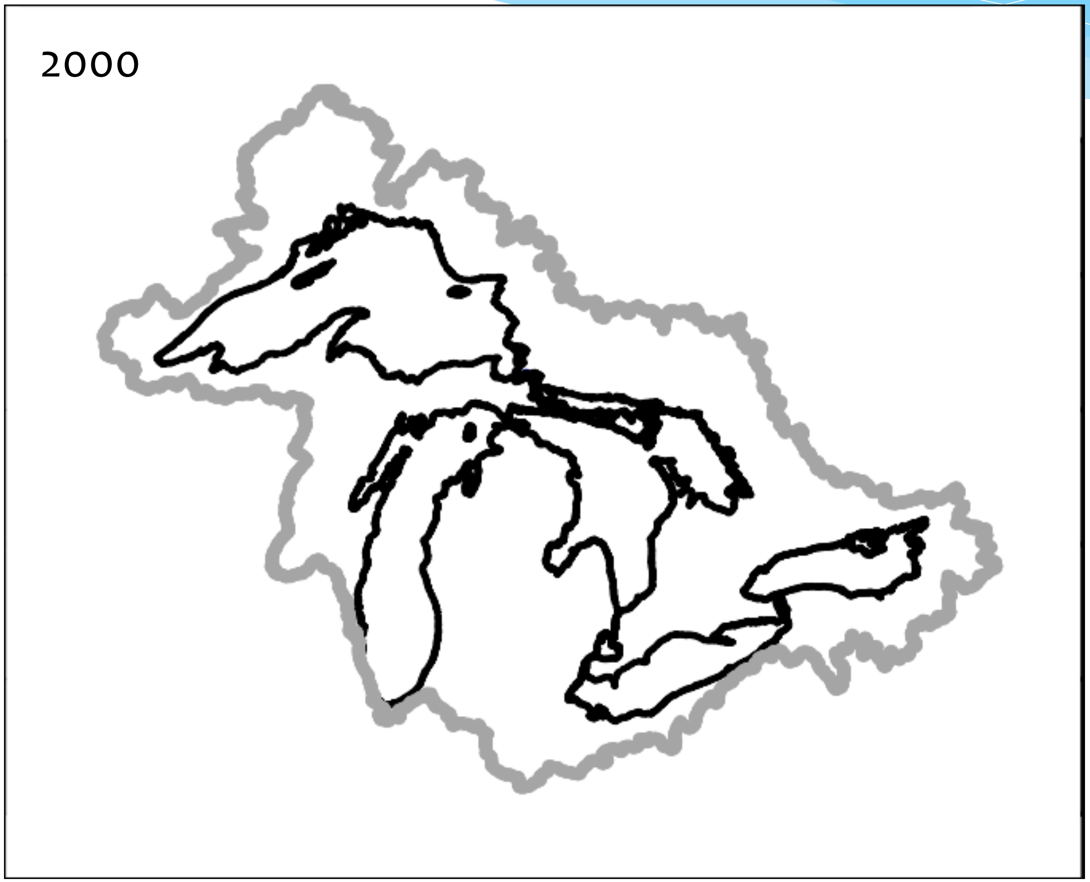
T.S. Hunter, et al. 2015

Runoff



T.S. Hunter, et al. 2015

Evaporation



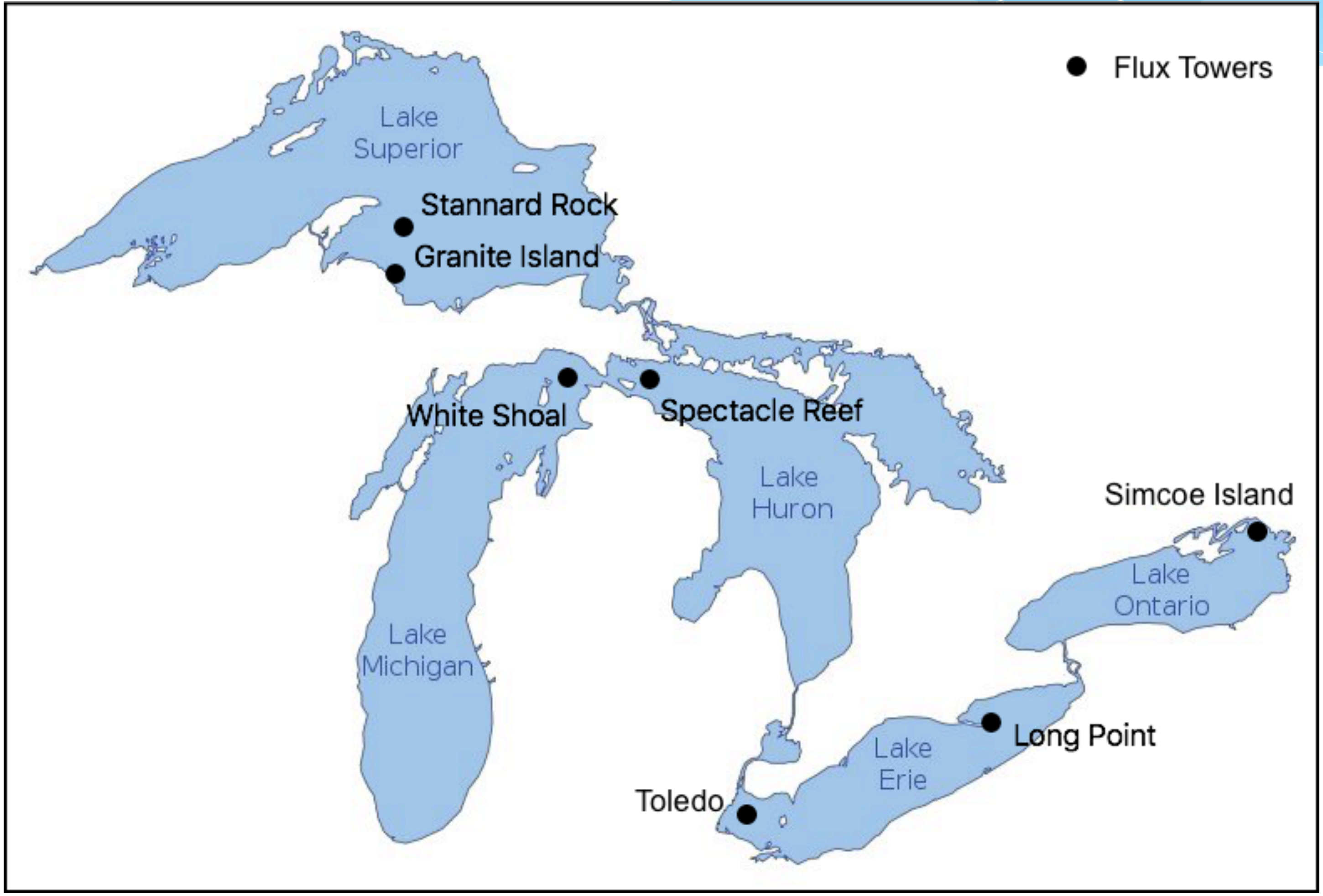
Great Lakes Evaporation Network

* Reduce uncertainty in water balance models
* International Joint Commission (IJC) funded project - 2008
* "Flux towers" installed in Superior and Huron
* Measure turbulent heat fluxes

Great Lakes Evaporation Network

Toledo Lighthouse #2

Great Lakes Evaporation Network



Great Lakes Evaporation Network

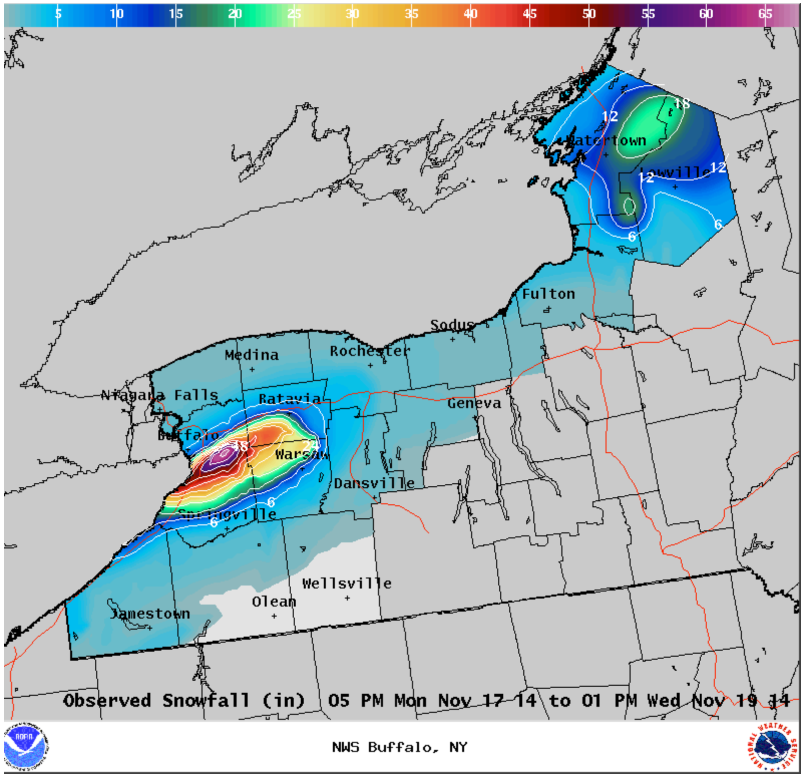
Can we use flux observations to analyze how evaporation contributes to lake effect snow?

November 2014 – near Buffalo, NY

http://www.iweathernet.com/educational/difference-between-single-vs-multiple-lake-effect-snow-bands#

Case Study

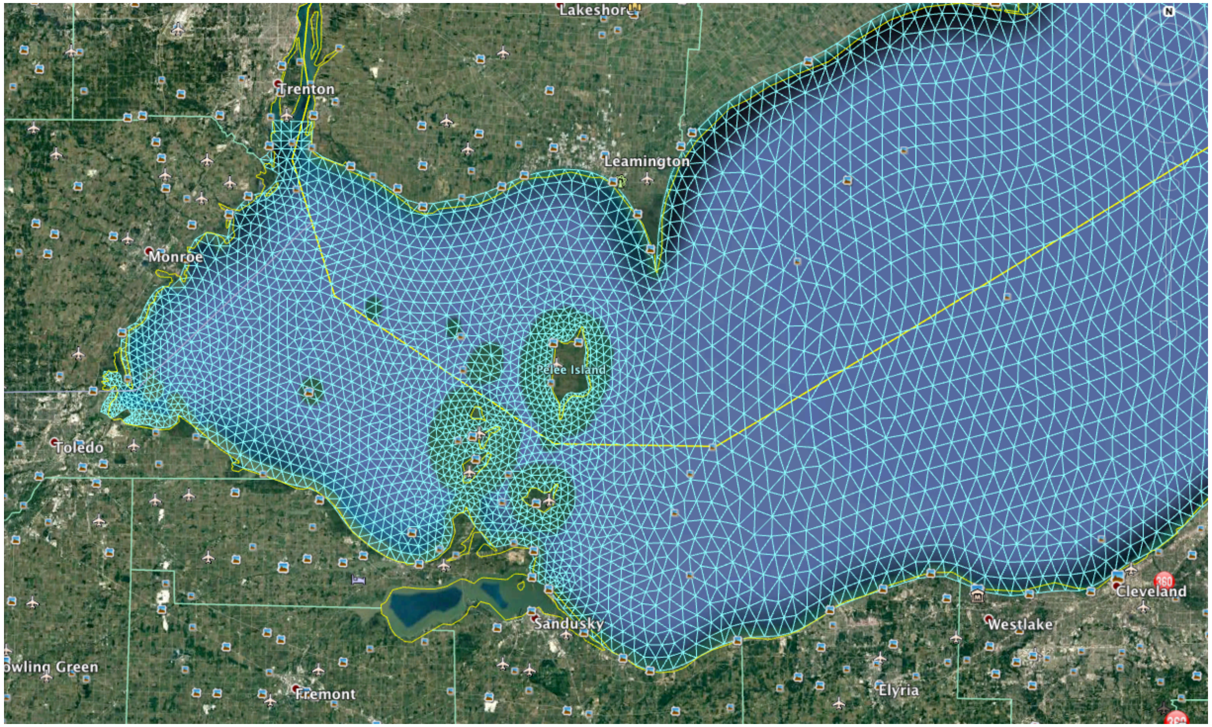
* November 2014 – areas near Buffalo, NY saw nearly 7ft of snow over a few days.
* Caused people to be stranded in cars on the highway, trapped in houses, shortage of food and supplies.
* Several fatalities



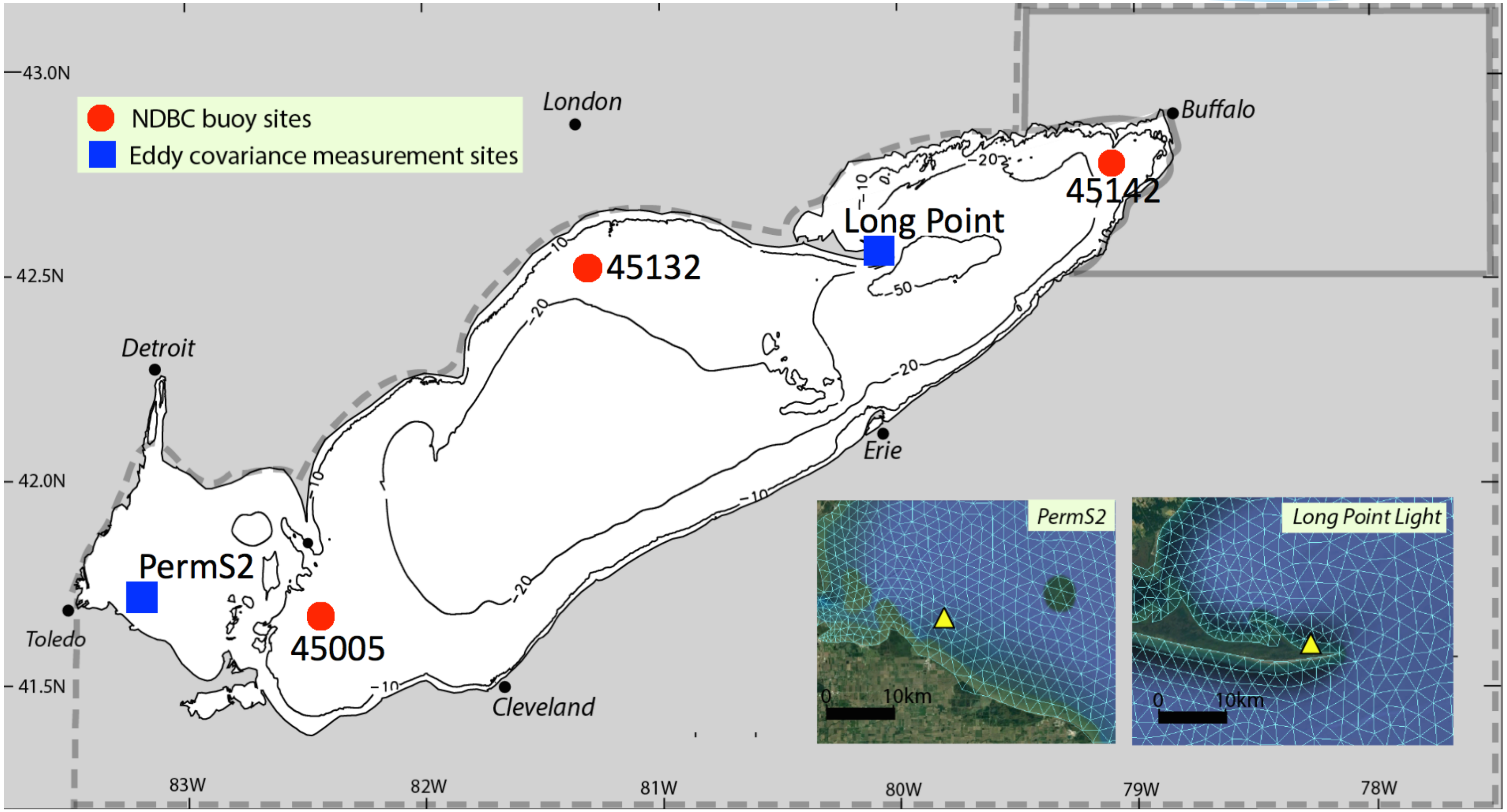
Case Study

* FVCOM – Finite-Volume Community Ocean Model
  * Unstructured grid
    * 100 m – 3 km
  * 3 algorithms
    * COARE
    * SOLAR
    * CICE
  * 3 met forcings
    * HRRR
    * Interp
    * CFSv2

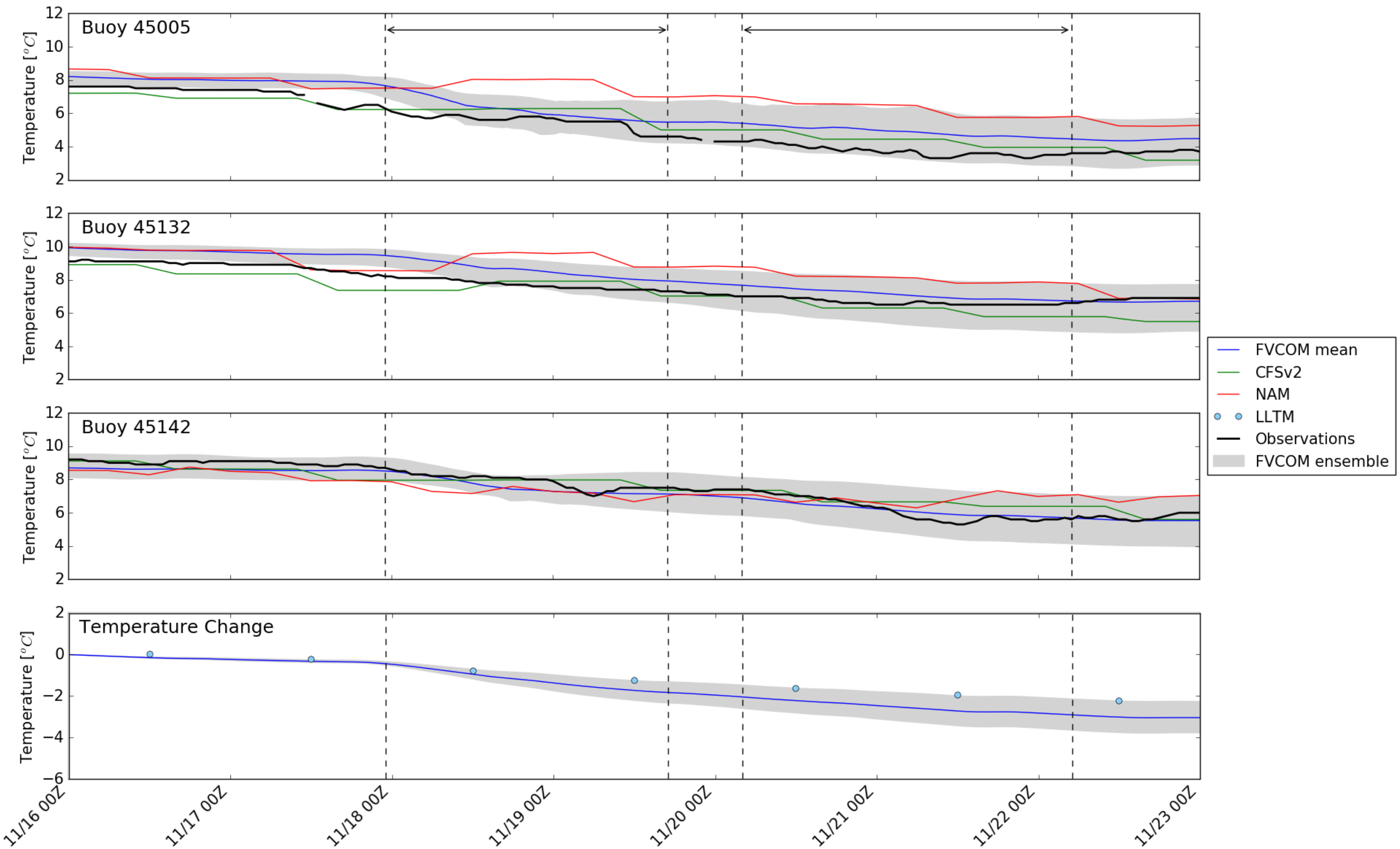
Lake Erie



Case Study

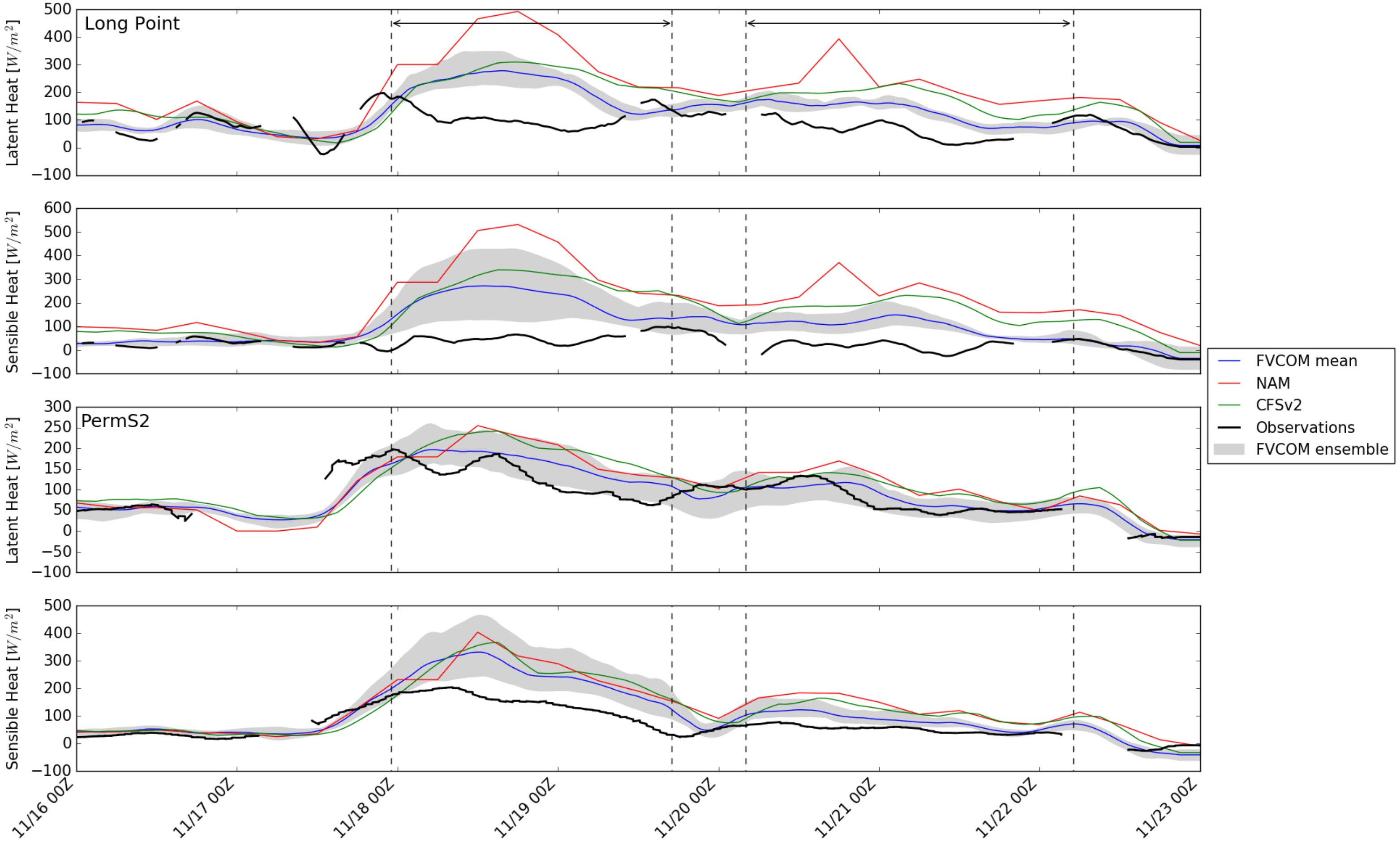

43.0N
42.5N
42.0N
41.5N
83W
82W
81W
80W
79W
78W
NDBC buoy sites
Eddy covariance measurement sites
London
Buffalo
Detroit
Toledo
Cleveland
Erie
45142
45132
45005
Long Point
PermS2
Long Point Light
0
10km

Case Study

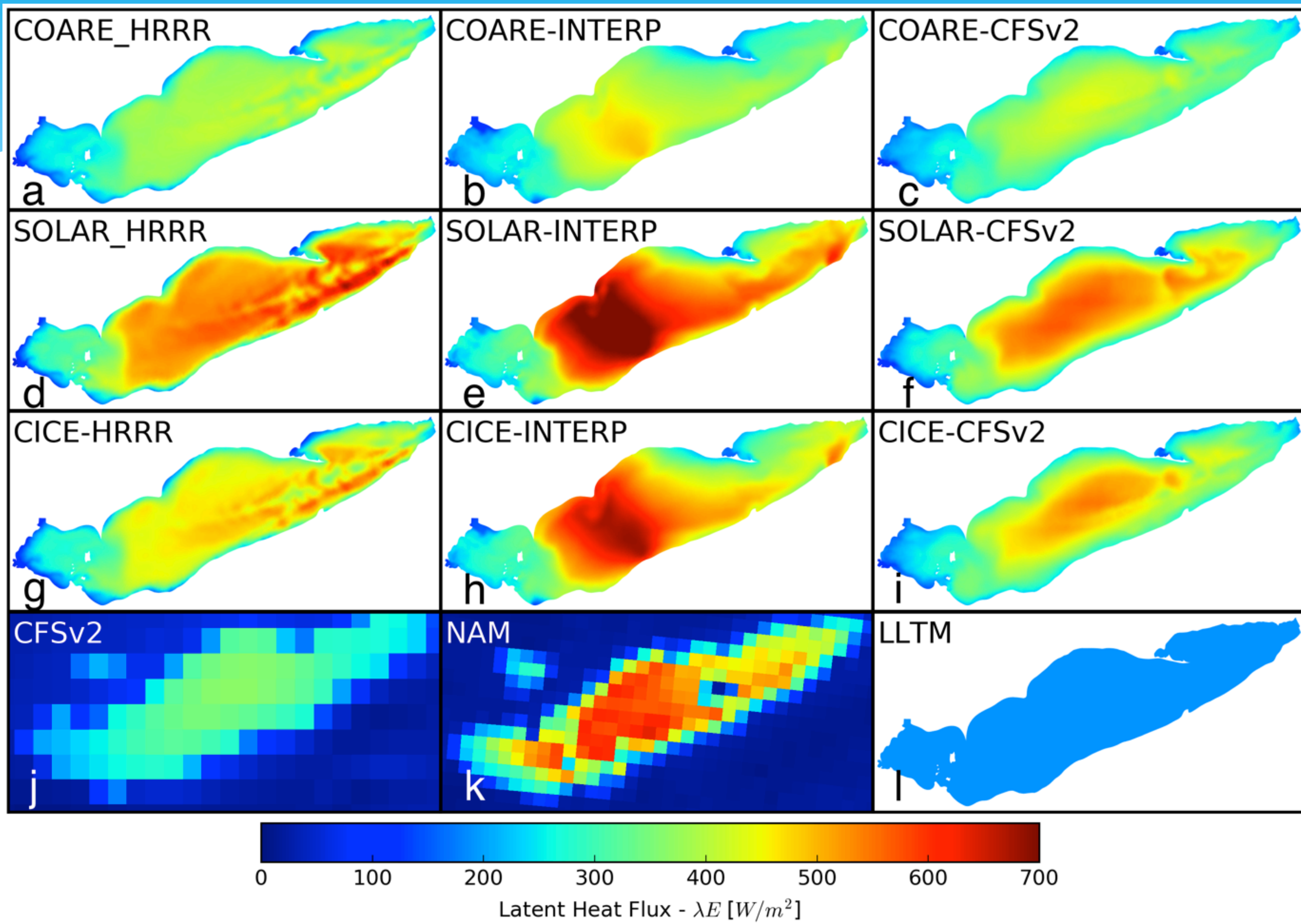


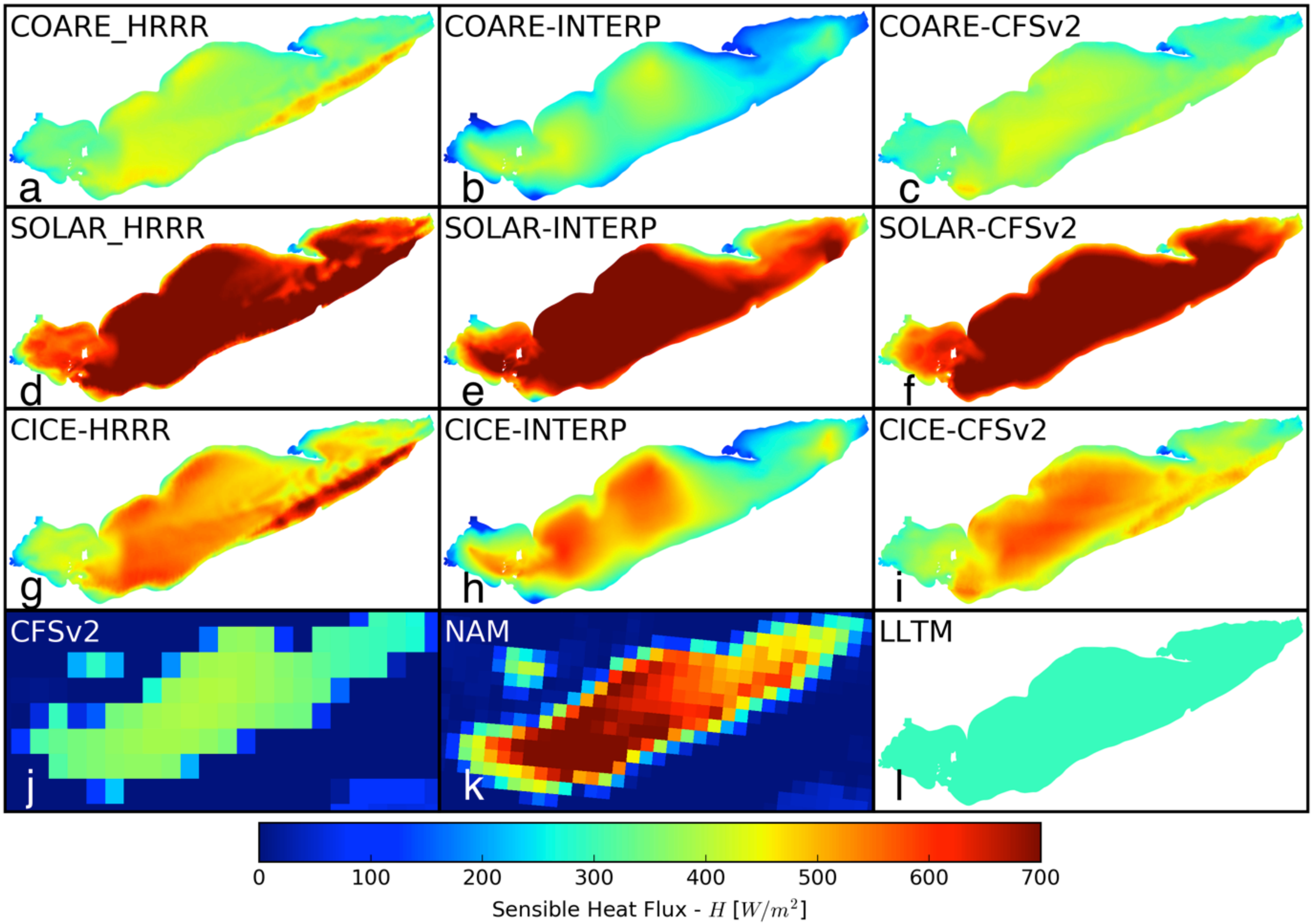
Buoy 45005
Buoy 45132
Buoy 45142
Temperature Change
Temperature [°C]
12
10
8
6
4
2
0
−2
−4
−6
11/16 00Z
11/17 00Z
11/18 00Z
11/19 00Z
11/20 00Z
11/21 00Z
11/22 00Z
11/23 00Z
FVCOM mean
CFSv2
NAM
LLTM
Observations
FVCOM ensemble

Case Study



Long Point
PermS2
Latent Heat [W/m^2]
Sensible Heat [W/m^2]
500
400
300
200
100
0
−100
600
250
150
50
−50
FVCOM mean
NAM
CFSv2
Observations
FVCOM ensemble
11/16 00Z
11/17 00Z
11/18 00Z
11/19 00Z
11/20 00Z
11/21 00Z
11/22 00Z
11/23 00Z


COARE_HRRR
a
COARE-INTERP
b
COARE-CFSv2
c
SOLAR_HRRR
d
SOLAR-INTERP
e
SOLAR-CFSv2
f
CICE-HRRR
g
CICE-INTERP
h
CICE-CFSv2
i
CFSv2
j
NAM
k
LLTM
l
0
100
200
300
400
500
600
700
Latent Heat Flux - λE $[W/m^2]$


COARE_HRRR
a
COARE-INTERP
b
COARE-CFSv2
c
SOLAR_HRRR
d
SOLAR-INTERP
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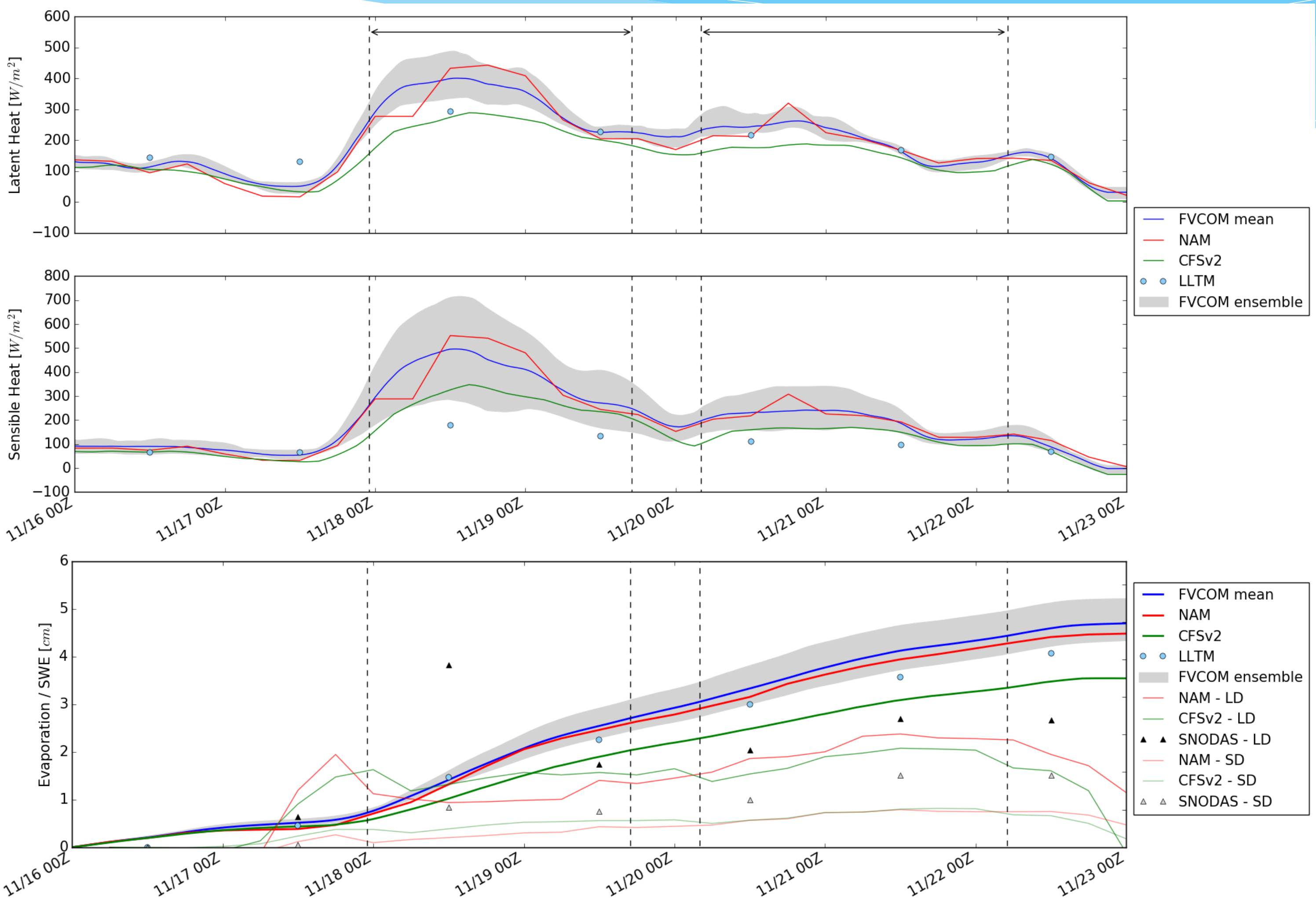
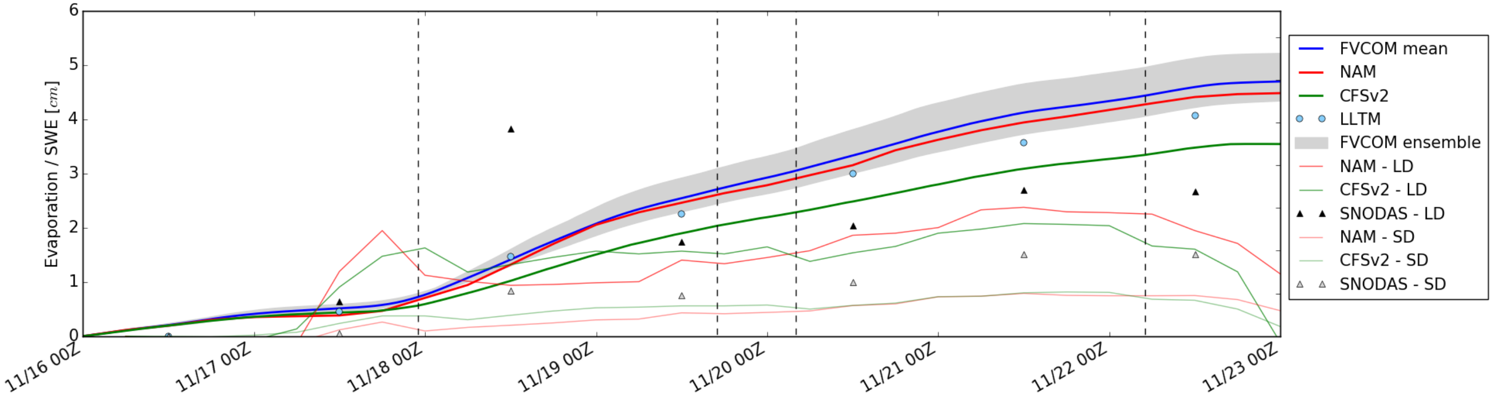
SOLAR-CFSv2
f
CICE-HRRR
g
CICE-INTERP
h
CICE-CFSv2
i
CFSv2
j
NAM
k
LLTM
l
0
100
200
300
400
500
600
700
Sensible Heat Flux - H $[W/m^2]$

Case Study

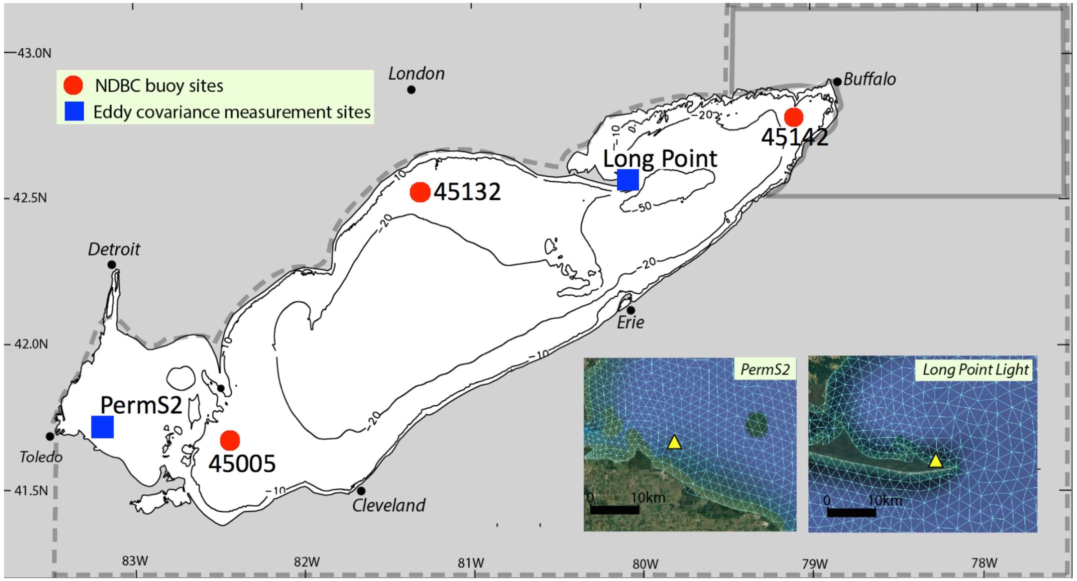


Latent Heat [W/m^2]
600
500
400
300
200
100
0
−100
Sensible Heat [W/m^2]
800
700
600
500
400
300
200
100
0
−100
11/16 00Z
11/17 00Z
11/18 00Z
11/19 00Z
11/20 00Z
11/21 00Z
11/22 00Z
11/23 00Z
FVCOM mean
NAM
CFSv2
LLTM
FVCOM ensemble
Evaporation / SWE [cm]
6
5
4
3
2
1
0
FVCOM mean
NAM
CFSv2
LLTM
FVCOM ensemble
NAM - LD
CFSv2 - LD
SNODAS - LD
NAM - SD
CFSv2 - SD
SNODAS - SD

Case Study



Evaporation / SWE [cm]
6
5
4
3
2
1
0
11/16 00Z
11/17 00Z
11/18 00Z
11/19 00Z
11/20 00Z
11/21 00Z
11/22 00Z
11/23 00Z
FVCOM mean
NAM
CFSv2
LLTM
FVCOM ensemble
NAM - LD
CFSv2 - LD
SNODAS - LD
NAM - SD
CFSv2 - SD
SNODAS - SD



NDBC buoy sites
Eddy covariance measurement sites
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42.5N
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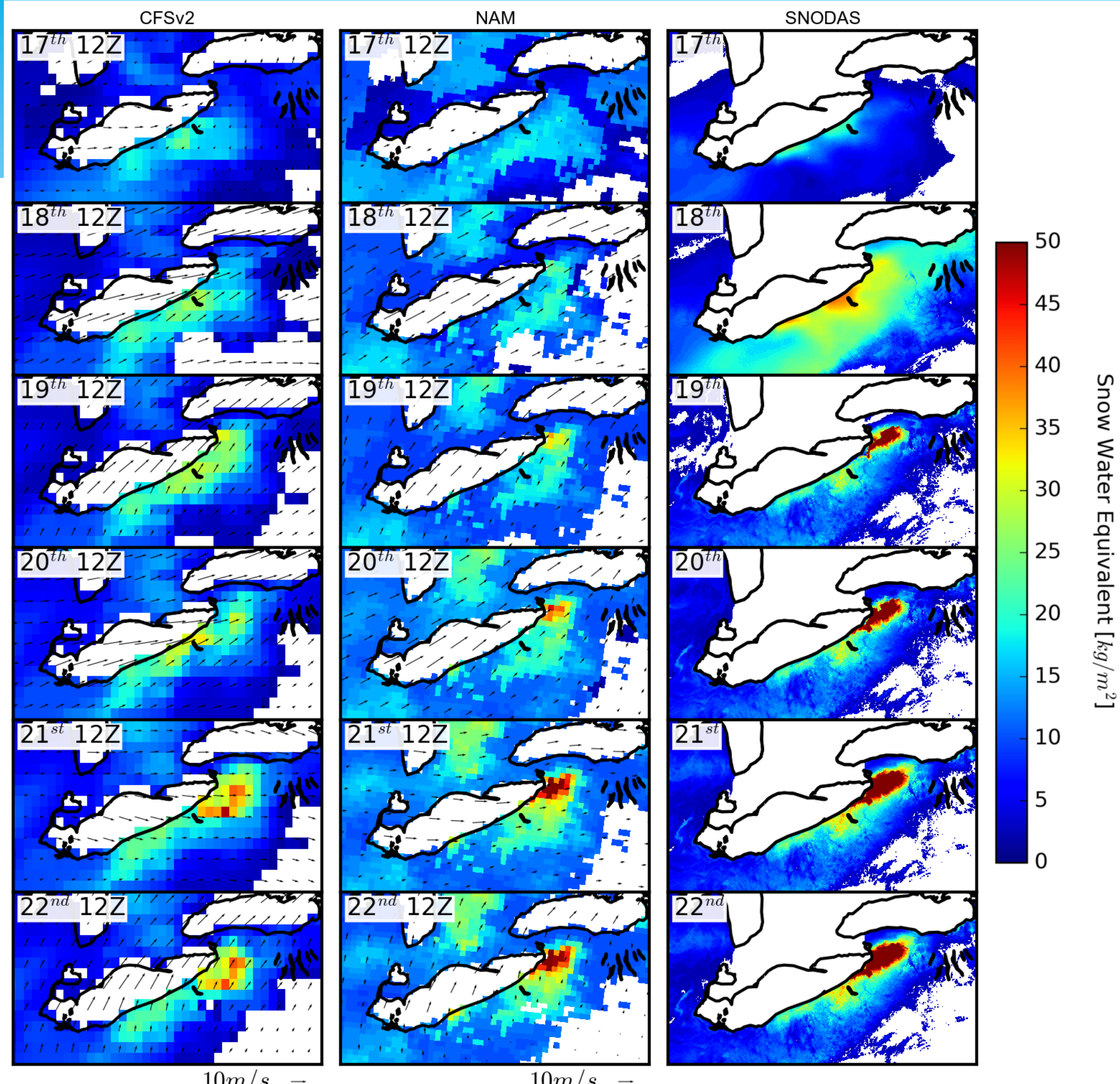
London
Buffalo
Detroit
Toledo
Erie
Cleveland
45142
45132
45005
Long Point
PermS2
Long Point Light
0
10km
83W
82W
81W
80W
79W
78W


CFSv2
NAM
SNODAS
17th 12Z
18th 12Z
19th 12Z
20th 12Z
21st 12Z
22nd 12Z
17th
18th
19th
20th
21st
22nd
10m/s
10m/s
Snow Water Equivalent [kg/m^2]
0
5
10
15
20
25
30
35
40
45
50

Turbulent Heat Fluxes during an Extreme Lake-Effect Snow Event

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ABSTRACT

Proper modeling of the turbulent heat fluxes over lakes is critical for accurate predictions of lake-effect snowfall (LES). However, model evaluation of such a process has not been possible because of the lack of direct flux measurements over lakes. The authors conducted the first-ever comparison of the turbulent latent and sensible heat fluxes between state-of-the-art numerical models and direct flux measurements over Lake Erie, focusing on a record LES event in southwest New York in November 2014. The model suite consisted of numerical models that were operationally and experimentally used to provide nowcasts and forecasts of weather and lake conditions. The models captured the rise of the observed turbulent heat fluxes, while the peak values varied significantly. This variation resulted in an increased spread of simulated lake temperature and cumulative evaporation as the representation of the model uncertainty. The water budget analysis of the atmospheric model results showed that the majority of the moisture during this event came from lake evaporation rather than a larger synoptic system. The unstructured-grid Finite-Volume Community Ocean Model (FVCOM) simulations, especially those using the Coupled Ocean–Atmosphere Response Experiment (COARE)-Met Flux algorithm, presented better agreement with the observed fluxes likely due to the model's capability in representing the detailed spatial patterns of the turbulent heat fluxes and the COARE algorithm's more realistic treatment of the surface boundary layer than those in the other models.

1. Introduction

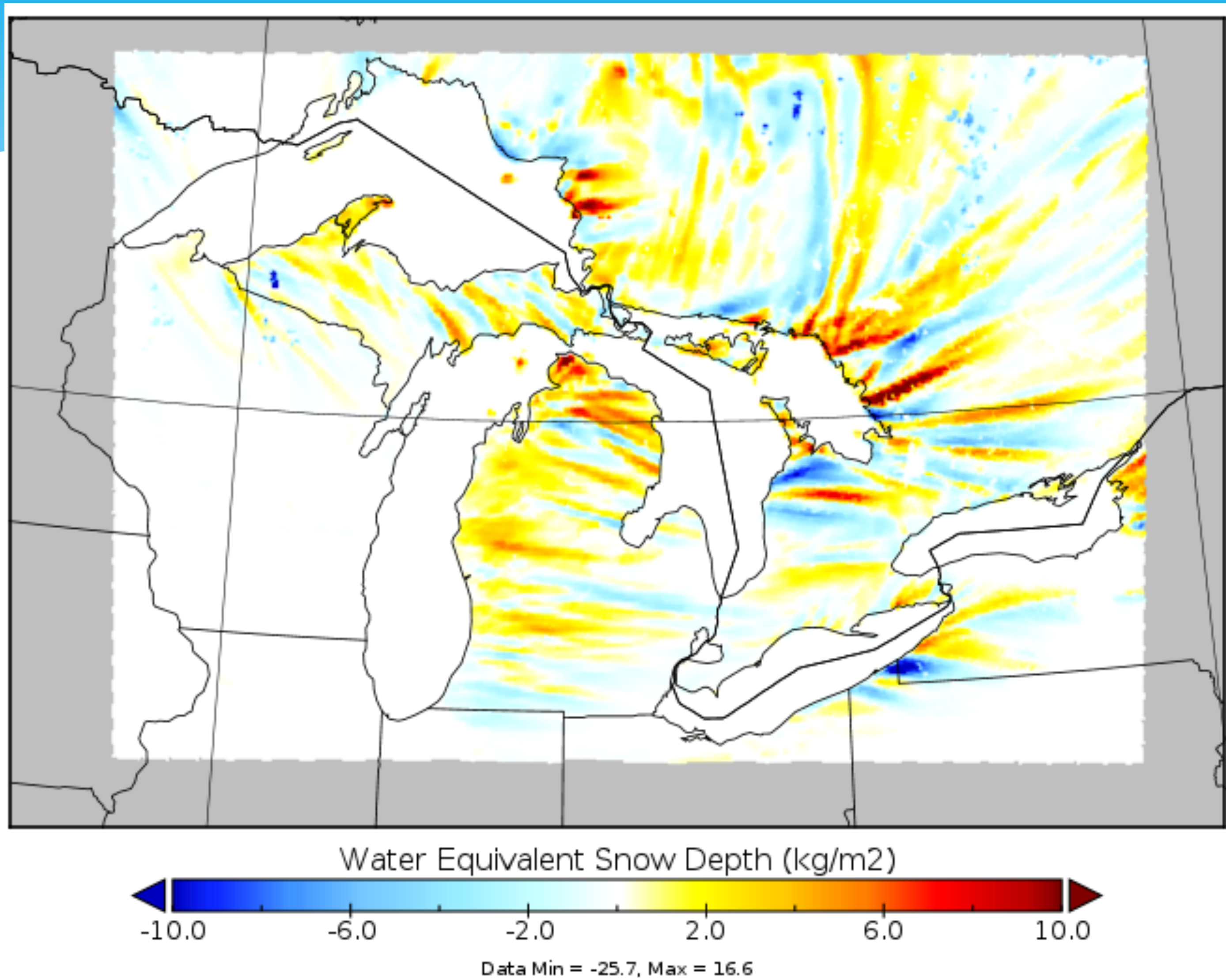
Communities around the world are becoming increasingly dependent on numerical geophysical model–based forecasts in order to prepare for and respond to hazardous mesoscale weather and hydrologic events

forcing) propagate into variability within a forecast ensemble. This understanding is particularly important for improving lake-effect snow (LES) forecasts, partly because there is often sparse monitoring data for verifying simulations of the turbulent heat fluxes from the lake surface, and partly because of the severe impacts LES

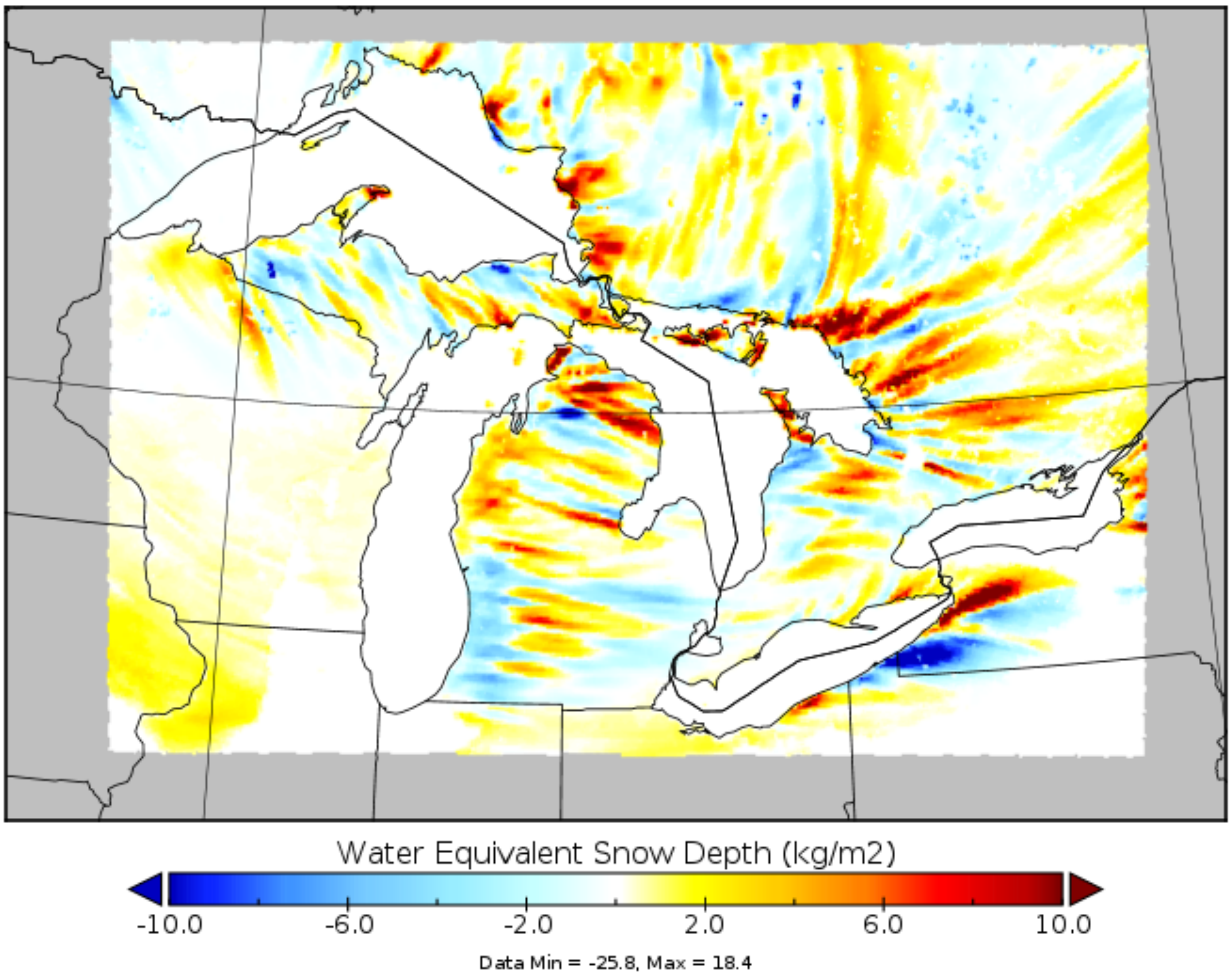
Big Picture Questions

* Can we use this to increase the accuracy of lake effect snow events in the Great Lakes?

* Can we use dynamic SSTs from FVCOM in operational models?



HRRRv3 (FVCOM dynamic SSTs) – HRRv3 (static RTGSSTs)



HRRRv3+ (FVCOM dynamic SSTs) – HRRv3 (static RTGSSTs)

Questions?

Acknowledgements and References

* This project was supported by NOAA's Costal Storms Project (CSP)
* Current and future research supported by the Office of Weather and Air Quality (OWAQ)
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Fujisaki-Manome, A., L. Fitzpatrick, A. Gronewold, E.J. Anderson, C. Spence, J. Chen, C. Shao, D. Wright, C. Xiao, 2017: Turbulent Heat Fluxes during an Extreme Lake Effect Snow Event, Journal of Hydrometerorology, doi: 10.1175/JHM-D-17-0062.1

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TABLE 1. Twelve model runs used in the study.

ID	Name	Core physical model	Flux algorithm	Boundary conditions	Lake physics	Horizontal resolution/data interval	Other
1	NAM	WRF Model	Łobocki (1993)	GFS, RTG_SST_HR (water surface temperature initial conditions)	Treated as ocean cells in MOM	12 km/6 hourly	Rogers et al. (2009), Janjić and Gall (2012); microphysics: Aligo et al. (2017)
2	CFSv2	GSM and MOM	Long (1986, 1990)	—		0.2° (~17 km)/ hourly	Saha et al. (2010, 2014); microphysics: Zhao and Carr (1997), Moorthi et al. (2016)
3	FVCOM	The unstructured-grid Finite-Volume Community Ocean Model	COARE (Fairall et al. 1996a,b)	HRRR	3D hydrodynamic model	200 m (nearshore)–3 km (offshore)/ hourly	
4				Interp			
5				CFSv2			
6			LS87 (Liu and Schwab 1987)	HRRR			
7				Interp			
8				CFSv2			
9			J99 (Jordan et al. 1999; Hunke et al. 2015)	HRRR			
10				Interp			
11				CFSv2			
12	LLTM	Large Lake Thermodynamic Model	Croley (1989b)	Integrated Surface Hourly Database	1D thermodynamic model based on a lumped parameter	Lake average/ daily	Hunter et al. (2015); Croley (1989a,b)