Hindcast Validation of Shallow Water Wave Processes in the Great Lakes using Unstructured Spectral Models

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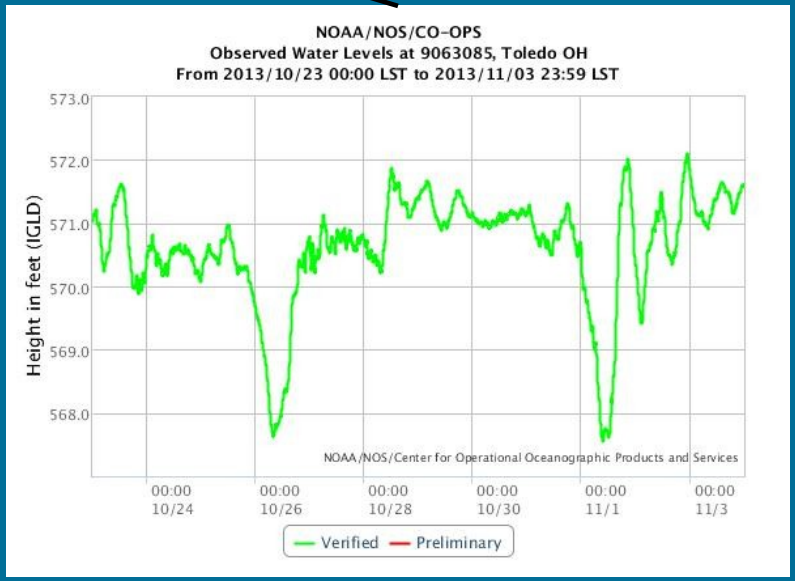
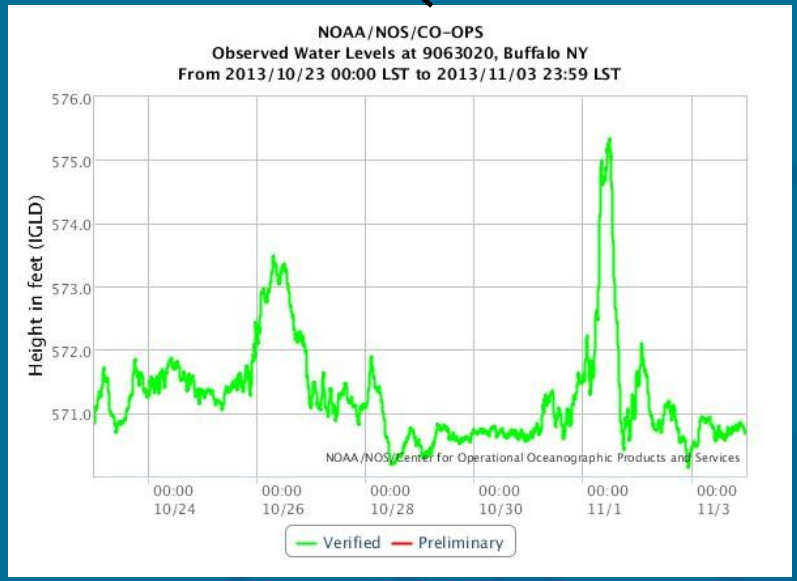
Contents

1. Introduction of project aim
2. Discussion of methods
3. Wind input
4. Grid development
5. Results and analysis
6. Coupled modeling

Motivation

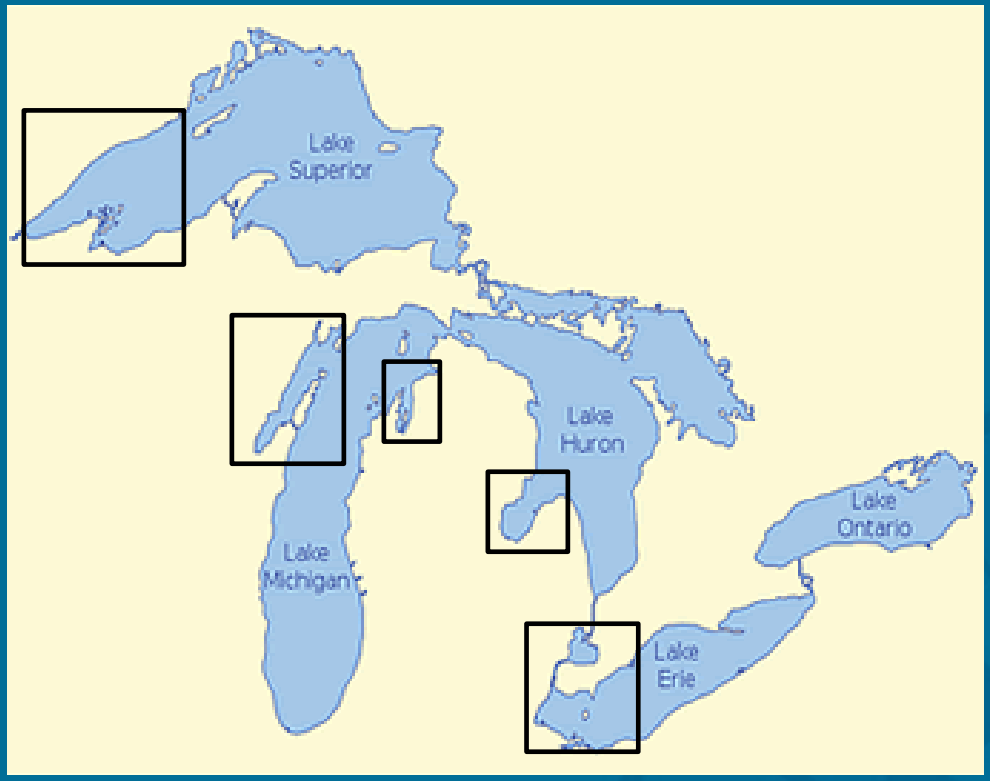
Lake Erie hindcast: Oct 23-Nov 3 2013





Study aim

Develop an operational coupled wave and 3D circulation model, run on a common unstructured grid, and forced by a high-resolution atmospheric model and ice model. Focus on coastal hazards in shallow regions.



Study Approach

Advanced meteorology forcing field

Use the WRF weather model to produce high resolution wind field (12km/4km/1km)

High-resolution unstructured mesh

Develop high-resolution grid (from ~2000m to 200m coastal resolution) to resolve multiple wave processes.

Configuration of WAVEWATCH III wave physics

- Standard ST4 physics (Ardhuin et al 2010, hereafter A10)

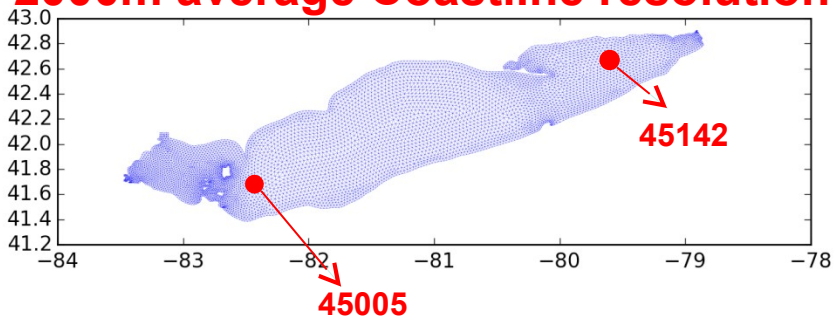
- Modified ST4 physics (Filipot & Ardhuin 2012, hereafter FA12)

Circulation-Wave coupled modeling

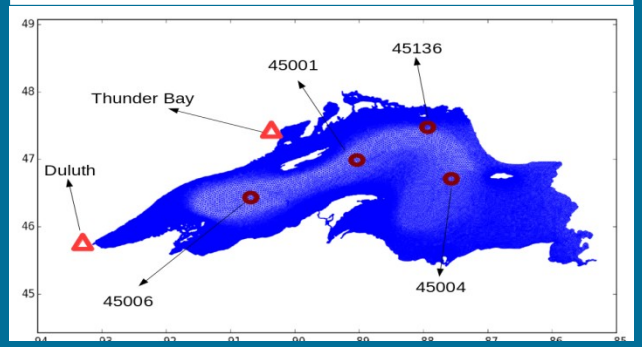
Integrate 3-D baroclinic circulation model FVCOM with 3rd generation wave model WAVEWATCH III

Grid Development

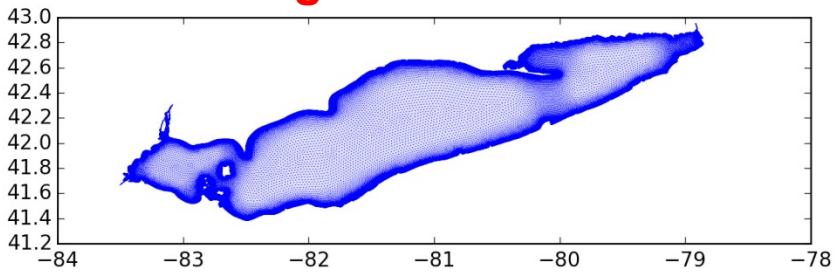
~2000m average Coastline resolution



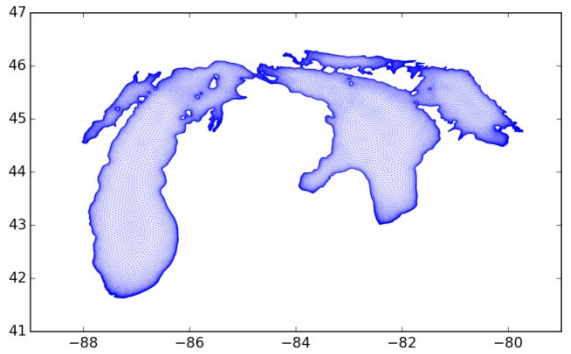
~500m average Coastline resolution



~200m average Coastline resolution

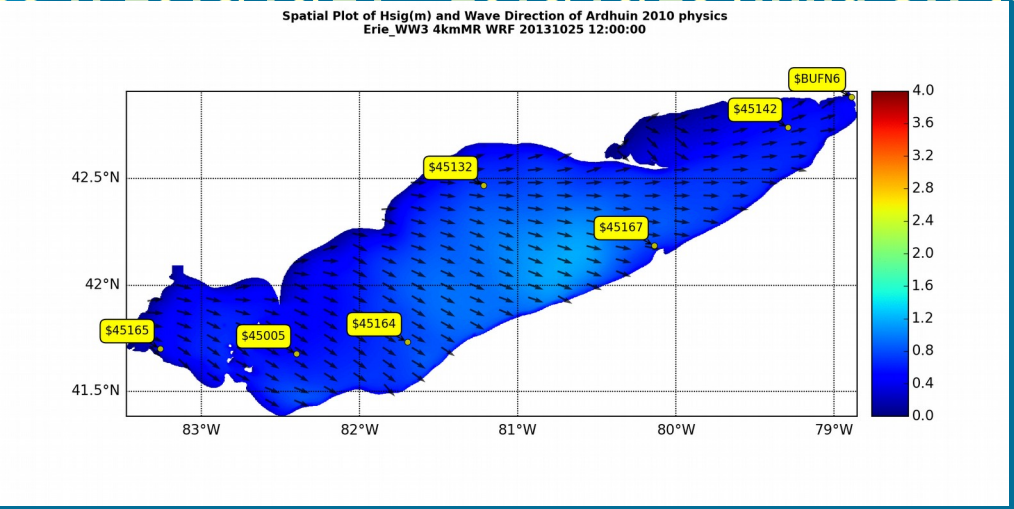


~500m average Coastline resolution

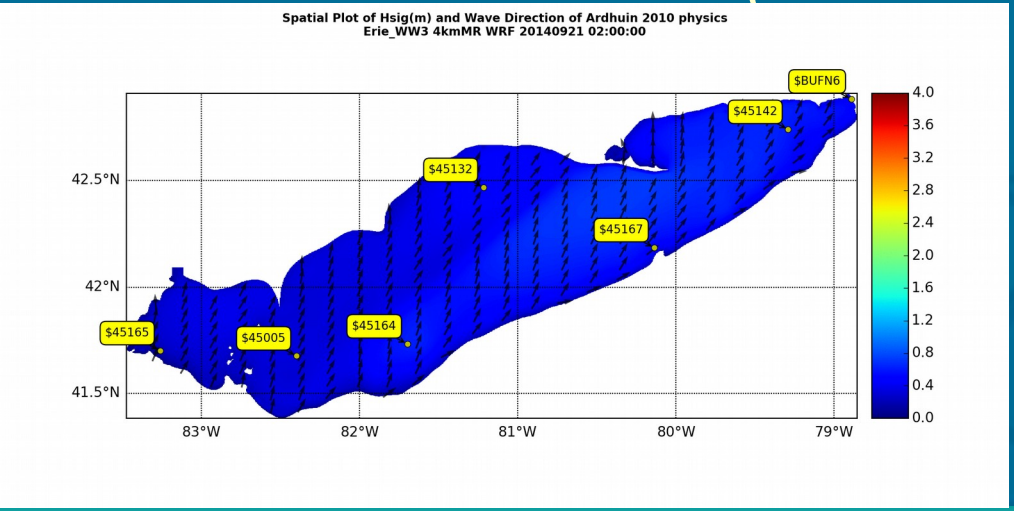


Hindcast cases: L Erie

Case 1: 2013/10/24 – 2013/10/28 (wind SW to NE)

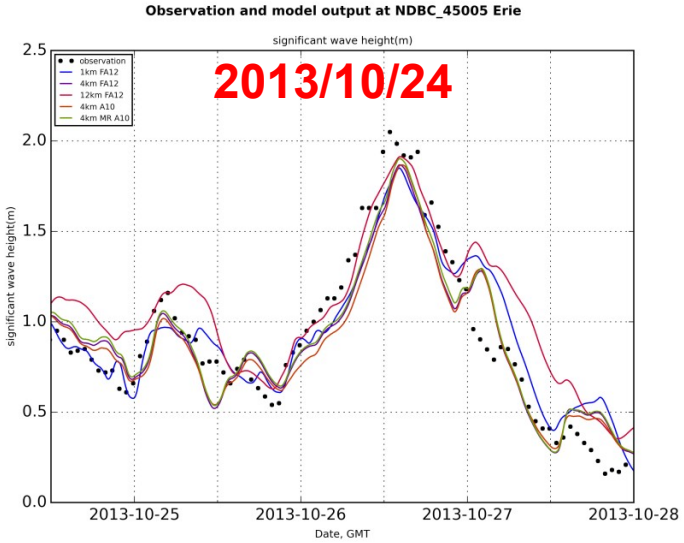


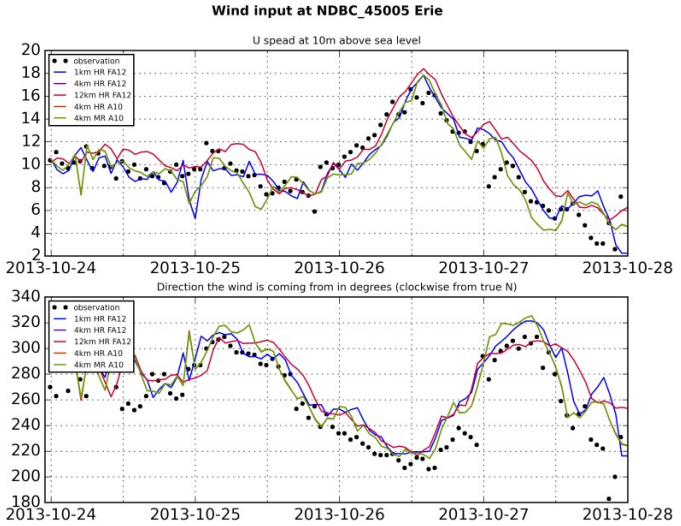
Case 2: 2014/09/20 – 2014/09/23 (wind NW to SE)

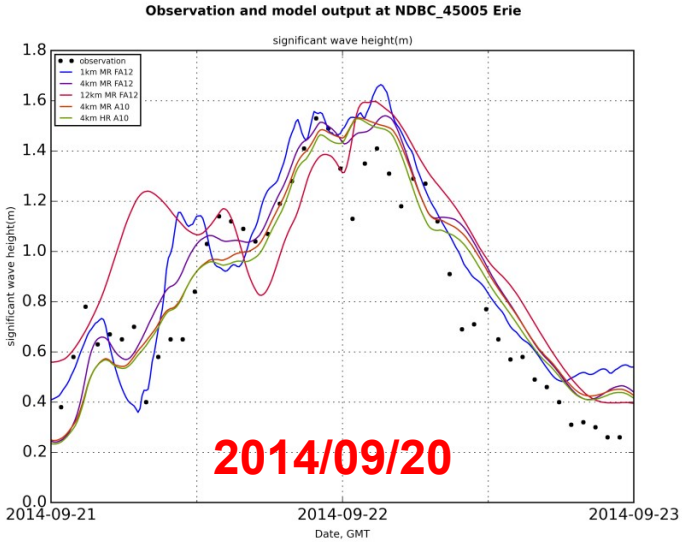


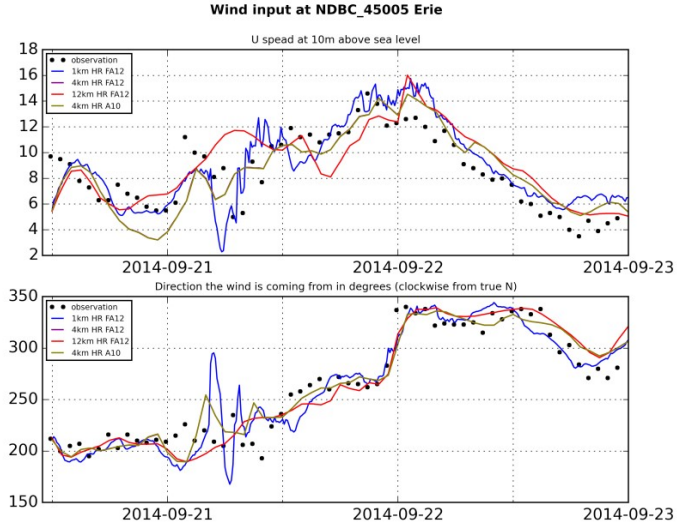
Hindcast results: 45005, L Erie

1km WRF FA12
4km WRF FA12
12km WRF FA12
4km HR WRF A10
4km MR WRF A10

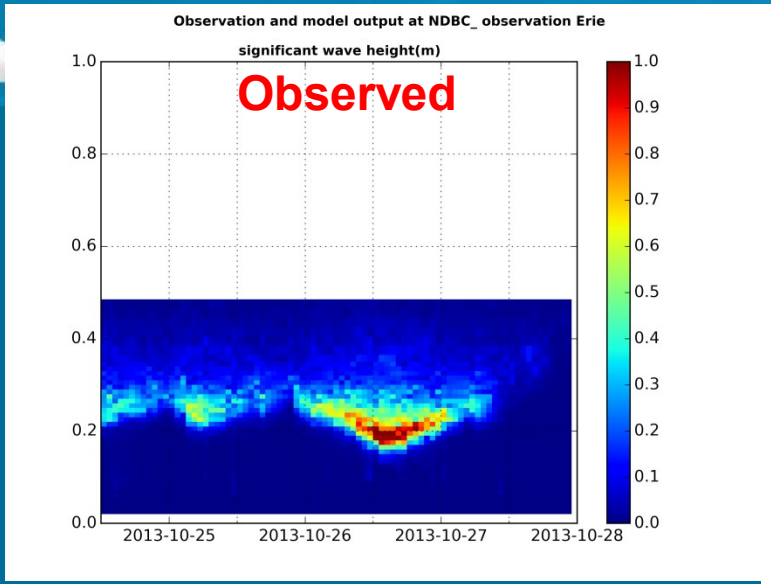


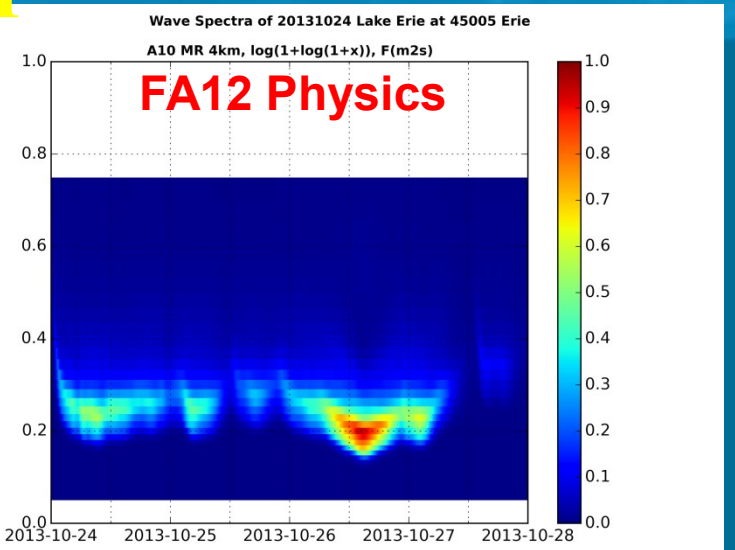


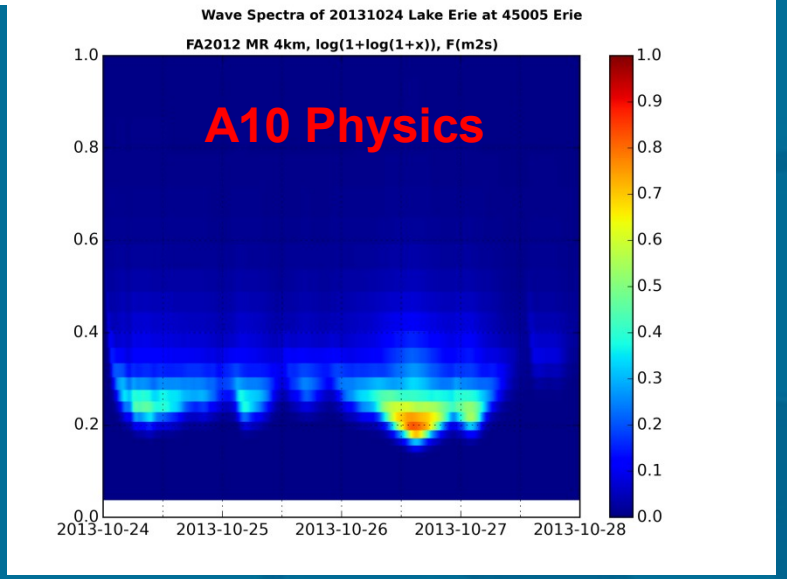




Hindcast results: Spectral evolution

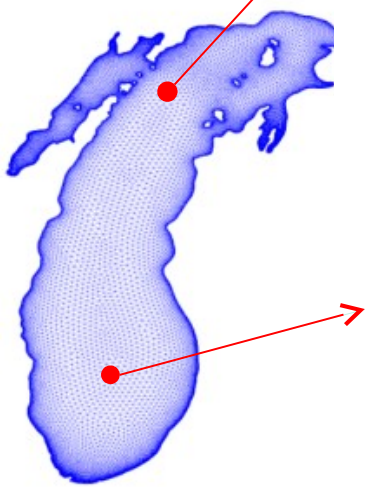


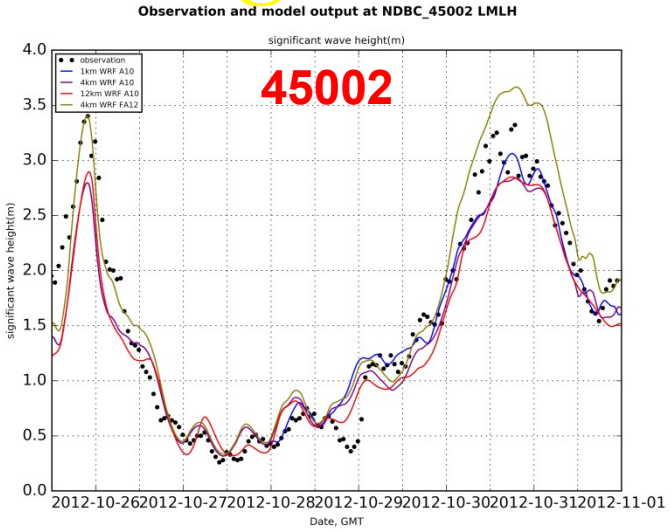


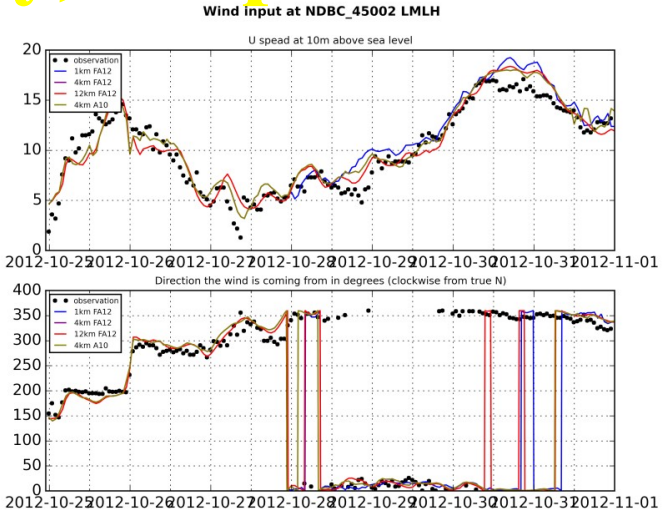


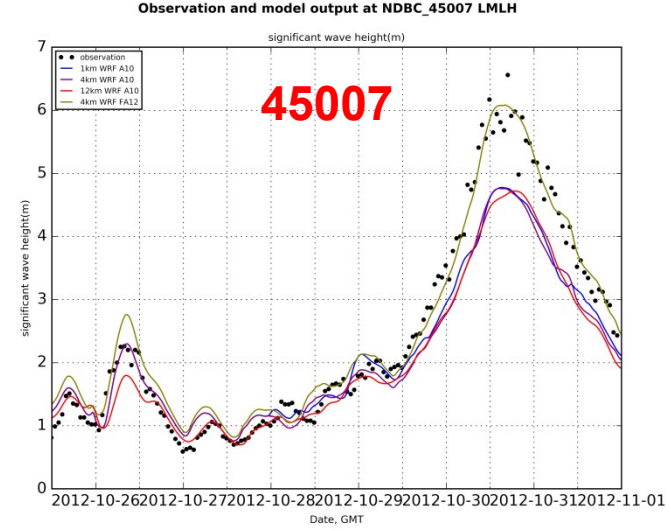
L Michigan: S. Sandy, deep water

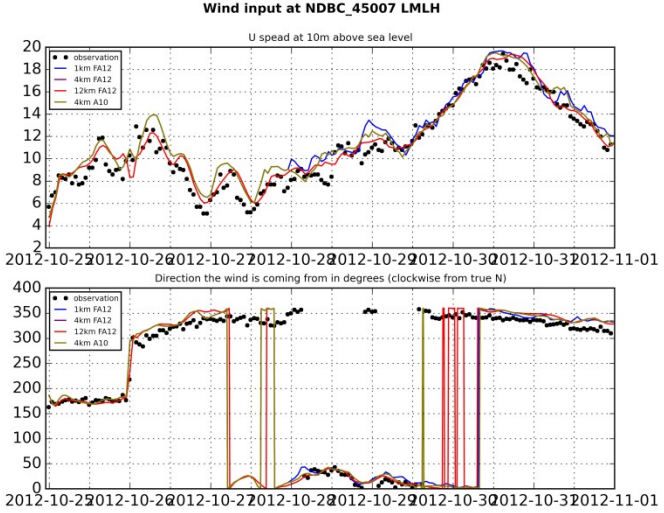
1km WRF A10
4km WRF A10
12km WRF A10
4km WRF FA12





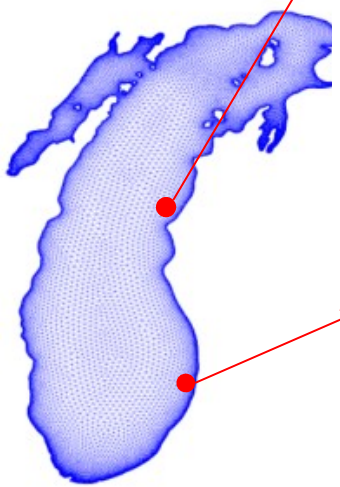


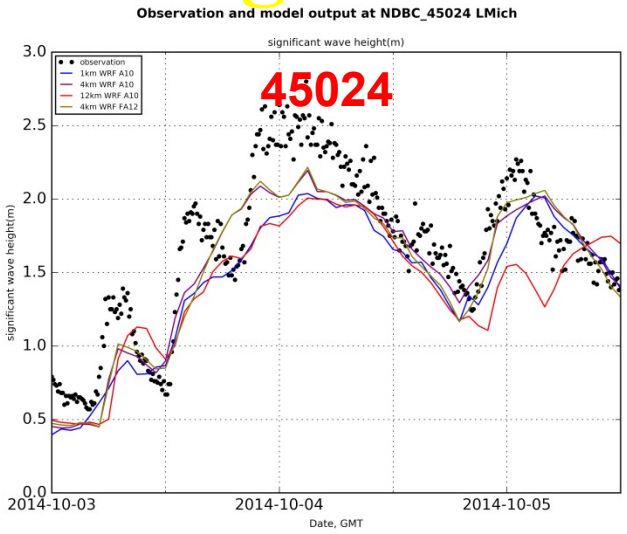


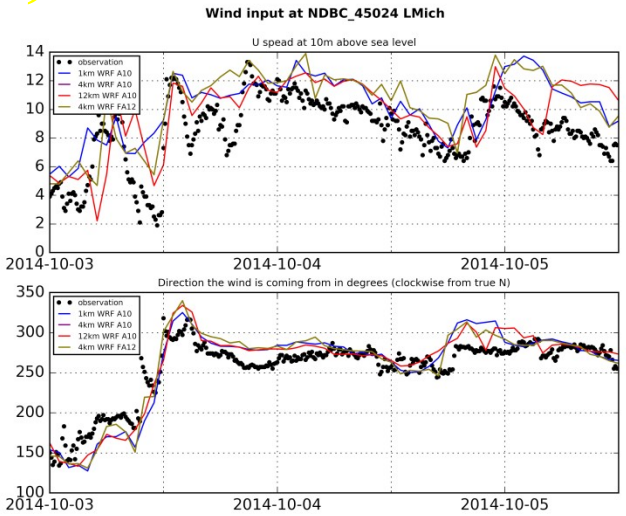


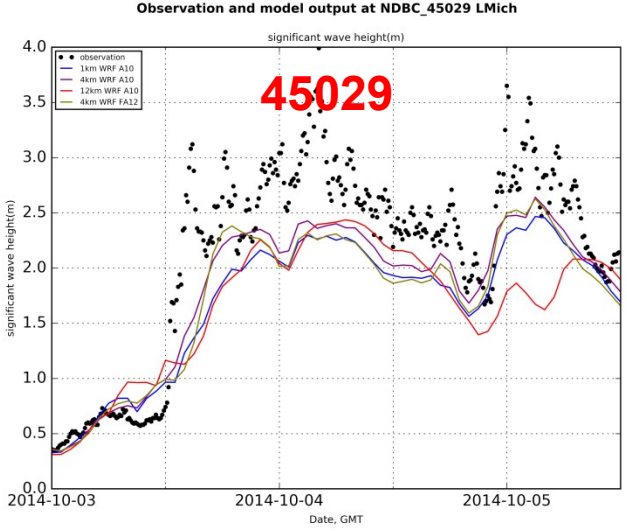
L Michigan: 2014/10, shallow water

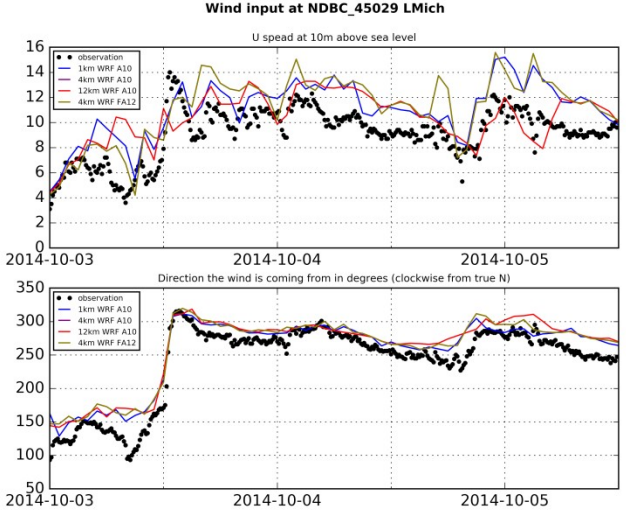
1km WRF A10
4km WRF A10
12km WRF A10
4km WRF FA12



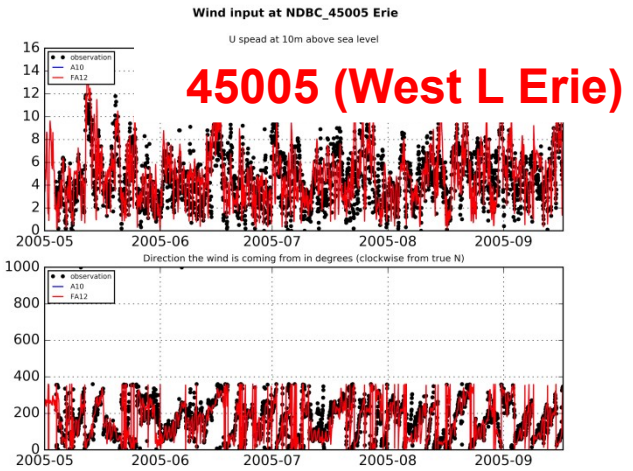




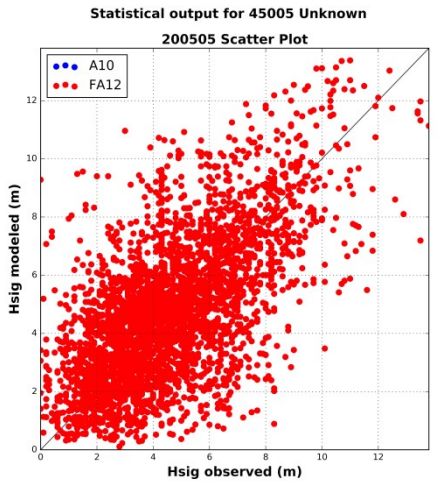




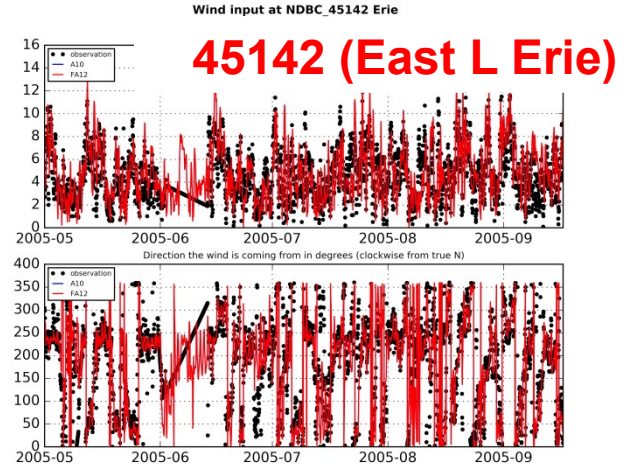
2005 Hindcast: Wind speed of 12km WRF



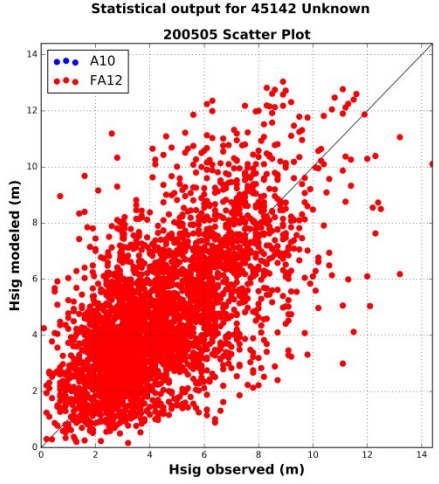
45005 (West L Erie)



Statistics	12km WRF
Rel. bias	0.043
RMSE(m)	0.147
SI	0.437



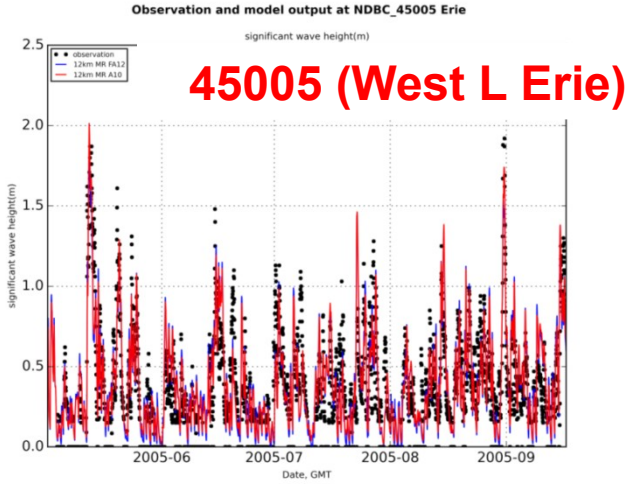
45142 (East L Erie)



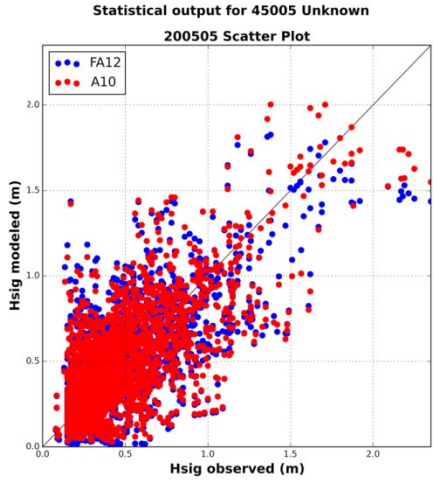
Statistics	12km WRF
Rel. bias	0.067
RMSE(m)	0.139
SI	0.448

2005 Hindcast: Significant wave height

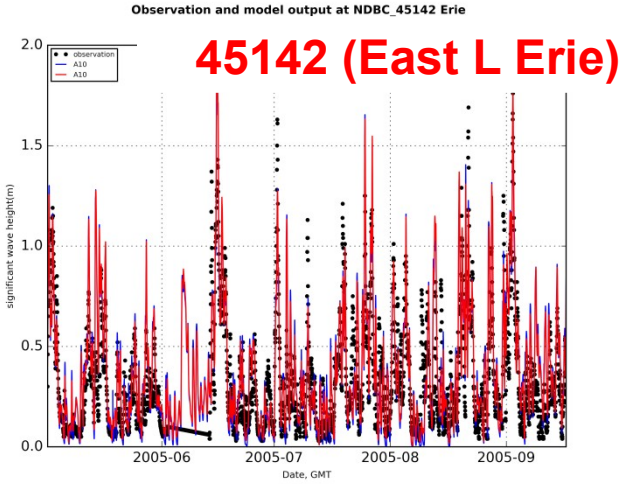
Forced by 12km WRF wind



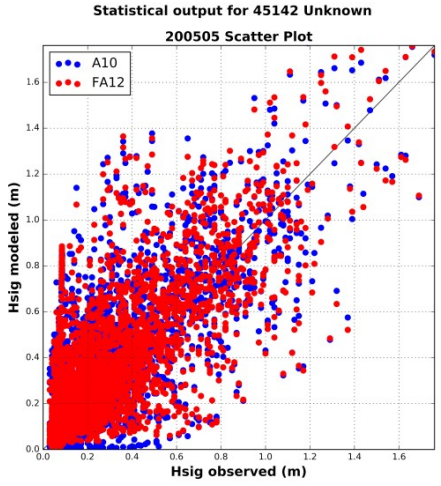
45005 (West L Erie)



Statistics	FA12	A10
Rel. bias	0.025	0.022
RMSE (m)	0.105	0.107
SI	0.489	0.501



45142 (East L Erie)



Statistics	FA12	A10
Rel. bias	0.141	0.140
RMSE (m)	0.111	0.115
SI	0.572	0.593

Sample statistics – wind field

Bias (m)/Relative Bias (-)

	1km WRF	4km WRF	12km WRF
2013/10/24 – 2013/10/28, L Erie			
45005	0.035/ 0.038	-0.012/ -0.013	0.161/ 0.175
45132	-0.118/ -0.082	-0.170/ -0.119	-0.035/ -0.024
45142	-0.350/ -0.187	-0.429/ -0.230	-0.271/ -0.145
2014/09/20 – 2014/09/23, L Erie			
45005	0.071/ 0.087	0.022/ 0.028	0.105/ 0.128
45132	-0.005/ -0.005	-0.010/ -0.010	-0.001/ -0.001
45142	-0.142/ -0.112	-0.108/ -0.085	-0.195/ -0.154
45167	-0.083/ -0.073	-0.112/ -0.098	-0.149/ -0.130

RMSE (m)/Normalized RMSE (-)

	1km WRF	4km WRF	12km WRF
2013/10/24 – 2013/10/28, L Erie			
45005	0.179/ 0.095	0.159/ 0.084	0.179/ 0.095
45132	0.366/ 0.111	0.363/ 0.110	0.366/ 0.111
45142	0.361/ 0.139	0.333/ 0.128	0.389/ 0.149
2014/09/20 – 2014/09/23, L Erie			
45005	0.180/ 0.142	0.183/ 0.144	0.225/ 0.177
45132	0.215/ 0.165	0.229/ 0.176	0.244/ 0.188
45142	0.306/ 0.180	0.266/ 0.156	0.359/ 0.211
45167	0.240/ 0.166	0.184/ 0.128	0.240 / 0.167

Comparison of wave physics

Bias (m)/Relative Bias (-)

	A10	FA12
2012/10/25 – 2012/11/01 (Sandy), L Michigan and Huron		
45002	-0.107/-0.071	0.142/0.094
45007	-0.261/-0.112	0.132/0.057
45003	-0.126/-0.078	0.111/0.069
45008	-0.293/-0.131	0.075/0.033
45137	-0.107/-0.072	0.108/0.072
45149	-0.425/-0.179	-0.046/-0.020

RMSE (m)/Normalized RMSE (-)

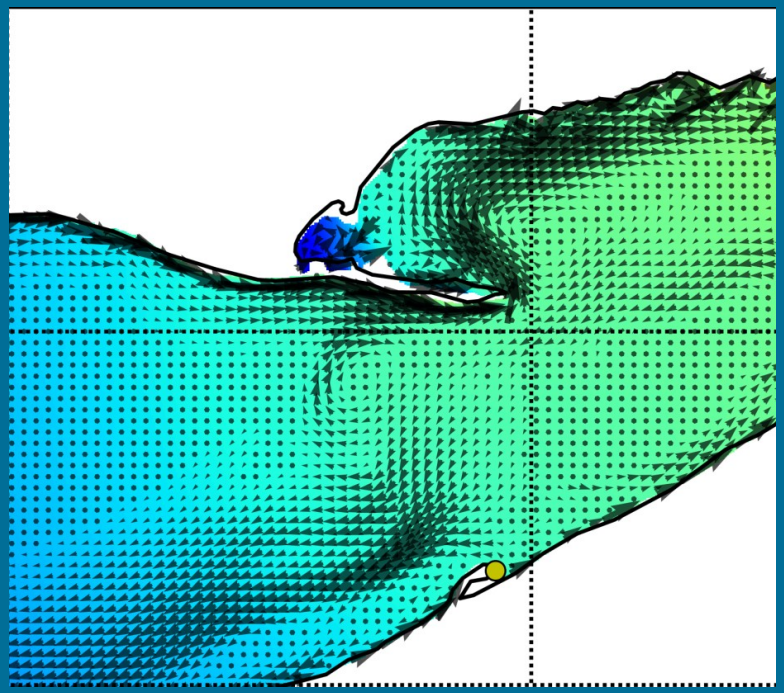
	A10	FA12
2012/10/25 – 2012/11/01(Sandy), L Michigan and Huron		
45002	0.272/0.087	0.275/0.088
45007	0.500/0.084	0.240/0.040
45003	0.219/0.062	0.285/0.081
45008	0.393/0.074	0.332/0.063
45137	0.297/0.087	0.264/0.077
45149	0.606/0.114	0.509/0.095

A10: Ardhuin et al (2010), Standard ST4 package
FA12: Filipot and Ardhuin (2012), upgrade of ST4 package

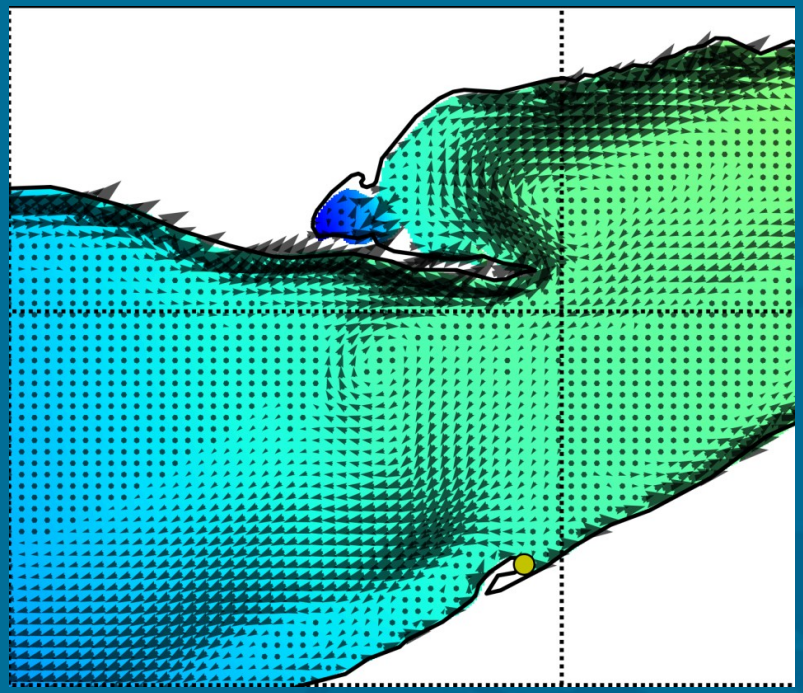
Next Step: Coupling

Define the model set up for wave-circulation coupled model. Assess model skill for different parameterization of 3D current and wave radiation stress. Used ADCIRC+SWAN (2D) for preliminary testing.

200m coastal resolution



2000m coastal resolution



Conclusions

1. 4km WRF wind produces the best wave model results for most cases compared to 12km and 1km, which also makes a good balance between quality and computing price.
2. Difference between Ardhuin et al (2010) physics and Fillipot &Ardhuin (2012) physics is much less significant. However, the FA2012 physics significantly improves the storm peak and wave spectrum output.
3. 200m resolution grid resolves the longshore currents much better than 2000m resolution grid. However 200m grid requires excessive computing power, and 500m grid is a good compromise between accuracy and numerical feasibility.
4. Next step: Coupling of WAVEWATCH III with FVCOM.
5. Future work: Couple hydrodynamic system with atmospheric model and ice.


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Thank you!