Development of the Alaska Coastal Ocean Forecast System ALCOFS

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Ayumi Fujisake-Manome[3*], Philip Chu[3] , Jia Wang[3], Jesse Feyen[3], Haoguo Hu[3*]
Carol Janzen[4], Jesse Lopez[5], Rob Bochenek[5]
Sergey Vinogradov[6], Saeed Moghimi[6], Edward Myers[6],
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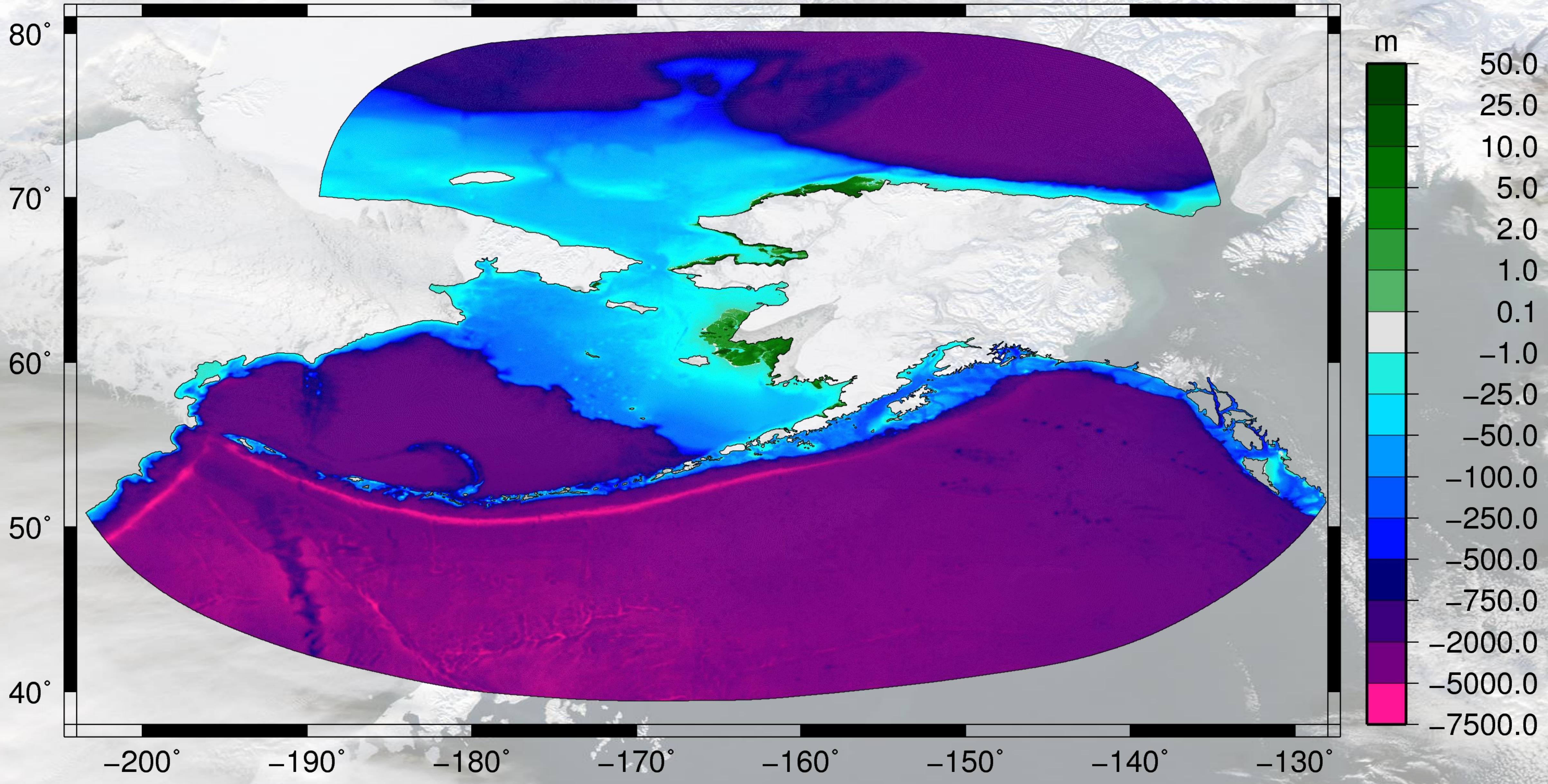
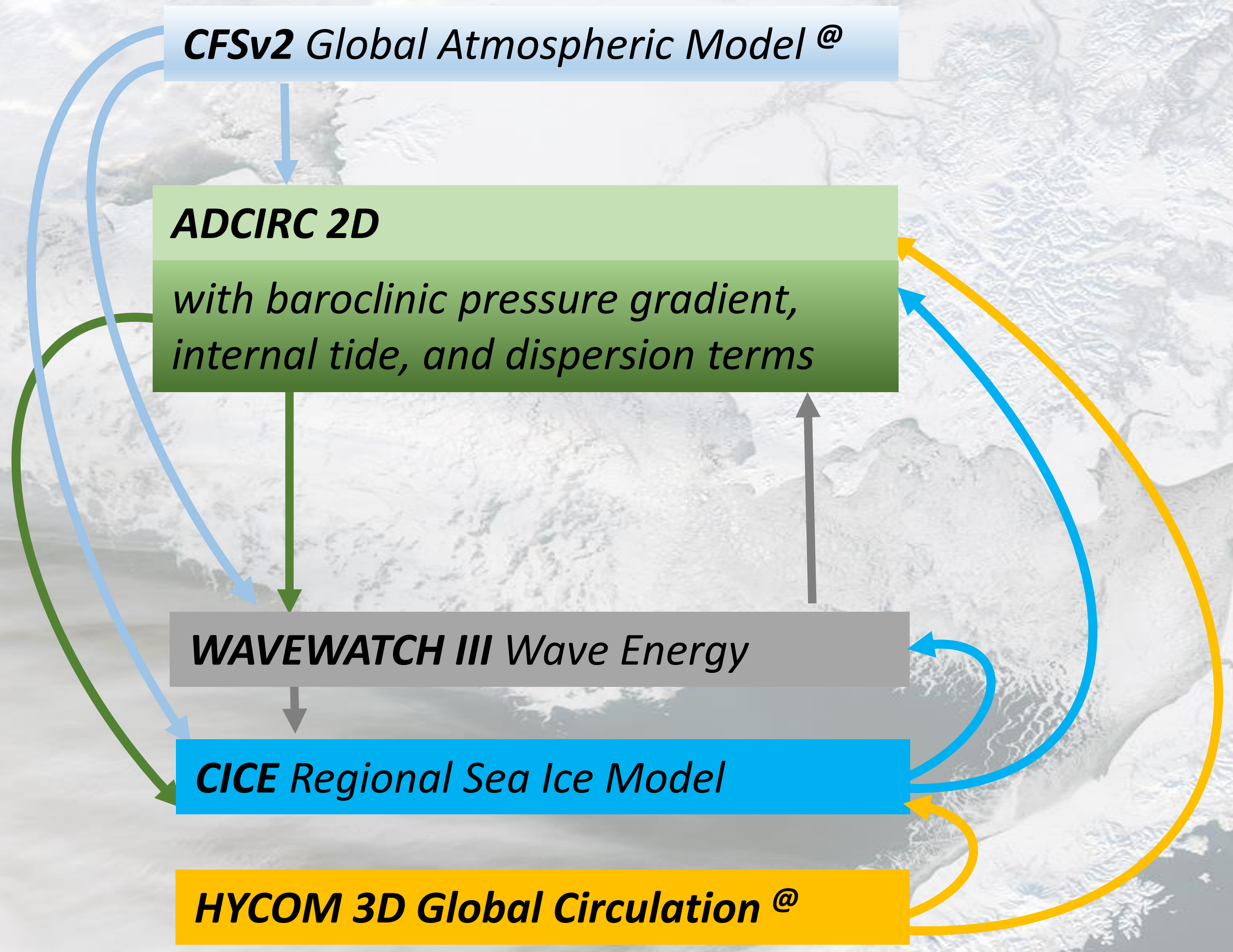
[6]CSDL NOS NOAA,[7]NCEP NWS NOAA

Workshop on Waves, Storm Surges and Coastal Hazards, Melbourne Australia
November 12, 2019

ALCOFS regional domain



ALCOFS framework for multi-physics fast operational modeling



Multi-physics interfacing heterogeneous models over a unified domain

Dynamic coupling of *ADCIRC 2D, WAVEWATCH III, HYCOM* and *CICE*

Interleafing over a unified domain on heterogeneous grids communicating through *ESMF/NUOPC*

@ Indicates standalone model component

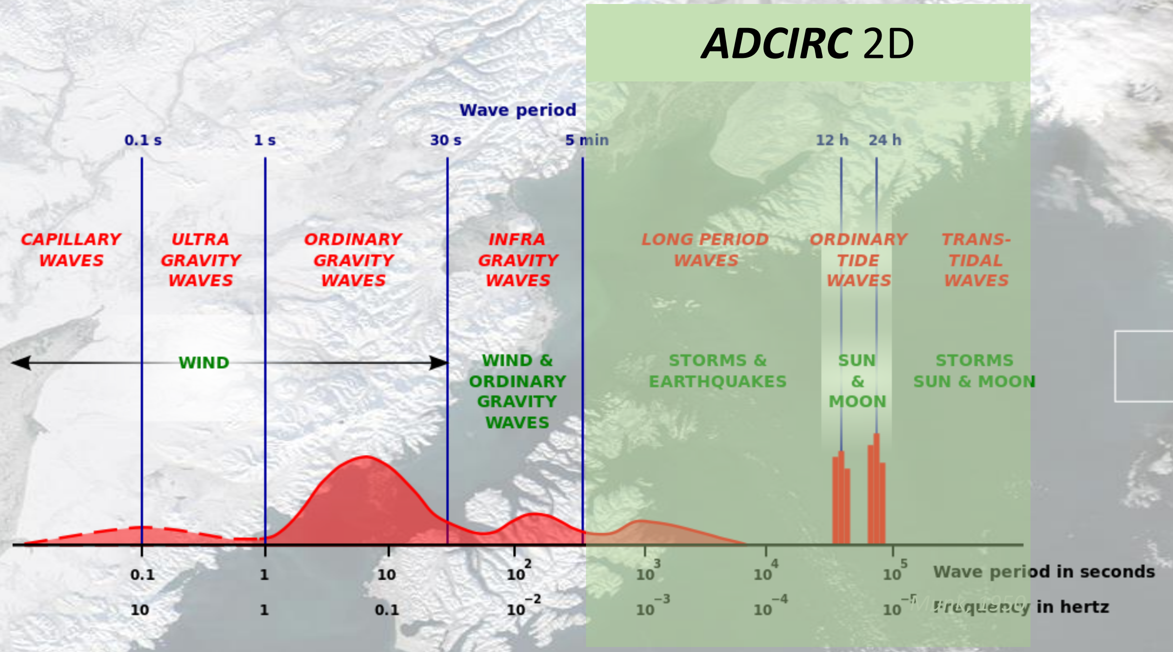
1. Evolving an Alaska tide and storm surge model within operational constraints

CFSv2 Global Atmospheric Model @

ADCIRC 2D

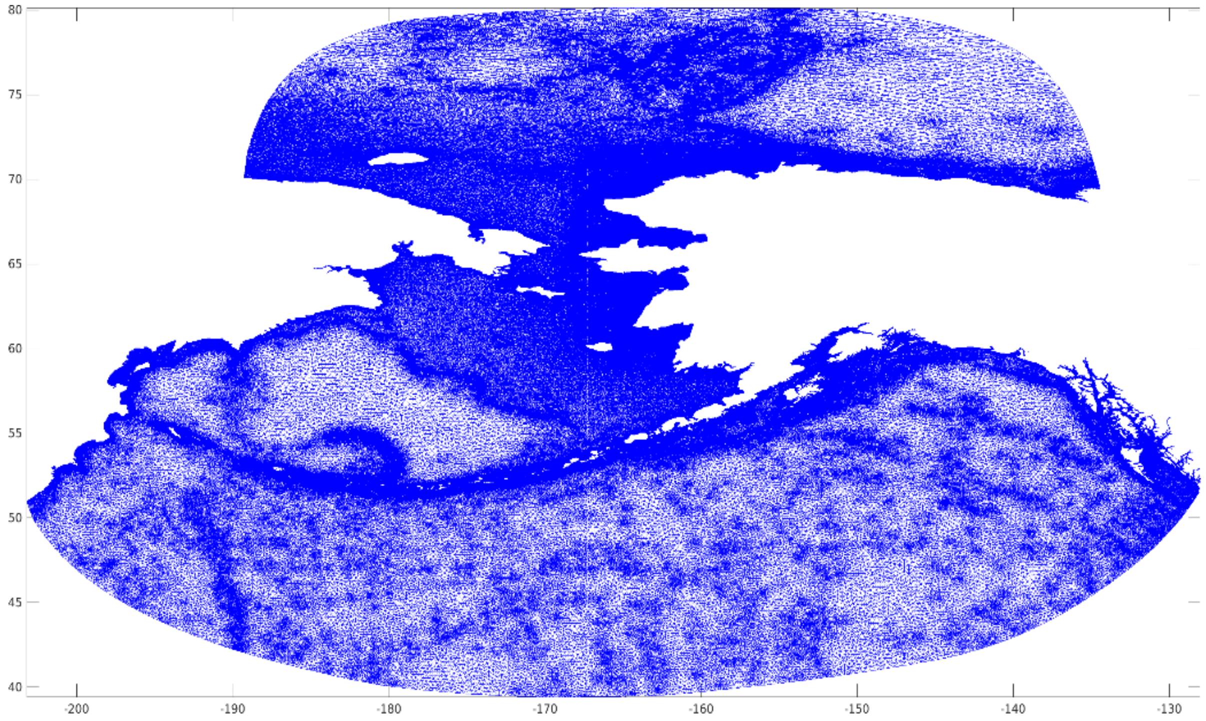
with baroclinic pressure gradient, internal tide, and dispersion terms

CFSv2 and GOFS3.1 *sea ice data* @

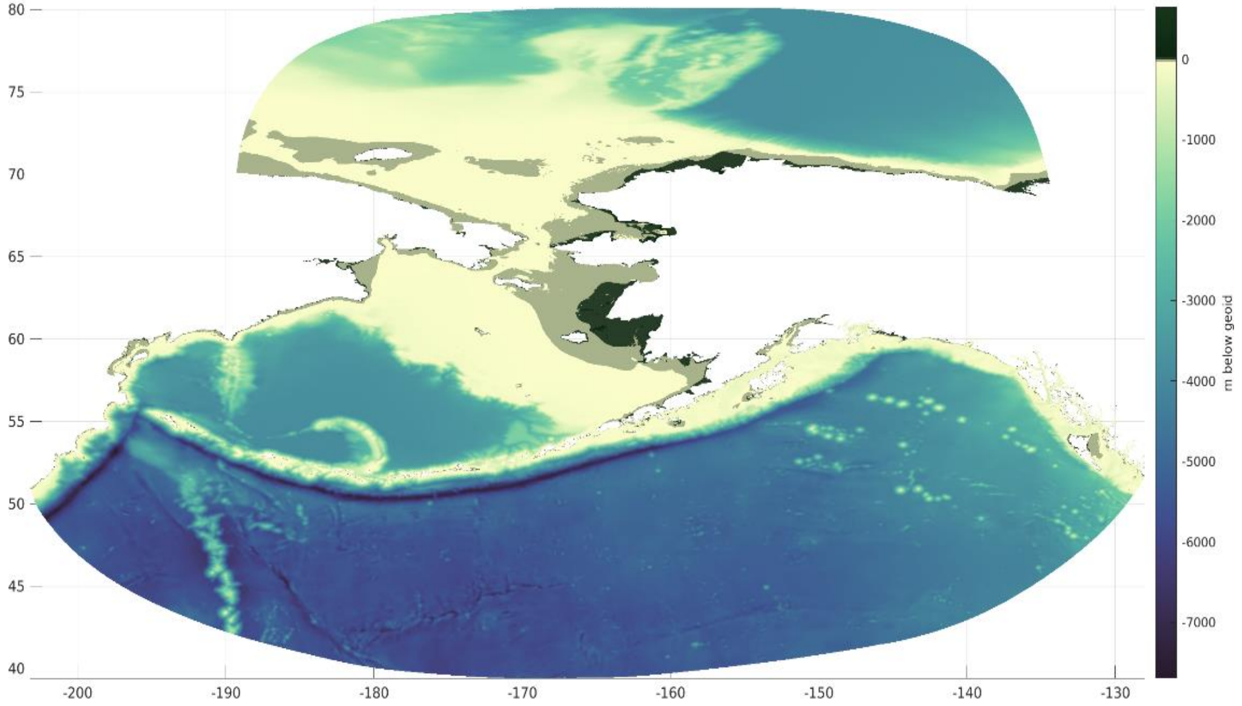


Development of a light operational mesh for the region

Mesh4-fp-v2 triangulation

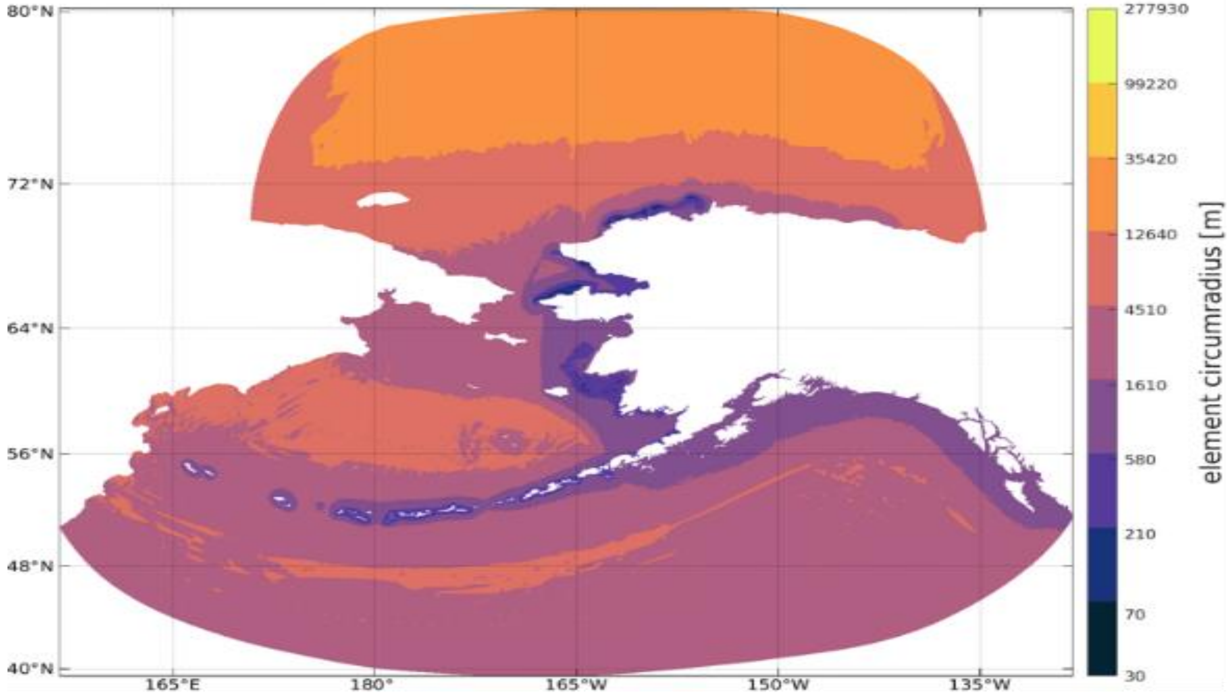


Mesh4-fp-v2 bathymetry

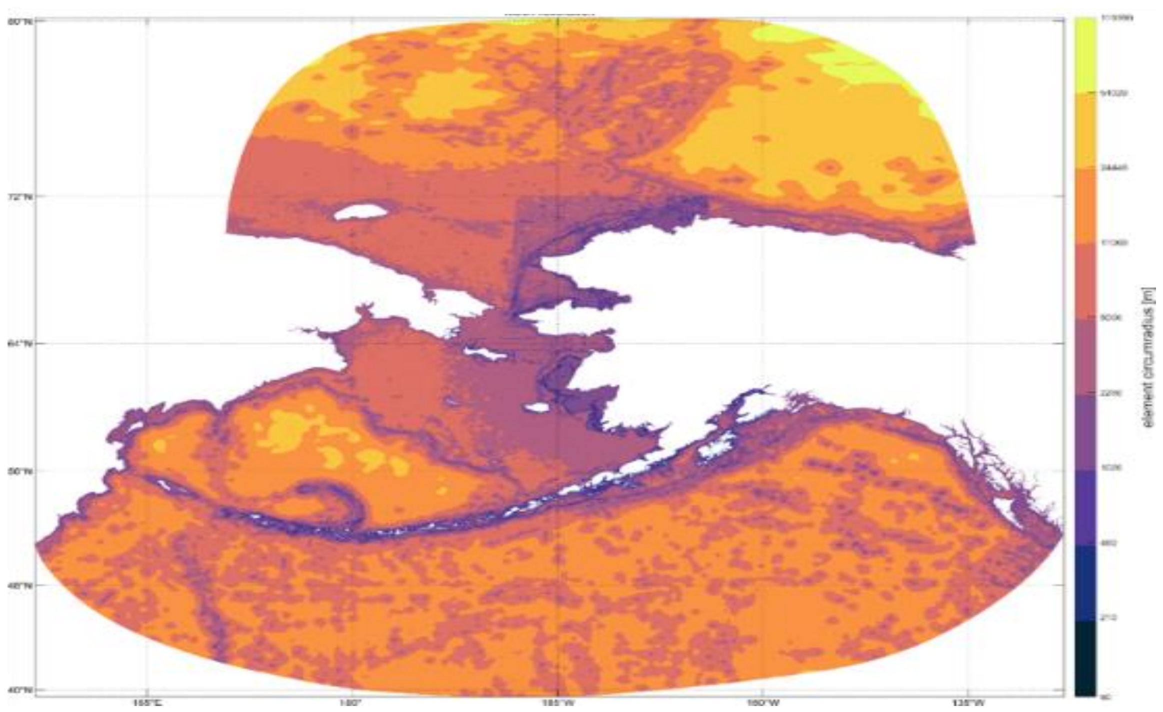


Development of a light operational mesh for the region

Mesh resolution (m)

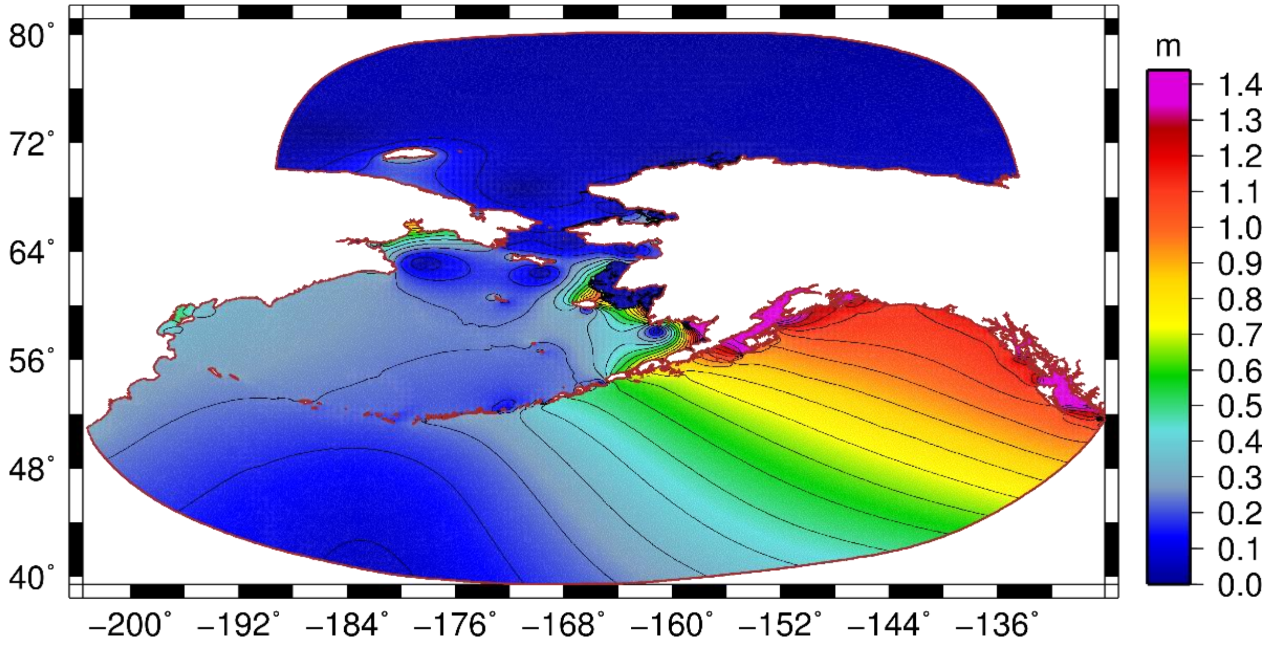


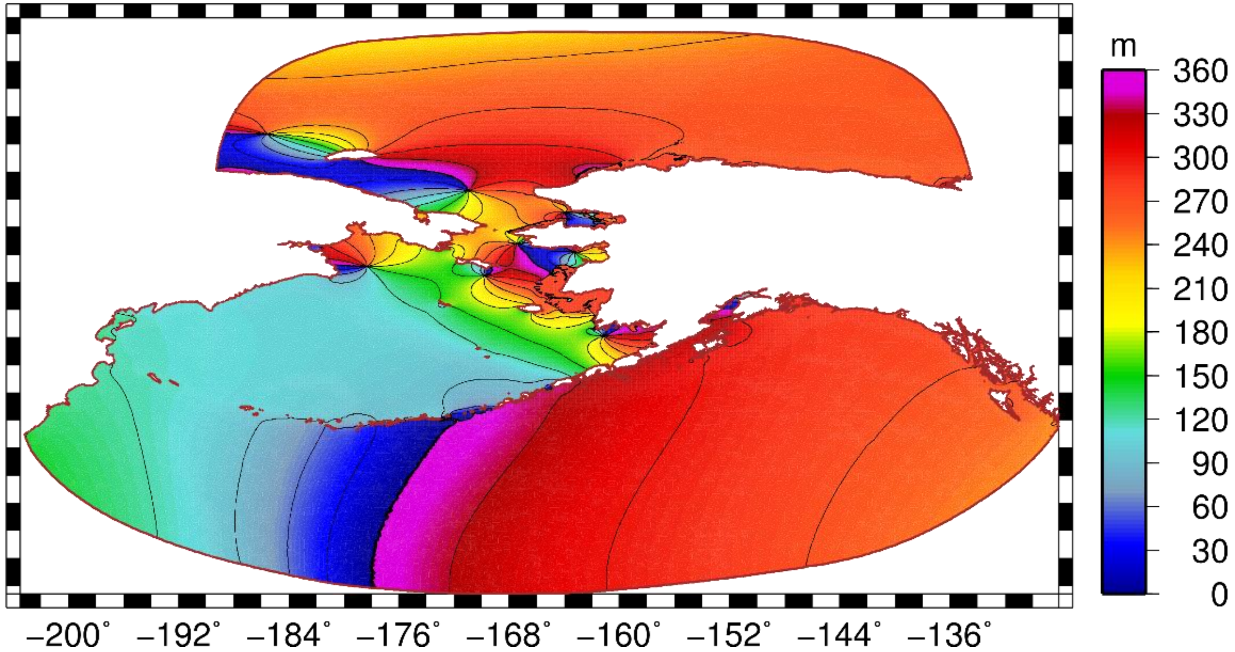
Mesh0 (Joyce et al. 2019)
4,055,605 nodes



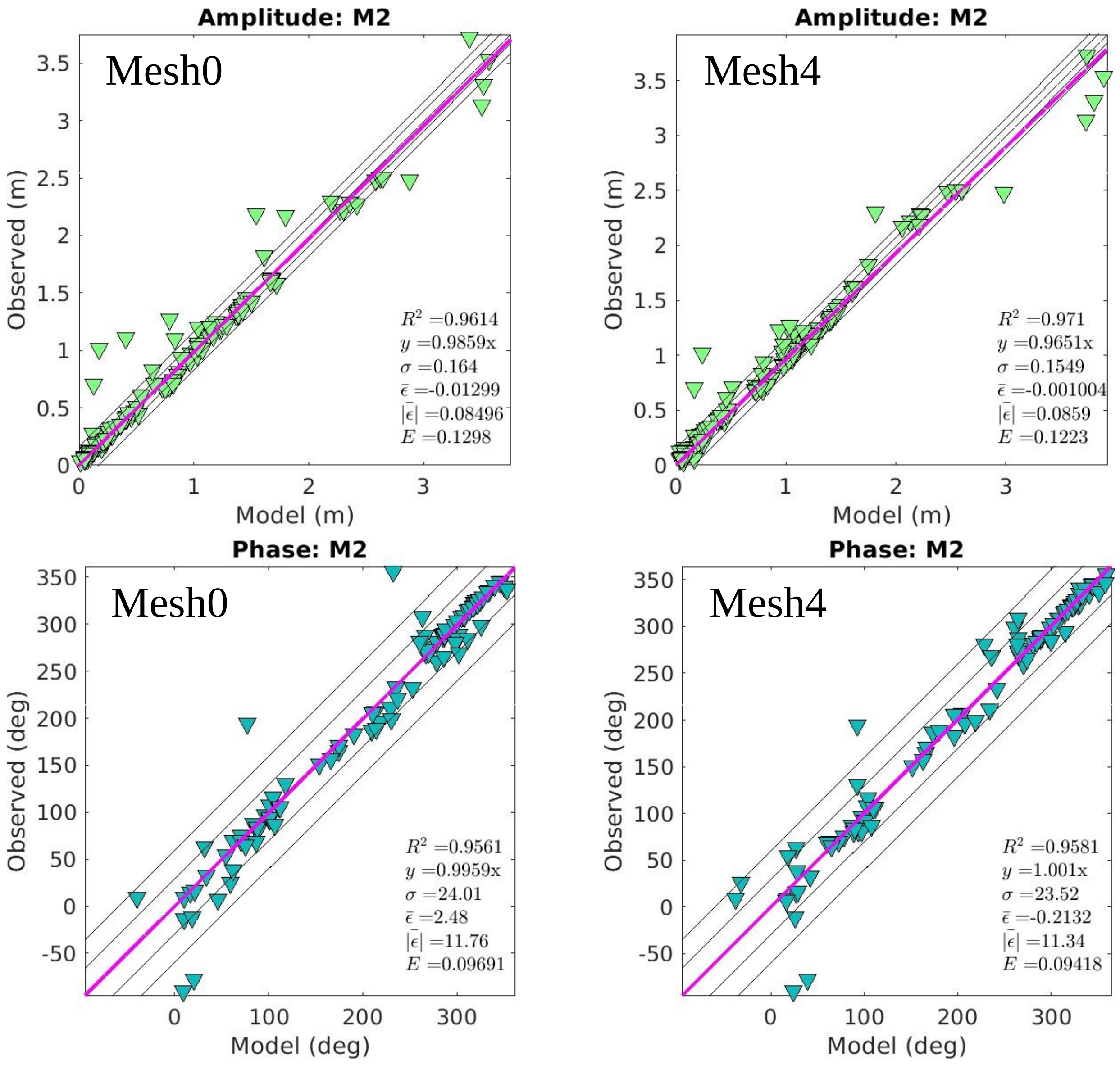
Mesh4-fp-v2
1,648,088 nodes

M_2 amplitudes (m) and phases (degrees) for Mesh4-fp-v2





M_2 amplitude (m) and phase (degrees) errors for Mesh0 and Mesh4-fp-v2



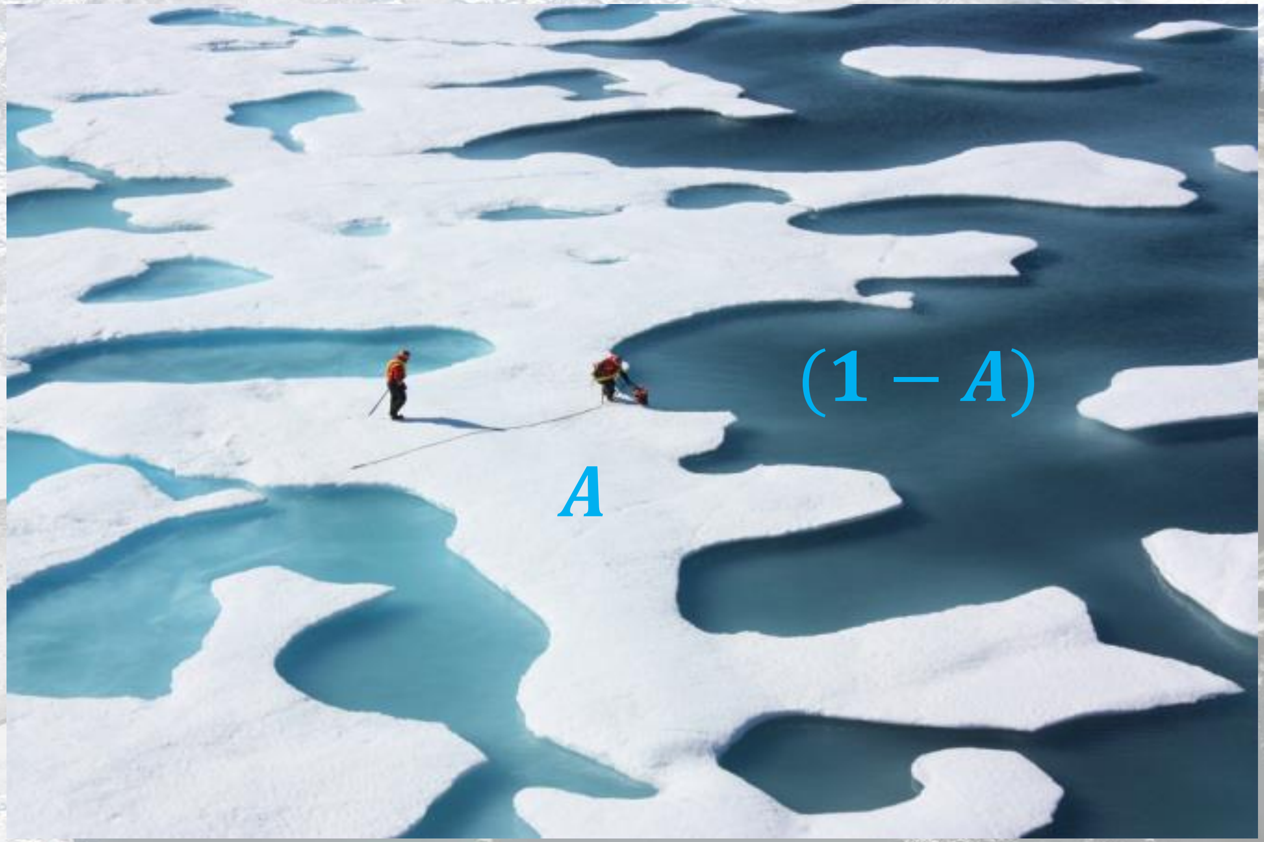
2. Optimizing *air through ice to sea* drag laws

CFSv2 Global Atmospheric Model @

ADCIRC 2D

with baroclinic pressure gradient, internal tide, and dispersion terms

CFSv2 and GOFS3.1 *sea ice data* @



$$C_{dn10} = (1 - A)\, C_{d,a\rightarrow w} + A\, C_{skin,a\rightarrow i\rightarrow w} + A\, C_{form,a\rightarrow i\rightarrow w}(1 - A)^{\beta}$$

2. Optimizing *air through ice to sea* drag laws

CFSv2 Global Atmospheric Model @

ADCIRC 2D

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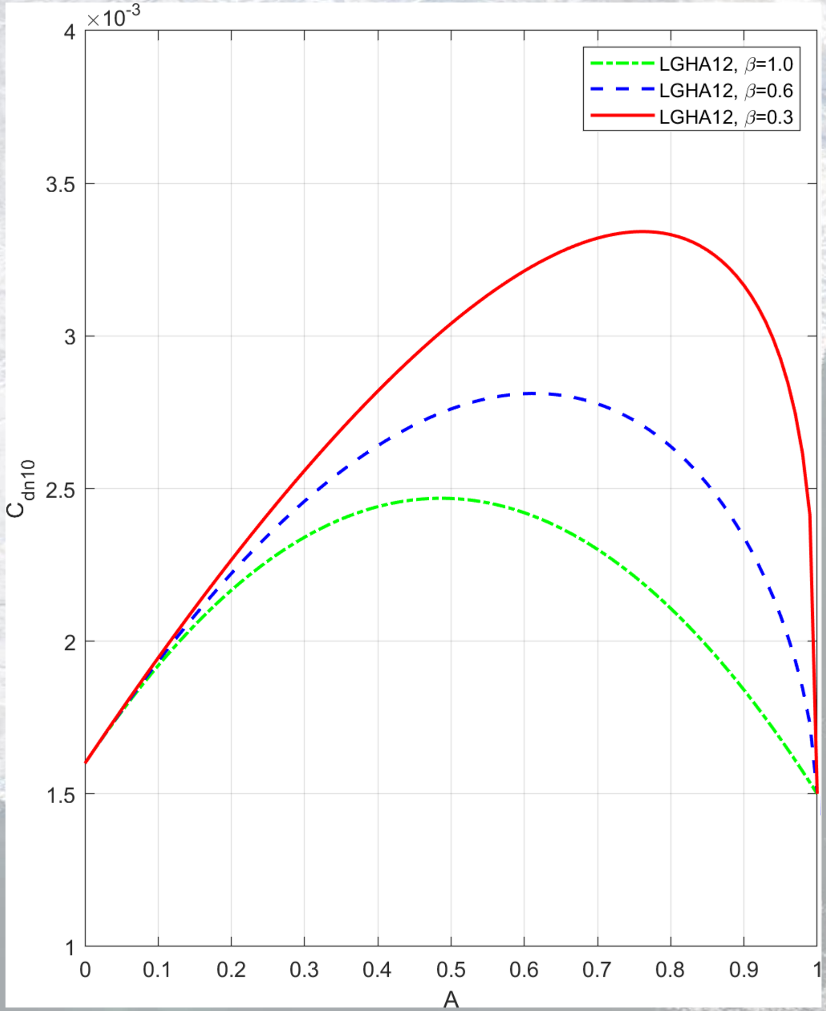
CFSv2 and GOFS3.1 *sea ice data* @



$$C_{dn10} = (1 - A)\, C_{d,a\rightarrow w} + A\, C_{skin,a\rightarrow i\rightarrow w} + A\, C_{form,a\rightarrow i\rightarrow w}(1 - A)^{\beta}$$

2. Optimizing *air through ice to sea* drag laws

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ADCIRC 2D

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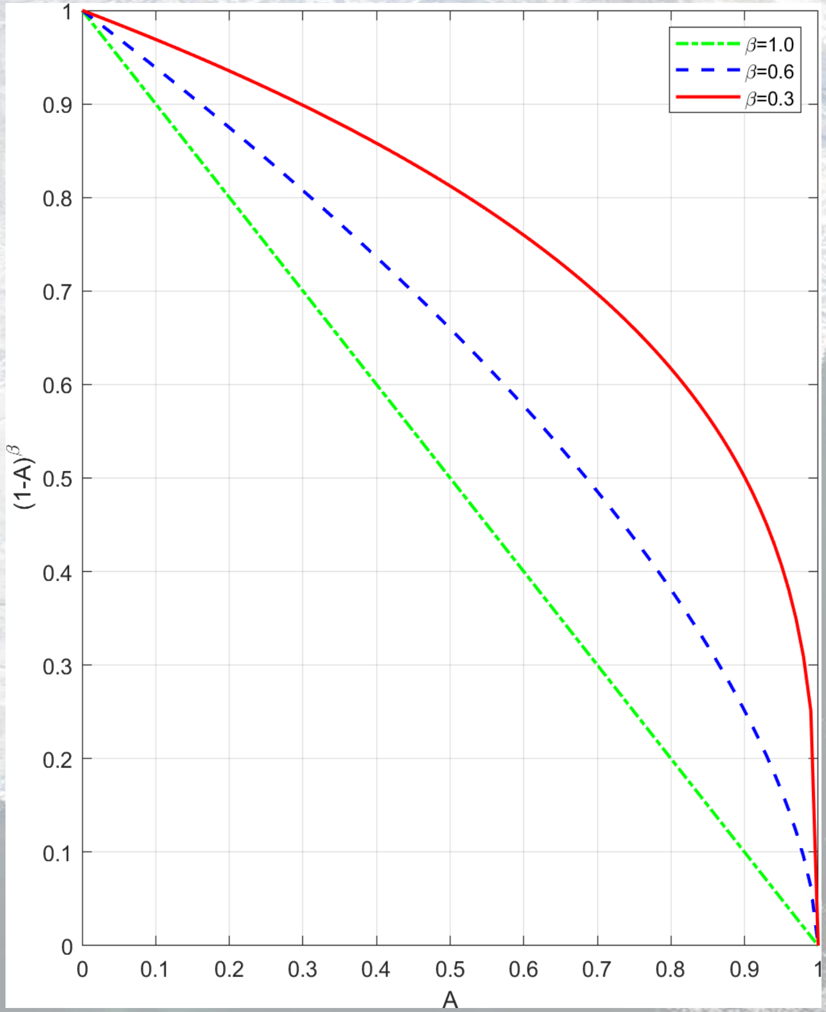


$$C_{dn10} = (1 - A)\, C_{d,a\rightarrow w} + A\, C_{skin,a\rightarrow i\rightarrow w} + A\, C_{form,a\rightarrow i\rightarrow w}(1 - A)^{\beta}$$

Form drag reduction as A increases is controlled by β

2. Optimizing *air through ice to sea* drag laws

CFSv2 Global Atmospheric Model @

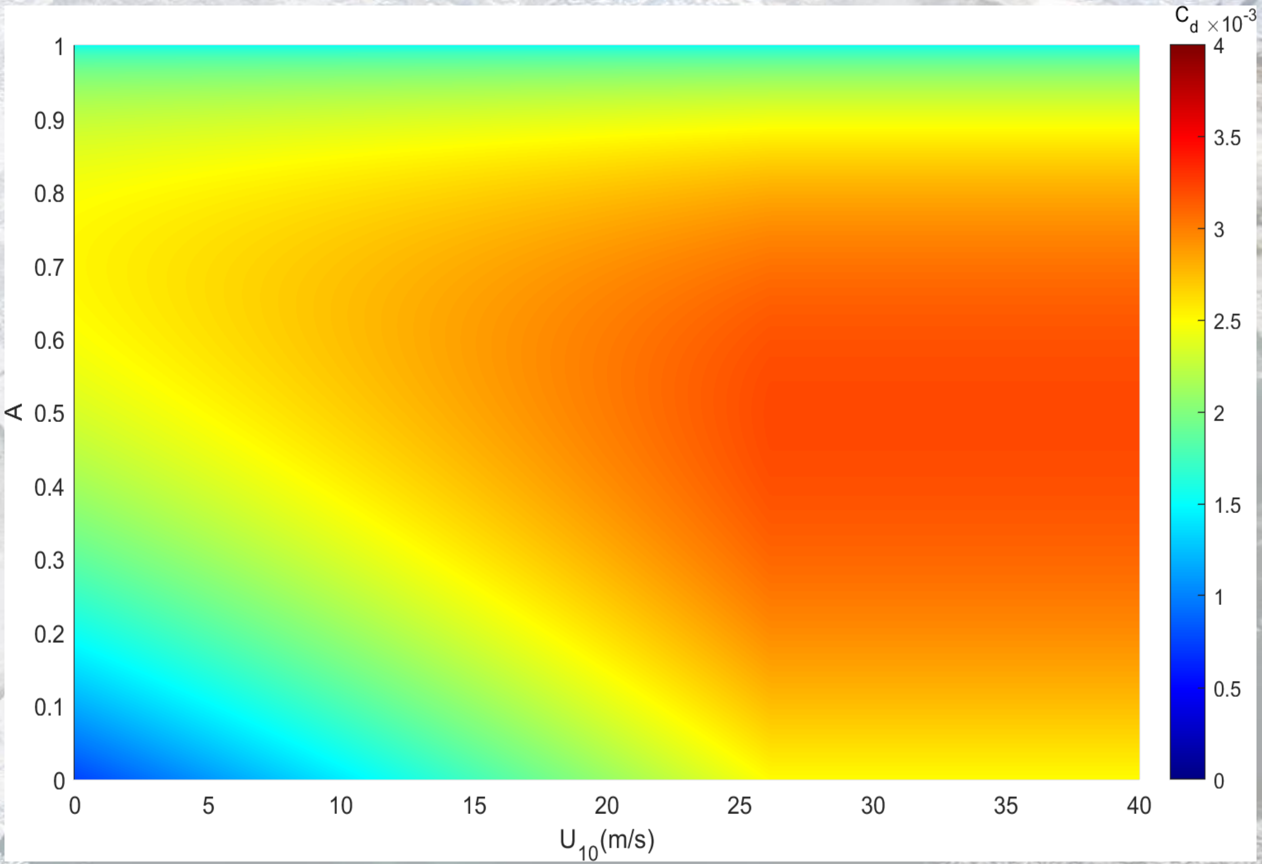
↓

ADCIRC 2D

with baroclinic pressure gradient, internal tide, and dispersion terms

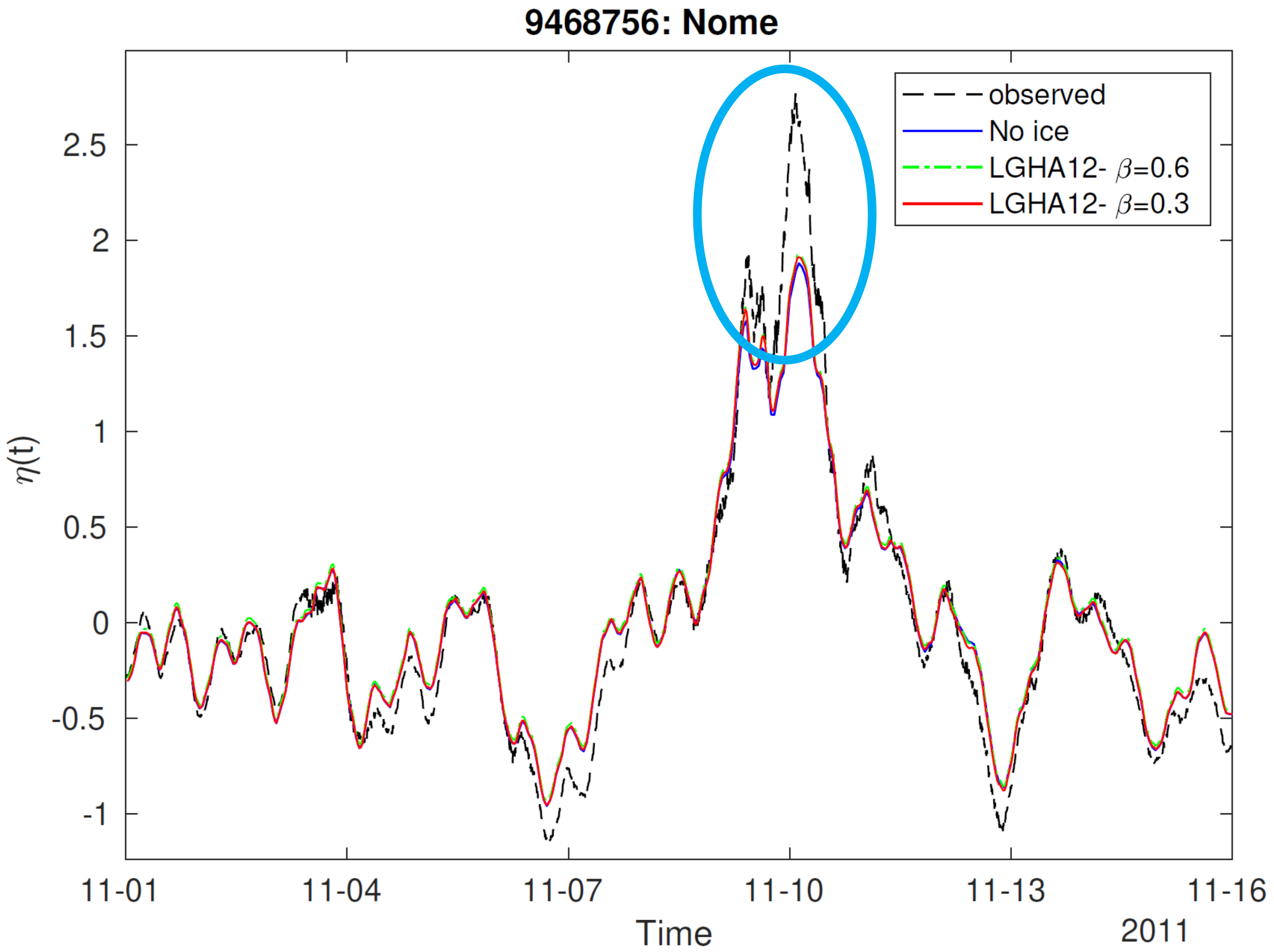
CFSv2 and GOFS3.1 *sea ice data* @

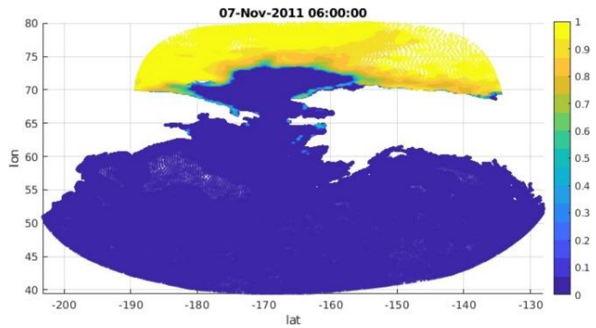
Total drag $C_{dn10}(A, U_{10})$ for $\beta = 0.6$



$$C_{dn10} = (1 - A)\, C_{d,a\to w} + A\, C_{skin,a\to i\to w} + A\, C_{form,a\to i\to w}(1 - A)^{\beta}$$

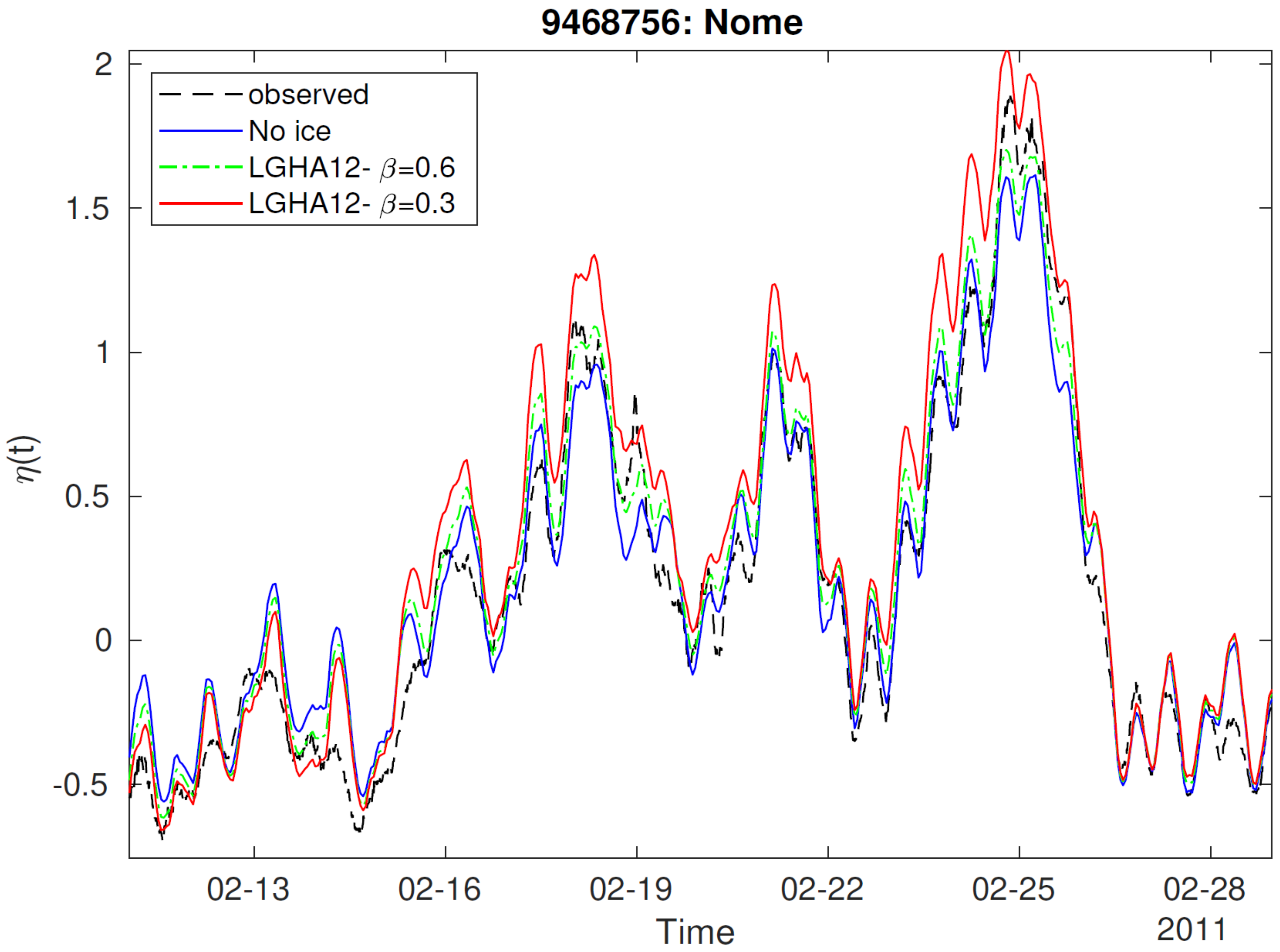
Optimizing *air through ice to sea* drag laws: *November 2011 Fringe ice*

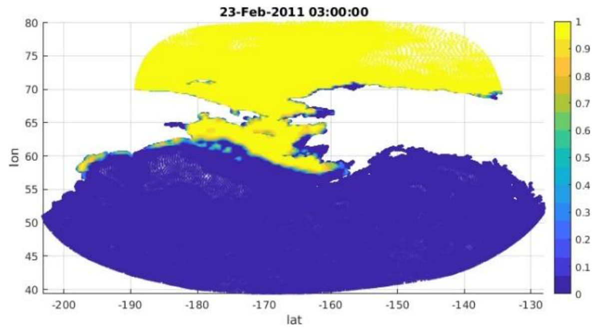




Computed water level with no ice and ice with varying β values in the C. Lüpkes et al. (2012) formula.

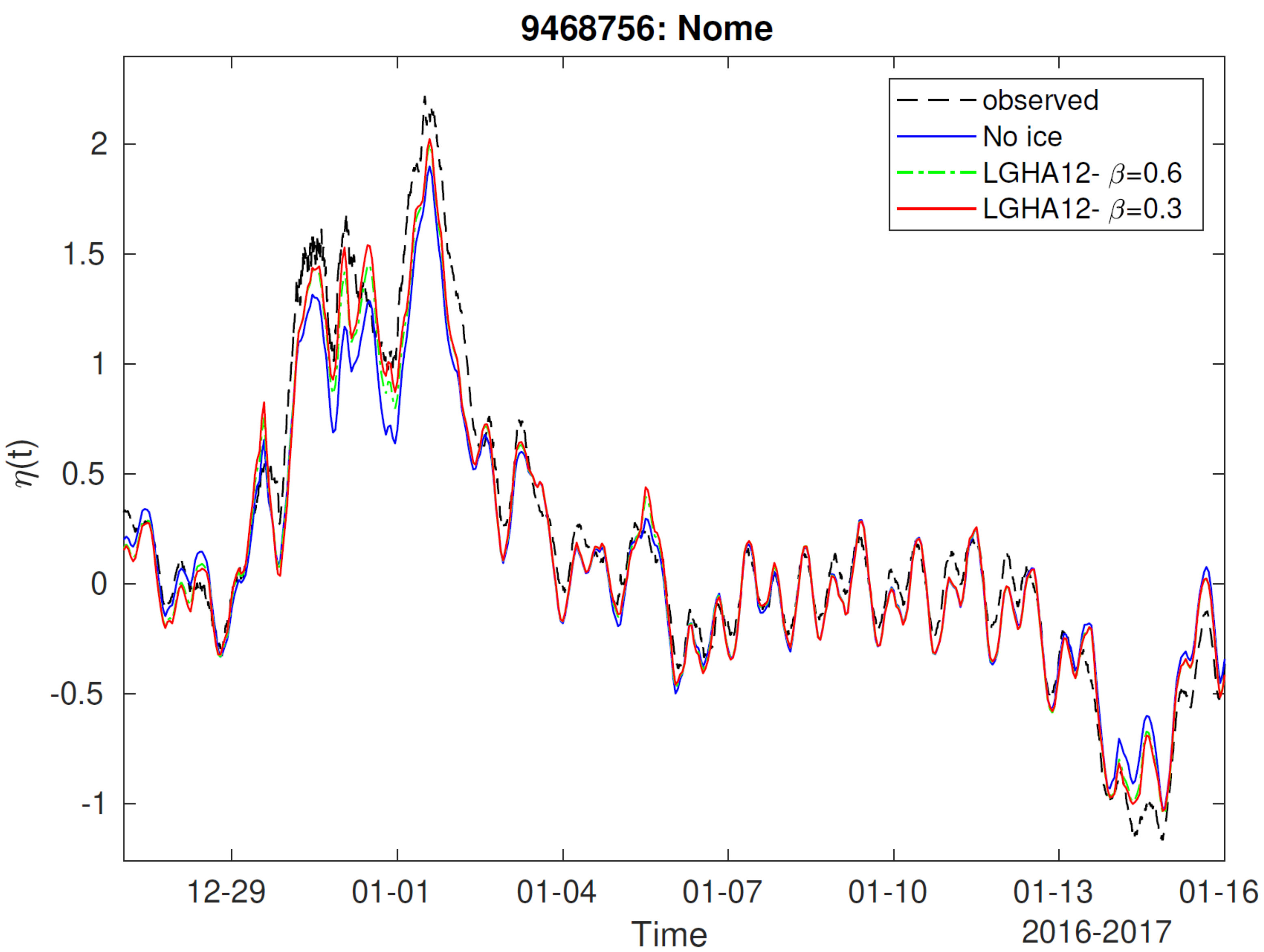
Optimizing *air through ice to sea* drag laws: *February 2011 Pack ice*

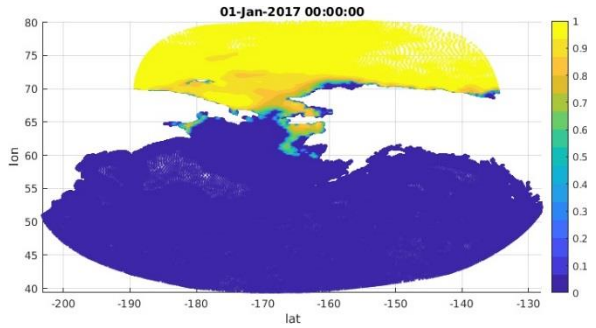




Computed water level with no ice and ice with varying β values in the C. Lüpkes et al. (2012) formula.

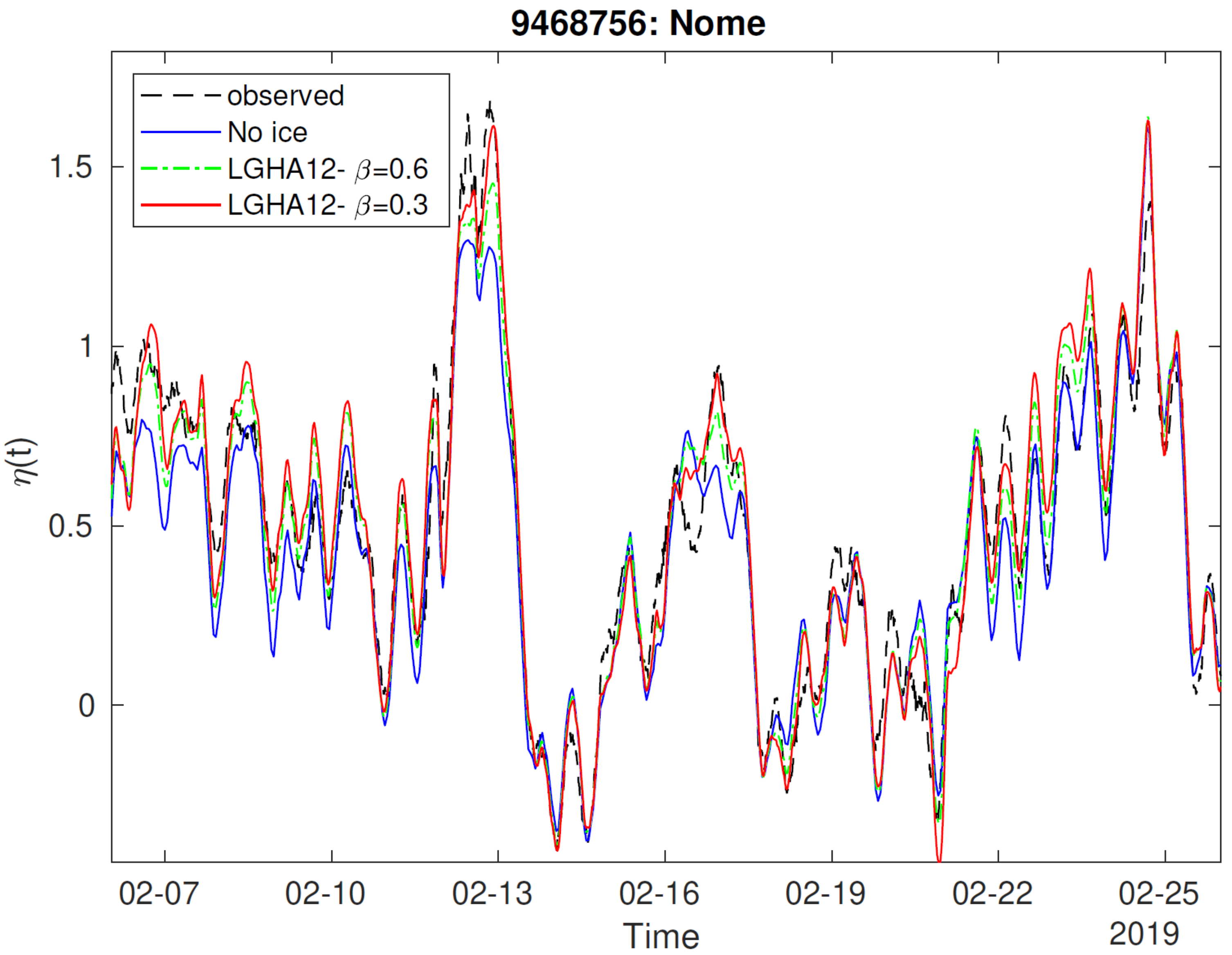
Optimizing *air through ice to sea* drag laws: *January 2017 Partial ice*

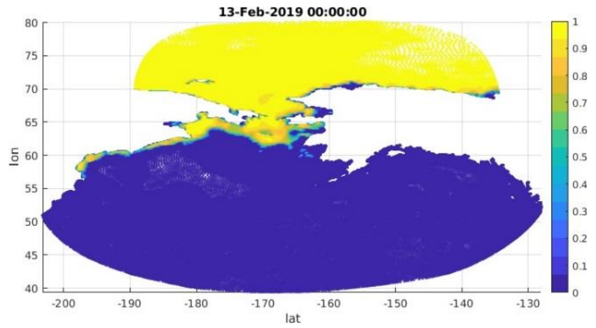




Computed water level with no ice and ice with varying β values in the C. Lüpkes et al. (2012) formula.

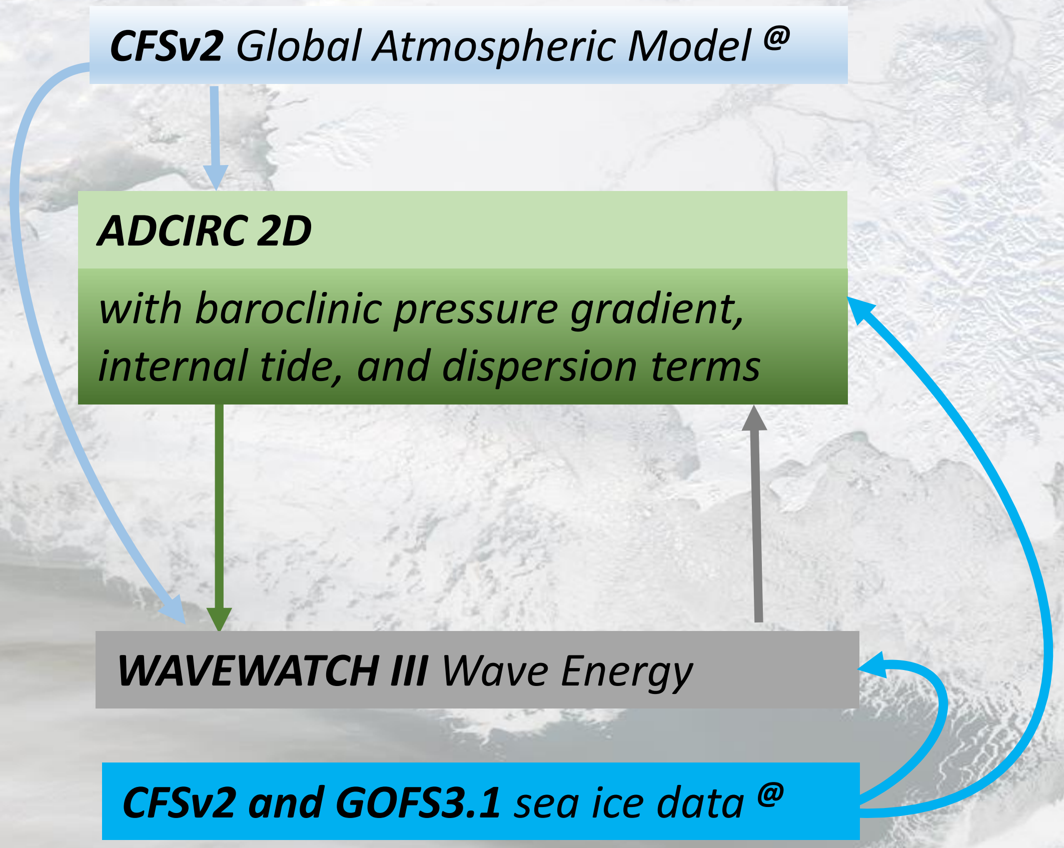
Optimizing *air through ice to sea* drag laws: *February 2019 Partial ice*

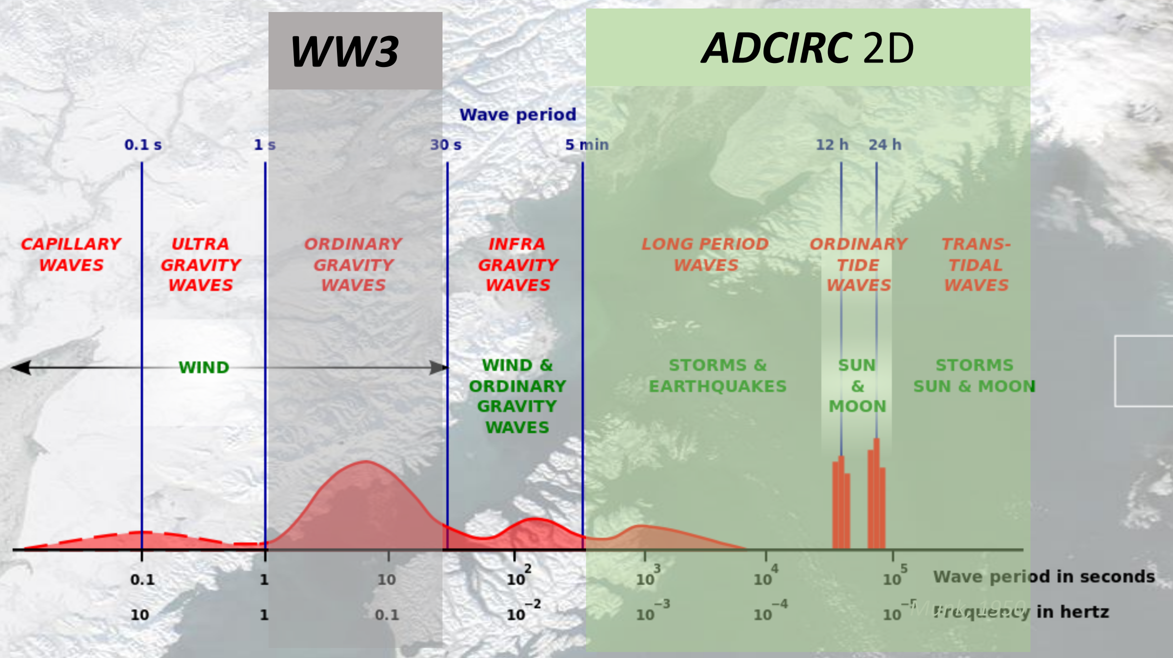




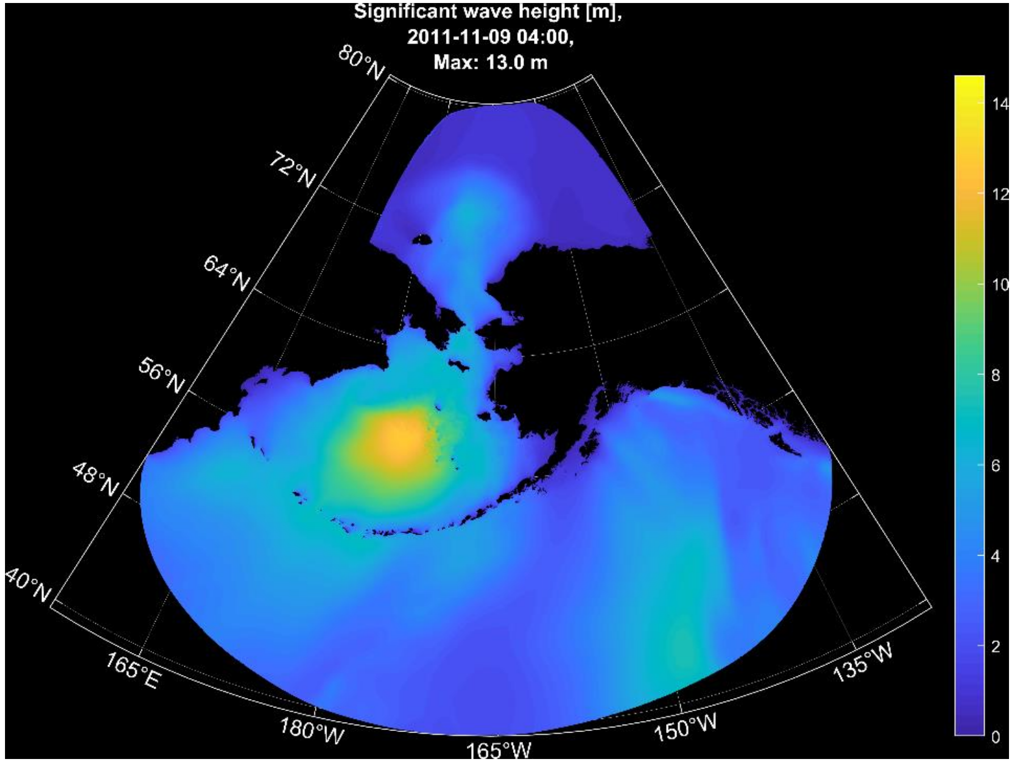
Computed water level with no ice and ice with varying β values in the C. Lüpkes et al. (2012) formula.

3. Evolving a coupled Alaska tide, storm surge and *wind wave* model

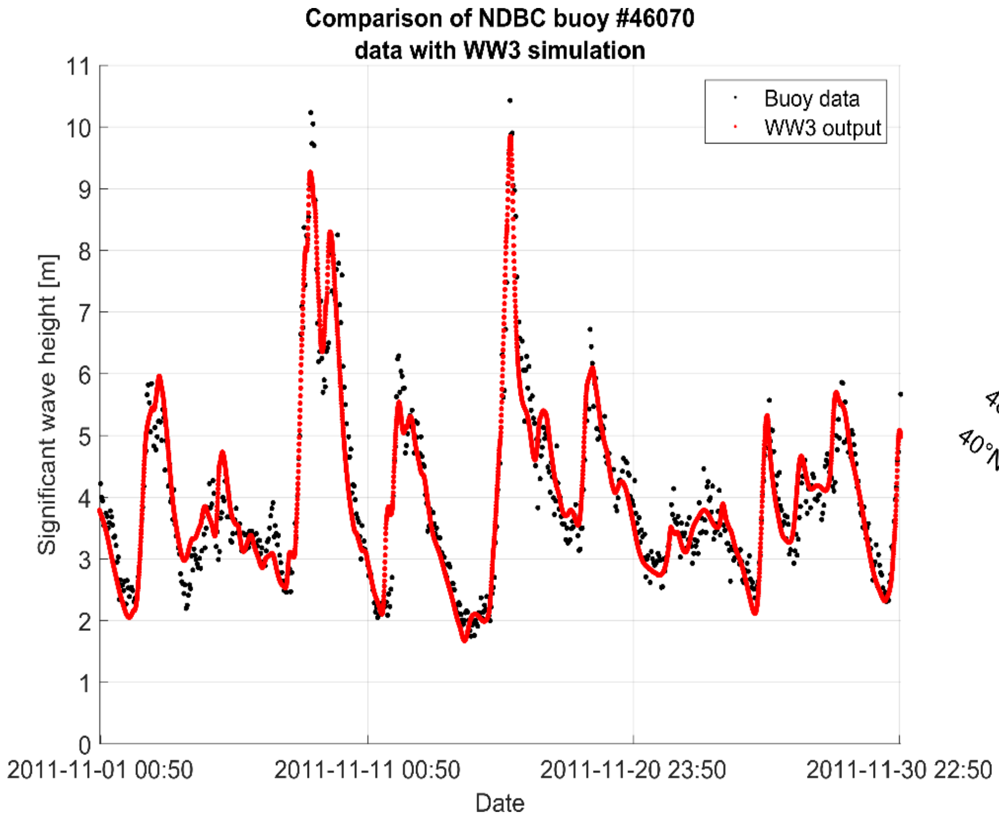


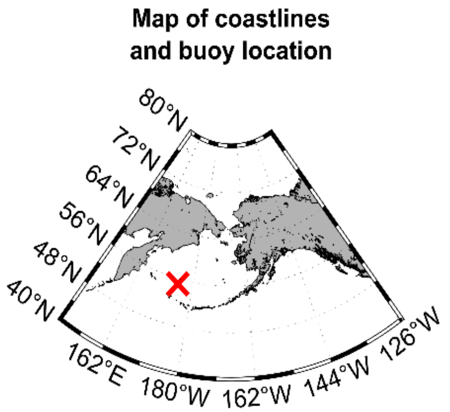


Evolving a coupled Alaska tide, storm surge and *wind wave* model



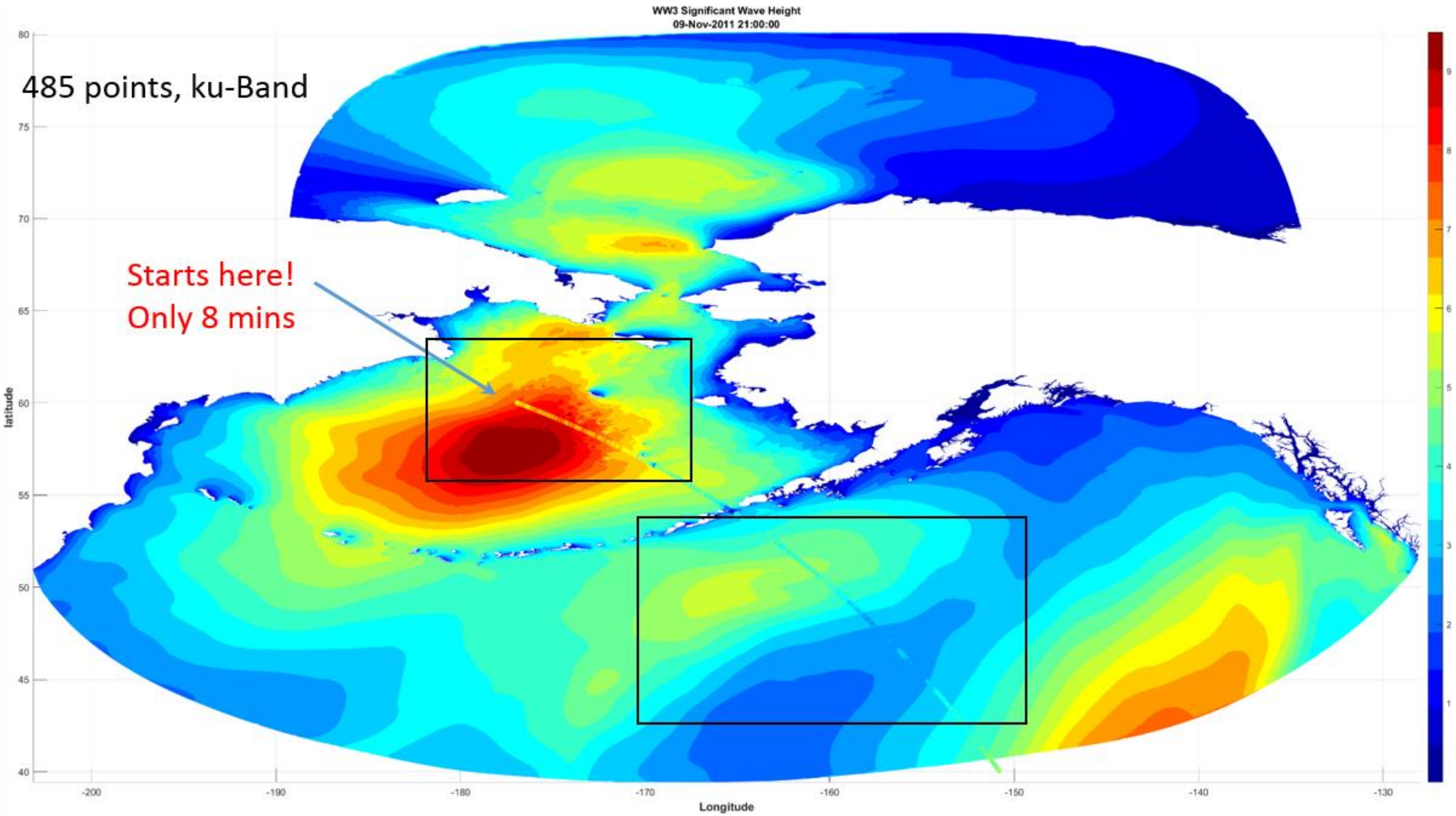
Significant wave height





Comparison of significant wave height with the physical location of buoy on the right

Evolving a coupled Alaska tide, storm surge and *wind wave* model



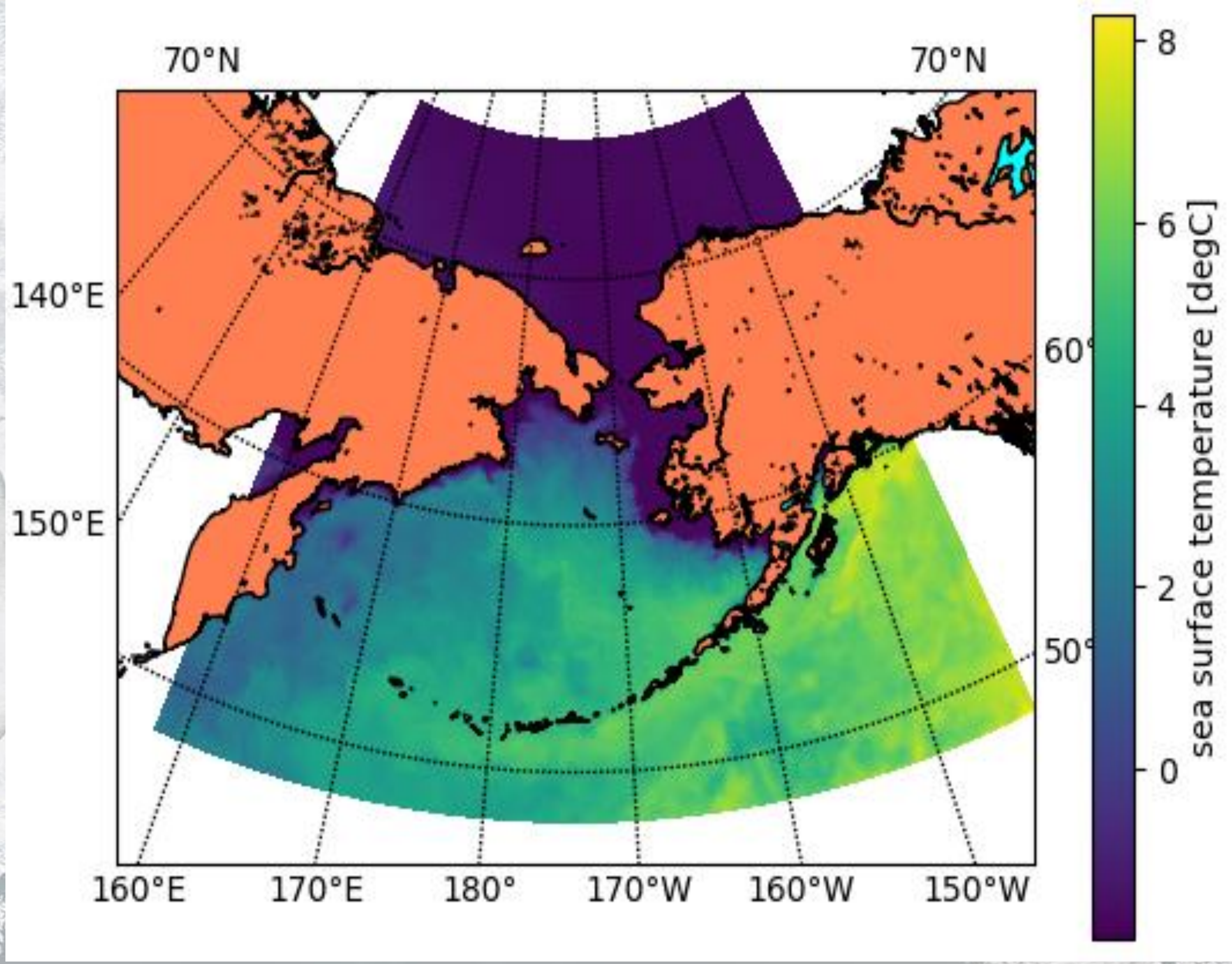
Comparison of significant wave heights computed with WW3 to JASON1-A Altimetry derived values on Nov. 09th 2011 around 20:50

4. Developing a high resolution CICE regional model component

***CFSv2** Global Atmospheric Model* @

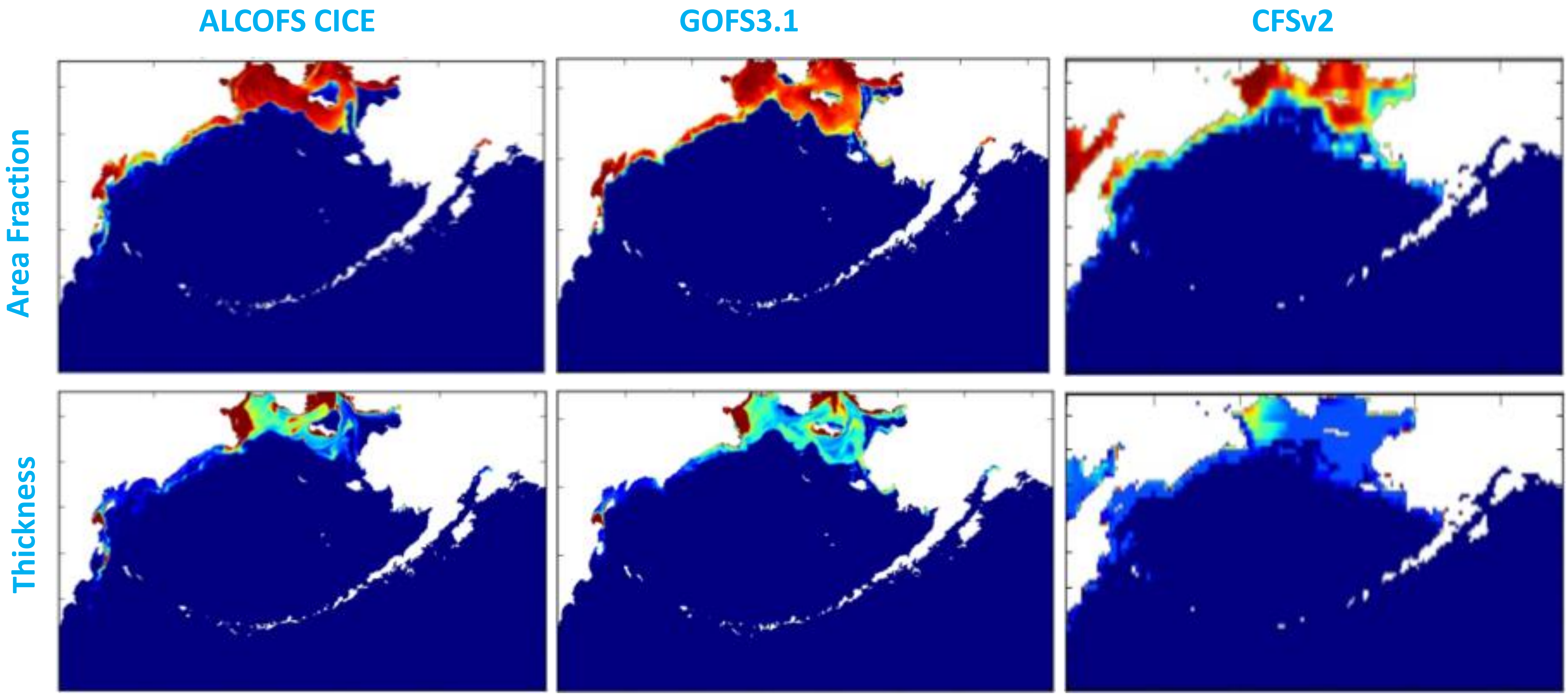
***CICE** Regional Sea Ice Model*

HYCOM 3D Global Circulation @



@ Indicates standalone model component

Developing a high resolution CICE regional model component



5. Baroclinicity as a driver of steric water level fluctuations and ocean currents

CFSv2 *Global Atmospheric Model* @

ADCIRC 2D

with baroclinic pressure gradient, internal tide, and dispersion terms

HYCOM 3D Global Circulation @

- Heterogeneous mode splitting

$$\frac{\partial \boldsymbol{u}}{\partial t} + (\boldsymbol{u}\cdot\nabla)\boldsymbol{u} + f\mathbf{k}\times\boldsymbol{u} = -\nabla\left[\frac{p_s}{\rho_0} + g(\zeta - \zeta_{EQ} - \zeta_{SAL})\right] + \frac{\nabla M}{H} - \frac{\nabla D}{H} - \frac{\nabla B}{H} + \frac{\boldsymbol{\tau}_s}{\rho_0 H} - \frac{\boldsymbol{\tau}_b}{\rho_0 H} - \mathcal{F}_{IT}$$

- Baroclinic pressure gradient (BPG):

$$\nabla B = \int_{-h}^{\zeta}\left(g\nabla\left[\int_{z}^{\zeta}\frac{\rho-\rho_0}{\rho_0}\right]dz\right)dz$$

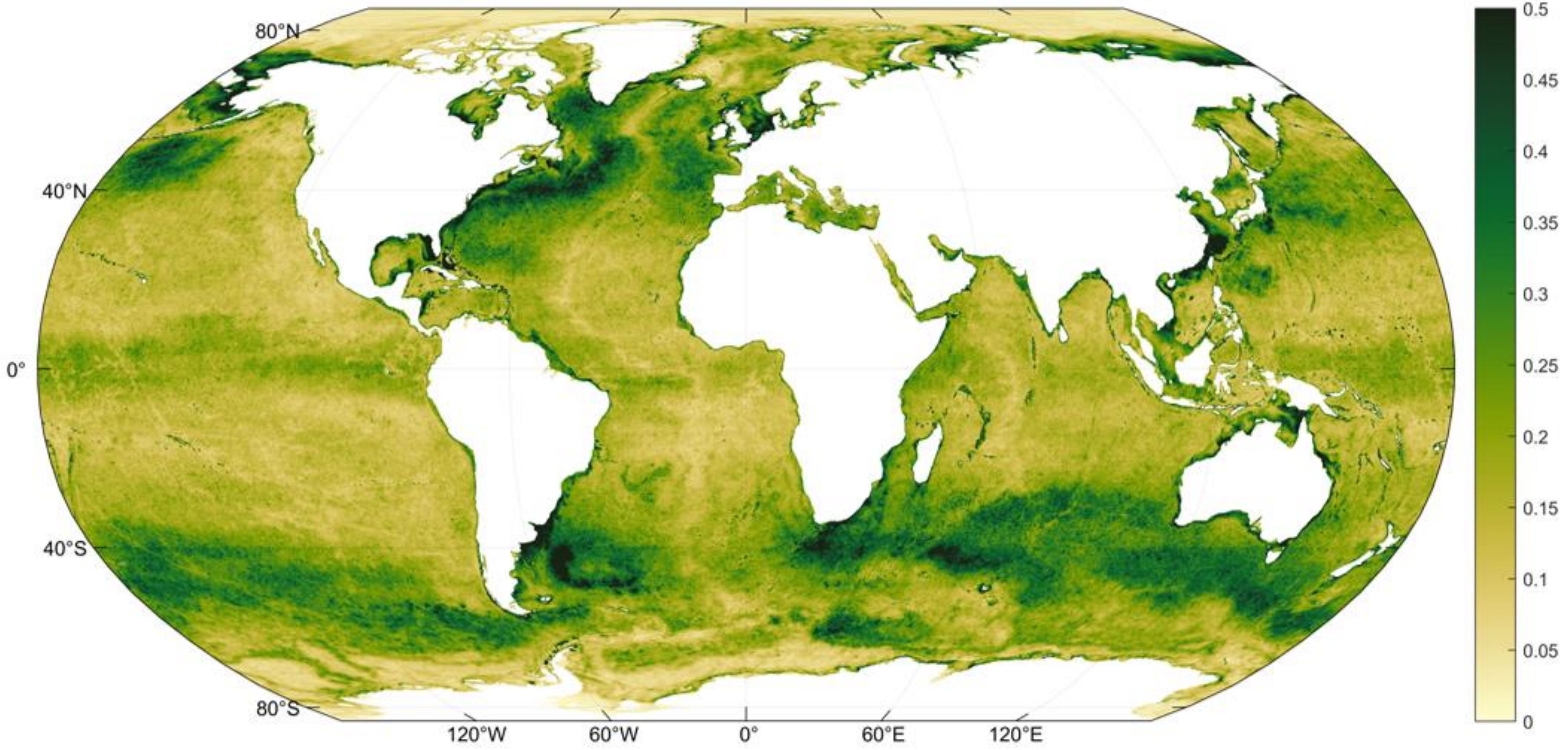
- Momentum Dispersion:

$$\nabla D = \nabla\int_{-h}^{0}\left[(\boldsymbol{v}-\boldsymbol{V})\cdot(\boldsymbol{v}-\boldsymbol{V})\right]dz$$

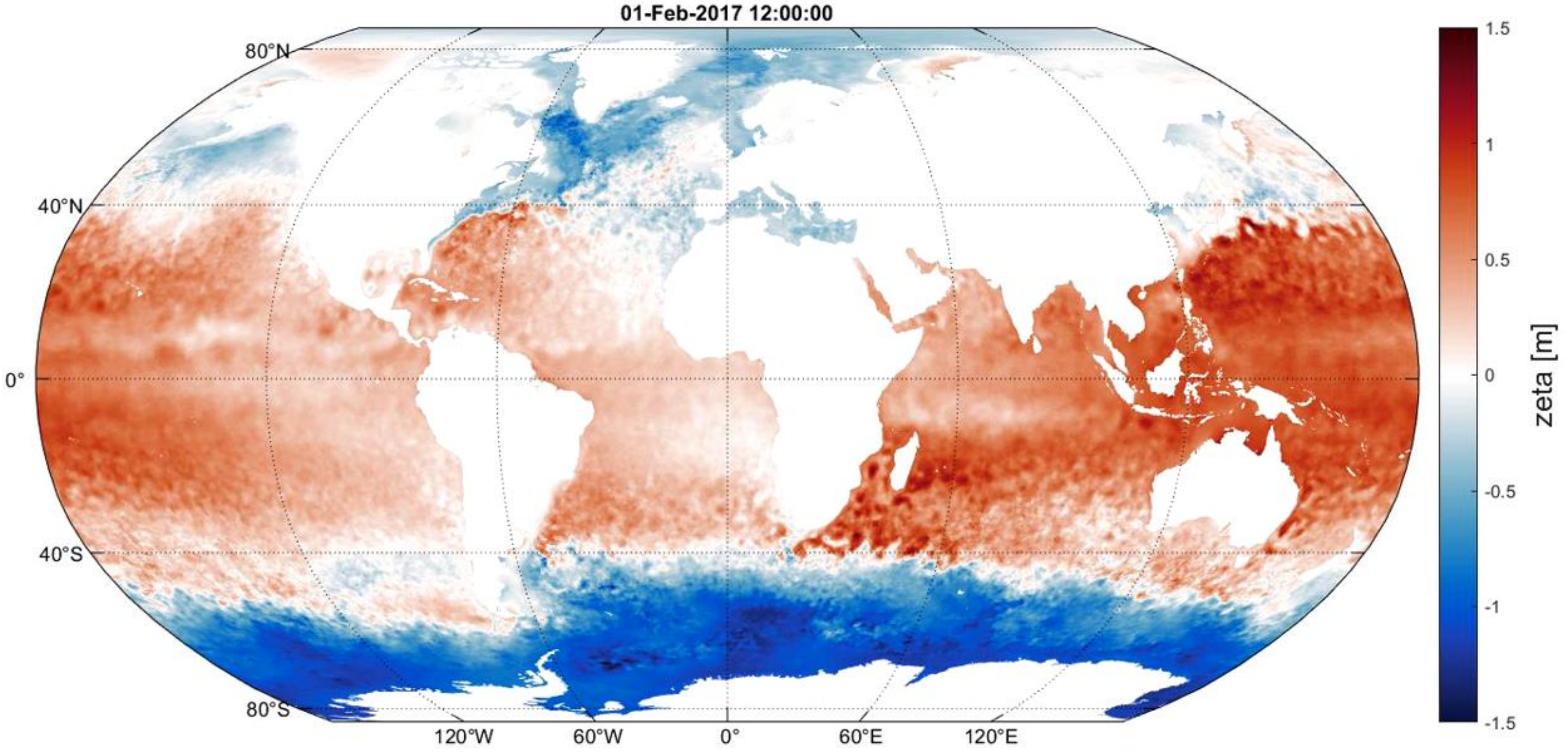
- Internal tide induced barotropic energy conversion:

$$\mathcal{F}_{IT} = C_{IT}\frac{\left[(N_b^2-\omega^2)(\tilde{N}^2-\omega^2)\right]^{1/2}}{\omega}(\nabla h\cdot\boldsymbol{u})\nabla h$$

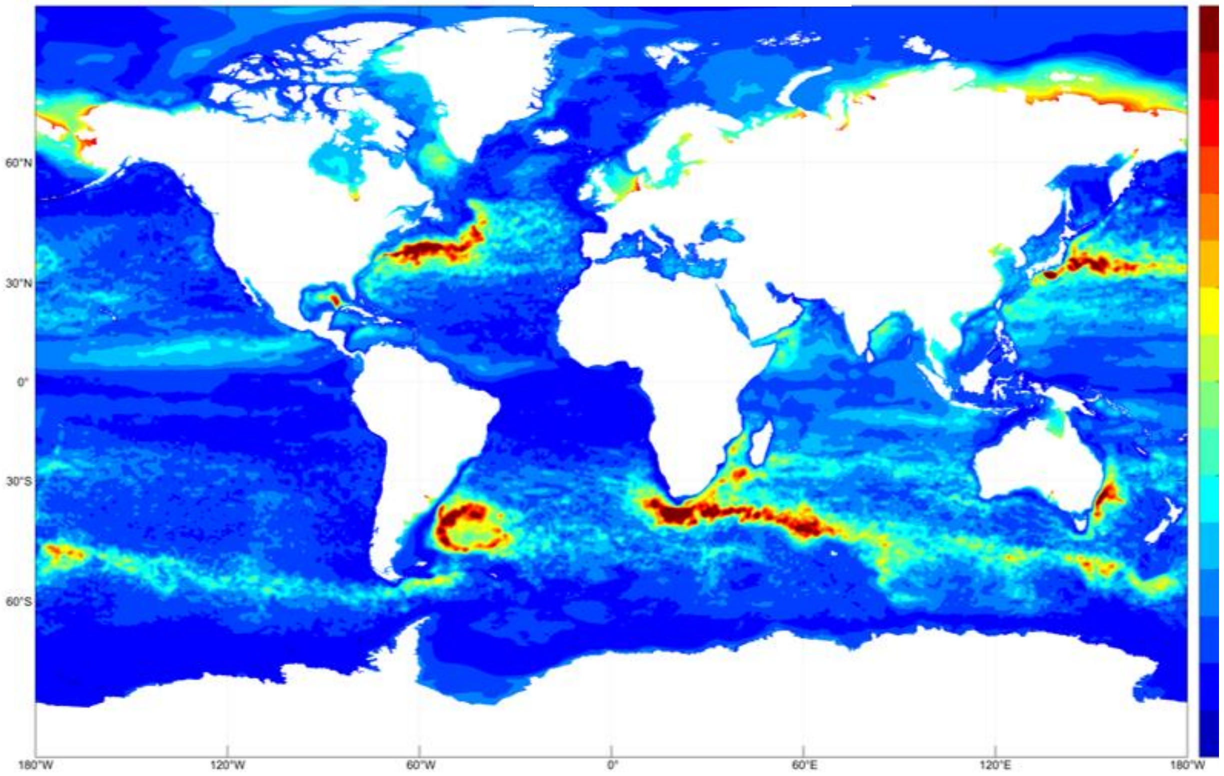
GOFS3.1 forcing of the ADCIRC global model: currents



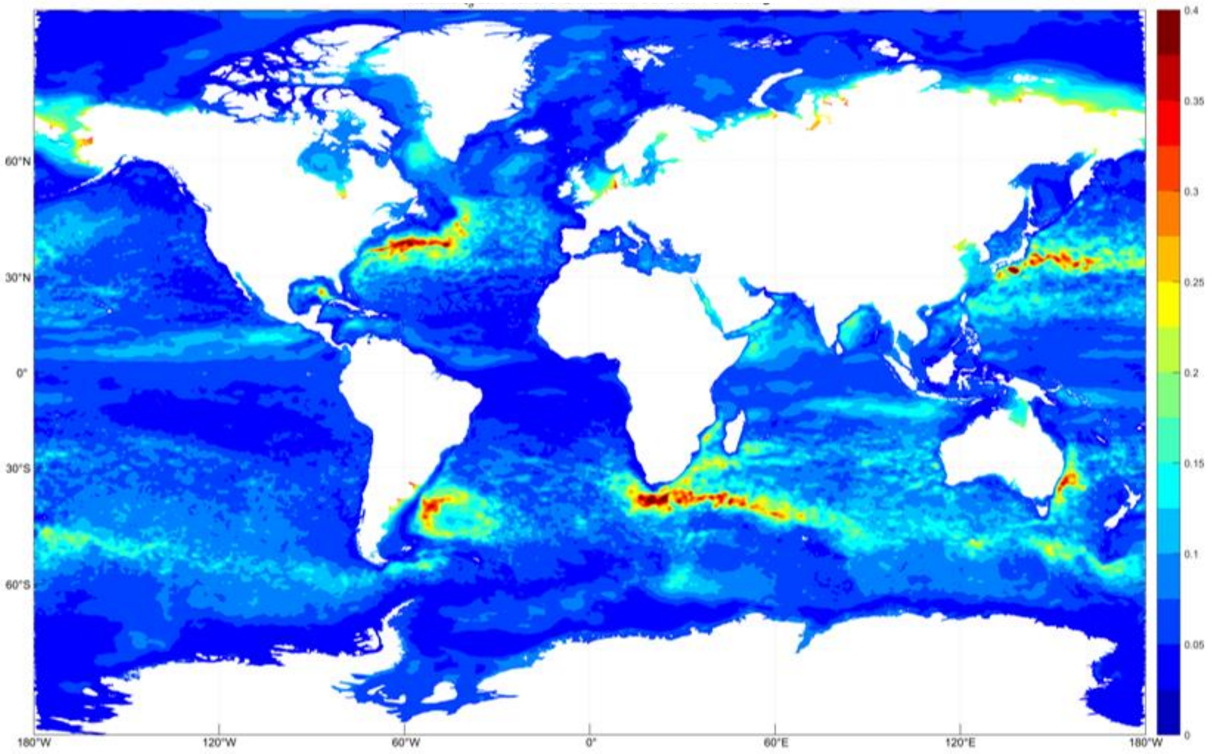
GOFS3.1 forcing of the ADCIRC global model: sea surface elevation



Comparison of sea surface height RMS variability between GOFS3.1 and ADCIRC forced with GOFS3.1 temperature and density fields

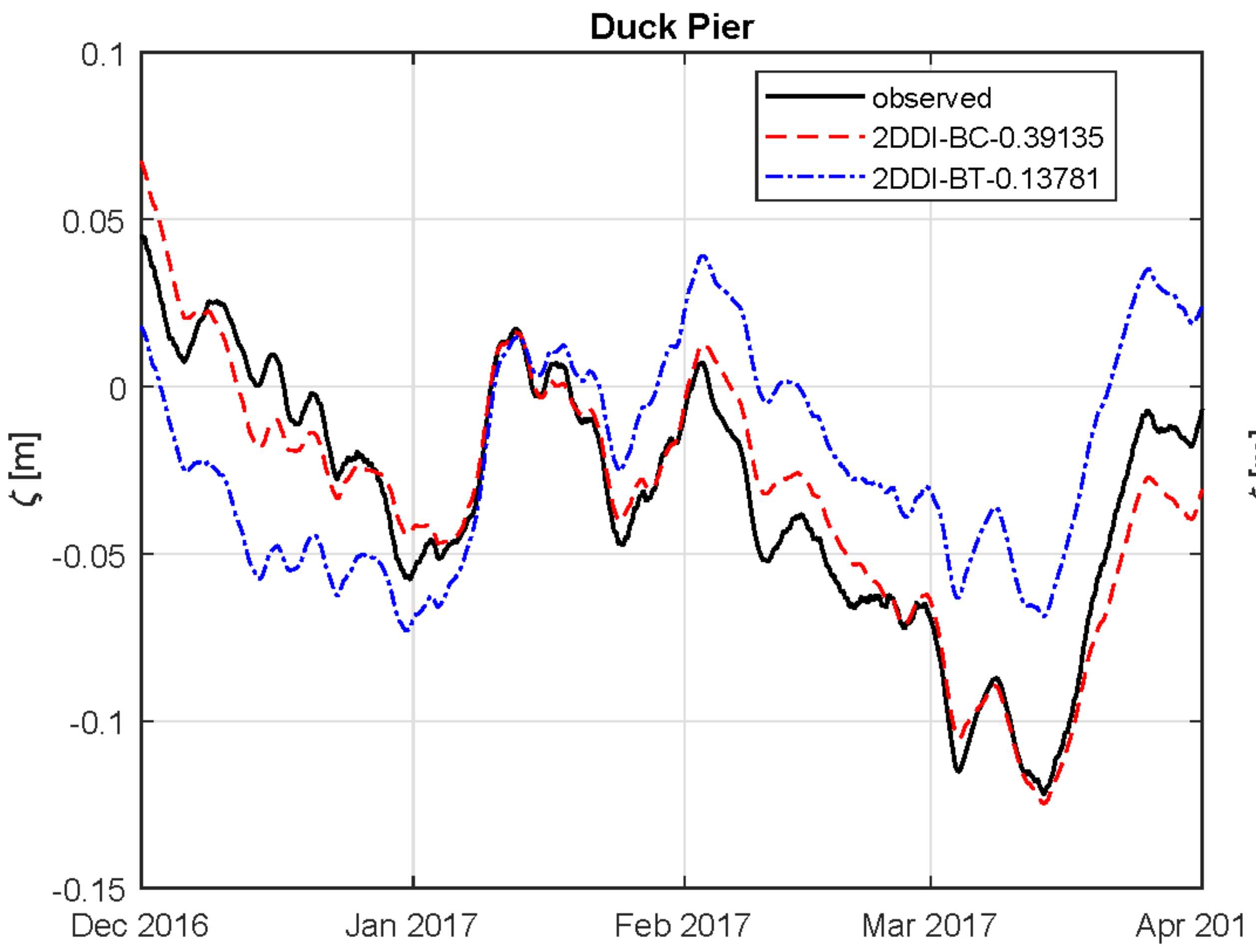


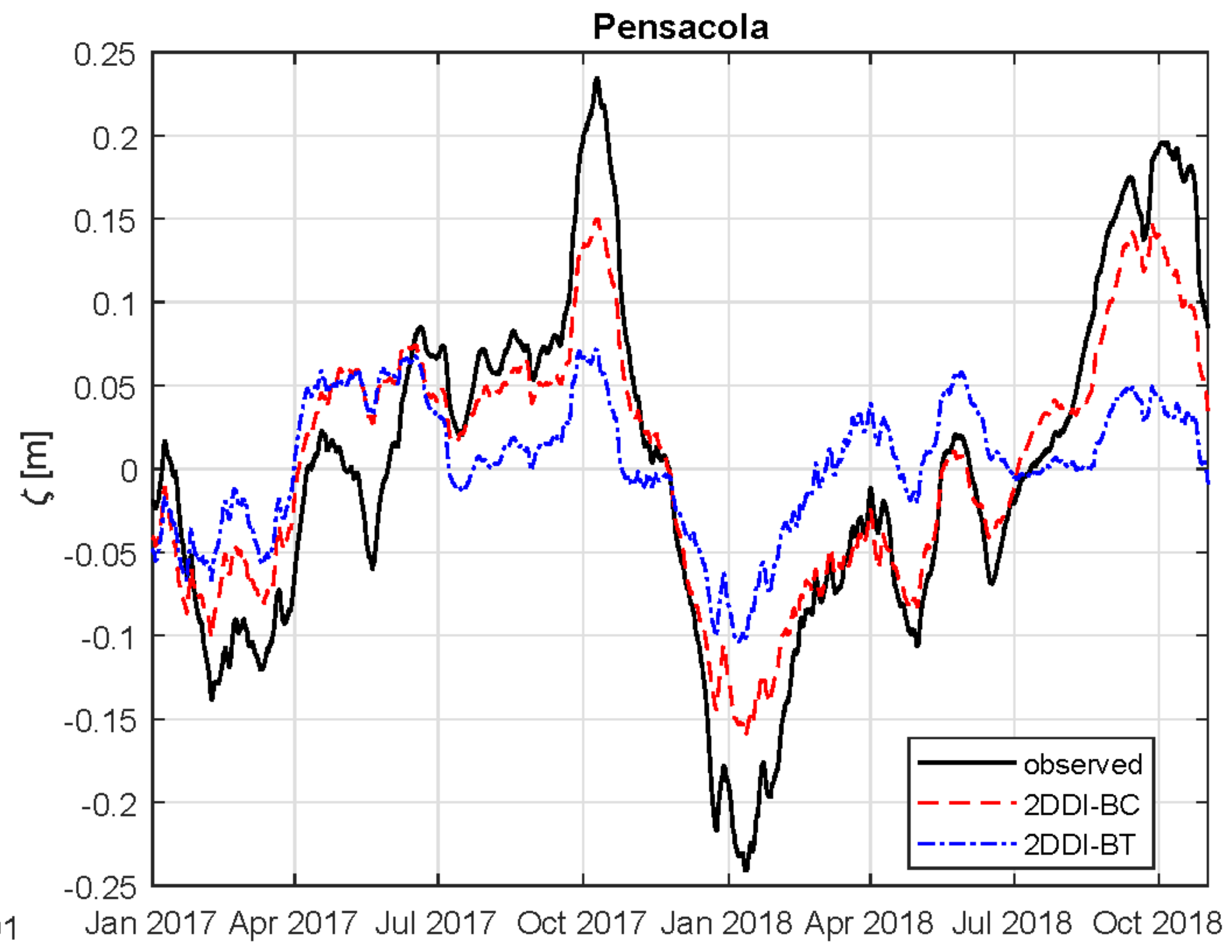
GOFS 3.1



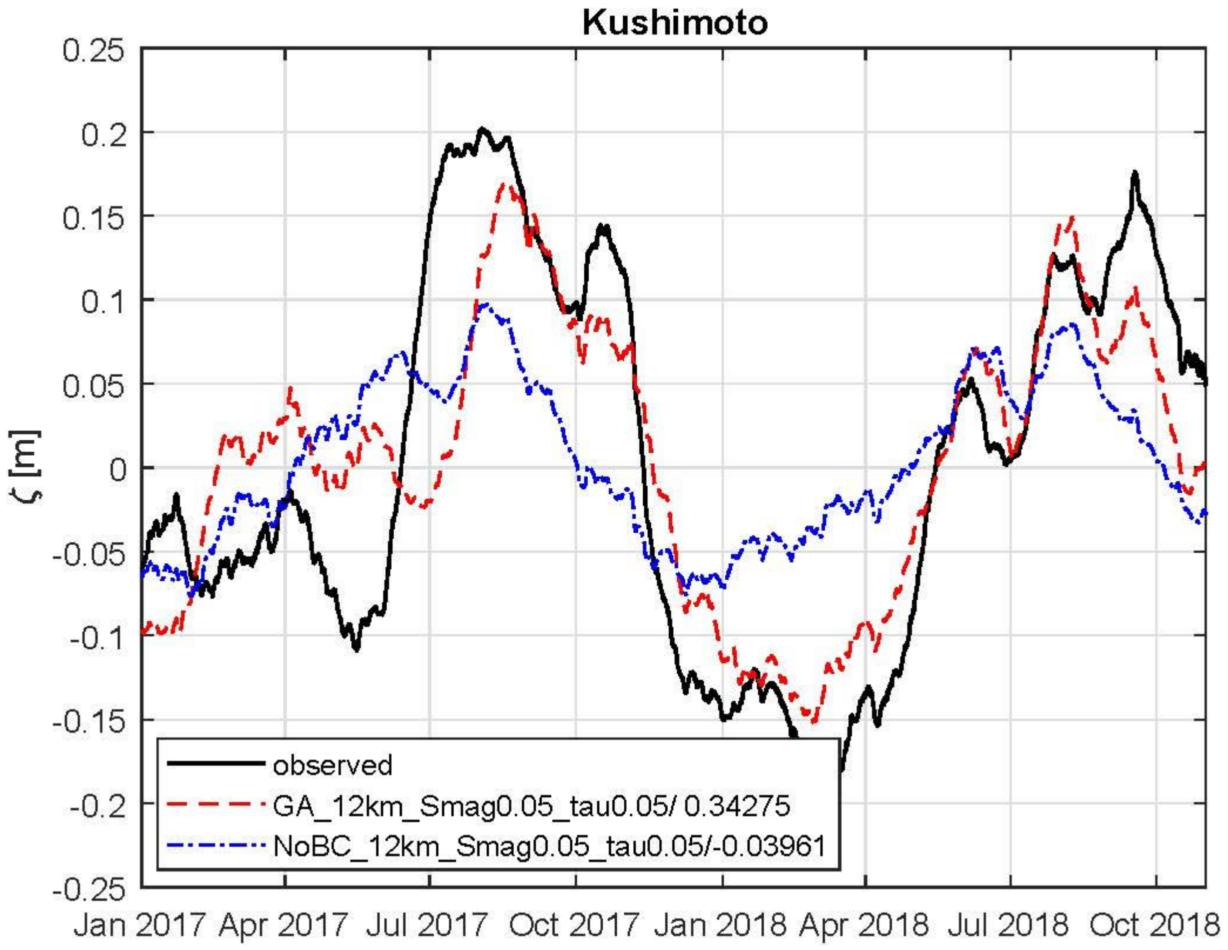
ADCIRC forced with GOFS 3.1 temperature and salinity fields

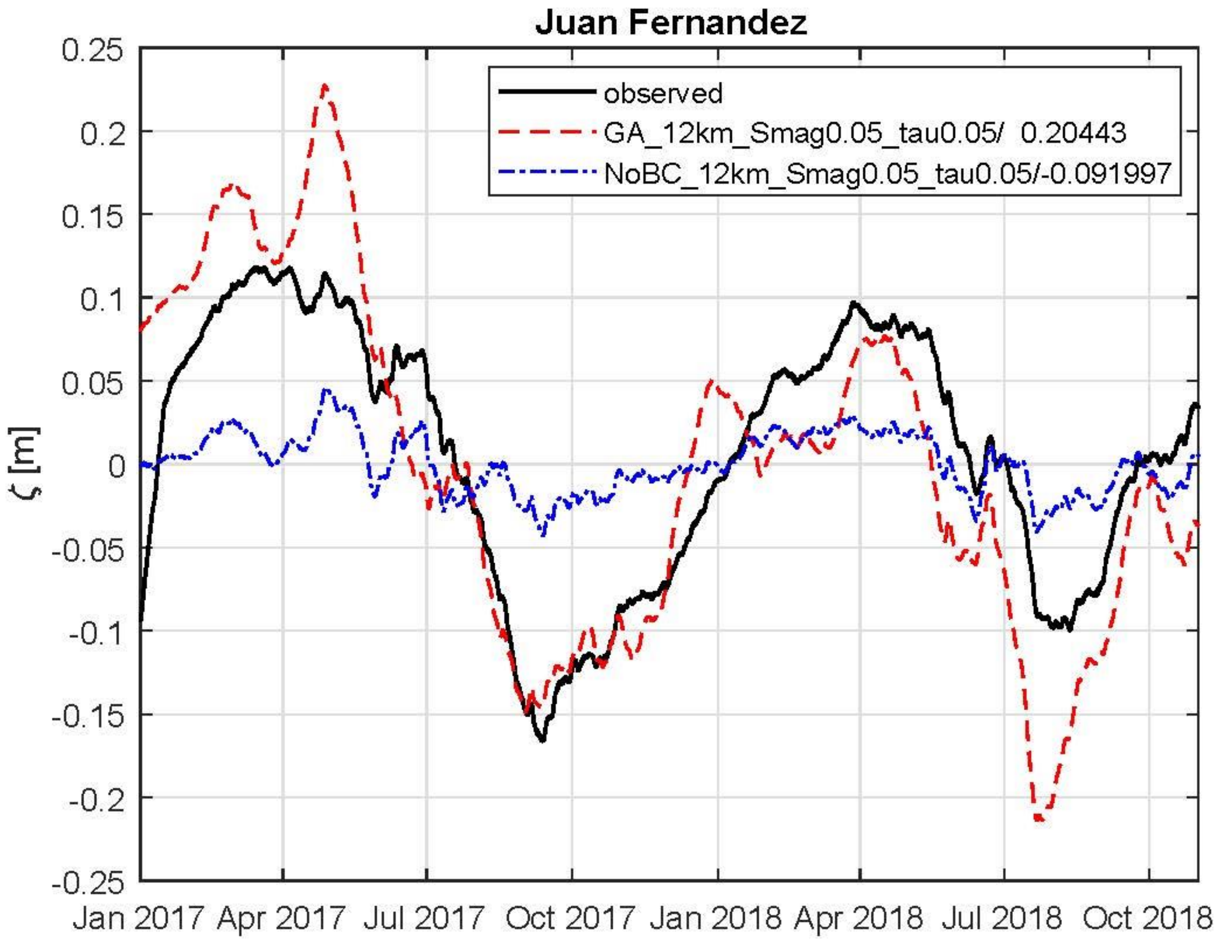
Sample comparison of 30 day averaged water levels – Atlantic Basin



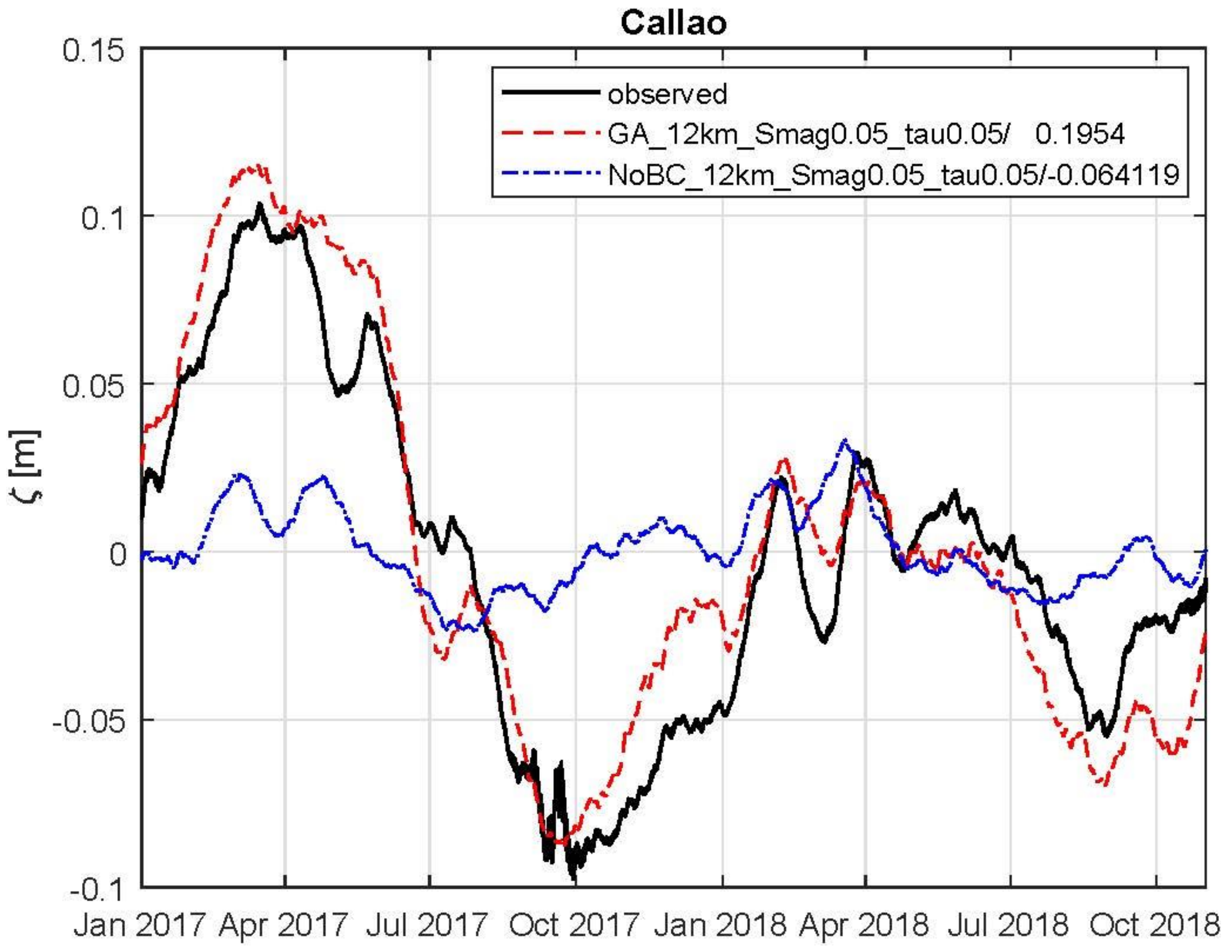


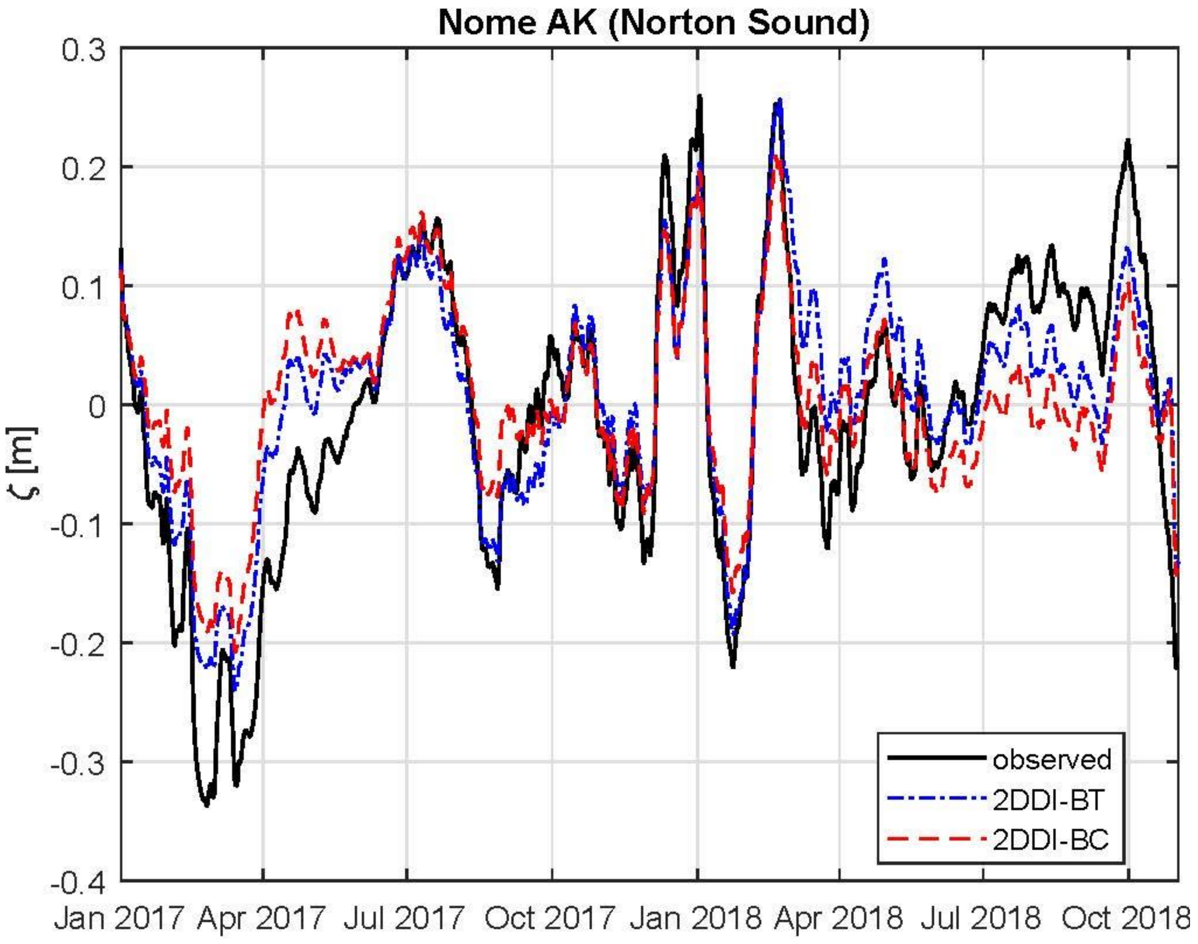
Sample comparison of 30 day averaged water levels – Western Pacific





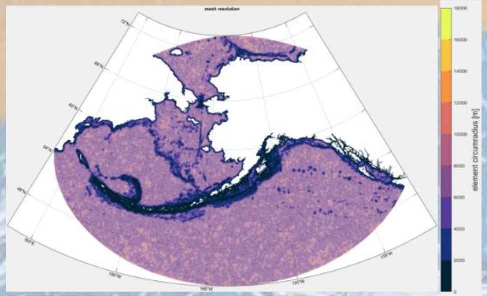
Sample comparison of 30 day averaged water levels – Eastern Pacific

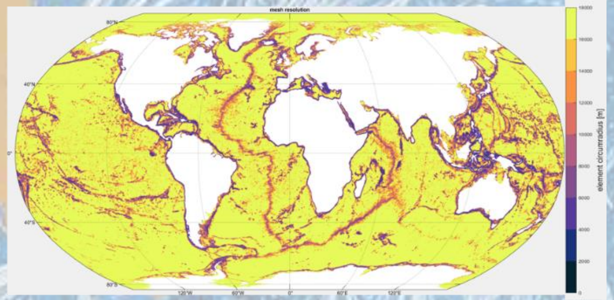


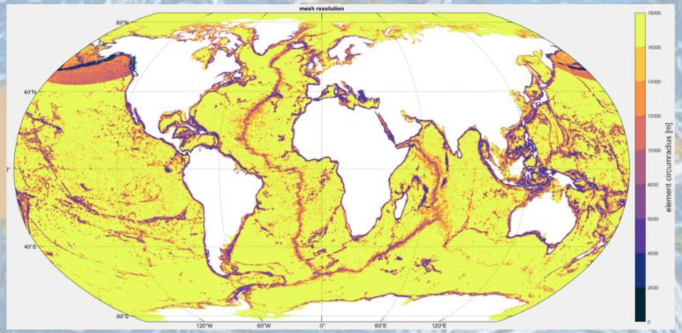


6. Global model tide sensitivity to bathymetry and high resolution insets

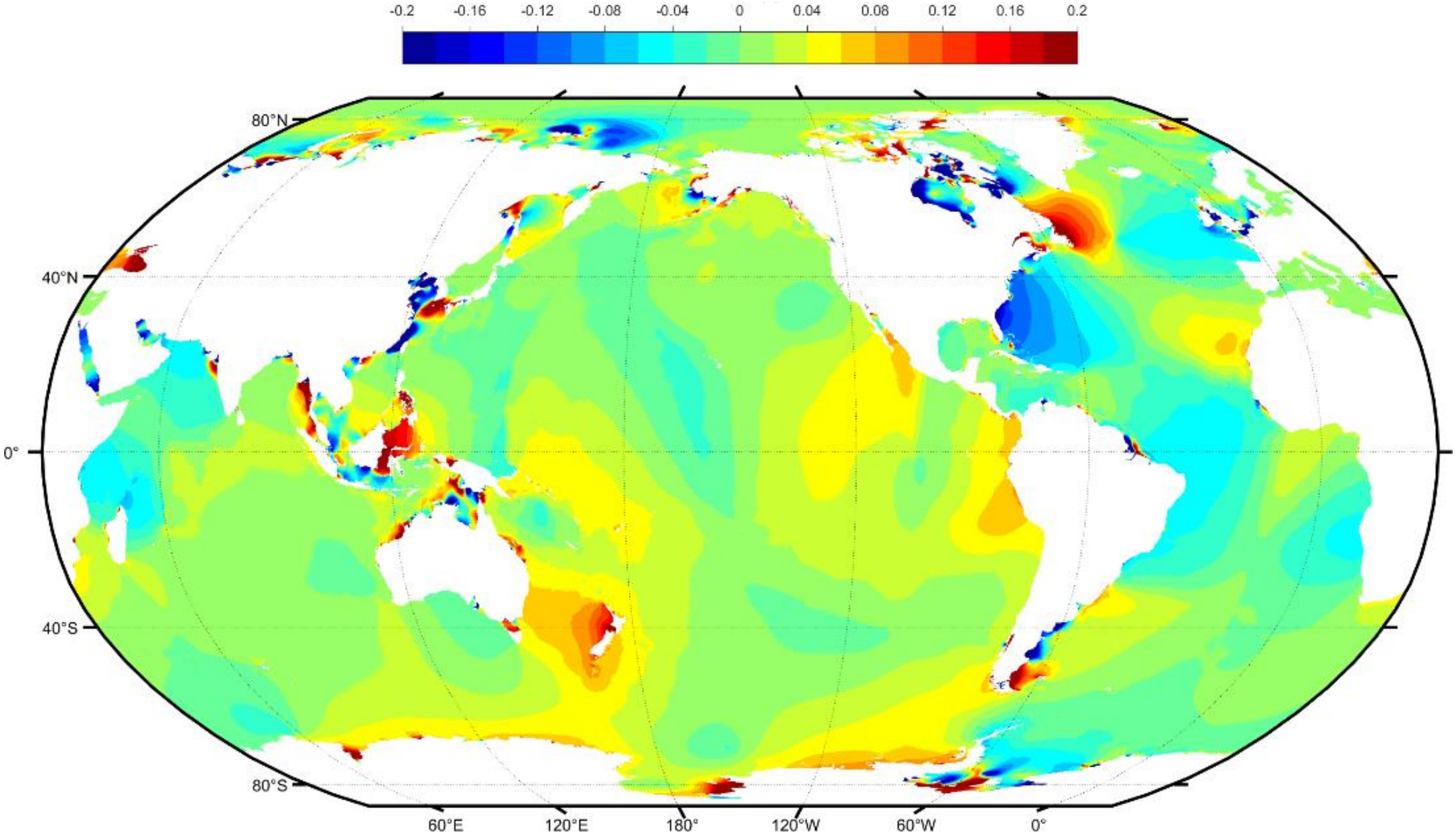
Mesh	Bathymetry
Global 24-2	GEBCO2015, Asia high res
Global 24-2	GEBCO2019, CHS NONNA-100
Global 24-2 + Mesh4-fp-v2	GEBCO2019, CHS NONNA-100, NOAA Alaska CRM



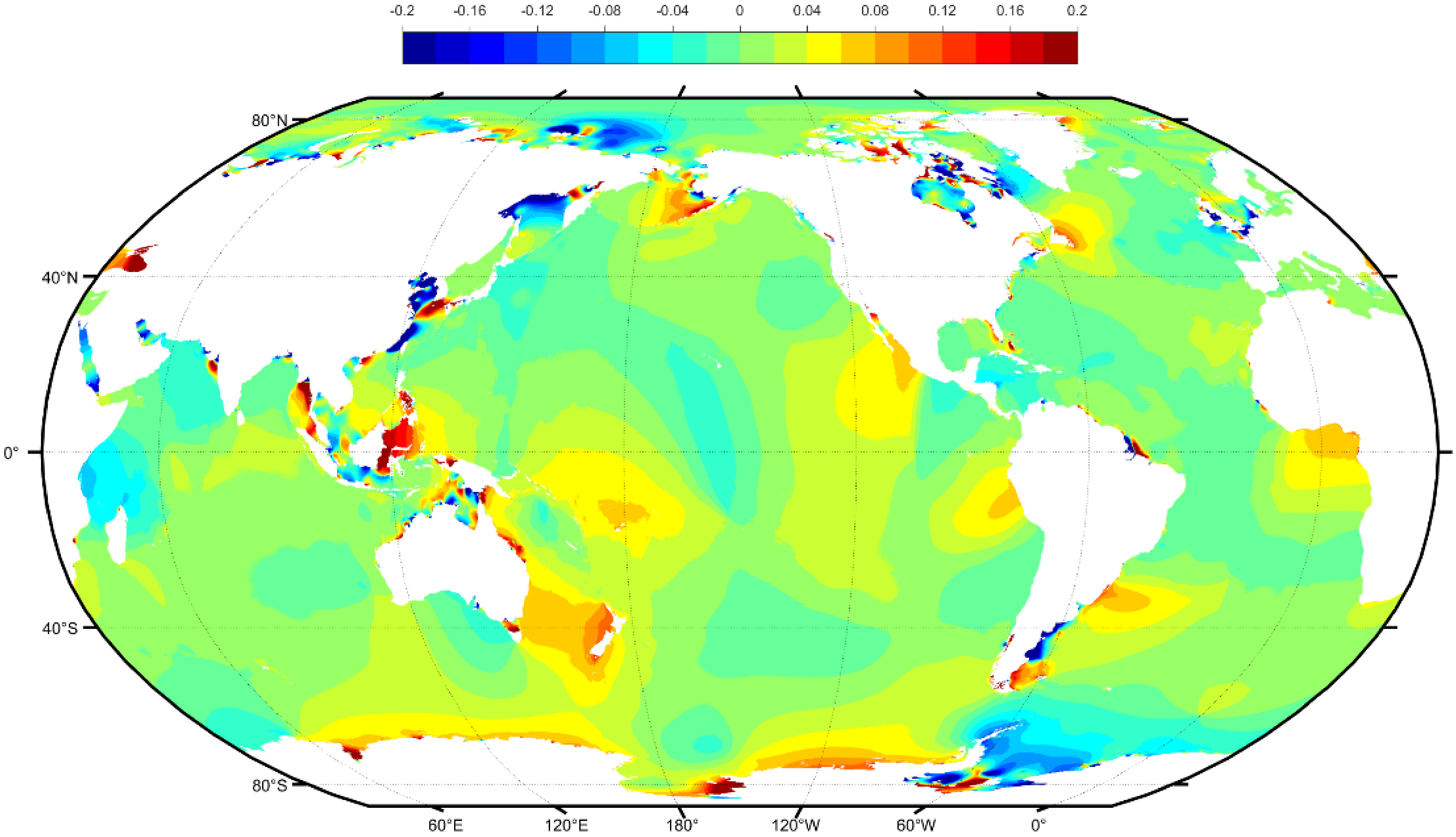




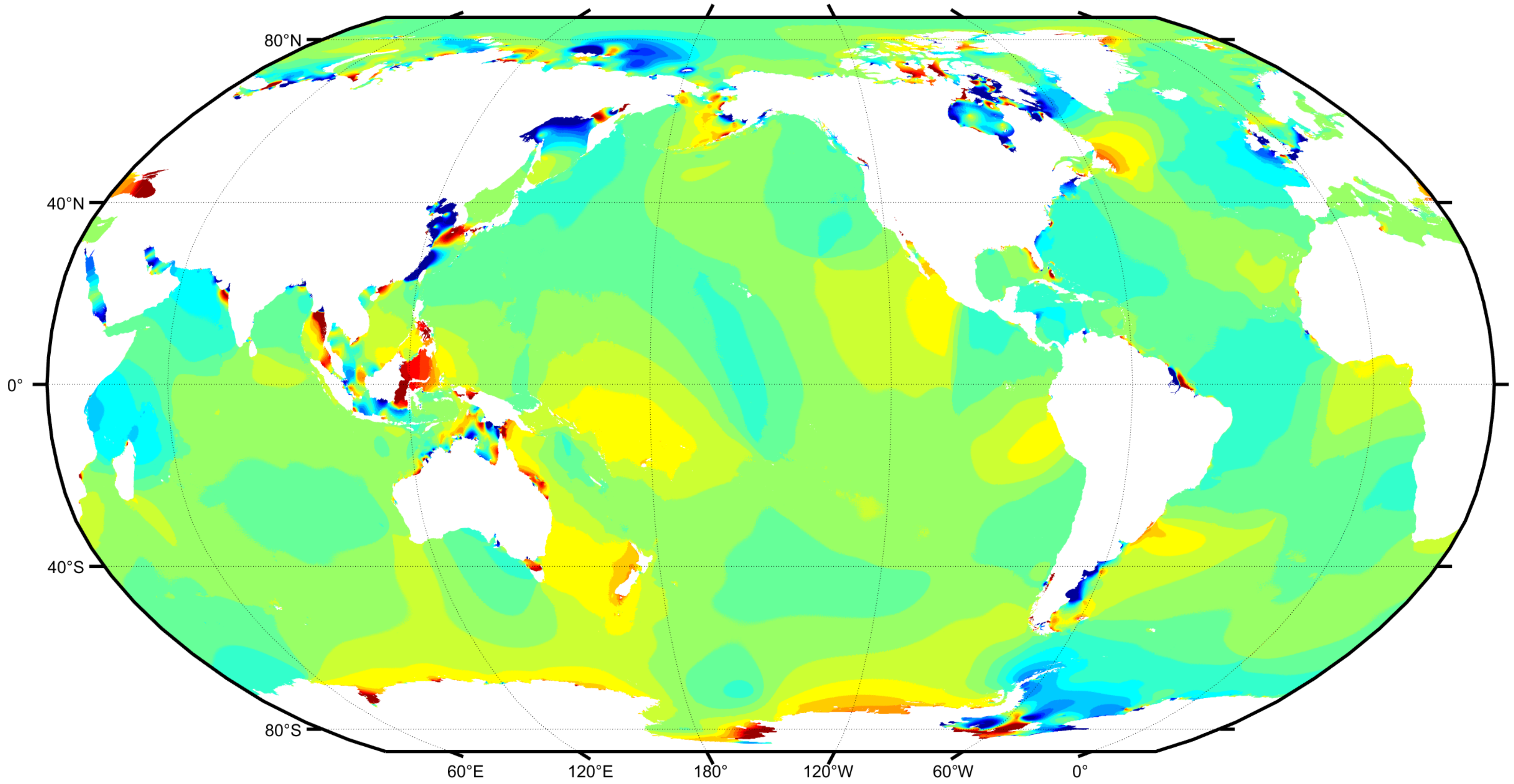
Global 24-2 M_2 tide with GEBCO2015 and HR Asia compared to TPX09 Atlas



Global 24-2 with GEBCO2019 & CHS NONNA-100 compared to TPX09 Atlas

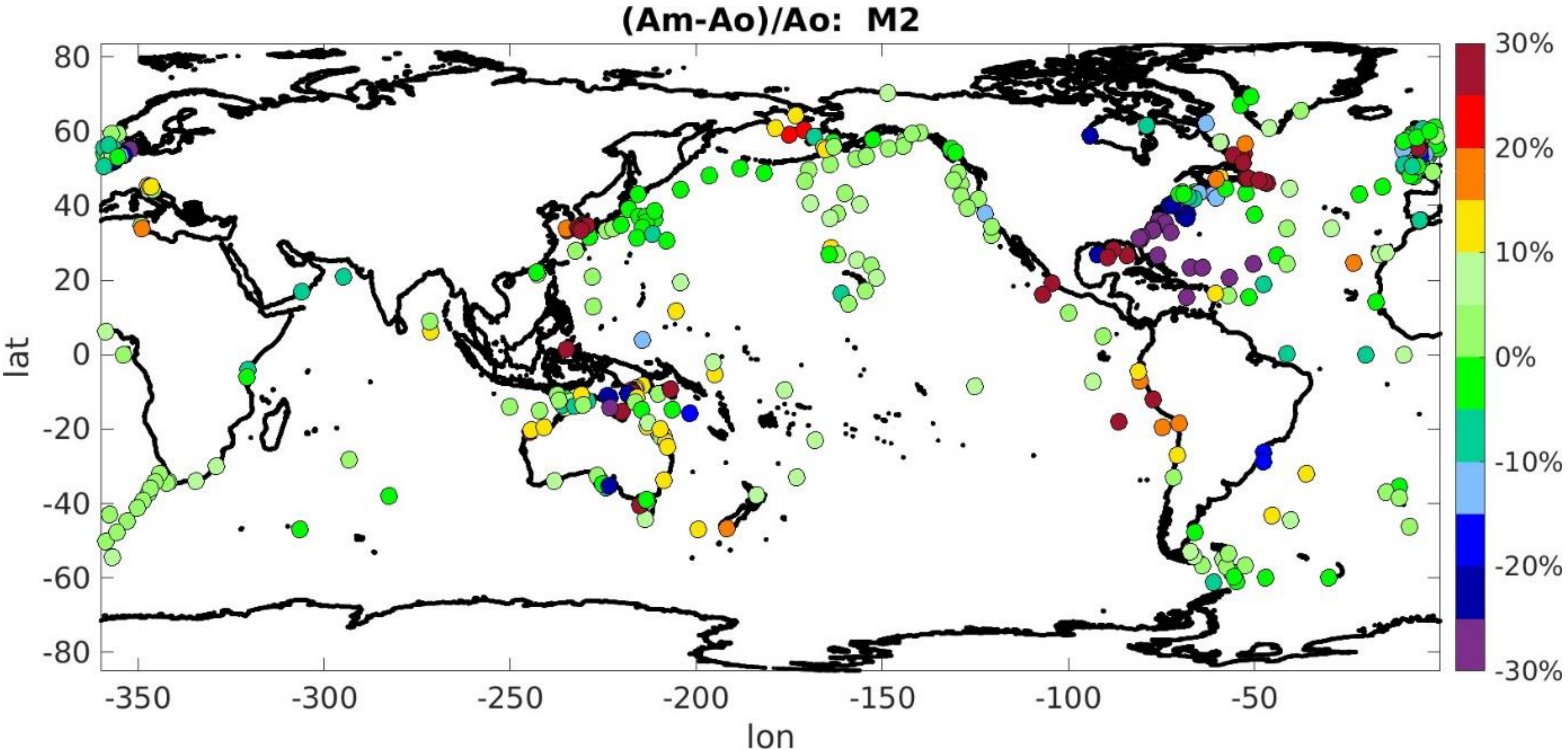


Global 24-2 + Mesh4-fp-v2 with GEBCO2019, CHS NONNA-100 and NOAA CRM compared to TPX09 Atlas

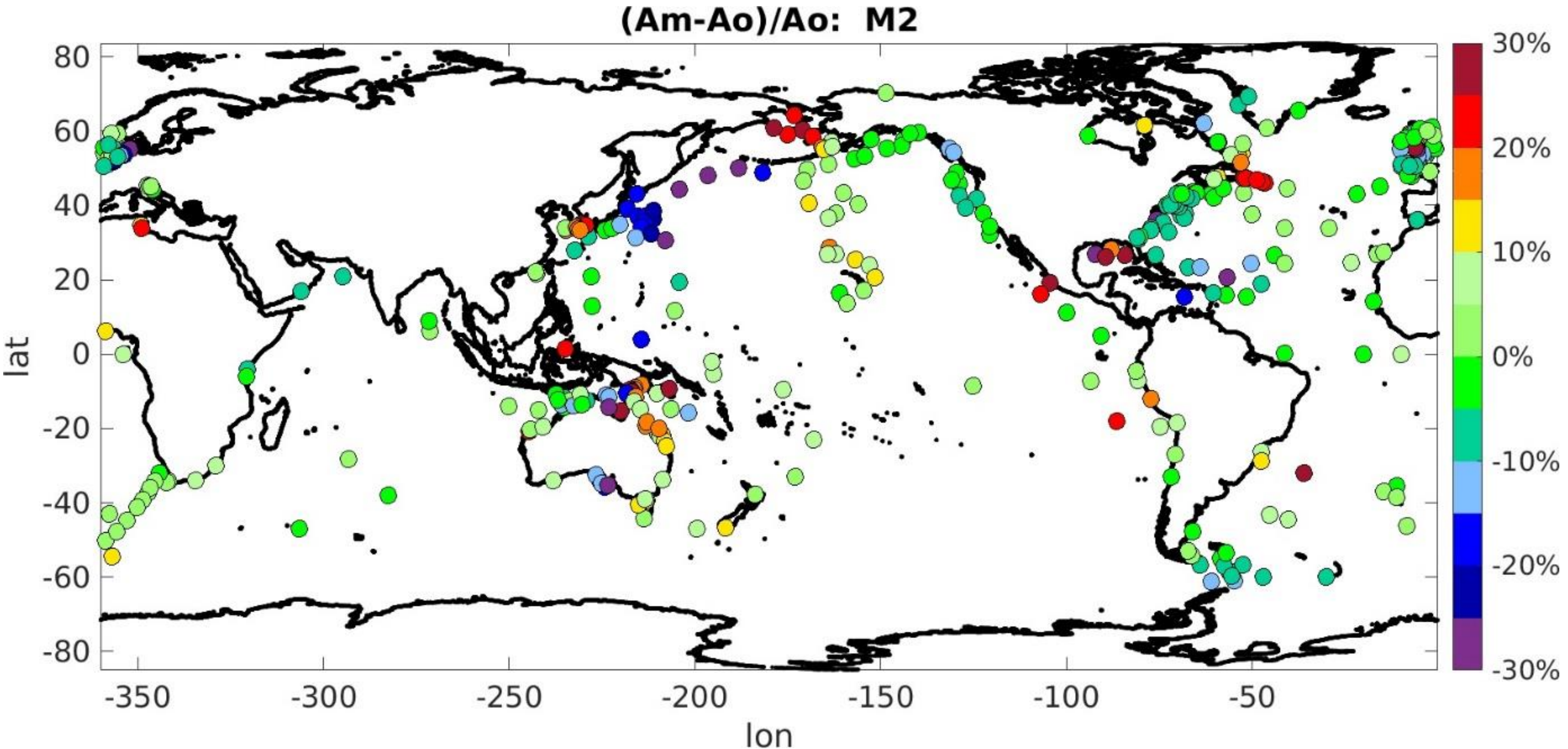


Global 24-2 with GEBCO2015 and HR Asia bathy compared to M_2 station data

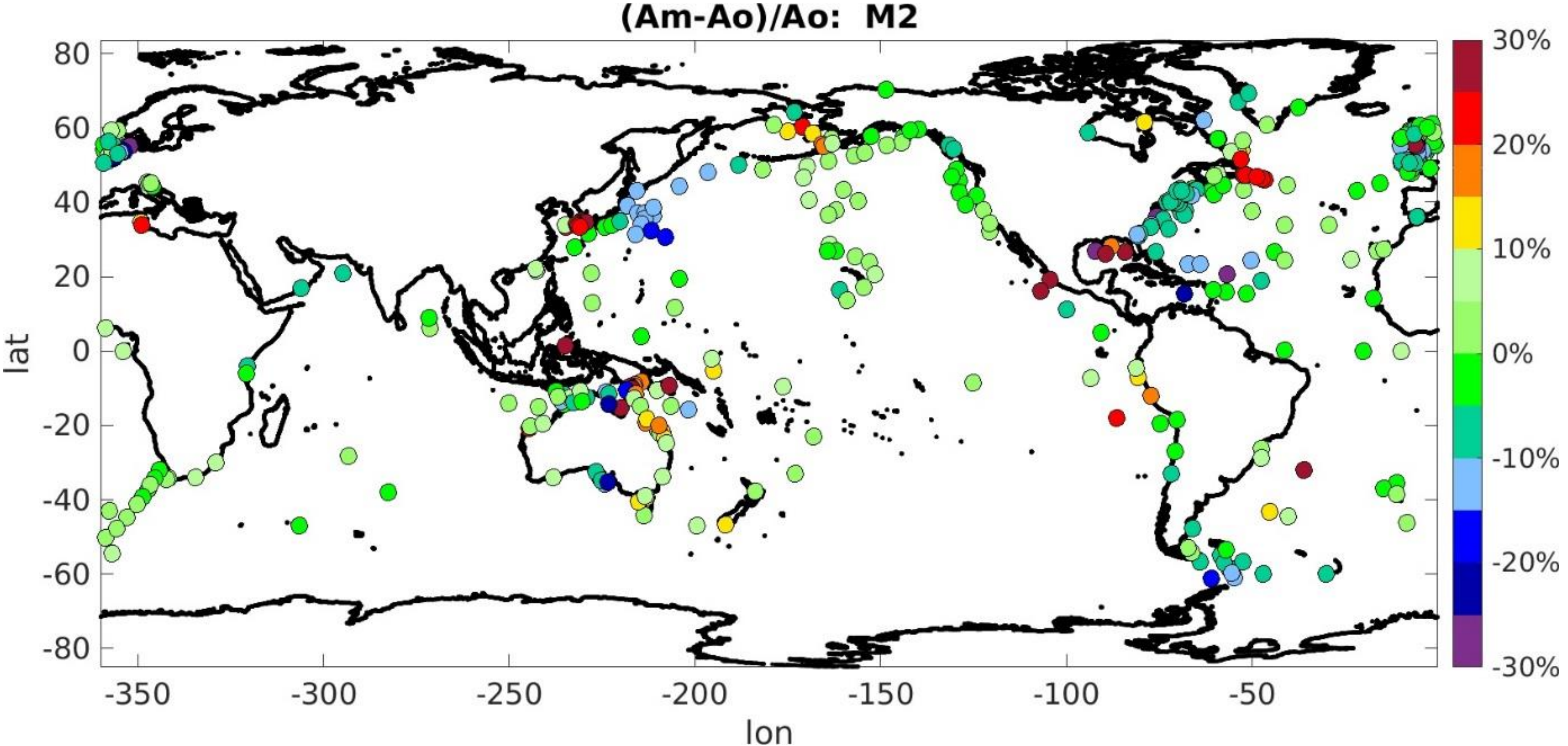
run with updated ADCIRC



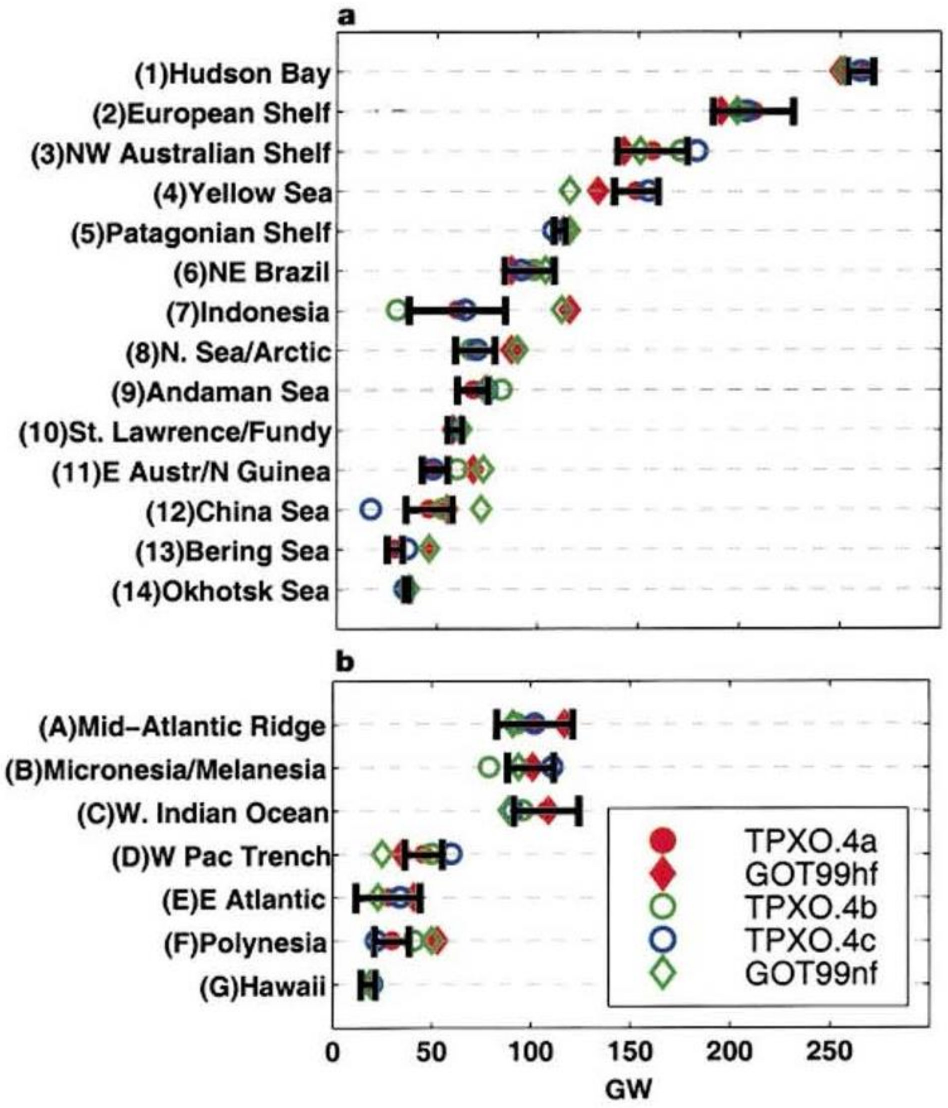
Global 24-2 with GEBCO2019 & CHS NONNA-100 bathy compared to M_2 station data run with updated ADCIRC



Global 24-2 + Mesh4-fp-v2 with GEBCO2019, CHS NONNA-100 and NOAA CRM compared to TPX09 Atlas

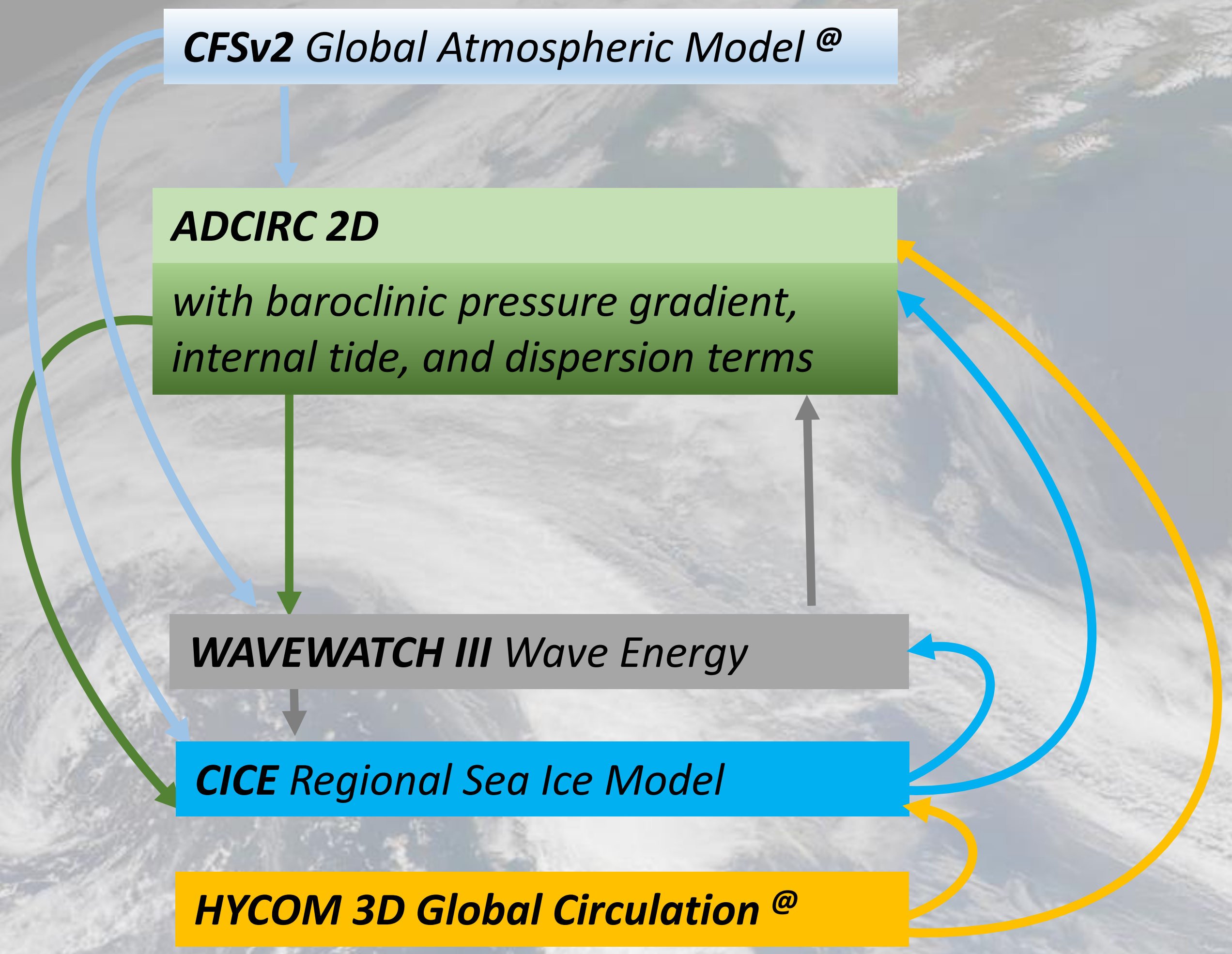


Regions of strong global tidal dissipation



Egbert and Ray, 2000

7. ALCOFS framework path forward



- Evolve meshes with higher inland detail
- Improve inner shelf and estuarine bathymetry
- Full integration into the updated global 24-2 shell
- Radiation stresses from wave model to ADCIRC
- Test various ice physics options in WW3
- Fully couple into high resolution CICE
- Integration of components using ESMF/NUOPC