A Regional Storm Surge Model for the Alaska Region and Updating Sea Ice Options in ADCIRC

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Western Alaska LCC

Outline

Outline

1. Alaska Regional ADCIRC Model
   - Model Description
   - Sea Ice Implementation to Circulation Modelling
   - Modelling Storm Surge in the Presence of Ice Coverage
     - November 2011
     - February 2011
     - January 2017
   - Moving Forward
2. Updating Sea Ice in ADCIRC

Outline

Region

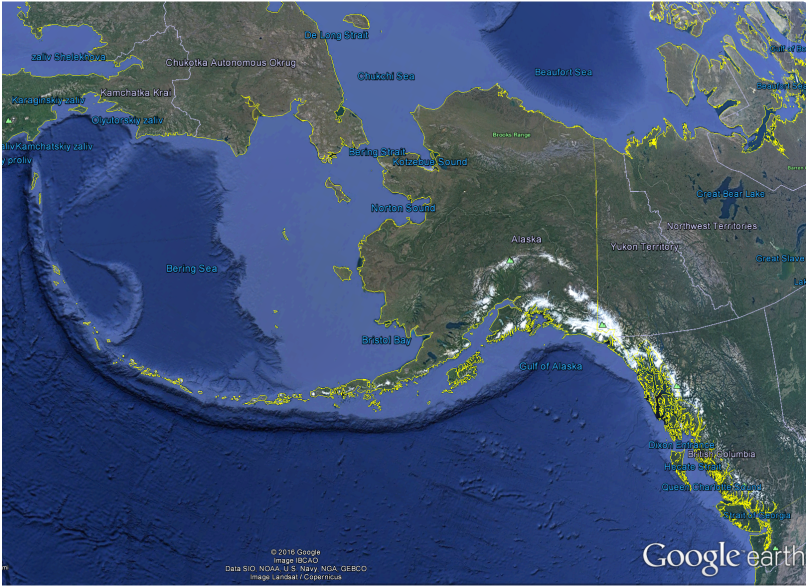
De Long Strait
zaliv Shelekhova
Chukotka Autonomous Okrug
Chukchi Sea
Beaufort Sea
Kamchatka Krai
Karaginskiy zaliv
Olyutorskiy zaliv
Kamchatskiy zaliv
Bering Strait
Kotzebue Sound
Brooks Range
Great Bear Lake
Norton Sound
Northwest Territories
Alaska
Yukon Territory
Bering Sea
Bristol Bay
Gulf of Alaska
Dixon Entrance
British Columbia
Hecate Strait
Queen Charlotte Sound
Strait of Georgia
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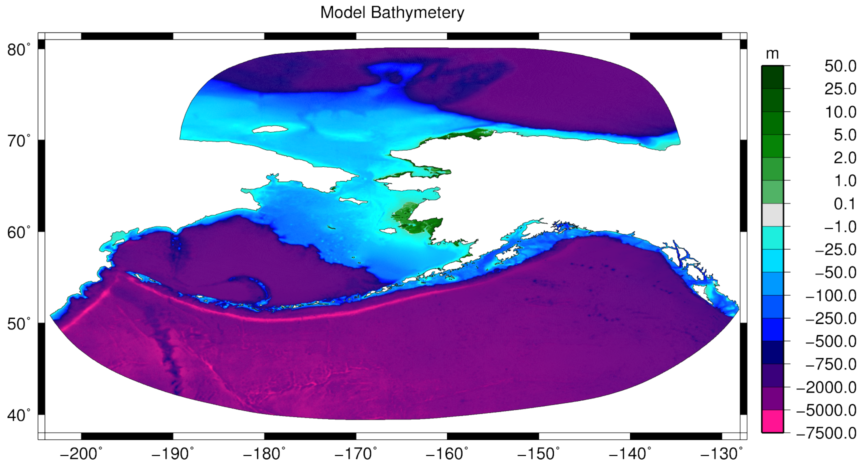
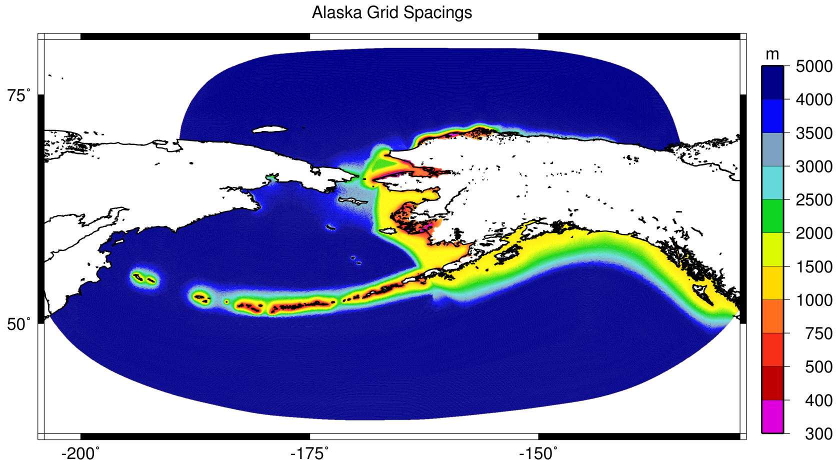
Image IBCAO
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Google earth

Grid Development



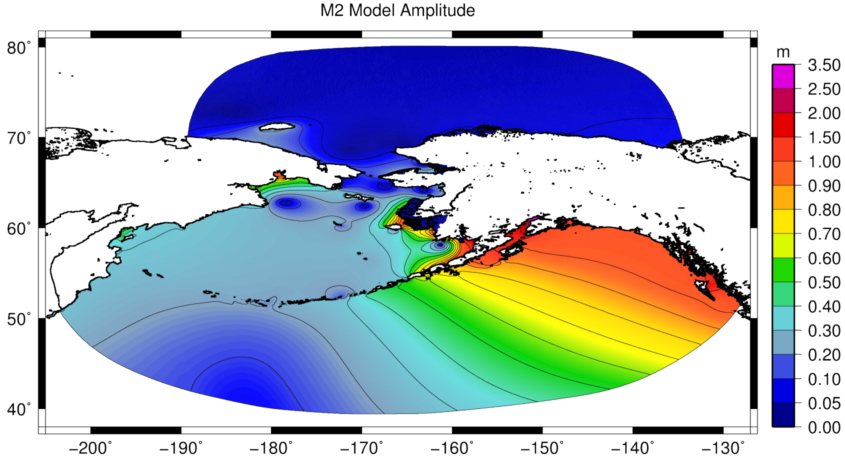
8070796 elements, 4061175 nodes, 25 m coastal resolution

Grid Development

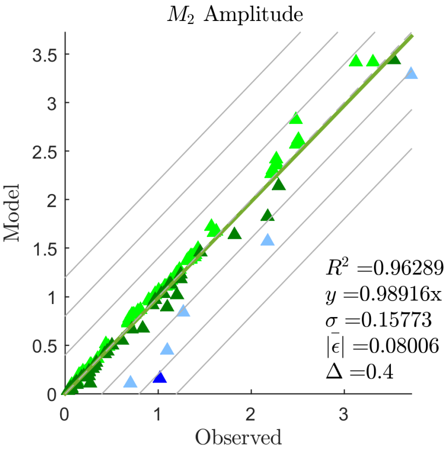


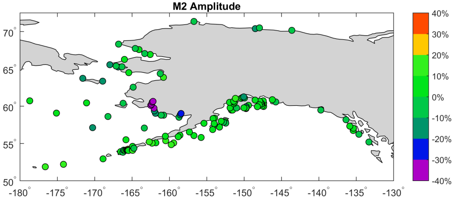
8070796 elements, 4061175 nodes, 25 m coastal resolution

M_2 Amplitude



M_2 Validation



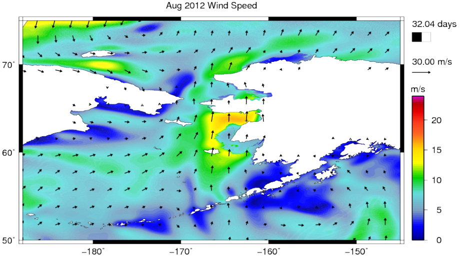


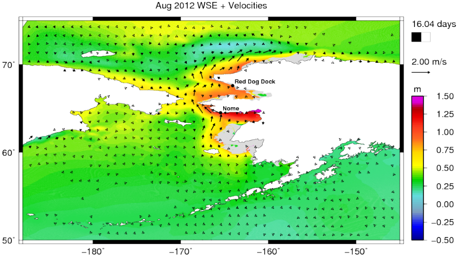
- Good performance everywhere but Kuskokwim River
- Includes SAL, parameterized internal tide dissipation, bottom friction - all contribute to accuracy of solution

Atmospheric Forcing

- National Centers for Environmental Prediction's Climate Forecast System Reanalysis (CFSv2) [4].
- Hourly wind speeds at a 10 m height with a horizontal resolution of 0.205 degrees by 0.204 degrees
- Hourly atmospheric pressure at a resolution of 0.5 degrees.

Ice Free Storms - August 2012

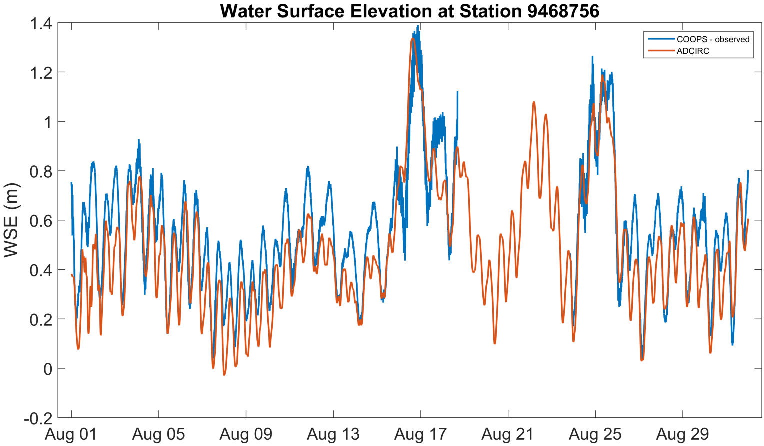




Stations

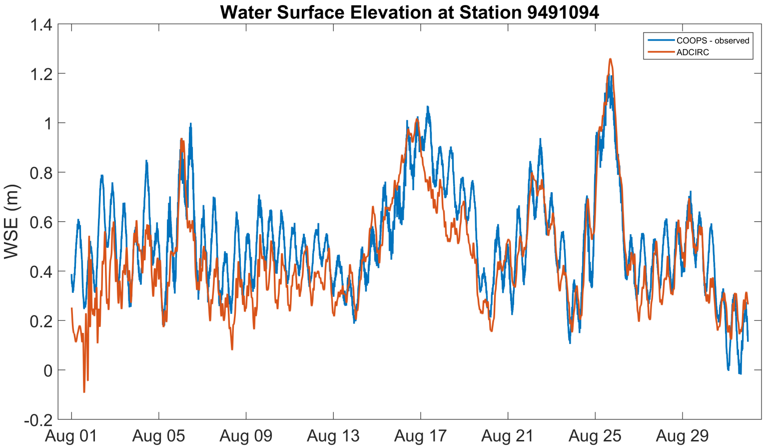
August 2012 Validation

Nome



August 2012 Validation

Red Dog Dock



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Base Implementation to ADCIRC

Used by ACOE (Chapman 2005, 2009)

$$C_{d,iceoriginal} = \max\left(C_{d,Garratt}, C_{d,Chapman}\right). \quad (1)$$

where

$$C_{d,Chapman} = 0.00075 + 0.0075AF - 0.009AF^2 + 0.002AF^3 \quad (2)$$

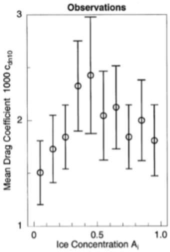


Fig. 2. Mean neutral drag coefficients at 10 m height c_{dn10} derived from observations (Hartmann et al., 1994; Kottmeier et al., 1994) as a function of ice concentration A_i.

[?]

- AF = area fraction ice
- Observation based
- Solely a function on AF
- Under high wind speeds, this drag coefficient essentially ignores the presence of ice coverage

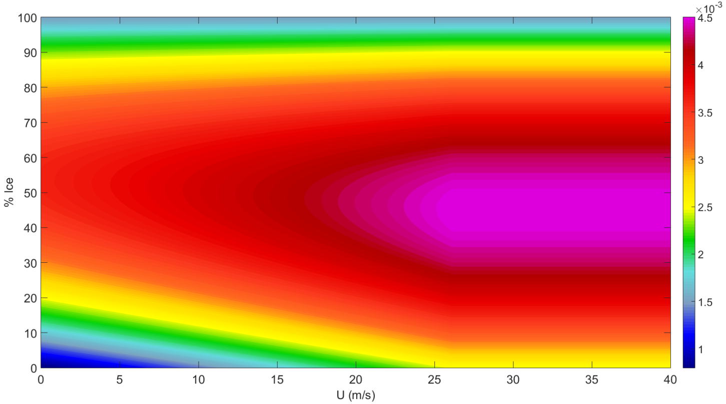
Our Implementation to ADCIRC

$$C_D = (AF)C_{D,is} + (1 - AF)C_{D,w} + C_{D,if} \quad (3)$$

$C_{D,is} = 0.0015$
$C_{D,w} = GarrattDrag$
$C_{D,if}(0) = 0$, $C_{D,if}(1) = 0$
$C_{D,if}(.5) = C_{D,if,max} = .0025$

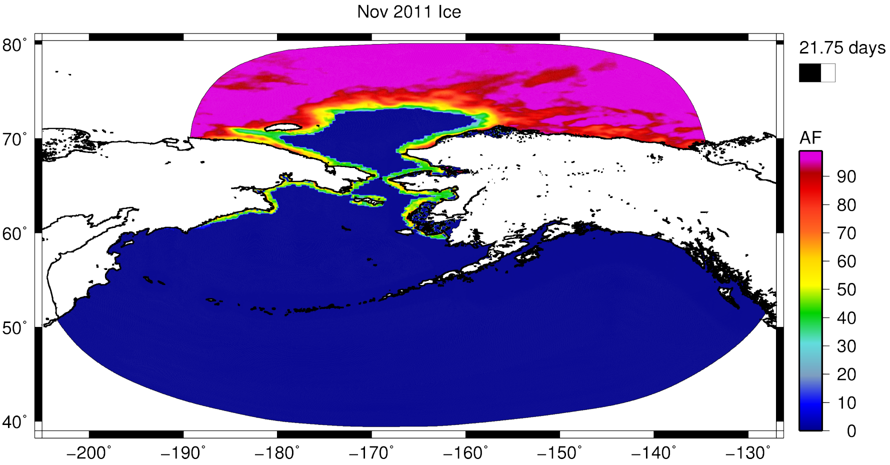
- Decompose the flux coefficient into contributions which are a function of both wind speed and ice coverage
- Area weighted approach [6, 1, 2]
- Considers both the form and skin drag over ice floes
- Form drag determined by number of ice face/obstacles
- Sea ice concentration from NCEP Automated Sea Ice Concentration Analysis - 5' resolution, satellite based

Ice Parameterization - C_d

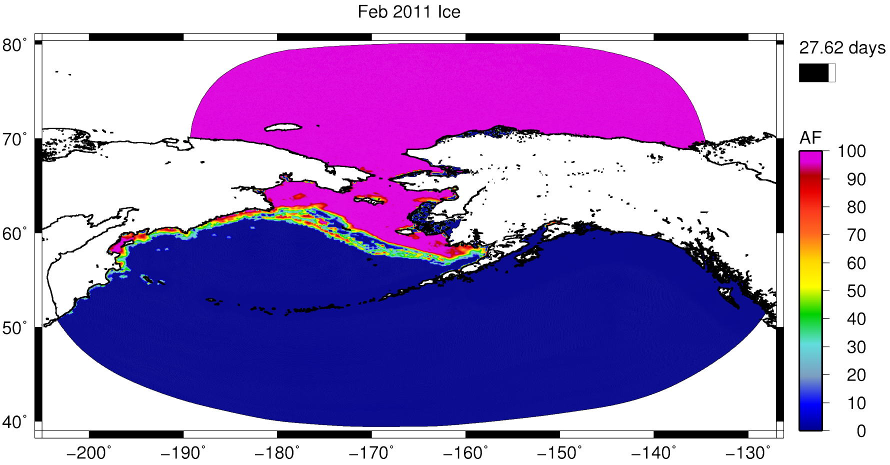


Outline

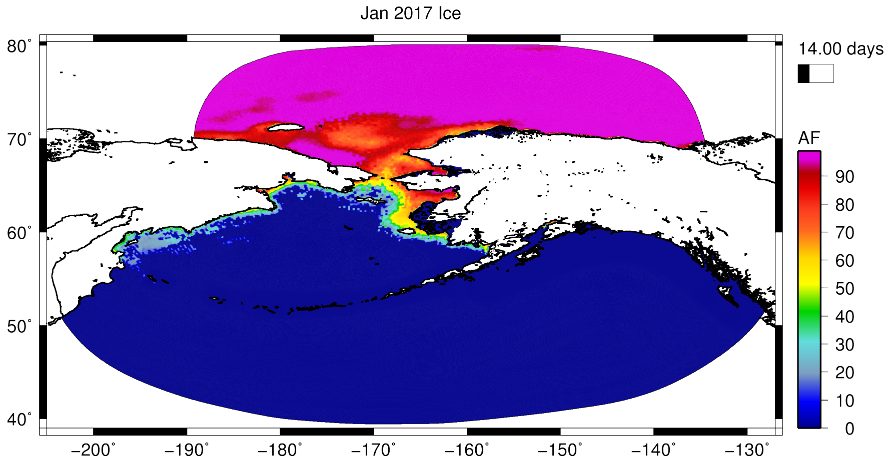
November 2011 Ice Coverage



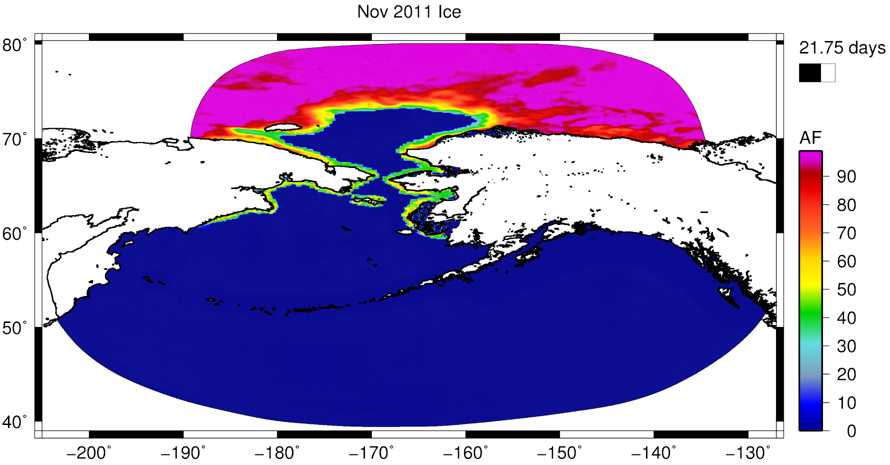
February 2011 Ice Coverage



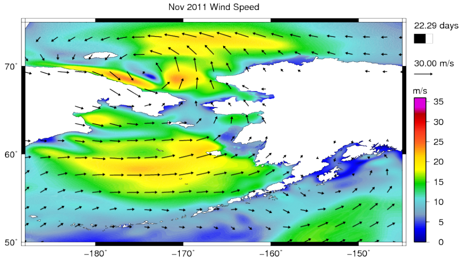
January 2017 Ice Coverage

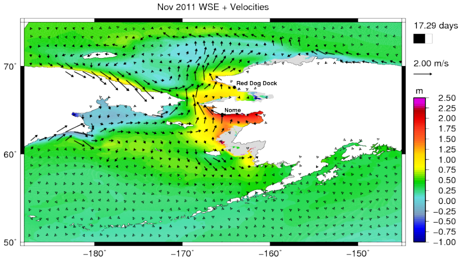


November 2011 Ice Coverage



November 2011

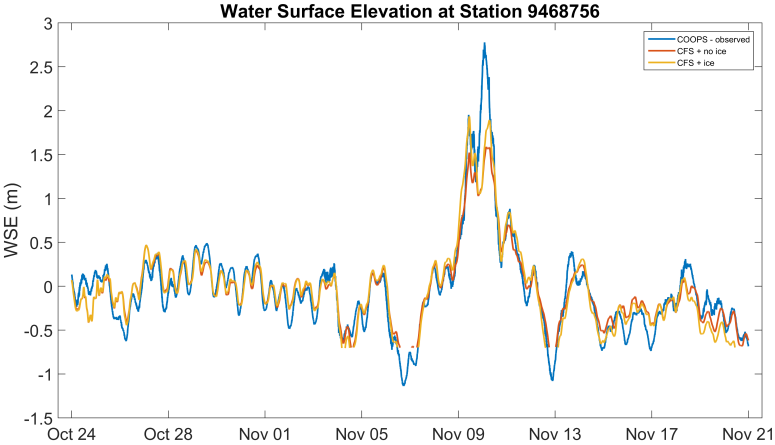




Stations

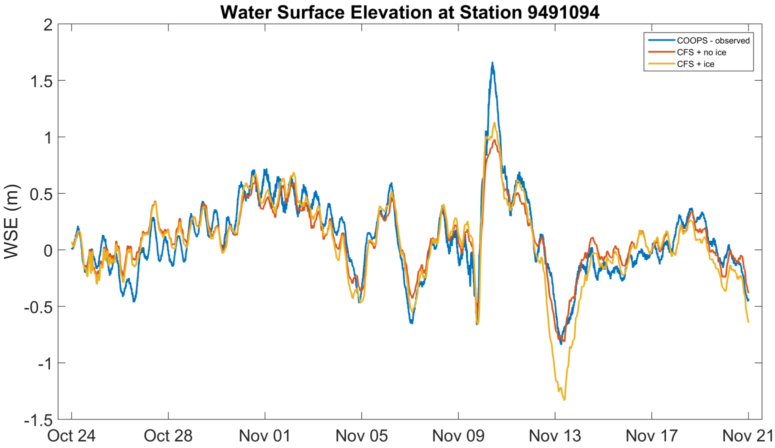
November 2011 Validation

Nome



November 2011 Validation

Red Dog Dock



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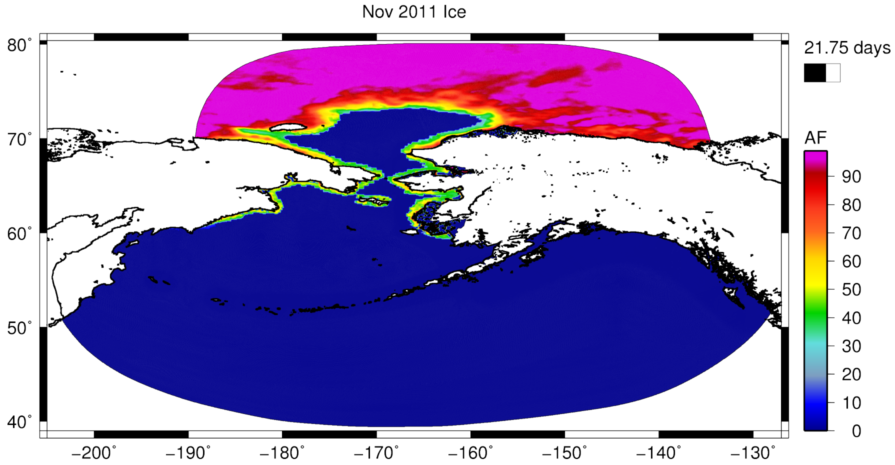
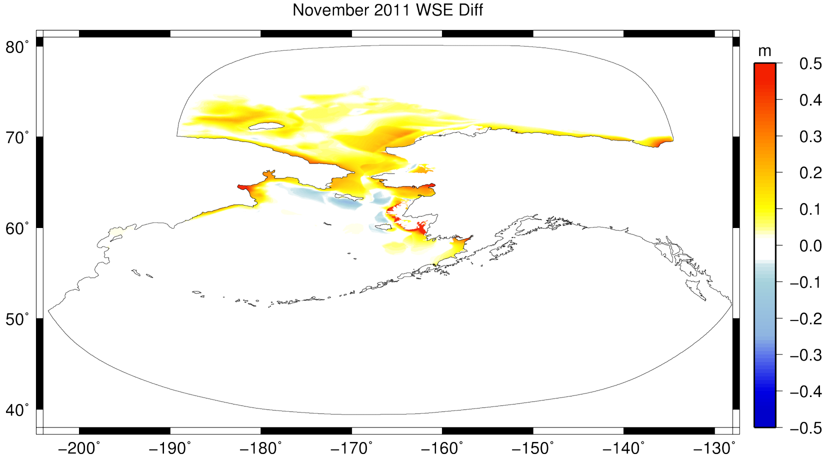
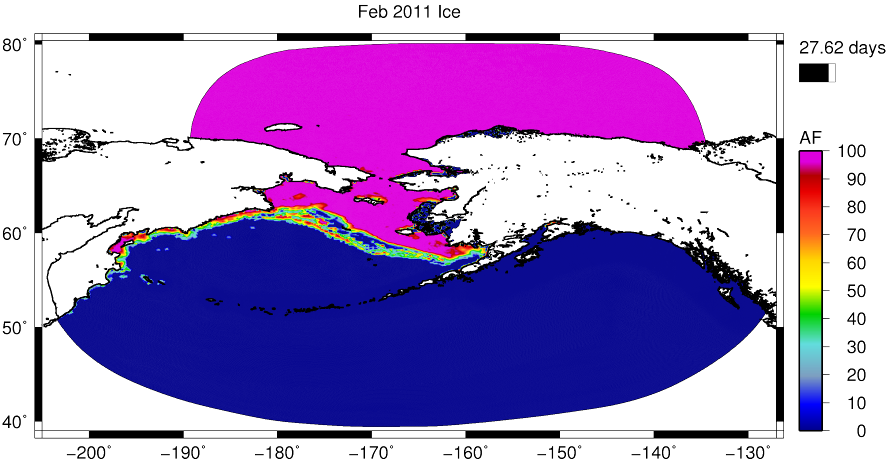


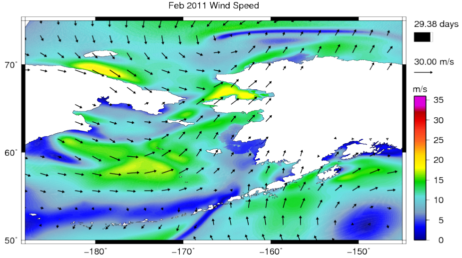
November 2011 Effect of Ice

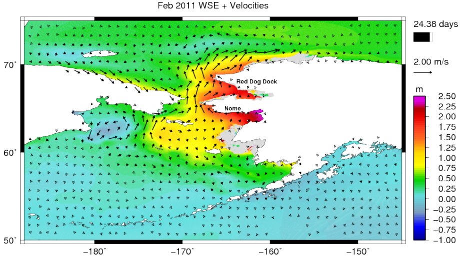


February 2011 Ice Coverage



February 2011





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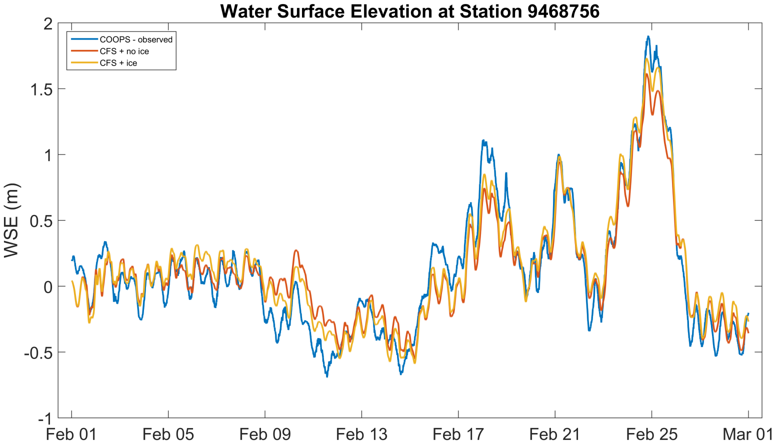

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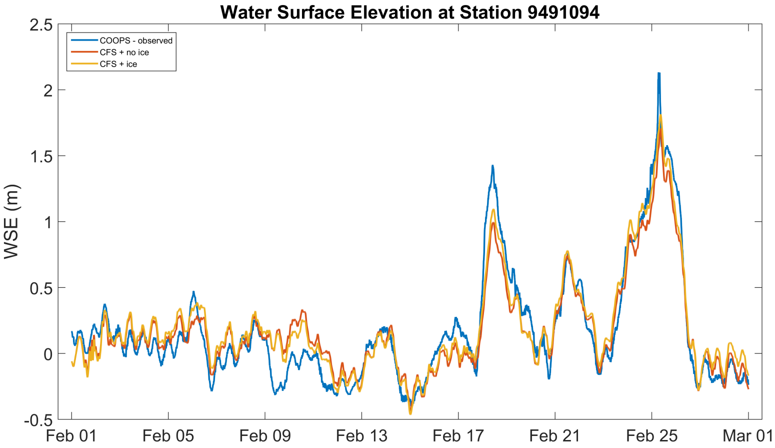

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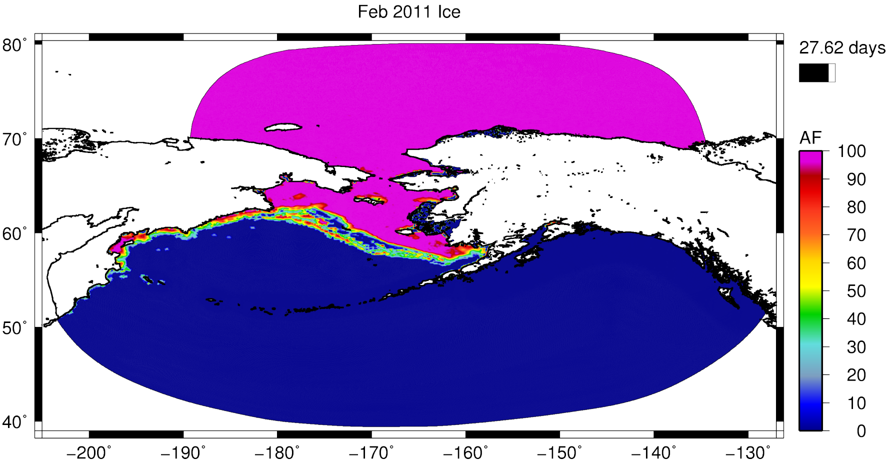

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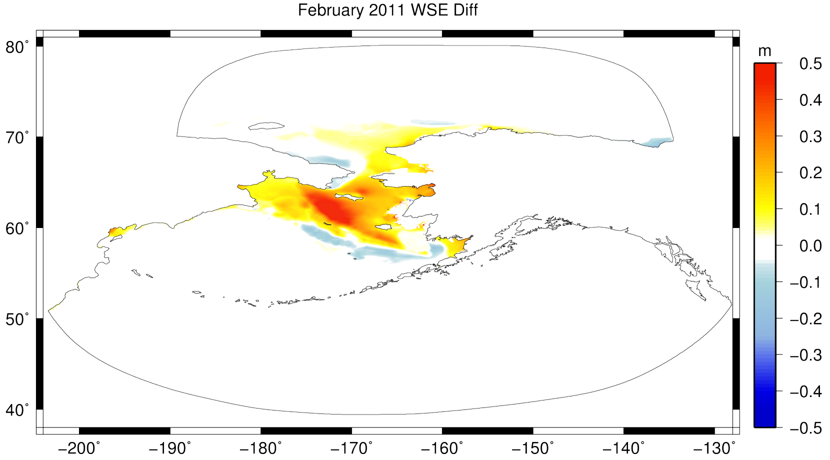

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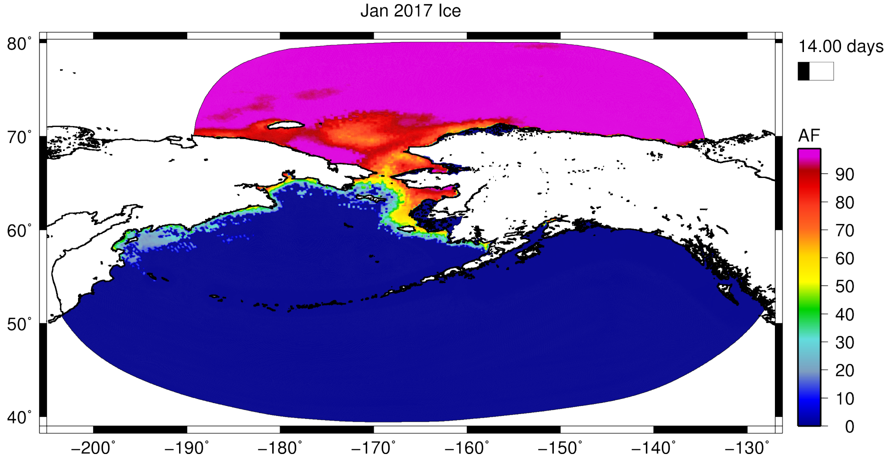
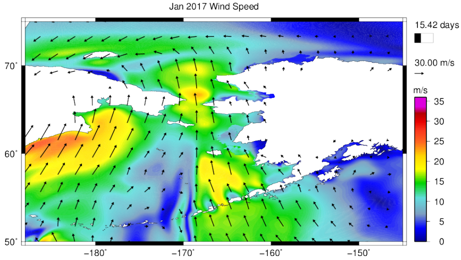
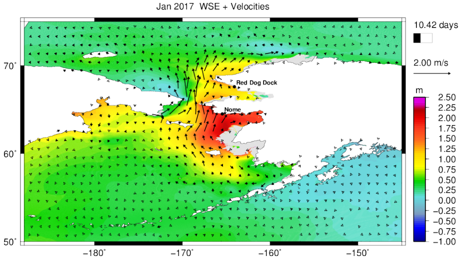


January 2017





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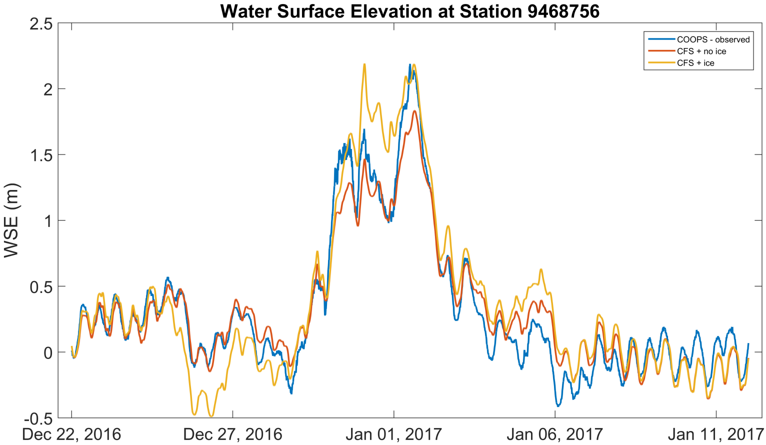
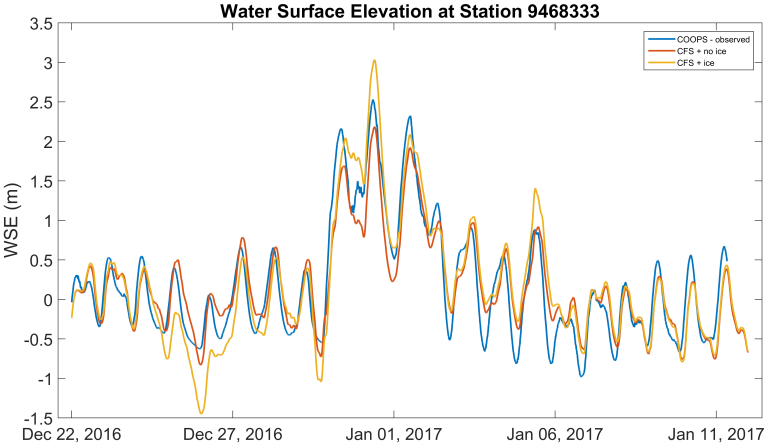

Water Surface Elevation at Station 9468756
WSE (m)
2.5
2
1.5
1
0.5
0
-0.5
Dec 22, 2016
Dec 27, 2016
Jan 01, 2017
Jan 06, 2017
Jan 11, 2017
COOPS - observed
CFS + no ice
CFS + ice

January 2017 Validation

Unalakleet



January 2017 Validation

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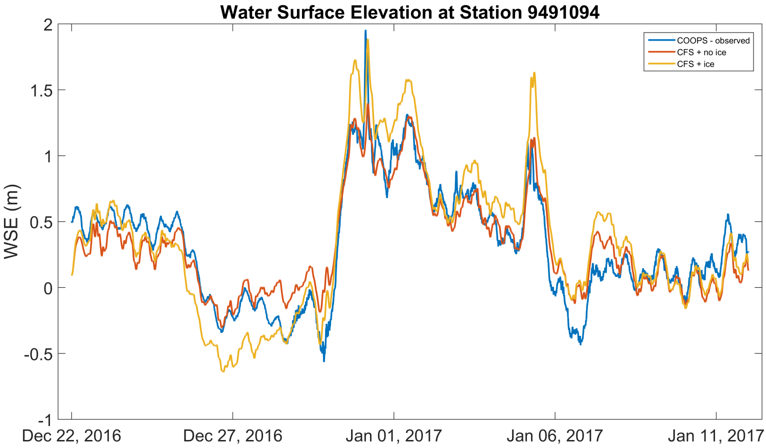
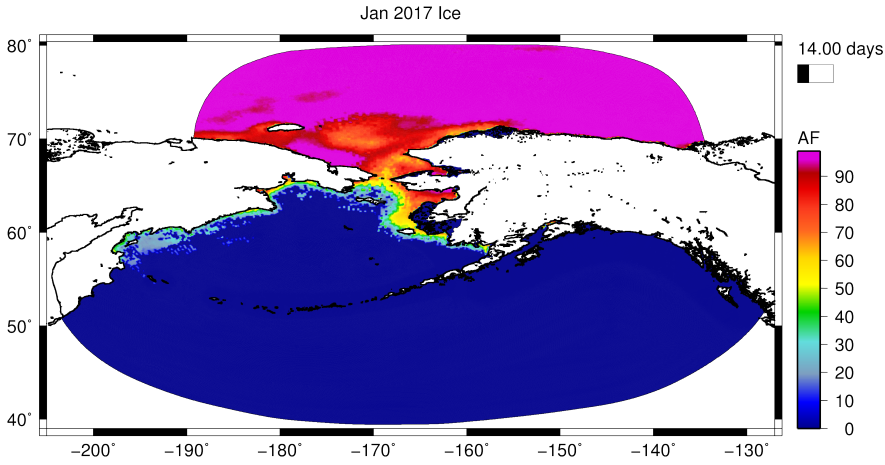


January 2017 Ice Coverage



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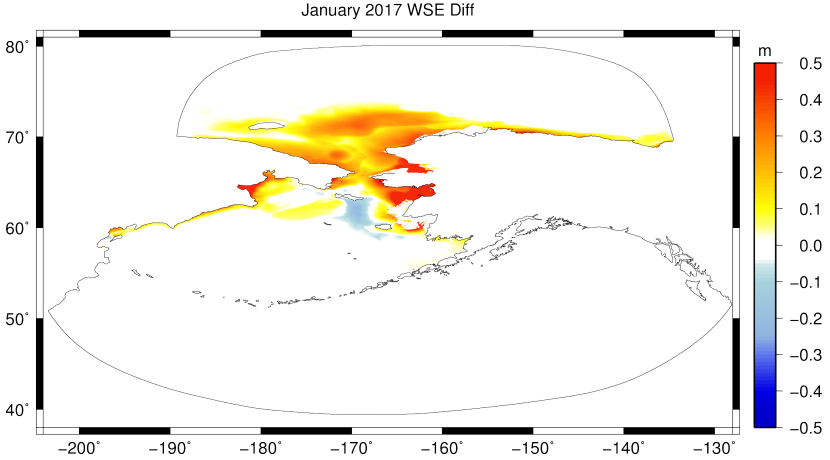

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2. Updating Sea Ice in ADCIRC

Coupled Wave Model

Already running with ADCIRC+SWAN — no real ice physics

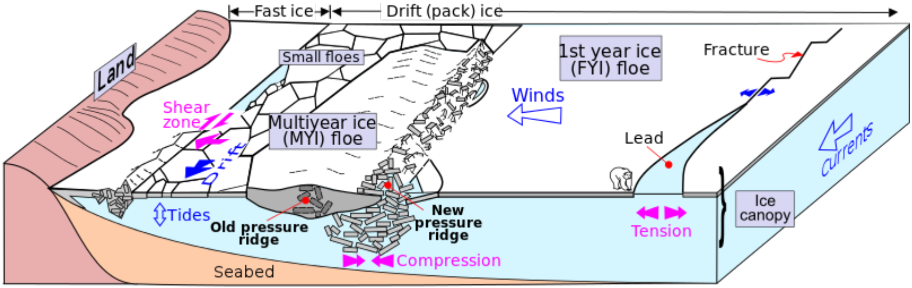
WAVEWATCH III wave model

- Incorporated ice physics developed as part of an Office of Naval Research (ONR) Directed Research Initiative (DRI)
- Four different options for wave dissipation due to ice that covers a variety of ice conditions. 3 are physics based, one empirical
- Allows for two wave scattering and dispersion due to ice as well as an option for ice breakup due to waves
- Earth System Modelling Framework (ESMF) provides structure and communication paradigm for coupling to be completed

Ice Parameterization - Assumptions and Limitations

- Still significant uncertainty in air-sea-ice interaction in this context
- Only considers atmospheric side
  - Assumes proportional relationship between the wind speed and the ice drift-ocean current differential
  - Assumes proportional relationship between air-ice drag and ice-ocean drag
  - Assumes no direction change in ice drift wrt wind speed
  - Does not affect tidal solution
- Doesn't consider fast ice
- Data limitations
  - Relatively low resolution in time (only daily evolution of the ice field)
  - Missing important sea ice parameters (only area fraction at high spatial resolution)

Sea Ice Types



Coupled Sea Ice Model

- Couple to a sea ice model (ex. Los Alamos Sea Ice Model (CICE))
  - Computes a number of factors including ice floe size, ridge height, and the presence of melt ponds
  - Includes a well developed description of the drag coefficient on both the atmosphere-ice and ice-ocean interfaces [5]
  - Computes ice drift speeds

$$C_{d,a-i} = C_{d,skin} + C_{d,ridge} + C_{d,floe} + C_{d,pond} \tag{4}$$

$$C_{d,i-o} = C_{d,skin} + C_{d,ridge} + C_{d,floe} \tag{5}$$

Coupled Sea Ice Model

Ice ocean stress [3]

$$\tau_{i-o} = \rho_w C_{d,i-o} |u_i - u_o| (u_i - u_o) \tag{6}$$

Total ocean stress

$$\tau_{ocn} = (1 - AF)\tau_{a-o} + (AF)\tau_{i-o} \tag{7}$$

- Compliant with ESMF for coupling with both ADCIRC+WWIII
- Requires wind velocity, specific humidity, air potential temperature, air temperature, incoming shortwave and longwave radiation, rainfall, snowfall, sea surface temperature and salinity (Through ESMF/other model solutions)
- ADCIRC+WAVEWATCH III will be capable of providing ocean currents and sea surface gradients

Outline

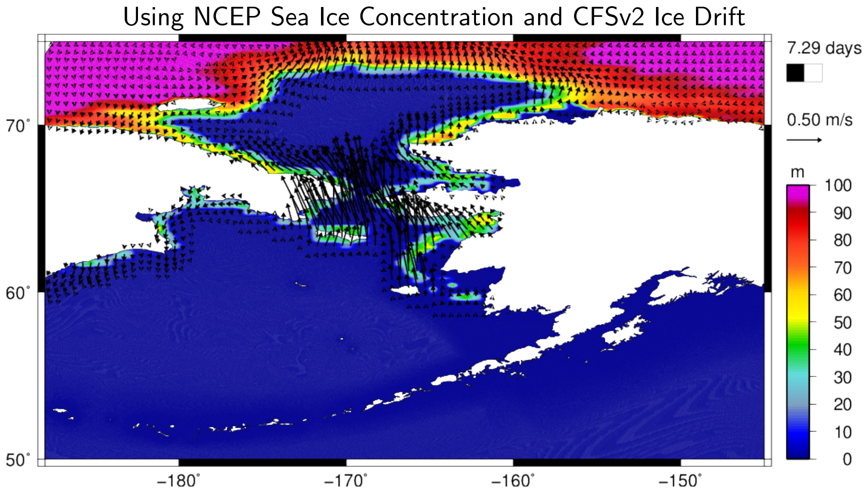
Sea Ice Drift

$$WSX = (1 - AF) * (WSX) + AF * WSX_{ice} \tag{8}$$

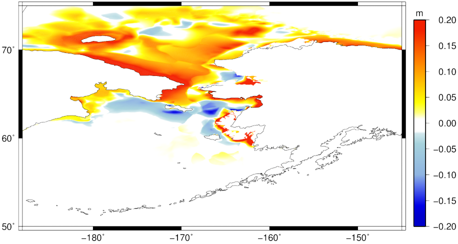
$$WSX_{ice} = C_{d-ice} * (IceDriftX - U/0.86) * IceDriftDiffMag \tag{9}$$

- Built into NWS options (NCICE $= 13$)
- Depth averaged current used to estimate surface current
- $C_{d-ice} = [0.0025, 0.018]$, highly dependent on sea ice type/size/thickness etc.
- Currently testing two approaches :
  - Data Driven Sea Ice Drift - from CFSv2 (0.5 degree resolution)
  - Parametric Ice Drift - 2 % at 30 degrees to the right of the wind speed (Nansen's rule)

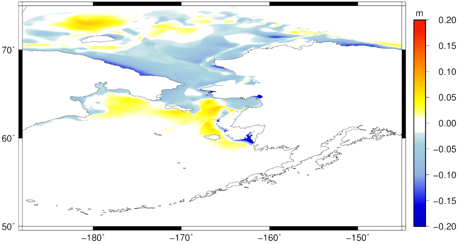
Sea Ice Drift - November 2011



Sea Ice Drift - November 2011



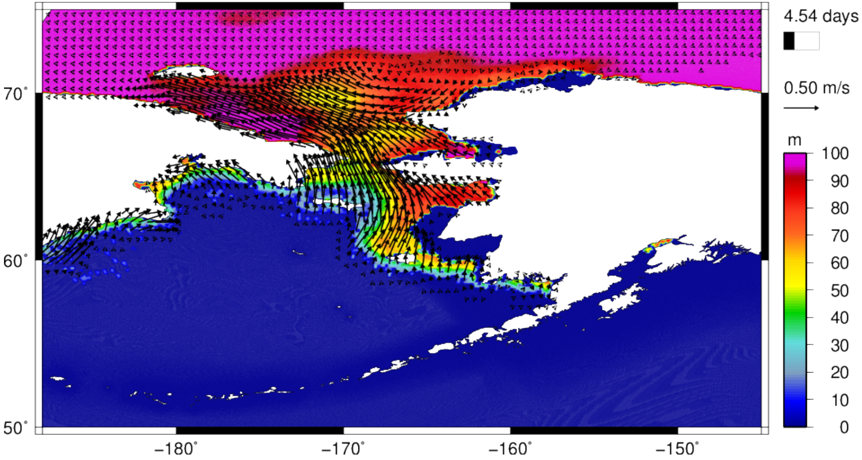
Paramterized Wind Drag



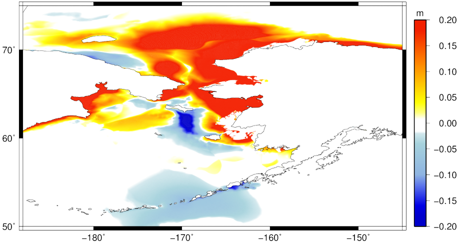
Sea Ice Drift

Sea Ice Drift - January 2017

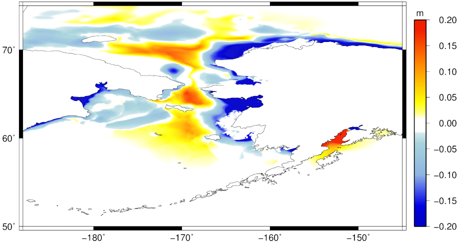
Using NCEP Sea Ice Concentration and CFSv2 Ice Drift



Sea Ice Drift - January 2017

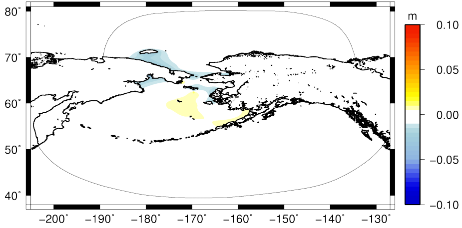


Paramterized Wind Drag

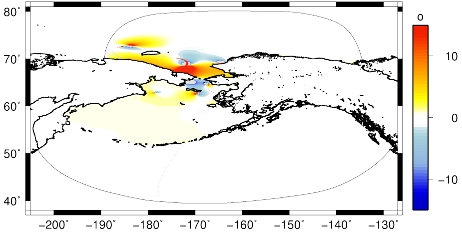


Sea Ice Drift

Sea Ice Drift - Tide Impact



Sea Ice Drift Effect on M_2 amplitude



Sea Ice Drift Effect on M_2 phase

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