Alaska Water Level Needs - Storm Surge and Wind Wave Modeling

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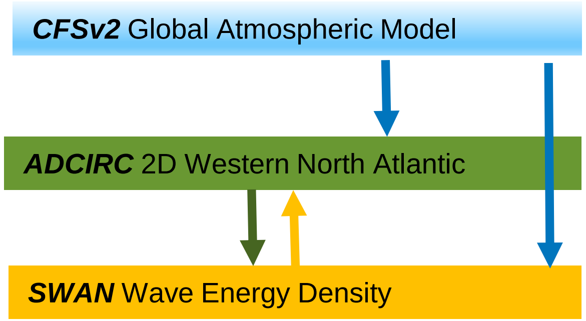
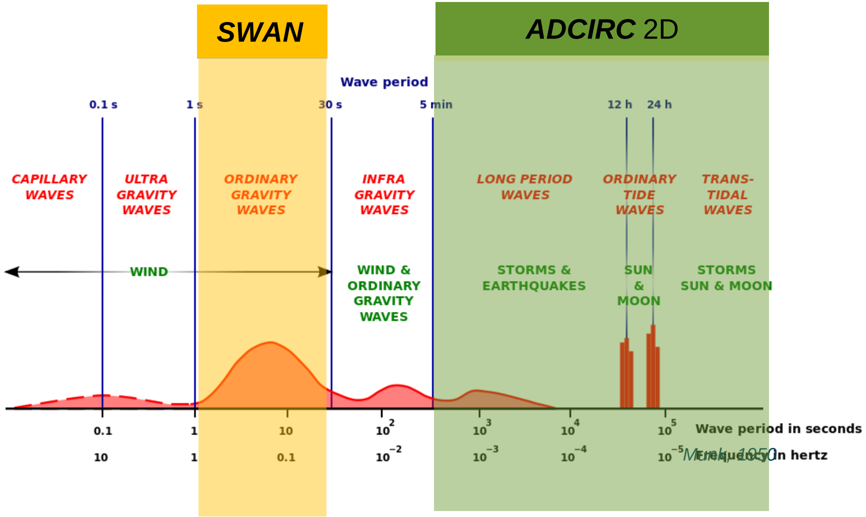
Outline

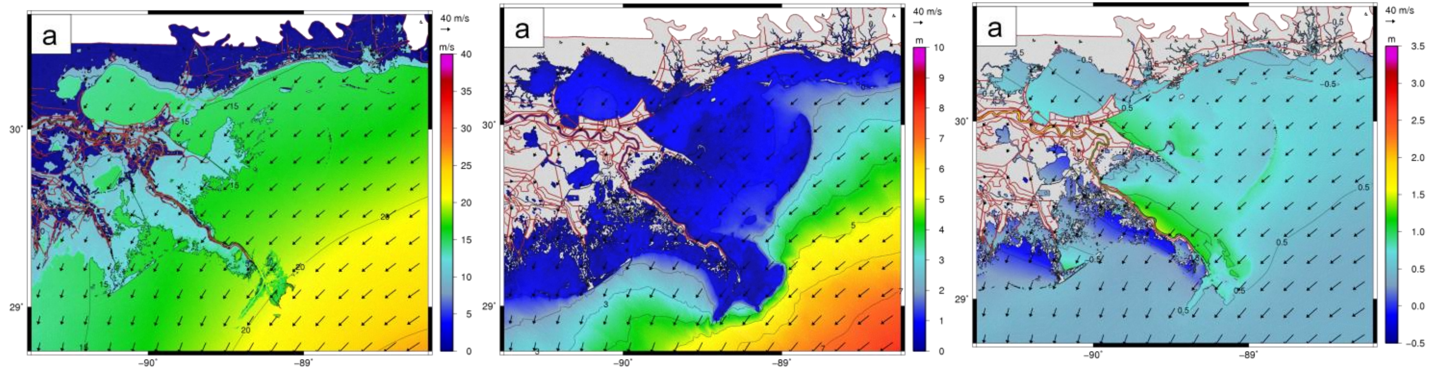
- **Model Introduction**
- Water Level Uses and Data Requirements
  - Tides
  - Storm Surge
  - Storm Waves
- Geographic Gaps and Priority Sites

Current operational coupled ADCIRC+SWAN modeling

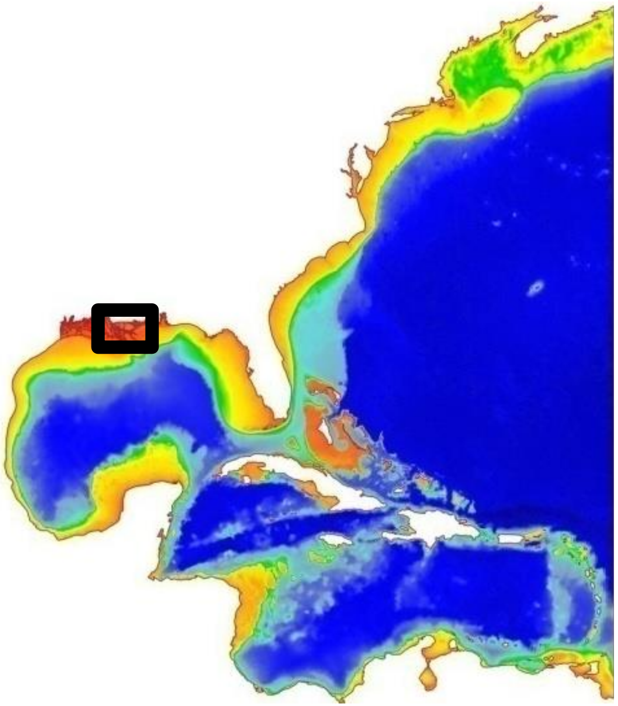
Dynamic ADCIRC & SWAN Coupling

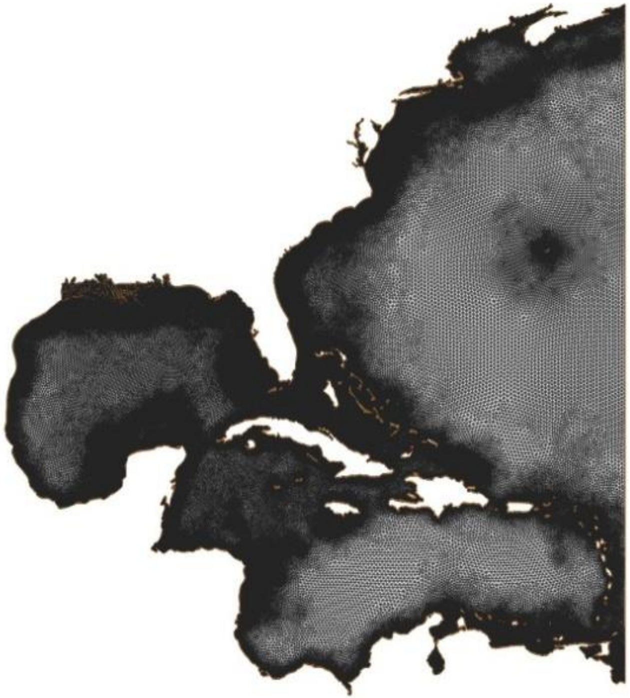






SL16v18 model bathymetry & topography and unstructured mesh

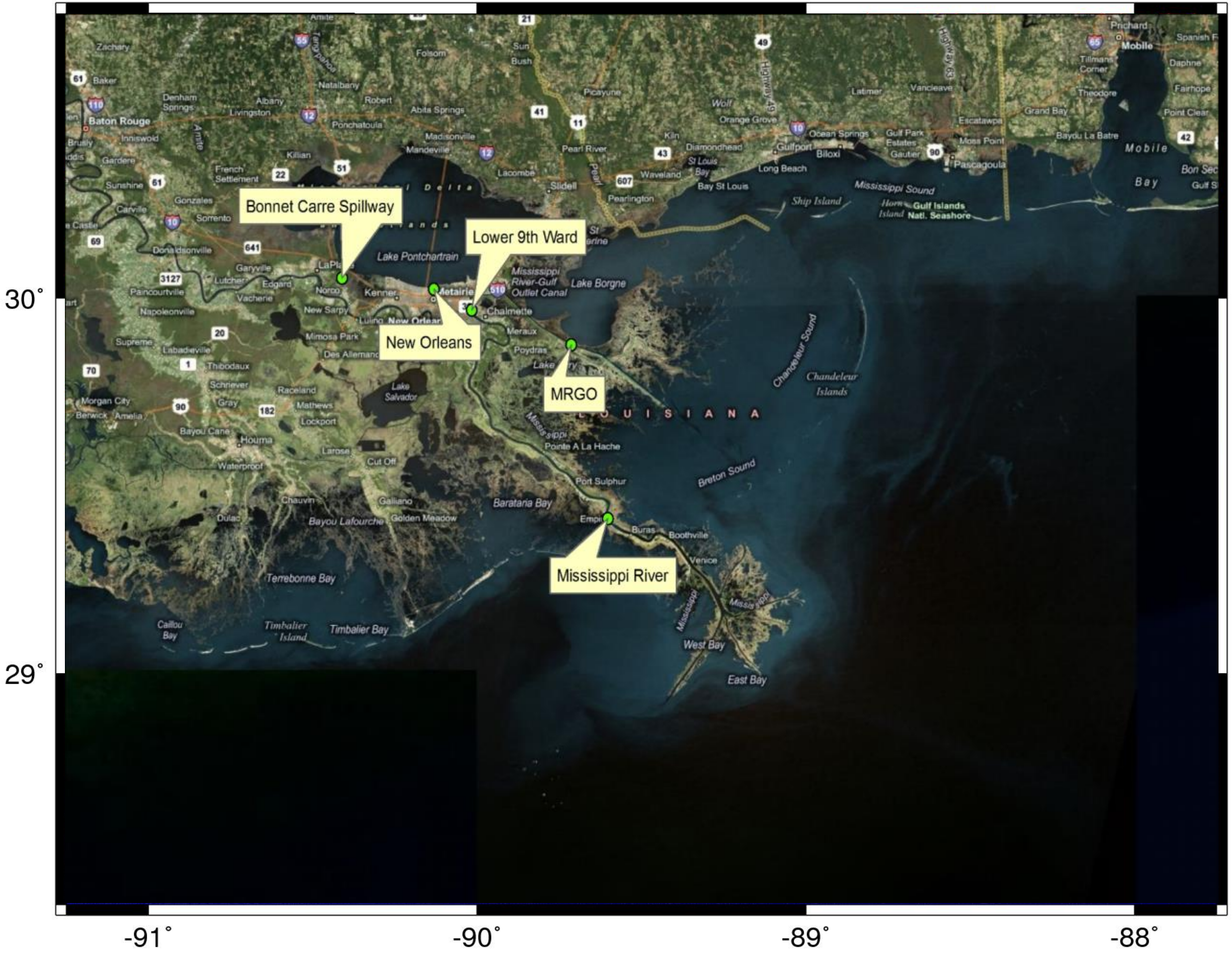




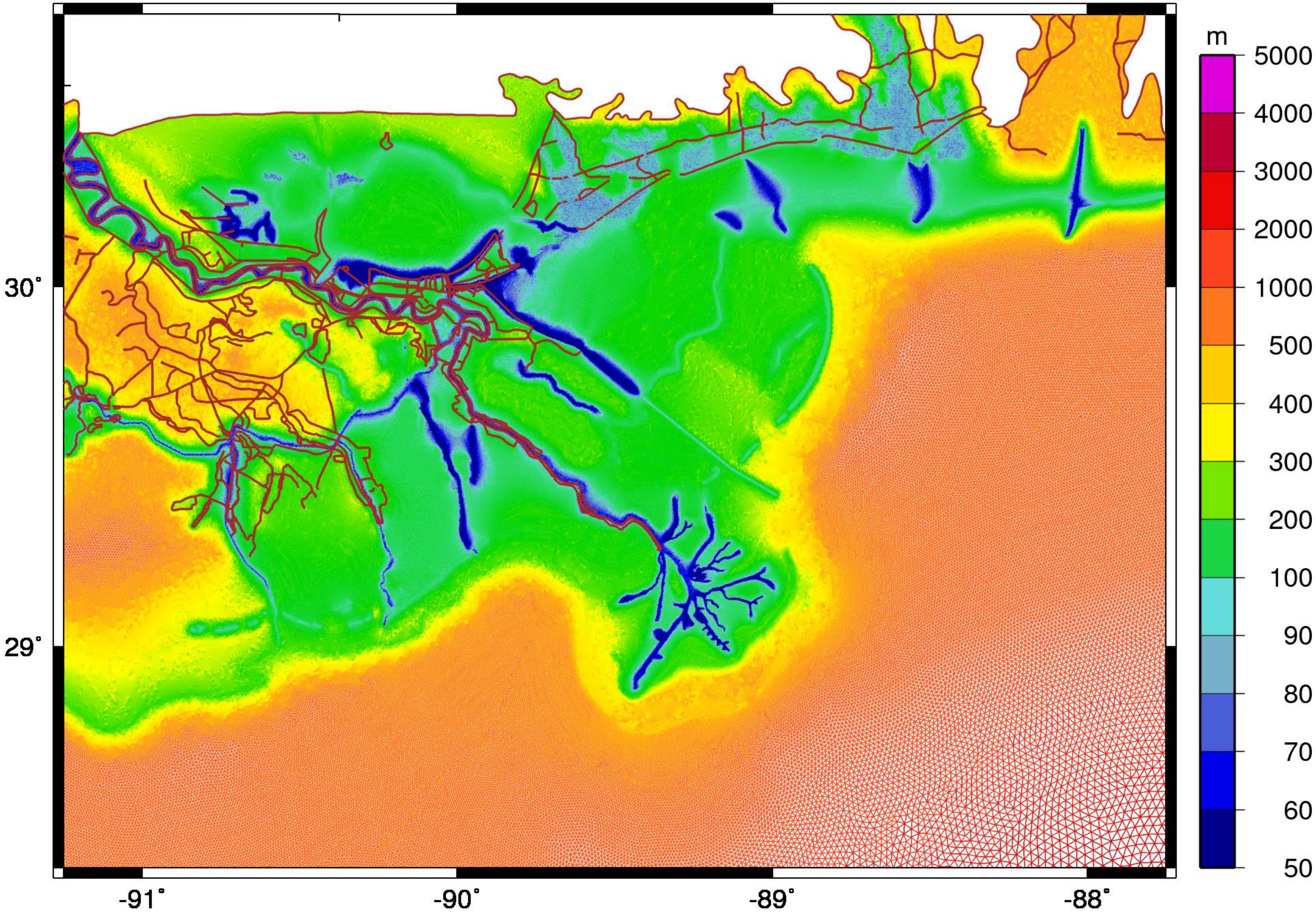
Dietrich et al., ***Monthly Weather Review***, **139**, 2488-2522, 2011.
Kennedy et al., ***Geophysical Research Letters***, **38**, L08608, 2011.
Kerr et al., ***Journal of Waterway, Port, Coastal, and Ocean Engineering***, **139,** 326-335, 2013.

Martyr et al., ***Journal of Hydraulic Engineering***, **139**, 5, 492-501, 2013.
Hope et al., ***Journal of Geophysical Research: Oceans***, **118**, 4424-4460, 2013.
Kerr et al., ***Journal of Geophysical Research: Oceans***, **118,** 5129–5172, 2013.

SL16v18 model bathymetry & topography in SE Louisiana

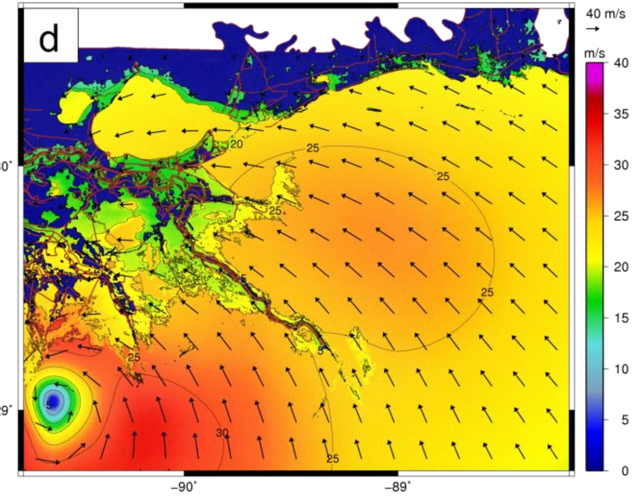


SL16v18 model bathymetry & topography in SE Louisiana

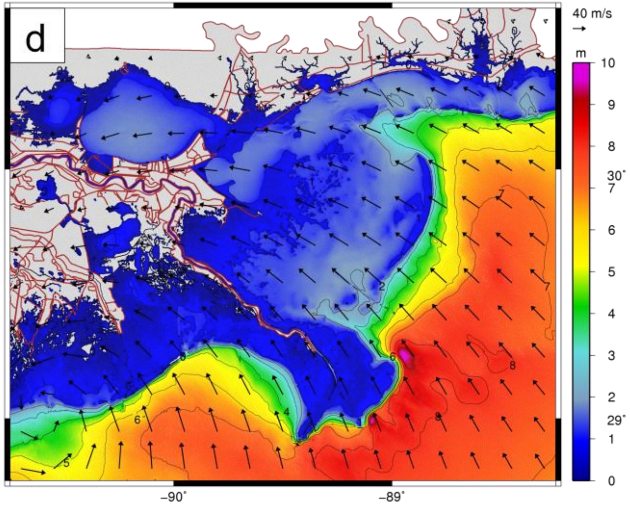


Hurricane Gustav: 2008 / 09 / 01 / 1400 UTC

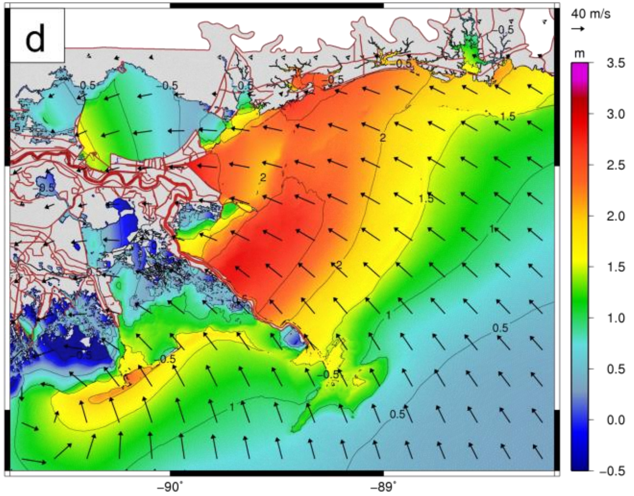
Winds (m/s)



Waves (m)



Water Elevations (m)



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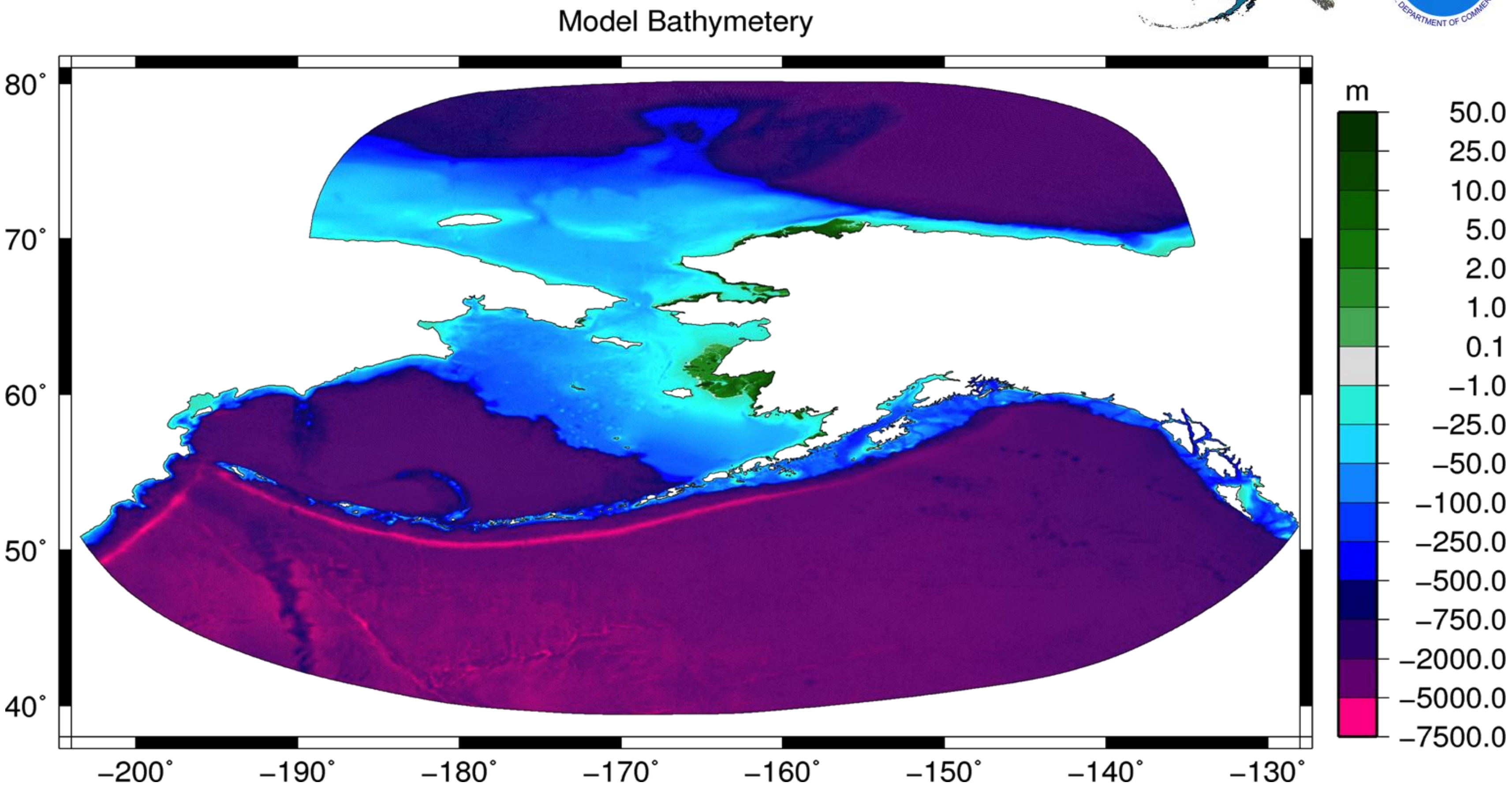
Outline

- Model Introduction
- **Water Level Uses and Data Requirements**
  - **Tides**
  - **Storm Surge**
  - **Storm Waves**
- Geographic Gaps and Priority Sites

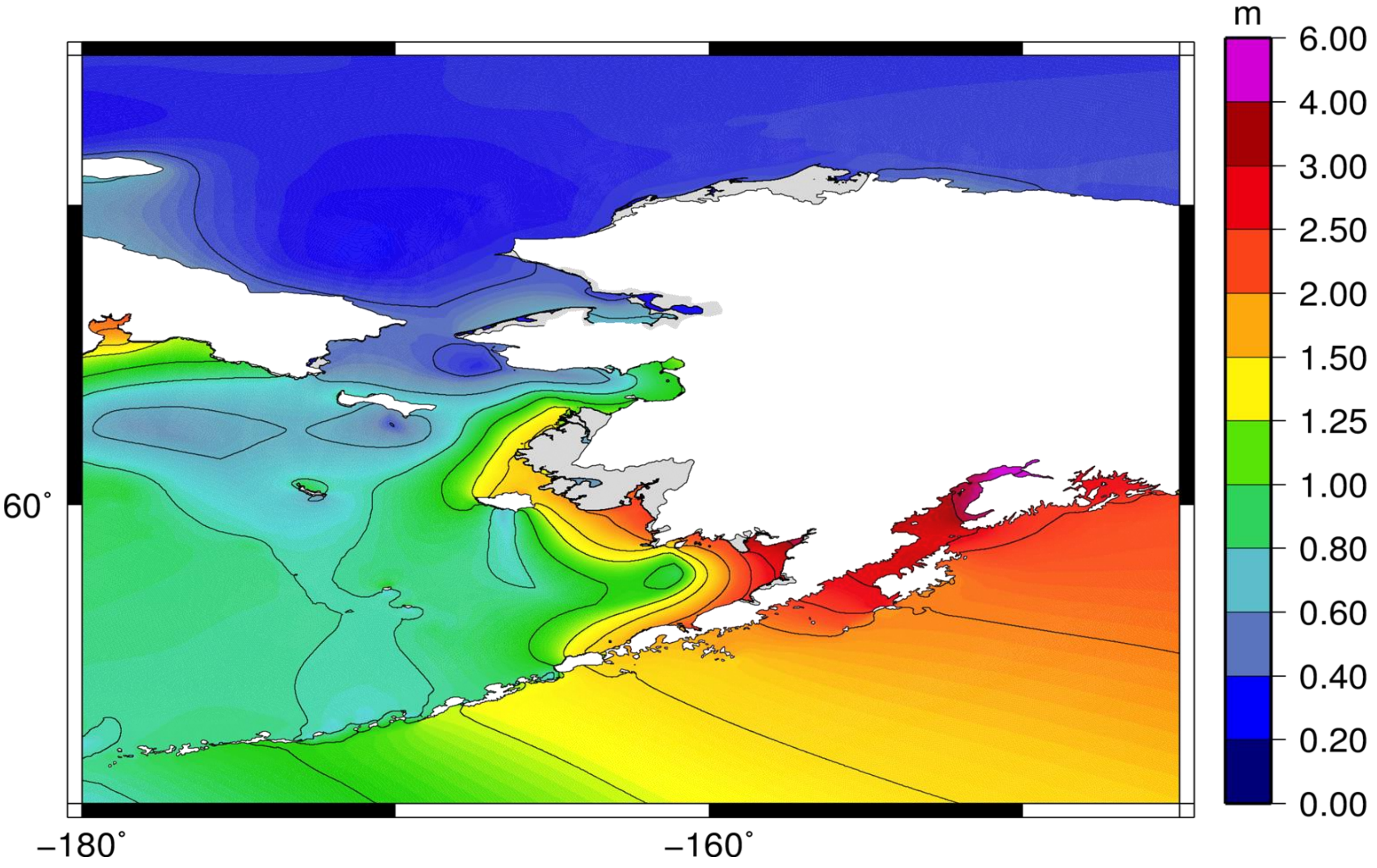
Current WALCC/ND/NCEP ADCIRC+SWAN Alaska model



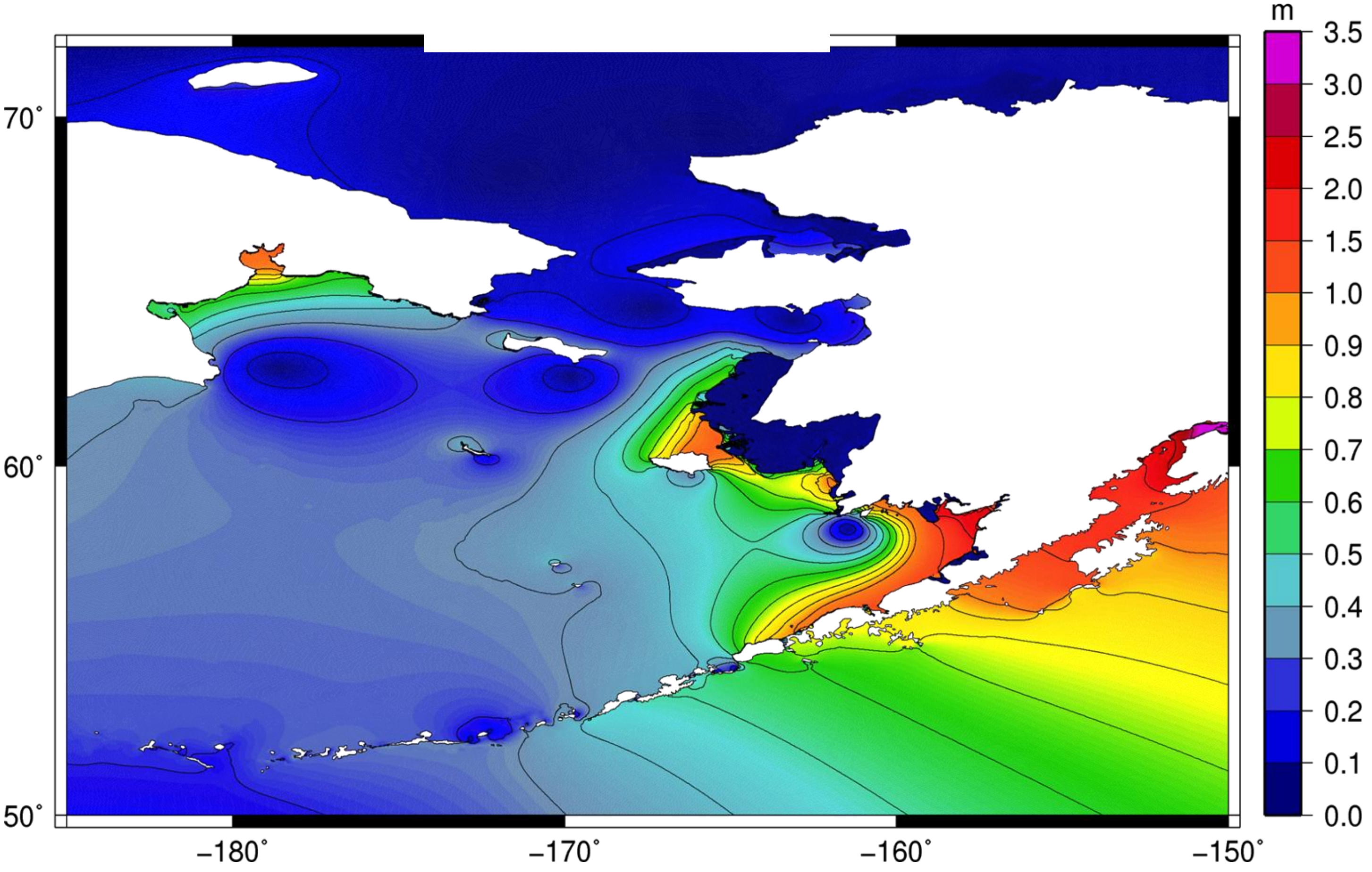
Tidal water level measurements

- **Use water level measurements to decompose signal into tidal harmonics**
  - Diurnal (ex. K_1,O_1,...)
  - Semi-Diurnal (ex. M_2,N_2,...)
- **Requires measurements at at least 1 hour intervals**
  - More frequent sampling increases accuracy
- **Used to compare against computed tidal harmonics from the ADCIRC model**
- **Most NOAA/NOS stations (tidesandcurrents.noaa.gov) inactive in AK**
  - Little information on seasonal change of constituents

Tidal maximum water level – all tides



Tidal M_2 amplitude



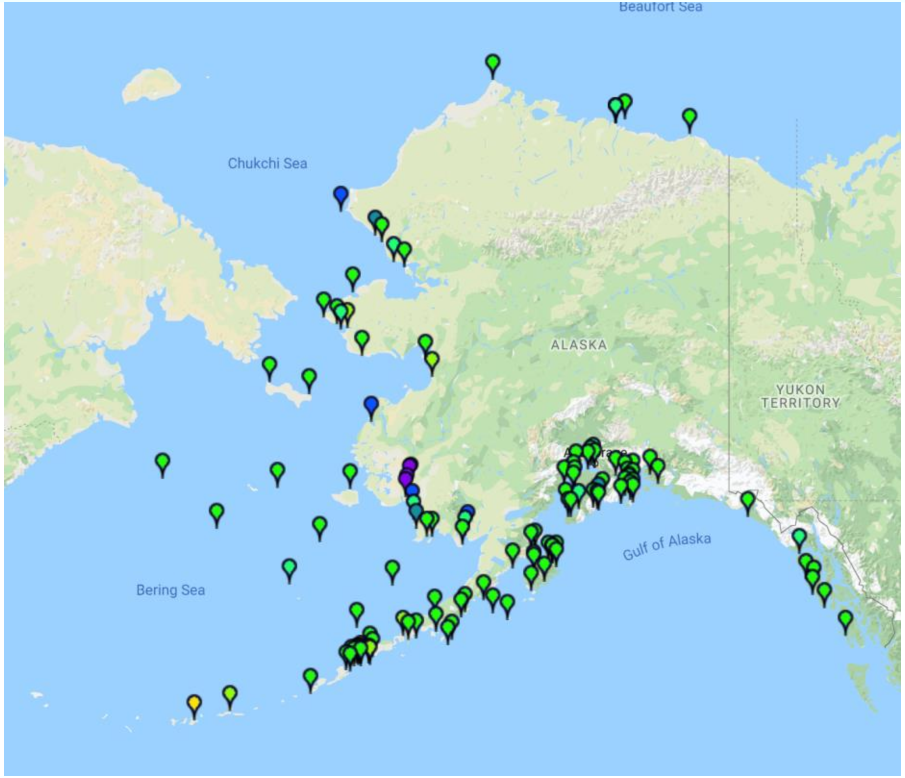
Alaska Tidal Validation

Amplitude Error (m / %)

gt. - 0.04 / - 40%	lt. -0.04 / - 40%	lt. -0.03 / - 30%	lt. -0.02 / - 20%	lt. -0.01 / - 10%	lt. +0.01 / + 10%	lt. +0.02 / + 20%	lt. +0.03 / + 30%	lt. +0.04 / + 40%	gt. +0.04 / + 40%

Phase Error (deg)

gt. -80	lt. -80	lt. -60	lt. -40	lt. -20	lt. +20	lt. +40	lt. +60	lt. +80	gt. +80



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Phase Error (deg)

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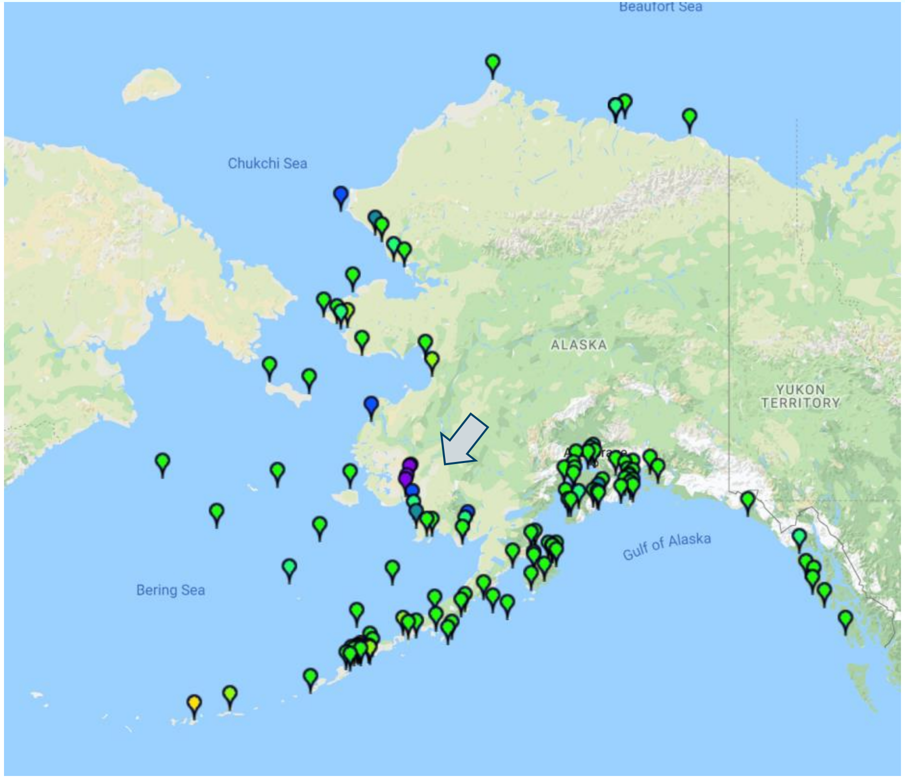
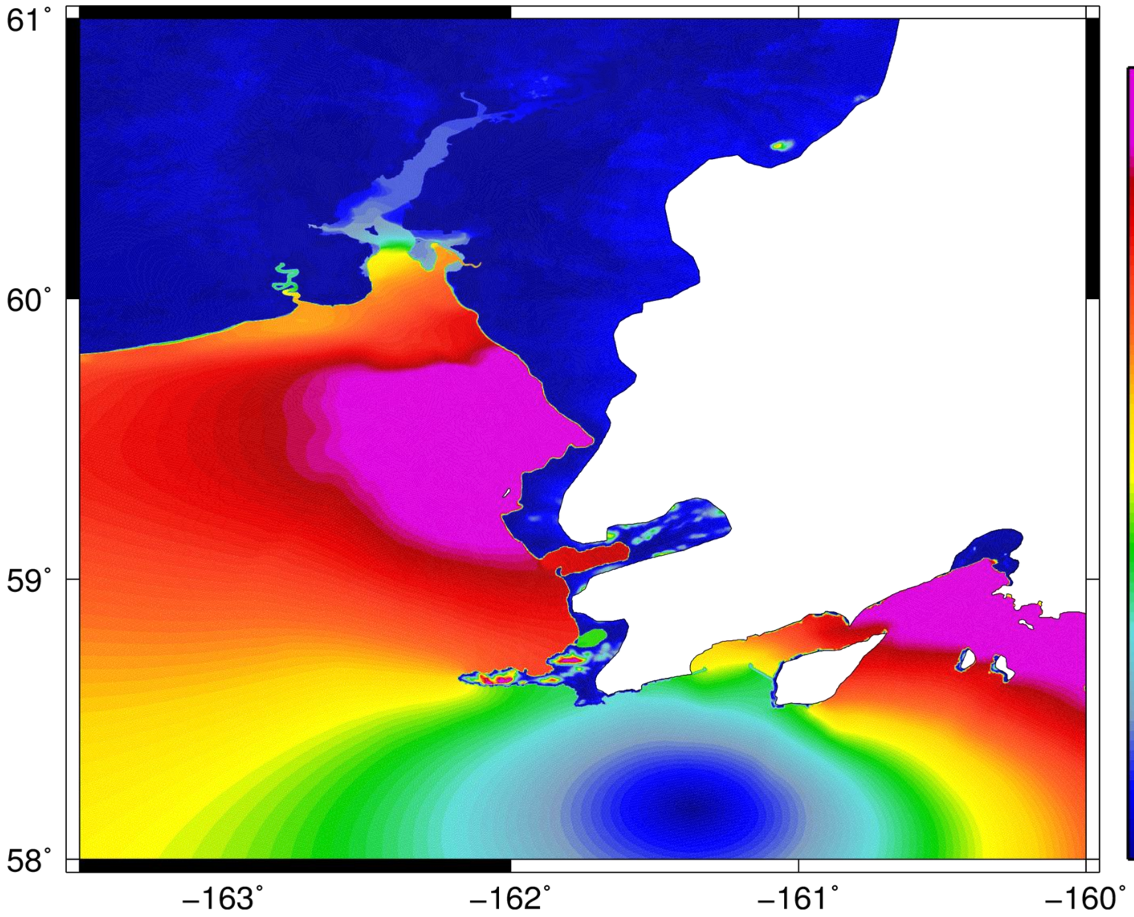
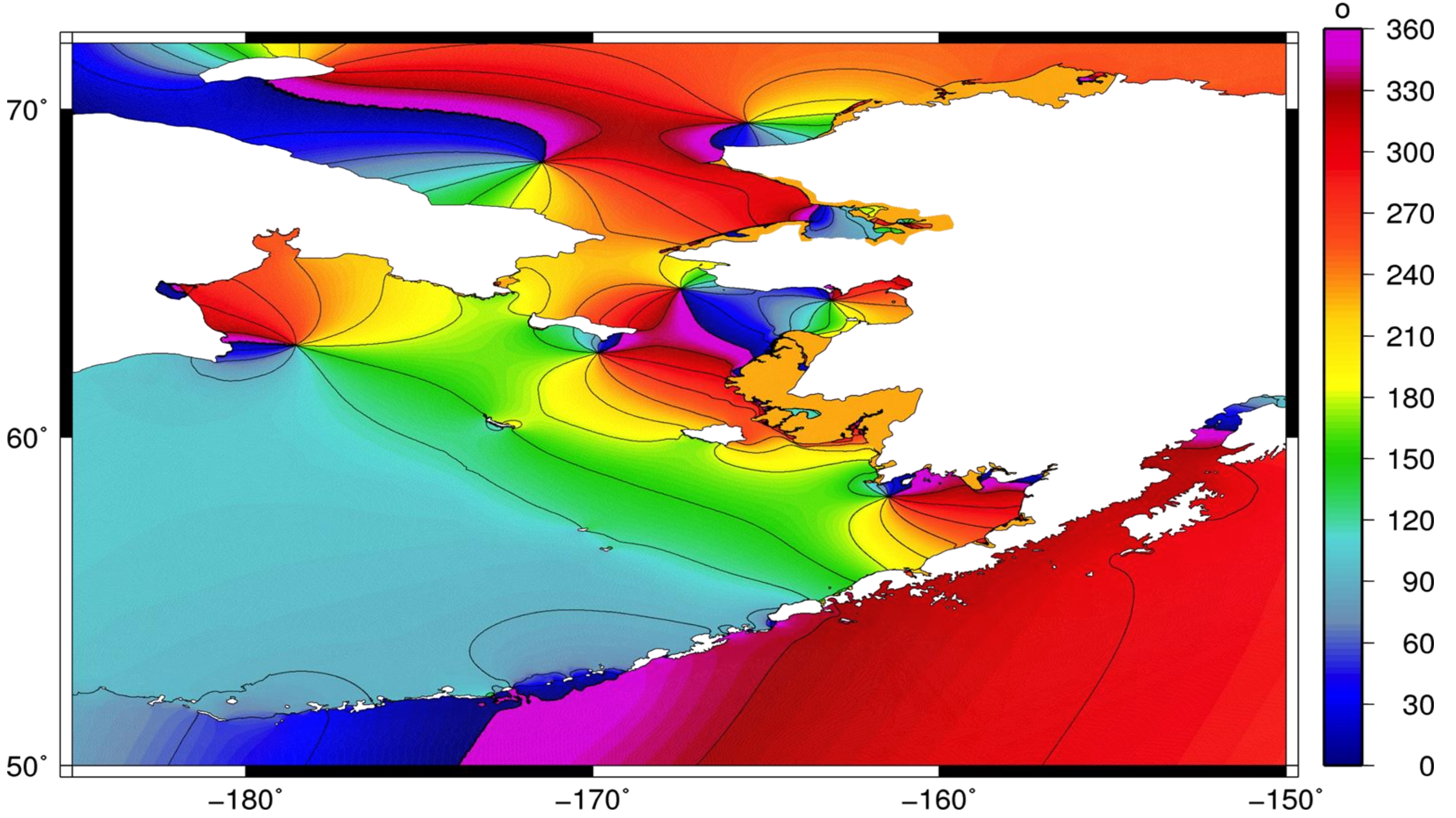


M_2 amplitude detail – Kuskokwim River



Tidal M_2 phase



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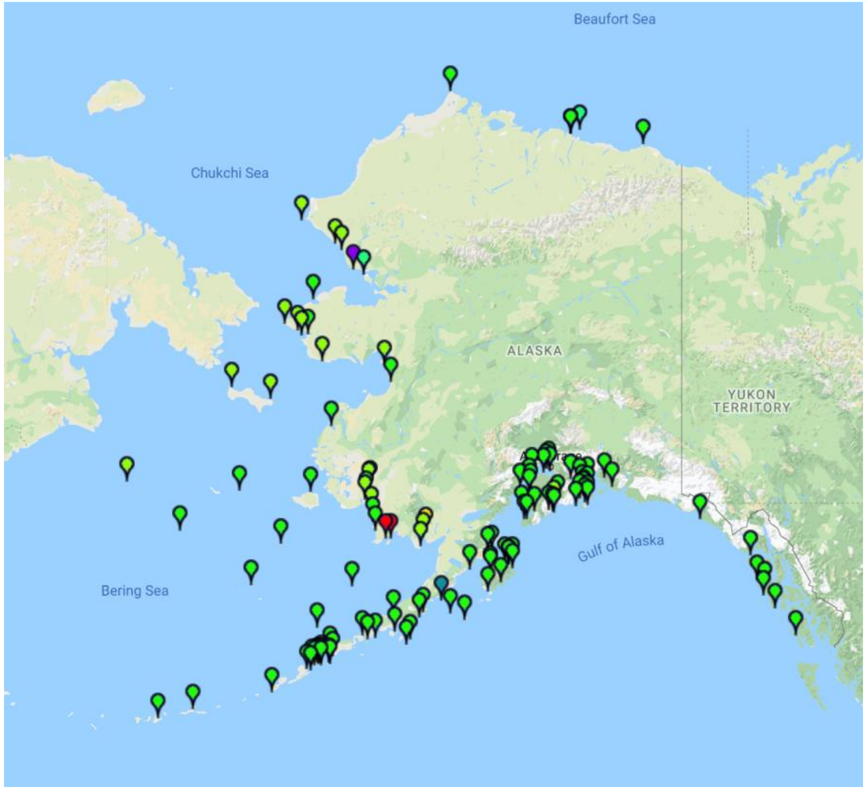
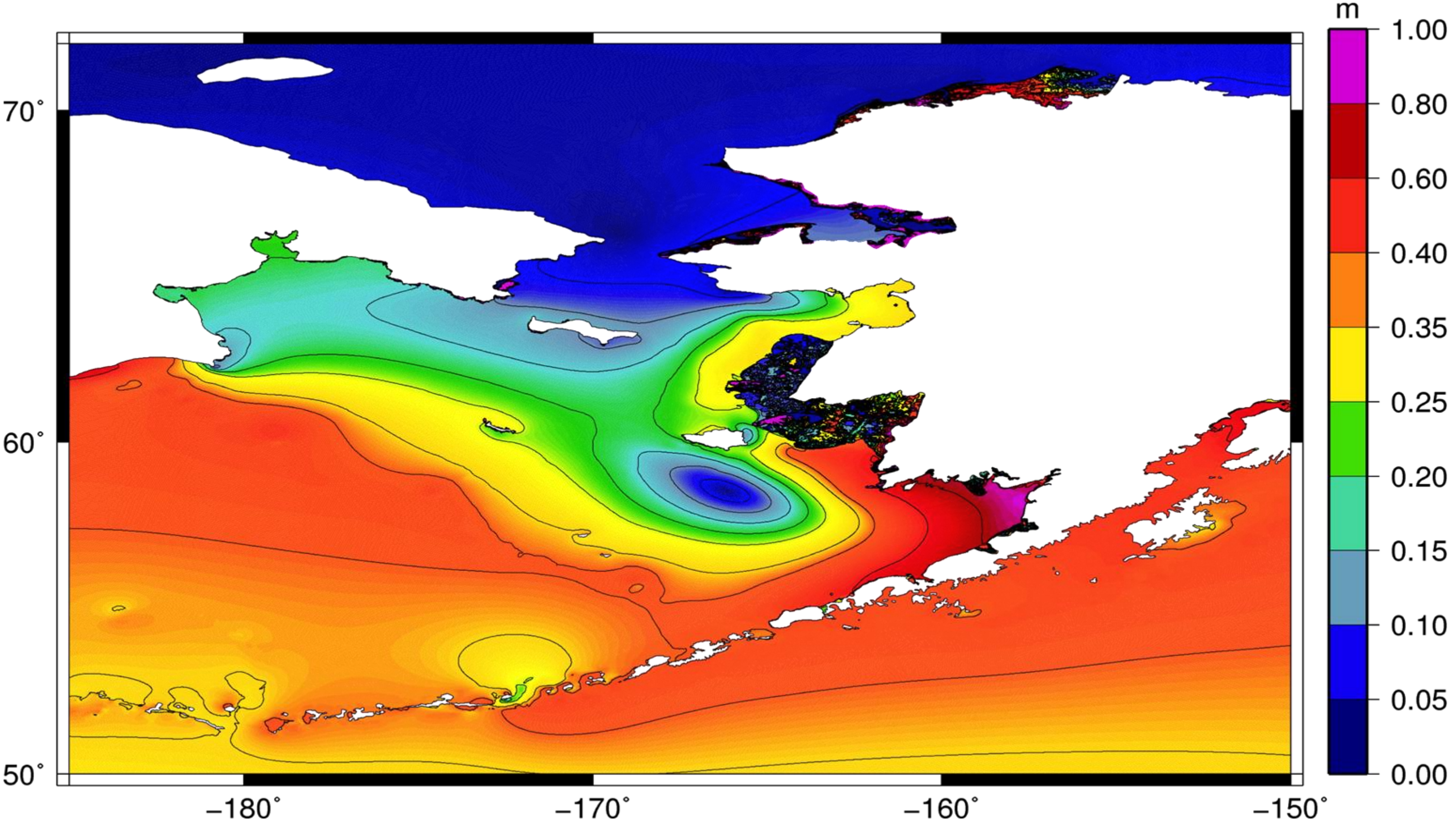
gt. -80	lt. -80	lt. -60	lt. -40	lt. -20	lt. +20	lt. +40	lt. +60	lt. +80	gt. +80



Tidal K_1 amplitude



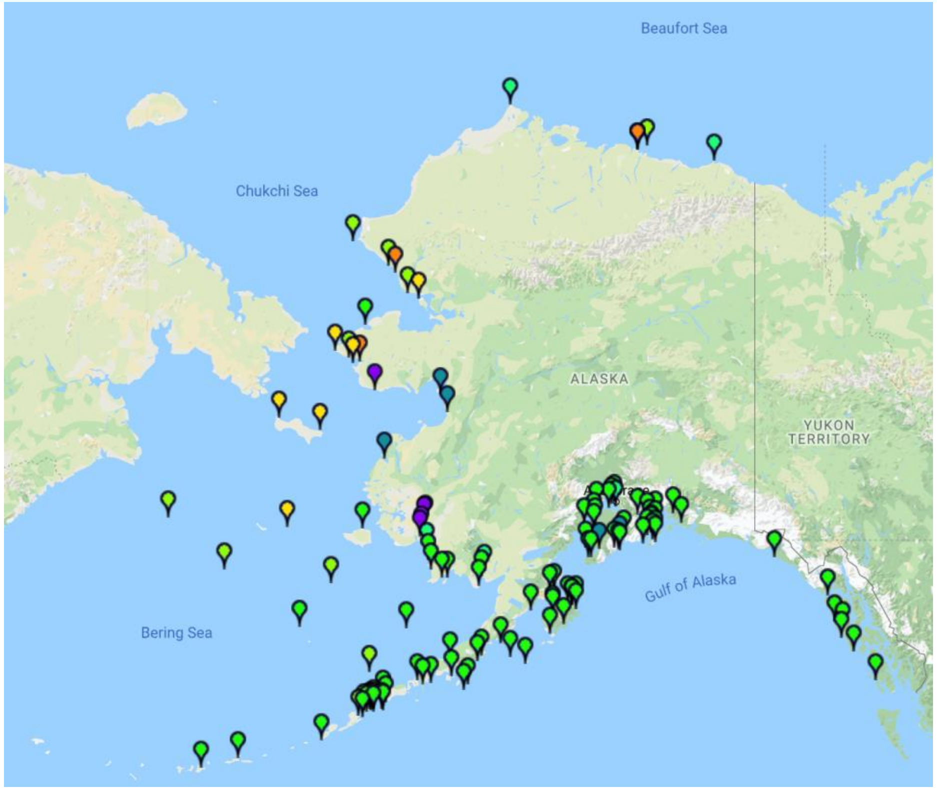
Alaska Tidal Validation

Amplitude Error (m / %)

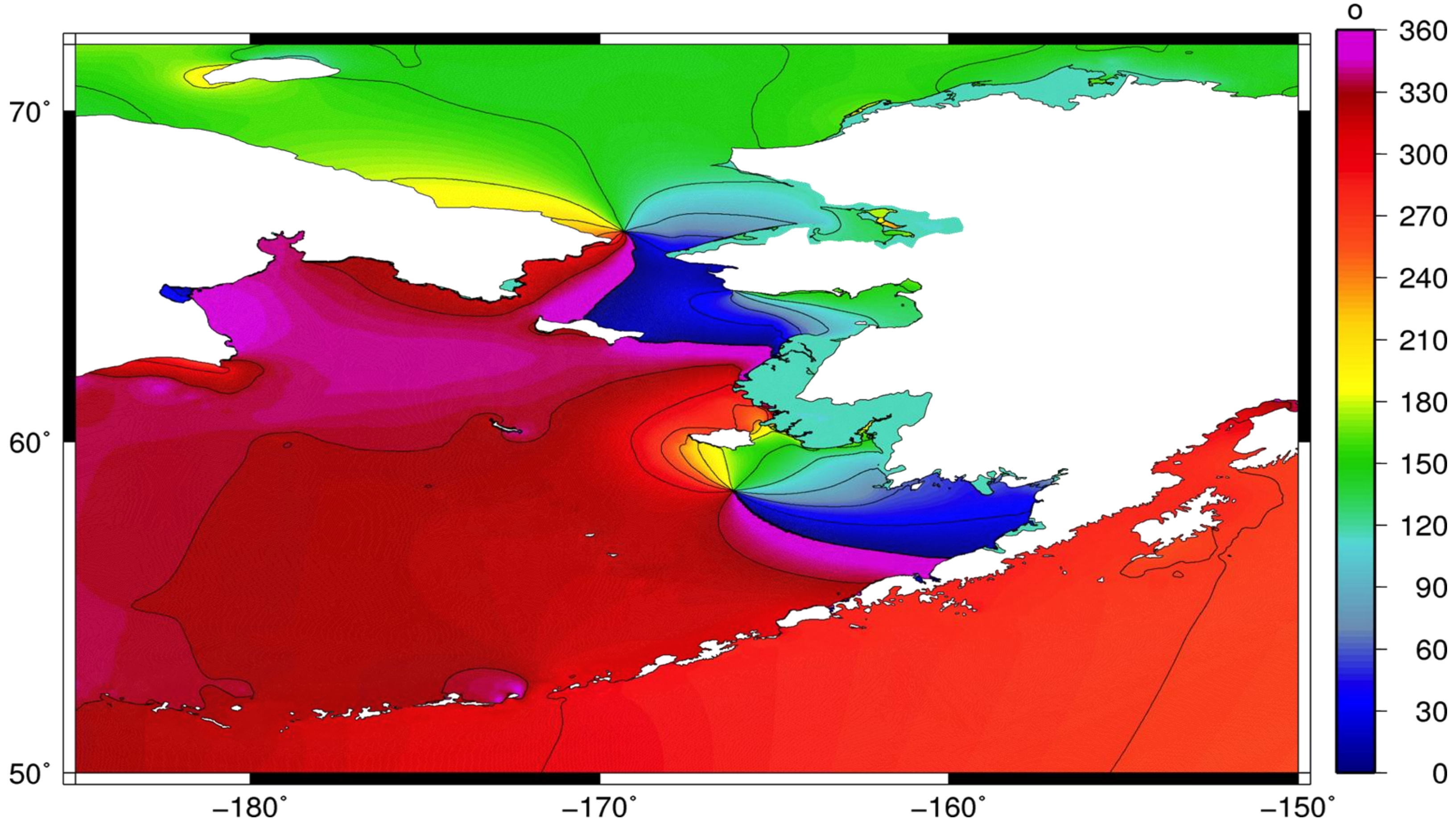
gt. - 0.04 / - 40%	lt. -0.04 / - 40%	lt. -0.03 / - 30%	lt. -0.02 / - 20%	lt. -0.01 / - 10%	lt. +0.01 / + 10%	lt. +0.02 / + 20%	lt. +0.03 / + 30%	lt. +0.04 / + 40%	gt. +0.04 / + 40%

Phase Error (deg)

gt. -80	lt. -80	lt. -60	lt. -40	lt. -20	lt. +20	lt. +40	lt. +60	lt. +80	gt. +80



Tidal K_1 phase



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Phase Error (deg)

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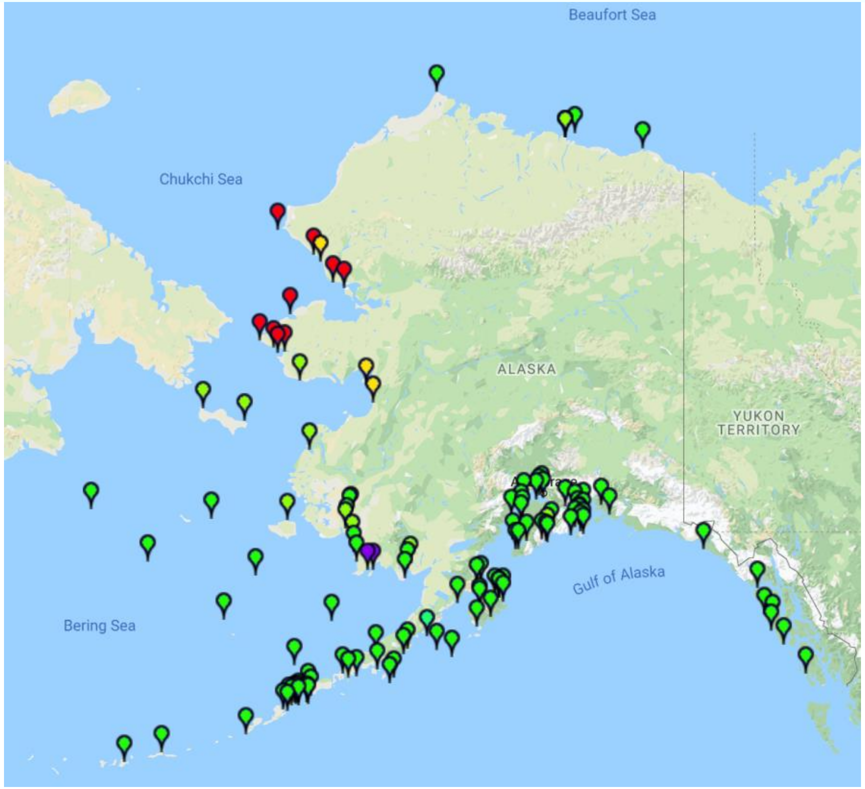

Alaska Tidal Validation

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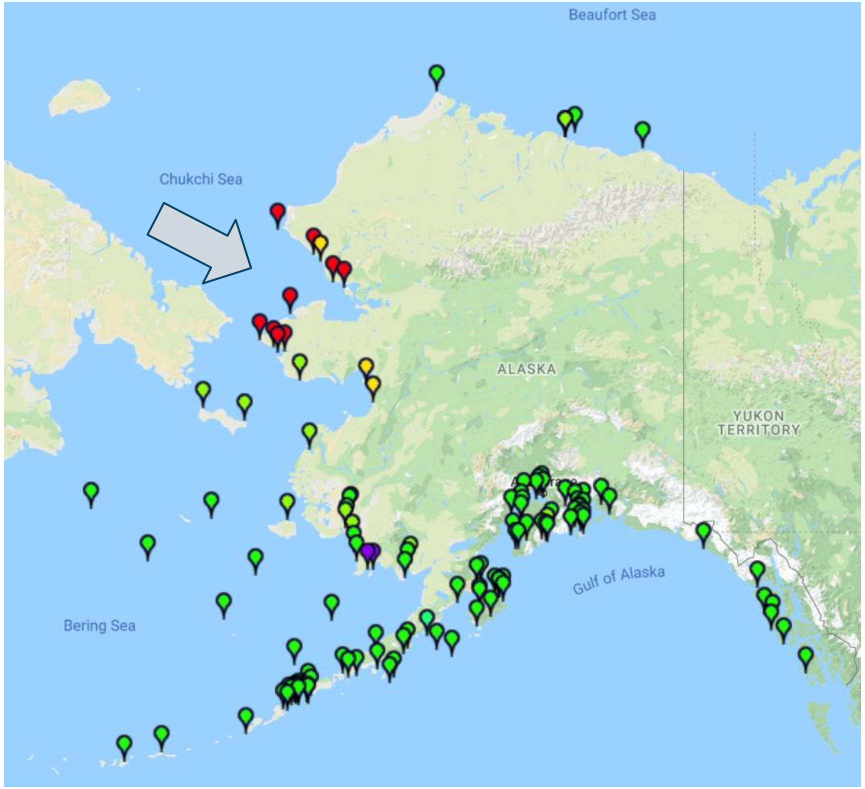
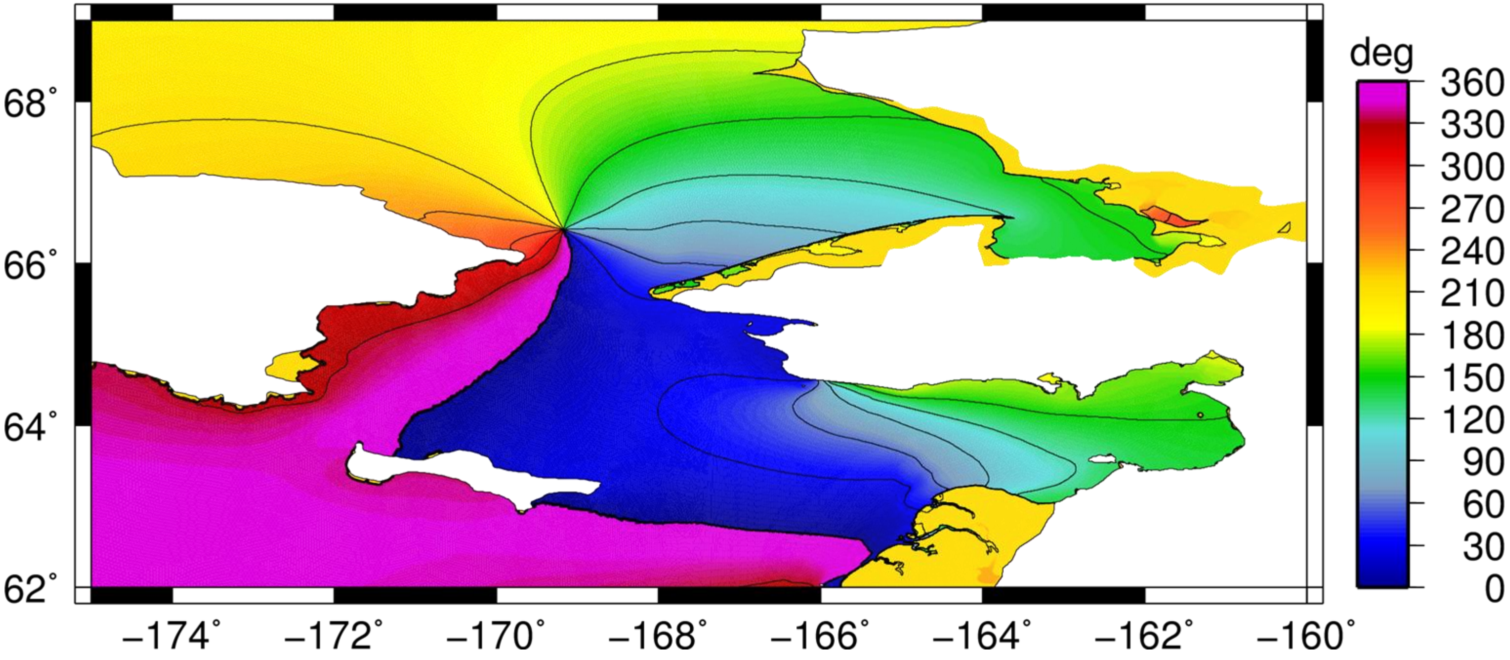
Phase Error (deg)

gt. -80	lt. -80	lt. -60	lt. -40	lt. -20	lt. +20	lt. +40	lt. +60	lt. +80	gt. +80

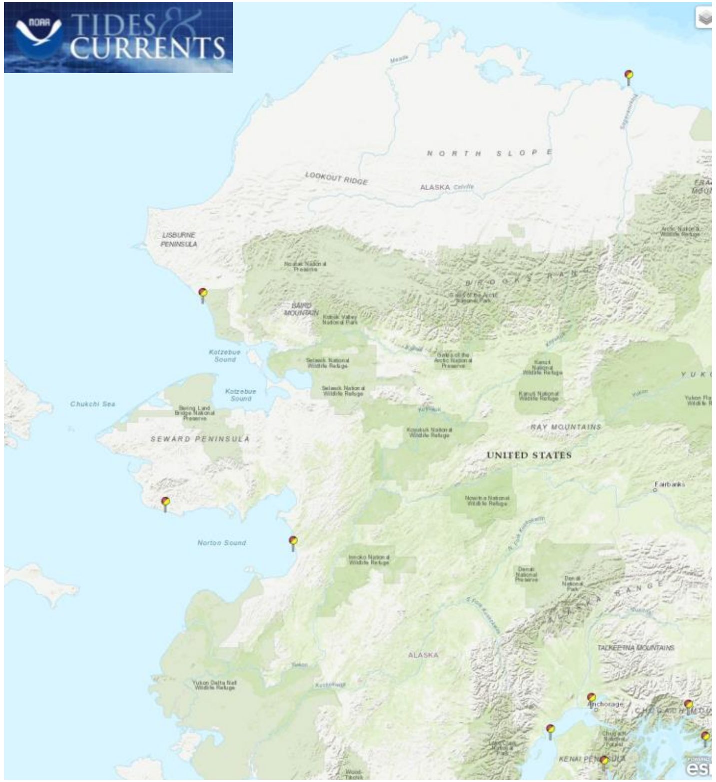


Tidal K_1 phase detail – Bering Strait

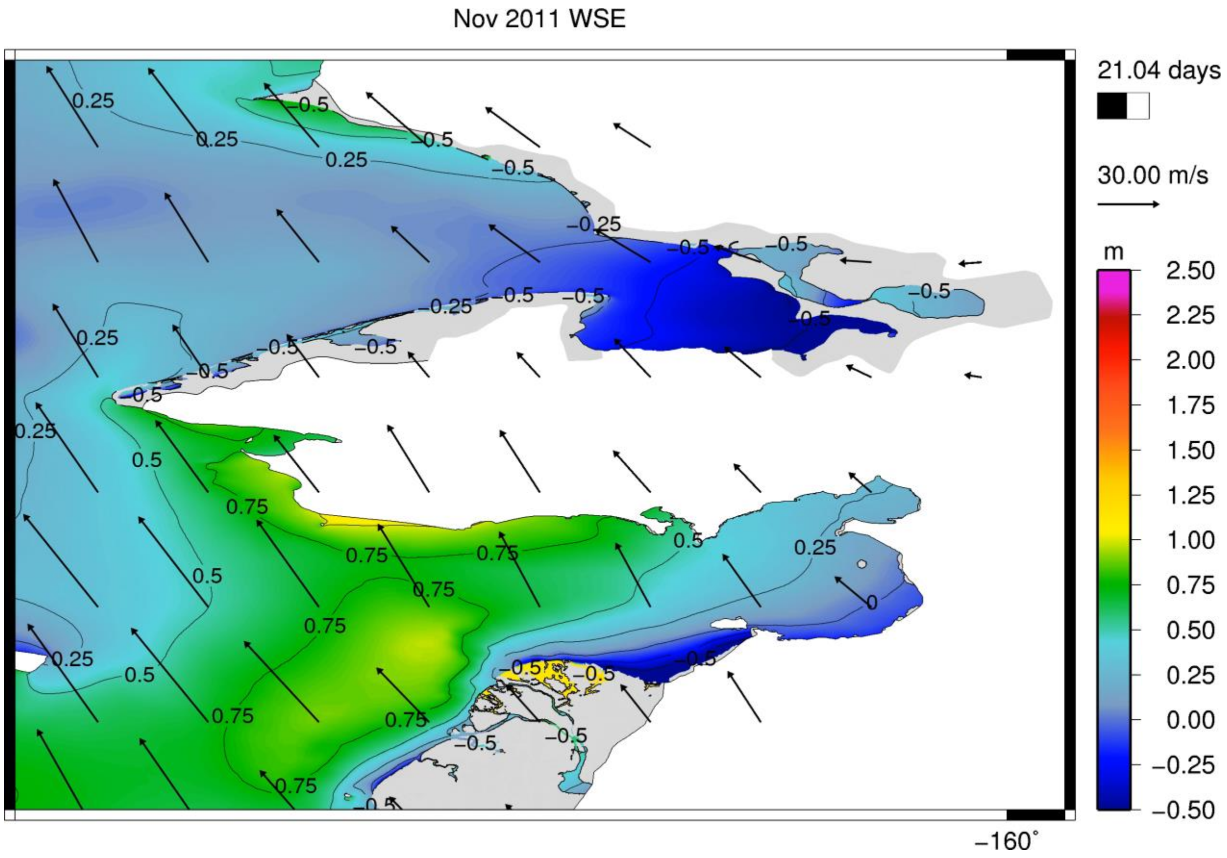


Storm surge water level measurements

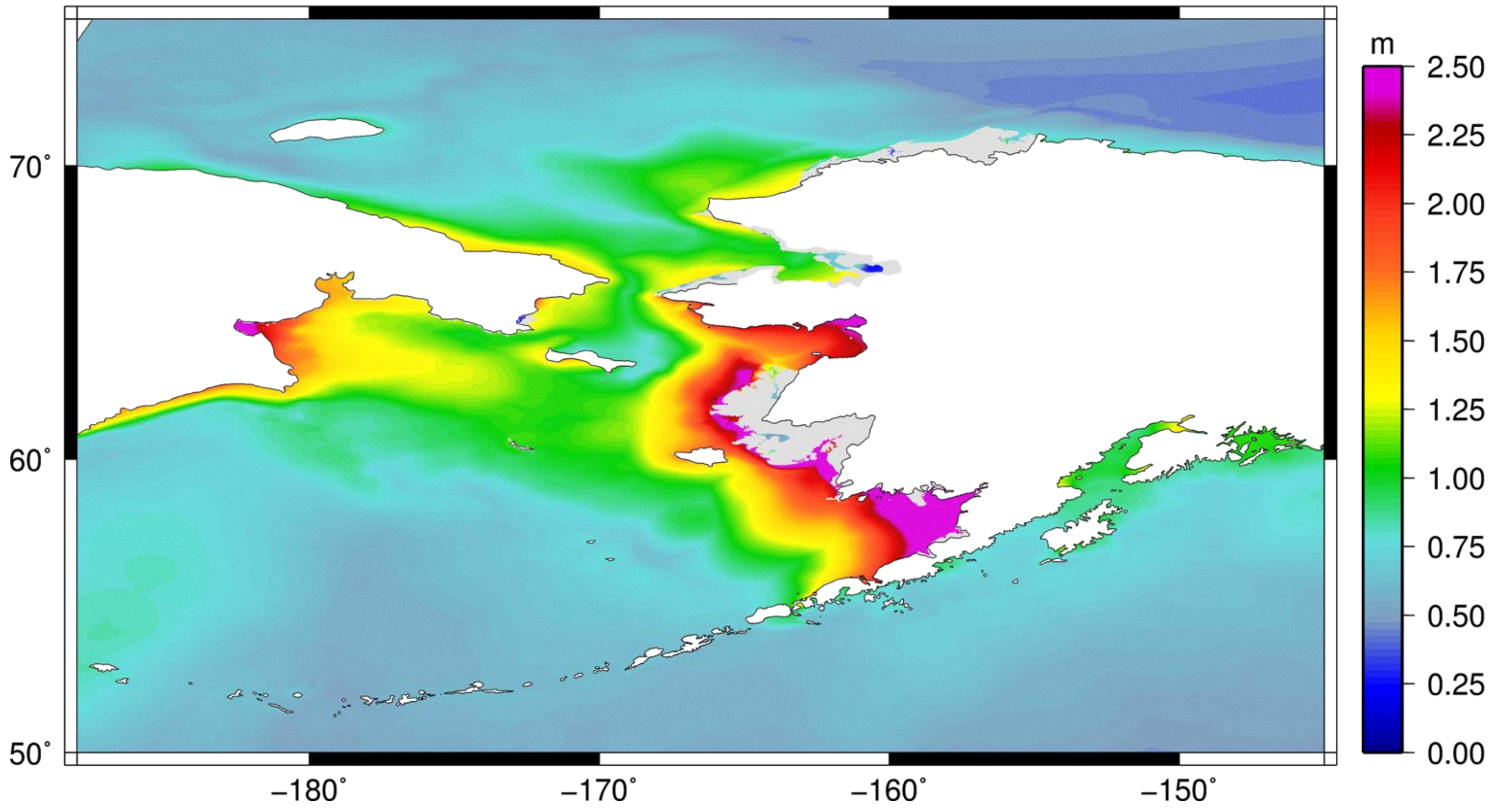
- Used to compare against computed water level
- Requires measurements at at least 1 hour intervals
  - More frequent sampling increases accuracy
- Only 4 NOAA/NOS stations (tidesandcurrents.noaa.gov) active in AK on the West and North coast



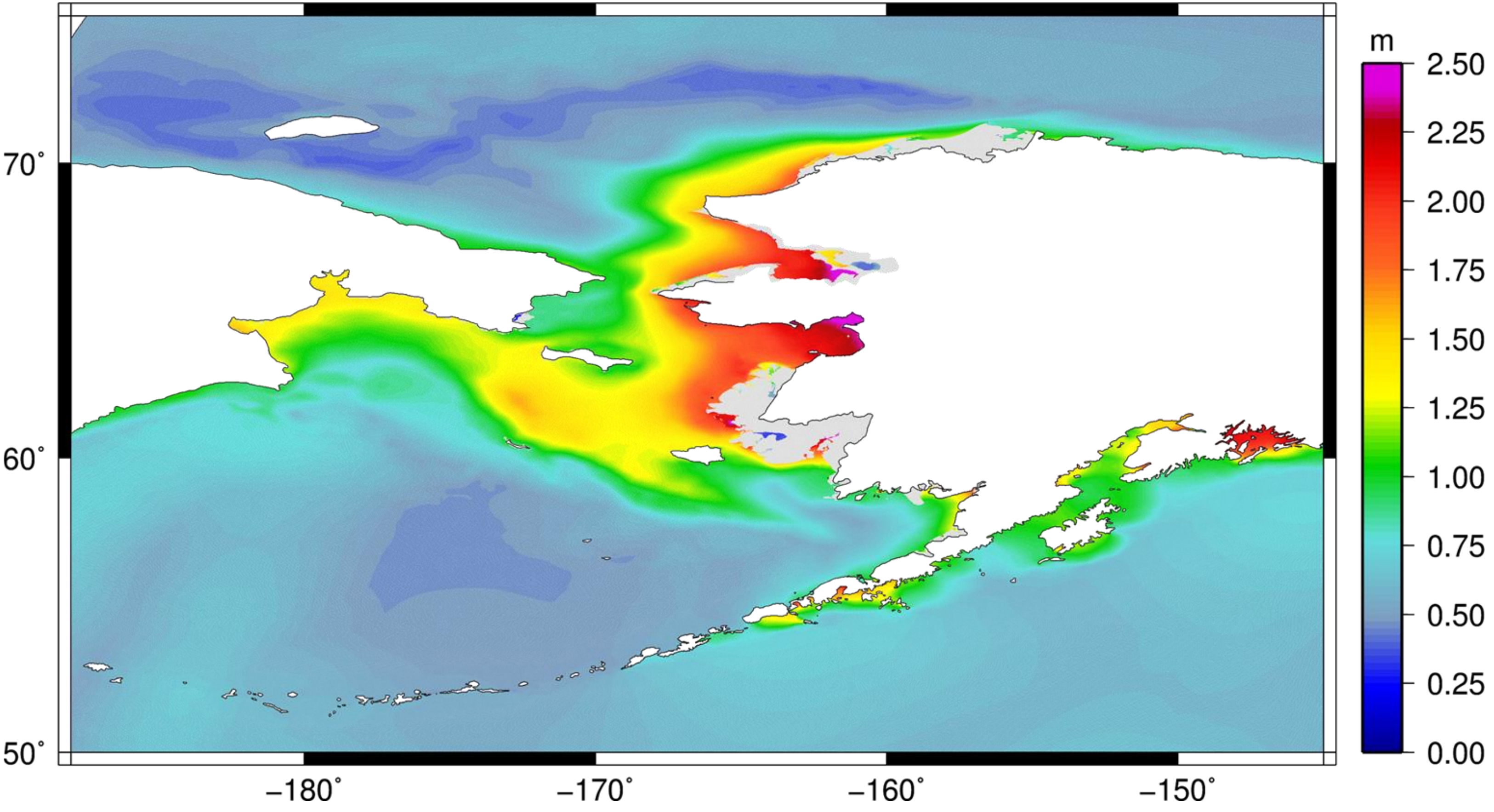
November 2011 - storm surge detailed winds and water levels



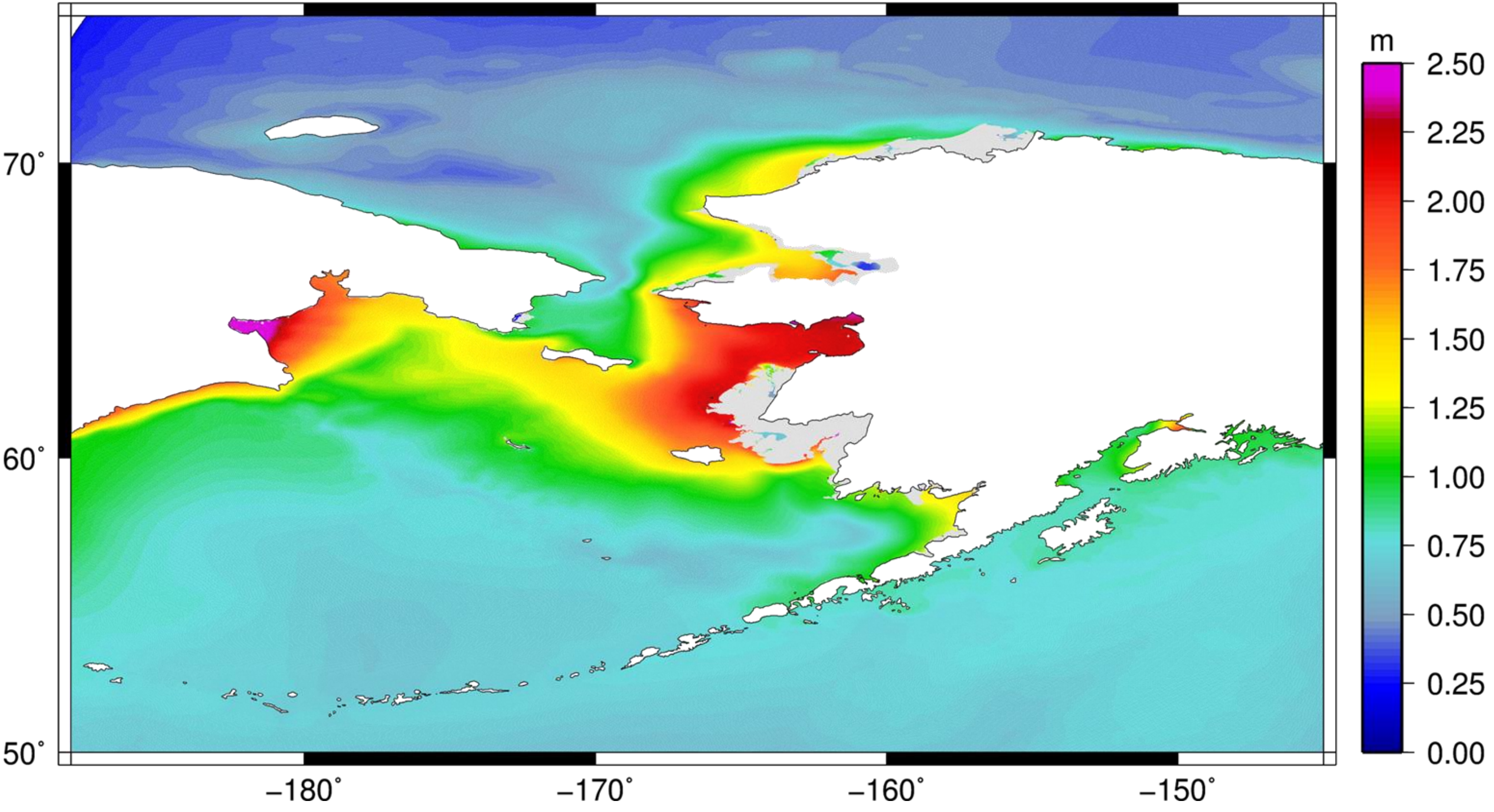
November 2011 – maximum storm surge (no tides)



February 2011 – maximum storm surge (no tides)

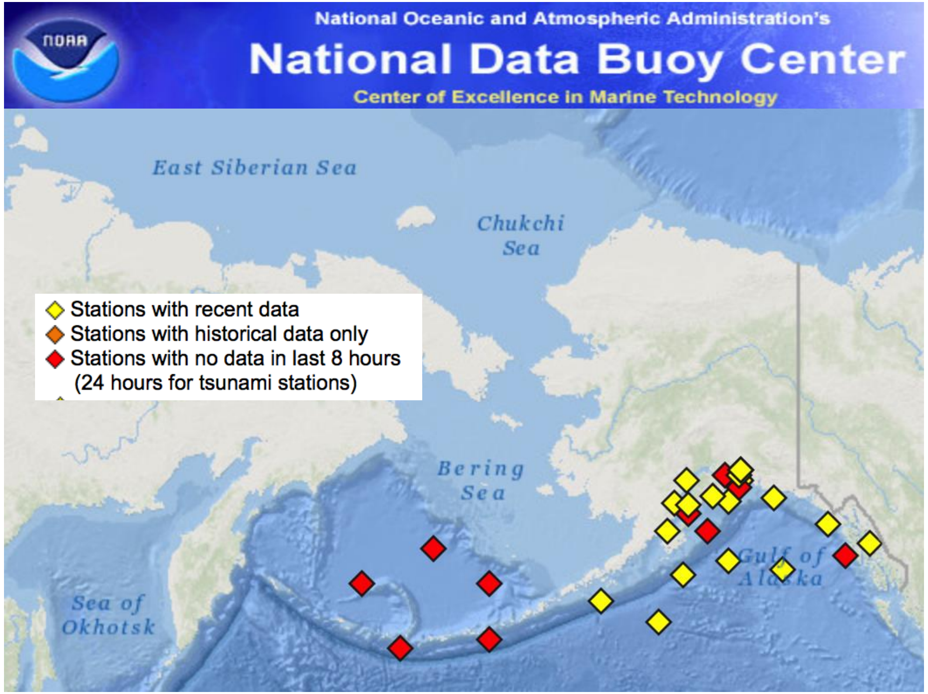


January 2017 – maximum storm surge (no tides)

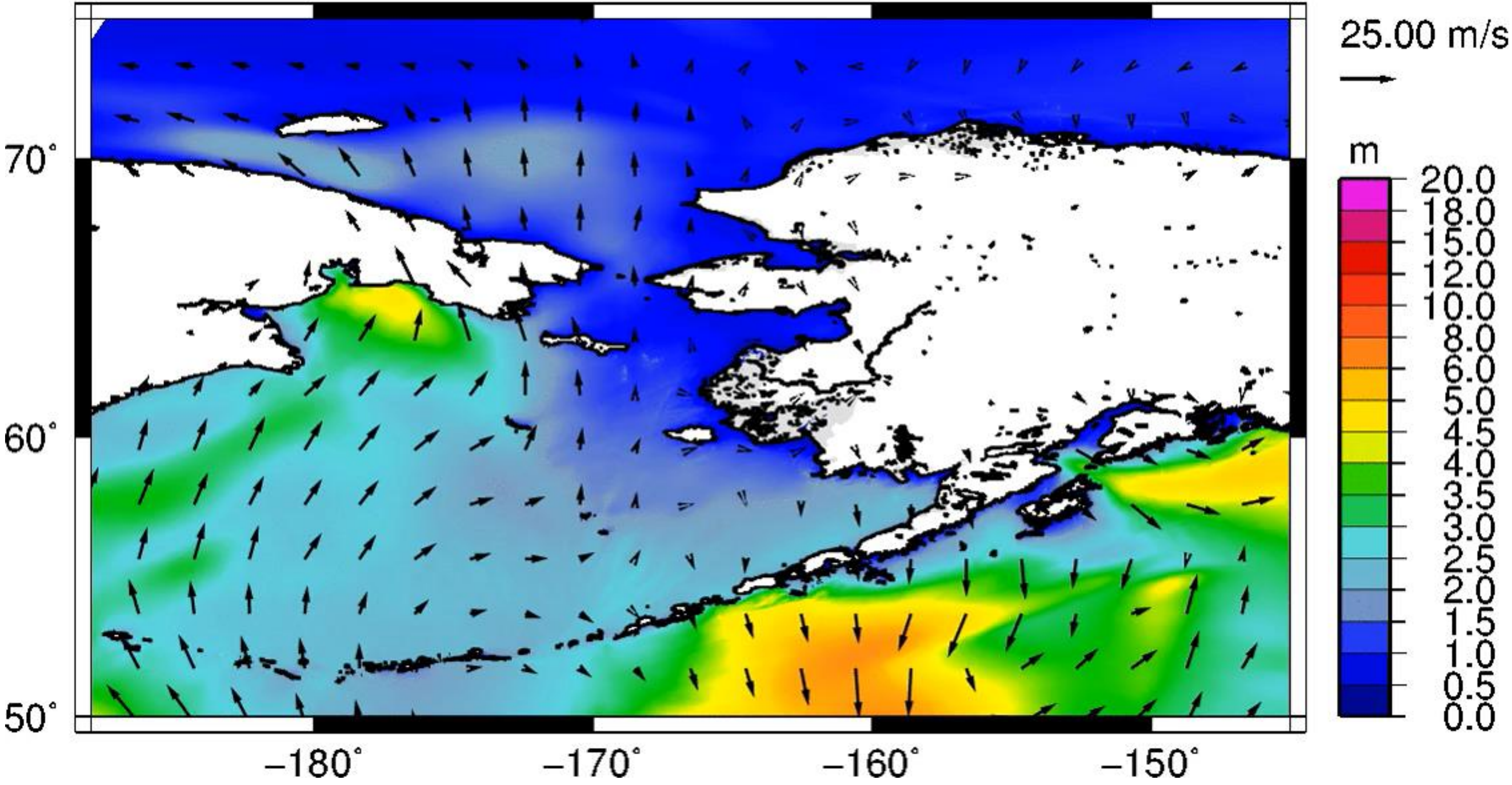


Storm wave measurements

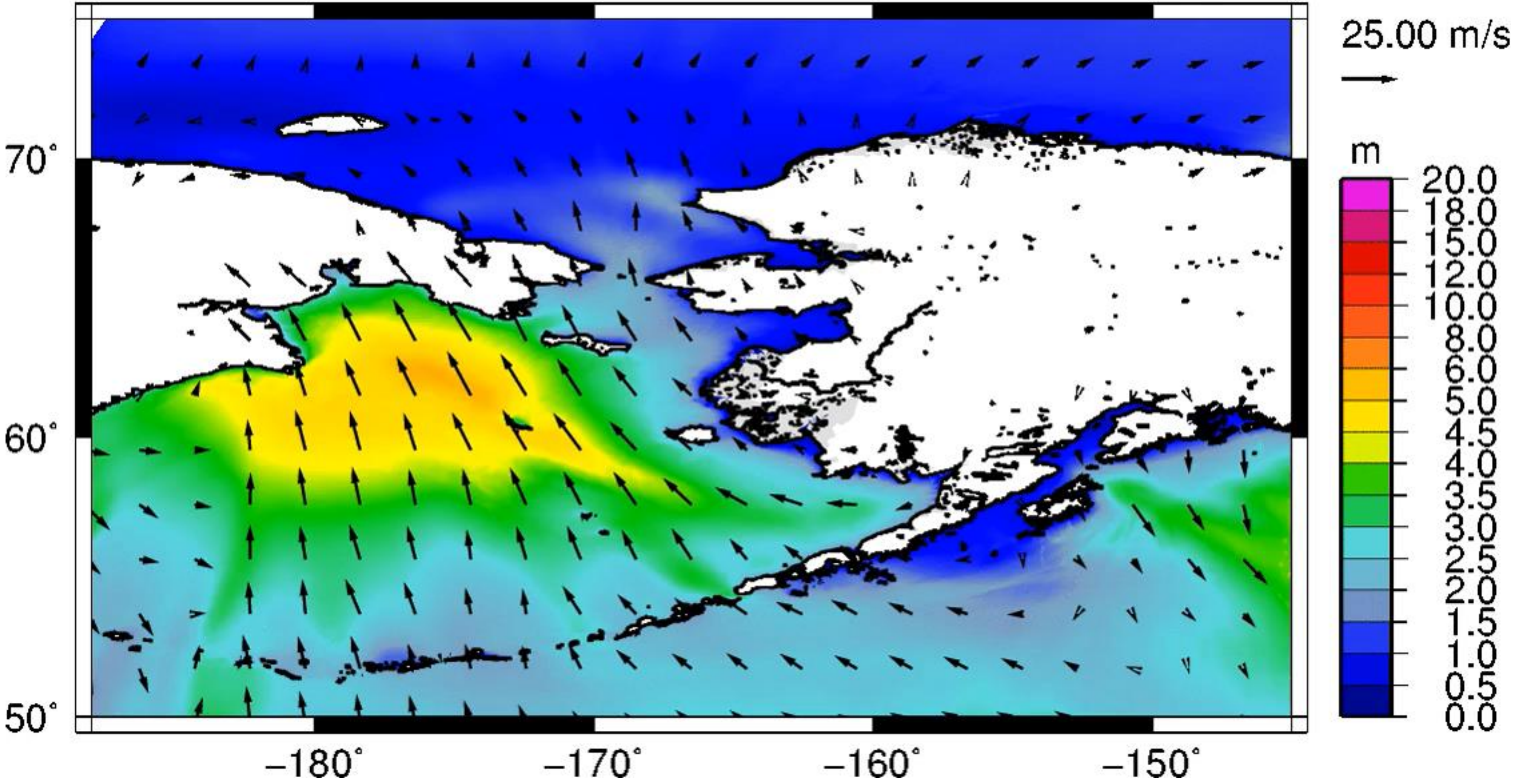
- Used to compare against computed wave height and other wave parameters
- Coupled ADCIRC+SWAN followed by ADCIRC+WWIII model
- Limited wave gauge coverage
    - Large gaps for Western AK



November 2011 – significant wave heights



February 2011 – significant wave heights



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Summary of needs

- Bathymetry – nearshore in waters less than 25 m and inshore in dynamic inlets, rivers and backbays
- Topography on lowlying floodplain and prominent features
- Tide stations
    - Relatively good coverage spatially
    - Limitations in the north and west
    - Station deep within Kotzebue Sound
    - NW Alaska between Point Hope and Barrow
    - No seasonality in measurements
        - Helpful in determining effect of ice/seasonality

Summary of needs

- Surge Water Level Stations
  - Active stations lacking along the West and North coasts
  - No active YK Delta stations
  - Bristol Bay station
  - Western Alaska vulnerable communities
    - Shishmaref
    - Teller
  - Kotzebue Sound
  - Between Point Hope and Barrow

Summary of needs

- Wave stations
  - Little to no coverage in Bering Sea
  - Necessary to validate coupled models for western Alaska
  - Across shelf and in the nearshore

Building a new regional forecast capacity

- IOOS Ocean Technology Transition (OTT) Funding Opportunity
- "Building Coupled Storm Surge and Wave Operational Forecasting Capacity for Western Alaska"

- Collaboration with:
  - University of Notre Dame
  - The University of Texas at Austin
  - NOAA's Great Lakes Environmental Research Laboratory (GLERL)
  - Alaska Ocean Observing System (AOOS) + Axiom Data Science.
  - NOAA NCEP, NOAA NOS CSDL (support)
  - Potential collaboration with : WALCC, NOAA NWS WFO, and the USACE Alaska District

OTT Project Plan – Year 1

- Complete coupling to WAVEWATCH III
- Initial stage of optimization of Air-Sea-Ice drag coefficient
- Begin coupling to CICE
- Build surge forecasting capability driven by GFS - hosted by AOOS
- Updated grid - more efficient for forecasting capabilities

	Deliverables and Outcomes	
Project Timeline (Year/Quarter)	**Project Deliverables**	**Project Outcomes**
YR1/Q1		Preliminary ***UQ of surge*** based on **ADCIRC** with AFGv1.0 and CDv1.0; ***differences between GFS and CFSv2 quantified***
YR1/Q2		
YR1/Q3	**e2ee** Integrated Alaska ***tide and surge model*** implemented within a ***prototype end to end environment.*** All Alaskan stakeholers will have ***real time access to surge guidance.***	Preliminary ***UQ of storm surge and waves*** based on **ADCIRC+WWIII** with AFGv1.0 and CDv1.0. ***Wave contribution to surge is quantified.***
YR1/Q4	Improved ***unstructured forecast grid*** for Western Alaska	

OTT Project Plan – Year 2

- **Next stage of optimization of Air-Sea-Ice drag coefficient**
- **Complete coupling to CICE**
- **Update surge forecasting capability driven by GFS to include WAVEWATCH III**

	Deliverables and Outcomes	
Project Timeline (Year/Quarter)	**Project Deliverables**	**Project Outcomes**
YR2/Q1	Improved data driven ***optimized air-sea drag*** relationship in the presence of sea ice	Preliminary ***UQ of surge and waves*** based on **ADCIRC+WWIII** with **AFGv2.0 and CDv2.0**. Preliminary ***assessment of how grid and air-sea drag formula upgrades improve surge and waves***;
YR2/Q2	**e2ee** Integrated Alaska ***tide, surge, and wave model with an upgraded grid and optimized air-sea drag.***	
YR2/Q3		Preliminary ***UQ of surge, waves, and ice*** based on **ADCIRC+WWIII+CICE** with AFGv2.0. Preliminary ***assessment of how fully coupled sea ice model upgrades improve surge.***
YR2/Q4		

OTT Project Plan – Year 3

- **Update surge forecasting capability driven by GFS to include CICE**
- **Finish uncertainty quantification so that final forecasting system uses most accurate combination of model coupling, forcing products, and model parameter**

	Deliverables and Outcomes	
Project Timeline (Year/Quarter)	**Project Deliverables**	**Project Outcomes**
YR3/Q1	Improved ***unstructured forecast grid*** for Western Alaska and **e2ee** Integrated Alaska ***tide, surge, sea ice, and wave model with an upgraded grid***	
YR3/Q2	Improved data driven ***optimized air-sea drag*** relationship in the presence of sea ice	Comprehensive multi-year ***UQ of surge and waves*** based on **ADCIRC+WWIII** with **AFGv3.0 and CD3.0**. Assessment of how ***grid and air-sea drag formula upgrades*** improve surge and waves. Assessment of differences between ***GFS and CFSv2*** forced systems.
YR3/Q3		Comprehensive multi-year ***UQ of surge*** based on **ADCIRC** with AFGv3.0 and CD3.0. Assessment of how wave-surge interaction and ***wave attenuation in the ice impacts the computed surge***.
YR3/Q4	e2ee Integrated Alaska ***tide, surge, sea ice, and wave model*** and ***tide, surge + optimized drag, and wave model*** implemented within a ***prototype end to end environment***	Comprehensive multi-year ***UQ of surge*** based on **ADCIRC+WWIII+CICE** with AFGv3.0. Assessment of ***an impact on surge due to sea ice interaction which directly computes ice drift and bases ice-sea stress on relative ice-current speeds***. Quantification of all system components and model improvements to ***determine operational capability and skill as well as operational robustness in e2ee.***