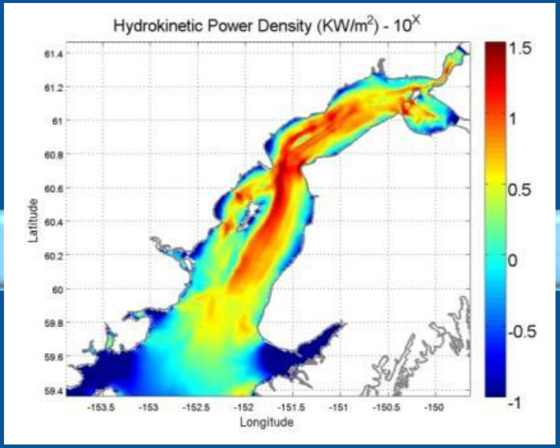
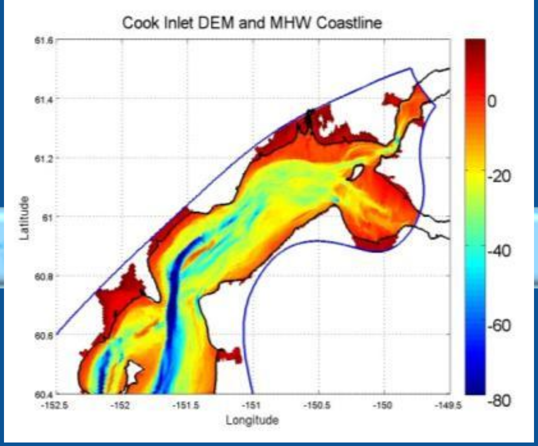
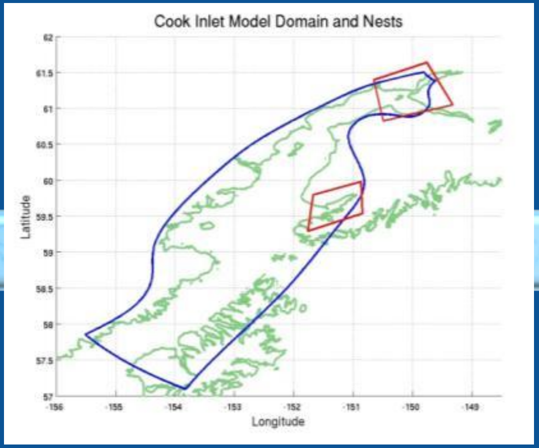



# Design and Implementation of a NOAA/NOS Cook Inlet and Shelikof Straits Circulation Modeling System

Presented at a NOAA/AEA Stakeholders Meeting,
August 24, 2011, Anchorage Alaska

Richard Patchen and Lyon Lanerolle

# Programmatic Objectives

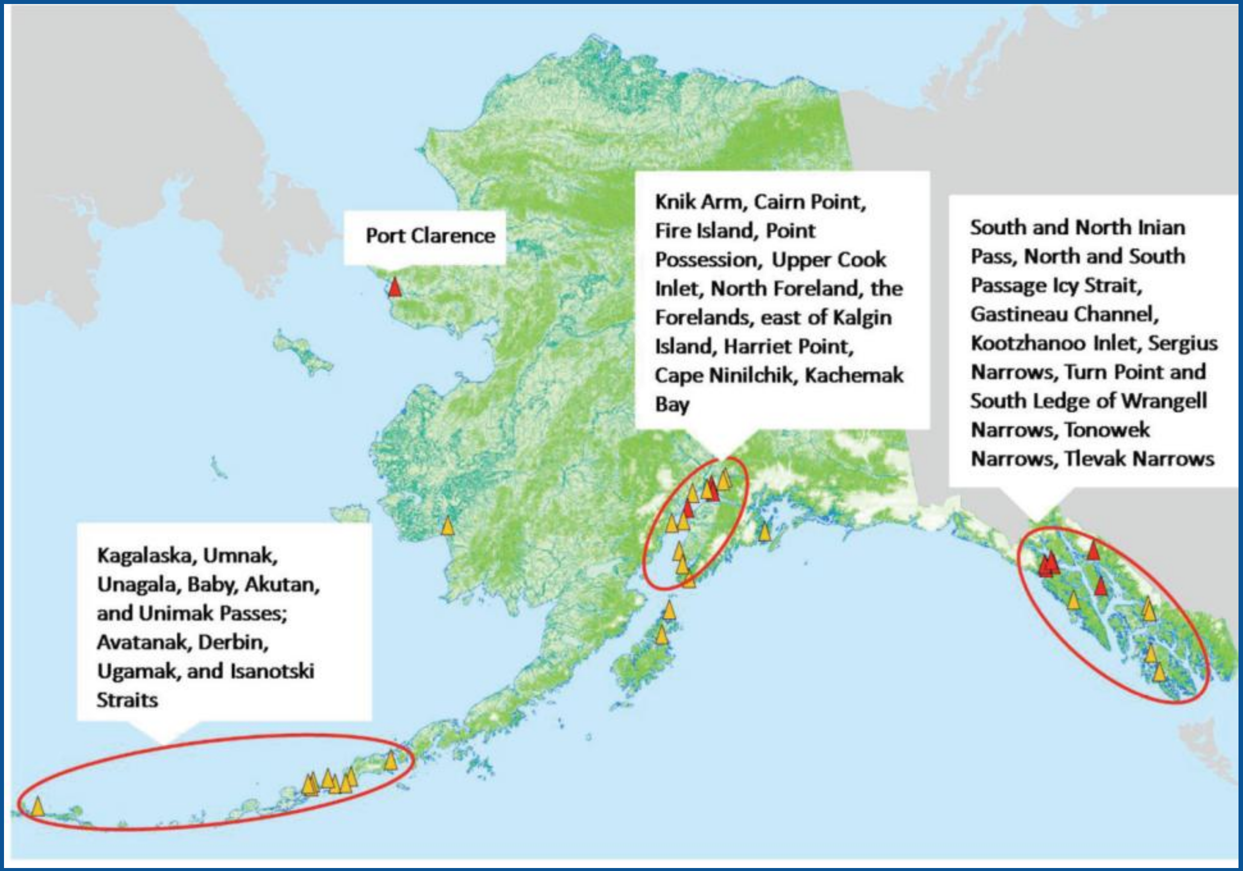
- Support Known Requirements for the Region
  - Marine Operations – Oil and Gas Platform and Port Facilities (Anchorage) Resource Management – Alaska Departments of Fish and Game and Natural Resources
  - Coastal Sciences – Climate Change/ocean acidification/coastal ecology, Kasitsna Lab, Kachemak Bay NERR, AOOS, and Universities
  - Oil Response – NOAA's ORR, Coast Guard, Cook Inlet Regional Citizens Advisory Council (CIRCAC), and local communities
  - Recreation – Charter sportfish industry, marine ecotourism
  - Renewable Energy –AGREEMENT BETWEEN THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL OCEAN SERVICE AND THE ALASKA ENERGY AUTHORITY FOR A BASELINE ASSESSMENT OF TIDAL KINETIC ENERGY IN COOK INLET, AK

- Develop Improved Navigational Products for the Region
  - Web enabled tide and tidal current charts and tables
  - Operational Forecast System (OFS)

# Proceeding from a Scientific Workshop Held on Environmental Effects of Tidal Energy Development, March 22-25, 2010

- Validated and calibrated ocean and hydrodynamic models can effectively address some critical uncertainties. Models are needed, both at the scale of a few turbines to address potential near-field effects and at regional scales to address potential far-field effects.

- Project and device developers should work with oceanographers and other researchers to share and discuss monitoring data collection, modeling methodologies, and study results



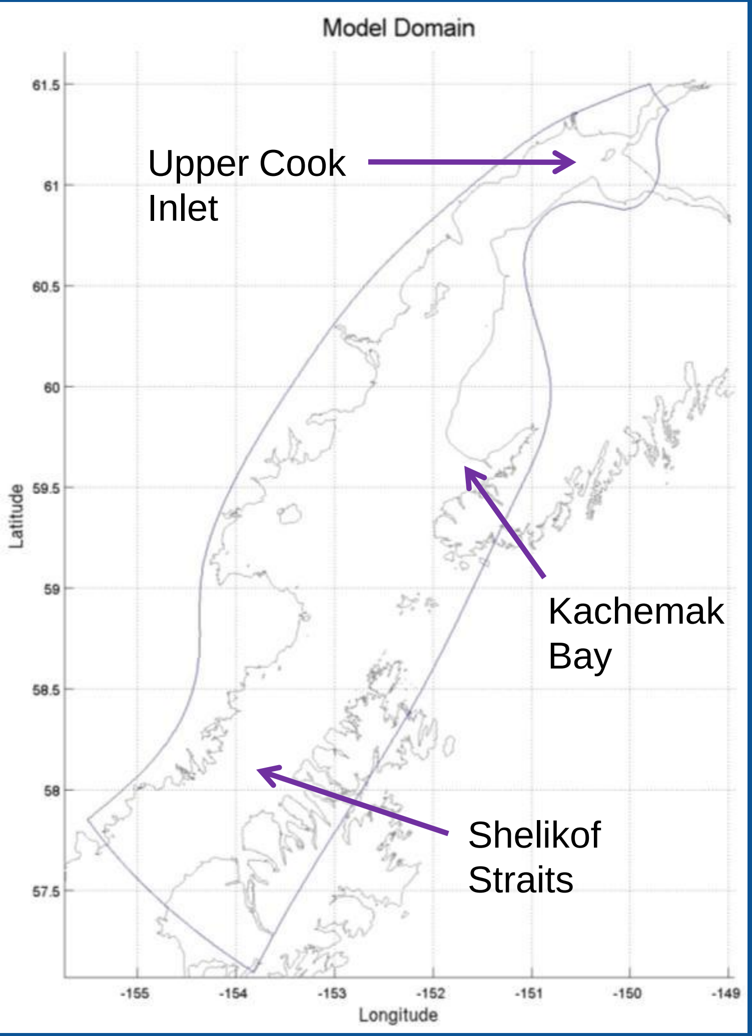

**Areas of significant hydrokinetic energy potential in Alaska (yellow triangles) and areas with pending or issued FERC permits (red triangles)**

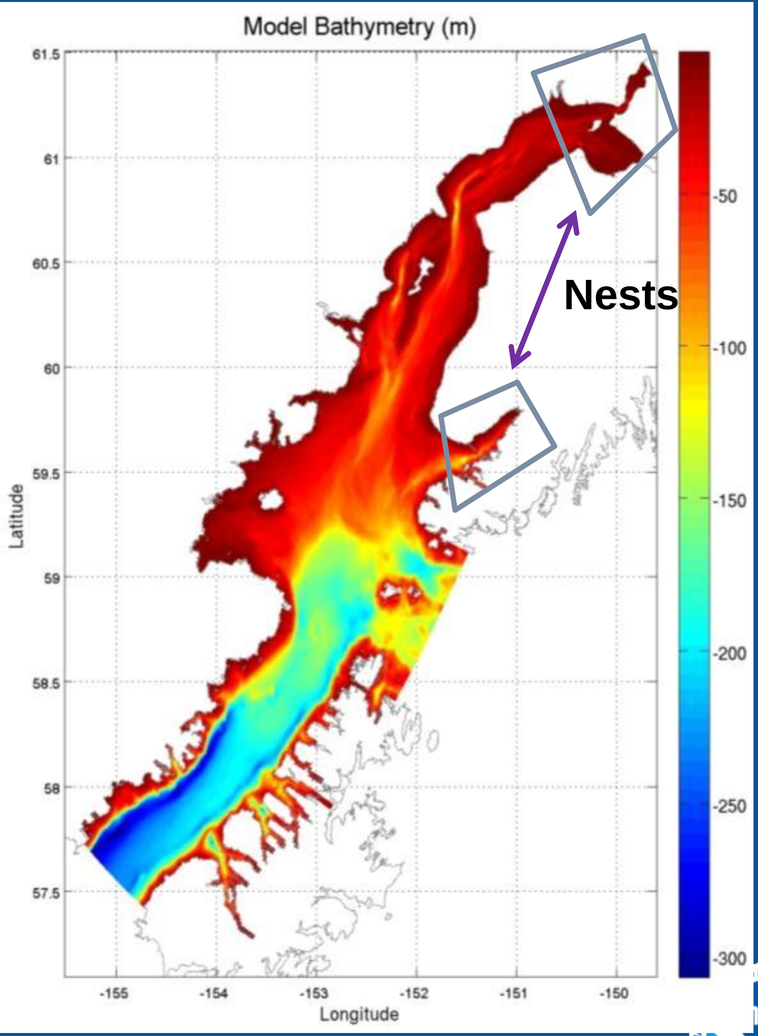
**From Proceeding of Environmental Effects of Tidal Energy Development, March 22-25, 2010**

# Model Simulation Strategy and Sequence

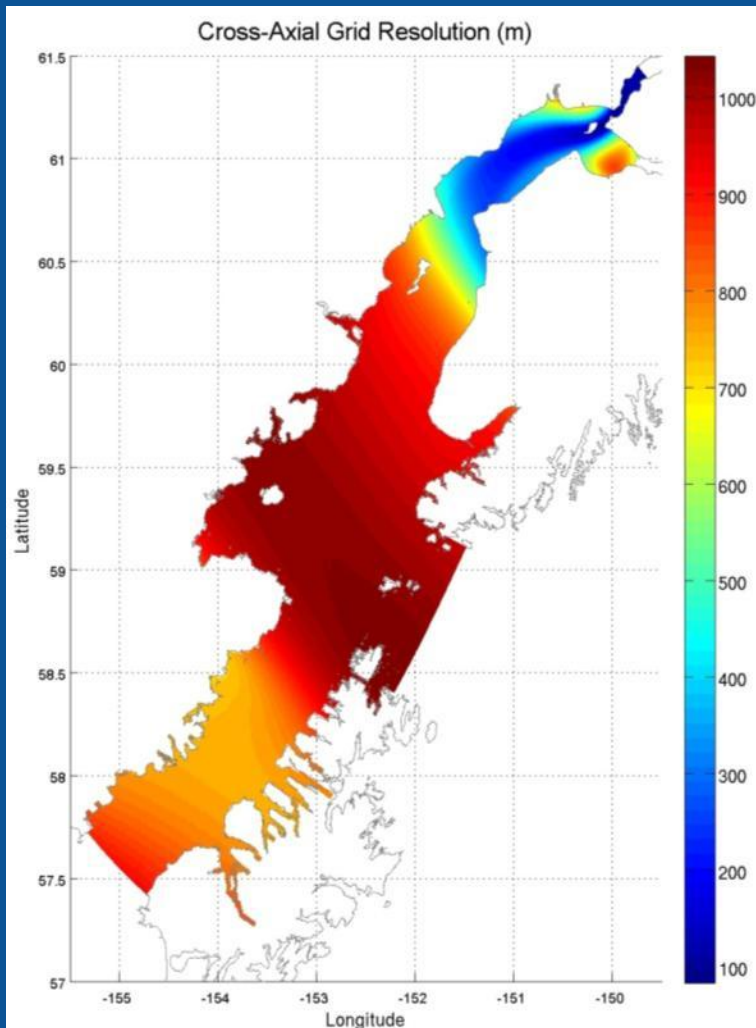
- Configure a regional model - uses Rutgers University's Regional Ocean Modeling System (ROMS)
  - Conduct a series of tidal simulations, without emerging and submerging shoals and constant density
- Establish a Digital Elevation Model (DEM)
  - Based on most recent Bathymetries Shorelines, and Topographies
- Enhance Regional model with local highly resolved nests, using the DEM
  - Conduct a series of hindcasts
  - Validate with historical and newly collect observations
- Complete Baseline Assessment of Tidal Kinetic Energy in Cook Inlet
- Establish NOAA Operational Forecast System for Region

# Model Domain and Bathymetry



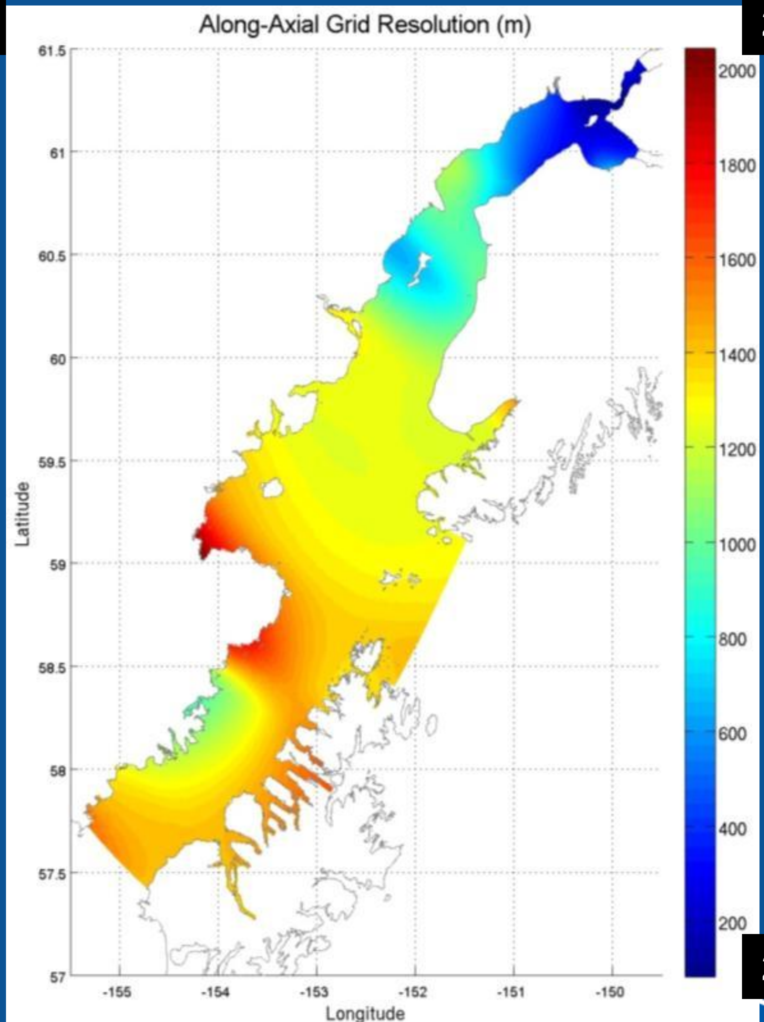



# Model Grid Spatial Resolution




1000 m

100 m




2000 m

200 m

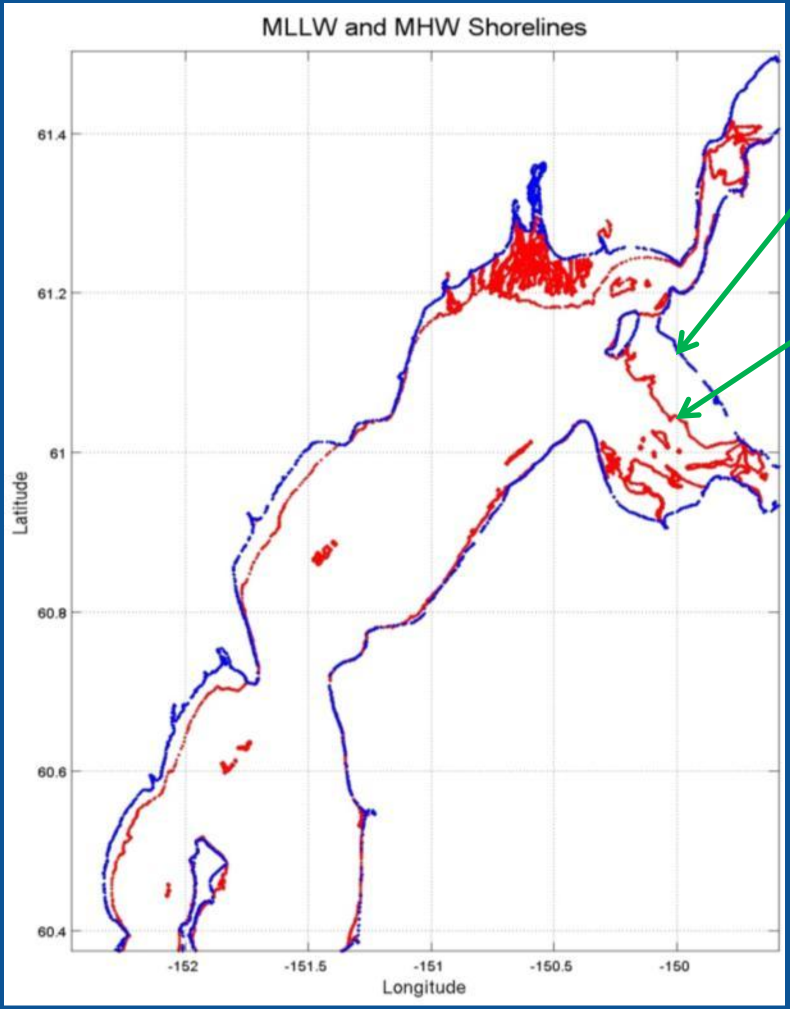
# Development of the Shelikof Straits –Cook Inlet Digital Elevation Model (DEM)

- Need a DEM to account for flooding/drying especially in upper CI
- DEM is built by combining :
  - Bathymetric sounding data
  - Shoreline data
  - Land topography data
- DEM needs to be seamless without “jumps” between above data sets
- Need to account for different native datums of the datasets

# DEM Development: Bathymetry

- Bathymetric soundings were from NOS surveys in the Shelikof Straits – Cook Inlet region
- Soundings have been quality controlled
- Soundings cover 1907–2004, 2008–2009 periods
- Data in Bathymetric Attributed Grid (BAG) file format need to be converted to ASCII before use
- All datasets are on a MLLW vertical datum
- Soundings interpolated to ROMS model grid in a supersession sequence (2009 $\longrightarrow$ 1907)
- Spatial interpolation via a $1/r^2$ algorithm with three expanding "radii" : $\pm \frac{1}{2}(\Delta x, \Delta y)$, $\pm (\Delta x, \Delta y)$, $\pm \frac{3}{2}(\Delta x, \Delta y)$ around model "wet" grid nodes
- The model grid "wet point" interpolation domain was determined by the MLLW shoreline

# DEM Development: Shoreline

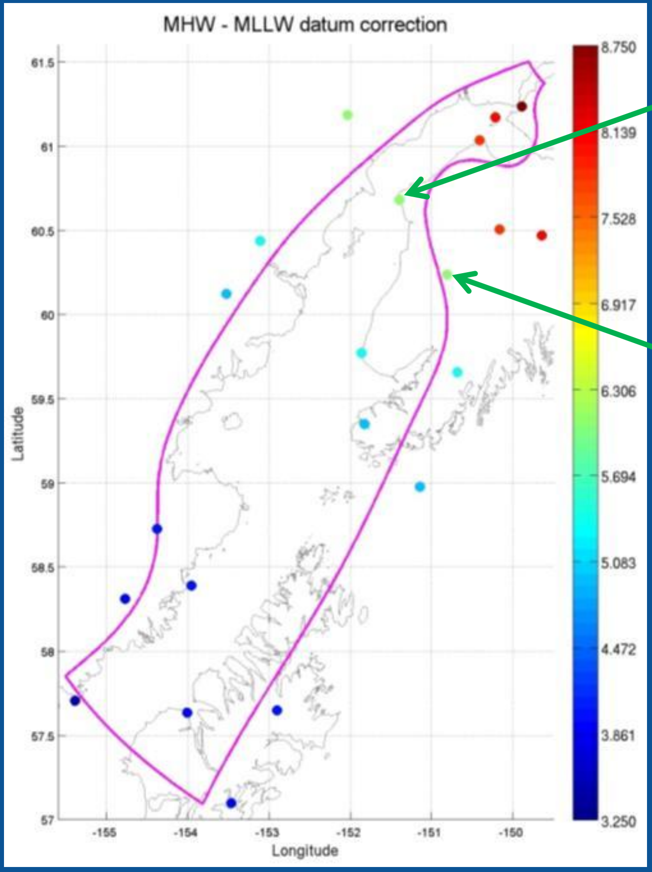



MHW shoreline relative to MLLW datum

MLLW shoreline

- Continue to use a MLLW vertical datum
- On MLLW shoreline assume h = 0 (m)
- Apply datum correction to MHW shore-line so that it has h > 0 relative to a MLLW datum (next slide)
- Using (i) previously interpolated bathymetry (at wet points) and (ii) MLLW shoreline with h = 0 and (iii) MHW shoreline with h > 0, spatially bi-linearly interpolate to define model grid point depths between the two shorelines on a MLLW datum

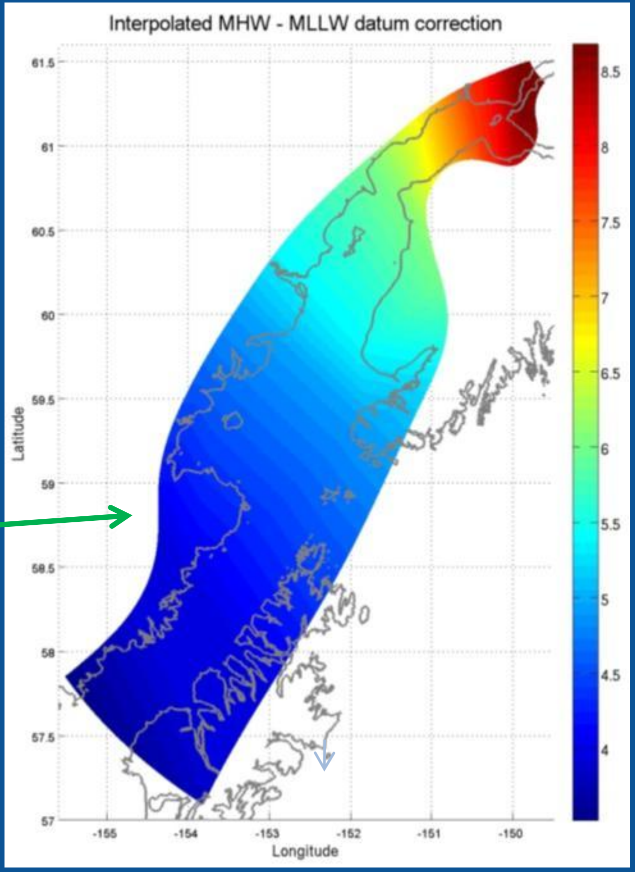
# DEM Development : Vertical Datum Transformations




Observed MSL, MHW, MHHW, MLLW heights and their differences from NOS/CO-OPS data sheets

Pseudo-data points to facilitate spatial interpolation (to generate datum difference fields)

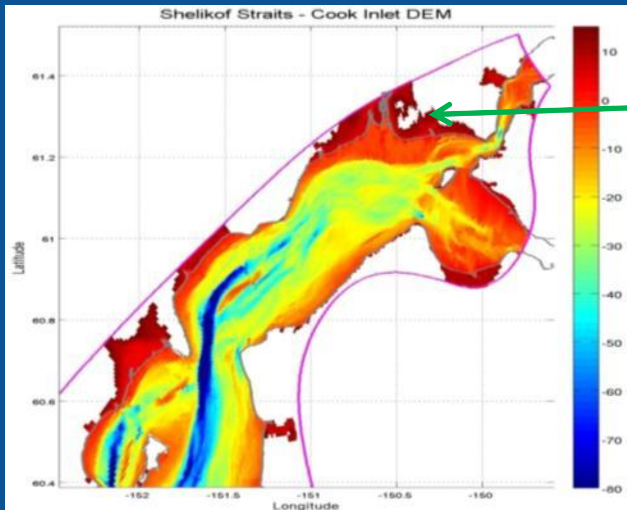
Bi-linear interpolation

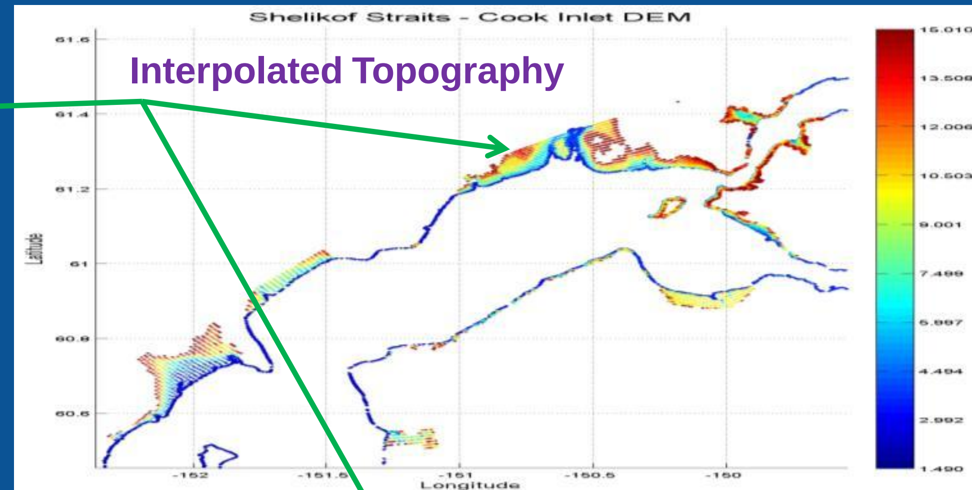


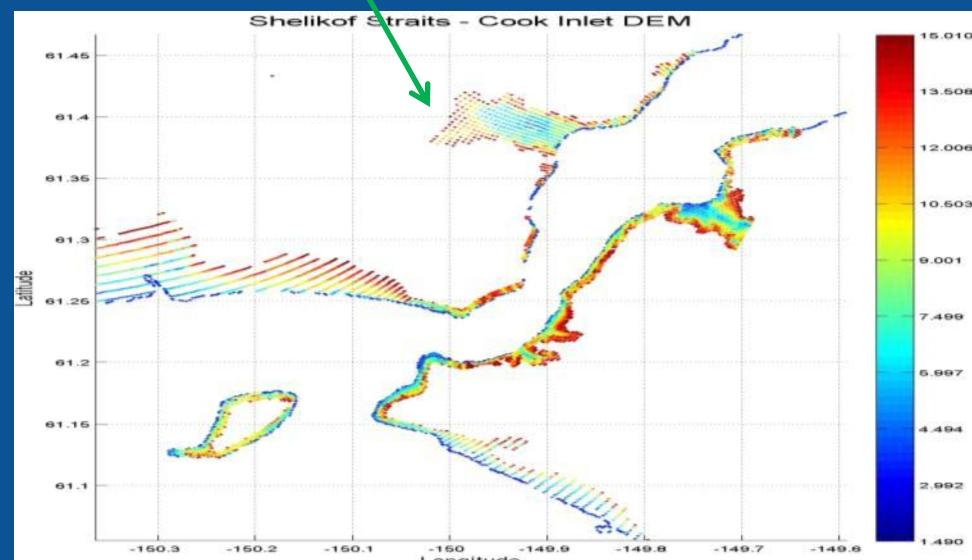
# DEM Development: Land Topography

- Land topography from two sources – USGS digitized elevation data and NOAA/NESDIS/NGDC 1/3” DEM for Kachemak Bay
- USGS data 4 spatial resolutions – 1/9”, 1/3”, 1” and 2”
- Datum for USGS unclear but zero-elevation contour matches NOAA/NESDIS/NGDC MHW shoreline well
- Assume both data sources are on a MHW vertical datum
- Interpolate USGS data from highest to lowest spatial resolution (1/9” 2”)
- Use same numerical interpolation algorithm as for bathymetry
- Clip topography at 15m elevation

# The Shelikof Straits – Cook Inlet DEM



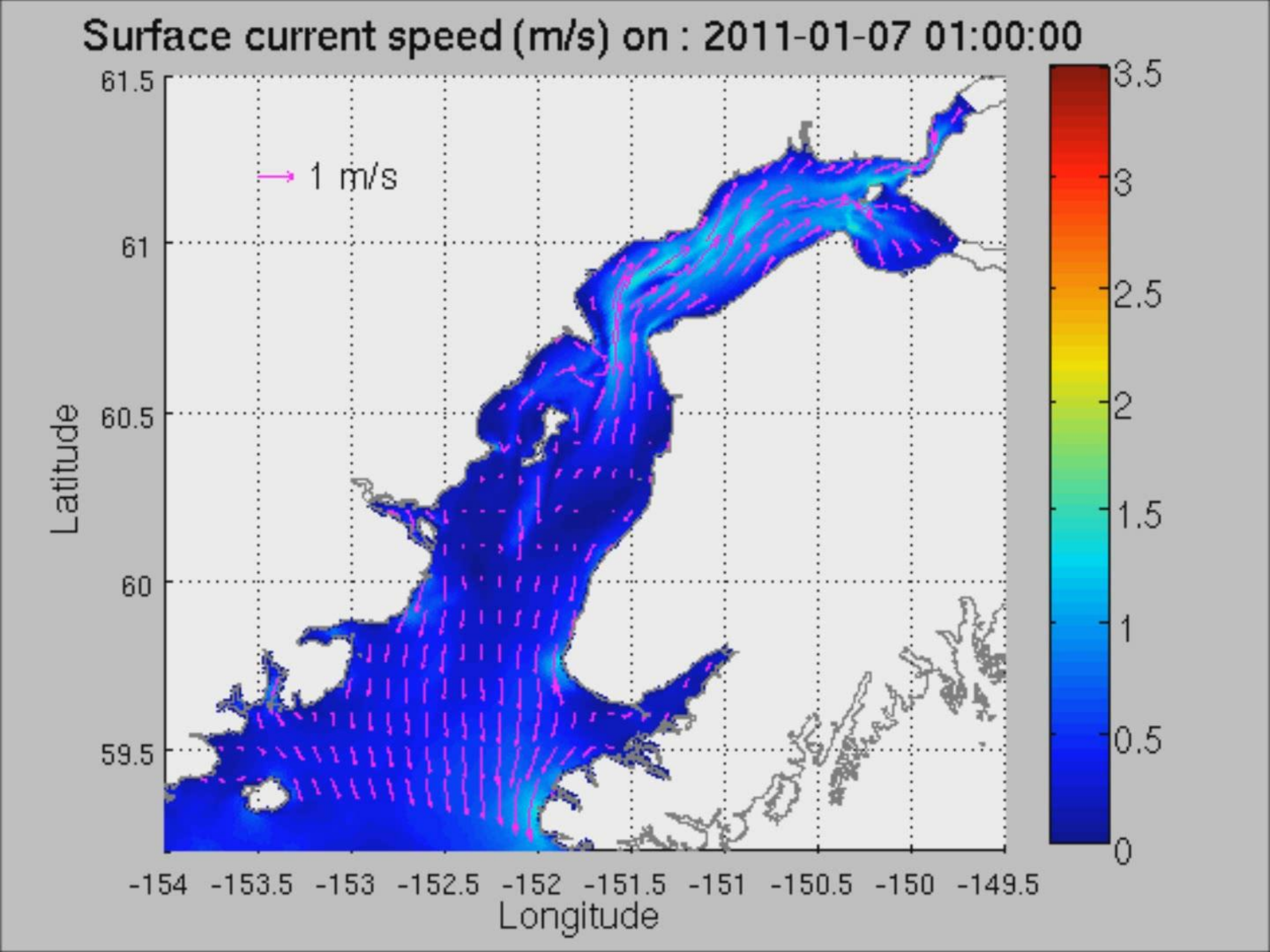

- Interpolated bathymetry and shoreline on MLLW brought to MSL
- Interpolated topography on MHW also brought to MSL
- DEM fully on MSL vertical datum
- Land topo. clipped at 15m height
- Needed to re-define land/sea masks on model grid

# Present Status

- Completed construction of a DEM for the region
- Completed initial configuration of the regional model and conducted a series of tidal simulations, without emerging and submerging shoals and constant density.

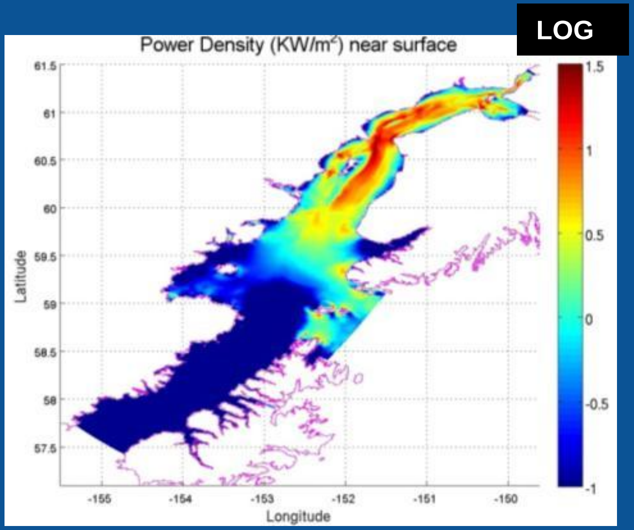
  - The M2 simulation provided:
    - a suitable calibration mechanism
    - evidence that water elevation amplitude and phases were very accurate
    - evidence that currents comparisons degrade in upper CI
    - evidence that the most effective bottom drag formulation was the Log formulation

  - A non flooding/drying simulation with 8 ADCIRC tidal constituents showed that :
    - water elevation phases were very accurate
    - water elevation amplitudes have ~50 cm (~12.5%) error in upper CI
    - model predicted currents have very accurate phases
    - the currents profiles deform in the upper CI region

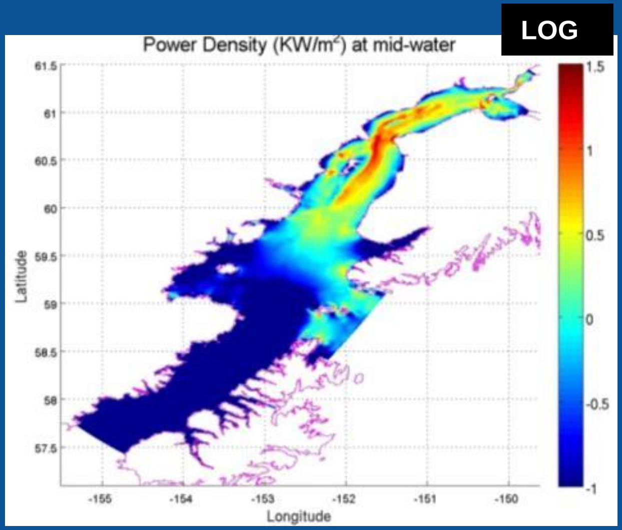


Surface current speed (m/s) on : 2011-01-07 01:00:00
1 m/s
61.5
61
60.5
60
59.5
Latitude
-154
-153.5
-153
-152.5
-152
-151.5
-151
-150.5
-150
-149.5
Longitude
3.5
3
2.5
2
1.5
1
0.5
0

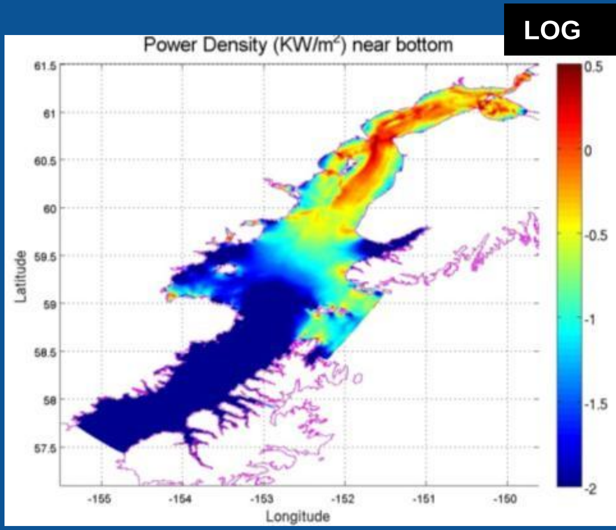
# Preliminary Examples of Renewable Energy Characteristics for Cook Inlet and Shelikof Straits




Near Surface

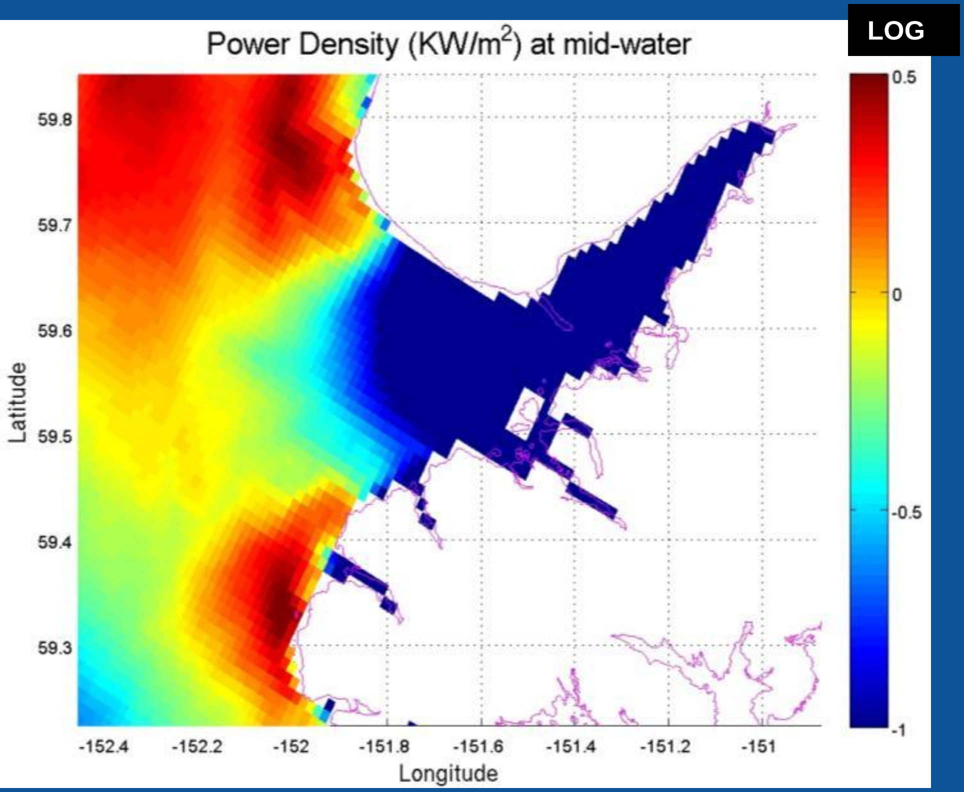


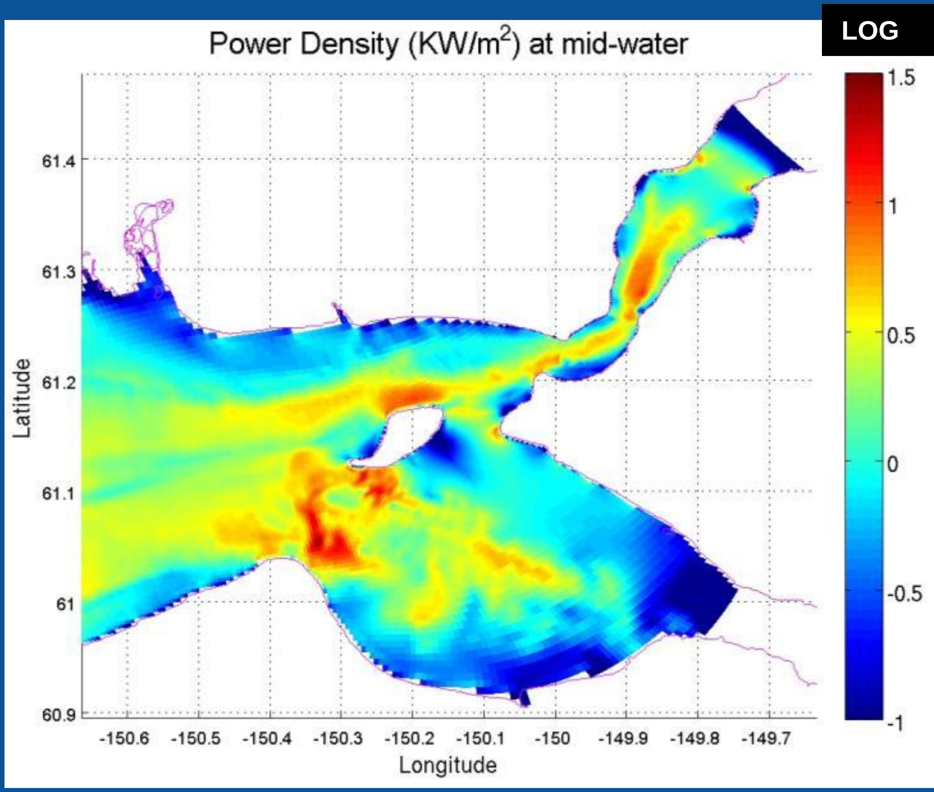

Mid-Depth




Near Bottom

# Preliminary Examples of Renewable Energy Characteristics for Cook Inlet and Shelikof Straits

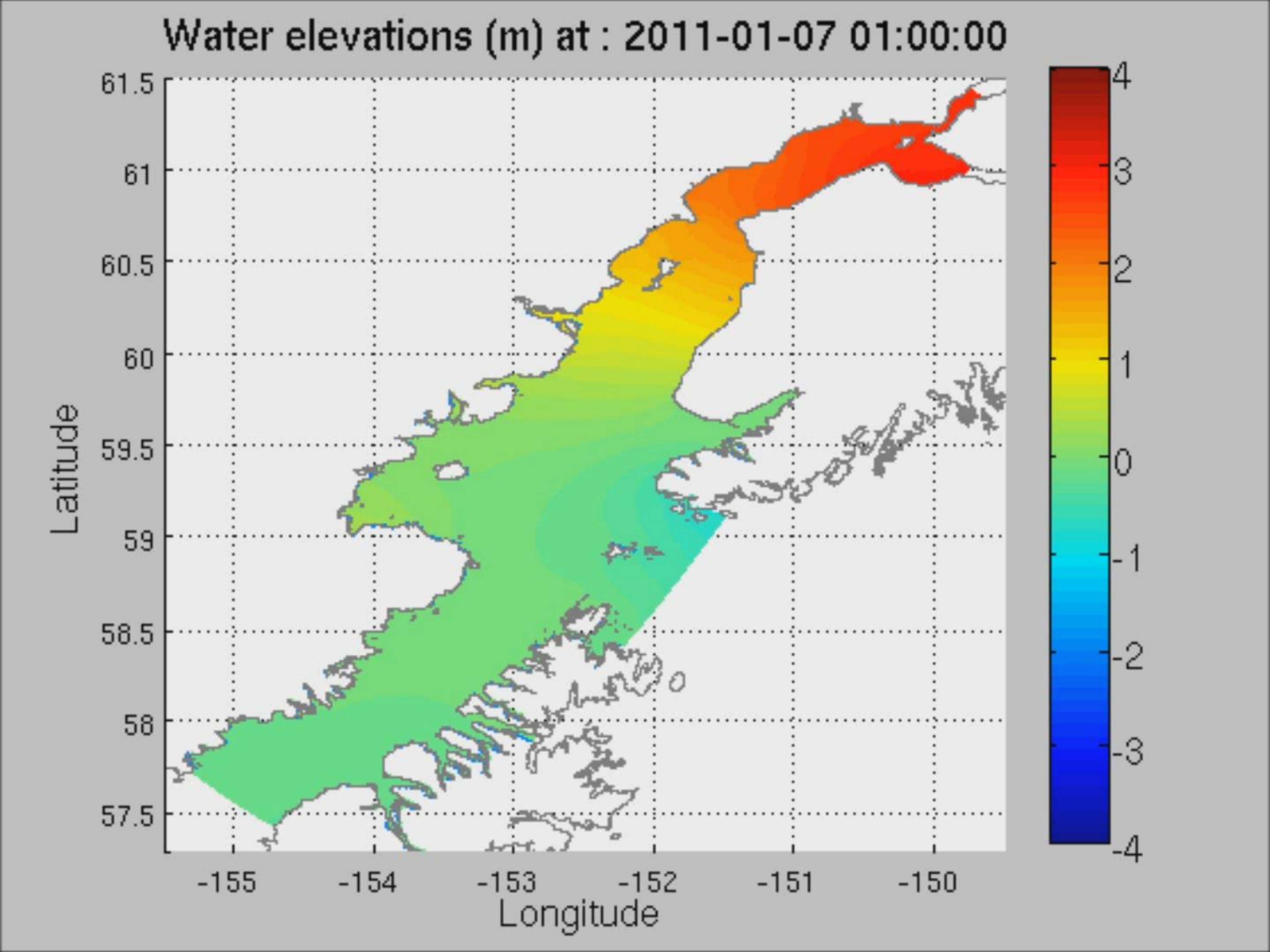


# Acknowledgments


- Doug Graham (NOAA/NOS/NGS) – MLLW shoreline
- Dean Gesch and Gayla Evans (USGS, South Dakota) – USGS 1/9” topography dataset and guidance on using USGS topography and vertical datum issues
- Barry Eakins (NOAA/NESDIS/NGDC) - Vertical datums for topography
- Dan Roman and Xiaopen Li (NOAA/NOS/NGS) - Datum transformation choices
- Kris Holderied (NOAA Kasitsna Bay Lab) - Kachemak Bay integrated ocean mapping, tidal energy collaboration concept, NOAA regional collaboration team
- Darcy Dugan (AOOS) - Cook Inlet modeling workshop/ongoing workgroup, stakeholder outreach

# Backup Slides

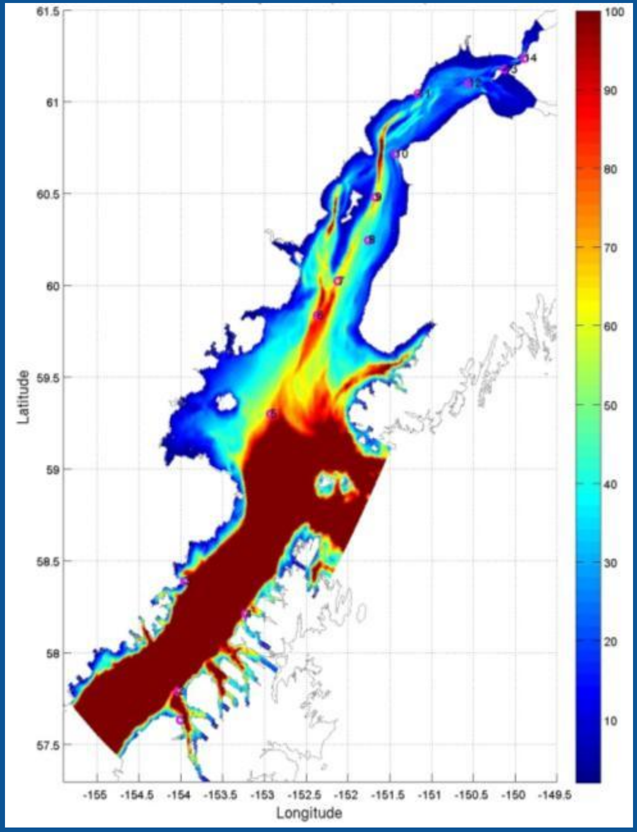


Water elevations (m) at : 2011-01-07 01:00:00
61.5
61
60.5
60
59.5
59
58.5
58
57.5
Latitude
-155
-154
-153
-152
-151
-150
Longitude
4
3
2
1
0
-1
-2
-3
-4

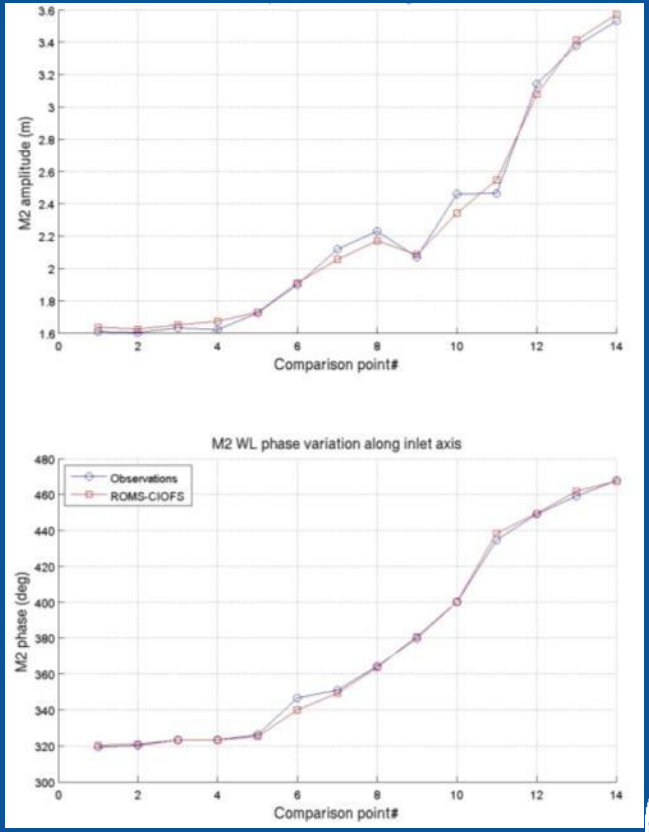
# M2 Water Elevation Validation

- Model calibrated via M2 amplitude and phase along domain axis
- Very sensitive to choice of bottom drag formulation – Log form. best

## WE Comparison Stations



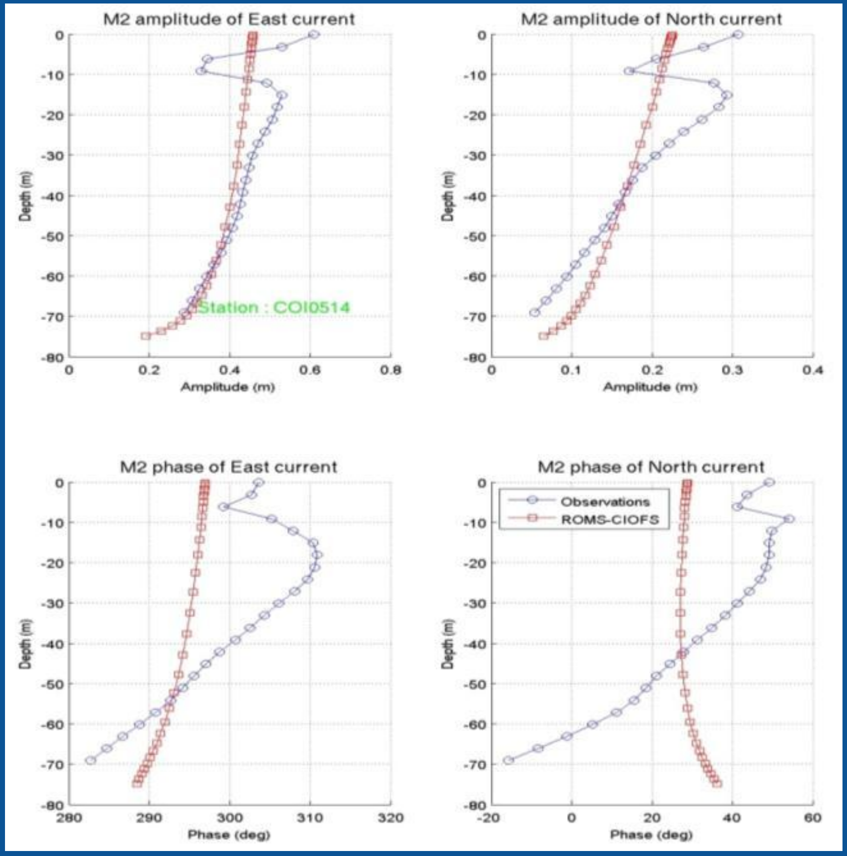

## WE Ampl. and Phase Comp.



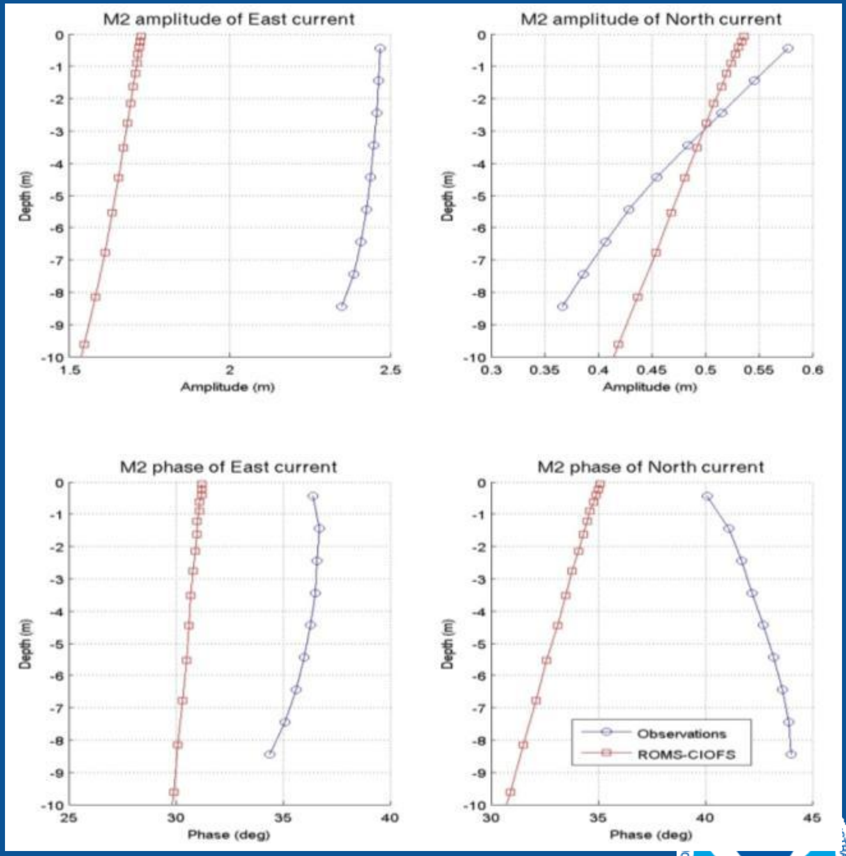
# M2 Current Validation

- In lower CI, both M2 amplitude and phase from model and obs. compare well
- In upper CI, phases compare well but model ampl. is damped relative to obs.

## Lower Cook Inlet



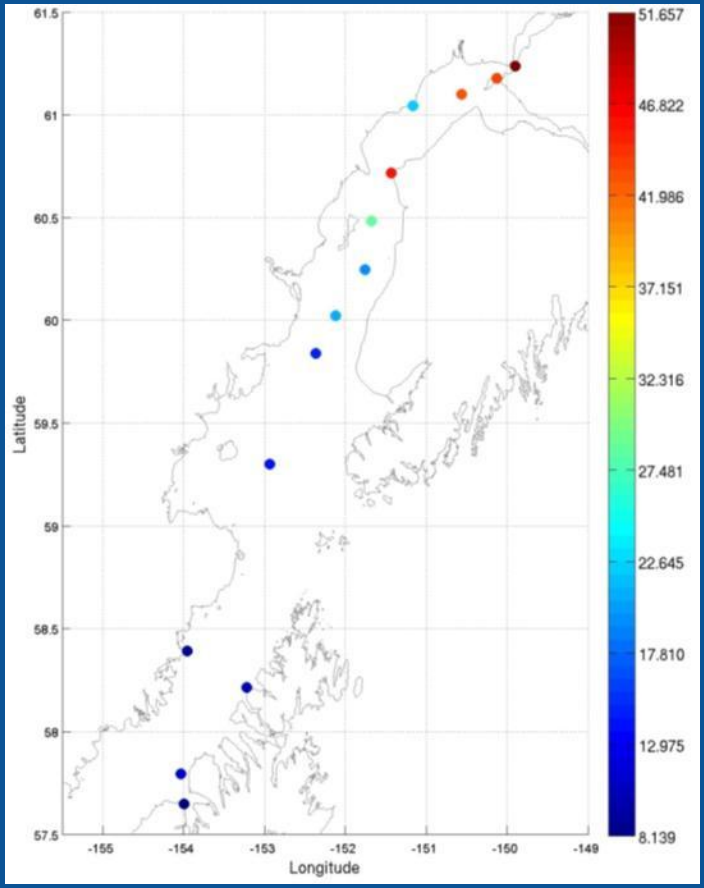

## Upper Cook Inlet



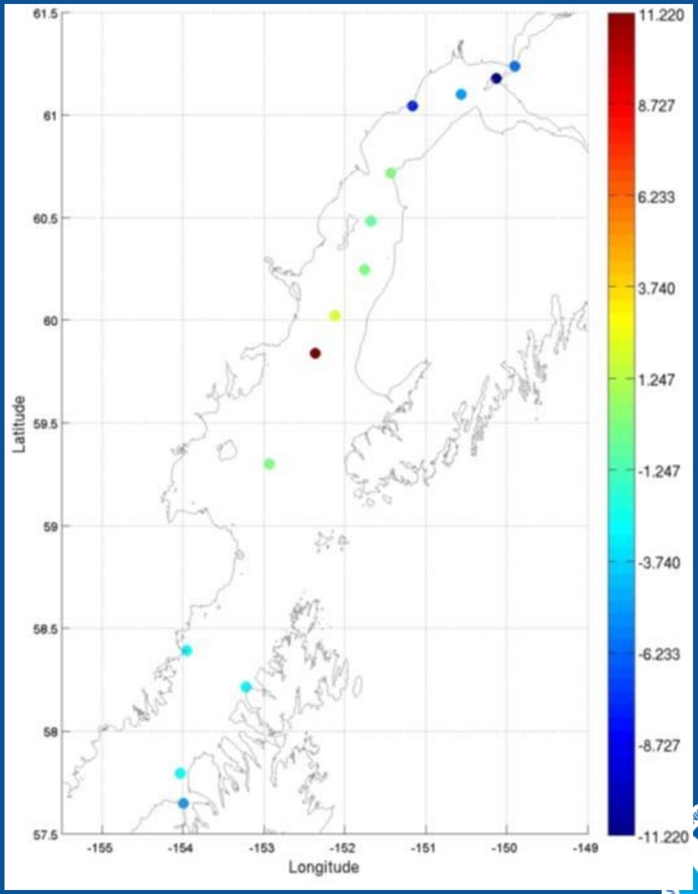
# Tidal Water Elevation Validation

- Amplitude errors increase when moving up CI and are ~50 cm
- Model predicted phases are highly accurate and are under 12 min.

**Ampl. Error (cm) Component**



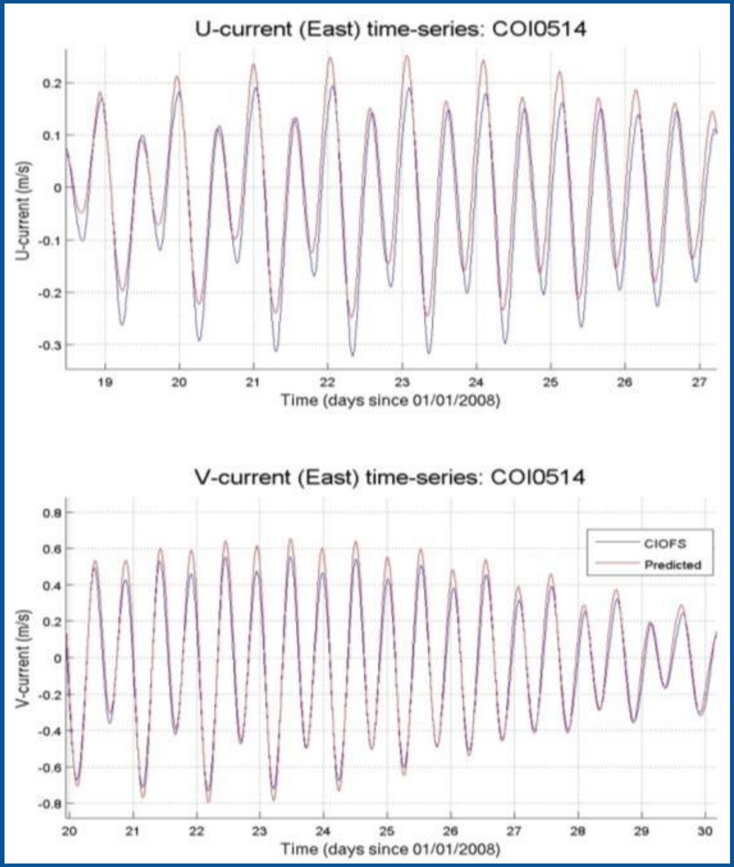

**Phase Error (min.) Component**



# Tidal Currents Validation

- Currents in lower CI match tidal predictions well
- In upper CI, the phases are accurate but model current profiles are distorted

## Lower Cook Inlet




## Upper Cook Inlet