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

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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)
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

- Upper Cook Inlet
- Kachemak Bay
- Shelikof Straits
- Nests
Model Grid Spatial Resolution

- Cross-Axial Grid Resolution (m):
  - 1000 m
  - 100 m

- Along-Axial Grid Resolution (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
- 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 → 1907)
- Spatial interpolation via a $1/r^2$ algorithm with three expanding “radii”:\n  $± \frac{1}{2}(\Delta x, \Delta y)$, $± (\Delta x, \Delta y)$, $± \frac{3}{2}(\Delta x, \Delta y)$ around model “wet” grid nodes
- The model grid “wet point” interpolation domain was determined by the MLLW shoreline
DEM Development: Shoreline

- Continue to use a MLLW vertical datum
- On MLLW shoreline assume \( h = 0 \) (m)
- Apply datum correction to MHW shoreline 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
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
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- 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
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