Implications of Ice Cover on Storm Surge Dynamics in the Beaufort Sea

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Background and Motivation

• Planned coastal resource development projects
• MSC Beaufort Project
  – Previously completed wind and wave climatology studies
  – 30+ year continuous hindcast simulation
• Complex storm surge/ice cover dynamics
Brief Description of Methodology

- Develop ADCIRC finite element mesh
- Astronomic tide resynthesis
- Validate storm surge during open water conditions
- Ice cover data and ICE CUBE method
- Fast ice and wind stress adjustment
Summary of Conclusions

• Model performs well during open-water conditions

• Ice cover impacts surge levels – sometimes significantly

• ICE CUBE method provides a flexible method for incorporating ice cover data under certain conditions

• Shore-fast ice also important in shallower waters
Finite Element Mesh

302,535 Nodes
591,940 Elements
Bathymetry DEM

Introduction → Mesh Development → Tides → Surge → Ice Cover → Conclusions
Mesh Node Spacing

Mesh Spacing
High: 33807
Low: 115

United States
Canada

Kilometers
0 250 500
Historical Data Stations

3 NOAA Tide Gauges

NOAA Tide Station
DFO Data Station
Model Boundary

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Introduction → Mesh Development → Tides → Surge → Ice Cover → Conclusions

Wave Workshop – October 29, 2013
Historical Data Stations

Introduction → Mesh Development → Tides → Surge → Ice Cover → Conclusions
ADCIRC Model

Advanced Circulation, Two-Dimensional Depth-Integrated (ADCIRC-2DDI) model

- Long-wave, coastal and ocean circulation model
- Finite element based
- Simulates astronomic tides and storm surge
Astronomic Tide Comparison

- Open Ocean Boundary Conditions
  - AODTM5 tidal database
  - 8 constituents - $K_1$, $K_2$, $M_2$, $N_2$, $O_1$, $Q_1$, $S_2$, and $P_1$
- 90-day simulation, 8-sec time step
- Harmonic analysis performed over final 45-days
- Resynthesize model results and compare to historical data
Storm Surge: Open Water Conditions

- August 6, 2004 – August 20, 2004
- Isolated surge event
- Open water conditions (relatively minimal ice cover)
- Wind/pressure field data input to the ADCIRC model
- Wind stress based on Garrett’s formulation
  - No adjustments due to ice cover data
Storm Surge: Ice Cover Data

- Expansive ice cover throughout the Beaufort Sea during the Fall, Winter, and Spring seasons
- Data available in a 5-km grid
- Simulating 30+ years of data
  - Parameterization vs. calibration
  - Need a flexible, yet robust method
- Adjust wind drag coefficient based on ice cover
Ice Cover Data Example – 9/12/80

19800912 on ADCIRCice Grid

Ice%  0  10  20  30  40  50  60  70  80  90  100

Introduction  →  Mesh Development  →  Tides  →  Surge  →  Ice Cover  →  Conclusions
Ice Cover Data Example – 9/26/80
ICE CUBE Method

- Developed by the USACE Coastal & Hydraulics Laboratory
- Assumes ice floe contributes to water momentum
- Wind stress based on percent ice cover and wind speed

Source: Chris Massey and Ray Chapman, USACE
Fast Ice

- Expansive, semi-rigid layer of ice (think Ice Road Truckers)
- Anchored to the shore or bottom
- Typically occurs in shallower waters
- Relatively minimal lateral movement due to winds or currents
Fast Ice

Introduction Mesh Development Tides Surge Ice Cover Conclusions
Conclusions and Future Work

• Model performs well during open-water conditions
• ICE CUBE method provides a flexible method for incorporating ice cover data under certain conditions
• Shore-fast ice also important in shallower waters
• Continue fast ice sensitivity analysis
• Perform full hindcast simulation with ICE CUBE and fast-ice adjustments incorporated
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