BOEM ENVIRONMENTAL STUDIES PROGRAM: Ongoing Studies

Study Area(s): Beaufort Sea, Chukchi Sea

Administered By: Alaska OCS Region

Title: Development of an Accurate Model of the Beaufort and Chukchi Ice Drift and Dispersion for Forecasting Spill Trajectories and Providing Decision Support for Spill Response (AK-13-03-03)

BOEM Information Need(s) to be Addressed: In the event of an oil spill, sea ice complicates the tracking of ice/oil trajectories and can hinder clean-up operations. There is a need for a sea ice model that can accurately simulate ice pack deformation and failure to improve ability to track ice/oil trajectories and support oil response operations. This information may be used by BOEM analysts and decision-makers in NEPA analysis and documentation for lease sales, EPs and DPPs.

Total Cost: $359,078
plus Joint Funding ($358,221)

Period of Performance: FY 2013-2017

Conducting Organization: CMI, UAF

BOEM Contact: Dr. Heather Crowley

Description:

Background: OCS oil and gas exploration and production activities in the Beaufort and Chukchi Seas can be significantly and adversely affected by sea ice. For example, in the event of an oil spill, the presence of sea ice vastly complicates the issues of tracking ice/oil trajectories and conducting clean-up operations. It becomes important to forecast the trajectory and dispersion of contaminated ice and to simulate the location of pressured ice, which can hinder transportation. Of particular interest is simulating realistic lead distributions (opening and closing rates), ice deformation, ice velocity, ice stress, ice flow trajectory, and the location of ice divergence and convergence zones.

The current state-of-the-art for coupled ocean-ice-atmosphere modeling makes use of a continuum model of sea ice kinematics originally developed by Hibler. Ice-ocean modeling of the Beaufort and Chukchi Sea areas is under development for BOEM using ROMS, which includes an ice model with elastic viscous-plastic (EVP) ice dynamics. This type of coupled ice-ocean models has difficulty in reproducing observed sea ice strain-rates. The representation of sea ice in the regional, pan-Arctic and global models currently used for simulating the coupled ice-ocean system or for ice forecasting does not represent the brittle failure behavior of the ice pack on the spatial scales these models attempt to resolve. The difficulty is that the continuum EVP models used to describe ice constitutive properties do not represent observed internal ice stresses and strain rates (opening and shearing), and they do not reproduce realistic patterns of localized shear zones. Hence these models cannot simulate the dispersion of sea ice well, which limits their utility in forecasting or hindcasting the trajectories of contaminated ice.

A discrete element method (DEM) sea ice model can simulate fracture patterns with intersection angles and spacing characteristics similar to those observed in Arctic pack ice. Although, to date, no regional model of sea ice has reproduced realistic deformation patterns, the DEM approach has been successful in simulating the density of fractures expected in the Beaufort Sea. The DEM approach directly accounts for discontinuities in the ice pack at which failure can occur and stresses concentrate to form cracks, unlike continuum approaches that use an isotropic rheology (such as CICE which uses the EVP model) and require artificial seeding of stress discontinuities in order to simulate cracks. As the DEM approach specifies the failure stress of weaknesses (defined as joints or contacts between grains or unit cell floes), control of fracture characteristics is more physically based in a DEM model.

Objectives: This project will build upon previous work funded by MMS and BOEM (OCS Study MMS 2005-068, OCS Study MMS 2008-020, OCS Study BOEM 2012-067) and NSF to:

- Develop a DEM model that accurately simulates ice velocity, kinematics and dispersion in the Beaufort and Chukchi Seas.
- Optimize the model to simulate realistic lead distributions (opening rate) and the location of pressured ice that hinders transportation.
- Build validation metrics appropriate for confining parameters in pack ice constitutive relations.
- Produce an open-source well-documented DEM sea ice model usable by the general sea ice community and readily incorporated into coupled sea ice/wind/ocean models

Methods: This study will build a model of sea ice interaction, simulating drift and deformation of the ice pack, with the DEM. The researchers will work to improve model parameters over previous DEM models by tuning the model to field data and investigate the effects on model simulations of varying the failure process from a gradual weakening ice strength during failure to a sudden rupture upon reaching failure criteria. In developing the model, they will identify appropriate representation of tensile, compressive and shear failure of pack ice.

The model domain will encompass the Beaufort and Chukchi Seas with zero velocity and stress gradients across the open ocean boundaries. This will ensure no artificial shear is imparted at the open boundaries that would manifest as unrealistic kinematic features. External forcing will be developed from available products. The validation metrics developed in the study will provide insight into the mechanical properties of pack ice. Sensitivity experiments will be conducted to tune the model.

Current Status: Awaiting final report

Final Report Due: July 2017

Publications Completed: None

Affiliated WWW Sites: http://www.boem.gov/akstudies/
http://www.sfos.uaf.edu/cmi/

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