

Numerical Modeling of Oil Fate and Transport in Ice

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Introduction

- ◆ Transportation and oil exploitation in Arctic is highly vulnerable to environmental incidents due to the harsh environment.
- ◆ Large scale fate and behavior models are used to predict the trajectory of oil after a spill occurs.
- ◆ Challenges of modeling the physics of ice formation and movement are magnified by the presence of oil in the ice.
- ◆ Currently, there is limited ability to model ice at necessary spatial scale.

Large field trial (20 m³) of oil in ice in the Barents Sea Marginal Ice Zone



Figure 1. Observed distribution of oil in open ice lead at 24 hours



Figure 2. Observed distribution of oil and water above ice at 24 hours
Source: M. Reed, SINTEF, 1993

Objectives

- ◆ Develop a numerical model with time series of exposure at the ice-water interfaces with oil entering the system: (i) on top of the ice or (ii) from below the ice
 - Integration of earlier work by other investigators into a consistent and comprehensive numerical framework
 - Focus scale of the dynamic model on the micro (mm) and meso (<1m) processes

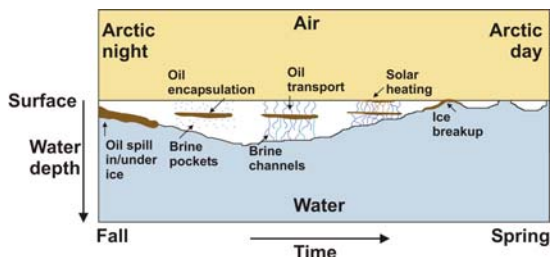


Figure 3. Seasonal progression of oil frozen into ice field in winter and released during melting and breakup in spring

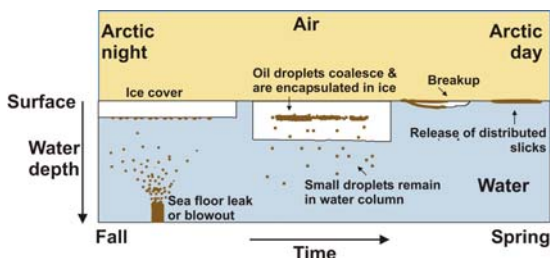


Figure 4. Oil may enter the ice from a subsea release or a surface release (i.e., on top of ice)

Expected Model Attributes

- ◆ 1- or 2- dimensional (vertical-horizontal)
- ◆ Time dependent
 - Simulate annual freezing-thawing cycle
- ◆ Radiative heat transfer (insolation)
 - Changes due to oil presence
 - May require experimental data
- ◆ Vertical transport in brine channels
 - Snow load induces transport upwards
 - Ice accretion induces transport downwards
- ◆ Oil representation as multiple components
 - e.g., evaporation, biodegradation, dissolution, toxicity

Anticipated Variables

- ◆ Total porosity
- ◆ Permeability (i.e., effective porosity)
- ◆ Thickness of ice
- ◆ Vertical temperature gradient
- ◆ Salinity

Long-Term Objectives

- ◆ Incorporate model development into full 3-dimensional model
 - e.g., vertical cross-section with each grid cell of a larger model