First Annual Partners’ Meeting

Oil Spill Modeling for the Bering, Chukchi, and Beaufort Seas

Arctic Domain Awareness Center (ADAC)
A DHS Center of Excellence

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Overview:

- The Coast Guard relies on the GNOME oil spill model and NOAA for expert guidance when responding to an oil spill.
- The existing GNOME oil spill model is not arctic-capable (e.g., it does not yet account for ice).
- ADAC has engaged with NOAA’s leading oil spill modelers (Glen Watabayashi and Catherine Berg) and has begun to give guidance on ways to incorporate ice into GNOME.
Accomplishments:

1. Review of 30 relevant research publications on oil spill – with a focus on research on oil spills in the Arctic.
2. Engagement and communication with NOAA experts on recommended approaches to account for the presence sea ice in oil spill modeling.
3. Mastery of GNOME oil spill model and communication of its use for oil spill and ship drift.
Accomplishment 1
[review of publications]


**Accomplishment 2** [engagement with NOAA]

Semester-long review of oil spill modeling with focus on the Arctic

Presentation to NOAA Office of Emergency Response and Restoration [Glen Watabayashi and Catherine Berg]

Review of GNOME and preliminary discussion of oil spill modelling of the Bering, Chukchi, and Beaufort Seas

The frequency, area, and duration of open waters in the Arctic is increasing as has the ability to navigate and respond to oil spills in the region. The potential for oil spills requires the ability to model oil spills in the region to aid in oil recovery. One such tool used by National Oceanic and Atmospheric Administration (NOAA) is the oil trajectory model Global Operational Oil Spill Modeling Environment (GNOME), and fate model Automated Data Inquiry for Oil Spills (ADDI), which is being integrated into GNOME.

GNOME does an excellent job modeling the trajectory of oil in open waters. However, in Alaska, its capabilities are limited by the lack of local knowledge, sparse data, and knowledge of how spills behave in the Arctic.

Local knowledge of the environmental conditions such as the location of local seeps, the quantity of oil available in a given season, the substrates, sediment loads, and oil types are all important factors in understanding what will happen during a spill.

While Alaska is the largest state geographically, it does not have a corresponding quantity of data. GNOME is heavily reliant on input data, real-time and forecast. Alaskan data sources need to be fully understood so that the effects of oil spills can be accurately predicted. The results properly interpreted. Accurate and up-to-date measurements of ocean currents, lakes, and rivers, wind, and ice conditions are important factors in modeling oil spills in the Arctic.

Finally, the trajectory and fate of oil will be influenced by Arctic conditions. The cold climate and the presence of ice will affect oil behavior, weather, and ice. The effects of climate and ice oil need to be understood. A summary of some of these processes can be seen in Figure 3.
Accomplishment 2 [engagement with NOAA, continued]

Spreading in pack ice: empirically

- 0-30% Open water
- 30-90% Linear decrease with increasing ice concentration
- 90+ Oil in ice
Accomplishment 2 [engagement with NOAA, continued]

Evaporation in drift Ice

Mass transfer coefficients

Evaporation on Ice, Under Snow and Among Drift Ice after Stiver and Mackay (1983)

\[ F = \left[ 1 - \left( \frac{BT_0}{T} \right)^{A \frac{BT_0}{T} \exp \left( A \frac{BT_0}{T} \right)} \right] \]

Where:
- \( F \) = volume fraction of the oil evaporated
- \( T_0, T \) = the intercept and slope of the modified ASTM distillation \([{^\circ}K]\)
- \( T \) = environmental ambient temperature \([{^\circ}K]\)
- \( A, B \) = dimensionless, oil-specific constants equal to the least-squares slope and intercept of a plot of the natural logarithm of the Henry's Law constant \((H = PcRT_0)\), which is dimensionally equal to the slope of the tangent to the curve of a plot of \( F \) vs \( \theta \) at the given point vs. \( T_0/\theta \)
- \( T_0 \) = boiling point of weathered crude oil at atmospheric pressure \([{^\circ}K]\)
- \( P \) = vapor pressure of the weathered crude oil \([Pa]\)
- \( R \) = gas constant \(8.314\) \([Pa m^3 K^{-1}mol^{-1}]\)
- \( \theta \) = dimensionless evaporative exposure

The expression is:
\[ \theta = \frac{k}{\bar{V}} = \frac{k}{x} \]

Where:
- \( k \) = mass transfer coefficient \([m/s]\)
- \( \bar{V} \) = initial volume of oil released \([m^3]\)
- \( x \) = thickness of snow \([m]\)

And, for the mass transfer coefficient used to calculate \( \theta \):

\[ \frac{1}{k} = \frac{1}{k_1} + \frac{k_2}{k_3} + \frac{k_4}{k_5} \]

Where:
- \( k_1 \) = overall mass transfer coefficient \([m/s]\)
- \( k_2 \) = air side mass transfer coefficient \([m/s]\)
- \( k_3 \) = liquid phase mass transfer coefficient \([m/s]\)
- \( k_4 \) = air-oil partition coefficient
- \( k_5 \) = diffusivity of oil vapor in snow \([m^2/s]\)
- \( x \) = thickness of snow \([m]\)
Accomplishment 3
[Mastery of GNOME Oil Spill model]

- Here, add snap shot of video of GNOME model in action.
Accomplishment 4
[identification of a suitable topic for a MS Thesis]

Simulation of an under ice release of oil – accounting for under-ice roughness

Figure 1. Schematic of a subsea blowout in shallow water under ice cover. Oil and gas rise through the inner plume and impact the ice surface, which deflects the oil and gas laterally, eventually forming a radial plume of oil and gas at the water and ice interface. A separated plume of dissolved hydrocarbons forms an intrusion (outer plume) below the surface.
Metrics:

- Number of reviews of studies on oil fate and transport in the arctic; incorporation of arctic oil fate and transport data within GNOME. Range: 10 studies reviewed to 30 studies reviewed.
  - 30 studies reviewed

- Level of improvement in resolution of GNOME model relative to conventional GNOME model. Resolution will go from 4 km to a target of 2 km.
  - To be covered in year 2 in partnership with Jinlun Zhang UW
Completed review of studies of oil fate and transport in the arctic. Provide guidance to NOAA on how to incorporate oil weathering, biodegradation, dispersion, etc. within the arctic GNOME model. Identify gaps in knowledge. Also provide guidance to NOAA Office of Response Restoration on how to incorporate ice conditions within GNOME. Years 1 and 2.

**ACHIEVED in year 1 – will continue in year 2.**

Completed development of the “Diagnostic Save Files” (or location files) using the high-resolution ocean currents and sea ice conditions generated from the Univ. of Washington ocean/sea ice modeling effort. Year 2.

**Year 2.**

Perform successful runs of GNOME model using the high resolution Diagnostic Save Files and compare output with that generated with conventional Diagnostic Save Files. Year 2.

**Year 2.**
Key Stakeholder Engagement

- Mr. Kurt Hansen and Mr. Richard I Hansen from the USCG R&D Center, Mr. James Robinson and Mr. Mark Everett (US Coast Guard, 17th Coast Guard District), and Glen Watabayashi (NOAA Office of Response and Restoration).

- Have identified and engaged with Glen Watabayashi. Have reached out to Mr. Hansen and Mr. Hansen. TO DO!
Lessons Learned:

- It is extremely valuable to reach out to stakeholders.
- It is extremely valuable to engage with researcher outside of the inner ADAC circle.
Next steps

- Continue to engage with NOAA Office of Response and Restoration.
- Provide additional suggestions on how to make GNOME Arctic-capable.
- Assist NOAA with GNOME development by trying out the new version of GNOME underdevelopment.
- Continue to engage with USCG R&D Center.
- Support NOAA by pursuing the under-ice oil spill modeling work.