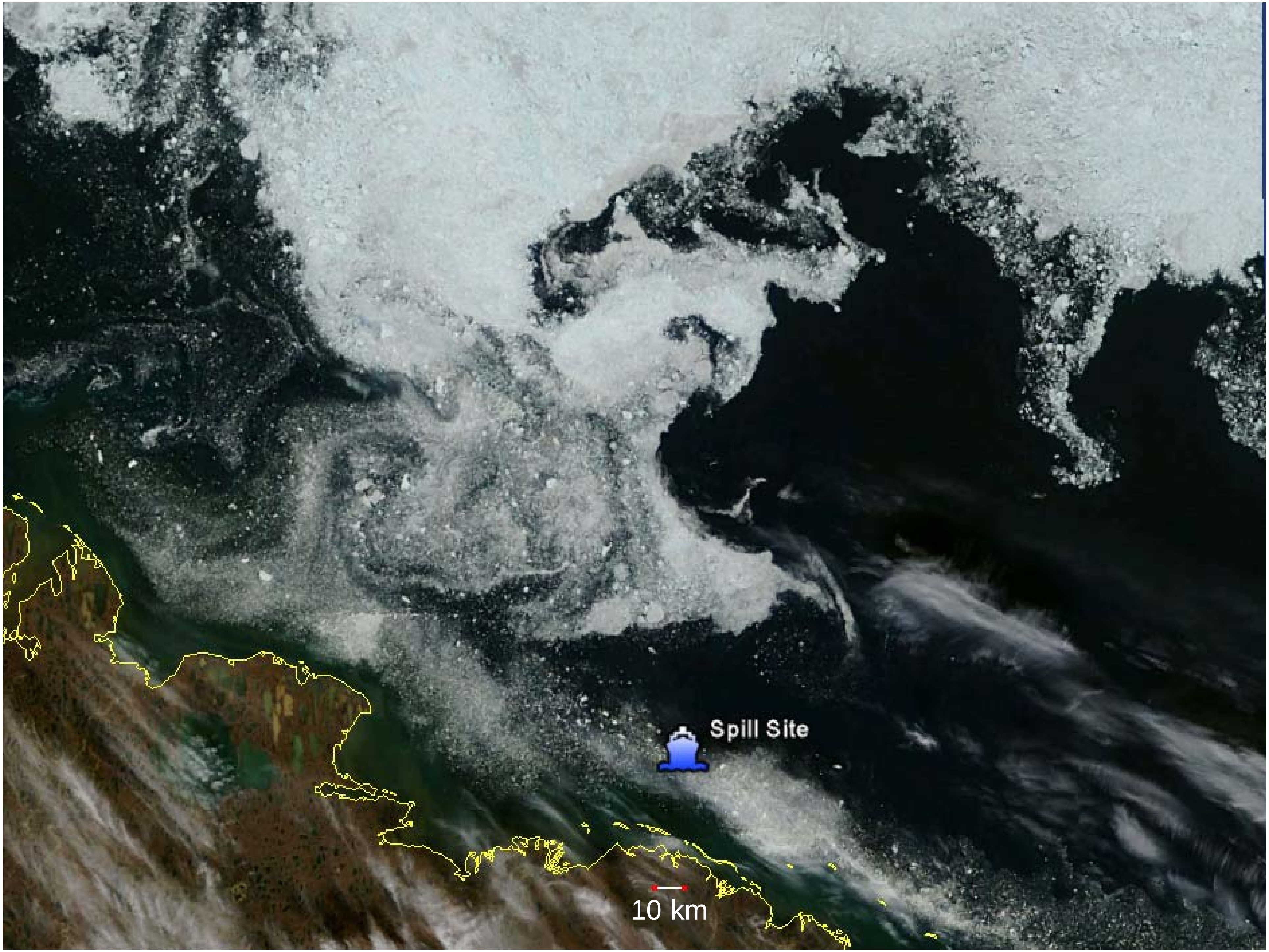
Oil Spill Scenario: Broken Ice

Kenneth Lee

Offshore Oil Centre for, Gas and Energy Research (COOGER)
Fisheries and Oceans Canada

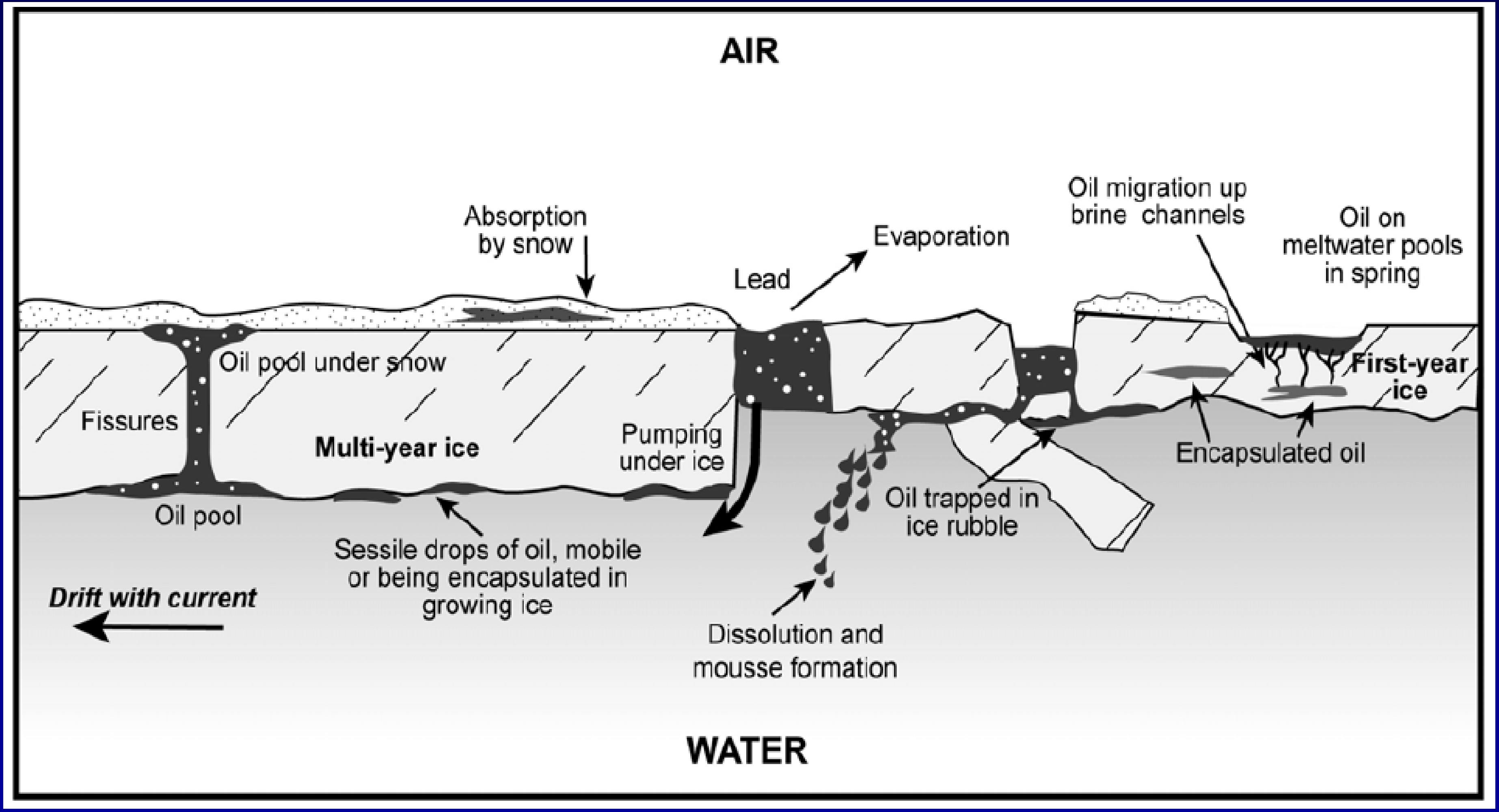
Broken Ice Spill Scenario

- Similar to the open water scenario but occurs on 05 September, 2006, *broken ice* is present at the study area
- An oil tanker on its way to Barrow (from a refinery in Canada), encounters rough weather and sank ashore on the barrier islands just west of Simpson Lagoon.
- Release of ~ 5000 m^3 oil (Density=900 kg/m^3 and viscosity=100 mPas s)
- Assume the current is U=3 to 7 cm/s and V=-7 to 5 cm/s
- Ice concentration 50-70%, thickness 0.7-1.5 m, and floe size ~12 m


Spill Site
10 km

Behaviour of Oil

Oil – Ice Interactions



Influence of Ice on Oil Spill Processes

- Oil Spreading: Dramatically curtailed by the presence of broken ice and brash ice. Spreading limited to the leads among the ice floes
- Evaporation: Not greatly affected, unless oil is trapped under or within ice
- Dispersion and Emulsification: Expected to be less than in open water as the ice tends to dampen the effects of wind.

Seasonable Variance

- During spring break-up, oil spilled in broken ice would be contained in the openings between floes and would coat the surrounding ice surfaces. The contaminated area increases as spring melt proceeds
- At high ice concentrations (>5/10), oil is effectively prevented from spreading and is contained by the ice
- As ice cover is reduced, oil will escape into larger leads as floe moves apart
- At less than 3/10 ice, oil behaviour is similar to that on open water
- During freeze-up, oil will be entrained in the solidifying grease and slush ice prior to forming sheet ice. Storm winds may break up and disperse the newly formed ice, leaving the oil to spread temporally in open water until incorporated in the next freezing cycle

Response Actions

- **Oil spills in ice are far more complicated to combat compared to oil spills in open waters**
- **Efficiency of booms and skimmers is reduced**
- **The weathering rate is normally much slower for an oil spill in ice**
  - **The rate of emulsification is reduced along with viscosity increases extending the "*window of opportunity*" for use of most response techniques.**
  - **The spreading of oil may be reduced resulting in an increased oil film thickness that may be favourable for oil spill response**
- **The formation, thickness, and percentage of ice coverage all affect the selection of response technologies**
- **One advantage of an oil spill in ice is that the ice can act as a natural containment in a variety of ice features such as floes, snow and ridges**

Response Actions

- **Predicting the fate of oil in the specific circumstances surrounding any incident, especially in an ice environment, is beyond the capacity of existing models.**
- ***New and improved algorithms are required* to take into account the seasonal variation, weathering, and other factors, that affect the behaviour of oil spilled on, in, or under ice.**
- **The spreading of oil under ice has been studied in laboratory and field experiments. Fewer efforts have been made to quantify the movement of oil in broken ice or amid smaller chunks of ice such as grease or brash ice.**
- **Simple models (such as Venkatesh et al., 1990; Yapa et al, 1997) are available but need to be validated against field experiments.**

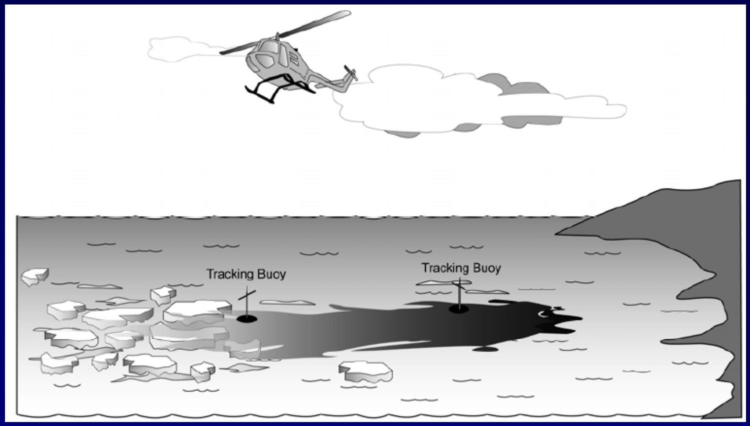
Response Actions

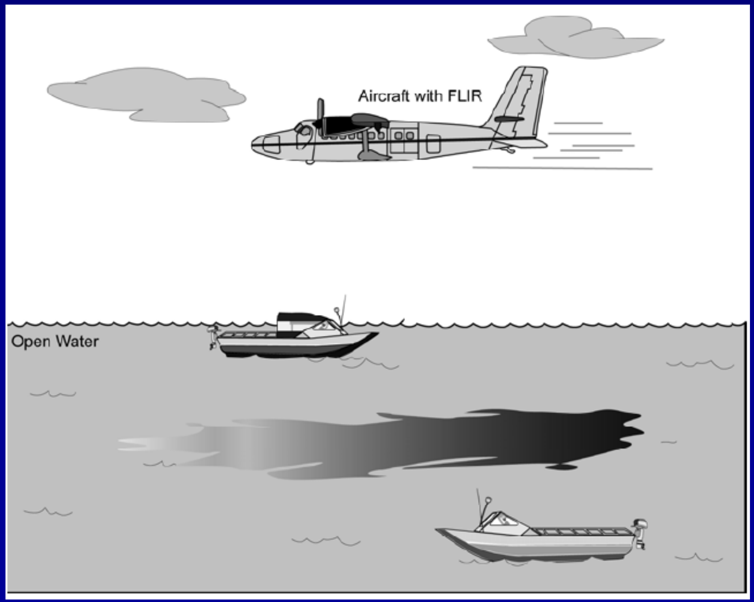
Estimated Impact Zone: 36 km^2

Response Actions

- Due to the limitation of models to predict oil-in-ice behaviour, real-time oil and ice surveillance and tracking are critical to response operations

- Available technologies: Tracking buoys, Satellite imagery, Airborne reconnaissance , Vessel surveillance etc.

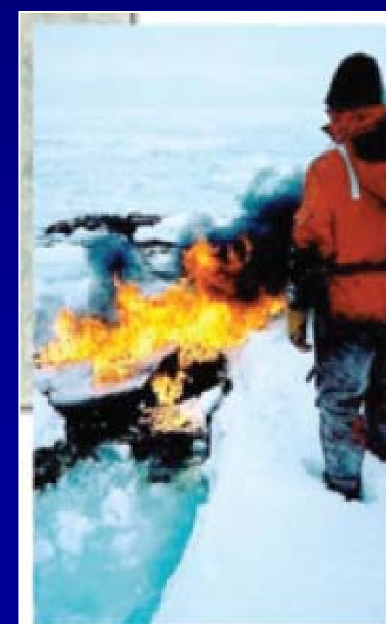




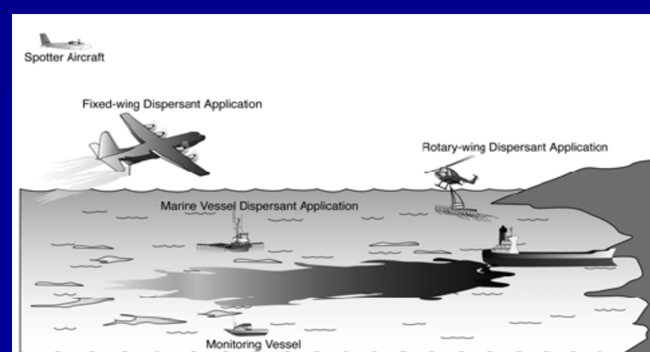
Response Actions

- Mechanical recovery: boom and skimmer

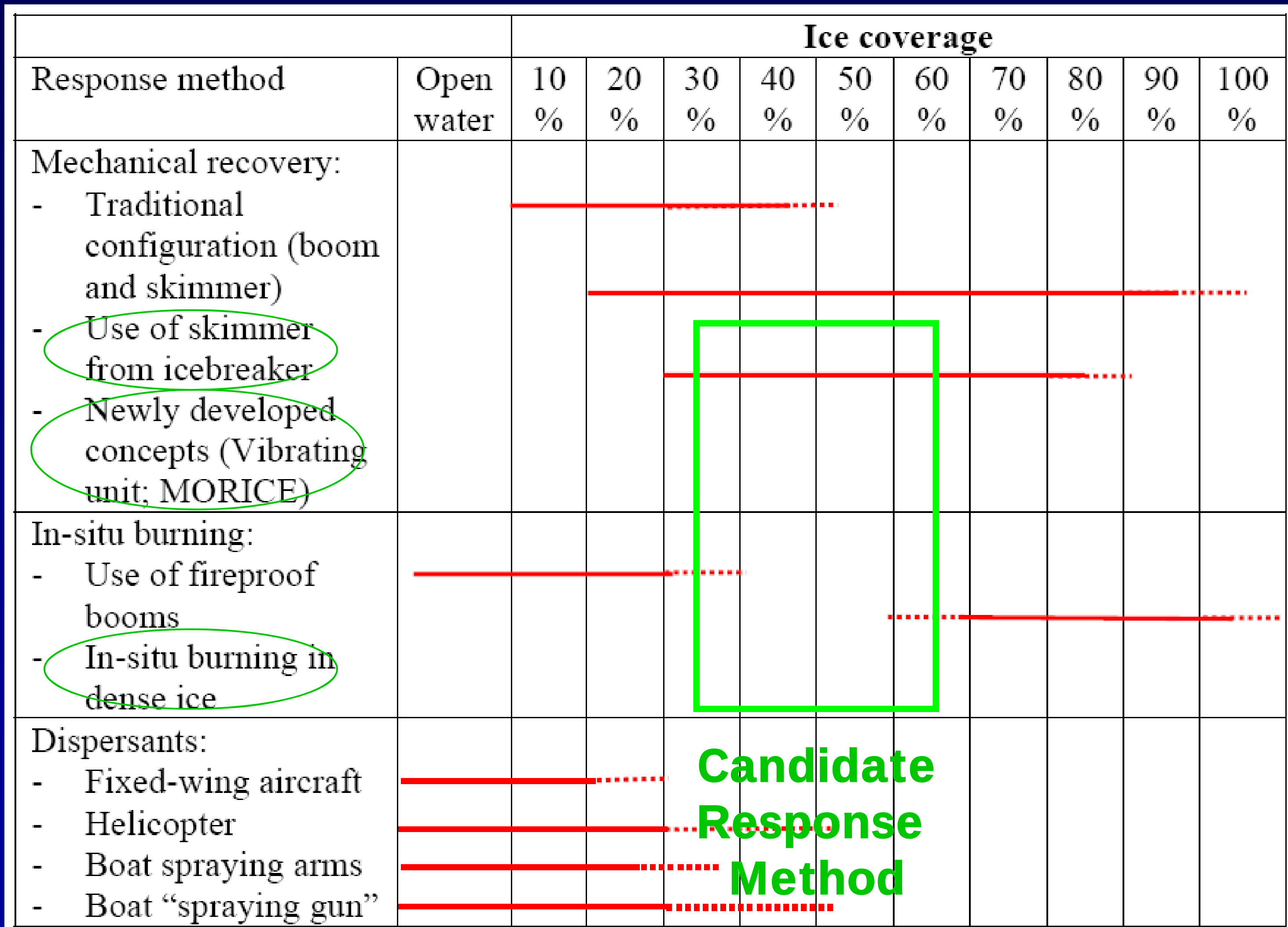
- In-situ burning



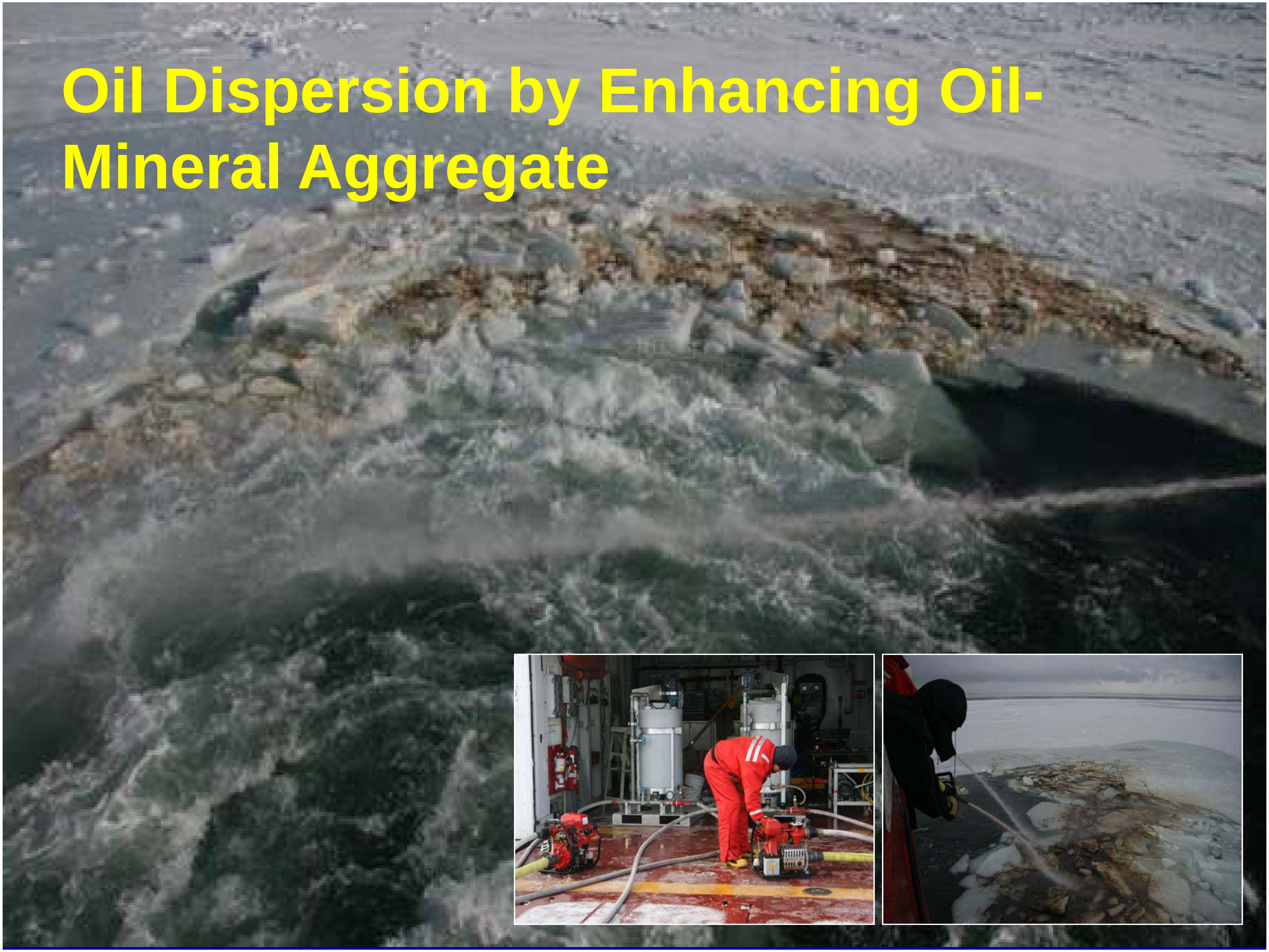
- Dispersant and Mineral treatment



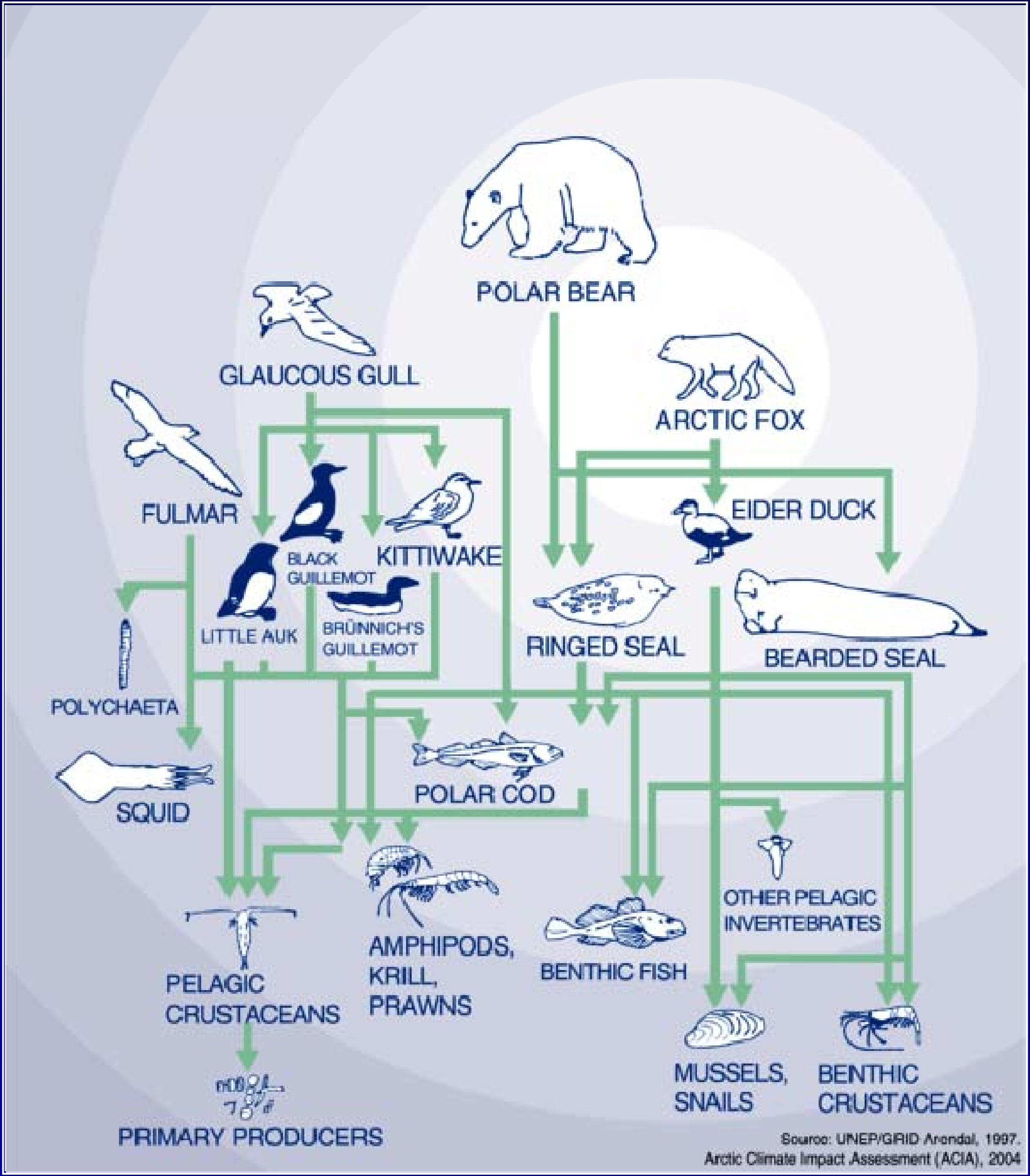
Effectiveness of Response Options as a Function of Ice Coverage (Evers et al, 2005)



Oil Dispersion by Enhancing Oil-Mineral Aggregate



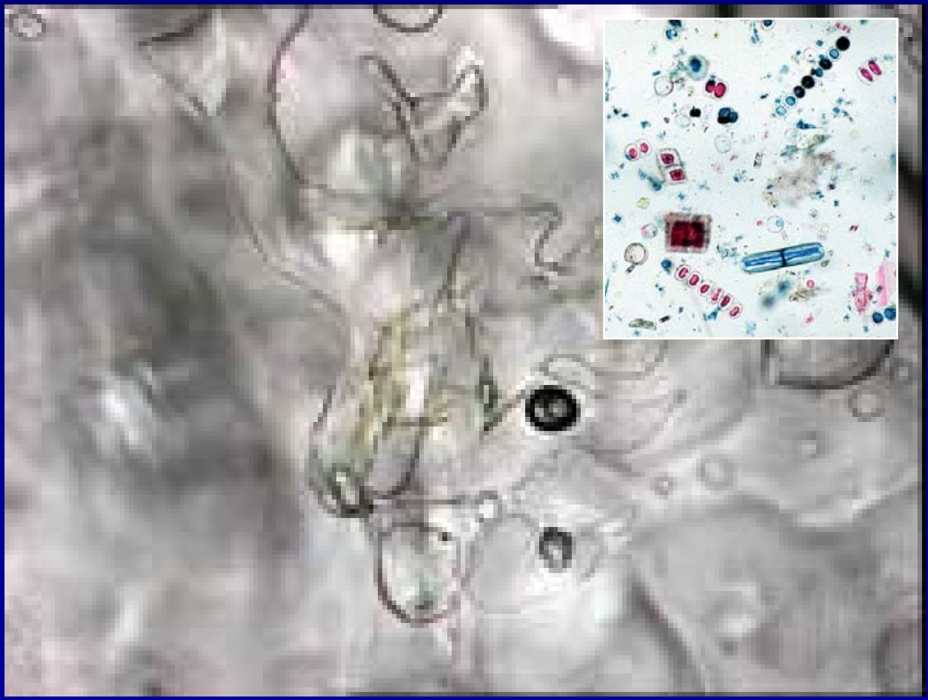
Organisms associated with sea ice in the Arctic



The ice algal community lives in and on the underside of sea ice and is comprised primarily of diatoms, as well as microflagellates and dinoflagellates

Algae mats form underside of the ice surfaces that may be very dense and attract other organisms which graze on them

About a quarter to one third of the overall primary production of the polar oceans is provided by algae associated with sea ice (Spindler, 1991).



Abundance of metazoans e.g. turbellarians, nematodes, rotifers and crustaceans (amphipods and copepods) which may feed on bacteria, algae and protozoa

A key species is the hyperiid amphipod *Themisto libellula* which connects the sea ice with deeper waters by means of feeding activities and migrations (Auel et al., 2002)

A swarm of amphipods under sea ice

The Arctic cod *Boreogadus saida* mainly prey on amphipods. In some regions of the Arctic, cod constitutes the only fish whose life-cycle is closely associated with the ice-edge ecosystem (Camus et al., 2006).

Cod under ice

Cod - *Boreogadus saida*

The induction of biomarkers in polar cod at very low bioavailable doses of B(a)P has been used to monitor contaminant oil in the Arctic (Nahrgang et al., 2009)

Higher trophic level predators at the ice edges that hunt and compete for zooplankton and fish include birds, seals and whales