Detection of Oil on and Under Ice – Phase III

Evaluation of Higher-Powered Airborne Radar Systems to Detect Oil Under Ice and Snow

1st Milestone Report

SCENARIO DESCRIPTIONS

Background

The following scenario outlines covering oil-ice and oil-snow configurations were finalized in discussions at the project review meeting held in San Diego July 5/6, 2007 aimed at defining the number and scope of the scenarios to be used as the focus for modeling GPR capabilities for oil under and in ice and oil on the ice surface under snow. This modeling effort represents the core project activity leading to the final report.

The scenario selection is based on a number of criteria:

- Having sufficient permutations and combinations to allow predictions of radar performance over a wide range of realistic spill situations.
- Demonstrated need linked to the scope and expected ice environments associated ongoing and projected exploration and production development activity on the Alaskan OCS in the Chukchi and/or Beaufort Sea regions.
- Practicality in terms of not trying to achieve the "impossible". For example detecting oil trapped under 60 feet of grounded pressure ridges and rubble in the shear zone.

The following matrix shows the range of spill types with water depth for exploration and production focusing on the Beaufort region (also applicable to the Chukchi area except that gravel exploration and or production islands are not likely given the steep nearshore seabed gradients in most locations).

Spill Source and Possible Oil in ice Configurations vs. Water Depth					
Spill Source	**Water depth (m)**	**Oil on Ice**	**Oil Under Ice**	**Trapped Layer**	**Comments**
Exploration					
Subsea blowout	2 to 20	N/A	N/A	N/A	To shallow for floating drilling rigs
Subsea blowout	30 to 200	N/A			Most likely oil under thin ice late Oct or Nov (20- 40 cm) or thick/deformed warm ice in Aug
Surface blowout	2 to 15		N/A	N/A	Fallout from surface plume, saturated snow around gravel islands and/or oil running off the island and onto the surrounding ice
Production					
Subsea blowout	Any depth	N/A	N/A	N/A	Floating rigs not likely for year-round production in ice
Surface blowout	Any depth		N/A	N/A	
Pipeline leak or rupture	Any depth	N/A			Could traverse shear zone, highly deformed ice (no detection possible)

The following matrix shows the expected range of applicability of GPR detection methods based on the existing knowledge base at the start of this study drawing on findings from the 2004 basin tests at CRREL and the 2006 field experiment at Svalbard. The team will revisit and revise this matrix at the conclusion of the project based on findings from the performance modeling targeting the specific scenarios outlined below.

Oil in or Under Ice configurations vs. Ice Stage of Development				
Ice Age or Stage of Development	**Ice Thickness (cm)**	**Oil Pool Depth (cm)**	**Oil Under Ice**	**Trapped Layer**
Level Ice forms				
New or nilas	<10	<2 cm	N/A All the oil migrates to surface leaving only a residue film in the skeletal layer	No distinct oil layer. Oil migrates rapidly to surface (minutes)
Young (Gray to Gray Wt.)	10 to 30	2 to 3 cm	Partial distinct layer, much of the oil migrates part way to surface	Diffuse boundary with only a % of the original spill represented in the trapped layer
Thin First-year	30 to 70	3 to 7 cm	Distinct film	Distinct film
Medium First-year	70 to 120	7 to 12 cm	Distinct film	Distinct film
Thick First-year	120 to 210	12 to 21 cm	Distinct film	Distinct film
Second-year	200 to 300	20 to 30 cm	Distinct film	Possible
Multi-year (3-12 years)	250 to 700	25 to 70 cm		
Deformed Ice				
Rafted first -year (2-3 layers)	30 to 200	3 o 20 cm		Multiple layers?
First-year rubble	100 to 400	10 to 40 cm		High porosity, voids
Multi-year rubble	200 to 1400	50 to 200 cm		High porosity, voids
First-year ridges (consolidated)	250 to 400	25 to 40		
Multi-year ridges	400 to 4000	N/A		

(pink)	N/A or highly unlikely due to issues such as high attenuation of radar energy due to trapped salts and lack of defined oil layer
(yellow)	Possible but complicated due to unpredictable nature of the oil layer and or extreme ice thickness in the case of multi-year
(green)	Most likely condition of GPR applicability based on knowledge gained at CRREL (2004) and Svalbard (2006). Applicability will shift from green to yellow late in the growth phase as internal ice temperatures lead to greater brine volumes above the trapped oil.

A number of scenario combinations were selected as a basis for modeling radar performance and as a means to confirm and validate the initial applicability matrix shown here.

Scenarios

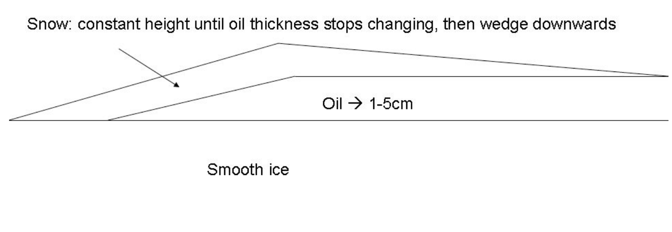
Two sets of scenarios are described here:

1. Oil absorbed in snow or on the surface of ice covered by snow
2. Oil trapped under solid first-year ice or within the ice sheet

Snow and Oil Configurations

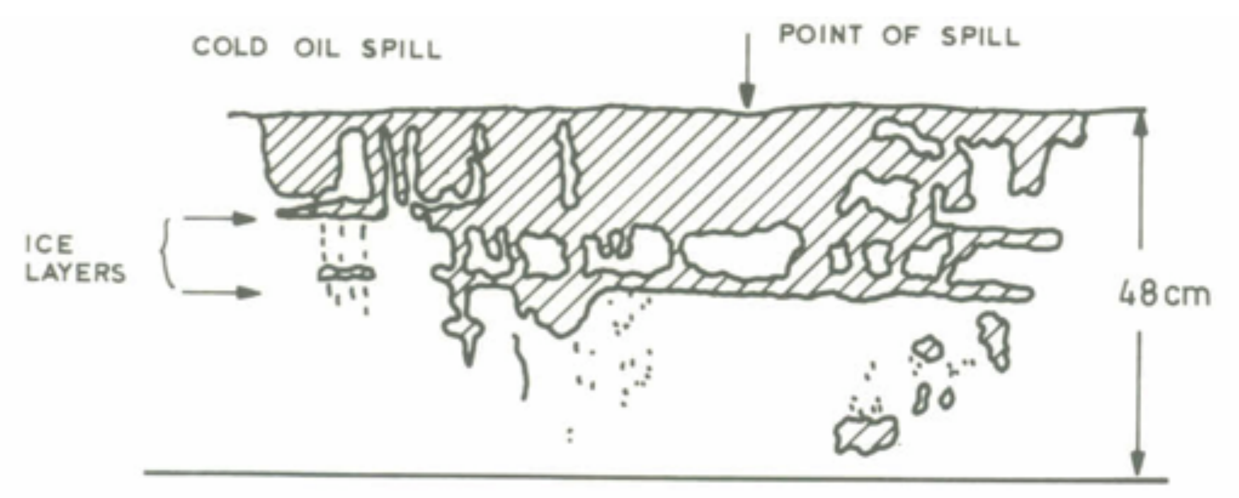
1. <u>Wedge model of snow saturated with oil</u> – smooth boundaries

Snow scenario 1



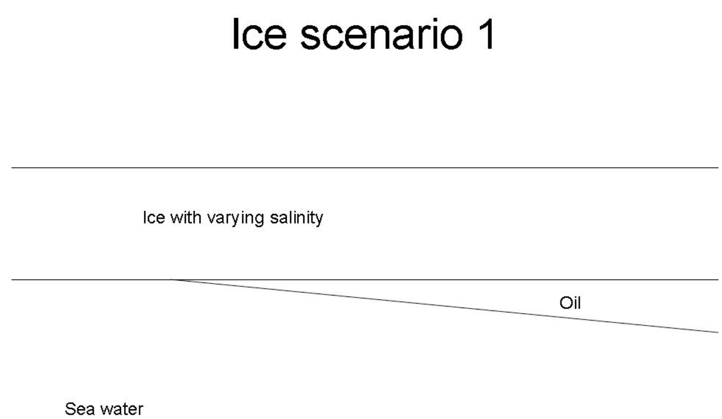
2. <u>Actual case study of oil penetration</u> - based on photograph of test trench with cold oil saturating snow in field trials (Ref. Mackay et al. 1974). Illustration below to be digitized.

Snow scenario 2

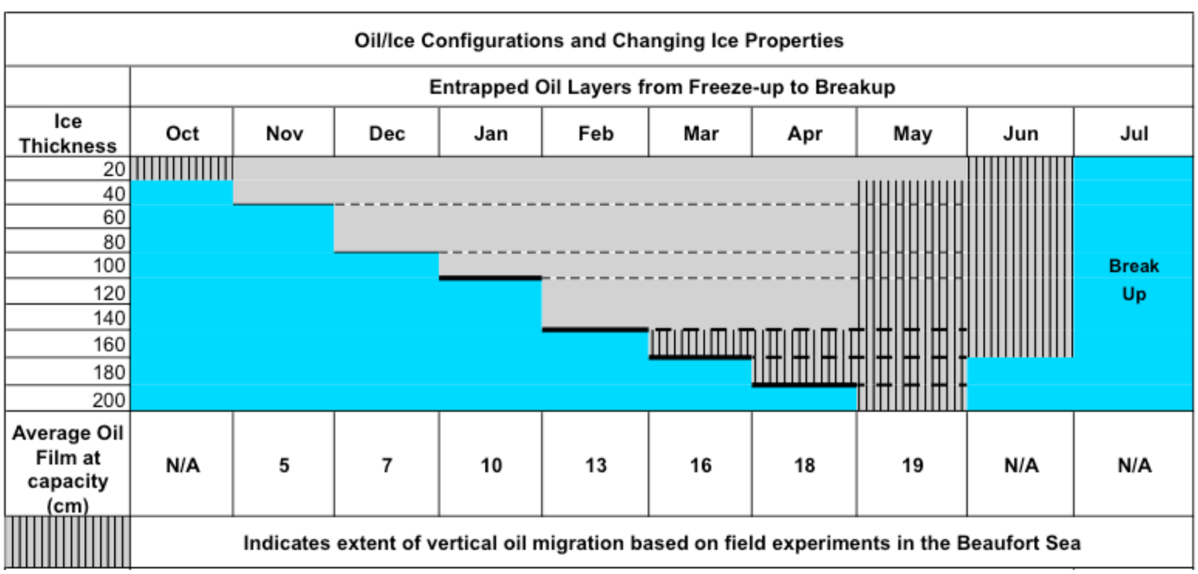


Ice and Oil Configurations

1. <u>1D reflectivity modeling</u>



The parameters and scope of this scenario are based on the following overall schematic of oil spilled under or trapped within a growing ice sheet (based on typical first-year fast ice growth at Prudhoe Bay) from October to June.



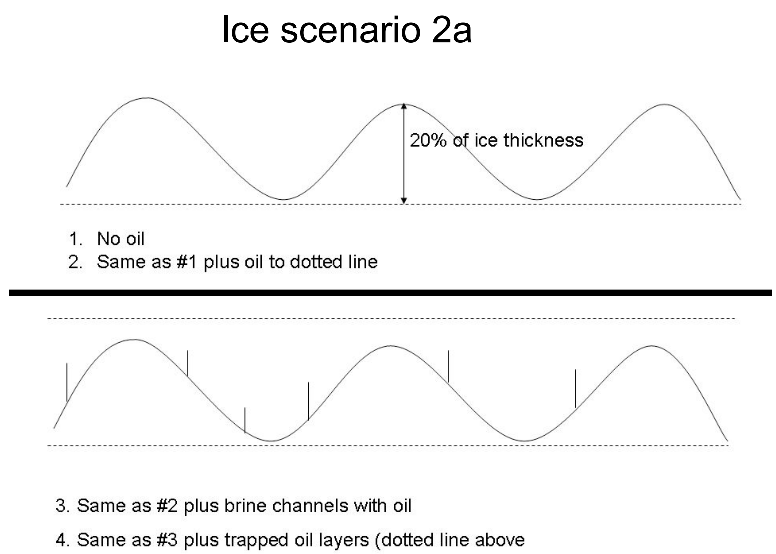
Subsets to Ice Scenario 1

a. Salinity and temperature varying within first-year ice according to actual profiles from historical field measurements from various studies e.g. Norcor 1975, Dickins and Buist 1981 (with corresponding computed brine volumes)
   - Oil wedge varying from 0 to 20% for a given ice thickness in monthly steps – November to April (2 m maximum ice thickness). Two cases:
     - No trapped oil
     - Trapped oil

b. Salinity jump noted in Balaena Bay field experiment above and below trapped oil layer (Norcor 1975) – model for a single month.

c. Varying snow depths modeled for a single month with constant air temperature
   - Assume linear temperature profile from derived value at the snow/ice interface to -1.8°C at the ice/water interface & calculate brine volume vs. depth in sheet using expression described in Sanderson (1988). Temperature gradient through the snow layer modeled after analytical method described in Cammaert and Muggeridge (1988) based on a paper by Nakawo and Sinha (1981).

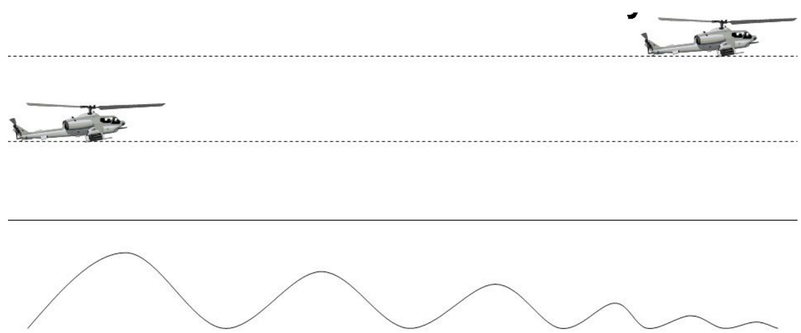
2. <u>2D Finite Difference (Sinusoidal)</u>
   a. Sinusoidal ice-water boundary (original model presented in Norcor 1977) with 4 subsets or cases as shown in the diagram below.



Note: *Subset 3 examines the effect of partial oil migration soon after being spilled, as noted in previous field experiments (using core photographs of the ice oil interface in Norcor 1975).*

b. Decaying sinusoidal ice-water boundary modeled from the surface and two different elevations to simulate low-flying helicopter

Ice scenario 2b



1. No oil
2. Oil
3. Test 3 elevations above ice 0, 15, and 30 m

3. <u>Slow chronic oil leak</u> (below detectable limits, 0.5 to 1% of flow) from a submerged pipeline under floating fast ice, resulting in a large pool of oily slush becoming encased in ice on all sides but free to the water column below. This scenario was originally created by Dickins Associates as part of the oil spill information documents submitted during the EIS process for BP's Northstar development.

Ice Depth (cm)	**Horizontal Distance**						
	20	40	60	80	100	120	140
20							
40							
60				ICE			
80							
100							
120							
140				Oil and Slush Mixture up to 40 cm depth (Mar-Apr leak)			
160							

Second Tier Scenarios

The project team identified a number of interesting scenarios that are viewed as lower priority in terms of their likelihood of occurrence and or geographic relevance to marine areas regulated by MMS. One of more of these situations could be further developed and modeled at a later stage in the project, given sufficient time and resources.

a. Oil with Gas: Scenario involving a subsea blowout under ice thick enough to contain large volumes of gas. Would involve modeling an ice/gas/oil/water interface combination (see diagrams in Norcor, 1977).
b. Multiyear ice: With recent documented shifts in the age distribution of the pack ice within the Arctic basin (e.g Rigor and Wallace 2005), the probability of significant concentrations of multi-year ice being associated with an exploration spill scenario is significantly reduced since the last period of intensive offshore exploration in the Beaufort (now in the order of less than a one year in ten return period).
c. 2D Snow Depth: Vary snow depths in the 2D model to introduce varying temperature profiles
d. Bottomfast Ice Spill: Oil pool trapped at the ice/seabed interface in the bottomfast ice zone – scenario involves chronic leak or rupture from a buried marine pipeline in shallow water where the fast ice rests on the seabed. This scenario is generally limited to State waters off the Alaskan North Slope in water depths less than 2 m.
e. Warm oil spilled onto snow: This scenario would appear to be limited to the case of on-land spills from pipeline ruptures or leaks.