

# Oil Spills in Coastal Areas: Prevention and Control

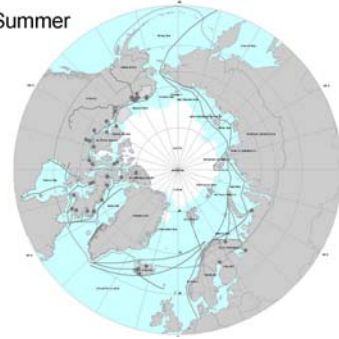
Lecture №4. Oil in ice-infested waters

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## Potential oil spill sources

Summer



## Potential oil spill sources

Winter



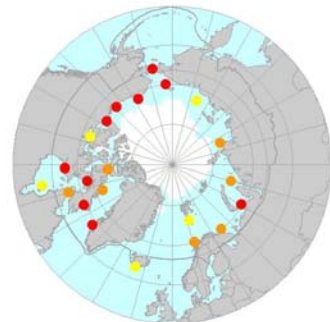
## Arctic food chain



## Arctic food chain



## Areas of concern



**Types of ice cover –**  
first year level ice

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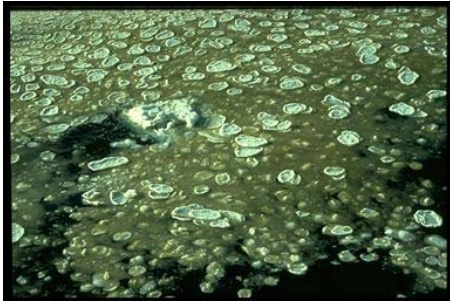
**Types of ice cover – frazil ice**

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**Types of ice cover– pancake ice**

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**Types of ice cover- pancake ice**

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**Types of ice cover-**  
lead in first year ice

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**Types of ice cover-**  
Ice stripes in the lead

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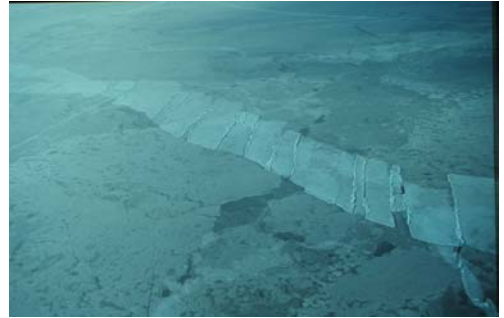
**Types of ice cover-**  
shuga (slush) ice

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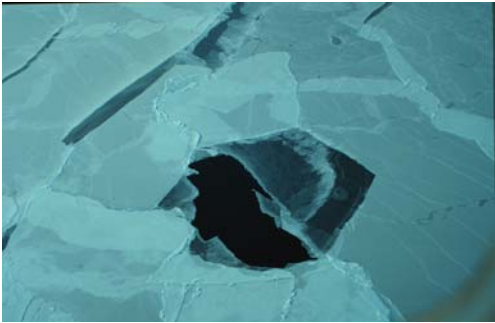
**Types of ice cover-** finger rafting

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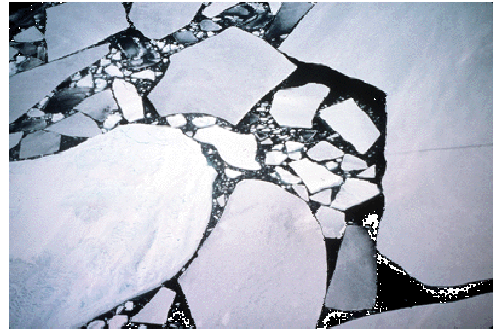
**Types of ice cover -** nilas

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**Types of ice cover-** broken ice

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**Types of ice cover-** ice ridges

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**Types of ice cover -** Iceberg

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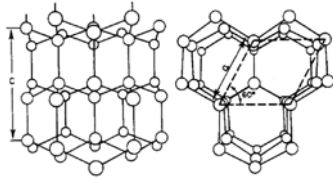
## Types of ice cover- Ice cover



## Sea ice grow

- Ice is a solid phase of water
- Ice is white
- Ice is less dense than water

## Sea ice grow



## Sea ice grow

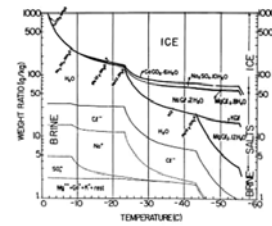


Figure 8.1  
The salt content in seawater causes ice to freeze at a temperature well below zero ( $-1.8^{\circ}\text{C}$  for 34.5 ppt). When seawater freezes, the first ice crystals start to form at  $-1.8^{\circ}\text{C}$ . As freezing proceeds, more and more pure ice forms and the remaining brine becomes more saline. As cooling history continues, different solid salts also precipitate from the brine. On the Fig. 1 one can see that at  $-10^{\circ}\text{C}$ , 1 kg of ice is composed of 760g ice, 4.2 g solid salt (4.0 g  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  and 0.2 g  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) and 238 g of brine composed of 195g  $\text{H}_2\text{O}$  and 32 g various ions. (Atmer, 1958)

## Sea ice grow

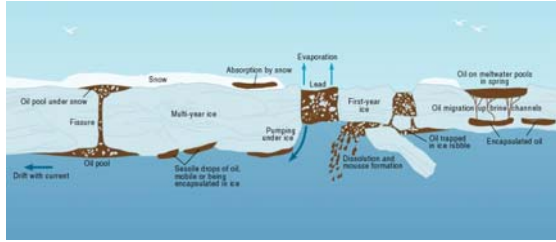


## Sea ice grow

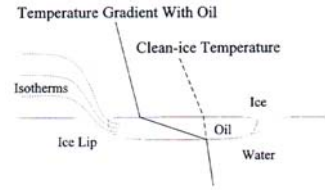


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## Oil in ice infested waters



## Oil in ice infested waters



## Oil in ice infested waters

Scenarios of oil slick spreading in Arctic:

- Oil spreading on water surface at low temperature,
- Oil spreading in water with broken ice at different concentrations,
- Oil spreading in slush ice,
- Oil spreading on ice cover (with or without snow),
- Oil spreading under solid ice sheet

## Oil in ice infested waters

The following must be considered when oil behaviour in broken ice is modelled:

- reduction in sea surface area caused by ice cover and hence
- decrease in evaporative exposure incurred by increasing of the oil film thickness
- lack of increase in viscosity
- dumping of waves and reduction of wind influence by the ice cover (low energy input) and correspondingly -
- decrease of water uptake and
- decrease of evaporation rate (again)

## Oil in ice infested waters

### Spreading

$I(t)$  is the percentage of ice cover [0-100]  
 $G_i(t)$  is the ice modification factor

These variables relates as follows:

$$G_i(t) = \begin{cases} 1 - \left(\frac{I(t)}{100}\right)^2 & 0 \leq I(t) \leq 95 \\ 0.1 & 95 < I(t) \end{cases} \quad (8.1)$$

The expression for  $G_i$  was chosen in order to obtain a reasonable fit to the MIZ evaporation data.

To model the fact that oil spreads more slowly with higher ice concentrations,  $G_i(t)$  becomes an additional factor in the arctic version of the Macleod equation:

$$dA_i(t)/dt = G_i(t) K_1 C_i(t)^{1.33} A_i(t)^{0.33} \quad (8.2)$$

In the original model, the oil is released instantaneously with an initial oil film thickness of  $h_0$  and a terminal oil film thickness of  $h_t$ . The arctic model modifies  $h_0$  with respect to  $I(t)$  such that the ice-adjusted initial thickness,  $h'_0$ , increases for higher values of ice cover:

$$h'_0 = h_0 / G_i(t) \quad (8.3)$$

## Oil in ice infested waters

### Evaporation

Based on the assumption that the ice influences evaporation primary through its effects upon oil spreading, the arctic evaporation model is identical to that of the original model.

## Oil in ice infested waters

### Oil-in-water-dispersion

Reduced energy input gives a reduction in both oil-in-water dispersion and water-in-oil emulsification rates. In order to fit experimental MIZ data, an ice parameter  $C_2(t)$  was introduced in dispersion and emulsification models. This cubic factor severely reduces dispersion in ice-infested waters.

$$C_2(t) = \begin{cases} 1 - \left(\frac{I(t)}{100}\right)^{3.5} & \dots\dots\dots 0 \leq I(t) \leq 95 \\ 0.1 & \dots\dots\dots 95 < I(t) \end{cases} \quad (8.4)$$

## Oil in ice infested waters

### Water uptake

In the original OWM, water uptake was calculated as a stepwise exponential:

$$W(t+\Delta t) = W_m(t) - [W_m(t) - W(t)] \cdot 0.5^{\frac{\Delta t}{t_{1/2}}} \quad (8.6)$$

$W_m(t)$  = maximum water content (%)

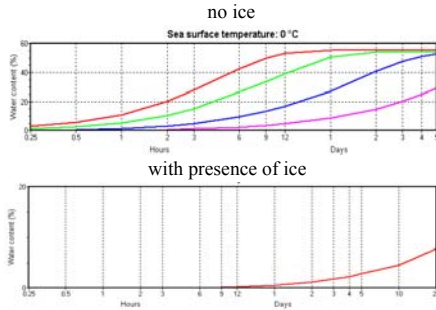
$\Delta t$  = the time-step (s)

$t_{1/2}$  = a wind dependent half life time for water uptake (s)

In arctic model, the change in water uptake is simply the change computed in the original model scaled by  $C_2(t)$ . This simplifies to:

$$dW(t)/dt = C_2(t) [W_m(t) - W(t)] (1 - 0.5^{\frac{\Delta t}{t_{1/2}}}) \quad (8.7)$$

## Water uptake modeling



## Oil in ice infested waters

Spatial modeling of the oil slick spreading in ice infested waters is largely depends on the ice field dynamics !!!

## Oil in ice infested waters

