Sea ice Risks

Sébastien Barrault

Safety Course

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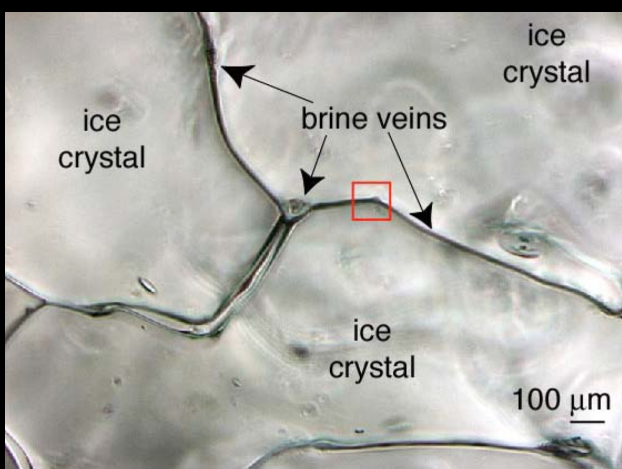
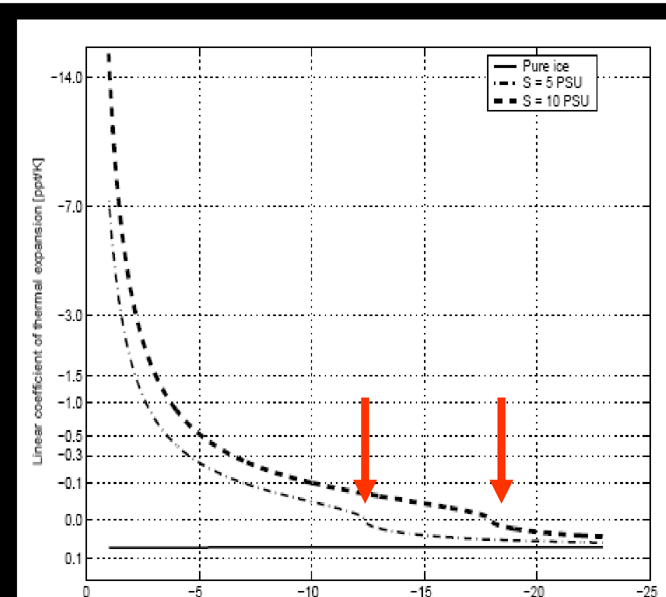
- Ice mechanics
- Ice cracks
- Ice bearing capacity
- Flooding
- Wind & current effect
- Ice conditions
- Breaking ice

Mechanical properties of ice

Sea ice is
- an unhomogeneous and porous medium
- made of water, pure ice, air, brine and solid salt crystals
- a visco-elastico-plastic material

Sea ice has
- an ”amazing” thermal expansion coefficient

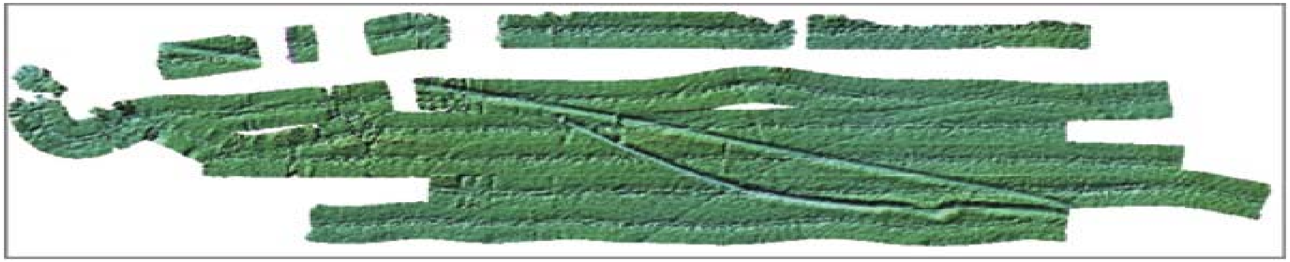




(Teigen, 2004)

Sea ice load



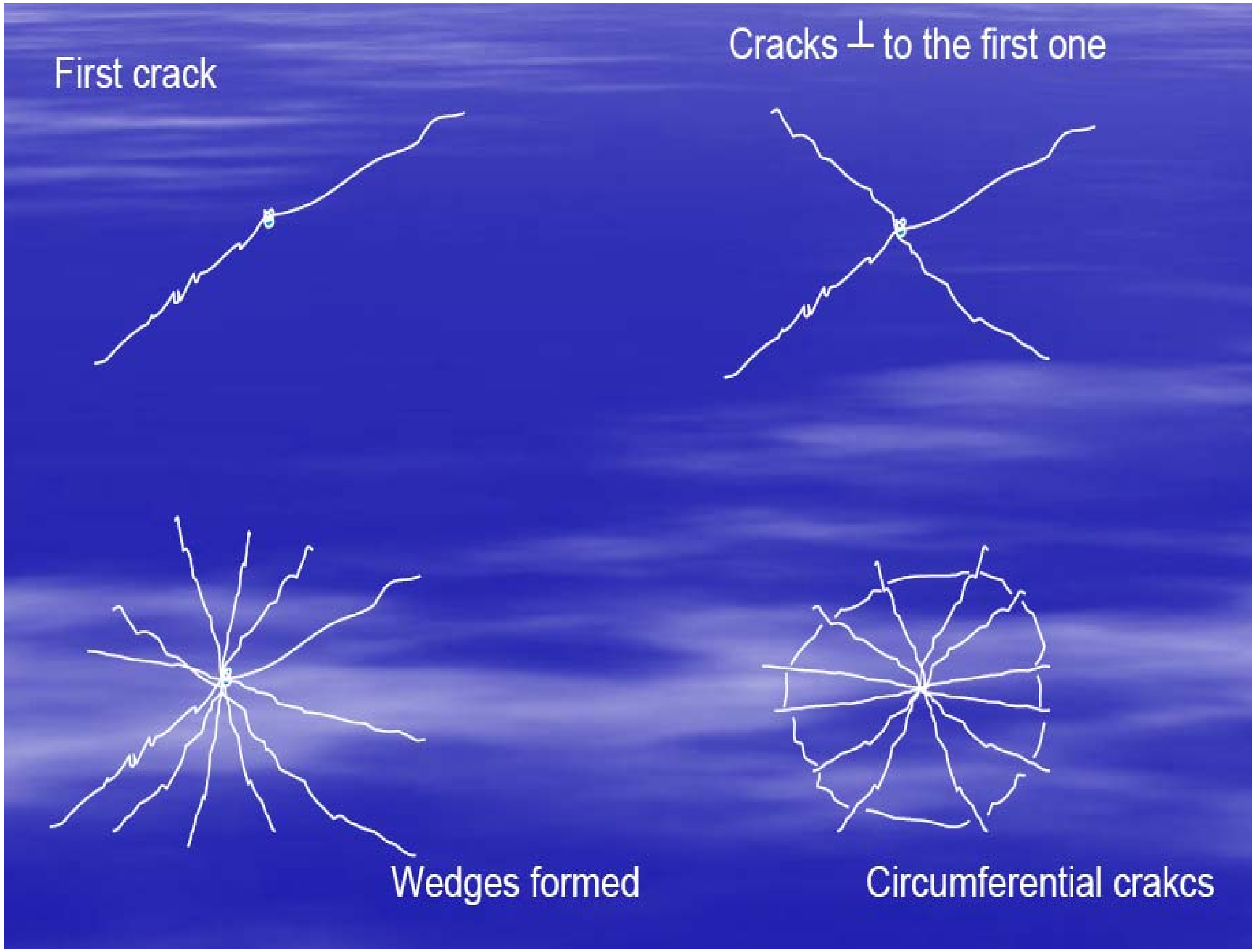



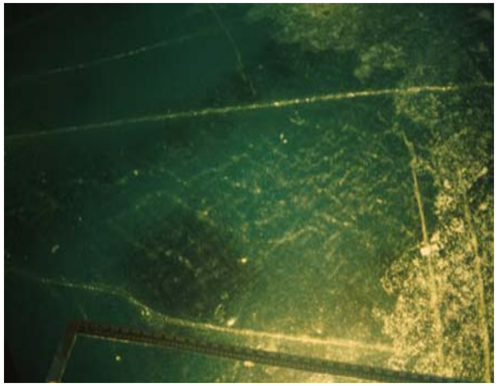
Natural cracks

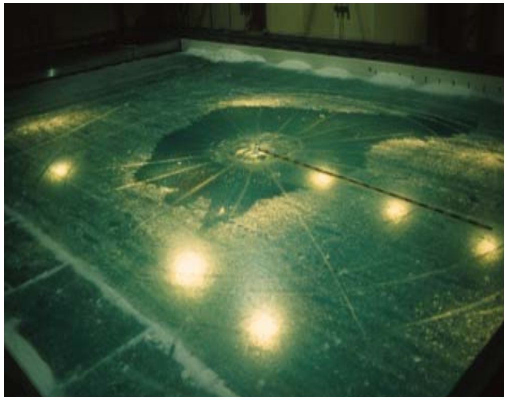
Tidal cracks

Thermal crack

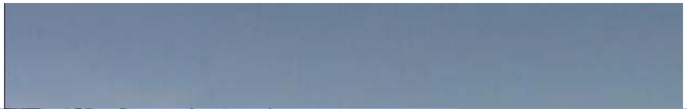
Cracks under load







Ice bearing capacity



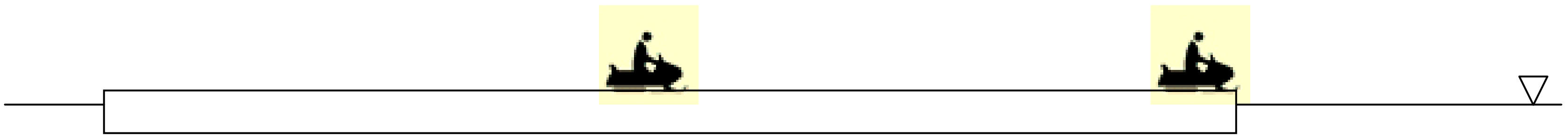
Short term load (no safety factor included)

- Distributed load
- Maximum load at a free edge

$$P = 1.25\sigma_f \cdot h^2 (1+0.84b/l)$$

$$P = 0.45\sigma_f \cdot h^2 (1+0.84b/l)$$

$l \sim 16h^{3/4}$
σ_f – *flexural strength (~750 kPa for cold ice)*
b – width



Adjustment of the flexural strength

$$\sigma_{f,mild} = \sigma_{f,cold} - \beta \cdot n$$

$$\sigma_{f,used} = \frac{\sigma_{f,cold} - \beta \cdot n}{N}$$

where

β = 50 kPa (experience)

n – number of mild days

N – safety factor

Example:

$n = 6$, $N = 1.4$

$\sigma_{f,cold}$ = *750 kPa*

$$\sigma_{f,used} = \frac{750kPa - 50kPa \cdot 6}{1.4} = 321kPa$$

Ice bearing capacity: pratical example I

Find maximum loads for h = 3 cm loaded by a person:

1. Skate
2. Foot
3. Lying on the ice

Solutions:

- Skate: b = 0 m -> P = 843 N · (1+0) = 843 N
- Foot: b = 0.1 m -> P = 843 N · (1+0.072) = 904 N
- Lying on ice: b = 0.5 m -> P = 843 N · (1+0.36) = 1148 N

Ice bearing capacity: pratical example II

1. Find required h for a tractor: 10 tons and 3 m wide
2. Find required h for a tractor: 10 tons and 3 m wide close to a free edge

1. $$10'000 \cdot 10 = 1.25 \cdot 750'000 \cdot h^2 (1 + 0.84 \cdot \frac{3}{16h^{3/4}})$$

$h^2(1+0.15 \cdot h^{3/4}) = 0.1$

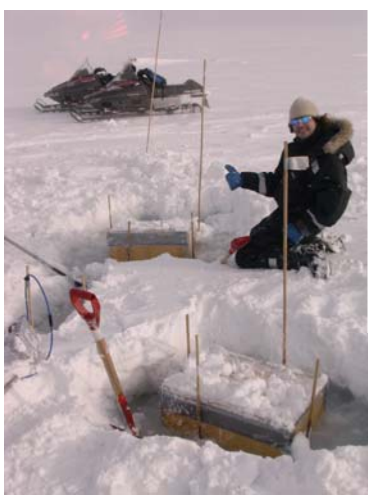
$\underline{h = 0.27 \text{ m}}$

2. $$10'000 \cdot 10 = 0.45 \cdot 750'000 \cdot h^2 (1 + 0.84 \cdot \frac{3}{16h^{3/4}})$$

$h^2(1+0.15 \cdot h^{3/4}) = 0.29$

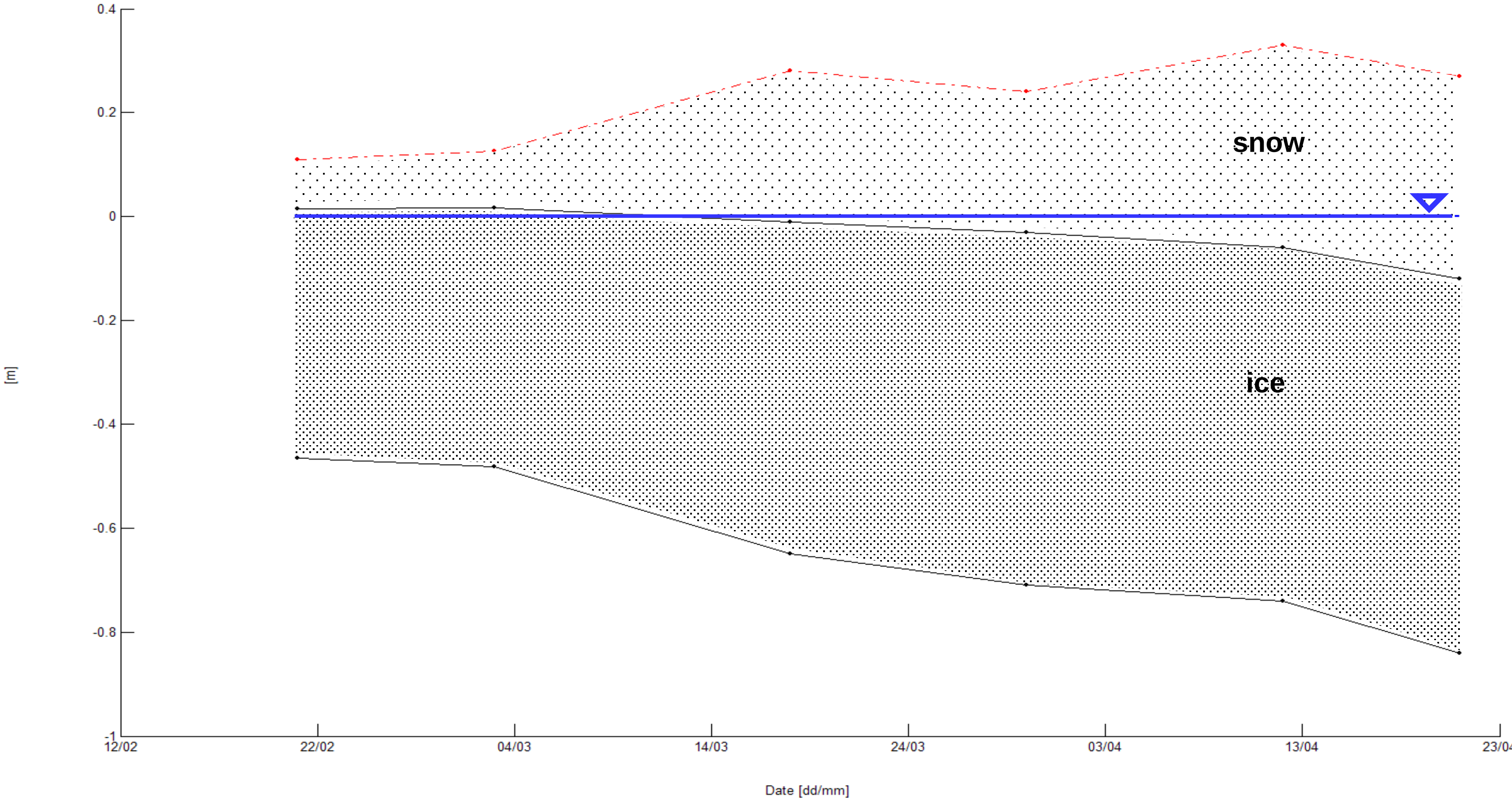
$\underline{h = 0.48 \text{ m}}$

Flooding



Barrault & Høyland (2007)

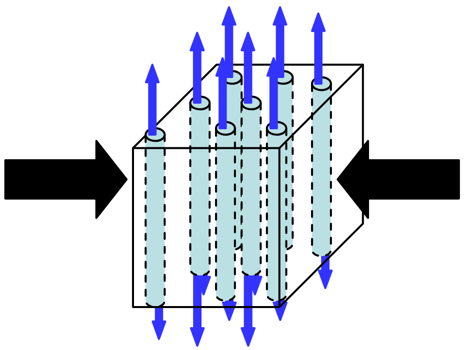
Flooding



Barrault & Høyland (2007)

Flooding

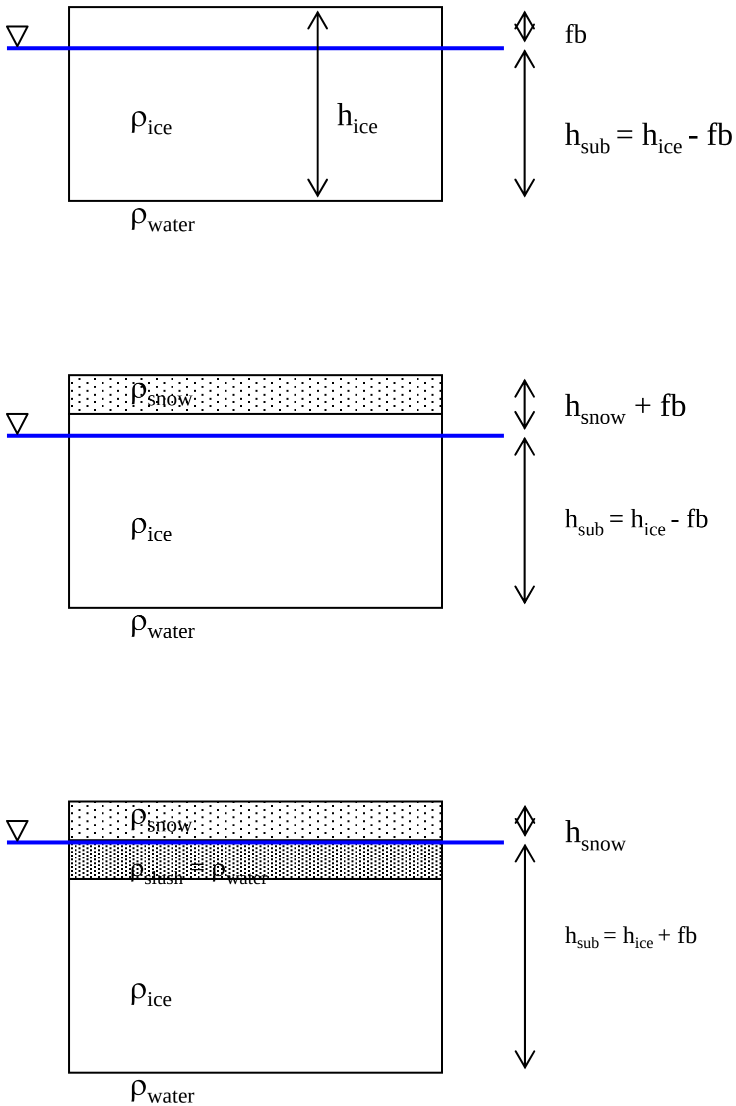
Ice is sinking!



- Flooding increased salinity
- Snow isolated slush
- Slush could not transform to firn
- With consequence of no possibility of increasing floatability

Barrault & Høyland (2007)

Flooding



Gravity forces < buoyancy forces

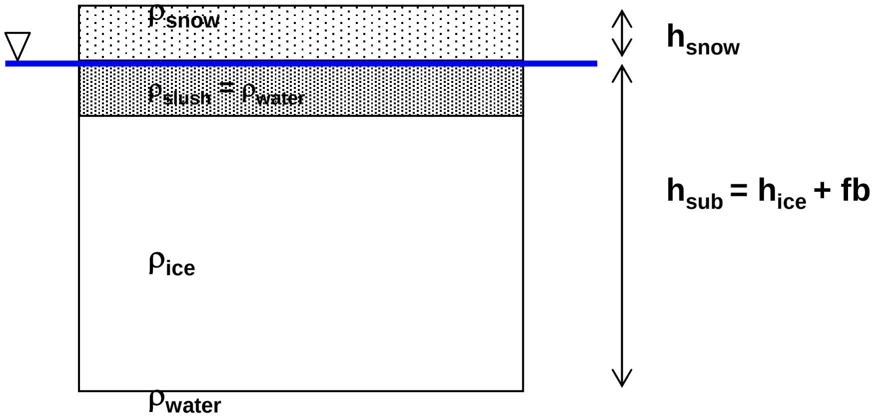
Gravity forces = buoyancy forces

Barrault & Høyland (2007)

Flooding

Gravity forces > buoyancy forces

$$\rho_{snow} h_{snow} > h_{ice}(\rho_{water} - \rho_{ice})$$



$$\frac{h_{snow}}{h_{ice}} > \frac{\rho_{water} - \rho_{ice}}{\rho_{snow}} = 0.37 - 0.55$$

Flooding condition

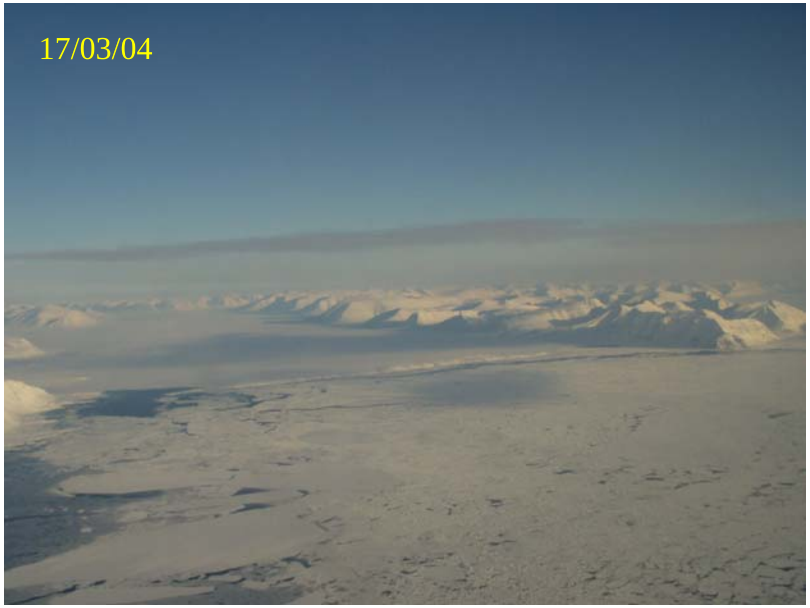
Barrault & Høyland (2007)

Slush & scooter driving

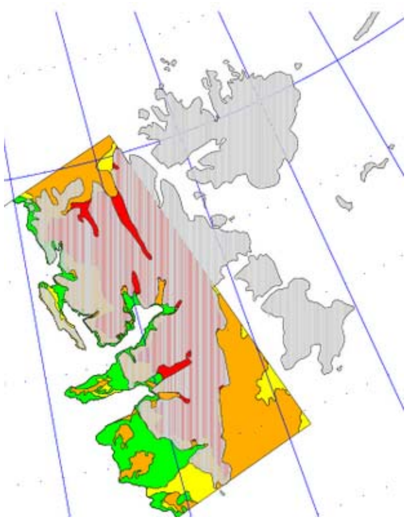
http://www1.nrk.no/nett-tv/klipp/317097

Wind & Current

Observation & Interpretation of ice maps



Photos© S. Gerland



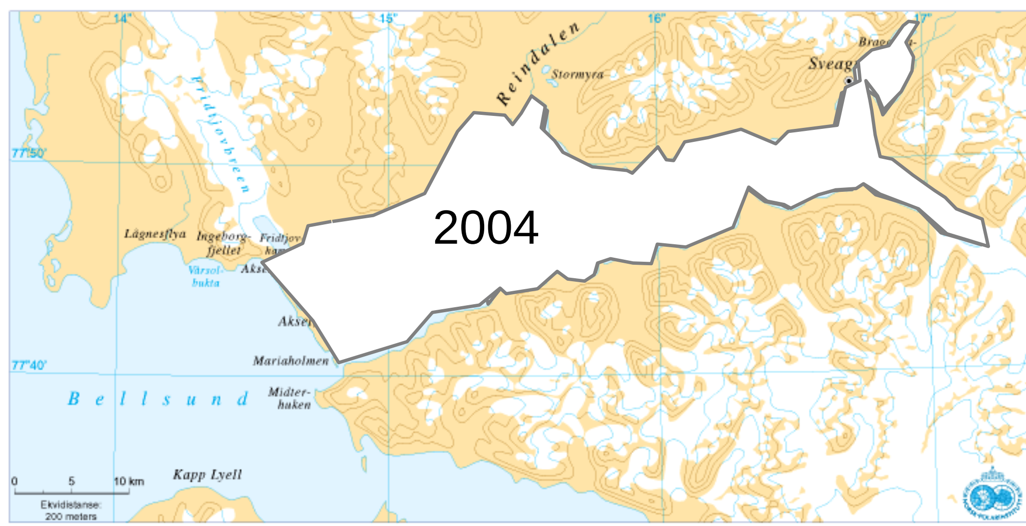


Fig.1: Kart over undersøkelsesområdet

Profile measurements in unknown ice area

$$h^2(t) - h_0^2 = \frac{2k}{\rho l} \int_0^t (T_s - T_f) dt \quad ?$$

Breaking ice - Ridge

Breaking ice – level ice




Sea ice people in LYB

- UNIS
  - Logistics department
  - Frank Nilsen – AGF

  - Aleksey Marchenko – AT

  - Lucie Strub-Klein – AT

  - Sébastien Barrault – AT

- NPI
  - Harvey Goodwin

Thank you!