Melt ponds in climate models

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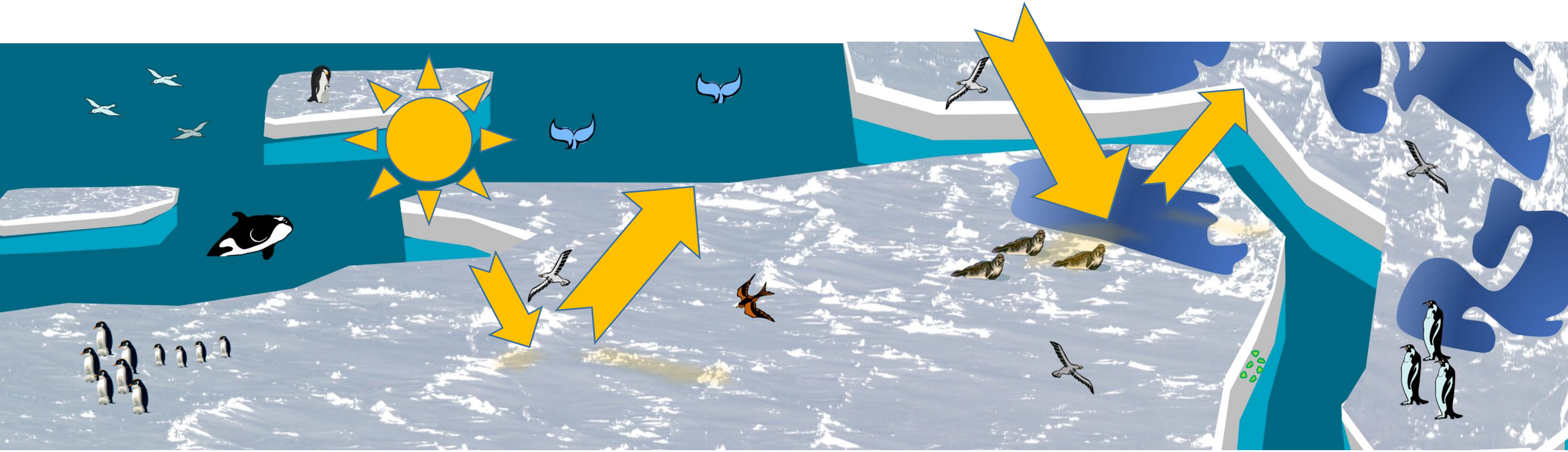
Earth & Life Institute

Outline

- Melt ponds : related physical processes and lifecycle
- Representing melt ponds in climate models
- Model skills
- Small scale physical issues to be addressed

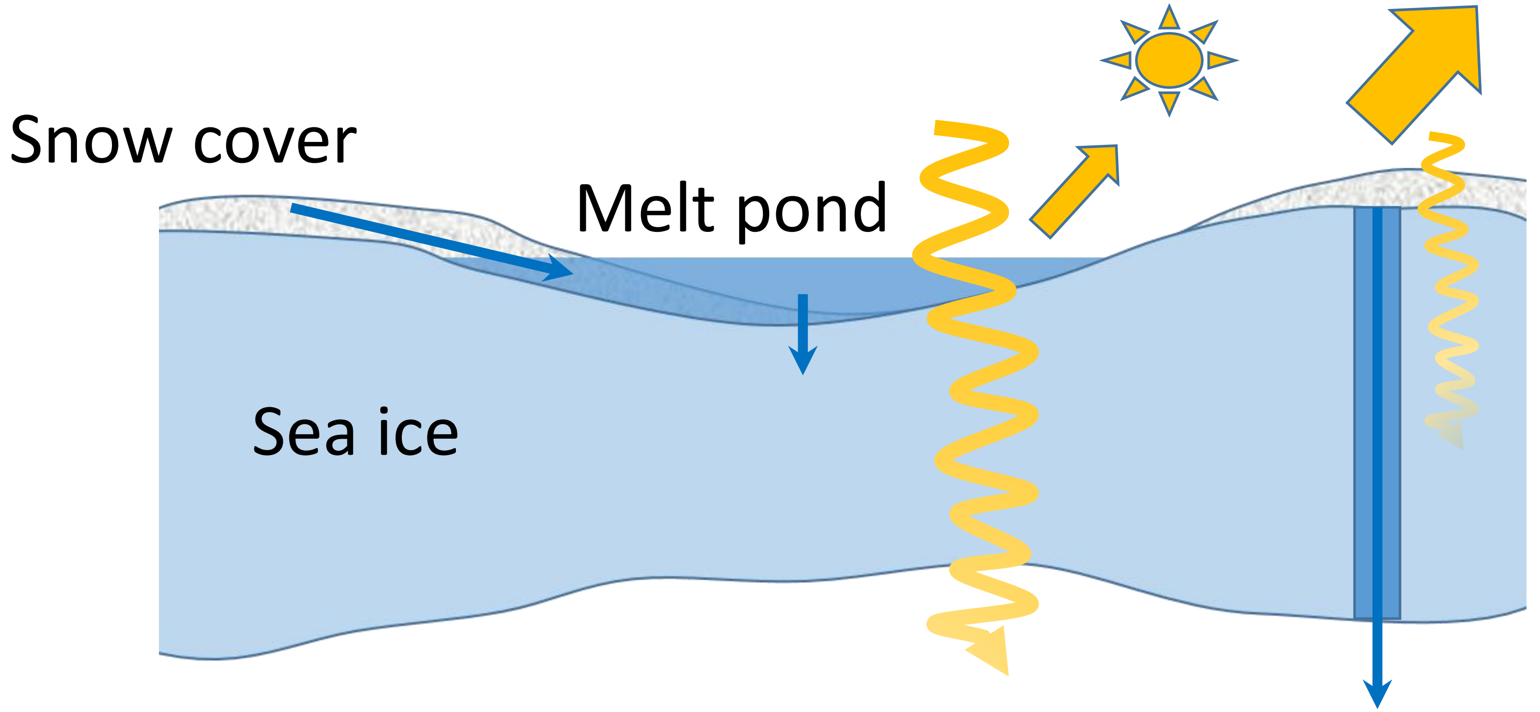
First order impact of melt ponds = lower albedo – absorbs greater fractions of solar radiation



Strengthen the ice-albedo feedback in the Arctic

Melt pond-related physical processes and lifecycle

Stage I : Formation, late May – Mid-June



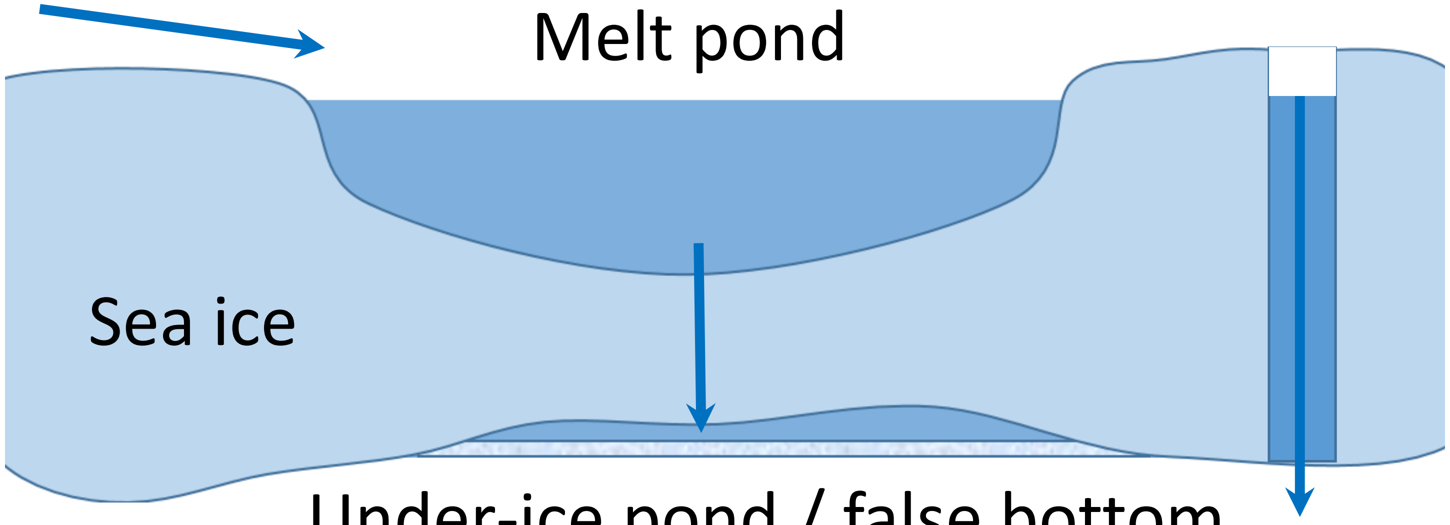
Eicken et al., 2002

- Snow and sea ice surface melt feed melt ponds
- Lateral water transport – losses in cracks
- Impermeable ice => large hydraulic head, initiation of vertical drainage

Melt pond-related physical processes and lifecycle

<u>Stage II</u> : Development, Mid-June – Mid-July

Eicken et al., 2002

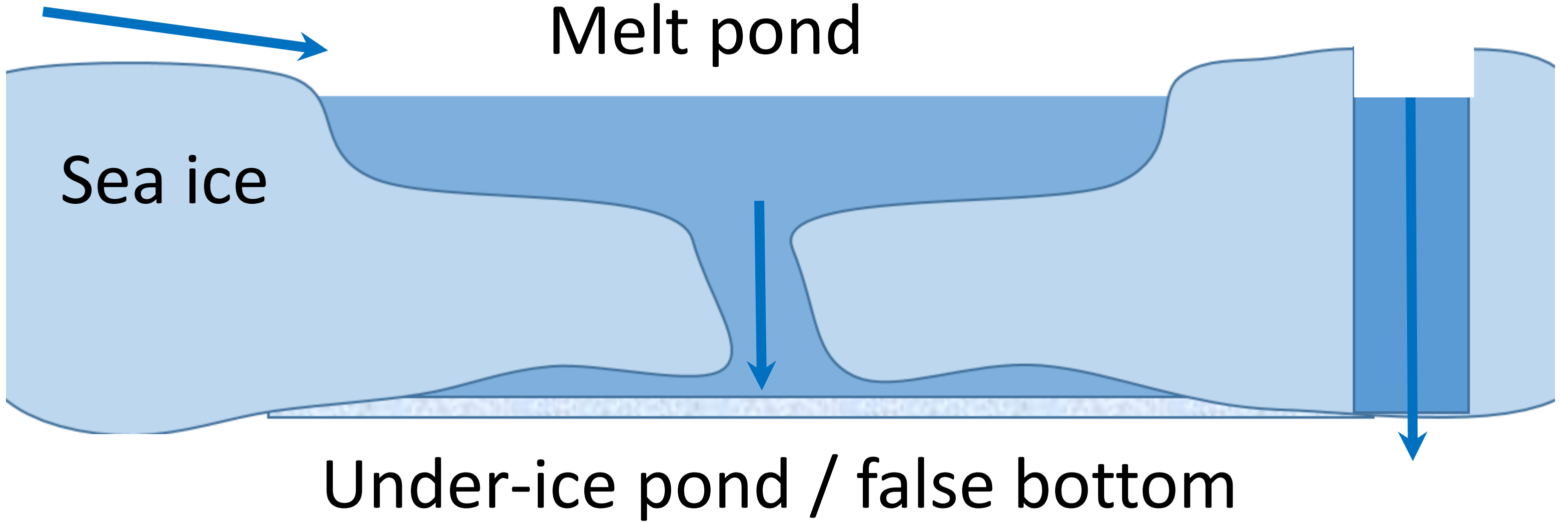


- Lateral and vertical water transport
- Permeable sea ice – reduction of hydraulic head
- Larger ponds and under-ice melt pond formation

Melt pond-related physical processes and lifecycle

Stage III : Floe disintegration, Mid-July – Mid-August

Eicken et al., 2002

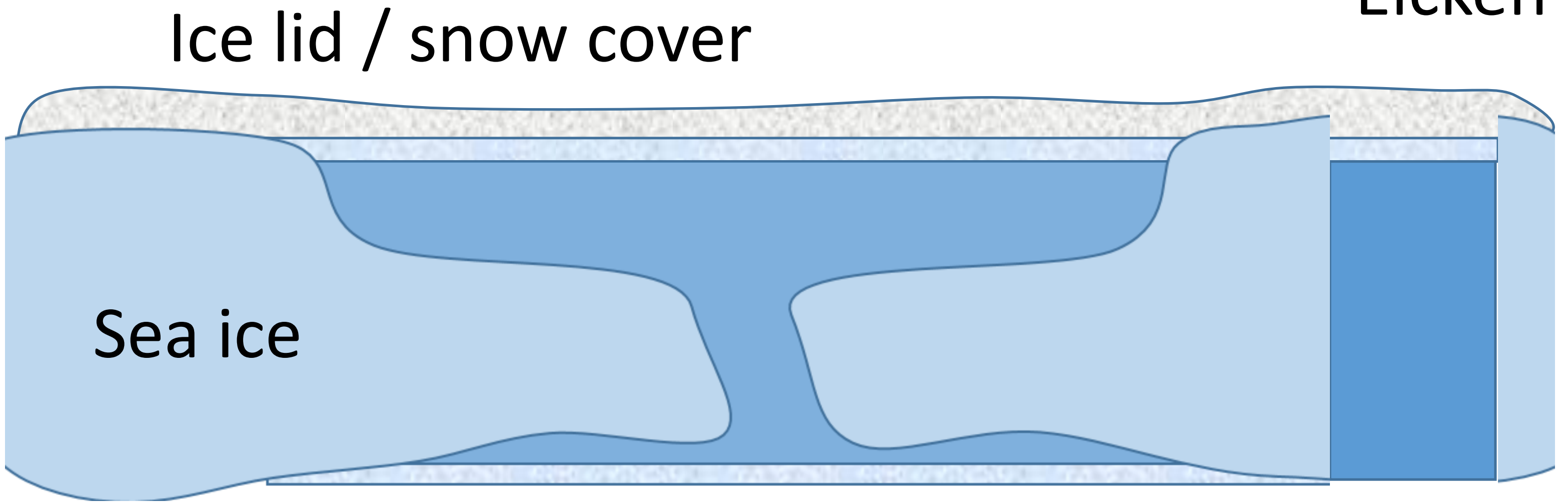


- Lateral and vertical water transport
- Sea ice breaks up underneath melt ponds

Melt pond-related physical processes and lifecycle

Stage IV : Freezing over

Eicken et al., 2002



- Melt ponds freeze over
- Snow may reaccumulate
- Bottom melting may continue or stop

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Representing melt ponds in climate models

1. Albedo parameterizations

Surface albedo: $\alpha = a_{pond}\alpha_{pond} + a_{ice}\alpha_{ice}$

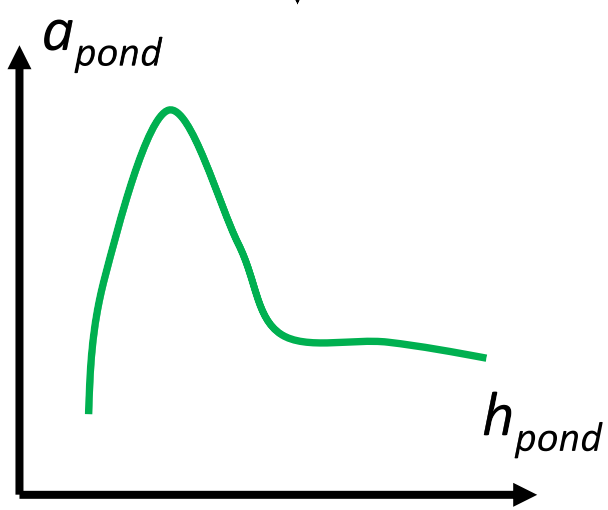
$$\alpha = f(\text{Surface temperature}, \text{surface type}, \text{snow depth}, \text{ice thickness}, \ldots)$$

$$if = \text{melting temperature}$$
$$\Rightarrow \alpha_{ponded\ ice} = \text{constante value}$$

$$\alpha_{pond} = \begin{cases} \text{constant value} \\ f(\text{pond depth}, \text{ice thickness} \ldots) \end{cases}$$

$$h_{pond} = f(\text{Surface melting rates})$$

(Assuming uniform slab of ice)



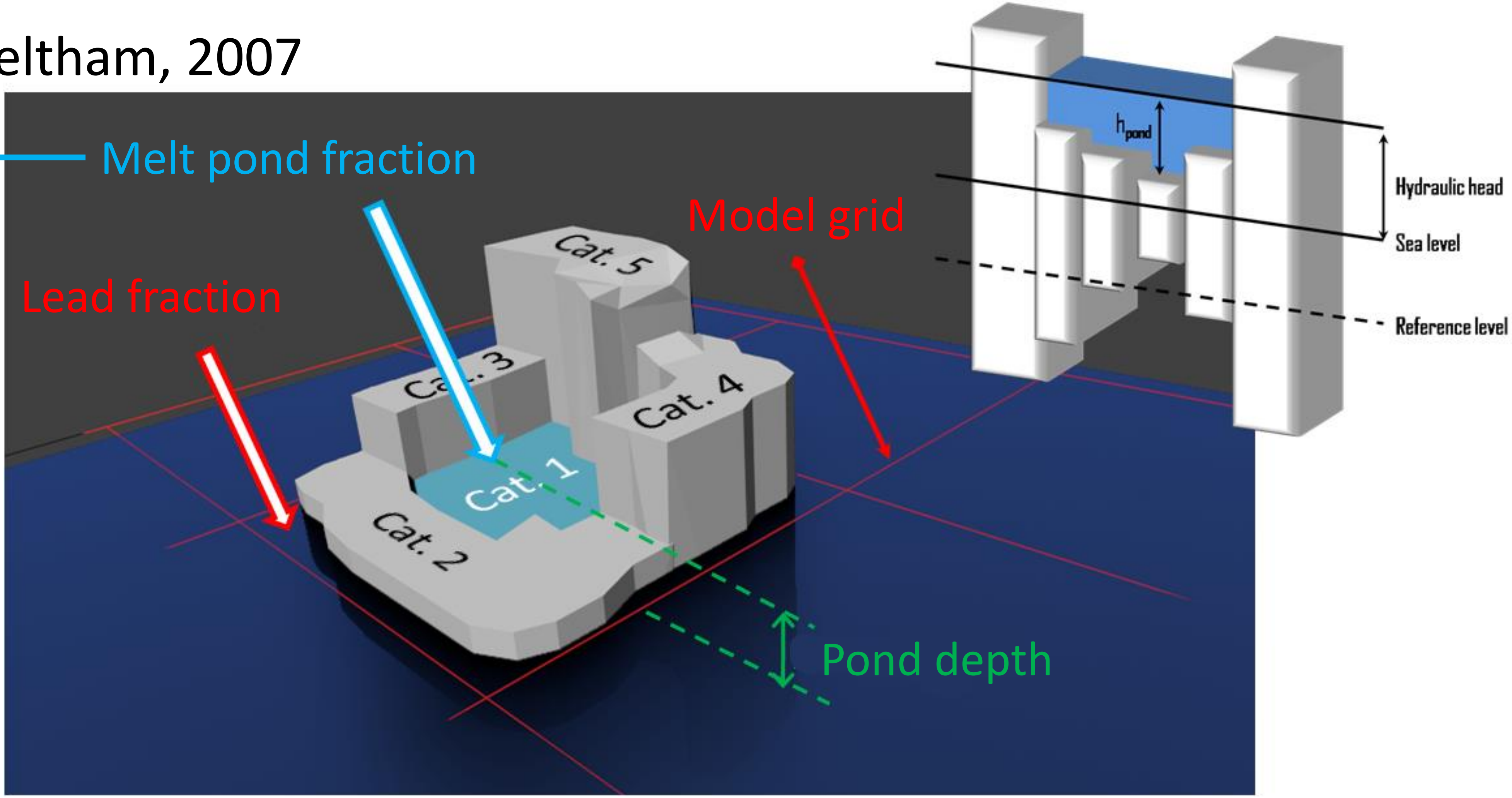
Representing melt ponds in climate models

2. Explicit – virtual – representation

Flocco and Feltham, 2007

$$\alpha = a_{pond}\alpha_{pond} + a_{ice}\alpha_{ice}$$

Impact on albedo “only” => virtual melt ponds

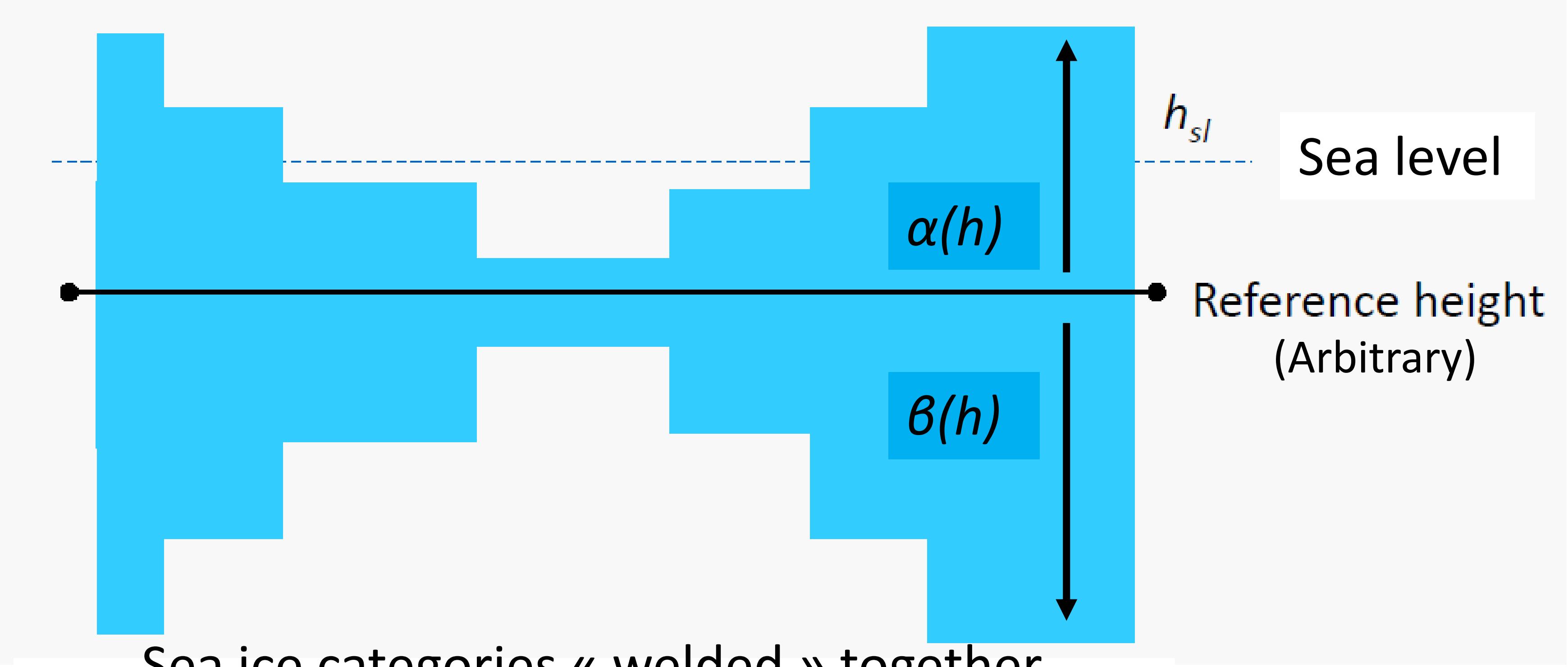


Representing melt ponds in climate models

Explicit representation : method

g(h) =>
α(h); β(h)
⇓

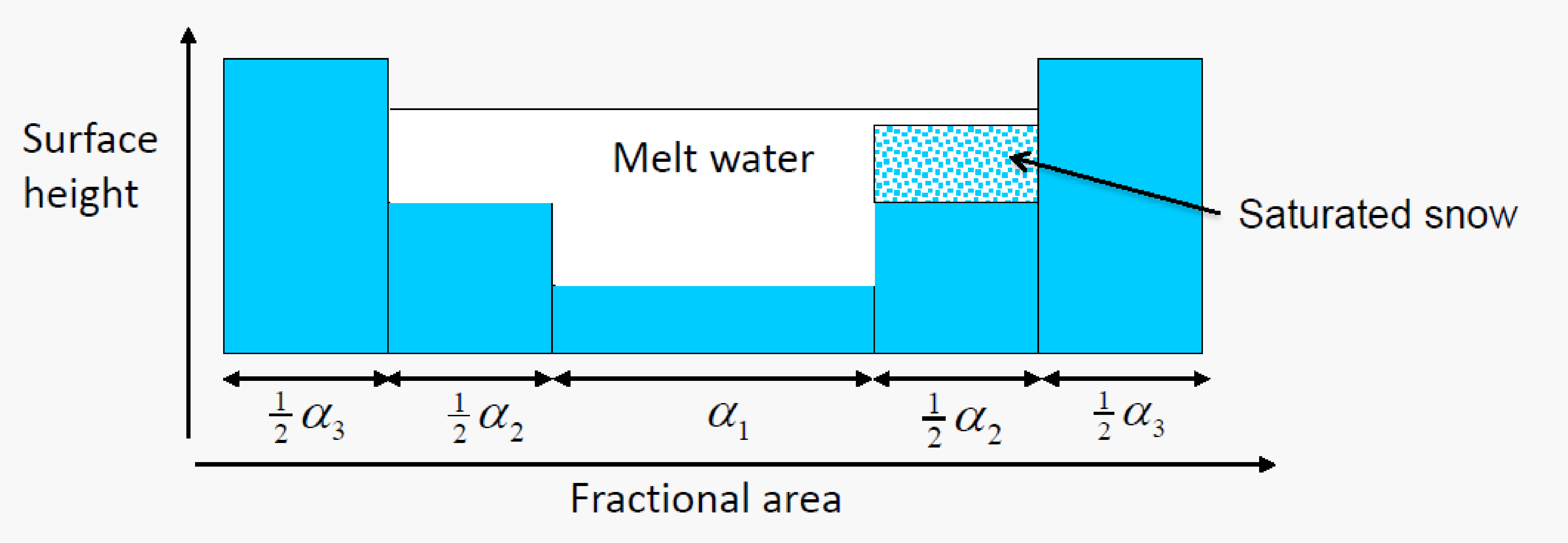
Do not represent the actual topography!



Sea ice categories « welded » together bofore applying hydrostatic equilibrium to the whole ice mass

Representing melt ponds in climate models

Explicit representation : method



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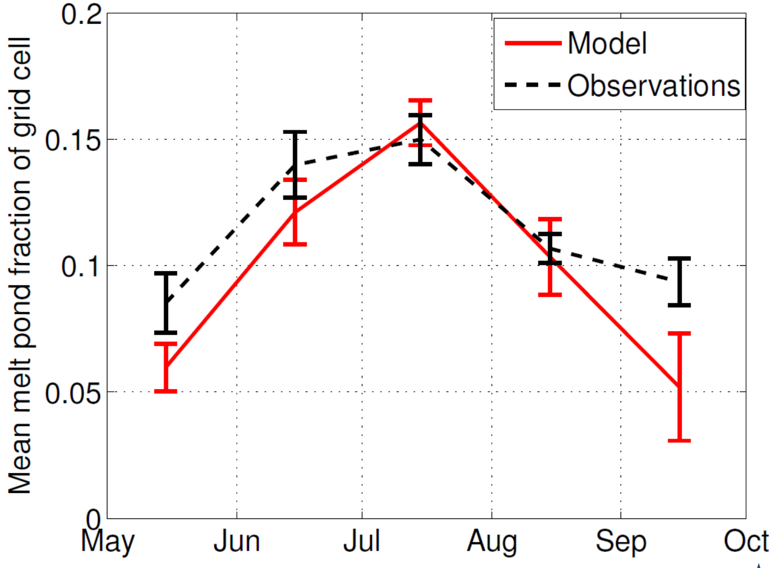
What's right and wrong with melt ponds in coupled sea ice – ocean models

Simulated vs. observed melt ponds

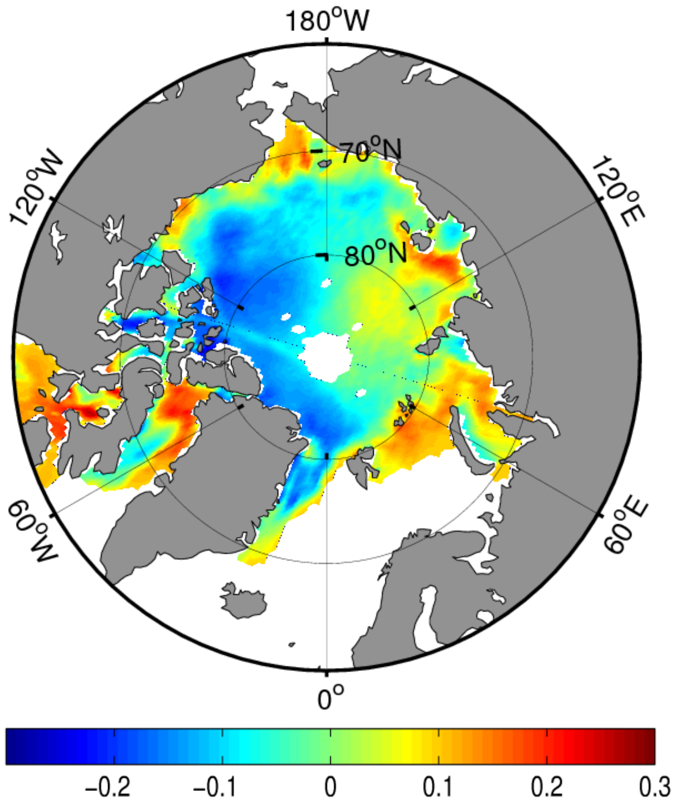


Mean seasonal cycle of melt pond fraction (over 2000-2011), expressed as a fraction of grid cell, from the model (red) and from

MODIS observations (Rösel et al., 2012) (dashed black).

✓ Good melt pond seasonal cycle overall, on average over the Arctic basin

Average spatial distributions of melt pond fraction deviations (Mod. - Obs., fractions of grid cell) over July 2000-2011.



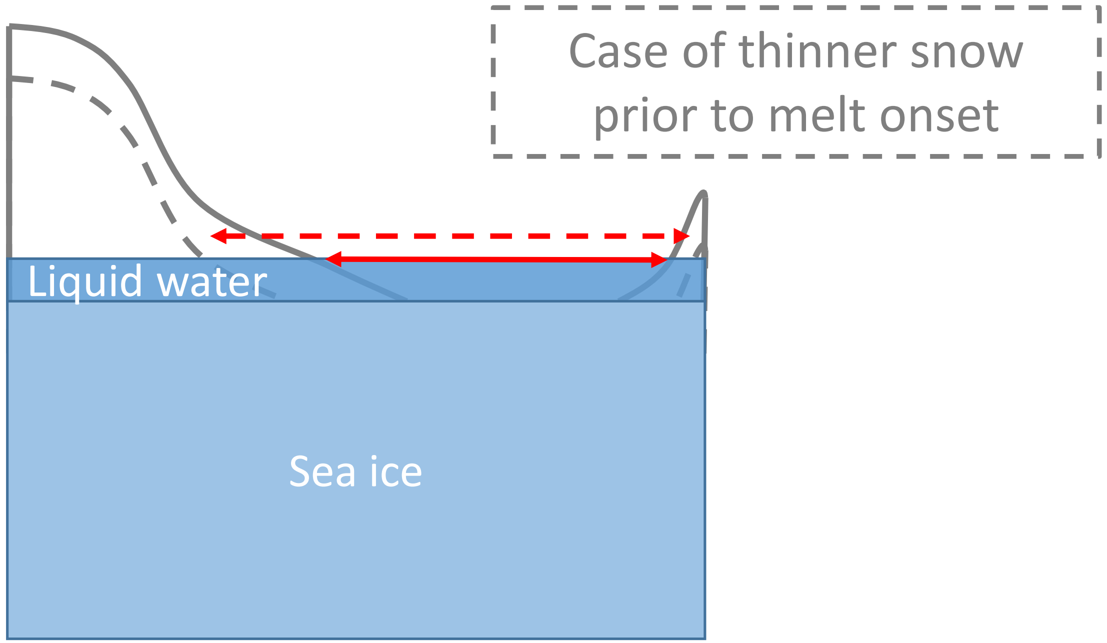
Regional discrepancies (with Obs.) :

- Overestimation of MP. fractions on FYI
- Underestimation of MP. fractions on MYI

Interactions with the snow cover : large uncertainties

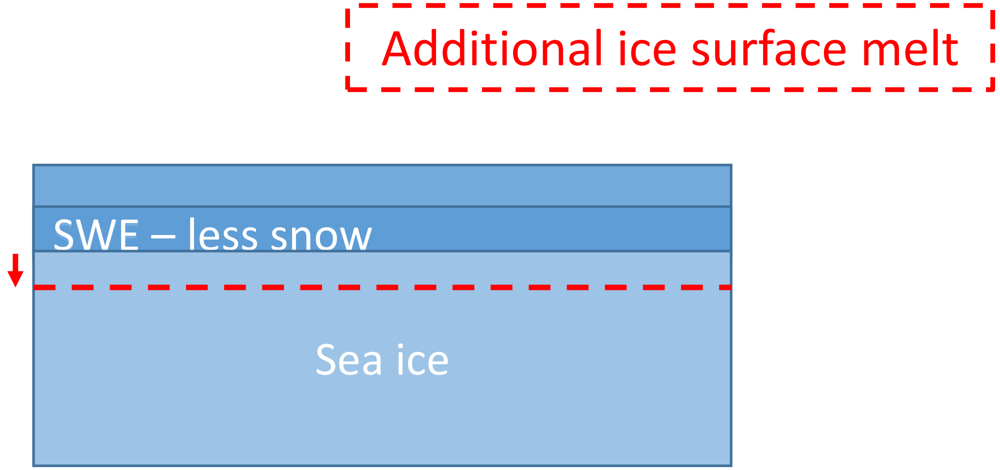
Two melt pond regimes – Two different sensitivities

Older/thicker ice
Potentially persistent snow



- Less (more) snow => larger (smaller) melt ponds
- Potentially large impact

Younger/thinner ice
Snow disappears entirely in summer

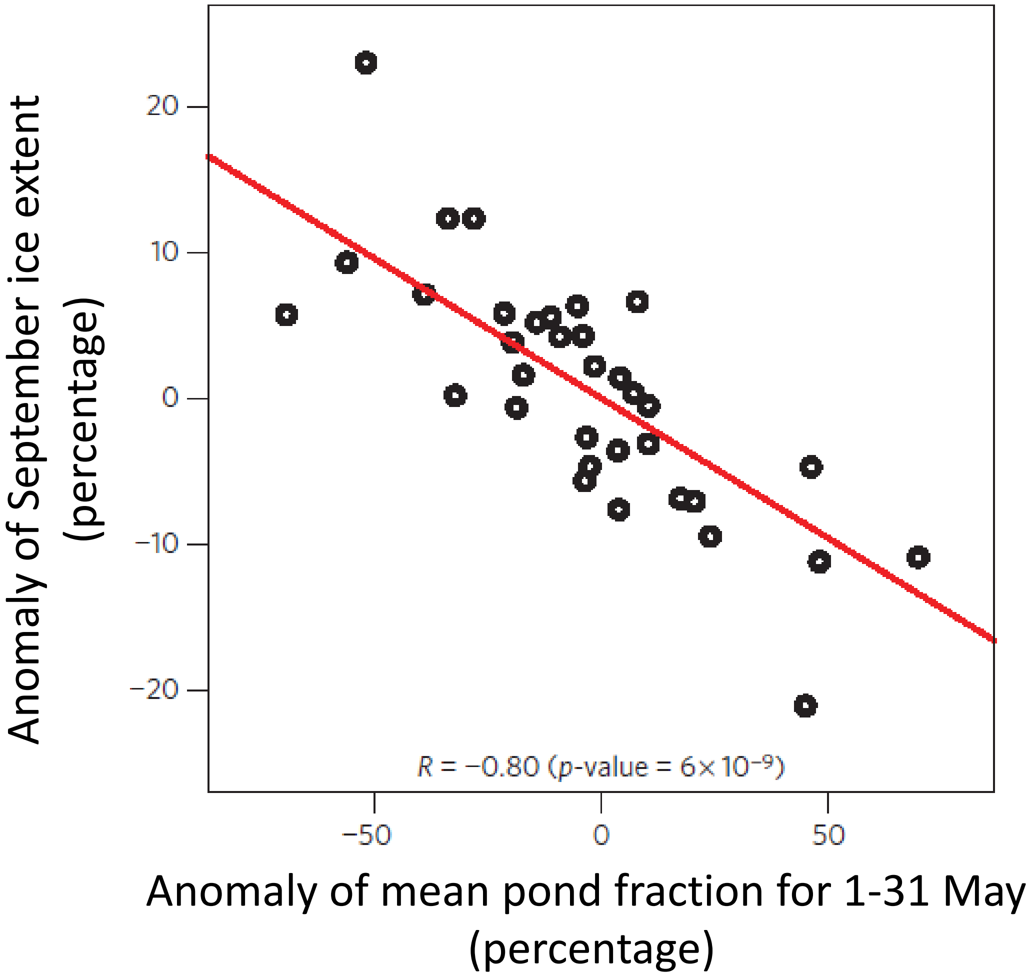


- Less (more) snow => less (more) liquid water to fill in melt ponds
- More (less) ice melt instead
- Water retention capacity of thin ice is limited
- Less (more) snow => smaller (larger) ponds but small impact

September Arctic sea-ice minimum predicted by spring melt-pond fraction

David Schröder*, Daniel L. Feltham, Daniela Flocco and Michel Tsamados

The area of Arctic September sea ice has diminished from about 7 million km^2 in the 1990s to less than 5 million km^2 in five of the past seven years, with a record minimum of 3.6 million km^2 in 2012 (ref. 1). The strength of this decrease is greater than expected by the scientific community, the reasons for this are not fully understood, and its simulation is an on-going challenge for existing climate models[2,3]. With growing Arctic marine activity there is an urgent demand for forecasting Arctic summer sea ice[4]. Previous attempts at seasonal forecasts of ice extent were of limited skill[5-9]. However, here we show that the Arctic sea-ice minimum can be accurately forecasted from melt-pond area in spring. We find a strong correlation between the spring pond fraction and September sea-ice extent. This is explained by a positive feedback mechanism: more ponds reduce the albedo; a lower albedo causes more melting; more melting increases pond fraction. Our results help explain the acceleration of Arctic sea-ice decrease during the past decade. The inclusion of our new melt-pond model[10] promises to improve the skill of future forecast and climate models in Arctic regions and beyond.



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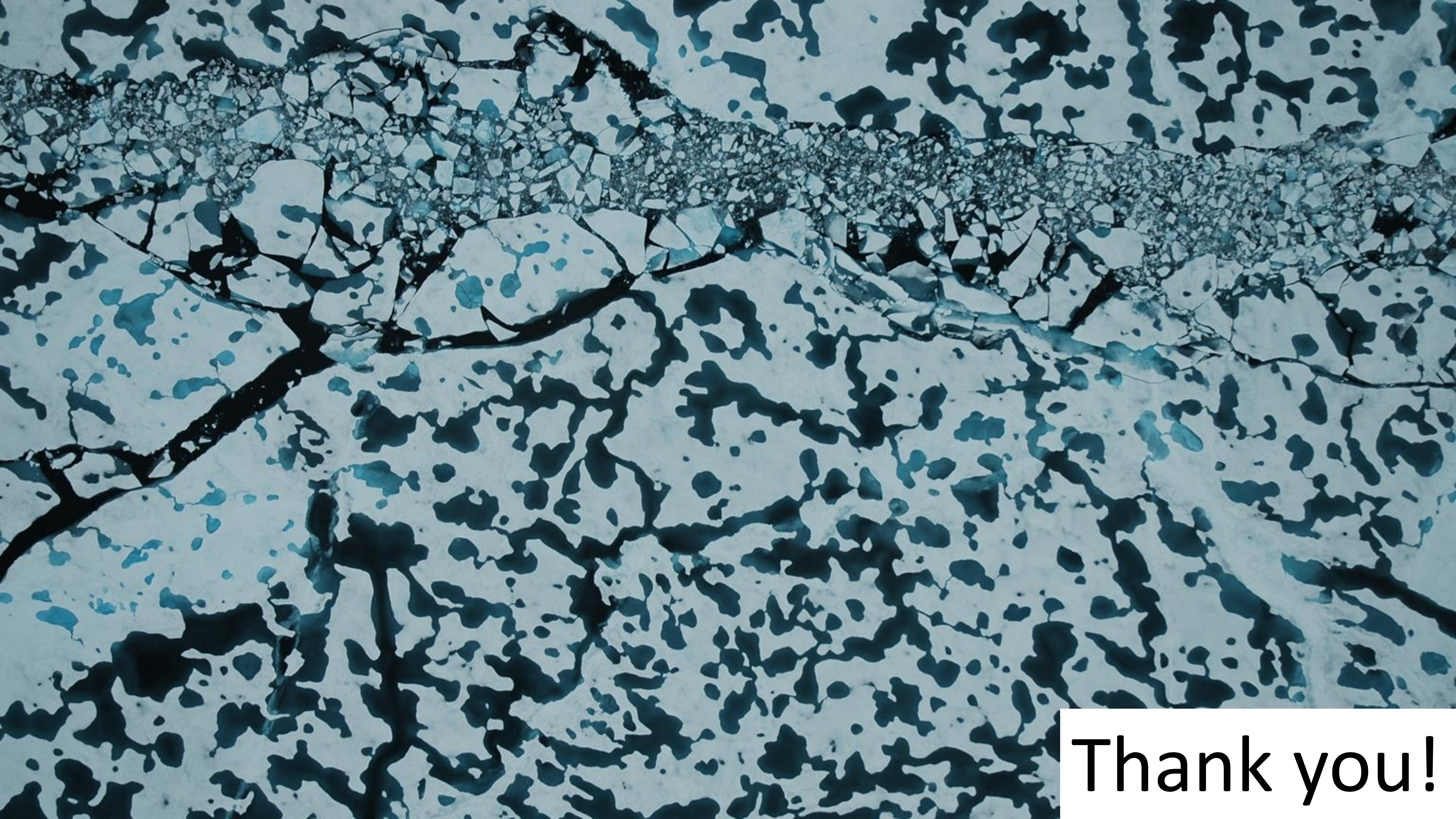
Melt pond related and unresolved issues : where a local scale model and high resolution would help…

- Albedo of melt ponds = *f(*albedo of underlying sea ice, snow*…)*
- Dynamics of melt ponds – runoff through cracks, importance of sea ice floe size distribution and topography
- Drainage processes through permeable ice
- Effects of snow :
  - => on geometry and size of melt ponds
  - => on topography (control over sea ice growth, superimposed ice formation)
  - => on sea ice permeability



Thank you!