Dynamical modelling of Kara Sea land-fast ice

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Introduction

A modified viscous-plastic ice model can be used to simulate land-fast ice in the Kara Sea in a realistic manner (Olason, 2012). This poster gives an overview of land-fast ice in the Kara Sea, the model modifications made, and presents some of the results. Comparing model results with observations shows that the mechanics of fast-ice formation and breakup are well captured by the model. This success shows that static arching place a crucial role in fast-ice formation in the Kara Sea. From the model results we can also estimate the critical thickness necessary for fast-ice to form in the Kara Sea.

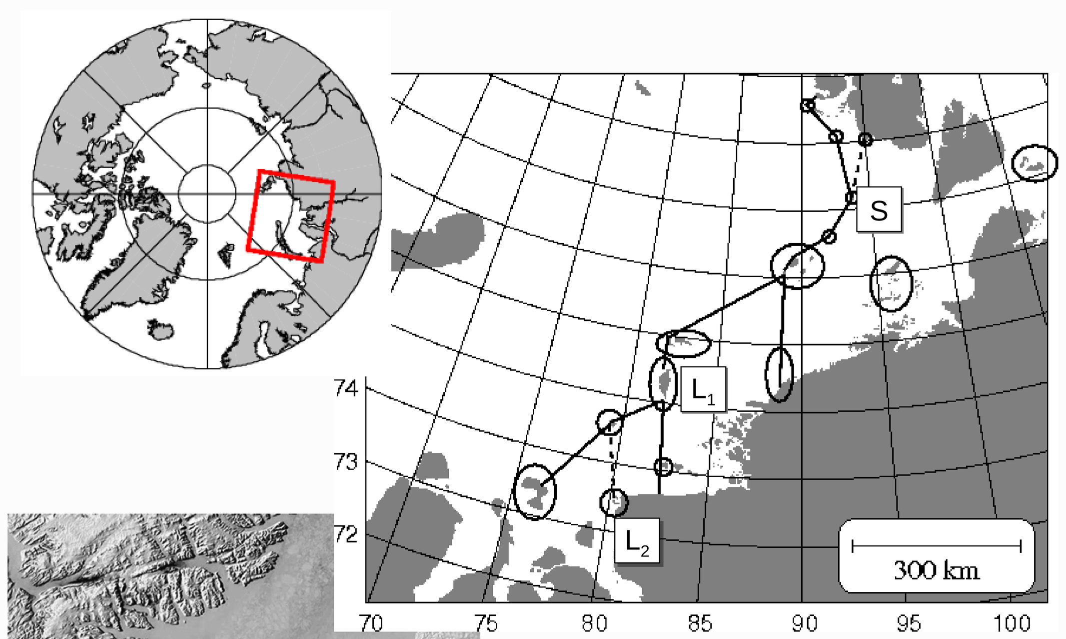
Kara Sea land-fast ice

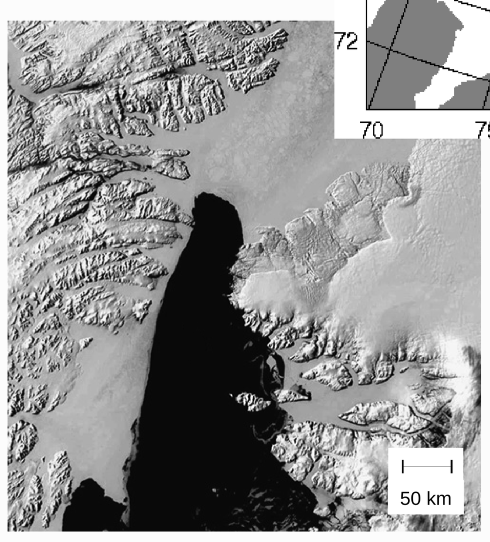
In the Kara Sea the land-fast ice:

- Follows a chain of islands
- Is found only in distinct modes
- Forms over deep waters

This indicates that the fast ice is held in place by arches in the ice cover, supported by the islands. Fast-ice formation has previously been linked with the grounding of pressure ridges, but this can only play a minor role in the relatively deep waters of the Kara Sea.

A sea-ice model capable of capturing static arching is therefore needed to simulate the formation and break up of the land-fast ice in the Kara Sea. This requires modifications to be made to the dynamical sea-ice models currently in use.





Top: The lines indicate the typical extent of fast ice for S, L1 and L2 modes (reproduced from Divine et al., 2005), with the dashed lines showing smaller S and L-mode variants.

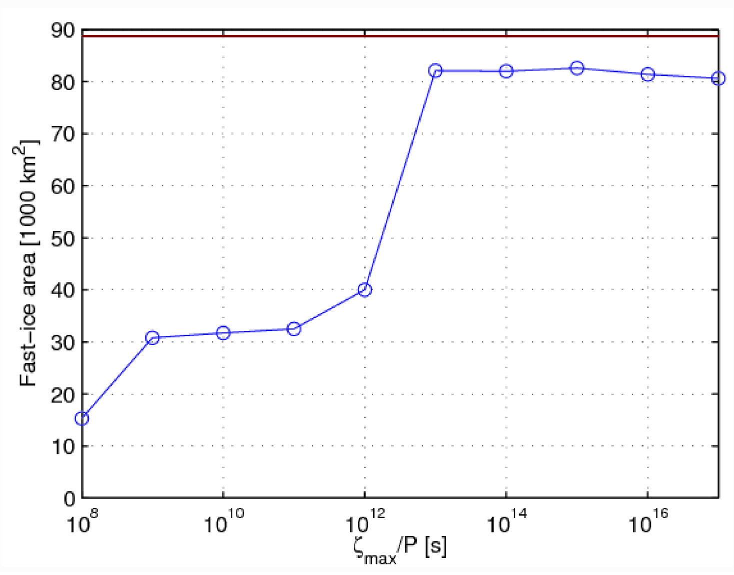
Left: Ice bridge formed via static arching in Smith Sound (Dumont et al., 2008)

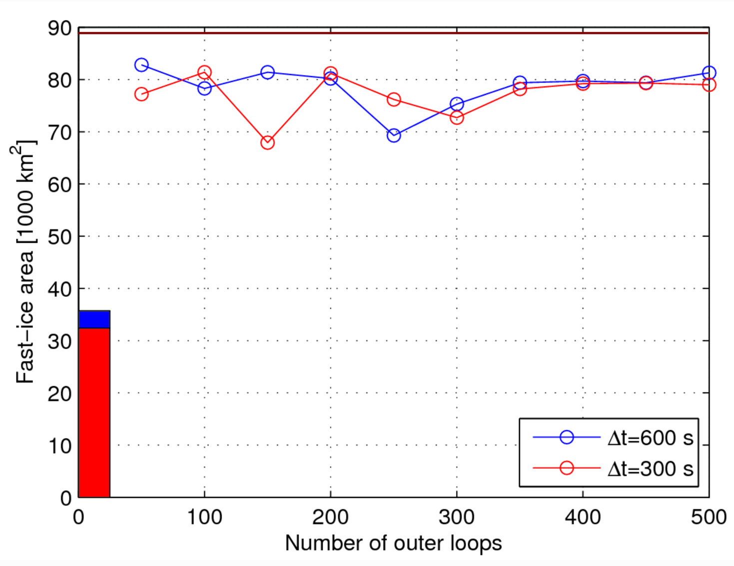
The model

I use a regional, 10 km resolution ice-ocean model of the Kara Sea. I modified the commonly used Hibler (1979) viscous-plastic model to include:

- A higher maximum viscosity
- A more accurate momentum solver
- A cohesive yield curve

Static arching does occur in the original model, due to it's plasticity, but is unrealistically weak unless the maximum viscosity is high enough. Without an accurate momentum solver spurious changes in velocity can destabilise the fast-ice.



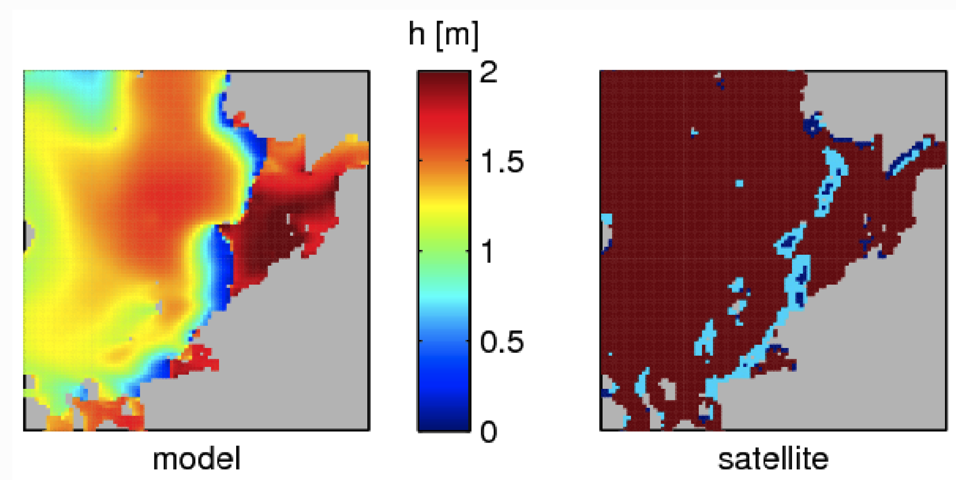


Top: Modelled fast-ice area at the start of April as a function of the maximum viscosity (ζ_{max} /P). The red line shows observed extent.

Bottom: Modelled fast-ice area at the start of April as a function of the number of outer loops using two different model time steps. The bar in the left corner shows the fast-ice area modelled using one pseudo time step.

Modelled fast ice

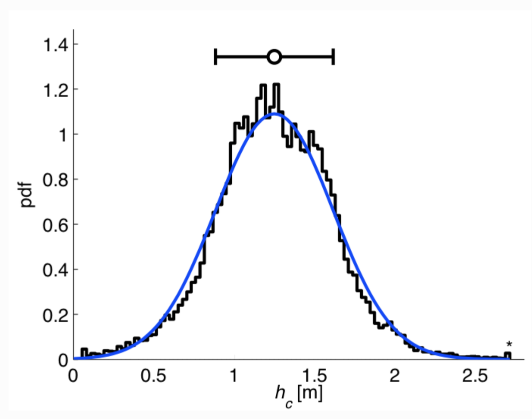
The model captures the basic formation and breakup of land-fast ice, but not inter-annual variability in extent. Flaw leads are captured and compare well with observations. Tuned to reproduce the 1998 fast-ice cover, the model also to produces land-fast ice for the periods 1967-74 and 1998-2005.



Left: Modelled ice thickness in the north-east Kara Sea on April 14th, 1998.
Right: Observed flaw polynias in the same region and at the same time; dark blue: open water, light blue: thin ice, brown: thick ice

Critical thickness

For fast ice to form the ice must reach a certain critical thickness, which can be estimated using the model. Modelling the periods 1967-74 and 1998-2005 shows a clear thinning trend in the land-fast ice. A continuation of that trend is a likely explanation for the changes in fast-ice behaviour in the Kara Sea observed since the turn of the century.



Histograms of ice thickness at each model grid cell when the fast ice first becomes stable in winter and when it breaks up in summer, during the periods of 1967–74 and 1998–2005. The mean value and standard deviation are also indicated on the graph. The mean thickness is interpreted as the critical thickness for fast-ice formation.

Conclusions

- The Kara Sea land-fast ice is held in place by static arching of the ice.
- The viscous-plastic rheology can be modified and tuned to capture the basic formation and breakup of land-fast ice.
- The ice needs to reach a critical thickness for fast ice to form and the model can be used to estimate this for the Kara Sea.

References

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