Investigating Surface Thickening and Snow Flooding for Arctic Sea Ice Restoration

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Introduction

Arctic sea ice has been melting rapidly since satellite records began in 1979 and an ice-free Arctic is likely by 2050 under all emissions pathways considered by the IPCC (Jahn et al., 2024). Arctic sea ice is essential for Arctic peoples and ecosystems whilst also keeping the Earth cool by reflecting vast quantities of solar radiation, it is therefore essential that we investigate techniques to protect Arctic sea ice beyond emissions reductions.

Two sea ice thickening techniques

The rate of natural sea ice growth is limited by the rate of heat conduction from the ice-ocean interface through the ice and any snow on its surface. We are researching two proposed methods to increase the freezing rate and thicken sea ice during the Arctic winter:

- **Surface Thickening**: Pumping seawater to the surface of snow-free ice. This bypasses the insulating effect of the existing sea ice as the seawater is directly exposed to cooling. Therefore, it freezes faster and thickens the sea ice from its top surface (Desch et al., 2017).
- **Snow Flooding***:* Flooding snow on the ice's surface to consolidate it into solid, more conductive, ice. The ice is thickened at the surface but the rate of natural freezing at the ice's base is also increased throughout the rest of the winter (Pauling & Bitz, 2021).

Despite initial large-scale modelling suggesting these could be effective at slowing/stopping sea ice loss (Desch et al., 2017; Zampieri and Goessling, 2019; Pauling & Bitz, 2021), neither of the ice thickening techniques have been thoroughly researched.

Modelling the sea ice thickening

We are investigating the underlying physics governing the behaviour of the sea ice restoration techniques with small-scale lab experiments and modelling. This involves simplified, one-dimensional modelling of the impact of **Surface Thickening**, **Snow & Snow Flooding** on ice growth shown in the figures below.

Figure 1: **Surface Thickening -** there is a slight reduction in natural growth at the ice's base. However, this is offset by the considerably increase in the thickness of the ice through direct freezing on its surface.

Figure 2: **Snow Flooding -** the ice growth is already slow, due to the insulating effect of the snow, hence consolidating it into solid ice increases the natural growth rate alongside the direct surface benefit.

Cold room experiments

To compliment and assess the validity of the modelling we are also conducting experiments of the two techniques, initially using freshwater. These are conducted in a cold room maintained at -10 °C, with water initially at its freezing temperature freezing due to cooling at its upper surface, the impact of **Surface Thickening, Snow & Snow Flooding** are then investigated by adding floodwater (at 0 °C) or snow (represented by ice shavings at -10 °C) on top of the ice.

The temperature of the air, snow, ice and water are measured at regular 10 mm intervals. The temperature field is then used to determine the ice thickness for comparison with the model data. Figure 3 shows a mock experimental dataset from the modelling as experiments are currently underway. The ice thickness is accurately extracted from the temperature-field data.

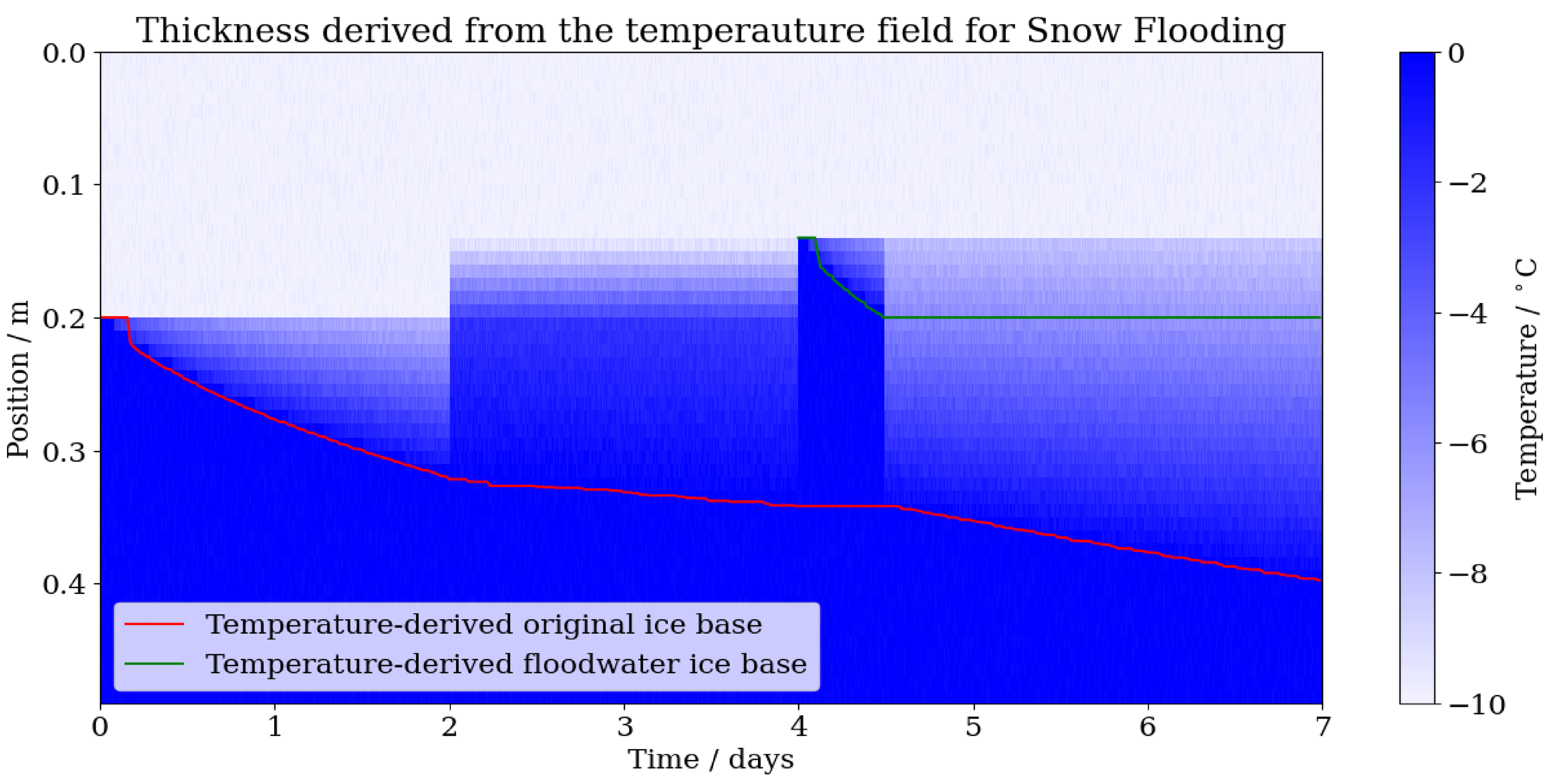

Figure 3: Temperature field-derived thickness for mock experimental data

Conclusions & Future Work

The initial modelling suggests that both **Surface Thickening** and **Snow Flooding** can thicken sea ice. Experimental results are required to compare with this modelling and validate its accuracy.

The future work will involve expanding current work to include salt in the modelling by treating the sea ice as a *mushy layer* and then conducting suitable experiments with salt. Understanding the physics governing the behaviour of the ice thickening techniques will allow them to be better represented in climate models.

We are also continuously collaborating on field experiments with our partners to feed the modelling/lab work develop all aspects of the research simultaneously.

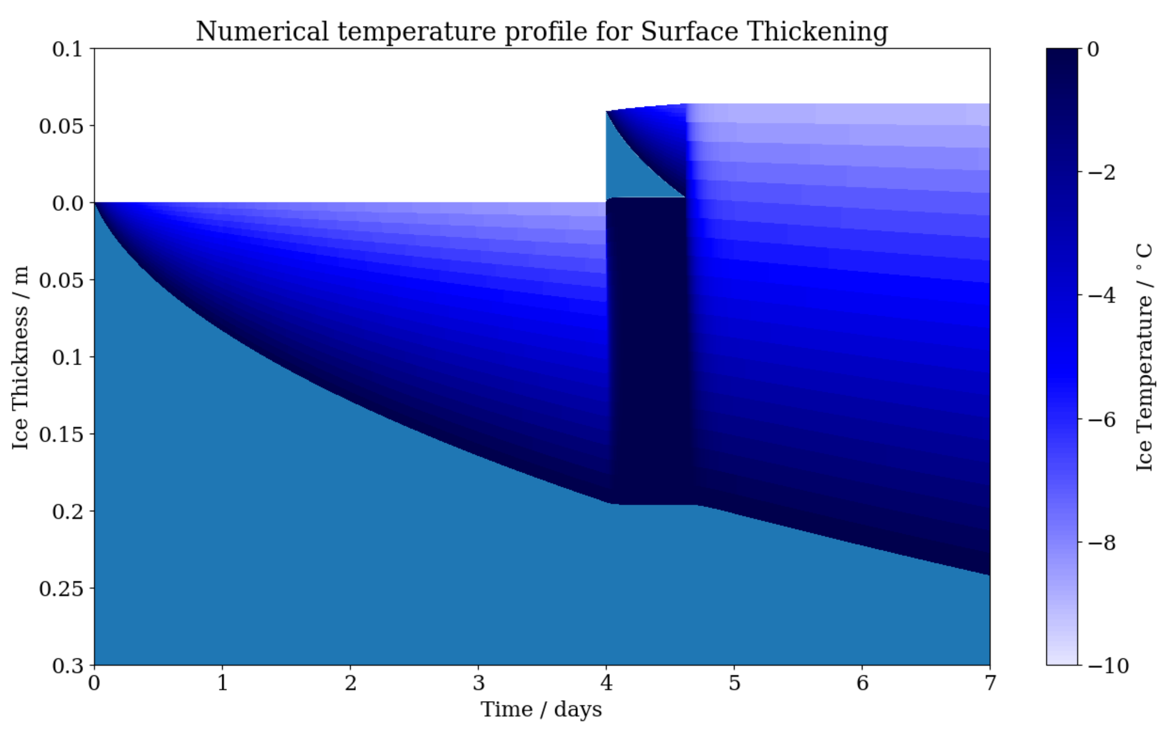

Figure 1: Ice Temperature field with Surface Thickening

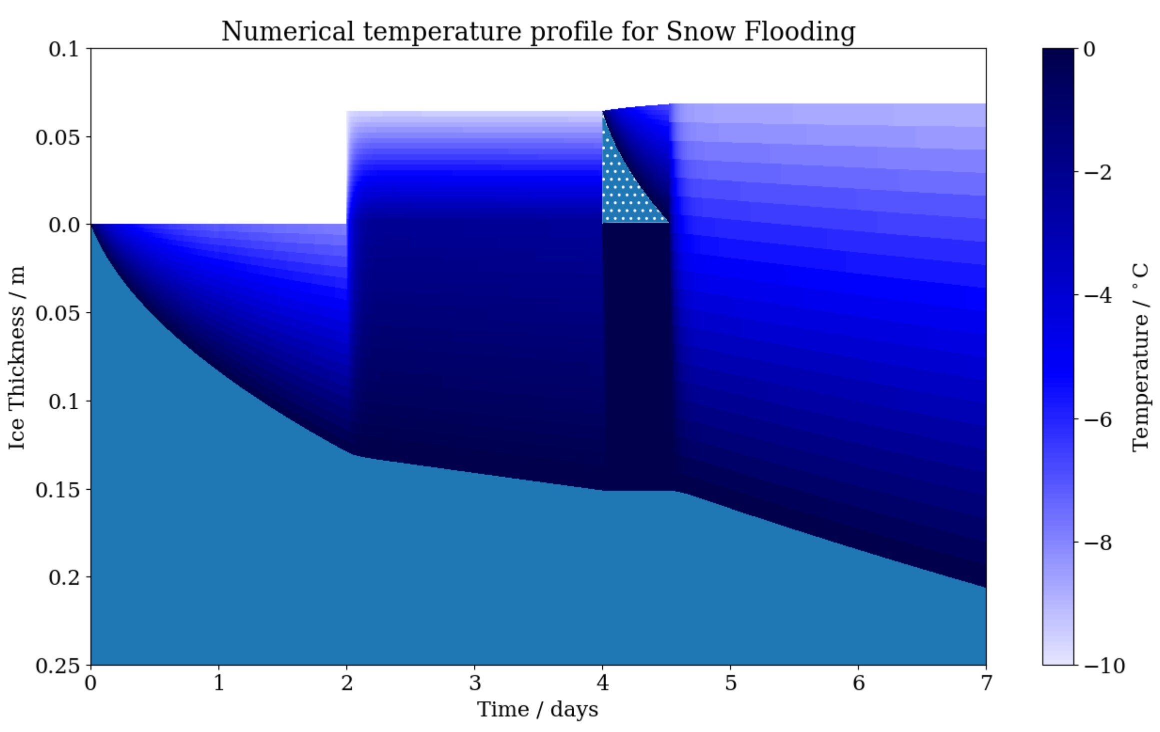

Figure 2 : Ice/Snow Temperature field with Snow Flooding

Figure 4: Field Experiments (Image credit: Real Ice)

References

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