Integrating In-Situ Observations with Process-Based Modelling of the Sea Ice Floe Size Distribution

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Abstract

The lateral size of sea ice floes is receiving increasing attention as an important variable for the polar climate system. We have developed a model for prognostic evolution of the floe size distribution, which emerges due to five key physical processes: new ice formation, welding of floes in freezing conditions, lateral growth and melt, and fracture of floes by ocean surface waves. As a result of the model’s foundation in the governing physics, free parameters occurring in the equations can be directly constrained by observations. Initial model experiments provided insight into the relative importance of various processes, showing floe freezing processes were particularly important for simulation of the floe size distribution. Previously, physical descriptions of lateral growth and welding together of floes had not been constrained by observations. This motivated an analysis of images obtained by drifting wave buoys (SWIFTs) deployed in the autumn Arctic Ocean to quantify these processes in-situ for the first time. We separated floe area growth due to welding from that due to lateral expansion, and compared observations to our physical descriptions of the individual processes. We also found a strong limitation on floe sizes imposed by the wave field. These results have been used to inform new physical descriptions of processes important for the sea ice floe size distribution.
Sea ice is composed of floes, which range in size across orders of magnitude and evolve in space and time. The floe size distribution (FSD) determines the amount of lateral melt, the rheological behavior of sea ice, its surface roughness and the spatial distribution of leads, as well as providing a measure of fragmentation relevant to polar operations.

**Aim:** advance understanding of and predictive capability for the sea ice floe size distribution

**How?** A combination of in-situ observations...

Two SWIFT buoys deployed in the Arctic Ocean during Fall captured a series of images showing floe size evolution over several hours. Images were processed to track the number of discrete floes and number of floe components, allowing us to separate floe growth by welding and floe growth by lateral expansion.

We use the joint floe size & ice thickness distribution: 
\[ f(r, h) dr dh \]

\( f(r, h) \) is the fraction of ocean covered by ice with thickness between \( h \) and \( h + dh \) and floe radius between \( r \) and \( r + dr \). The FSD emerges from the interaction of different physical processes:

- Advection
- Ripping/rafting
- Discharge
- Wave formation
- Vertical thermodynamics

We incorporated the coupled ocean-sea ice model, using forcing from atmospheric reanalysis and an ocean surface wave model hindcast

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- gained insight into the relative importance of various processes for simulation of the FSD
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- used observational results to inform new physical descriptions of FSD processes

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