SEA ICE RESEARCH IN THE DEEP SOUTH CHALLENGE

The Deep South National Science challenge has funded both sea ice observational research (Targeted Observation and Process-Informed Modelling of Antarctic Sea Ice (TOPIMASI)) and climate modelling research over nine years of the Challenge. With the evolution of this research, this programme has produced improvements to climate models, such as the physical core of the New Zealand Earth System Model (NZESM), which have built on the observational sea ice research [1].

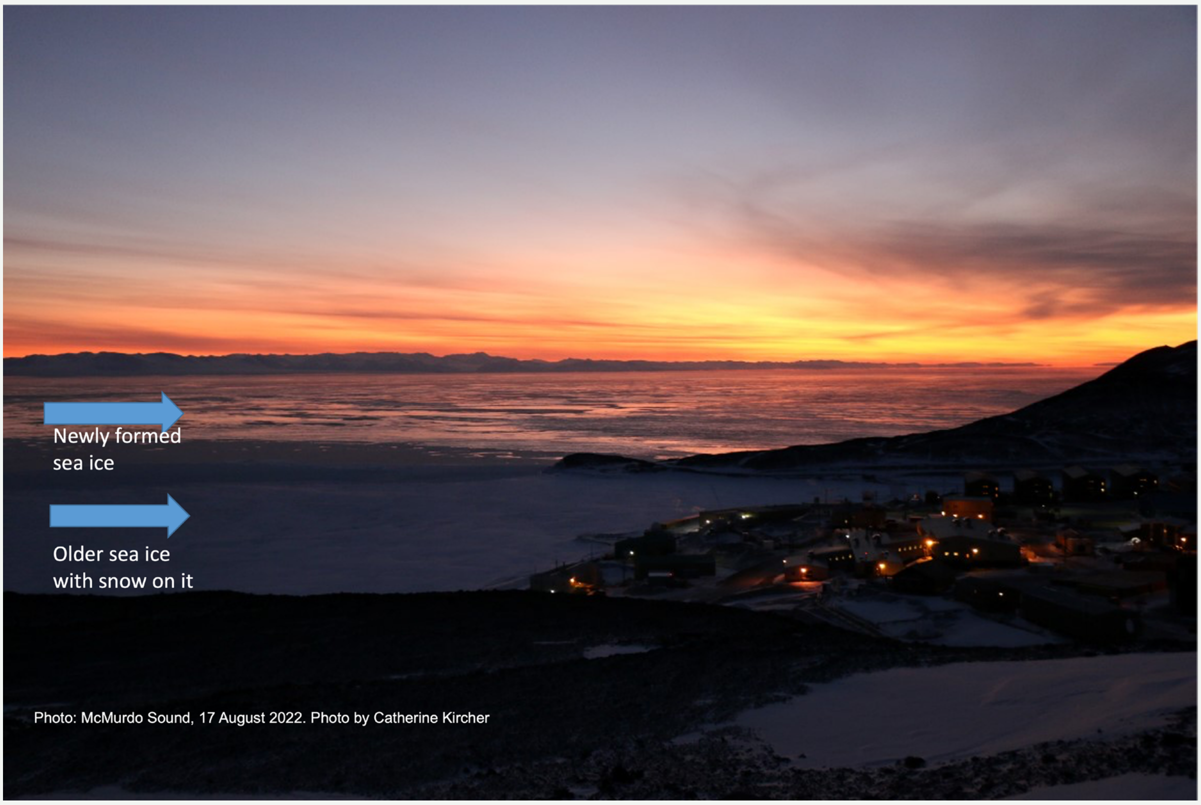


Photo: McMurdo Sound, 17 August 2022. Photo by Catherine Kircher

WHAT ARE WE TRYING TO UNDERSTAND?

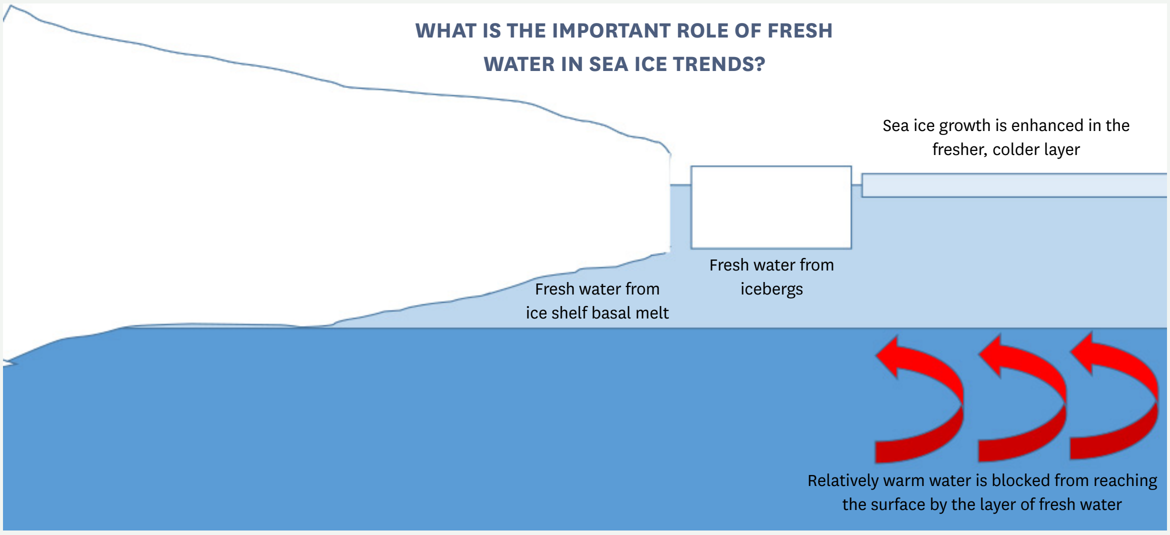
Climate models are missing fresh water input to the Southern Ocean from Antarctic ice sheet mass loss. Including this missing fresh water results in increased Antarctic sea ice and cooling over the Southern Ocean and further afield, but, this cooling is not included in temperature projections for global or New Zealand climate. We have run climate model simulations to quantify the effect of this missing process and have found it is important for Antarctic sea ice. Work to quantify the effects for New Zealand is ongoing.

WHAT IS SEA ICE?

Sea ice is the layer of frozen seawater covering the ocean surface at both poles. In Antarctica, the formation of sea ice each winter and subsequent melting each summer represents one of the largest seasonal changes on Earth. The areal coverage varies by about 16 million km² (about 60 times the area of New Zealand) between the summer and winter. Sea ice is important to global climate because it reflects sunlight, insulates the ocean, and drives cold, salty water into the deep oceans.

WHAT IS THE PROBLEM?

Climate models, our best tools for making projections of future climate, are at present unable to represent the changing amount of land ice in the Antarctic ice sheet. Antarctica is losing mass over time and, since models currently do not represent this, there is a missing source of fresh water to the Southern Ocean in the models. This missing fresh water has been proposed as a reason that models have failed to reproduce the observed trends in Antarctic sea ice. From 1979-2015 models showed declining Antarctic sea ice area, in contrast to the slight increase that actually occurred. Adding fresh water near the ocean surface increases the density gradient between the surface and deeper water, inhibiting vertical transport of relatively warm water from depth. The net result of this is surface cooling that extends over much of the Southern Ocean and further afield, and increased sea ice area. Because Antarctic mass loss is not represented in climate models, this cooling is also not a part of future temperature projections for the world or New Zealand. Our work as part of the Deep South National Science Challenge has been to investigate, using NeSI High Performance Computing resources, the effect of this missing fresh water on Antarctic sea ice trends and New Zealand climate in the UK Met Office's HadGEM3-GC3.1 climate model, which forms the physical core of the New Zealand Earth System Model (NZESM).



OUR WORK:

We have run simulations including the missing fresh water under pre-industrial control conditions[2] and in a scenario where atmospheric CO_2 increases by 1% each year[3]. Adding the fresh water results in greater Antarctic sea ice area relative to the simulation without it in both scenarios, and also results in a decline in Antarctic Bottom Water formation, highlighting the important role of Antarctic sea ice in the global ocean circulation. We have tested the effect of adding fresh water as either melting icebergs or basal melt of the ice shelves[2], and found that while the responses are similar, there is greater ocean warming at depth when the fresh water is added as basal melt.

In further work that was jointly funded by the Antarctic Science Platform, we have also found that adding fresh water was able to offset ocean warming due to increased atmospheric CO_2 over the continental shelf in several regions around Antarctica[4]. The magnitude of the effect depends on the specific continental shelf geometry, the climate state, and the vertical distribution of the fresh water.

Finally, we have been contributing simulations to the Southern Ocean Freshwater Input from Antarctica (SOFIA) initiative[5], an international model intercomparison that aims to better understand the climate response to the fresh water. We have conducted several of the model simulations outlined as part of the SOFIA protocol, and analysis and comparison to multiple other models from around the world is ongoing. Results from this model intercomparison will allow us to quantify the magnitude and uncertainty in the climate implications for New Zealand.

FOR MORE INFORMATION ABOUT THESE PROJECTS, SEE:

- Modelling Antarctic sea ice: https://deepsouthchallenge.co.nz/research-project/modelling-antarctic-sea-ice/
- Sea ice observational research: https://deepsouthchallenge.co.nz/research-project/antarctic-sea-ice/

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