



The White Knight: Ice Professor Helen Czerski

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Ice plays a critical role in shaping Earth's climate, but physical hazards and remote locations mean that most icy regions are relatively inaccessible to humans. The earliest polar science was done by western explorers who were often keen to emphasize the value of the environmental measurements they made. This was not without compromise: famously Captain Scott (with competing aims of geographical exploration, scientific measurements and being first) was beaten to the South Pole by Amundsen (whose primary focus was reaching the Pole). The most creative and original polar expedition was led by Fridtjof Nansen in 1893-1896, who designed a ship called Fram ("Forward") to be deliberately frozen into the Arctic Sea ice. The expedition succeeded in proving the existence of the Transpolar Drift and set a new record for the Furthest North, but failed to reach the North Pole. Over the 130 years since Nansen returned home, modern ships, satellites, underwater autonomous vehicles and a huge scientific effort have revealed the complexity of both ice itself and ice-dominated environments. Scientific progress on this topic is now more urgent than ever, as climate change reduces the quantity of ice on Earth before we fully understand what is being lost.

Ice Physics

Water ice has a number of very distinctive physical features that are critical to its function within the Earth system. Most significantly, water ice floats on the liquid it froze from, which is exceptionally unusual – almost all solids are more dense than the liquid they formed from and would therefore sink. This matters because the frozen ice stays at the surface, acting both to insulate the ocean surface and to reflect light. Pure ice is a very dramatic blue, but we rarely see that colour because whether ice is formed by the slow accumulation of snow or by the ocean surface freezing, it's full of internal channels, bubbles and boundaries. This internal structure strongly influences its reflectivity or "albedo", so sea ice reflects about 60% of the light falling on it while fresh snow reflects 90%. When sea ice freezes, it also rejects salt, effectively "unmixing" salt from the ocean and providing a mechanism for different water masses in the ocean to have different salinities. Finally, freezing and thawing water ice requires a colossal quantity of energy to be ejected or absorbed (known as "latent heat"). This allows ice to act as a buffer, limiting temperature change while storing or giving up energy.

Where ice is

Large quantities of ice are found as sea ice, glaciers, icebergs and ice sheets. Although glaciers are distributed around the world and are often an important water source for communities living downstream, we will focus here on polar ice. Together, the Arctic and Antarctic ice sheets contain more than 99% of the land ice and more than 68% of all the fresh water on Earth. However, they are dynamic systems, and although ice in the centre of these ice sheets can be very old, there is a constant exchange going on at the edges. Even if we were not warming the planet, icebergs would calve naturally as glaciers flow downwards under gravity to the ocean. However, climate change is threatening the stability of ice sheets. In recent

years, the news has covered enormous icebergs (which can be 100km long) breaking away from Antarctica and floating out into the ocean. They can last for several years, and recent science demonstrates that they change the environment around them, mixing nutrients upwards and causing phytoplankton blooms in their wake.

MOSAiC

The MOSAIC expedition took place over a year from September 2019 until September 2020, continuing through the pandemic (with some modifications to the original plan). The aim of this huge international experiment was to re-create Nansen's original drift experiment on Fram, freezing a ship into the sea ice in the Arctic ocean, and being carried by the Transpolar Drift for a whole year. One year was sufficient for this, both because there is less ice in the Arctic now than in 1893 and because modern icebreakers made it easier to control the entry and exit points. The German ship Polarstern was the centre of the experiment, but six other ships were involved in either working nearby or ferrying scientists to and from the drift site over the year. Overall 442 people took part, from 20 nations, following the Arctic sea ice, weather, biology and oceanography throughout the polar night. The data from this enormous effort is still being analysed and published, but it will provide an enormously valuable baseline for the years to come.

Changing Ice

We are all familiar with the general picture: sea ice is in dramatic decline as the climate warms, and there is a clear correlation between greenhouse gas emissions and sea ice loss. But we now know that the biology and chemistry of changing polar oceans also matter, not just the physics. In particular, as pollution increases dark particulates can settle on ice surfaces, causing it to absorb more solar energy and therefore warm. Understanding these feedbacks is critical for predicting the future, but the big message is clear: reducing greenhouse gas emissions is the most direct route to ensure that Earth's ice is still playing its role in the climate system in the future.

References and Further Reading

Nansen and the Fram

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MOSAiC

MOSAiC website: <https://mosaic-expedition.org/>

Blog with photos comparing the Fram 1893 expedition with MOSAiC: <https://framsenteret.no/retrospective-drifting-with-ice-from-the-schooner-fram-to-ultramodern-rv-polarstern/>

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