Max-Planck-Institut für Meteorologie

Sea Ice: The Great Melt in the Arctic

Arctic sea ice is disappearing notably faster than predicted by climate models. Will the Arctic Ocean soon be entirely ice-free in summer? What causes the great melt? Why are climate models (still) unable to reproduce the speed of the melting? The Max Planck Research Group "The Sea Ice in the Earth System", led by Dr. Dirk Notz, is trying to answer these questions experimentally and theoretically.

While this year's summer weather has been quite unsettled and rainy over Central Europe, unusually high air temperatures in the Arctic have caused a further decline in sea ice there. In July 2011, Arctic sea ice reached its lowest extent for this particular month since the beginning of reliable measurements (figure 1). Also in August, Arctic sea ice extent was at a record low, second only to August 2007. Because of this low sea ice extent and relatively thin ice the German research vessel "MS Polarstern" was able to reach the North Pole through thin first-year sea ice on 19 August without major problems. Because of the low extent, both the Northern Sea Route and the Northwest Passage were free of ice for several weeks.

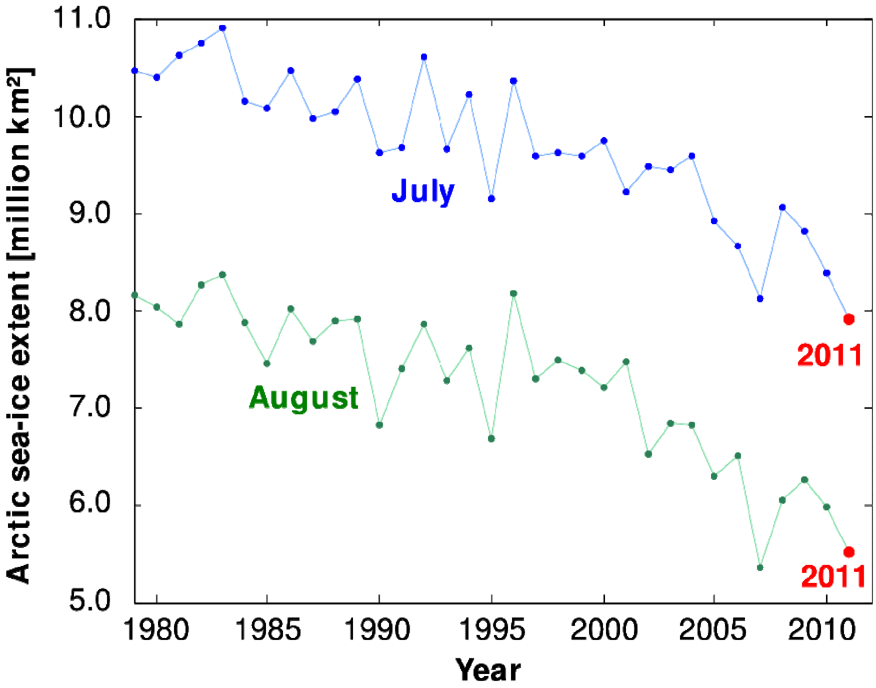

Fig. 1: Arctic sea ice extent (data: NSIDC, figure: D. Notz)

Interestingly, this low sea ice extent has not evoked any major media attention – corresponding news seemed out of place in the light of this rainy summer, some journalists said. But climatologically, July's Arctic sea ice record minimum is very important, says Dirk Notz: usually, sea ice serves as a solar mirror and reflects the incoming sunlight back into outer space – with a strong cooling effect for the Arctic region. If, like this year, this solar mirror is significantly reduced at a point in time when the sun is high in the sky around the clock, the cooling effect is much smaller.

The unusually large areas of open water take up significant amounts of heat, which in turn causes additional melt of the remaining ice at its bottom. The heat uptake by the ocean additionally delays the formation of new ice in autumn.

In this context, the members of the Max Planck Research Group “The Sea Ice in the Earth System” around Dirk Notz are investigating how this loss of sea ice influences the Arctic sea ice’s future evolution and why climate models are still largely incapable of realistically simulating the very quick sea-ice retreat.

According to Dirk Notz, one of the main reasons for this problem could be that climate models are not yet able to represent the development of the internal structure of so-called first-year sea ice properly. The term “first-year ice” refers to sea ice which forms in open water and has not yet survived an entire summer. Due to larger and larger open water areas in the Arctic, this particular type of ice is becoming more and more widespread whereas the area covered by multi-year ice that has survived one or more summers is decreasing rapidly. The ice models used in today’s climate models are primarily based on the characteristics of multi-year ice, which differ significantly from those of first-year ice.

In order to understand these differences, it is necessary to take a look at the internal structure of sea ice: sea ice is not a solid body throughout but consists of a complex mixture containing pure freshwater ice, liquid salty brine and gas inclusions. In first-year ice, the fraction of pure freshwater ice is considerably lower than in multi-year ice. Hence, less energy is needed to melt first-year ice compared to multi-year ice. But how much energy really is needed to melt ice of a certain thickness cannot be realistically simulated by climate models yet.

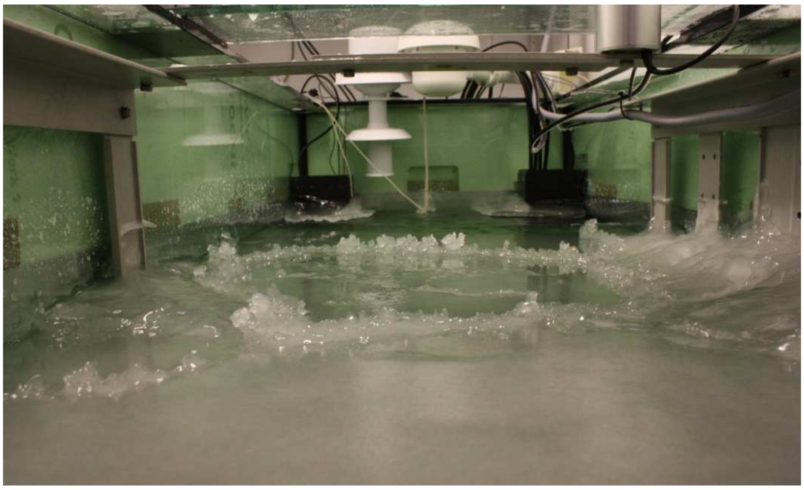

Fig. 2: Sea ice growth in the ice tank (photo by Ann Kristin Naumann)

To overcome this limitation, the Max Planck Institute’s Sea Ice Group is running an ice lab (figure 2) which allows for precisely measuring the development of the sea ice’s internal structure by using a worldwide unique instrument. This instrument can determine with a high spatial and temporal resolution how much pure ice there is in sea ice, which allows the researchers to improve their knowledge of the governing processes.

In a lab tank containing 1,500 litres of salt water the group is also studying the impact of wind, waves, currents and oceanic heat fluxes on the formation of ice in open water, and the subsequent development of the sea ice’s internal structure.

Based on such measurements, the group is currently developing a new sea-ice model which is able to better represent the sea ice's internal structure compared to previous models. This newly developed model also allows for more realistic simulations of the salt flux from sea ice into the ocean: the salty brine within the sea ice is not rigidly enclosed in the ice but can slowly flow into the underlying ocean, which changes the oceanic circulation because of the accompanying density change of the underlying water. The interplay of the escaping salty brine and the water underneath the ice is another piece of the puzzle that is not yet fully understood according to the sea-ice scientists.

To find out how model and lab results relate to reality, the Sea Ice Group carries out extensive field experiments. The largest experiment carried out by the group so far took place off the coast of Greenland in winter 2009/2010 (figure 3). During that experiment, the Max Planck researchers studied how first-year ice develops throughout the year, from its initial formation in winter to the melting in the following summer.

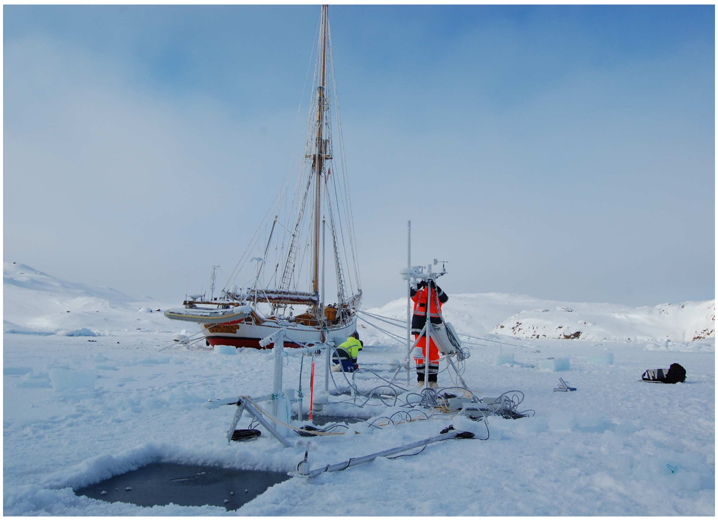

Fig. 3: In situ measurements off the coast of Greenland (photo by Dirk Notz)

By combining data gained from such field experiments with the new knowledge acquired in the lab and through the use of improved models, the work carried out by the Max Planck researchers will soon allow for better projections of the future evolution of sea ice. But already now it seems certain that this summer's records of low sea extent will not stand for very long. The decrease in Arctic sea ice will continue, leading to new record minima in the years to come.

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