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Dramatic changes in atmospheric circulation connected to the disappearance of sea ice

Martin Stendel (1), Shuting Yang (1), Peter Langen (1), Christian Rodehacke (1), Ruth Mottram (1), and Jens Hesselbjerg Christensen (2)

(1) Danish Meteorological Institute, Copenhagen, Denmark (mas@dmi.dk), (2) Niels Bohr Institute, University of Copenhagen, Denmark

Since medieval times, a “see-saw“ in winter temperatures between western Greenland and the Canadian Arctic on one side and north-central Europe on the other is well-known. It is associated with pressure anomalies (the North Atlantic Oscillation, NAO) not only near the region of interest, but over large parts of the Northern Hemisphere. Recent research has pointed out the role of sea ice in maintaining circulation anomalies, thus leaving the NAO and consequently the see-saw in either its positive or its negative phase over prolonged periods. This may affect the upper-tropospheric jet stream and thus have an effect on temperature and storm tracks over large parts of the Northern Hemisphere. Recent research has addressed the question whether these changes are triggered by the retreat of sea ice over the last few decades.

But what would happen if Arctic sea ice were to disappear completely? In the framework of the FP7-funded project ice2ice, we have tried to answer this and related questions. We have conducted a very long global simulation with a global climate model interactively coupled to a Greenland ice sheet component, covering the period 1850-3250 at a horizontal resolution of approximately 125 km. Up to 2005, the forcing comes from observed greenhouse gas concentrations, and from 2006 onward it follows the extended RCP8.5 scenario, in which greenhouse gas concentrations continue to increase and eventually level out around 2250. With such a strong forcing, all Arctic sea ice has completely disappeared by roughly the same time, and the mass balance of the Greenland Ice Sheet becomes strongly negative.

We investigate how the atmospheric circulation behaves in such an ice-free world. As the centers of action in the atmosphere in an ice-free world may not be located where they are found today, a tool is needed to extract diagnostic information from huge datasets without any a priori assumptions about the signal to be identified. Self-organizing maps (SOMs) have these properties, and we have conducted such a SOM analysis on daily 500 hPa fields for the entire 1400 year period and compared past and present-day climate with a seasonally and later a totally ice free Arctic. The changes in sea ice cover have a profound effect on the atmospheric circulation over large parts of the Northern Hemisphere and over extended time scales.