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Springtime atmospheric transport controls Arctic summer sea-ice extent

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The sea-ice extent in the Arctic has been steadily decreasing during the satellite remote sensing era, 1979 to present, with the highest rate of retreat found in September. Contributing factors causing the ice retreat are among others: changes in surface air temperature (SAT; Lindsay and Zhang, 2005), ice circulation in response to winds/pressure patterns (Overland et al., 2008) and ocean currents (Comiso et al., 2008), as well as changes in radiative fluxes (e.g. due to changes in cloud cover; Francis and Hunter, 2006; Maksimovich and Vihma, 2012) and ocean conditions. However, large interannual variability is superimposed onto the declining trend - the ice extent by the end of the summer varies by several million square kilometer between successive years (Serreze et al., 2007). But what are the processes causing the year-to-year ice variability?

A comparison of years with an anomalously large September sea-ice extent (HIYs - high ice years) with years showing an anomalously small ice extent (LIYs - low ice years) reveals that the ice variability is most pronounced in the Arctic Ocean north of Siberia (which became almost entirely ice free in September of 2007 and 2012). Significant ice-concentration anomalies of up to 30% are observed for LIYs and HIYs in this area. Focusing on this area we find that the greenhouse effect associated with clouds and water-vapor in spring is crucial for the development of the sea ice during the subsequent months. In years where the end-of-summer sea-ice extent is well below normal, a significantly enhanced transport of humid air is evident during spring into the region where the ice retreat is encountered. The anomalous convergence of humidity increases the cloudiness, resulting in an enhancement of the greenhouse effect. As a result, downward longwave radiation at the surface is larger than usual. In mid May, when the ice anomaly begins to appear and the surface albedo therefore becomes anomalously low, the net shortwave radiation anomaly becomes positive. The net shortwave radiation contributes during the rest of the melting season to an enhanced energy flux towards the surface.

These findings lead to the conclusion that enhanced longwave radiation associated with positive humidity and cloud anomalies during spring plays a significant role in initiating the summer ice melt, whereas shortwave-radiation anomalies act as an amplifying feedback once the melt has started.

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