



## **Anomalous slow sea ice recovery in fall and winter 2016 by an extreme warming event in mid-latitudes**

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Satellite observations have revealed that Arctic sea ice extent have continuously diminished since the late 1970s. Since 2002, sea ice anomaly starts to be highlighted. The Arctic sea ice extent in September 2002 was the lowest since 1978 due to anomalous southerly warm winds and ice divergence by consistent low pressure and high temperatures in the Arctic. The sea ice anomaly in September continues in 2007 and 2012 as well. The higher sea surface temperature (SST) and the fraction of open water were likely to contribute to the sea ice extent anomaly in September 2007. A considerable attention focused on sea ice extent in September 2012 owing to the historical minimum extent,  $3.4 \times 10^6$  km<sup>2</sup>. Preconditioned sea ice and a strong storm in the central Arctic in August 2012 were identified as major reasons for the lowest sea ice extent.

Arctic sea ice in the winter season has experienced anomalous phenomena as well. Strong winds bring humid and warm air from the Atlantic Ocean to the Arctic in January and February 2005-2006. Especially, a strong cyclonic-storm contributed to sea ice anomaly around Barents, Kara Seas in winter 2015-2016. The anomalous atmospheric conditions in the winter season considerably delay ice growth, accelerating melt following spring and summer seasons. For example, the sea ice extents in January, February, and April 2017 were recorded as minimum, which are apparently influenced by sea ice minimum anomaly in fall and winter 2016. Anomalous sea ice conditions in the fall and winter seasons should be further investigated to increase predictability of sea ice in the spring season and to better understand the nature of sea ice anomaly in the fall and winter seasons.

The objective of this study is to investigate Arctic sea ice anomaly in November 2016, which is strongly connected to extreme warming in mid-latitudes and atmospheric circulation from August to October 2016. Sea ice concentration and CryoSat-2-derived sea ice thickness are used to represent the monthly characteristics of sea ice. Atmospheric circulation is examined by Modern-Era Retrospective Analysis for Research Applications version 2 (MERRA-2) atmospheric reanalysis. The SST data was also used to identify warming from the Pacific and Atlantic oceans. The results show that there are four major reasons for sea ice minimum extent in November 2016: 1) preconditioned sea ice, 2) extreme warming in mid-latitudes, 3) warm southerly winds with a strong cyclonic storm, and 4) high SST. Various factors influenced on sea ice anomaly in November 2016. In addition to extreme warming, global climate modes such as Arctic Oscillation (AO) and Northern Atlantic Oscillation (NAO) were also investigated with sea ice anomaly in November 2016.