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Dynamics and drivers of extreme seasons in the Arctic region

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Single extreme weather events such as intense storms or blocks can have a major impact on polar surface temperatures, the formation and melting rates of sea-ice, and, thus, on minimum and maximum sea-ice extent within a particular year. Anomalous weather conditions on the time scale of an entire season, for example resulting from an unusual sequence of storms, can affect the polar energy budget and sea-ice coverage even more. Here, we introduce the concept of an extreme season in a distinct region using an EOF analysis in the phase space spanned by anomalies of a set of surface parameters (surface temperature, precipitation, surface solar and thermal radiation and surface heat fluxes). To focus on dynamical instead of climate change aspects, we define anomalies as departures of the seasonal mean from a transient climatology. The goal of this work is to study the dynamical processes leading to such anomalous seasons in the polar regions, which have not yet been analysed. Specifically, we focus here on a detailed analysis of Arctic extreme seasons and their underlying atmospheric dynamics in the ERA5 reanalysis data set.

We find that in regions covered predominantly by sea ice, extreme seasons are mostly determined by anomalies of atmospheric dynamical features such as cyclones and blocking. In contrast, in regions including large areas of open water the formation of extreme seasons can also be partially due to preconditioning during previous seasons, leading to strong anomalies in the sea ice concentration and/or sea surface temperatures at the beginning of the extreme season.

Two particular extreme season case studies in the Kara-Barents Seas are discussed in more detail. In this region, the winter of 2011/12 shows the largest positive departure of surface temperature from the background warming trend together with a negative anomaly in the sea ice concentration. An analysis of the synoptic situation shows that the strongly reduced frequency of cold air outbreaks compared to climatology combined with several blocking events and the frequent occurrence of cyclones transporting warm air into the region favored the continuous anomalies of both parameters. In contrast, the winter of 2016/17, which shows a positive precipitation anomaly and negative anomaly in the surface energy balance, was favored by a strong surface preconditioning. An extremely warm summer and autumn in 2016 caused strongly reduced sea ice concentrations and increased sea surface temperatures in the Kara-Barents Seas at the beginning of the winter, favoring increased air-sea fluxes and precipitation during the following months.

Our results reveal a high degree of variability of the processes involved in the formation of extreme seasons in the Arctic. Quantifying and understanding these processes will also be important when considering climate change effects in polar regions and the ability of climate models in reproducing extreme seasons in the Arctic and Antarctica.