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Identification, characteristics, and dynamics of Arctic extreme seasons in ERA5 and CESM climate simulations

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The Arctic atmosphere is strongly affected by anthropogenic warming leading to long-term trends in surface temperature and sea ice extent. In addition, it exhibits strong variability on time scales from days to seasons. While recent research elucidated processes causing long-term trends as well as synoptic extreme conditions in the Arctic, we investigate unusual atmospheric conditions on the seasonal time scale. We introduce a method to identify extreme seasons – deviating strongly from a running-mean climatology – based on a principal component analysis in the phase space spanned by the seasonal-mean values of surface temperature, precipitation, and the atmospheric components of the surface energy balance. Given the strongly varying surface conditions in the Arctic, this analysis is done separately in Arctic sub-regions that are climatologically characterized by either sea ice, open ocean, or mixed conditions.

Using ERA5 reanalyses for the years 1979-2018, our approach identifies 2-3 extreme seasons for each of winter, spring, summer, and autumn, with strongly differing characteristics and affecting different Arctic sub-regions. Results will be shown for two contrasting extreme winters affecting the Kara and Barents Seas, including their substructure, the role of synoptic-scale weather systems, and potential preconditioning by anomalous sea ice extent and/or sea surface temperature at the beginning of the season.

To statistically quantify and confirm these results, we further apply our method to large ensemble simulations of the CESM climate model, using roughly 1000 years of data in present-day (1990-2000) and end-of-century (2091-2100) climate, respectively. Results show a strong similarity between the characteristics of extreme seasons in ERA5 and CESM for the present-day period. The identified seasons predominantly show the most extreme seasonal-mean anomalies of the applied surface parameters, confirming that our approach captures seasons with extraordinary conditions. Preliminary results will also be shown about our current investigation of possible changes in the characteristics and driving mechanisms of Arctic extreme seasons in the warmer end-of-century climate.

The framework developed in this study and the insight gained from analyzing both, reanalysis and climate model data, will be insightful for better understanding the effects of global warming on Arctic extreme seasons.