Dynamics and drivers of extreme seasons in the Arctic region

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Arctic extreme **season** =

Combination of considerable seasonal anomalies of several parameters over a sizable area in the Arctic region. Here, we focus on surface variables, namely, 2m-temperature, surface energy balance and freshwater fluxes.

Research Questions:

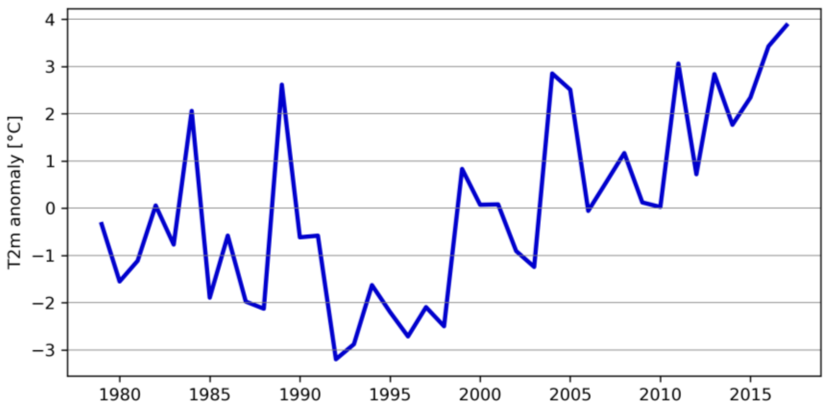
→ What is the temporal sub-structure of an Arctic extreme season?

→ What are the dynamical drivers?

→ What ist the relative importance of different processes?

Why in the **Arctic**?

- Rapid surface warming and sea-ice decline in last decades → Arctic Amplification
- Large internal variability



Seasonal T2m anomaly (DJF) for > 80°N (ERA5 reanalysis data, ECMWF)

Method (1/2): Data & Definition of Regions

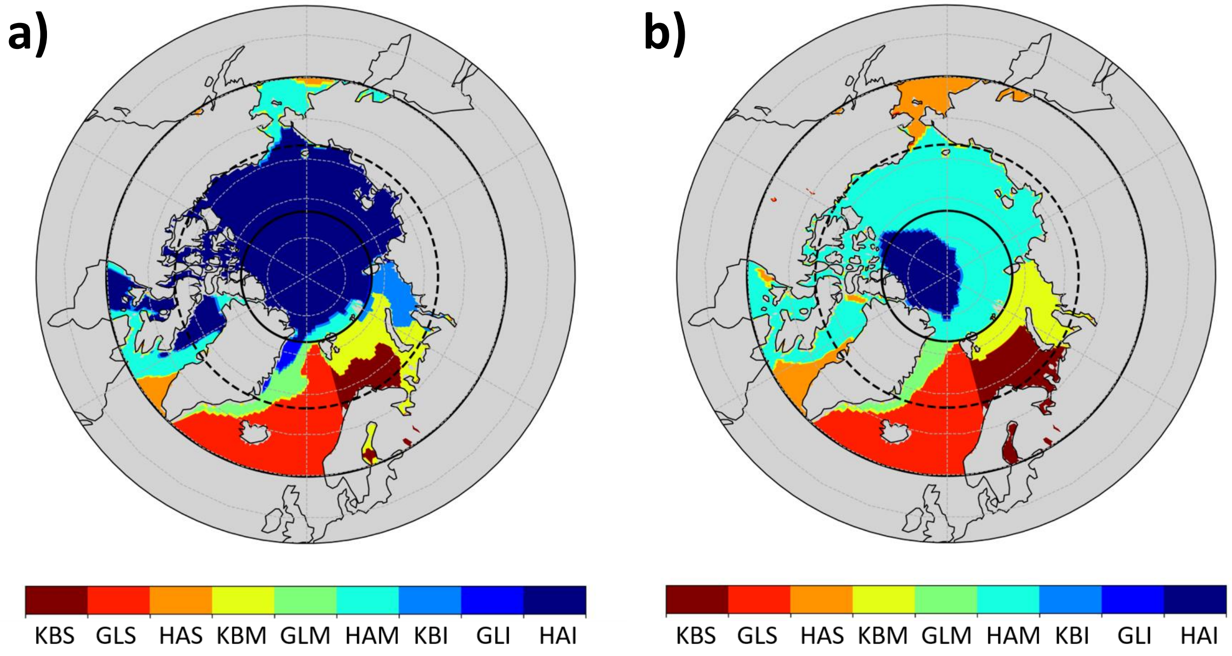
Data: ERA5 reanalysis data from ECMWF
- 1979-2018, 1h temporal resolution
- 0.5°x0.5° horizontal grid, 137 vertical levels

→ In this project we consider anomalies defined as deviations from a transient climatology. The transient climatology is computed using a 21-day running mean filter and 9-year running mean.

Division of Arctic into distinct subregions:

- Greenland Sea (GL), Kara-Barents Seas (KB) and Residual part (including High Arctic, HA)
- Considering surface conditions according to the climatological sea-ice concentration (SIC_{clim}):

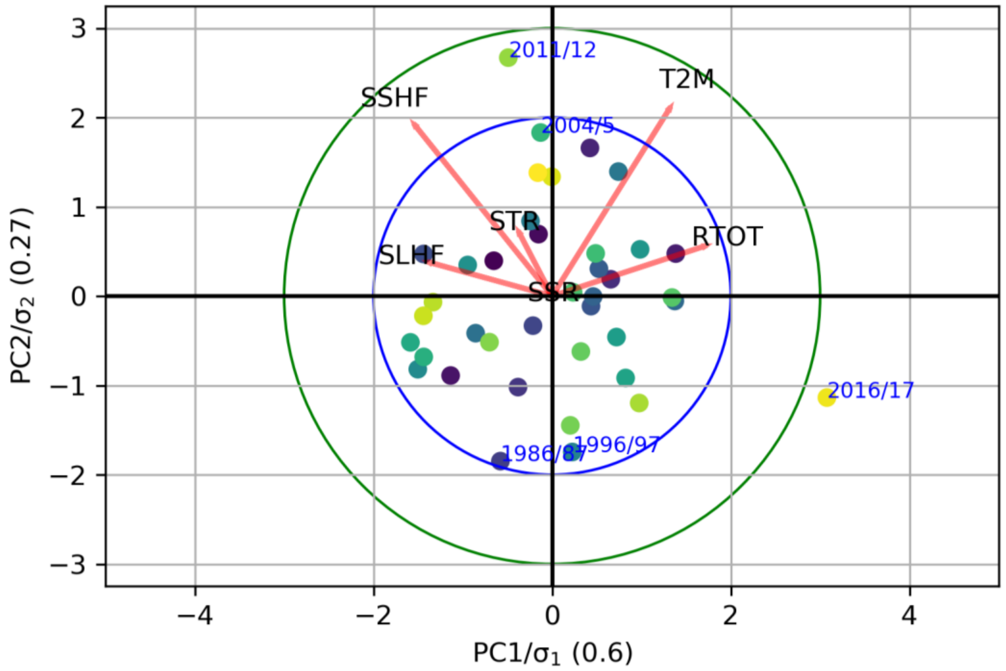
Ice (I): $SIC_{clim} > 0.9$
Sea (S): $SIC_{clim} < 0.1$
Mixed (M): SIC_{clim} between 0.1 and 0.9



Subregions defined based on sea-ice criterion (color) for (a) DJF and (b) JJA. Black lines show 60° and 80° latitude, respectively, black dashed-line shows 70° latitude.

Method (2/2): Definition of Extremeness

Arctic extreme seasons during the ERA5 period in each subregion are defined by analysing the seasonal anomalies of six parameters: 2m-temperature (**T2m**), surface sensible heat flux (**SSHF**), surface latent heat flux (**SLHF**), surface solar radiation (**SSR**), surface thermal radiation (**STR**) and total precipitation (**RTOT**).



PCA biplot for region KBM (Kara-Barents mixed) in DJF. PC1 component normed by its standard deviation σ_1 is shown along x-axis, PC2 component (normed by σ_2) along y-axis (in brackets percentage of explained variance by PC1 and PC2). Each dot corresponds to a single season, colored chronologically. Red lines represent the coefficients of the original parameters. Blue (green) circle represents ED=2 (ED=3).

PCA analysis

[as parameters are often correlated, dependent on the surface conditions]

→ Seasonal anomalies from DJF 1979/80 until 2017/18

→ Normalization with the intra-seasonal standard deviation (scaling variables SSHF, SLHF, SSR and STR by the maximum standard deviation of the individual parameters)

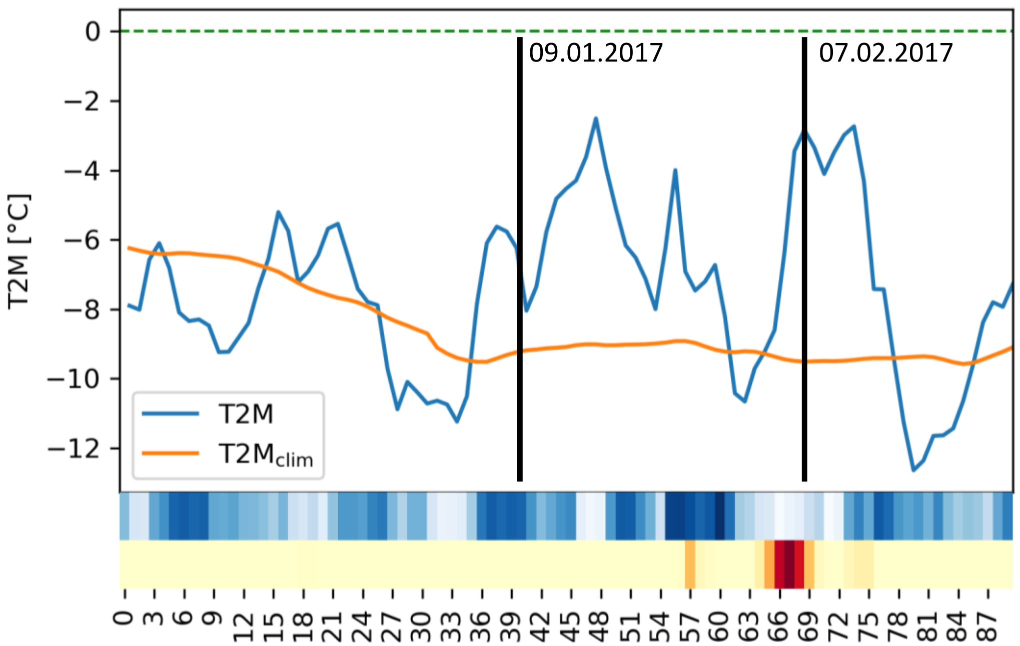
→ Reducing to 2-dimensional space

→ Define anomalous and extreme seasons, respectively, according to their combination of PC1 and PC2:

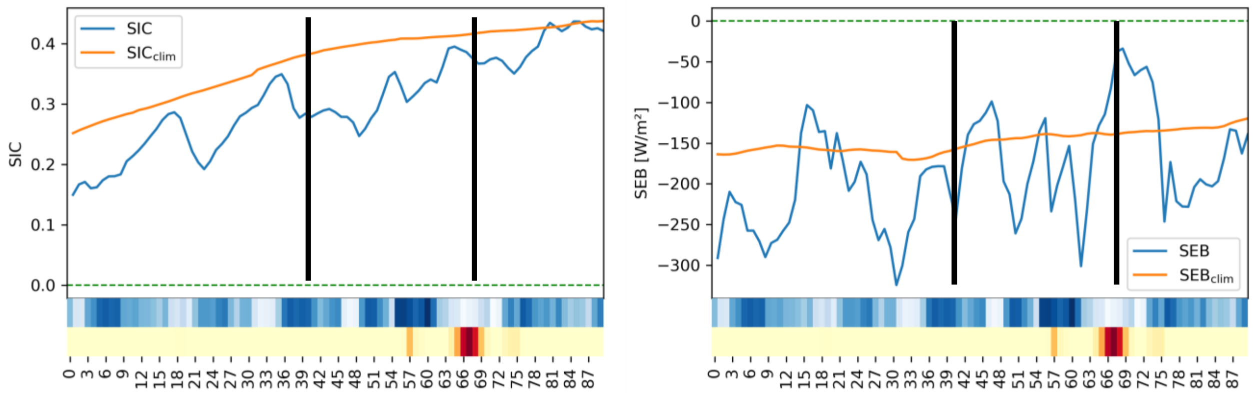
Euclidian distance in PCA biplot: ED = $\sqrt{\frac{PC1^2}{\sigma 1^2} + \frac{PC2^2}{\sigma 2^2}}$

Case Study (1/2): Overview

DJF 2016/17 occurs as extreme season in the Kara-Barents Seas



Daily mean T2m in °C (blue line) and running mean climatology (orange line) during DJF 2016/17 for the Kara-Barents Seas. Blue bars show daily mean coverage of the region by a cyclone [1]. Orange bars show daily mean coverage of the region by blocking [2,3] (the darker the color the higher the coverage).

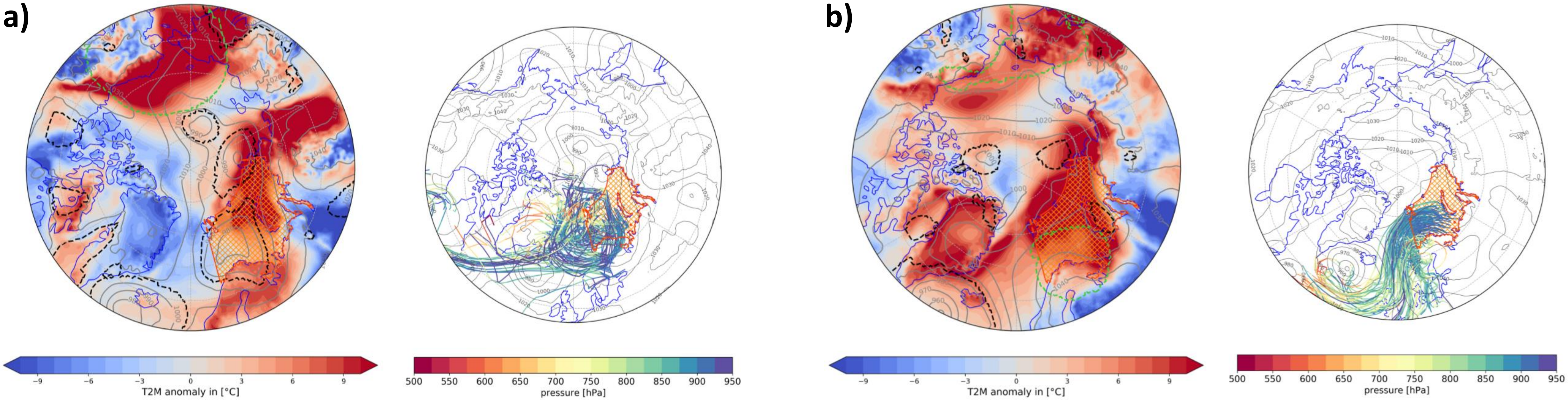


Daily mean sea-ice concentration (SIC, left panel) and surface energy balance (SEB) in W/m² (right panel) compared to running mean climatology during DJF 2016/17 for the Kara-Barents Seas.

Results:

- Several episodic warm events, deviating more than 5K from the climatological mean surface temperature
- SEB consistent with T2m changes, slightly positive trend
- SIC lower than usual, formation of SIC stagnating or even decreasing during warm events
- Due to negative SIC anomaly enhanced energy loss due to heat fluxes → trend in SEB anomaly

Case Study (2/2): Synoptic Situation



Left panel: Daily T2m anomaly in °C (colored); sea-level pressure (SLP, grey contour), cyclone mask (dashed black contour) and blocking mask (dashed green contour) at 00 UTC for (a) 09.01.2017 and (b) 07.02.2017. Region of Kara-Barents Seas is marked with orange grid. Right panel: SLP (grey contour) and 5-day backward trajectories (colored according to pressure) started at the respective time steps from gridpoints with T2m>0°C at 900hPa.

Warm event in January:
→ Sequence of multiple cyclones, transporting warmer air from the southwest towards KB-Seas (similar e.g. in [4,5]).

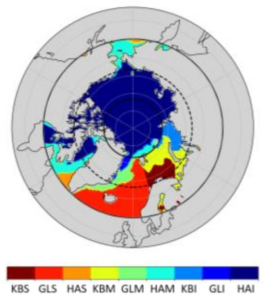
Warm event in first half of February:
→ Blocking in southern part of KB-Seas, transport of air from the south, possibly subsidence-induced adiabatic warming and increased STR (similar e.g. in [6,7]).

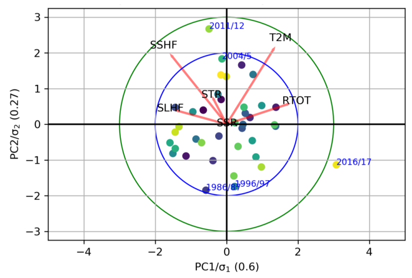
Conclusion: Single warm events during the season were driven by different synoptic processes. The accumulation of several such events made the season especially extreme.

Summary and Outlook

Summary:

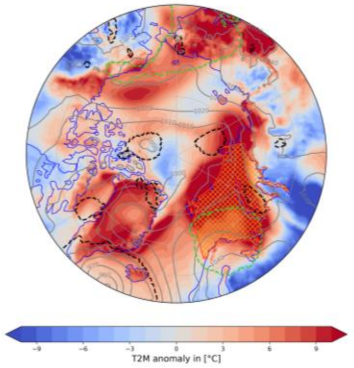
→ Novel approach to identify extreme seasons in the Arctic based on seasonal anomalies of surface temperature, precipitation, surface heat fluxes and surface radiation in distinct regions

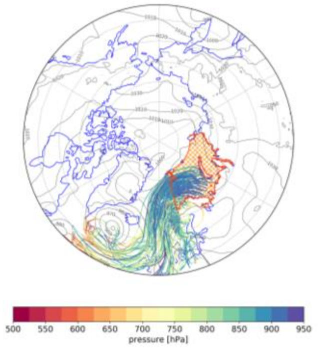




→ DJF 2016/17: several warm events (duration ~5-10 days) lead to extraordinary winter in Kara-Barents Seas, driven by different synoptic processes:

- Persistent transport of relatively warm air from lower latitudes by cyclones
- Ural blocking favouring advection of low-latitude air masses as well as subsidence-driven adiabatic warming





Outlook:

- Ongoing analysis of the large-scale features for the presented case study in combination with backward trajectories
- Additional case studies of other Arctic extreme seasons
- Quantification of the relative importance of different processes such as warming induced by meridional transport or subsidence

Contact:
If you have any questions, comments or ideas, please leave a comment or contact Katharina Hartmuth.

References

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