SUPPLEMENTAL MATERIAL

Cold wintertime air masses over Europe: Where do they come from and how do they form?

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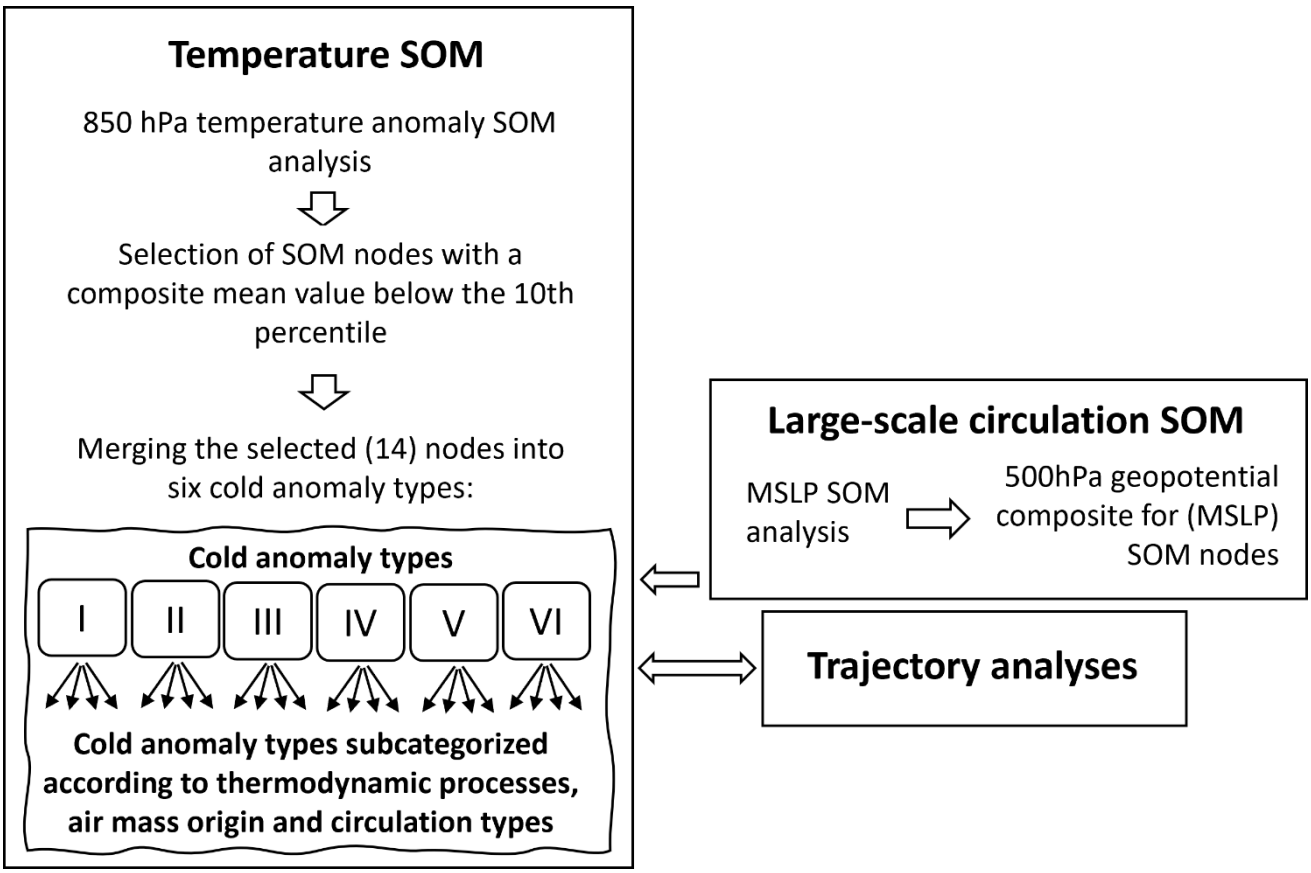
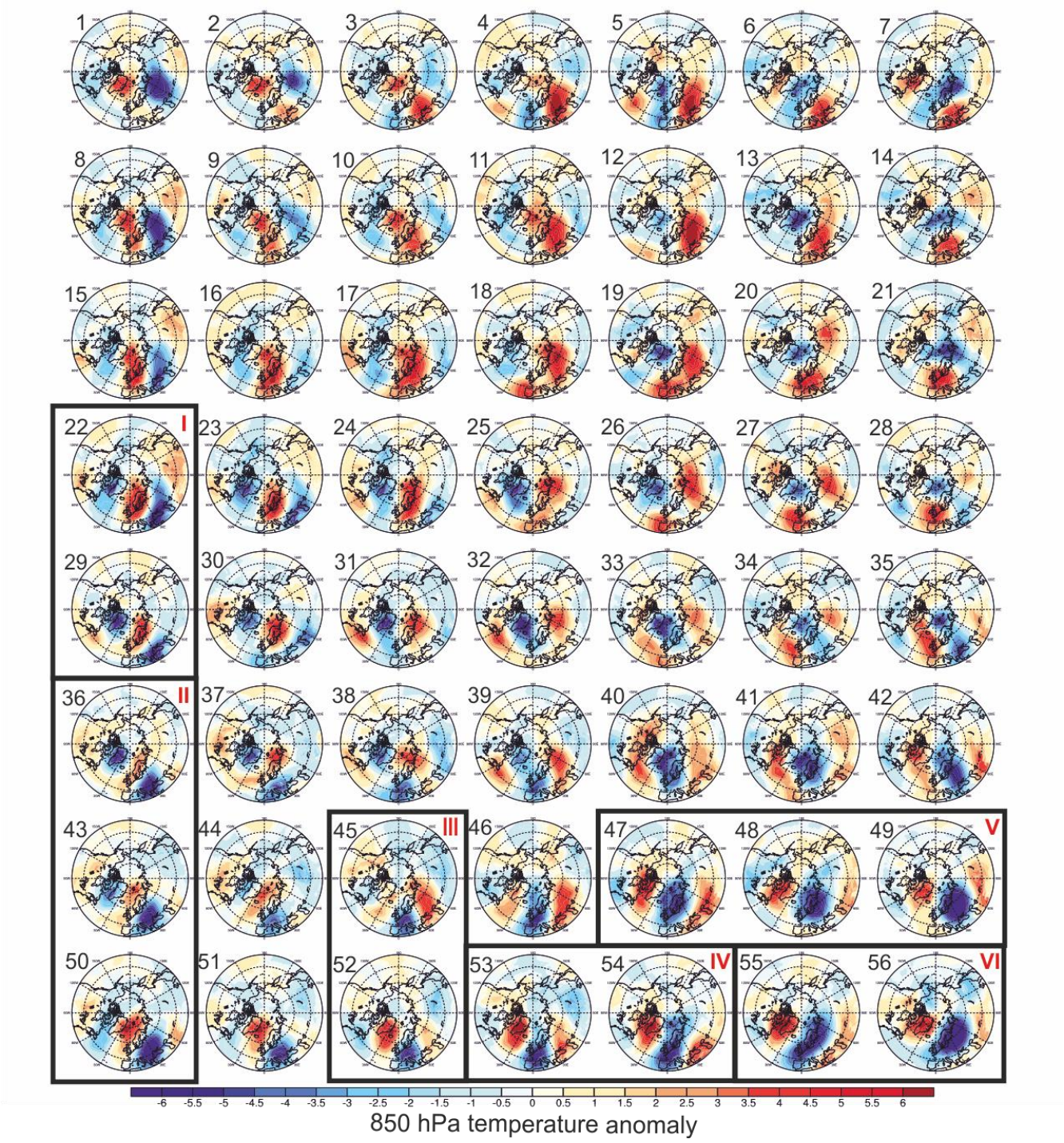
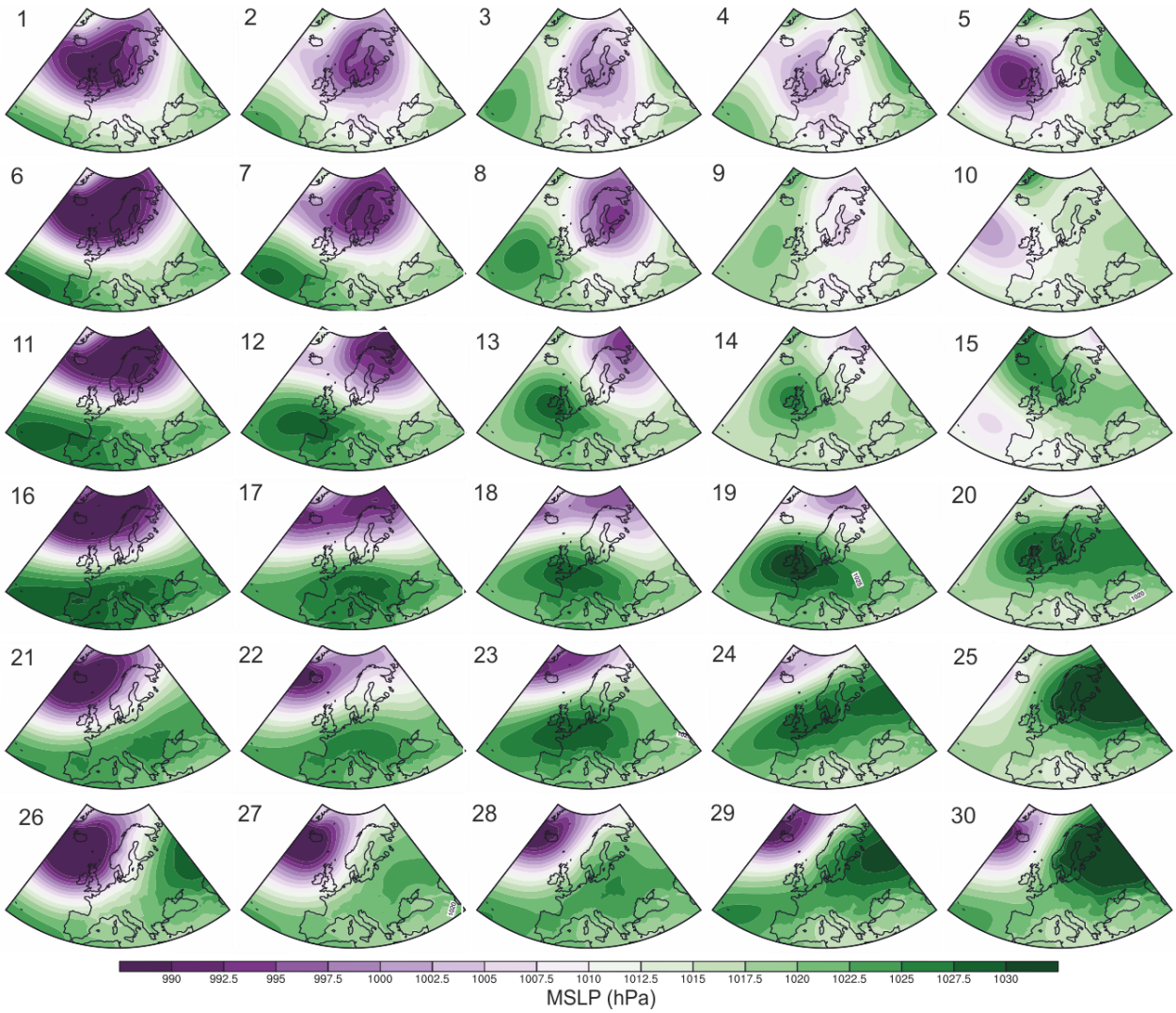


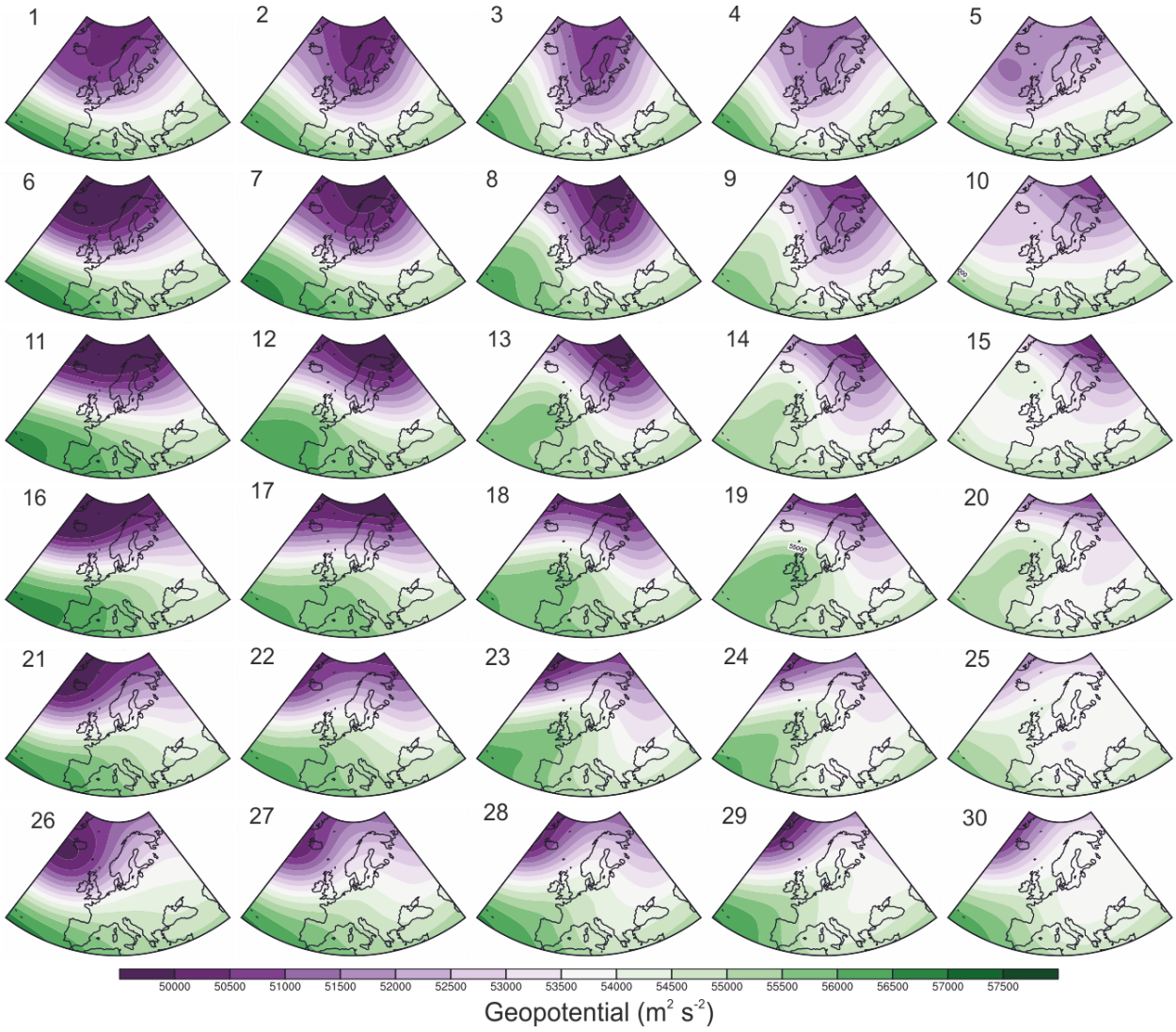
Supplementary Fig. 1 Overview of the methods used in the paper.



Supplementary Fig. 2 A 7 x 8 SOM composite array of daily 850 hPa temperature anomalies in November–March 1979–2020 over the circumpolar region north of 35°N. Note that the SOM analysis is only made for Europe (see the region in Fig. 2). Anomalies outside Europe thus indicate connections with anomalies over Europe. The six cold anomaly types (I-VI) of Europe are marked.



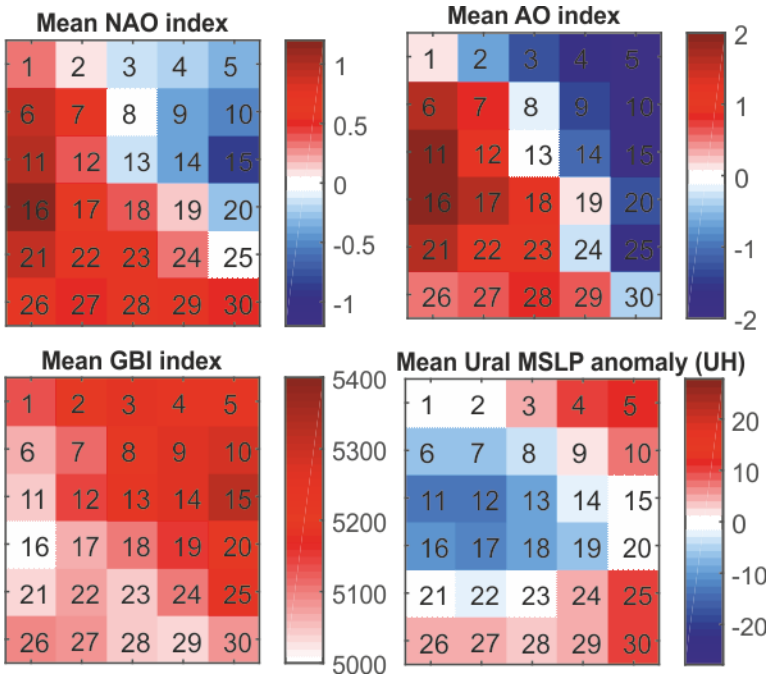
Supplementary Fig. 3 A 5 x 6 SOM composite array of daily mean sea level pressure in November–March 1979–2020.



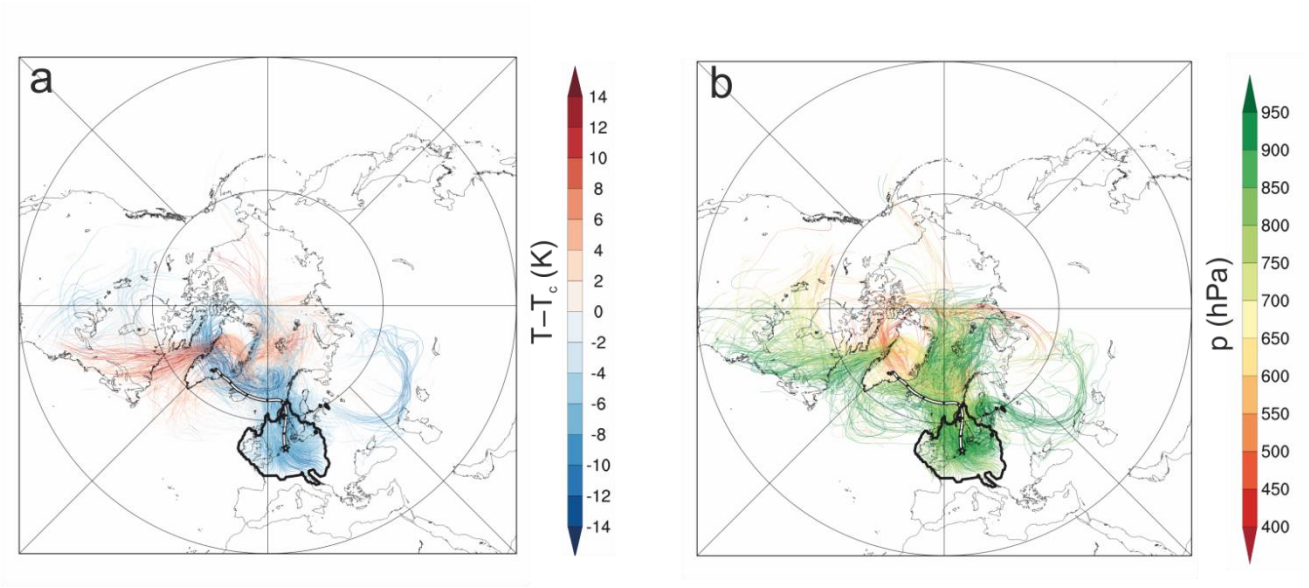
Supplementary Fig. 4 A 5 x 6 SOM composite array of daily mean 500 hPa geopotential in November–March 1979–2020.

Climate indexes linked to circulation types

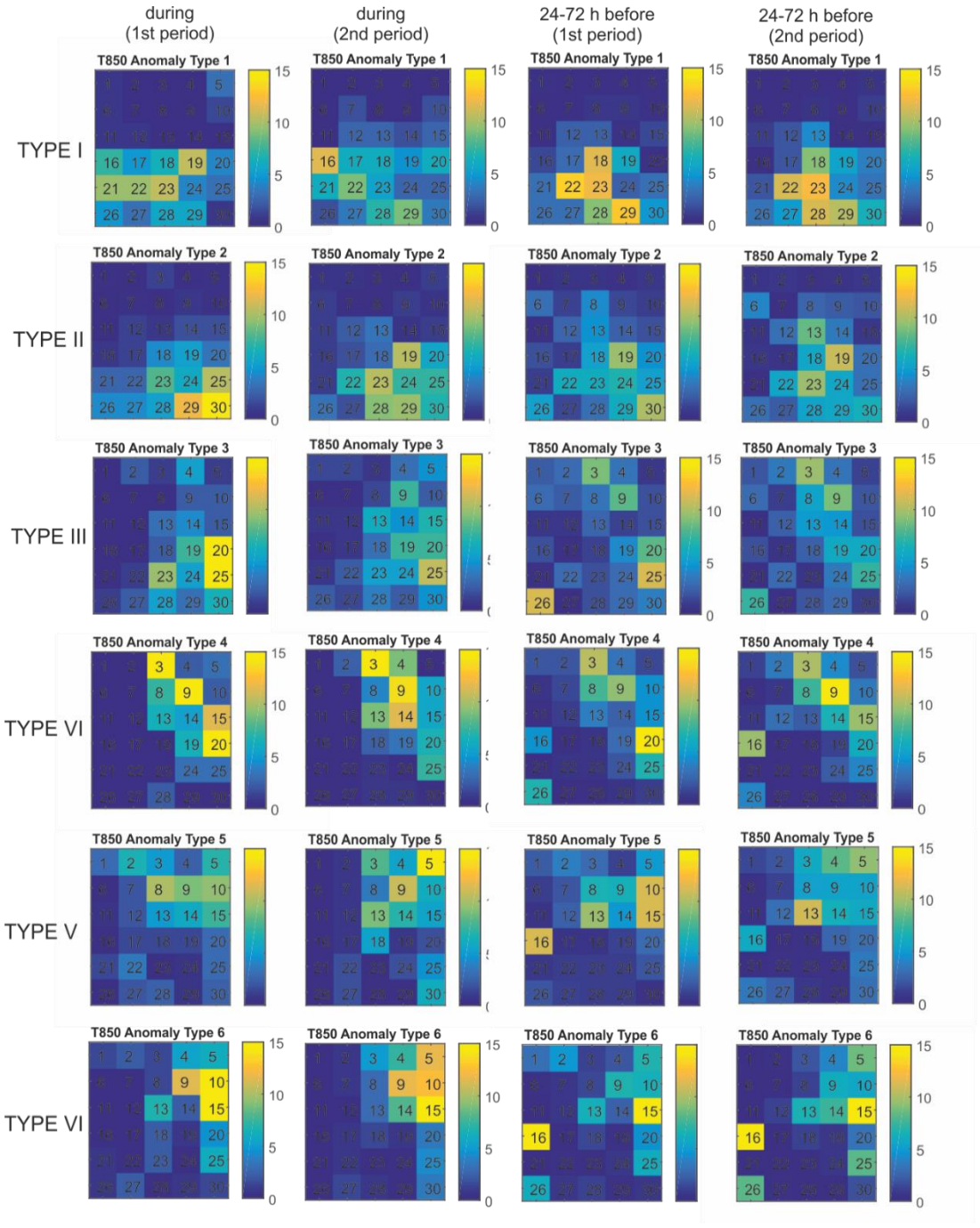
Mean NAO and AO index in each SOM circulation type was calculated from the daily values obtained from the websites of Climate Prediction Center of National Oceanic and Atmospheric Administration (NOAA) (https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml, https://ftp.cpc.ncep.noaa.gov/cwlinks/norm.daily.ao.index.b500101.current.ascii, last visit 30 May 2022). Similarly, daily values of the Greenland blocking index (GBI), defined as the 500 hPa geopotential height averaged over the region 60-80°N, 20-80°W, was obtained from NOAA (https://psl.noaa.gov/gcos_wgsp/Timeseries/Data/gbi.day.data, last visit 25 October 2022). The Ural high (UH) was estimated based on MSLP fields for the region 55°–70°N, 40°–80°E, following the method of Sui et al. (2022). The seasonal cycle of Ural MSLP, based on ±5 days running mean, was removed. Positive MSLP anomalies in SOM circulation type composites for the Ural region were considered as UH, but none of the SOM composite anomalies exceeded the threshold of 27.8 hPa, defined by Sui et al. (2022) for the UH.



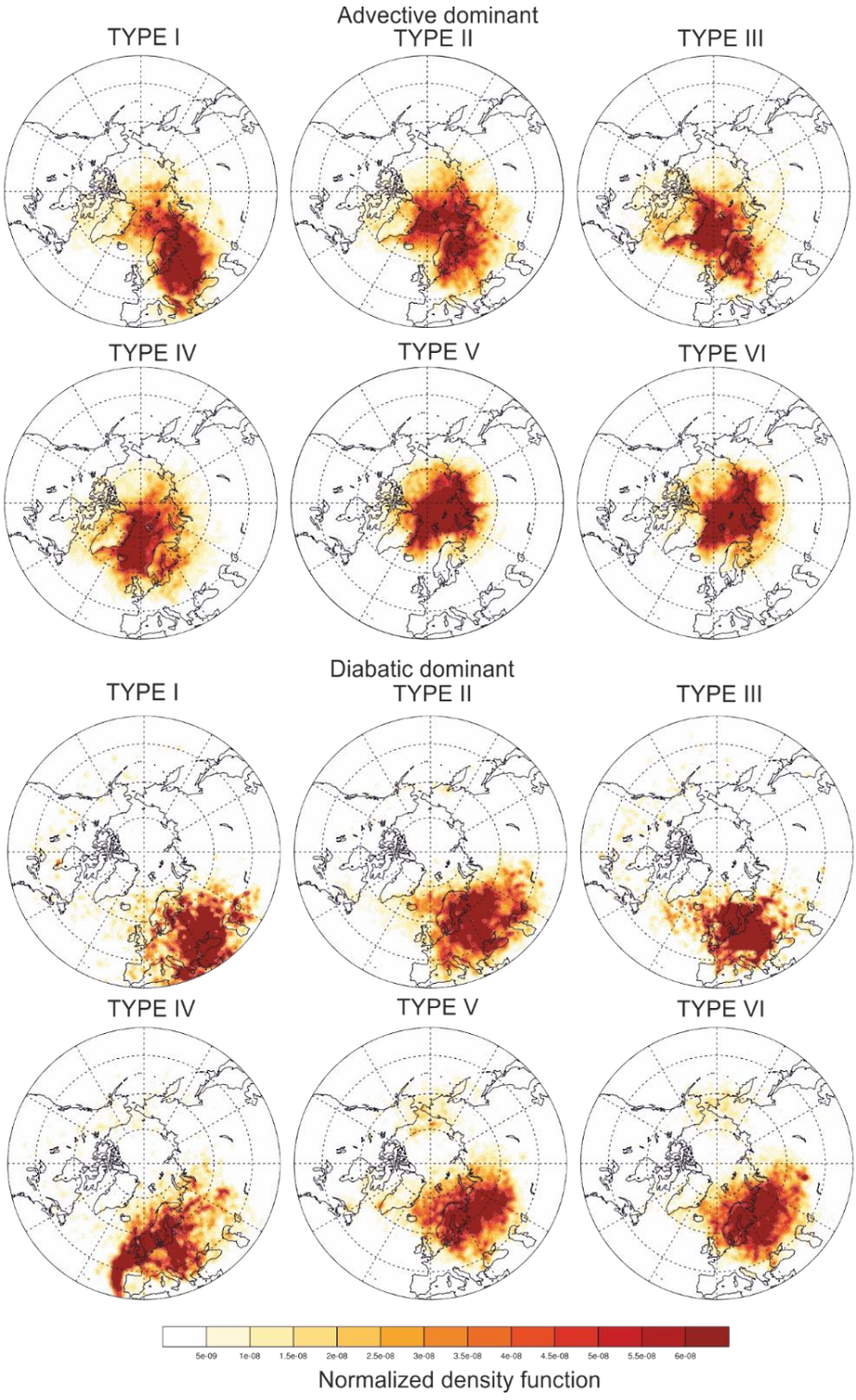
Supplementary Fig. 5 Mean NAO (left top), AO (right top), GBI index (left down) and mean Ural MSLP anomaly, representing UH, (right down) linked to MSLP (and 500 hPa geopotential) SOM patterns. Numbers (1–30) refer to MSLP SOM node numbers in Supplementary Fig. 3 (and to 500 hPa geopotential SOM composite in Supplementary Fig. 4).



Supplementary Fig. 6 (a) Evolution of the temperature anomaly ($T–T_C$), and (b) pressure along backward trajectories (10 days) associated with a cold anomaly event on 31 March 1996 (cold anomaly Type IV). The region indicated by a black line is the cold anomaly region (where 850 hPa temperature was lower than the 10^{th} percentile) of this event. Trajectory ensemble end points are at the 850 hPa level in the marked cold anomaly region. The end point regions were determined for each individual case separately, by taking the area with 850 hPa temperature being lower than the 10^{th} percentile. The centroid trajectory is marked with a thick line and black dots indicate the air parcel position in daily intervals.



Supplementary Fig. 7 Relative distribution of circulation types during (two columns on the left) and 24–72 h before the start of (two column on the right) the six cold anomaly types. Results for 1979–1999 (firstperiod) and 2000–2020 (second period) are shown separately. Numbers (1–30) refer to MSLP SOM node numbers in Fig. 3 (and in 500 hPa geopotential SOM composite in Supplementary Fig. 4).



Supplementary Fig. 8 Normalized density of trajectory positions at the time of cold anomaly genesis for advective dominant and diabatic dominant trajectories in each cold anomaly type (Types I–VI).