Supplementary material for

Arctic lower tropospheric warm and cold extremes: horizontal and vertical transport, diabatic processes, and linkage to synoptic circulation features

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• Supplementary figure S1: Climatological potential temperature at 50 hPa AGL
• Supplementary figure S2: Inter-annual variability of trajectory categories
• Supplementary figures S3 and S4: Sensitivity of air mass classification to time horizon
1 Climatological potential temperature at 50 hPa AGL

Figure 1: Climatological potential temperature at 50 hPa AGL for (a) winter and (b) summer.
Inter-annual variability of trajectory categories

Figure 2: Fraction of trajectories in each category for (a, b) wintertime and (c, d) summertime extreme (a, c) cold and (b, d) warm anomalies separately for the periods 1979 - 1991 (left bars), 1992 - 2004 (middle bars), and 2005 - 2017 (right bars).
3 Sensitivity of air mass classification to time horizon

Sensitivity tests for the classification of the air masses are performed based on the time horizon used for the determination of $\Delta \theta$ and $\Delta T$. Specifically, the classification using the full 10 days (as in the study) is compared to using the final 8, 6, or 4 days only (Fig. 3). Three important observations can be made:

1. In terms of cold extremes, there is a decrease in the fraction of $\Delta \theta - \Delta T^-$ trajectories in both seasons when a shorter time horizon is used. This decrease is compensated by an increase in the fractions of the other three categories.

2. The fraction of $\Delta \theta + \Delta T^+$ trajectories associated with warm extremes is barely affected by the choice of time horizon.

3. The fraction of $\Delta \theta - \Delta T^+$ trajectories decreases with shorter time horizons in both seasons, compensated by an according increase in the fraction of $\Delta \theta - \Delta T^-$ trajectories.

It is crucial to note that with a change of the time horizon, also the physical nature of the categories of

Figure 3: Fraction of trajectories in each category for (a, b) wintertime and (c, d) summertime extreme (a, c) cold and (b, d) warm anomalies using (from left to right) the 10, 8, 6, and 4 days prior to arrival in the high Arctic for the classification of trajectories.
trajectories changes. To illustrate this point, Fig. 4 shows $\theta - T$ diagrams for the groups of trajectories obtained if a time horizon of 4 days is used for the classification (i.e. the time $t = -96 \text{ h}$ to $t = 0 \text{ h}$). While the classification still manages to separate trajectories into categories with different evolution during the final 4 days, the evolution between $t = -240 \text{ h}$ and $t = -96 \text{ h}$ becomes more similar for the different categories. In particular, also $\Delta \theta - \Delta T^-$ trajectories associated with warm extremes subside strongly during that period. This is in line with the fact that trajectories classified with a 10-day time horizon as $\Delta \theta - \Delta T^+$, are classified as $\Delta \theta - \Delta T^-$ if a time horizon of 4 days is used.

Why does this shift from $\Delta \theta - \Delta T^+$ to $\Delta \theta - \Delta T^-$ occur? This can be understood based on the evolution of temperature considering the original classification (Fig. 4 in the study). Most of the subsidence takes place before the 24 - 48 h prior to arrival of the air masses in the high Arctic. Hence, if the shorter time horizon is used for the classification, some of the subsiding air masses have already reached their final (low) altitude and do no longer experience adiabatic warming. Consequently, $\Delta T$ becomes negative and trajectories are classified as $\Delta \theta - \Delta T^-$. The choice of time horizon for the study is guided by the following three aspects:

1. An as clear as possible separation of air masses in terms of thermodynamic evolution, vertical and poleward motion, as well as geographical origin.

2. Capturing the entire air mass evolution throughout the synoptic time scale, which also includes the pre-conditioning prior to the formation of the potential temperature anomaly.

3. The identification of a trajectory as the identical air mass throughout the entire period under consideration. This requirement is well satisfied up to a trajectory integration times of no more
than approximately 10-12 days (cf. also Sprenger and Wernli, 2015).

Because of (3), longer time horizons than 10 days have not been considered. In terms of (2), time horizons between 6-10 day may be acceptable, though the preconditioning of $\Delta \theta + \Delta T$+ warm extreme air masses typically takes place more than 6 days before arrival in the high Arctic. In terms of (1), a time horizon of 10 days yielded the best possible separation of air masses with respect to their thermodynamic evolution, vertical and poleward motion, as well as geographical origin.