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Lagrangian Analysis of the Dynamical and Thermodynamic Drivers of Greenland Melt Events during 1979-2017

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Specific atmospheric circulation patterns can lead to strongly positive near-surface temperature anomalies over Greenland, fostering the occurrence of extensive surface melt events. In this study, we objectively identify 77 Greenland melt events in June-August 1979-2017, which also affect high-elevated regions of the Greenland ice sheet (GrIS), from ERA-Interim reanalysis data. Eight-day backward trajectories from the lowermost 500 m above the GrIS are used to investigate the air mass history and the synoptic, dynamical, and thermodynamic drivers of Greenland melt events. The key synoptic feature is a high-pressure system, in 65% of the events classified as atmospheric blocking, southeast of the GrIS. It is favorably located to induce rapid and long-range poleward transport of anomalously warm air masses (compared to climatology) from the lower troposphere to the GrIS. Due to orographic and dynamical lifting, latent heating from condensation of water vapor contributes additionally to the air mass' warm anomaly - most important for melt events on top of the GrIS. Adiabatic warming by subsidence, however, is insignificant, in contrast to warm events in the central Arctic. Exemplarily, the warm anomaly of air masses arriving in the Summit area during the most extensive melt event in early July 2012 arose due to strong meridional transport, mainly from the western North Atlantic, and latent heat release during ascent to Greenland. The simultaneous occurrence of a North American record heat wave did not play any direct role for the Greenland melt event. Further, regionally varying short- and longwave radiative effects induced by the warm-moist air masses enhance melt all over the GrIS. The identified mechanisms that cause Greenland melt events imply that the understanding of the formation of high-pressure systems and their representation in climate models is crucial in determining future GrIS melt. More generally, we highlight the importance of atmospheric dynamics and air flow patterns for Greenland melt events as they eventually determine the temperature pattern and surface energy budget over the GrIS with consequences for global sea-level rise.