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Importance of tropopause polar vortices for generating the most intense cold air outbreaks from Fram Strait

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Tropopause polar vortices (TPVs) are ubiquitous dynamical features of the Arctic troposphere that are characterized by a positive potential vorticity anomaly aloft and a dome of anomalously cold air underneath. When such TPVs propagate over open ocean, a strong air-sea temperature contrast ensues, thus resulting in an especially intense marine cold air outbreak (CAO).

Here, we first demonstrate the intimate relation between TPVs and the formation of particularly intense CAOs in a case study of a long-lived TPV which induced two CAOs downstream of Fram Strait within two weeks, one of them the third most intense since 1979. Using kinematic backward trajectories we show that the TPV contributes to the formation of the two CAOs in two complementary ways: (I) The dynamical structure of the TPV provides a quasi material boundary in its core, trapping the cold, converging lower tropospheric air masses allowing for sustained diabatic cooling and the formation of a highly anomalously cold air mass. (II) The cyclonic flow in the surroundings of the TPV's core and the long lifetime of the TPV lead to a long-range transport of already relatively cold air masses from Siberia through the high Arctic to Fram Strait.

Second, we present a climatology of CAO events from Fram Strait since 1979 ranked by their intensity in terms of air-sea temperature gradient. An automated tracking of TPVs, reveals that 40% of the top-40 CAO events are associated with a TPV, whereas this applies to only around 20% of the less intense CAO events. This underpins the importance of TPVs for inducing most intense CAOs, which are also those that provide the strongest air-sea heat flux forcing to ocean and atmosphere and are, thus, of special importance in the climate system.