Project: **48**

Project title: **VERNAER - Variability and extremes of poleward breaking Rossby waves over the North Atlantic-European region**

Project lead: **Dieter H.W. Peters**

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Sub-project: Subtropical and tropospheric influences on major sudden stratospheric warming events

During a major sudden stratospheric warming (MSSW) event the polar night jet breaks down accompanied by a stratospheric temperature increase. These events represent the greatest part of intra-seasonal variability in the winter stratosphere/ mesosphere and are hard to predict for more than 10 days (Tripathi et al. 2015). Matsuno (1971) developed a dynamical model in which tropospheric forced planetary wave packets propagate upwards into the stratosphere and break. The deposition of their angular momentum (EP flux convergence) leads to a weakening and breakdown of the polar night jet.
Several processes influencing the occurrence of MSSW events in the Northern Hemisphere: like quasi-biennial oscillations (QBO) and solar cycle (e.g., Labitzke 1987; van Loon and Labitzke 1987), like zonally asymmetric ozone changes (e.g., Peters et al. 2015), El Nino-Southern Oscillation (ENSO) (e.g., Butler and Polvani 2011) and Madden-Julian Oscillation (MJO) (e.g., Garfinkel et al. 2012). Liu et al. (2014) showed that the relationship between MJO and the occurrence of MSSWs is stronger for splitting events, because of the stronger and more coherent eastward propagation of the MJO. All these processes change the forcing of planetary waves in the troposphere including a link to the subtropics or change its propagation into the stratosphere (mainly wave 1 to 3; Charney and Drazin 1961; Dickinson 1969). Under the acting EP-Flux convergence caused by the stratospheric breaking of the planetary waves the polar vortex breaks down (e.g., Andrews et al. 1987). The EP-flux convergence results from the strong poleward zonal mean eddy heat fluxes of the ultra-long planetary waves (waves 1-3). Newman et al. (2001) showed that the poleward eddy heat flux at 100 hPa is a good proxy for upper stratospheric EP-flux convergence. This proxy is used in this paper where the role of tropospheric forcing processes of planetary waves is examined in more details.

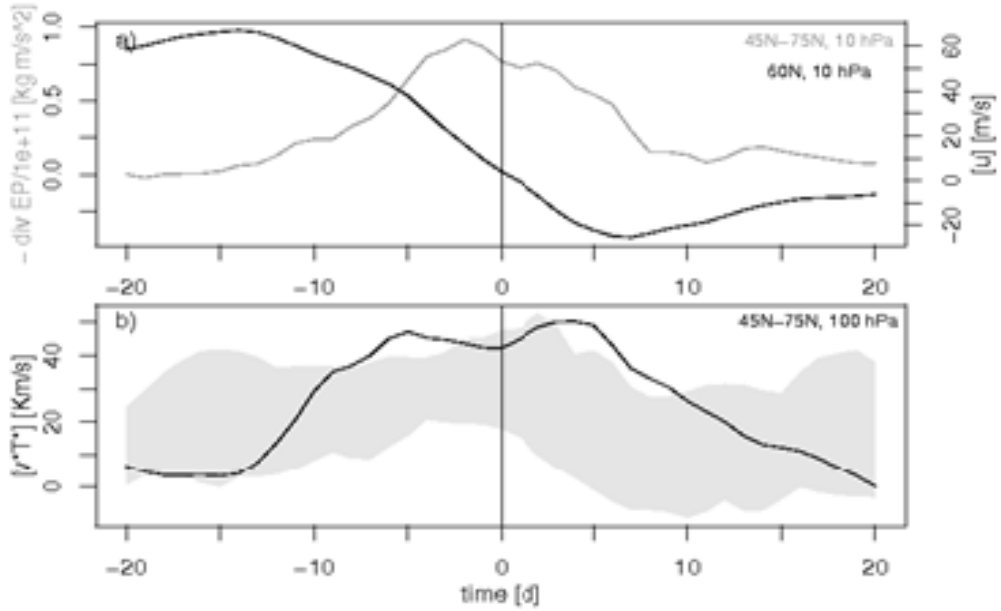

Figure 1: Temporal evolution of a) zonal mean zonal wind at 60°N (black line, right axis) and of the divergence of EP flux (grey line, left axis) averaged between 45°-75°N, both at 10 hPa, and b)

zonal mean eddy heat flux averaged over 45°-75°N at 100 hPa (black line) shown as 5-day running mean. Shading in b) denote the climatological mean variability of MSSWs around CD (zonal mean eddy heat fluxes of MSSWs prior to 2009 in the ERA-Interim period, in total 17 MSSWs). The vertical line at zero indicates CD.

Tropospheric forcing processes of planetary wave 2 are examined in the pre-phase of the major SSW event in January 2009 (MSSW2009). Due to a huge increase of Eliassen–Palm fluxes induced mainly by wave 2 (shown in Figure 1), easterly angular momentum is transported into the Arctic stratosphere and de-accelerated the polar night jet. Studies of Harada et al. (2010) and Ayarzagüena et al. (2011) are confirmed showing that during the pre-phase of MSSW 2009 strongest eddy heat fluxes linked to wave 2 occur at 100 hPa. In extension, the eddy heat flux of anomalies together with the correlations between v* anomaly and La Nina T* climatology, and between La Nina v* and T* climatology attribute mainly to the increase. Furthermore, it is shown that enhanced dual tropospheric wave forcing over Alaska and Scandinavia are caused by tropical processes.

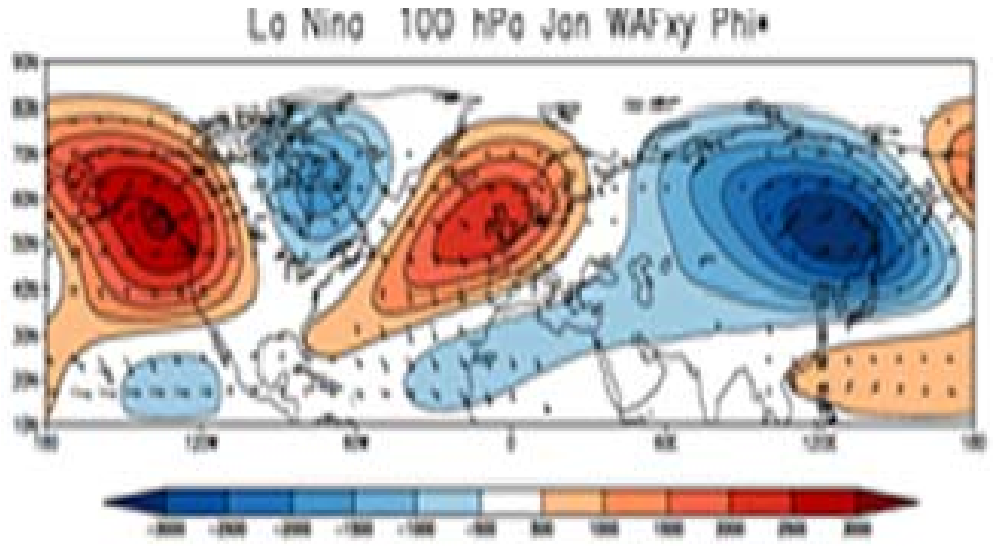

Figure 2 : Horizontal cross-section of horizontal WAF (m2/s2) and geopotential disturbance (m^2/s^2) for mean La Nina configuration. Quantities are shown for mean January at 100 hPa.

La Nina creates in a climatologically sense two regions of enhanced anticyclonic flow as shown in Figure 2: over Alaska and over Scandinavia. The Scandinavian ridge is maintained by wave trains emanating from the Alaskan ridge propagating eastward, including an enhanced transport of eddy kinetic energy.
This is an extraordinary case showing the importance of tropospheric forcing of La Nina on different spatial and temporal scales in the enhancement of wave-2-induced zonal mean eddy heat flux.

Paper in preparation!