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Dynamical heating of the polar summer mesopause induced by solar proton events

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Satellite observations made with the MLS/Aura showed a maximum increase of > 10 K in zonally averaged temperatures around the southern polar summer mesopause during the solar proton event (SPE) in January 2005 (v. Savigny et al., 2007, GRL). The anomalous warming was likely also the cause for the simultaneously observed disappearance of NLCs observed with SCIAMACHY/Envisat. In the present study we propose a dynamical interpretation for these observations.

The main direct effect of an SPE is enhanced ionization in the lower mesosphere, leading to ozone depletion and hence diabatic cooling in this region. This cooling can last for 5 days and typically has a maximum value of about 2 K/d around 65 km above the summer pole. We use the Kuehlungsborn mechanistic general circulation model (KMCM) to simulate the pure dynamical consequences of such a lower mesospheric cooling on the wave driving in the mesopause region. The KMCM is a
spectral model with high spatial resolution and a sophisticated parameterization of turbulence, giving rise to a self-consistent and explicit simulation of gravity waves in the MLT (Becker, 2009, J. Atmos. Sci.). An SPE is mimicked in the following way: We start with a control simulation for permanent January conditions, extract an arbitrary snapshot, and integrate the model with an additional lower
mesospheric cooling. This cooling is switched off after 5 days and the model is integrated for another 15 days. The resulting 20 day time series constitutes an SPE-related perturbation simulation when compared to the corresponding 20-day time series of the control simulation. To improve statistics, the procedure is repeated several times and composite time series are constructed.

The model response in the SPE case clearly reproduces the warming of the summer mesopause. The underlying mechanism is a reduction of the gravity-wave drag, giving rise to reduced adiabatic cooling. As expected, approximately the same vertical gravity-wave flux of eastward momentum enters the lower mesosphere in each case, but the resolved gravity waves are damped at lower altitudes in the SPE case because they attain larger vertical wavenumbers from the lower mesosphere on. This change in propagation conditions results from the anomalous eastward zonal wind component associated with the lower mesospheric cooling.