Coupling of stratospheric warmings with mesospheric coolings

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The proper simulation of the stratosphere includes their dynamical coupling with the troposphere and the mesosphere by Rossby waves and gravity waves. We study winterly anomalies of the middle atmosphere in order to provide a benchmark test for the model dynamics. The vertical coupling between the stratosphere and the mesosphere is diagnosed from polar cap temperatures averaged over 60–90 °N with a new method: the joint occurrence of a warm stratosphere at 10 hPa and a cold mesosphere at 0.01 hPa. The investigation of an 11-year-long dataset (2004–15) from Aura-MLS observations shows that such mesospheric coupling days appear in 7 % of the winter. During major sudden stratospheric warming events mesospheric couplings are present with an enhanced average daily frequency of 22 %. This daily frequency changes from event to event and broadly results in five of seven major warmings being classified as mesospheric couplings (2006, 2008, 2009, 2010, and 2013). The observed fraction of mesospheric coupling events (71 %) is compared with simulations of the Kühlungsborn Mechanistic Circulation Model (KMCM), the Hamburg Model of the Neutral and Ionized Atmosphere (HAMMONIA), and the Whole Atmosphere Community Climate Model (WACCM). The simulated fraction of mesospheric coupling events ranges between 57 % and 94 %, which fits the observations. In searching for causal relations weak evidence is found that major warming events with strong intensity or split vortices favor their coupling with the upper mesosphere. More evidence is found with a conceptual model: an effective vertical coupling between 10 and 0.01 hPa is provided by deep zonal-mean easterlies at 60 °N, which are acting as a gravity-wave guide. The explained variance is above 40 % in the four datasets, which indicates a near-realistic simulation of this process.

Key words: stratospheric warming, mesospheric cooling, Rossby waves, gravity waves, vertical coupling

References

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