What determines the downward transport of nitrogen oxides from the lower thermosphere to the stratosphere?

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Energetic particles enter Earth's atmosphere in the polar regions. Via ionization and chemical reactions this particle precipitation leads to the production of nitrogen oxides (NOx). Observations and model simulations show that during winter NOx of thermospheric origin can be transported downward to the mesosphere and stratosphere, where it depletes ozone and impacts atmospheric dynamics. However, it is still uncertain which processes determine the descent of NOx through the mesopause region, and why models often underestimate it. Here, we analyze this transport in the Hamburg Model of the Neutral and Ionized Atmosphere (HAMMONIA) focusing on the northern hemisphere winter 2008/2009, which is characterized by a strong stratospheric warming in January.

In the first part of the study we analyze the relative importance of advective transport, molecular and eddy diffusion simulating an artificial passive tracer with single transport processes switched on and off. In the standard configuration of the model molecular diffusion dominates (not surprisingly) in the thermosphere. Lower down, the descent is mainly due to advection. The diurnal variability of winds, likely related to tides, plays an important role for this advective transport around the mesopause. Eddy diffusion is less important, but turbulent diffusion coefficients used in the model might be underestimated. Sensitivity experiments with doubled coefficients show a much more dominant role for eddy diffusion.

In the second part of the study we discuss how sensitive the dynamics of the middle atmosphere in HAMMONIA and the related tracer transport are to changes of the parameterized gravity wave sources. We show that a reduction of the amplitude of the gravity wave sources enhances the downward transport. This is related to smaller amplitude waves being able to propagate higher up into the atmosphere and thereby extending upward the region of middle atmospheric polar downwelling. The descent of NOx is rather controlled by the altitude at which gravity waves deposit their momentum than by the total amount of momentum deposited.

Key words: energetic particle precipitation, polar winter mesosphere, tracer transport, nitrogen oxides