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Model simulations of stratospheric ozone loss caused by enhanced mesospheric NOx during Arctic Winter 2003/2004

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Satellite observations show that the enormous solar proton events (SPEs) in October–November 2003 had significant effects on the composition of the stratosphere and mesosphere in the polar regions. After the October–November 2003 SPEs and in early 2004, significant enhancements of NO_x(=NO+NO_2) in the upper stratosphere and lower mesosphere in the Northern Hemisphere were observed by several satellite instruments. Here we present global full chemistry calculations performed with the CLaMS model to study the impact of mesospheric NO_x intrusions on Arctic polar ozone loss processes in the stratosphere. Several model simulations are preformed with different upper boundary conditions for NO_x at 2000 K potential temperature (≈50 km altitude). In our study we focus on the impact of the non-local production of NO_x, which means the downward transport of enhanced NO_x from the mesosphere to the stratosphere. The local production of NO_x in the stratosphere is neglected. Our findings show that intrusions of mesospheric air into the stratosphere, transporting high burdens of NO_x, affect the composition of the Arctic polar region down to about 400 K (≈17 – 18 km). We compare our simulated NO_x and mixing ratios with satellite observations by ACE-FTS and MIPAS processed at IMK/IAA and derive an upper limit for the ozone loss caused by enhanced mesospheric NO_x. Our findings show that in the Arctic polar vortex (equivalent lat.$>70^\circ$ N) the accumulated column ozone loss between 350 – 2000 K potential temperature (≈14 – 50 km altitude) caused by the SPEs in October–November 2003 in the stratosphere is up to 3.3 DU with an upper limit of 5.5 DU until end of November. Further, we found that about 10 DU, but in any case lower than 18 DU, accumulated ozone loss additionally occurred until end of March 2004 caused by the transport of mesospheric NO_x-rich air in early 2004. The solar-proton-produced NO_x above 55 km due to the SPEs of October-November 2003 had a negligibly small impact on ozone loss processes through the end of November in the lower stratosphere (350 – 700 K≈14 – 27 km). The mesospheric NO_x intrusions in early 2004 yielded a lower stratospheric ozone loss of about 3.5 DU, and clearly lower than 6.5 DU through the end of March. Overall, the non-local production of NO_x is an additional variability in the existing variations of the ozone loss observed in the Arctic.