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Formation of stratospheric nitric acid by a hydrated ion cluster reaction: implications for the effect of energetic particle precipitation on the middle atmosphere

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Enhancements in nitric acid (HNO_3) are often observed in satellite or ground-based data in the winter polar upper stratosphere, and are thought to be linked to energetic particle precipitation. These enhancements are poorly represented in chemistry-climate models. In order to improve this effect of energetic particle precipitation, we have modelled the chemical and dynamical middle atmosphere response to the introduction of a chemical pathway that produces HNO_3 by conversion of N2O5 upon hydrated water clusters H+•(H_2O)n. We have used an ensemble of simulations with the National Center for Atmospheric Research (NCAR) Whole-Atmosphere Community Climate Model (WACCM) chemistry-climate model. The chemical pathway alters the internal partitioning of the NO_y family during winter months in both hemispheres, and ultimately triggers statistically significant changes in the climatological distributions of constituents including: i) a cold season production and loss of HNO_3 and N2O5, respectively, and ii) a cold season decrease and increase in NO_x/NO_y-ratio and O_3, respectively, in the polar regions of both hemispheres. We see an improved seasonal evolution of modelled HNO_3 compared to satellite observations from Microwave Limb Sounder (MLS), albeit not enough HNO_3 is produced at high altitudes. Through O_3 changes, both temperature and dynamics are affected, allowing for complex chemical-dynamical feedbacks beyond the cold season when the pathway is active. Hence, we also find a NO_x polar increase in spring-to-summer in the southern hemisphere, and in spring in the northern hemisphere. The springtime NO_x increase arises from anomalously strong poleward transport associated with a weaker polar vortex. We argue that the weakening of zonal-mean polar winds down to the lower stratosphere, which is statistically significant at the 0.90 level in spring months, is caused by strengthened planetary waves induced by the mid-latitude zonal asymmetries in O_3 and short-wave heating.