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Quantifying the Energetic Particle Precipitation Influences on the Budgets of Stratospheric NO_y and Ozone using a new 'tagging' scheme in the Whole Atmosphere Community Climate Model

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Energetic particle precipitation (EPP) is thought to be one of the ways the geospace environment can affect the middle and lower atmosphere. EPP leads to ionization of the major molecular species, and through a series of neutral and ion reactions leads to the production of odd-hydrogen (HO_x = {H, OH, HO_2}) and odd-nitrogen (NO_x = {N, NO, NO_2}). NO_x is of particular interest because it can catalytically destroy ozone, affecting the energy budget of the stratosphere. Energetic particles that precipitate in the stratosphere, mesosphere include medium energy electrons (MEE, 30 keV - 300 keV), energetic solar protons (1-300 MeV), and galactic cosmic rays (GCRs). These EPP NO_x sources are now part of the recommended forcings used to drive upcoming simulations for Coupled Model Intercomparison Project Phase 6 (CMIP6). To date, it has been difficult to quantify the influence of EPP on the budgets of stratospheric total inorganic nitrogen (NO_y) and ozone. In this work, we employ the approach developed for tropospheric chemistry studies [Emmons et al., Geosci. Model Dev., 2012] to 'tag' NO_y from specific sources and the associated ozone production and loss. This 'tagging' approach allows us to quantify the relative impacts on NO_y and ozone loss rates from each of the GCR, MEE, and proton EPP sources. Furthermore, we are able to calculate the residence time of EPP NO_y in the stratosphere following a large EPP event; a necessary step in understanding solar cycle induced variability on stratospheric ozone. The Chemistry Climate Model Initiative (CCMI) version of the NCAR Community Earth System Model Whole Atmosphere Community Climate Model is used in this study. The CCMI REF-C1SD scenario is followed with the inclusion of the updated CMIP6 EPP forcings. The model is 'nudged' to the NASA Global Modeling and Assimilation Office Modern-Era Retrospective analysis for Research and Applications, Version 2 meteorological fields. Using assimilated meteorology allows us to remove the any perturbation based dynamical variability and just focus on the chemical signature from the above mentioned EEP process.