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Planetary wave-driven enhanced NO descent into the top of the Arctic polar vortex during major and minor sudden stratospheric warmings

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The polar vortices play a central role in vertically coupling the Sun-Earth system by facilitating the descent of reactive odd nitrogen (NO_x = NO + NO_2) produced in the atmosphere by energetic particle precipitation (EPP-NO_x). Downward transport of EPP-NO_x from the mesosphere-lower thermosphere (MLT) to the stratosphere inside the winter polar vortex is particularly impactful in the wake of prolonged sudden stratospheric warming (SSW) events. This work is motivated by the fact that state-of-the-art global climate models severely underestimate EPP-NO_x abundances in the polar MLT. It is not clear whether this deficiency is due to a missing NO_x source or to inadequate transport processes. As a step toward understanding the transport pathways by which MLT air enters the top of the polar vortex, we explore the extent to which planetary waves impact the geographic distribution of NO near the polar winter mesopause in the Whole Atmosphere Community Climate Model with thermosphere-ionosphere eXtension combined with data assimilation using the Data Assimilation Research Testbed (WACCMX+DART). We present planetary wave-driven NO patterns near the polar winter mesopause during 16 case studies from the Arctic winters of 2005/2006 through 2018/2019. During all cases the model is in reasonable agreement with Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) derived zonal winds and Solar Occultation For Ice Experiment (SOFIE) and Atmospheric Chemistry Experiment-Fourier Transform Spectrometer (ACE-FTS) NO measurements. Superposed Epoch Analysis is employed to diagnose typical mesopause planetary wave behavior and vertical transport characteristics during 10 minor and 6 major SSW events. Results show that descent of NO into the top of the polar vortex is enhanced by about a factor of 4 in traveling planetary wave troughs vs. in ridges and that this planetary wave-driven enhanced NO descent occurs during both minor and major SSW events. These results present a new conceptual model of zonally varying, vs. zonally uniform, polar descent in the MLT.