Geophysical Research Abstracts
Vol. 20, EGU2018-1773, 2018
EGU General Assembly 2018

Comparison of ECHAM5/MESSy Atmospheric Chemistry (EMAC) Simulations of the Arctic winter 2009/2010 and 2010/2011 with Envisat/MIPAS and Aura/MLS Observations

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We present model simulations with the atmospheric chemistry-climate model ECHAM5/MESSy Atmospheric Chemistry (EMAC) nudged toward European Center for Medium-Range Weather Forecasts (ECMWF) reanalyses for the Arctic winter 2009/2010 and 2010/2011. We have chosen these two extreme Arctic winters to evaluate the formation of polar stratospheric clouds (PSCs) and the representation of the chemistry and dynamics of the polar winter stratosphere in EMAC. The EMAC simulations are compared to observations by the Michelson Interferometer for Passive Atmospheric Soundings (Envisat/MIPAS) and the Aura Microwave Limb Sounder (Aura/MLS). The Arctic winter 2010/2011 was one of the coldest winters on record, leading to the strongest depletion of ozone measured in the Arctic. Although the Arctic winter 2009/2010 was one of the warmest winters, it was distinguished by an exceptionally cold stratosphere (colder than the climatological mean) from mid December 2009 to mid January 2010, leading to prolonged PSC formation and existence. Significant denitrification, the removal of HNO_3 from the stratosphere by sedimentation of HNO_3 containing polar stratospheric cloud particles, occurred. The comparisons between EMAC simulations and satellite observations show that model and measurements compare well for these two Arctic winters and thus that EMAC nudged toward ECMWF reanalyses is capable of giving a realistic representation of the evolution of PSCs and the associated sequestration of gas-phase HNO_3 in the polar winter stratosphere. However, the simulated PSC volume densities are several orders of magnitude smaller than the ones derived from Envisat/MIPAS observations. This underestimation of PSC volume density and vertical extension of the PSCs results in an underestimation of the vertical redistribution of HNO_3 due to denitrification/re-nitrification.