Arctic winter 2009/2010, 2010/2011 and 2015/2016 in comparison: Denitrification and polar stratospheric cloud formation

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The Arctic winters 2009/2010, 2010/2011 and 2015/2016 were quite exceptional. The Arctic winter 2010/2011 was one of the coldest winters on record leading to the strongest depletion of ozone measured in the Arctic. The Arctic winter 2009/2010 was, from the climatological perspective, one of the warmest winters on record. However, it was characterised by an exceptionally cold stratosphere (colder than the climatological mean). Cold temperatures prevailed from mid December 2009 to mid-January 2010, leading to prolonged Polar Stratospheric Cloud (PSC) formation and significant denitrification. The 2015/2016 Arctic winter was also one of the coldest stratospheric winters in recent years. Temperatures were at record lows from December 2015 to early February 2016 with an unprecedented period of temperatures below the ice formation threshold leading to extensive ice PSC formation. Model simulations with the atmospheric chemistry-climate model ECHAM5/MESSy Atmospheric Chemistry (EMAC) nudged toward European Center for Medium-Range Weather Forecasts (ECMWF) reanalyses as well as satellite observations from Aura/MLS and Envisat/MIPAS are used to investigate PSC formation and denitrification during these winters. While PSCs were present during the Arctic winter 2010/2011 over nearly four months, from mid-December to end of March, they were not as persistent as the ones that occurred during the shorter (one and two month) cold periods during the Arctic winters 2009/2010 and 2015/2016. Although the PSC seasons during the Arctic winters 2009/2010 and 2015/2016 were much shorter than in 2010/2011, significant denitrification was observed in all three winters. The nudged EMAC simulations show that the model 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, simulated PSC volume densities are significantly smaller than the ones derived from observations and denitrification is underestimated.

Key words: PSC, Arctic winters, model simulations, satellite observations