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Arctic stratospheric dehydration - Unprecedented observations and microphysical modeling study

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Polar stratospheric clouds (PSCs) may form in the lower stratosphere above the winter poles at sufficiently low temperatures. Ice PSCs require the coldest conditions, with temperatures some degrees below the frost point to nucleate ice particles. When the particles grow to sizes large enough to sediment, they may result in dehydration, i.e. irreversible redistribution of water vapor, as it frequently occurs above the Antarctic. Conversely, there are no observations above the Arctic that would have provided clear evidence for vertical redistribution of water vapor. Here we report on unequivocal in situ observations in January 2010 above Sodankylä, Finland, which mesh with vortex-wide satellite measurements. Within the LABPIAT-II field campaign, a series of balloon-borne aerosol backscatter and water vapor measurements has been performed. The balloon payload comprised the backscatter sonde COBALD in combination with the cryogenic frost point hygrometer CFH and the fluorescent Lyman-Alpha stratospheric hygrometer FLASH-B. Together with satellite measurements from the Aura microwave limb sounder MLS and the cloud-aerosol lidar CALIOP, a unique and coherent picture of de- and rehydration in the Arctic vortex will be presented within this paper. An extensive coverage of synoptic scale ice PSCs has been observed by CALIOP and COBALD by mid-January due to exceptionally low temperatures in the Arctic vortex. This observation goes along with a simultaneously measured strong reduction in water vapor by 1.6 ppmv relative to background conditions. Subsequent sedimentation and sublimation of ice particles led to a vertical redistribution of water inside the vortex, which was tracked remotely and could be quantified again by in situ measurements some five days later. By means of a microphysical column model, we are able to connect the individual balloon soundings by trajectories and simulate the formation, evolution and sedimentation of the ice particles. Simulated water vapor profiles are verified by CFH, FLASH-B and MLS measurements. Optical T-Matrix calculations enable us to additionally compare the simulations with COBALD and CALIOP backscatter measurements. We examine the effect of different PSC formation pathways – in particular homogeneous vs. heterogeneous ice formation – and changing temperatures and finally show that synoptic scale ice PSCs and concurrent reduction in water vapor are tightly linked with the observed de- and rehydration signatures.