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Investigation of transport and mixing in the 2015/16 Arctic UTLS using airborne in situ CO_2 and tracer observations

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During the POLSTRACC/GW-LCYCLE/SALSA (PGS) campaign the German High Altitude and LOng range research aircraft (HALO) intensively probed the bottom of the polar vortex and the adjacent mid to high latitude upper troposphere / lower stratosphere (UTLS) up to 15 km altitude throughout the entire winter/spring during the extraordinarily cold Arctic winter 2015/16. One main objective of this campaign was to study the chemical structure of the Arctic UTLS region and how it is influenced by the outflow of the polar vortex and by the dynamical situation.

During PGS, the University of Wuppertal deployed the High Altitude Gas Analyzer –V (HAGAR-V), a new 5-channel (2xGC/ECD, 2xGC/MS, and a NDIR-analyzer) in-situ tracer instrument developed for HALO. Measurements of a set of long-lived trace gases with different lifetimes is a suitable tool to study the transport and mixing of air masses in this special region. For our analysis we use mixing ratios of CFC-11, CFC-12, SF6 (measured by HAGAR-V using GC/ECD), CO_2 (measured by HAGAR-V using NDIR), and N2O measured by University of Mainz with the TRIHOP instrument using QCLAS (quantum cascade laser absorption spectroscopy) as well as model calculations from the Lagrangian model CLaMS. From the SF6 data we also calculate the mean age of air.

Tracer profiles and correlations are affected by both diabatic descent and isentropic mixing. For tracers which have their main sources in the troposphere, diabatic descent decreases the tracer mixing ratios on a certain potential temperature level whereas isentropic mixing (with air from lower latitudes) increases them. Diabatic descent alone only changes the vertical profiles while isentropic mixing changes both profiles and tracer correlations. Between January and March 2016 we observe a change of the CO_2-N2O correlation, which indicates that isentropic mixing has occurred. We compare the observed tracer distributions during PGS with numerical simulations by the Lagrangian model CLaMS and with older observations on board the M55 Geophysica during previous Arctic campaigns. In particular, vertical tracer profiles during the cold and dynamically quiet winter 2016 exhibit much older air (up to 5 years of age at 400K) than those observed during the dynamically very active winter 2010 (RECONCILE campaign), despite the expectation that the 2010 profiles should have experienced more descent owing to stronger wave driving. This underlines the importance of isentropic mixing on the vertical distribution of long-lived tracers and suggests that wave breaking affects the chemical composition of the Arctic UTLS more strongly by isentropic mixing than by driving diabatic descent.