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Airborne tracer observations in the Arctic stratosphere during RECONCILE 2010: Quantification of transport and mixing

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We present new in situ tracer observations taken both in- and outside the 2010 Arctic stratospheric vortex during the RECONCILE campaign and use them to quantify large-scale diabatic descent, isentropic transport across the vortex boundary, and small-scale irreversible mixing. The measurements (of N_2O, CFC-11, CFC-12, Halon-1211, CH_4, SF_6, H_2, and CO_2) were taken with the High Altitude Gas Analyzer (HAGAR) on board the M55 Geophysica aircraft during 13 flights from Kiruna, Sweden, between January and March 2010. Early winter reference profiles for a number of tracers are provided by satellite data from the ACE-FTS experiment.

We use the observed distribution of the N_2O mixing ratio as function of potential temperature to define and calculate empirical fractions of vortex air for all sampled air parcels. Vortex descent can then be derived to first order from the evolution of vertical tracer profiles of nearly undiluted vortex samples. Transport across the vortex boundary is quantified by analysing these fractions of vortex air in- and outside the vortex boundary as function of potential temperature and equivalent latitude. Finally, irreversible isentropic mixing of entrained extra-vortex air is assessed by analysing the evolution of the non-linear tracer correlations throughout the winter.

We infer significant entrainment of mid- and even low-latitude air into the vortex after the vortex split up and reformed in late February. Irreversible mixing of some of this entrained air is also clearly evident as a mixing line in the CFC-11/N_2O correlation at 500 K during the last flight on March 10. Apart from this mixing signature, however, the CFC-11/N_2O correlation inside the vortex remains remarkably compact and unchanged between January and March, suggesting that effects of mixing on trace gas budgets remained small overall, at least until mid March. We will compare these results with simulations by the Chemical Lagrangian Model of the Stratosphere (CLaMS), in particular with calculated air mass origin spectra. Comparisons will also be made with observations during the winter 2002/03 when substantial vortex dilution and irreversible mixing had occurred throughout the vortex after a similar vortex split and reformation.