A case study of water vapor in-mixing into the LS from GLORIA measurements acquired during the WISE campaign

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During autumn of 2017, the WISE campaign operated from a base in Shannon, Ireland, using the German research aircraft HALO. The aircraft carried a comprehensive payload of in situ instruments that allow for highly precise measurements of a variety of trace gases at aircraft position as well as remote sensing instruments providing spatially resolved cross-sections of selected species. Here, we focus on measurements of the remote limb imager GLORIA. This instrument employs a 2-D detector array to acquire simultaneously 6144 infrared spectra from 750 cm^{-1} to 1400 cm^{-1} with a spectral resolution of 0.2 cm^{-1} or 0.0625 cm^{-1} (in 3 s or 10 s, respectively), depending on scientific demands. Using dedicated flight patterns in combination with the ability to point GLORIA at different azimuthal directions, a 3-D reconstruction of observed air masses is feasible.

On October the 12th and 14th, we could probe a LC1 Rossby wave breaking event over Iceland that initially exhibited a very strong tropospheric inversion layer and a warm conveyor belt lifting wet air masses to high altitudes. During the breaking of the Rossby wave, wet tropospheric air was mixed into the lowermost stratosphere between 330 K and 250 K. Our observations show the two-dimensional spatial structure of the intruded air masses in the tracers of water vapor, ozone, CFC-11, and nitric acid. The filaments are still well localized and cover only about 800 m vertically and about 200 km horizontally. First 3-D reconstructions of the filament show the full spatial extent and thus allow a quantification of the amount of in-mixed water vapor. A trajectory study and simulations with the CLaMS model are used to analyze the recent history of the Rossby wave breaking event and analyze the exchange process and mixing history in detail. The air masses are heavily influenced by two consecutive Rossby wave-breaking events that caused the irreversible transport deep into the LMS. However, the data suggests that the tropospheric air was already previously mixed with stratospheric air within the core of the jet-stream.

This is consistent with older observations of GLORIA that show that typical Rossby wave-breaking mainly transports air masses from the jet-stream core into the LMS. The jet stream core forms the boundary between troposphere and stratosphere and, due to the convergence, divergence, and wind shear, is of a mixed nature. GLORIA allows to observe the resulting anomalies in water vapor and ozone and thus to quantify the stratosphere-troposphere exchange by this mechanism and to validate the proper modelling of these events by NWP and GCM models.