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3-D tomographic observations of Rossby wave breaking over the Northern Atlantic during the WISE aircraft campaign in 2017

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We present measurements of ozone, water vapour and nitric acid in the upper troposphere/lower stratosphere (UTLS) over North Atlantic and Europe. The measurements were acquired with the Gimballed Limb Observer for Radiance Imaging of the Atmosphere (GLORIA) during the Wave Driven Isentropic Exchange (WISE) campaign in October 2017. GLORIA is an airborne limb imager capable of acquiring both 2-D data sets (curtains along the flight path) and, when the carrier aircraft is flying around the observed air mass, spatially highly resolved 3-D tomographic data. We show a case study of a Rossby wave (RW) breaking event observed during two subsequent flights two days apart. RW breaking is known to steepen tracer gradients and facilitate stratosphere-troposphere exchange (STE). Our measurements reveal complex spatial structures in stratospheric tracers (ozone and nitric acid) with multiple vertically stacked filaments. Backward trajectory analysis is used to demonstrate that these features are related to several previous Rossby wave breaking events and that the small-scale structure of the UTLS in the Rossby wave breaking region, which is otherwise very hard to observe, can be understood as stirring and mixing of air masses of tropospheric and stratospheric origin. It is also shown that a strong nitric acid enhancement observed just above the tropopause is likely a result of NO_x production by lightning activity. The measurements showed signatures of enhanced mixing between stratospheric and tropospheric air near the polar jet with some transport of water vapour into the stratosphere. Some of the air masses seen in 3-D data were encountered again two days later, stretched to very thin filament (horizontal thickness down to 30 km at some altitudes) rich in stratospheric tracers. This repeated measurement allowed us to directly observe and analyse the progress of mixing processes in a thin filament over two days. Our results provide direct insight into small-scale dynamics of the UTLS in the Rossby wave breaking region, witch is of great importance to understanding STE and poleward transport in the UTLS.