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Analysing trace gas filaments in the Ex-UTLS by 4D-variational assimilation of tomographic retrievals

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Fields of atmospheric gases in the extratropical upper troposphere – lower stratosphere (Ex-UTLS) are dominated by sharp trace gas gradients on small horizontal and vertical scales, which are highly sensitive to chemical and dynamical processes. This case study investigates the potential for chemical state analysis at the Ex-UTLS with airborne limb-images, assimilated into an advanced spatio-temporal system. The investigation is motivated by the limited capability of both, nadir and limb-viewing satellite sensors to resolve highly filamented structures in the Ex-UTLS. The EURopean Air pollution Dispersion -Inverse Model (EURAD-IM) is applied as assimilation system and designed to extend the flight path confined retrievals from GLORIA (Gimballed Limb Observer for Radiance Imaging of the Atmosphere) to both, larger areas and detailed vertical structures by a tomographic flight pattern. Related potential and limitations of the method are studied with the following features applied: (i) airborne tomographic observations of the Ex-UTLS, (ii) spatio-temporal extension by 4-dimensional variational data assimilation (iii) correlation between ozone and potential vorticity (PV) as an indicator of airmasses and (iv) anisotropic and inhomogeneous horizontal background error correlations in the Ex-UTLS, spreading information towards unobserved regions along PV isopleths. This setup demonstrated substantial improvements to basic approaches in exploring new data on the spatial extend and alignment of airmasses down to small-scale filaments in the Ex-UTLS. Tomographic observations provide detailed insight for reconstructing filamentary tropopause foldings along airmass boundaries during this case study.

The study is complemented by assessment of the uncertainties of the chemical state analysis in the Ex-UTLS to inaccurate forecasts of wind fields. Making use of the adjoint model in the EURAD-IM system, non-trajectory backward-plume calculations provide estimations of location and relative contributions of source areas of specific airparcels. The meteorological driver WRF (Weather Research and Forecasting) is initialized by an ensemble of global GFS (Global Forecast System) predictions to account for dynamical uncertainties. This is enhanced by the problem of precise localization of a saddle point, which controls the convergence of airmasses over large areas. This motivates the need for a realistic consideration of meteorological uncertainties for investigating the predictability of chemistry transport forecasts.