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Spatio-temporal variability of water vapor investigated by lidar and FTIR vertical soundings above Mt. Zugspitze

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Water vapor is the most important greenhouse gas and plays a key role for meteorological phenomena and climate. Different from most other greenhouse gases water vapor has a very high spatial and temporal variability which is not yet understood in quantitative terms. We present an analysis of a five-year series of water vapor measurements in the free troposphere above Mt. Zugspitze (Germany, 2962 m a.s.l). Our results are obtained from a combination of measurements of integrated water vapor (IWV), recorded with a solar Fourier Transform Infra Red (FTIR) spectrometer on the summit of Mt. Zugspitze, and of water vapor profiles, recorded with the nearby differential absorption lidar (DIAL) at the Schneefernerhaus research station. From a recent validation study using a subset of these data we learned that the particular geometrical arrangement of both instruments allows investigating the spatio-temporal variability of integrated water vapor on a time-scale of less than one hour and on a spatial scale of less than one kilometer (Vogelmann et al., 2011).

By taking the advantage of the geographical arrangement of both measurement systems we find that the spatial variability of IWV within a time interval of 20 minutes becomes significant for horizontal distances above 2 km, but only during the warm season ($\sigma_{\mathrm{IWV}}(\Delta x < 2\,\mathrm{km}) \approx 0.35\,\mathrm{mm}$) while there was no sensitivity to the horizontal distance observed during the winter season ($\sigma_{\mathrm{IWV}}(\Delta x < 8\mathrm{km}) < 0.2\mathrm{mm}$). Investigating the 30-minute variability of IWV within the entire horizontal field observed as a function of season we come to the result that the variability peaks in July and August ($\sigma_{\mathrm{IWV}} > 0.55$ mm, mean distance = 2.5 km) and has its minimum around midwinter ($\sigma_{\mathrm{IWV}} < 0.2$ mm, mean distance > 5 km). By appropriate limiting the horizontal mismatch of IWV recordings from both instruments we derived information about the temporal variability. For a short time interval of 5 minutes σ_{IWV} is 0.05 mm and increases to more than 0.5 mm for a time interval of 15 hours.

The short-term variability of the vertical water-vapor distribution was derived by analyzing subsets of water-vapor profiles from the DIAL which have been recorded within a certain time interval (e.g., 1 h – 5 h). The lowest relative variability was observed in the lower free troposphere (3.8 km – 5 km a.s.l., $\sigma_{\mathrm{1h}} < 0.22$). Above 5 km a.s.l. the relative variability increases continuously up to the tropopause region (11 km, $\sigma_{\mathrm{1h}} \approx 0.6$). From analysis of the covariance matrix of the vertical profile variability we come to the finding that the variability of water vapor in the upper troposphere above 6 km is due to a more coherent flow of heterogeneous air masses from changing remote sources, while at lower altitudes, the variability is also driven by local atmospheric dynamics.

Reference:

Vogelmann, H., Sussmann, R., Trickl, T., and Borsdorff, T.: Intercomparison of atmospheric water vapor soundings from the differential absorption lidar (DIAL) and the solar FTIR system on Mt. Zugspitze, Atmos. Meas. Tech., 4, 835-841, doi:10.5194/amt-4-835-2011, 2011.