Investigating Water Vapor Variability by Ground-Based Microwave Radiometry

Research Highlight

This study introduces a new approach to characterize small-scale humidity variations using ground-based microwave radiometry. For that purpose, a microwave profiler routinely performed different scan patterns during its deployment at the ARM Mobile Facility in the Black Forest, Germany. Individual azimuth scans at 30° elevation revealed spatial variations in integrated water vapor up to ± 10%. Aircraft observations were used to evaluate the performance of the microwave observations by comparing derived humidity fields with integrated water vapor retrieved along individual directions of the microwave radiometer. Distinct humidity signals were reproduced by both observations. Residual uncertainties can be attributed to the temporal variations during the time it took the aircraft to cover the boundary layer and uncertainties in the interpolation. Long-term scanning observations will be further explored to investigate land-surface interaction and to characterize subgrid variability.

To evaluate the potential of the scanning MWR, the Metair-Dimona aircraft mapped the water vapor within the Murg Valley. The flight pattern was star-like, with six vertical planes spaced by 30° in azimuth angle. The first plane was flown N-S (0–180°), the second NNE-SSW (30–210°), and so on (illustrated by the double-headed arrows in the top part of Figure 2). In each azimuth plane, the aircraft was descending (or ascending) from around 1500 m to 50 m above ground. At the same time, the HATPRO-MWR (Humidity and Temperature Profiler) performed synchronous elevation scans in the azimuth planes and in between some azimuth scans to observe both the temporal and spatial variability. The aircraft data were interpolated from the flight path into the azimuth plane in order to construct 2D humidity fields. The interpolated humidity fields were then used to derive the integrated water vapor (IWV) at different elevation angles according to the angles used in the HATPRO elevation scans. The data from July 26 (Figure 1) reveal strong variations in IWV (no airmass correction) in a well-developed boundary layer with dry convection and no clouds. The synoptic situation inhibited the development of convective clouds during the whole day. A comparison of the MWR-retrieved IWV at 30° elevation with the deduced IWV from the interpolated humidity field is shown in Figure 2. If the real atmosphere were accurately represented by the interpolated humidity field, the deduced IWV should be the temporal mean of the HATPRO measurements in each azimuth direction. Due to the limited coverage of the aircraft measurements, the IWV deduced from the interpolation field differs from the temporal mean of the MWR measurements by up to 2 kg×m-2—especially in those azimuth directions where the aircraft only flew short legs. However, the strong decrease of 4–7 kg×m-2 in IWV from 12–14 UTC, as well as the strong difference between the complementary azimuth directions in the E-W direction, is evident in both data sets. Additionally, the HATPRO measurements show a strong temporal variability in IWV at one and the same observation angle. In summary, the results from HATPRO's different scan modi show good structural agreement with the aircraft-derived interpolated humidity fields, even though these cannot completely represent the atmosphere.

We demonstrated the potential of scanning microwave observations to continuously monitor the spatial variability of water vapor. Remarkable fluctuations of the water vapor field could be observed even in cloud-free scenes on several days. Airborne observations are well-suited to resolve strong spatial variations in humidity that cannot be resolved by passive profiling systems. However, aircraft measurements cannot resolve temporal changes well, which we have shown to be well-captured by scanning MWR measurements in terms of path-integrated IWV. Such observations can be helpful for characterization of land-surface exchange of humidity, subgrid variability, and investigation of convective initiation.

Figure 1. Water vapor mixing ratio (g × kg-1) [colorbar] along a SSW (210°)–NNE (30°) transect as a function of height above the AMF site (511 m asl). Thick tracks represent observations. Dashed lines refer to the elevations at which MWR observations were taken. Black regions symbolize the local orography. The underlying humidity field is a combination of interpolated aircraft measurements and the closest AMF radiosonde.

Figure 2. Temporal development of IWV during the aircraft flights on July 26. Lines show the temporal evolution of the 30°-IWV measured by HATPRO elevation scans in the current flight direction, illustrated by the double-headed arrows. The deduced IWV values from the interpolated humidity fields are plotted as symbols. Eastern azimuth directions (0–150°) are shown as solid lines/asterisks, and western azimuth directions (180–330°) are drawn as dashed lines/plus signs.

Reference(s)

Kneifel S, S Crewell, U Löhnert, and J Schween. 2009. "Investigating water vapor variability by ground-based microwave radiometry: Evaluation using airborne observations." Geoscience and Remote Sensing Letters, 6(1), doi:10.1109/LGRS.2008.2007659.

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Working Group(s)

Cloud Properties