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Latent heat fluxes and TKE dissipation rates over complex terrain from airborne lidar observations

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The combination of a water vapour and a wind lidar on an aircraft is an interesting new tool that allows to measure latent heat flux profiles and the small- to mesoscale variability beneath the aircraft along the flight track. During the Convective and Orographically-induced Precipitation Study (COPS) in July 2007 over the Black Forest low-mountains in south-west Germany, a differential absorption lidar (DIAL) and a Doppler wind lidar were collocated nadir-viewing onboard the DLR Falcon research aircraft. One of the main goals was to measure the vertical humidity transport within the convective boundary layer (CBL) over the Rhine valley and the Black Forest on days when deep convection was expected to be mainly forced by the local orography and surface humidity. From the remotely-sensed wind and water vapour fluctuations at multiple heights within the CBL, a representative latent heat flux profile can be obtained from a single over-flight of the area under investigation using the eddy-correlation technique. The lidars' horizontal and vertical resolution is 200 m, which is just sufficient to resolve the dominant contributions to the flux, as parallel higher-resolved in-situ measurements by another research aircraft show. The flights were performed early enough, around noon, in order to avoid too many clouds that obstruct the lidar measurements. However, scattered fair-weather cumuli, as well as the presence of instrumental noise in the lidar signals do not significantly hinder the flux retrieval, as the comparisons with the in-situ measurements demonstrated.

The presentation will highlight methodical advances, accuracy assessments, validations by the collocated in-situ aircraft measurements over the mountains, as well as the study of a post-frontal situation in which the latent heat flux played a key role in humidifying the boundary layer. On this exemplary day, 30. July 2007, the lidar-derived latent heat fluxes in the CBL over the mountains vary between 100 – 500 W/m2 on parallel flight tracks but are roughly constant with height. The observed positive fluxes moisten the growing CBL by upward transport of humidity from surface evaporation due to previous days' rain. However, they were probably too low to generate the deep convection predicted on that particular day. Fourier spectra of the wind lidar's vertical velocity measurements in the mid-CBL enable to estimate the dissipation rate of turbulent kinetic energy (TKE) following the Kolmogorov-Obukhov empirical relationship in the inertial subrange. It amounts to 5•10-4 m2 s-3 in the Rhine Valley between 400 and 1200 m height above ground, using a Kolmogorov constant of 0.55, valid for one-dimensional velocity spectra. This is in accordance with the mid-CBL results of the in-situ vertical velocity spectra in the valley. Over the mountains, the in-situ spectra show higher levels, as expected due to higher TKE, and bring dissipation rates of up to 10-3 m2 s-3.