Quantifying energy budgets in the Atmospheric Boundary Layer over western Germany

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Keywords: synergy, mixing diagrams, bulk Richardson number, advection.
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The processes involved in land-atmosphere interaction are crucial for weather and climate prediction. Their influence in extreme events, such as heat waves, can be better understood utilizing measurements. Quantifying energy budgets in the daytime boundary layer is challenging but necessary to better parametrize them in models (Milovac et al. 2016). The increasing availability of high-quality measurements of the driving variables in the Atmospheric Boundary Layer (ABL) provides an excellent starting point for performing this task.

Instrument synergy

We utilized measurements at the Jülich Observatory for Cloud Evolution (JOYCE, ACTRIS National Facility),in particular, temperature and humidity profiles from an azimuth-scanning MicroWave Radiometer (MWR) and 3D wind vector from a Doppler Wind Lidar (DWL). Synergistic variables are obtained: Richardson bulk number for ABL height determination, as well as local temperature and humidity advection. In turn, these variables are utilized to then quantify energy budgets with the mixing diagram approach.

Richardson bulk number Ri_B

Ri_B is a measure of instability in the ABL that can be estimated combining thermodynamic (MWR) and dynamical (DWL) measurements, which are available from most ACTRIS cloud remote sensing stations.

$$Ri_B = \frac{g}{\theta_0}\frac{(\theta_z - \theta_0)z}{u^2 + v^2}$$

In the present work, Ri_B is plotted (Fig. 1) and qualitative differences are clearly seen for two summer days (with and without heat wave). Furthermore an applied threshold in Ri_B provides an estimate of ABL height, which considers turbulent mixing processes associated to both shear and buoyancy.

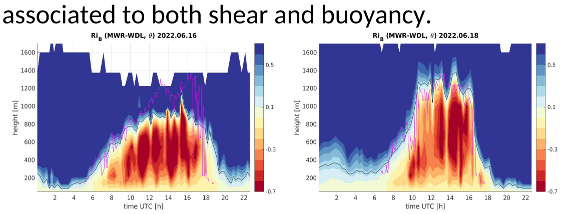

Figure 1. Daytime Ri_B evolution for days without heat wave (left) and with heat wave (right). Black contours are the ABL heights via threshold Ri_B.

Advection estimations

A novel approach for estimating advection is implemented. Horizontal inhomogeneities of temperature and humidity are estimated from the MWR azimuth-scans at 30° elevation and horizontal velocities from DWL are employed. Appropriate weighting and averaging is applied to derive local values of temperature and humidity advection within the ABL.

Mixing diagrams

Within the mixing diagram (Fig. 2), we show the temporal co-evolution of the vertically-averaged ABL sensible and latent heat over a defined time interval. Over this time interval, these energies transferred into the ABL must be balanced by surface fluxes, advection, and entrainment fluxes. These diagrams are built up as follows:

1. $C_p\theta$ vs Lq Evolution: obtained from MWR from surface up to ABL height (from Ri_B).
2. Surface sensitive and latent heat fluxes: obtained from a close-by Eddy-Covariance station (ICOS).
3. Advection: estimated from MWR horizontal inhomogeneities and velocities from DWL.
4. Entrainment: estimated as a residual vector as in Santanello et al. (2009).

With the vector representation as given in Fig. 2, we can characterize the contributions to the ABL energy budget and thus identify dominant process for different situations.

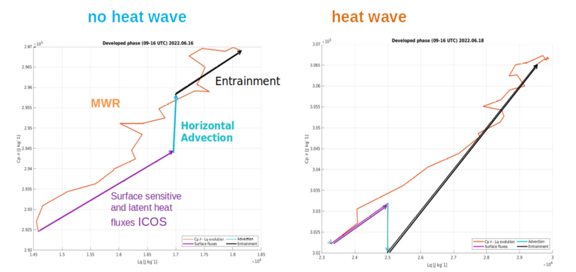

Figure 2. Mixing diagrams obtained for a non heat wave and a heat wave day from 0900 to 1600 h.

References

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