Classifying the Cloudy Boundary Layer for Land Surface - Atmosphere Interactions at JOYCE

Marke[1], T., U. Löhnert[1], J. Schween[1], A. J. Manninen[2], E. J. O'Connor[2]
[1] Institute of Geophysics and Meteorology, University of Cologne, [2] Finnish Meteorological Institute, Helsinki

1. Exploiting JOYCE Ground Based Observations

Fig. 1: JOYCE Instruments (left to right): Doppler lidar, Microwave Radiometer, Ceilometer, Cloud Radar,120 m Meteorological Tower and Eddy Covariance station

The Jülich Observatory for Cloud Evolution (**JOYCE**) provides continuous and highly-resolved measurements of the **boundary layer** since 2011, with applications for site characterization (Fig. 2) and instrument synergies (Fig. 3).

joyce.cloud

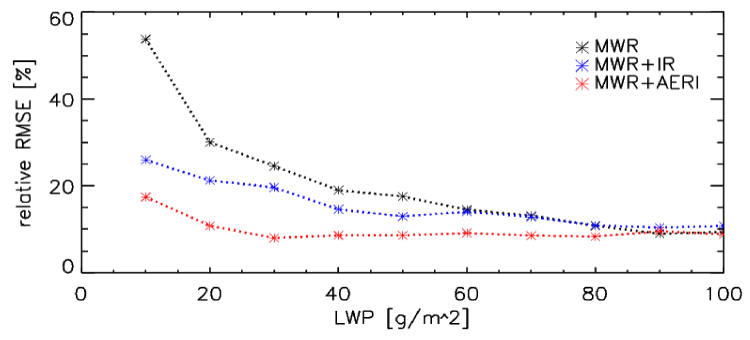

Fig. 2: *Instrument synergy of microwave and infrared observations for retrieving microphysical properties of thin liquid water clouds.*

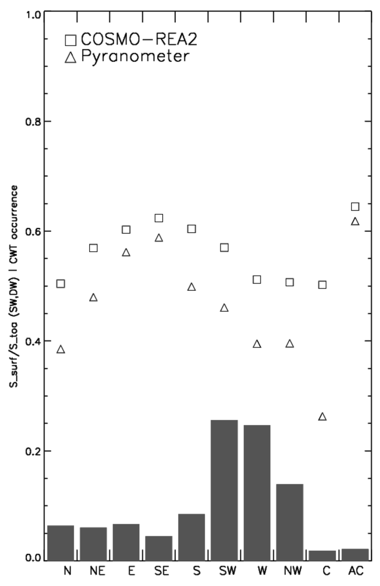

Fig. 3: *Circulation Weather Type classification and measured / modeled down-welling shortwave radiation.*

2. Clear Sky Boundary Layer Characteristics

Water vapor variability and boundary layer development

- Microwave Radiometer (MWR) PPI **scans** at 30° elevation at JOYCE
- Integrated quantities of water vapor (**IWV**) and liquid water (**LWP**) obtained from statistical retrievals between 2012-2015
- Diurnal pattern of IWV related to the azimuth direction (Fig. 4, left)
- Boundary layer height corresponds to IWV variability (Fig. 4, right)

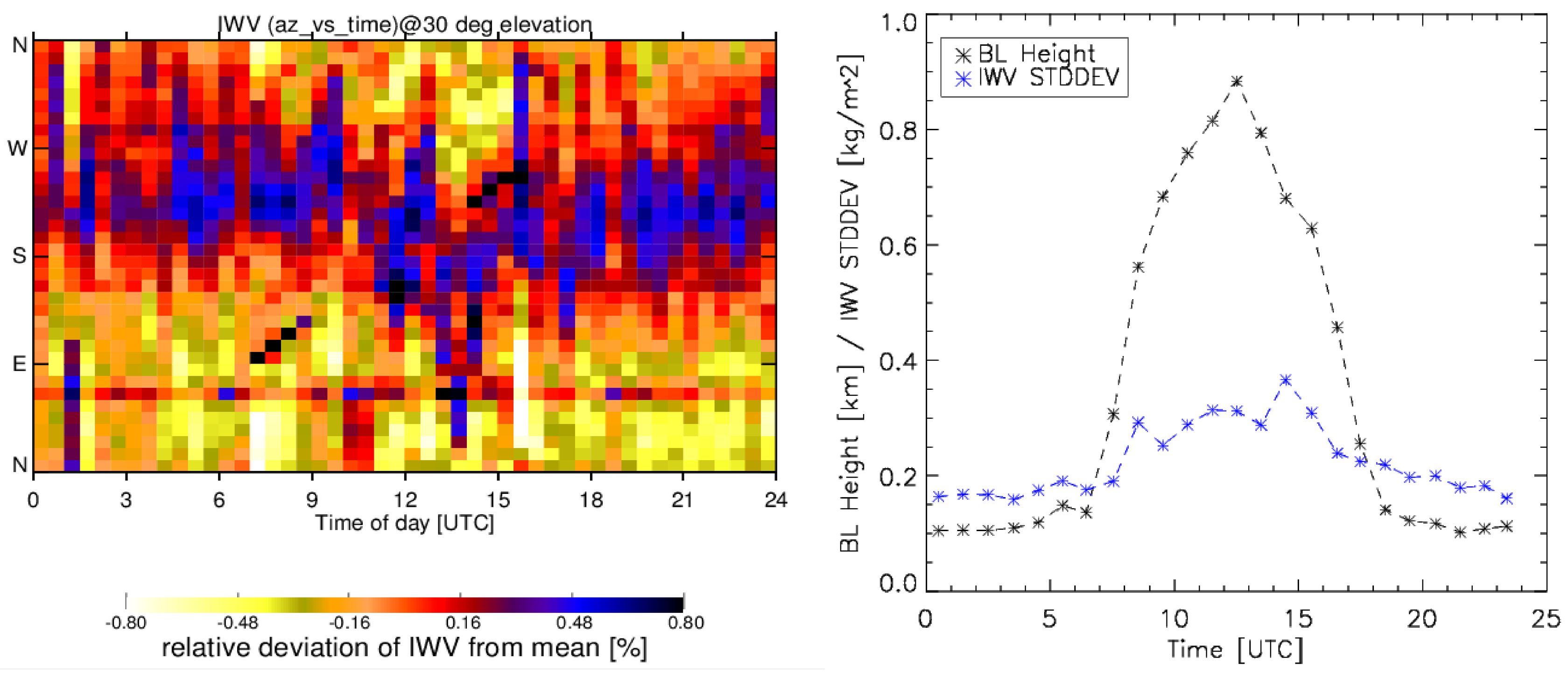

Fig. 4: *Relative IWV deviation from the mean of each MWR scan with LWP <10 g/m² between 2012-2015 (left). IWV standard deviation (STDDEV) for each scan with boundary layer height derived from the vertical velocity STDDEV [3] of the Doppler lidar (right).*

Evaluation of Doppler lidar derived wind direction and speed

- Doppler lidar three beam swinging method for wind estimates during low LWP times
- Turning of wind direction during the day and nearly constant with height in convective situations (Fig. 5, left)

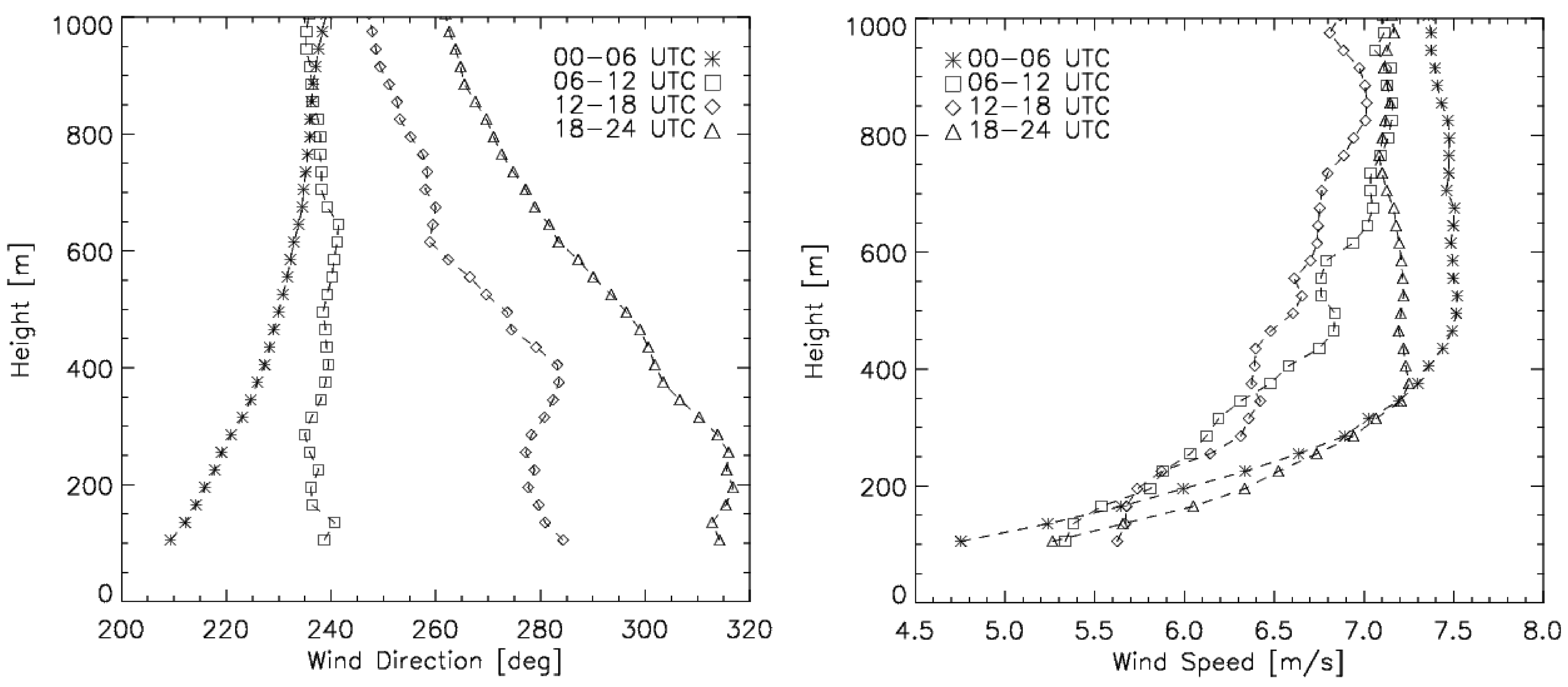

Fig. 5: *Doppler lidar derived wind direction (left) and wind speed (right), averaged in four different time intervals during the MWR scans between 2012-2015.*

4. Connection to Land Surface Processes

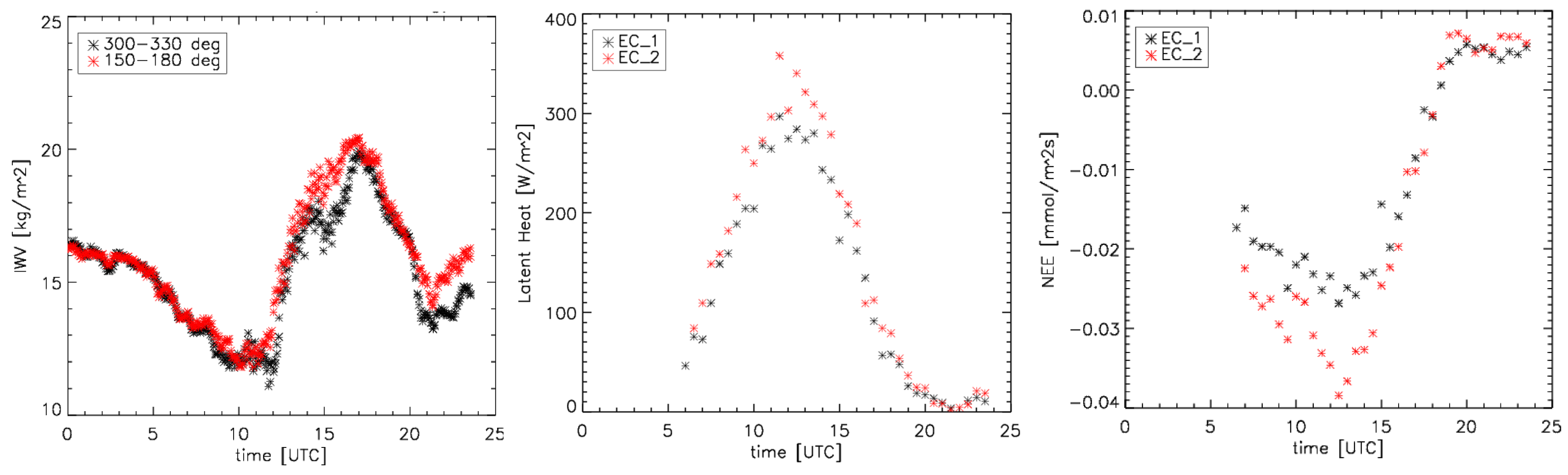

Fig. 6: MWR-IWV (left) in two different sectors (NW, SE) directing to the Eddy Covariance stations (EC_1 black, EC_2 red) with measured Latent Heat (center) and Net Ecosystem Exchange of CO_2 (NEE, right).

- Eddy Covariance stations (Fig. 6, center, right) and high-resolution airborne imaging give insight into plant activity and near surface fluxes.
- Comparison to MODIS satellite products (Fig. 8) in the research area around the JOYCE site (Fig. 7)

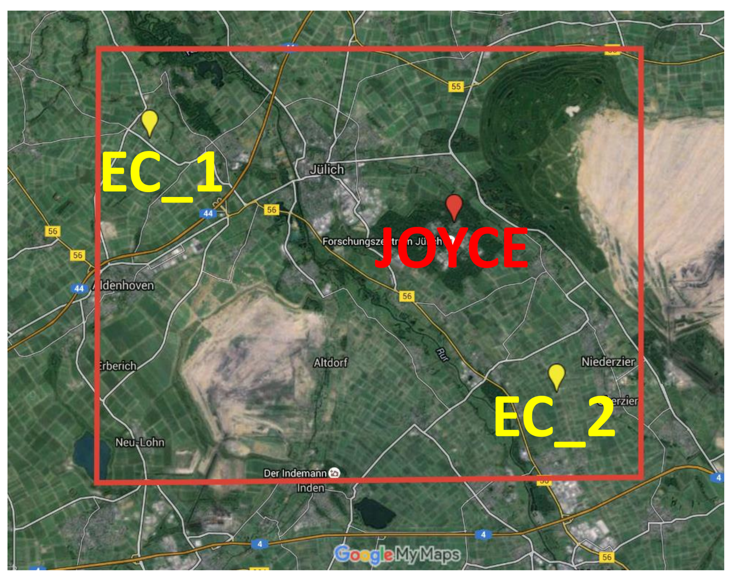

Fig. 7: *Research area around JOYCE site (red marker), with Eddy Covariance stations (yellow markers).*

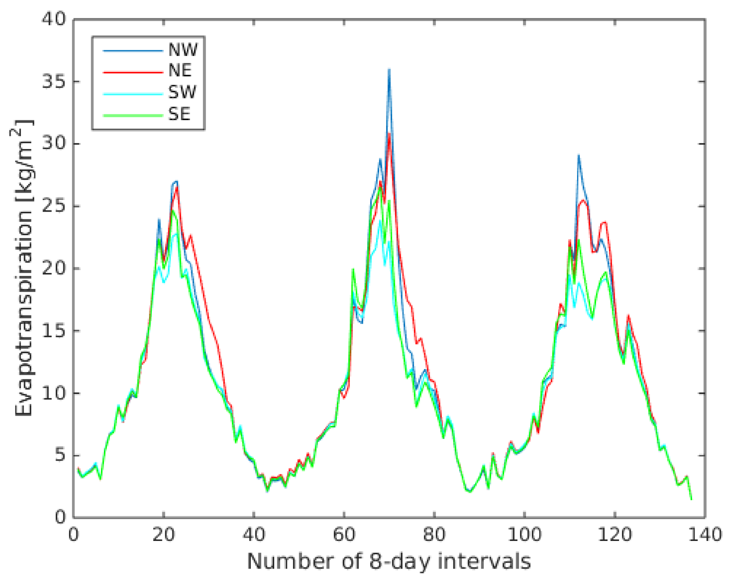

Fig. 8: *MODIS 8-day interval derived Evapotranspiration divided in four sectors within 11x11 km around JOYCE (red square in Fig. 7) between 2012-2014 [2].*

5. Boundary Layer Classification Scheme – Clear Sky

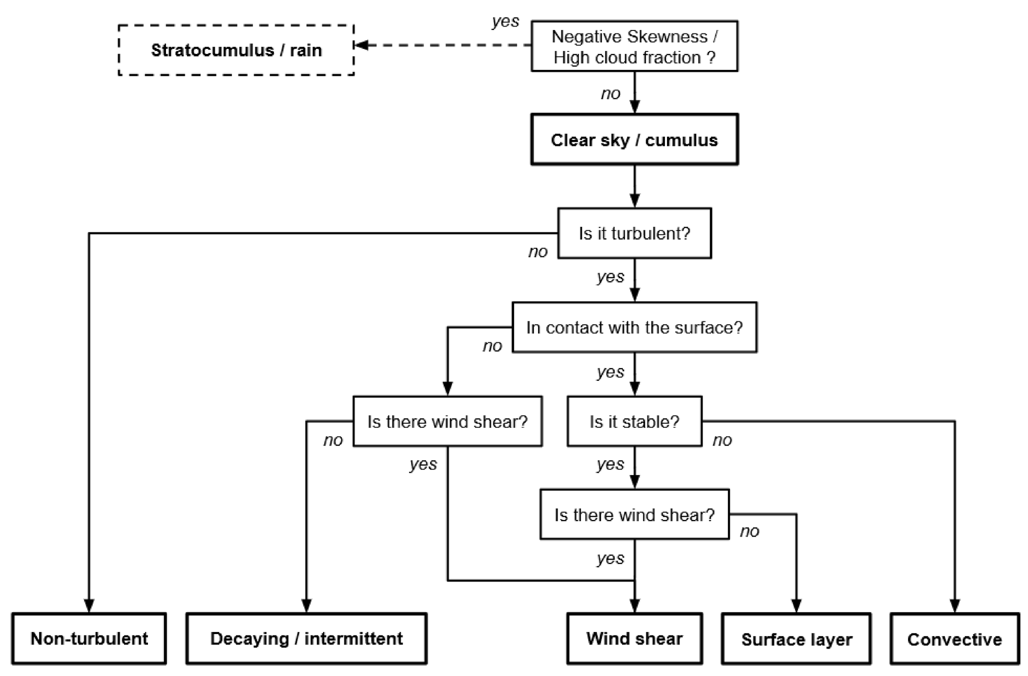

Fig. 9: *Extract of the boundary layer classification scheme for clear sky cases.*

- **Concept:** Examine the evolution of mixing processes and determine the origin of turbulence in the boundary layer
- **Applications:**
  - Identify situations for statistical analysis of land surface - atmosphere coupling
  - Evaluation of model parameterization in Large-Eddy-Simulations (LES)
  - Large potential for Doppler lidar network
- **Further development:** Include clouds, detect drizzle or rain and provide probabilities as an uncertainty estimate

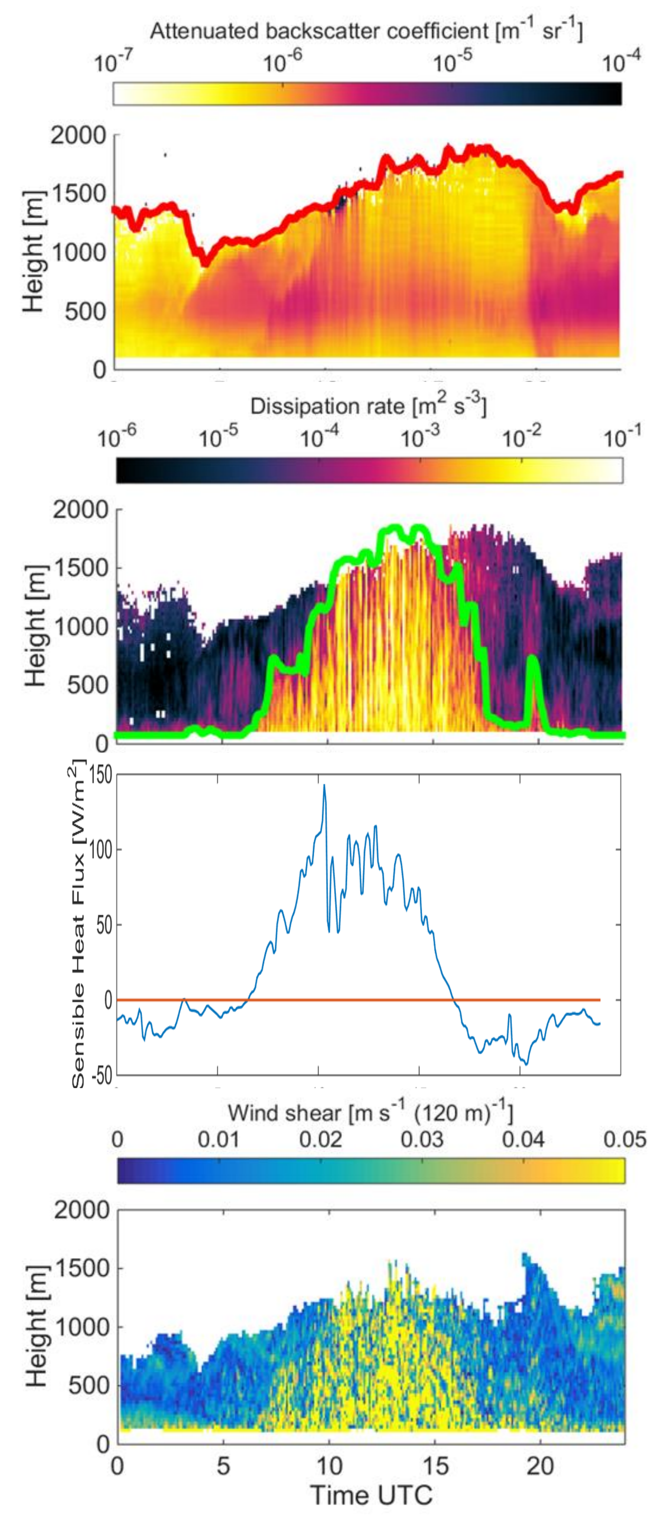

Fig. 10: *Time series of the attenuated backscatter coefficient, dissipation rate [1], latent heat and vector wind shear (from top to bottom) used for the classification.*

References:

[1] Ewan J. O'Connor, Anthony J. Illingworth, Ian M. Brooks, Christopher D. Westbrook, Robin J. Hogan, Fay Davies, and Barbara J. Brooks: A Method for Estimating the Turbulent Kinetic Energy Dissipation Rate from a Vertically Pointing Doppler Lidar, and Independent Evaluation from Balloon-Borne In Situ Measurements. Journal of Atmospheric and Oceanic Technology 2010 27:10, 1652-1664.

[2] ORNL DAAC. 2008. MODIS Collection 5 Land Products Global Subsetting and Visualization Tool. ORNL DAAC, Oak Ridge, Tennessee, USA. Accessed May 31, 2016. Subset obtained for MOD16A2 product at 50.9086N,6.4133E, time period: 2012-01-01 to 2014-12-27, and subset size: 11 x 11 km, doi: 10.3334/ORNLDAAC/1241

[3] Schween, J. H., Hirsikko, A., Löhnert, U., and Crewell, S.: Mixing-layer height retrieval with ceilometer and Doppler lidar: from case studies to long-term assessment, Atmos. Meas. Tech., 7, 3685-3704, doi:10.5194/amt-7-3685-2014.

tmarke@meteo.uni-koeln.de