THE HUMIDITY STRUCTURE OF THE CONVECTIVE BOUNDARY LAYER - SIX WEEKS MEASUREMENTS WITH A GROUND-BASED DIFFERENTIAL ABSORPTION LIDAR (DIAL)

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Barbara Hennemuth* , Klaus Ertel
Max-Planck-Institute for Meteorology, Hamburg, Germany

1 INTRODUCTION

The earth's surface is the source of water vapour in the climate system. Water vapour is transported upwards by turbulent and convective eddies, but the strength of the temperature inversion on top of the atmospheric boundary layer (ABL) controlls the transport into the "free atmosphere". Without clouds water vapour can in the first approximation be treated as a passive scalar, and thus reflects the temperature-driven mixing processes. Entrainment at the top of ABL in most cases is a sink for the humidity budget of the ABL - contrary to the temperature budget. These processes result in a different humidity than temperature stratification. The idealized humidity profiles in a well-mixed layer (Stull, 1988) are not in all cases observed.

2 MEASUREMENTS

During three measuring campaigns in the frame of the project EVA-GRIPS (regional EVAporation at GRId/Pixel Scale) at Lindenberg, an agricultural site in eastern Germany measurements of the absolute humidity have been performed with two Differential Absorption Lidar Systems (DIAL) (Bösenberg (1998), Bösenberg and Linné (2002), Ertel (2004)). Both systems have a time resolution of 10 s and are able to measure over up to 12 h. Short interruptions are due to maintenance and adjustment. One of the systems gives reliable results of water vapour density above 300 m agl, the other above 700 m agr. Time-height sections from 6 to 18 UT and up to 3000 m asl of 25 days under different synoptic situations illustrate the variability of the the humidity ABL appearance. Time-height sections of the backscattered signal - namely,

*Corresponding author address: Barbara Hennemuth, Max-Planck-Institute for Meteorology, Bundesstr.55, D-20146 Hamburg, FRG, e-mail: hennemuth@dkrz.de

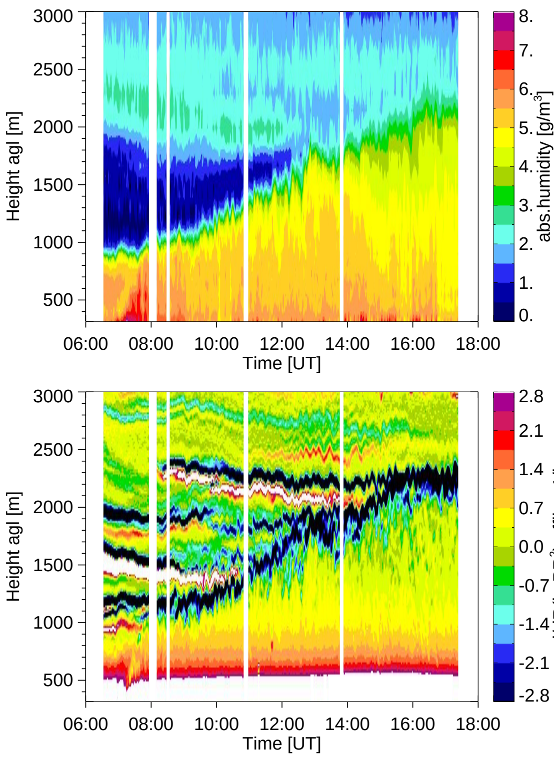

FIG. 1: Time-height section of absolute humidity (upper panel) and of logarithmic gradient of range-corrected backscattered signal (lower panel) on 30 May 2003 at Lindenberg

the logarithmic gradient of the range-corrected backscatter signal - give some more information on motions in the atmosphere. As can be seen in the lower panel of Fig.1 the top of the convective boundary layer (CBL) is marked by a dark colour, i.e. strong negative gradients, indicating a strong decrease of backscattering aerosols. Above the CBL and within the morning residual layer more such structure are present and hint at stable stratification. The rising and subsiding of those structures reflects vertical movements like waves.

Radiosonde and surface data complete the data set. Part of the observations fell into an untypically dry period.

3 BOUNDARY-LAYER STRUCTURE

On days with high pressure systems and sufficient insolation the evolving CBL is clearly seen in the humidity field and the backscatter signal. Fig.1 illustrates this development by time-height-sections of absolute himidity (upper panel) and backscatter gradient (lower panel).

In most cases the growing CBL is clearly present in the morning, but synoptic-scale or mesoscale features often disturb the 'stationary' daytime ABL. On May 30 the convective boundary layer does not reach its maximum height around noon but steadily increases due to decreasing pressure.

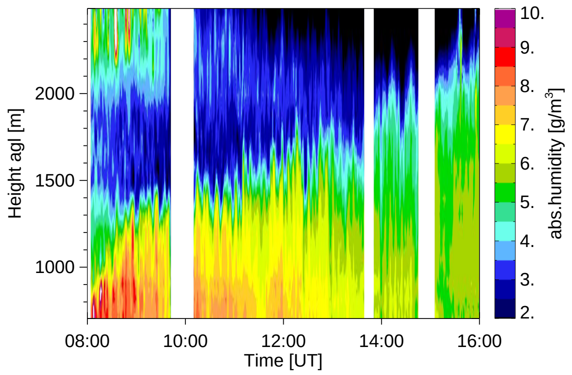

FIG. 2: Time-height section of absolute humidity on 13 June 2003 at Lindenberg

Fig.2 illustrated some other observed features of the convective boundary layer.

- The variability of the top of ABL due to single convective structures may be as large as 300 m with a time scale of several minutes, depending on the mean wind speed. This has to be taken into account when ABL heights are derived from radiosoundings (see Hennemuth and Lammert (2004) at this conference).

- Nearly in all cases the high humidity values in the growing ABL decreases before the top height is reached: the supply of water by evapotranspiration is not sufficient for mixing up to the top of ABL. This effect is clearest in situations when the well-mixed residual layer is high and the ABL grows 'explosively' fast.

- Entrainment of dry air from above the ABL is often observed and results in a supplementary drying of the CBL and in a humidity gradient in the upper BL which is no more well-mixed in the afternoon. Measurements of turbulent water vapour fluxes within the CBL with two lidar systems show that entrainment flux can reach through half of the CBL (Hennemuth et al. (2004) at this conference).

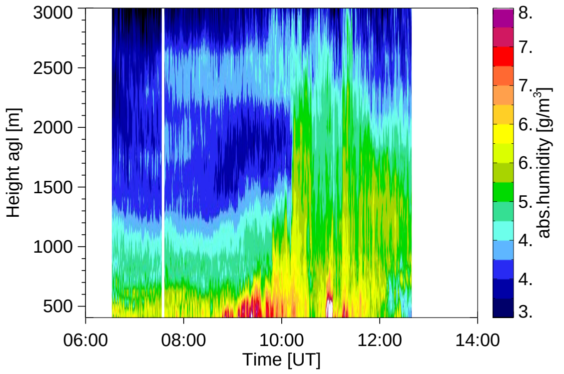

FIG. 3: Time-height section of absolute humidity on 31 May 2003 at Lindenberg

On 31 May 2004 a convergence line passed over Lindenberg and could be observed by DIAL because there was no rain and the cloud bases were at heights of 2000 m. Fig. 3 shows that the observed low-level convergence leads to upwinds which break through the ABL inversion and transport humidity into higher levels.

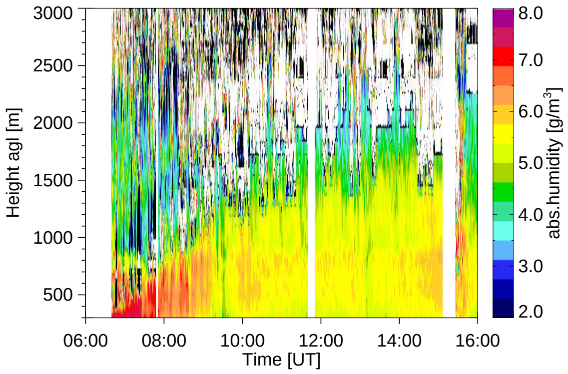

FIG. 4: Time-height section of absolute humidity on 22 May 2003 at Lindenberg

Fig.4 shows that low-level cloud bases - here identified by white or black colours - are lifted with the growing ABL. As can be seen from radiosounding this is caused by heating of the growing CBL with unchanged humidity and thus a rising condensation level.

Another feature in the layer above the CBL is documented by Fig.5. During the growing of the CBL the layered features in the stably stratified lower kilometers subside. On 8 June 2003 Lindenberg was situated in the western part of a high-pressure system with weak gradients. Surface pressure decreased during the day. The vertical profiles of temperature and humidity from radiosoundings do not essentially contribute to the explanation of this phenomenon.

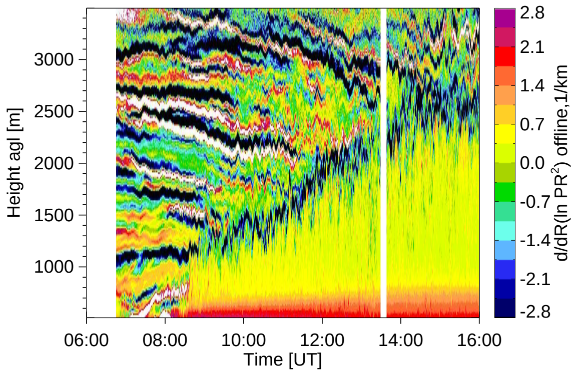

FIG. 5: Time-height section of logarithmic gradient of range-corrected backscattered signal on 8 June 2003 at Lindenberg

4 CONCLUSIONS

Ground-based DIAL systems are capable of monitoring the humidity boundary layer over many hours and thus give pictures of humidity structures up tp 4000 m heights. The features of the humidity ABL may differ strongly from those of the temperature ABL, in particular over land surfaces with low soil moisture.. The transport mechanisms are temperature-dominated and humidity is mainly a passive scalar. With weak evaporation from the ground the humidity mostly decreases within a growing CBL. Entrainment plays a great role and can further decrease the humidity when dry air is lying above the CBL.

Some observed features like the subsidence of aerosol layers above the growing CBL need further investigation in order to explain and assess the involved processes.

Acknowledgements

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