VALIDATION OF ATMOSPHERIC BOUNDARY LAYER SIMULATIONS WITH REMO BY GROUND-BASED LIDAR MEASUREMENTS

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1 INTRODUCTION

Simulating the energy and water cycle in the Baltic Sea catchment area is one of the aims of BALTEX(the Baltic Sea Experiment, BALTEX (1995)), one of the GEWEX (The Global Energy and Water Cycle Experiment) continental scale experiments. This includes the modeling of sensible and latent heat fluxes at the surface and the transport of heat and water vapour from the surface into higher atmospheric levels. The strongest barrier in the vertical transport is the atmospheric boundary layer (ABL) inversion.

If the boundary layer is not realistically simulated, the amount of heat and vapour which is available for cloud formation or dissolution is unrealistic. Land surfaces with their complex soil and vegetation structure are not yet fully described in models.

This study compares simulations of a regional atmospheric model with observations in the boundary layer over a rather flat terrain in Eastern Germany. The landscape is typical for the southern catchment area of the Baltic Sea with agricultural landuse. The measurements took place within the project EVA-GRIPS (Regional **Eva**poration at **Gri**d/**P**ixel **S**cale over Heterogeneous Land Surfaces) which is part of the German Climate Research Programme (DEKLIM). The measuring site is Lindenberg in Brandenburg, Germany (52°10' 02" N, 14°07' 24" E), the time period was the main vegetation period (May/June) of 2003. This period turned out to be one of the driest seasons in Eastern Germany with dramatically reduced soil moisture and evaporation. In the measuring period from 20 May to 14 June 2003, light rainfall occurred on 6, 8 and 12 June.

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2 THE MODEL REMO

REMO is a three-dimensional hydrostatic atmospheric regional model (Jacob and Podzun, 1997). It's original set-up was dedicated for simulations within BALTEX . The dynamical core of REMO is based on the operational Europamodell of Deutscher Wetterdienst (DWD) and can be used as a climate or forecast model (Majewski, 1991). For this study the version REMO5.1 with physical parameterisations derived from ECHAM4 (Roeckner et al., 1996) is used. The model domain comprises Northern and Central Europe.

FIG. 1: Model domain of REMO5.1 1/6° over northern and central Europe. The location of Lindenberg is marked with "X"

REMO is set up in a 1/6° -grid, which corresponds approximately to 18 km x 18 km in a rotated spherical grid (with the pole at 170° W, 32.5° N). The initial and boundary conditions are supplied by a REMO run with 1/2° horizontal resolution, which is driven by ECMWF analyses. REMO is run in the forecast mode - i.e. it is initialised every 24 and run for 30 h and skipping the first 6 h, the discontinuity is at 00 UT. The soil parameters are initialized from a long-term REMO run which allows for a suitable spin-up of the parameters.
For comparison with observations the variables are extracted at the grid point of Lindenberg

as hourly means (surface fluxes) or as instananeous values (atmospheric values humidity and temperature).

3 MEASUREMENTS WITH DIAL

The lidar technique offers observation of atmospheric values with high temporal and spatial resolution in the atmospheric boundary layer (Bösenberg and Linné, 2002).

A rather new system is the DIfferential Absorption Lidar (DIAL), measuring the density of water vapour. In DIAL system the laser emits short light pulses (ca.200 ns duration) of two different wavelengths, one in the absorption line of water vapour ("ONLINE") and one just beside this line ("OFFLINE"). The offline pulse is backscattered by aerosol particles and molecules, and the online pulse is in addition weakened by absorption. The combination of the backscattered signals of the two wavelengths allows the calculation of the absolute humidity. The frequency of the laser is 20Hz, the wavelengths are e.g. λ_{online} = 728.9387 nm und $\lambda_{offline}$ = 728.7619 nm. The time resolution is 10 s.

An example of the backscattered signal - here: the logarithmic derivative of the range corrected backscattered signal - is shown in Figure 2. Dark colors mark layers of decreasing aerosols and thus often the tops of aerosol-loaded layers associated with inversions. By this, the top of the boundary layer is clearly visible.

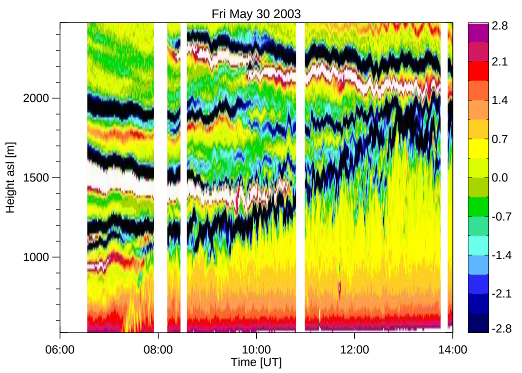

FIG. 2: Time-height section of logarithmic gradient of backscatter signal over Lindenberg on 30 May 2003.The units of the colourbar is 1/km.

In general, lidar measurements were performed during daytime between 06 and 18 UT, short interrupts are due to technical problems or the passage of low clouds.

4 ATMOSPHERIC BOUNDARY LAYER CHARACTERISTICS

The model REMO is run for the whole measuring period and the evolution of the boundary layer is studied and compared to the measurements. Figure 3 and 4 show examples of time-height sections of measured and simulated humidity over 3-day-periods.

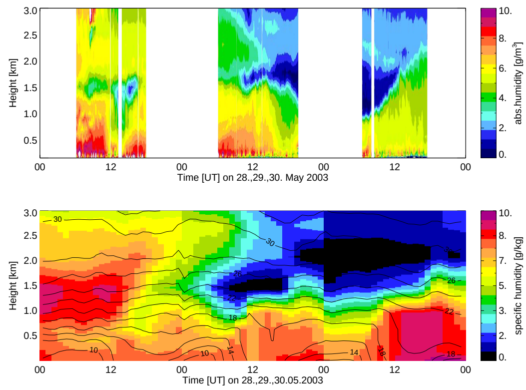

FIG. 3: Time-height section of absolute humidity over Lindenberg for 28/29/30 May 2003, measured by DIAL (upper panel) and simulated by REMO (lower panel). In the REMO panel, isolines of the potential temperature are plotted.

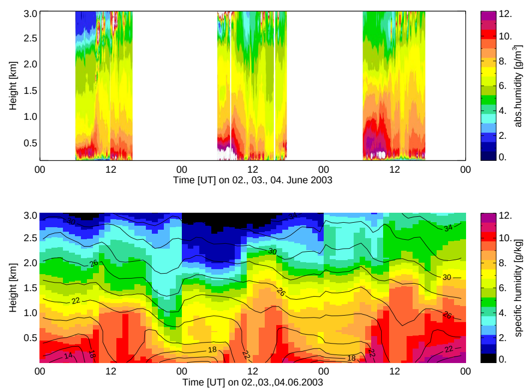

FIG. 4: Same as Fig.3 but for 2/3/4 June 2003.

One of the dominating features of ABL evolution during this experiment is that the humidity decreases in time when the ABL grows and that the humidity in the fully developed ABL is not well mixed but decreases with height. This may be due to the low supply of water from the rather dry surface. These features are well reproduced in the model.

Other results of the comparison are:

- The general evolution of the ABL is well simulated.

- The top of the simulated ABL is in most cases too low.
- Humidity in the simulated ABL is higher than observed.
- The typical drying of the growing ABL is well simulated.
- The synoptic situation is not always realistically simulated.

The reasons for the mentioned deviations in the ABL structure are manifold.
One of the most important shortcomings of the present version of the model is its low vertical resolution of 20 levels. By this, the height interval from the surface to 3000 m is represented by only 9 vertical levels. This has a strong effect on both the simulated height of the ABL and on the humidity gradient at the top of the ABL.
A too low height of the ABL implies a too moist ABL because the evaporated water vapour mainly stays within the layer. But additionally, the simulated evaporation - the source of water vapour - is too high. Figure 5 compares the evaporation in the Lindenberg gridbox with measurements over a rape field, one of the dominant landuse cultures. This shows that the extreme dryness of the 2003 vegetation period is not captured by the model. The improvement of regional model SVATs (Surface-Vegetation-Atmosphere Transfer modules) is one of the aims of EVA-GRIPS.

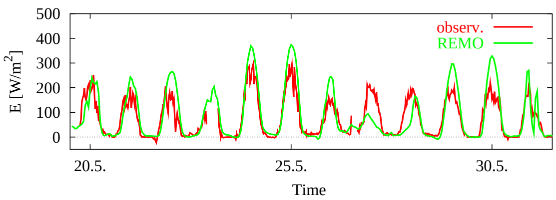

FIG. 5: Latent heat flux at Lindenberg from 20 to 31 May 2003, simulated by REMO (green) and measured over a rape field (red) by GKSS (Geesthacht). Note that all measured fluxes are plotted despite of their fetch.

The synoptic situation - here mainly reflected in the advection of dry or moist air above the ABL - is in general realistically simulated, but due to the coarse vertical resolution of the model, some features are missing. This is the dry layer between ABL and 'free atmosphere' on 28 May (Fig. 3) and the extent of moist air up to 3000 m on 3 June (Fig. 4).

5 CONCLUSIONS AND OUTLOOK

Although there are some deviations in model results from observations, the model REMO is even in its standard version capable for giving most features of the ABL over a rather flat agricultural region. Details of the ABL evolution cannot be resolved in a model with as few as 20 vertical levels.

The comparison of model results with lidar observations is more stringent than with e.g. radiosonde data because data are available over the whole period of ABL development. Thus the growth of the ABL in the morning, the structure of the fully developed ABL and the state of the atmosphere above the ABL can be checked. So ground-based remote sensing observations are an excellent tool for the validation of ABL simulations, particularly in regional models.

In the future, REMO will be run with higher vertical resolution in order to resolve ABL structures in a better way. The transport processes of water vapour within and through the top of the ABL will be studied and compared with observations. Turbulent fluxes of water vapour in the ABL can be determined by combining the DIAL measurements with radar-RASS-measurements (Senff et al., 1994) or Doppler lidar measurements (Bösenberg and Linné, 2002) which have been performed during EVA-GRIPS, too.

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References

BALTEX (1995). Baltic Sea Experiment BALTEX. initial Implementation Plan. In *Technical report, International BALTEX Secretariat*, page 84pp. GKSS Research Center, Geesthacht, Germany.

Bösenberg, J. and Linné, H. (2002). Laser remote sensing of the planetary boundary layer. *Meteorol.Z.*, 11:233 – 240.

Jacob, D. and Podzun, R. (1997). Sensitivity studies with the regional climate model REMO. *Meteorol.Atmos.Phys.*, 63:119–129.

Majewski, D. (1991). The Europa-Modell of the Deutscher Wetterdienst. In *Seminar Proc. ECMWF 2*, pages 147–191.

Roeckner, E., Arpe, K., Bengtsson, L., Christoph, M., Claussen, M., Dümenil, L., M.Esch, Giorgetta, M., Schlese, U., and Schulzweida, U. (1996). The atmospheric general circulation model ECHAM-4: Model description and simulation of present day climate. Report 218, Max-Planck-Inst.f.Meteorologie, Hamburg, Germany.

Senff, C., Bösenberg, J., and Peters, G. (1994). Measurement of water vapor flux profiles in the convective boundary layer with lidar and radar-rass. *J.Atm.Ocea.Techn.*, 11:85–93.