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Using Microwave Profiling to Evaluate Mesoscale Model Boundary Layer Forecasts

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1. Introduction.

Ground-based microwave remote sensing is a well established technique to observe temperature and humidity profiles as well as cloud liquid water path (LWP). Recently, advances in instrument sensitivity, stabilization and automatisation have made them a valuable tool for continuous monitoring of the atmosphere. Typically, the radiometer is operated in zenith direction which is preferable for synergetic use with cloud radar or lidar. In the zenith observation mode the profiles of humidity and temperature are retrieved from the spectral characteristics of the 22 GHz water vapor line and the 60 GHz oxygen band, respectively. The accuracy for the absolute humidity is below 1 gm^{-3} and 2 K for temperature with a vertical resolution of 1 km close to the surface which decreases strongly with altitude. Under the assumption of horizontal homogeneity a much better resolution in the boundary layer can be achieved by adding angular information in addition to the spectral one: The lower the elevation angle the more information comes from the lowest atmospheric layers. For the highly opaque channels of the oxygen line this information is only useful when the brightness temperatures can be observed at least with an accuracy of 0.1 K putting high constraints on radiometer accuracy. If this achieved the uncertainty in the temperature profile reduces to 0.5 K in the lowest kilometer with a vertical resolution of about 100 m. Above about 2 km the boundary layer scan can not achieve a better accuracy than the zenith pointing mode (Appendix, Fig. 3). In the past mesoscale models have shown problems in accurately forecasting inversion strength and height. These analyses are based on comparisons with conventional radiosoundings which are typically performed twice per day. The operation of the highly stable Humidity and Temperature Profiler (HATPRO) [Rose et al., 2005] during the LAUNCH campaign (September/October 2005) at the German Weather Services (DWD) Observatory at Lindenberg (52.17 N, 14.12 E) allowed not only an accuracy assessment of the retrieved boundary layer temperature profiles but could also be exploited to evaluate the forecasts by the Lokal-Modell-Kürzestfrist (LMK) which is currently under test before it will be operationally at DWD in 2007.

2. Observations

HATPRO was operated at DWDs boundary layer measurement site at Falkenberg 4 km south of Lindenberg located in flat and homogeneous grassland. Typically the radiometer was operated in zenith scanning mode with elevation scans performed about every 30 m. The comparison of the retrieved profiles during all weather conditions with observations by a 99 m tower (6 levels: 10, 20, 40, 60, 80 and 98 m) confirmed with an RMS of <0.5 K at the 100 m level the theoretical results. Even for the retrieval of the temperature gradient (Fig.1) very promising results especially for the stable boundary layer were achieved. During strong solar heating of the surface the results degrade as the radiometer probes air masses further away from the tower.

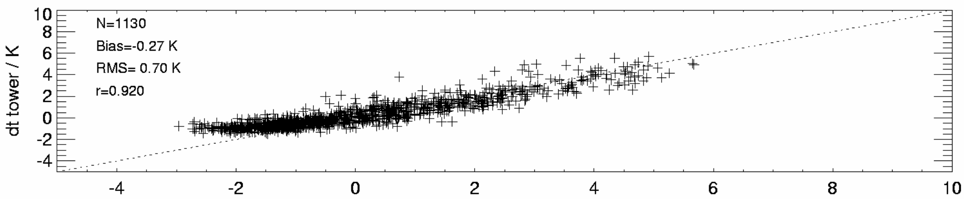

Fig. 1. Comparison of temperature gradients between 10 and 100 m retrieved by HATPRO with corresponding values of the100 m mast at Lindenberg.

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3. Model Comparisons

September 14, 2005 is chosen as an example to demonstrate the usefulness of HATPRO observations for model evaluation. The night was clear leading to strong inversion of about 6 K which slowly resolves after sunrise. In the afternoon low level (cloud base ~1200 m) clouds developed partly caused by the advection of more humid air and persisted through the night. Routine radiosoundings were performed at Lindenberg four times per day and provide a rough view (Fig. 2a) on the temporal evolution of the complex boundary layer development predicted by LMK. This model was run with ~2.8 km horizontal resolution, 50 vertical layers and a time step of 20 s for the whole area of Germany. In order to get a better view on how well the LMK can reproduce the temporal development the +24 hour forecast was compared with HATPRO boundary layer scans (Fig. 2.b). During the night the model is not able to reproduce the strength of the inversion correctly. A possible reason is the introduction of a new transfer scheme which favors a stronger coupling between the surface and the atmosphere. The deviations during the first half of the day indicate a too cold boundary layer and a too warm free troposphere pointing at problems in the entrainment formulation. In the second half of the day synoptic influence led to cloudiness was influence cause a positive temperature bias of about 2 K in the LMK (compare also sounding at 1715 UTC).

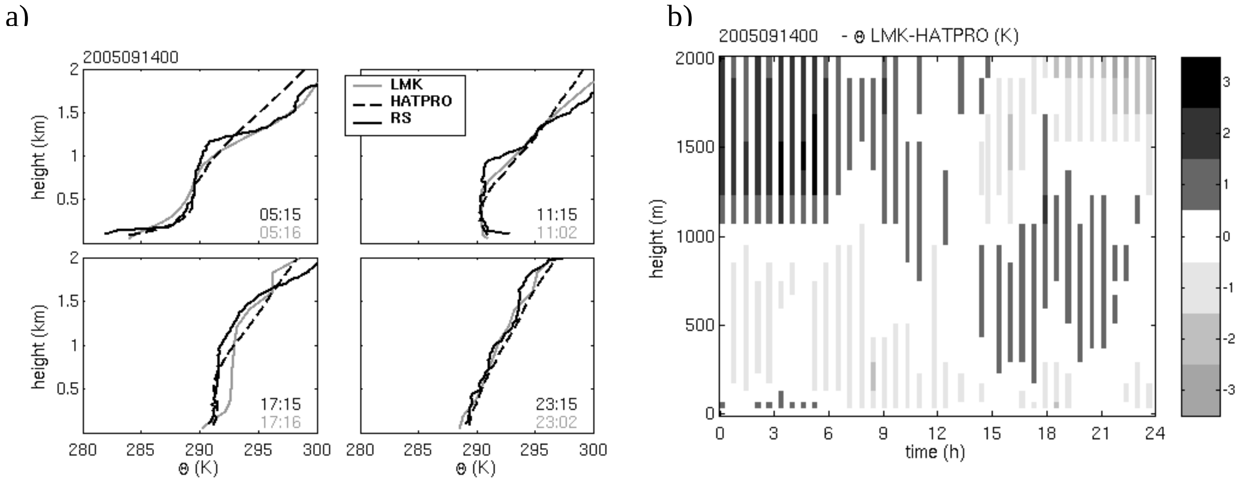

Fig. 2. a) Potential temperature profiles by LMK and HATPRO compared to radiosoundings at Lindenberg on September 14, 2005. b) Difference in potential temperature (LMK - HATPRO) for that day.

4. Discussion and Outlook

Observations with a new microwave radiometer can continuously provide highly accurate boundary layer temperature profiles whose quality was quality was confirmed by simultaneous tower and radiosonde observations. For a specific case study the comparison with model forecasts could reveal problems in the formulation of the stable boundary layer. In order to confirm this, the whole campaign is currently analyzed and specific cases will run with other turbulence schemes available in the LMK. In future, the observation cycle of the microwave radiometer including elevation angles, integration times and repetition times will be optimized in order to perform a systematic long-term model evaluation. This will be performed over the full year 2007 when the radiometer will be placed next to the ARM mobile facility in the Black Forest region as part of the German COPS experiment (see contribution by Wulfmeyer).

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Rose T., S. Crewell, U. Löhnert, C. Simmer, 2005: A network suitable microwave radiometer for operational monitoring of the cloudy atmosphere, *Atmospheric Research* 75, 183-200

Appendix

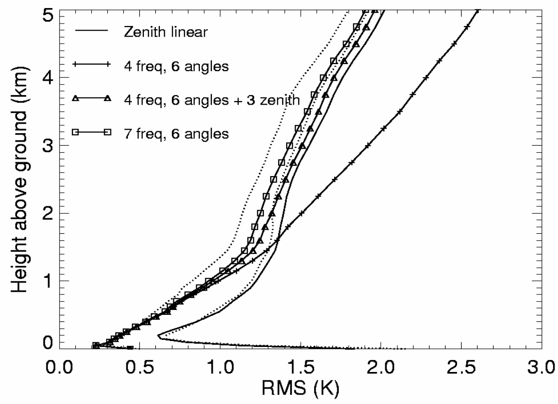

Fig. 1. Theoretical accuracy of boundary layer temperature retrievals for different combinations of observations. The noise level of all brightness temperatures is 0.3 K. For the zenith retrieval (7 frequencies) and the combination of all (7) frequencies and angles (6) the dotted line gives the RMS value in clear sky conditions. Please note that in clear sky conditions the error in the surface value increases to over 2 K because local heating of the surface occurs.