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INITIAL EVALUATION OF PROFILES OF TEMPERATURE, WATER VAPOR, AND CLOUD LIQUID WATER FROM A NEW MICROWAVE PROFILING RADIOMETER

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Introduction

To measure the vertical profiles of temperature and water vapor that are essential for modeling atmospheric processes, the Atmospheric Radiation Measurement (ARM) Program of the U. S. Department of Energy launches approximately 2600 radiosondes each year from its Southern Great Plains (SGP) facilities in Oklahoma and Kansas, USA. The annual cost of this effort exceeds $500,000 in materials and labor.

Despite the expense, these soundings have a coarse temporal resolution and reporting interval compared with model time steps. In contrast, the radiation measurements used for model evaluations have temporal resolutions and reporting intervals of a few minutes at most. Conversely, radiosondes have a much higher vertical spatial resolution than most models can use. Modelers generally reduce the vertical resolution of the soundings by averaging over the vertical layers of the model.

Recently, Radiometrics Corporation (Boulder, Colorado, USA) developed a 12-channel, ground-based microwave radiometer capable of providing continuous, real-time vertical profiles of temperature, water vapor, and limited-resolution cloud liquid water from the surface to 10 km in nearly all weather conditions (Solheim *et al.*, 1998a). The microwave radiometer profiler (MWRP) offers a much finer temporal resolution and reporting interval (about 10 minutes) than the radiosonde but a coarser vertical resolution that may be more appropriate for models.

Profiles of temperature, water vapor, and cloud liquid water are obtained at 47 levels: from 0 to 1 km above ground level at 100-m intervals and from 1 to 10 km at 250-m intervals. The profiles are derived from the measured brightness temperatures with neural network retrieval (Solheim *et al.*, 1998b).

In Figure 1, profiles of temperature, water vapor, and cloud liquid water for 10 May 2000 are presented as time-height plots. MWRP profiles coincident with the 11:31 UTC (05:31 local) and 23:47 UTC (17:47 local) soundings for 10 May are presented in Figures 2 and 3, respectively. These profiles illustrate typical

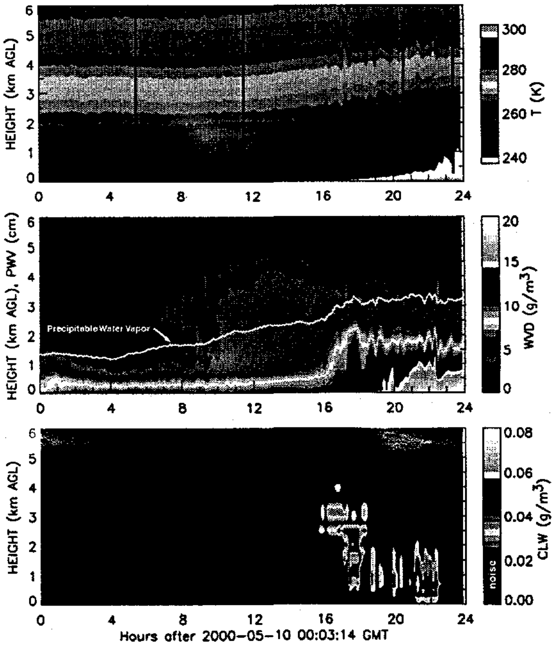

Figure 1. Time-height contours of temperature (top), water vapor (center), and liquid water (bottom) from the MWRP for 10 May 2000. The vertical lines in the top panel indicate the radiosonde launch times. The white line in the center panel indicates the precipitable water vapor from the MWRP, which doubles in magnitude over the day. In the bottom panel, values of liquid water content less than the instrument sensitivity are set to black.

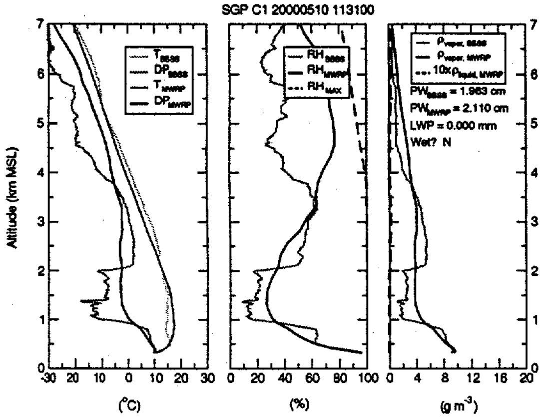

Figure 2. Profiles of temperature and dew point (left panel), relative humidity (center panel), and water vapor and liquid water density (right panel) from the MWRP and the Vaisala balloon-borne sounding system (BBSS) for 11:31 UTC (05:31 local time) on 10 May 2000. The dashed line in the center panel indicates the ratio of saturation mixing ratios for ice and liquid water for sub-freezing temperatures. The right panel also lists the precipitable water vapor from both BBSS and MWRP, the liquid water path (LWP) from the MWRP, and the status of the MWRP rain sensor.

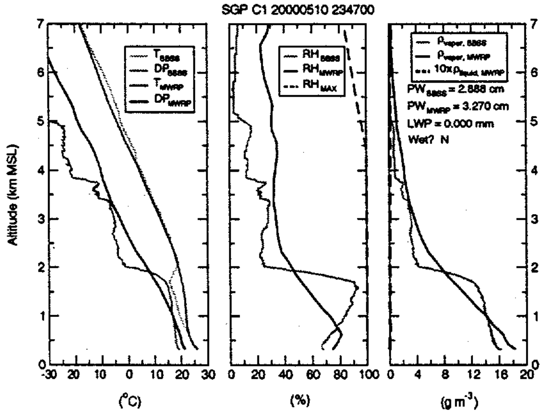

Figure 3. Same as Figure 2 for 23:47 UTC (17:47 local time) on 10 May 2000.

performance for temperature inversion and lapse conditions.

Profile Comparisons

To evaluate the performance of the new MWRP, the radiometer was deployed at the ARM SGP central facility from 15 February to 8 August 2000. The profiles of temperature and water vapor density derived from the MWRP brightness temperatures were compared with routine soundings from the Vaisala balloon-borne sounding system (BBSS) using RS-80H radiosondes. MWRP profiles were also compared with boundary layer profiles (up to 3 km) derived from the atmospherically emitted radiance interferometer (AERI) infrared spectrometer, as described by Smith *et al.* (1999). The mean difference ("bias") and the root-mean-square difference ("rms error") between the MWRP or AERI and the BBSS for the period from 15 February to 8 August 2000 are presented in Figure 4. The nearly all-weather capability of the MWRP yielded about 30% more valid profiles coincident with BBSS soundings than were obtained with the AERI (349 vs. 269).

Both the MWRP and AERI compare well with the BBSS, with rms errors significantly less than the standard deviation about the mean of the soundings. Gueldner and Spaenkuch (2000) obtained similar results with an identical MWRP.

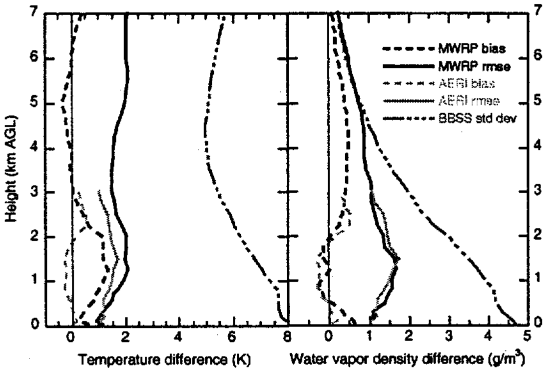

Figure 4. Comparison of temperature and water vapor profiles from the MWRP and AERI infrared spectrometer with profiles from the BBSS. In each plot the dotted lines indicate the mean difference (bias), the solid lines indicate the root-mean-square difference (rms error), and the dot-dashed line indicates the standard deviation about the mean of the radiosonde profiles (i.e., "climatology").

Model Comparisons

To make an initial assessment of the suitability of the MWRP for radiation modeling applications, we used delta two- and four-stream radiative transfer models (Toon *et al.*, 1989; Liou *et al.*, 1988) to compute the downward longwave and shortwave irradiance, respectively. In the radiative transfer calculations gaseous absorption was computed by using the k–distribution method and correlated-k tables developed by Kato *et al.* (1999) and Mlawer *et al.* (1997) for shortwave and longwave radiation, respectively. We used the measured water vapor profiles up to 10 km and added the mid-latitude summer standard atmosphere above 10 km. We also used mid-latitude summer standard profiles of ozone, nitrous oxide, and methane. Because we were concerned only with the effects of the different temperature and water vapor profiles on the model results, we fixed the solar zenith angle at 60 degrees and the surface albedo at 0.2. No clouds were inserted. We applied the models to 12 cases (of which AERI profiles were available for only 7) between 10 and 16 May 2000. The results are shown in Figure 5.

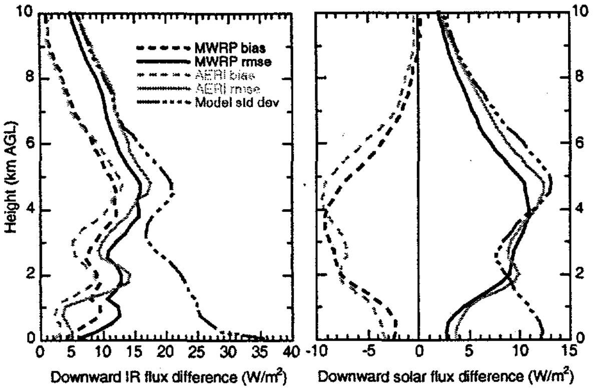

Figure 5. Mean differences (bias) and rms differences (rmse) in downward infrared and solar fluxes, calculated by using temperature and moisture profiles from the MWRP or AERI and the BBSS.

The rms errors are less than the variation about the mean for the BBSS-based model results. The errors are also less than those of the pyranometers and pyrgeometers typically used to measure the radiation fluxes.

Conclusions

This initial evaluation of the MWRP suggests that its accuracy is comparable to that of the AERI boundary layer profiler; however, the MWRP can operate to greater altitudes and over a wider range of sky conditions. The vertical resolution of the MWRP profiles, while coarser than that of the BBSS profiles, appears to be sufficient for the solar and infrared flux models we used.

Evaluation of the liquid water profiles will be undertaken once comparable data from combined cloud radar and two-channel microwave radiometer become available.

Acknowledgements

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