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GROUND-BASED MICROWAVE RADIOMETER MEASUREMENTS DURING PRECIPITATION

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ABSTRACT

Liquid water and ice on a microwave radiometer radome or antenna degrade the accuracy of atmospheric brightness temperature measurements. We present results using rain effect mitigation methods that minimize the accumulation of liquid water and ice on the radiometer radome during precipitation (patent pending). Brightness temperatures observed during precipitation by collocated radiometers with and without rain effect mitigation are compared. We find that precipitable water retrieved from a radiometer with rain effect mitigation is in good agreement with estimates from ground-based GPS observations. Radiosonde soundings are compared with radiometric retrievals at time of launch and at the time of maximum precipitation. The results demonstrate the capability for accurate temperature and humidity retrievals during precipitation from profiling radiometers using rain effect mitigation.

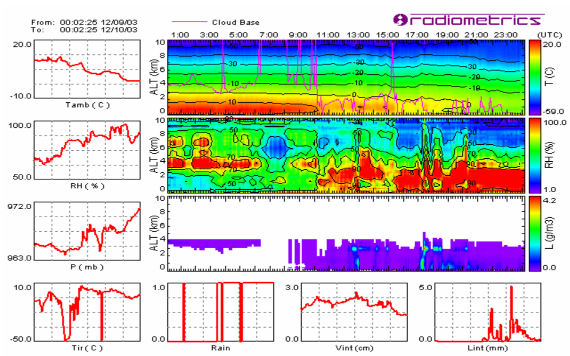

Fig. 1. Temperature, humidity and liquid contours to 10 km height retrieved from a radiometric profiler with rain effect mitigation. Surface temperature, humidity, and pressure, cloud base temperature, rain sensor, and integrated water vapor and liquid are shown (counterclockwise) in the 24-hr time series plots.

1. EXPERIMENT DESCRIPTION

The U.S. Department of Energy operates microwave radiometers at its Southern Great Plains Central Facility (SGPCF) in Oklahoma as part of its Atmospheric Radiation Measurement (ARM) program. In early December 2003, Radiometrics WVR-1100 and TP/WVP-3000 radiometers were in operation at the SGPCF. One of the radiometers (the 3000) was outfitted with rain effect mitigation and the other (the 1100) was not. Precipitation totaling 11.5 mm was measured by a tipping bucket at the SGPCF on 9 Dec 2003. This precipitation event provided the opportunity to evaluate radiometer rain effect mitigation.

2. RESULTS

Temperature, humidity and cloud liquid retrievals from zenith observations by a profiling radiometer using rain effect mitigation are shown in Fig. 1. Frontal passage with rain, snow, and up to 25 C cooling in the boundary layer occurred between the times of radiosonde soundings shown in Fig.'s 5-8. Neural network methods [1] and recent refinements in radiative transfer modeling [2] were used to obtain radiometric retrievals. The temperature and humidity profiles and the integrated water vapor time series are free from unreasonable variations that are typical during precipitation when rain effect mitigation is not used. Brightness temperatures observed by collocated radiometers with and without rain effect mitigation are shown in Fig. 2.

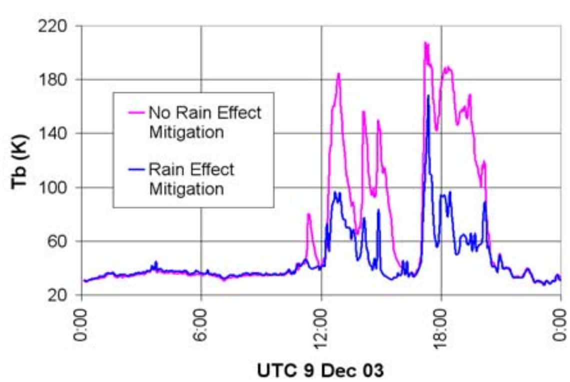

Fig. 2. Brightness temperature measurements at 23.235 GHz by collocated radiometers with and without rain effect mitigation. Up to 100 K reduction in brightness temperatures is seen with rain effect mitigation.

Rain effect mitigation reduces the observed brightness temperatures by as much as 100 K. Brightness temperatures can be directly assimilated in numerical weather models to improve short term forecasting [3]. Precipitable water retrievals are shown in Fig. 3. Unreasonably sharp increases in precipitable water as large as 5 cm are seen without rain effect mitigation.

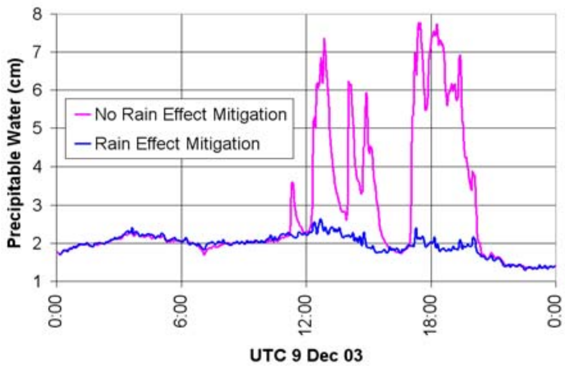

Fig. 3. Precipitable water retrievals from collocated radiometers with and without rain effect mitigation. Sharp increases of more than 5 cm are seen without rain effect mitigation.

Validation of the precipitable water retrievals is obtained by comparison with estimates from GPS observations in Fig. 4. The estimates are derived from 30-min averages of GPS propagation delay observations above 7 degrees elevation. Taking temporal and spatial averaging into account, the two measurements are in good agreement. Rain rate measurements by a tipping bucket at the SGPCF are also shown in Fig. 4. The rain rate maximum of 3.2 mm/30-min occurs at 1720 UTC. Estimates of rain rate can also be obtained from radiometer observations [4].

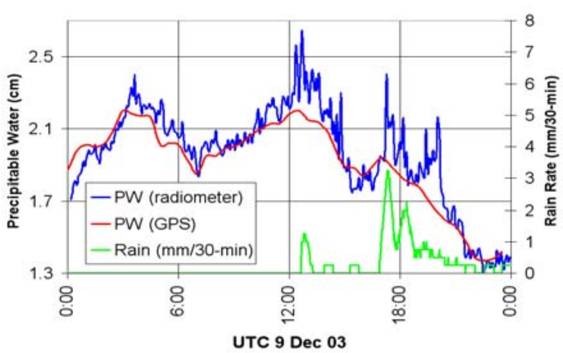

Fig. 4. Precipitable water retrieved from a radiometer with rain effect mitigation (blue), and estimated from GPS observations (red). Rain rate measured by a tipping bucket is also shown (green).

3. RADIOSONDE COMPARISON

Temperature and humidity soundings from radiosondes launched from the SGPCF are compared with retrievals from a radiometer at the same site with rain effect mitigation in Fig.'s 5-8. The radiosonde launch time and the radiometer observation time are listed in the header, along with station altitude, zenith infrared temperature, liquid water accumulation on top of the radiometer (Y=liquid water, N=no liquid water), and retrieved integrated vapor and liquid. Cloud base height is indicated by a blue horizontal bar labeled "CB" on the temperature profile. A simultaneous radiometer retrieval and radiosonde sounding at 0528 UTC are shown in Fig. 5.

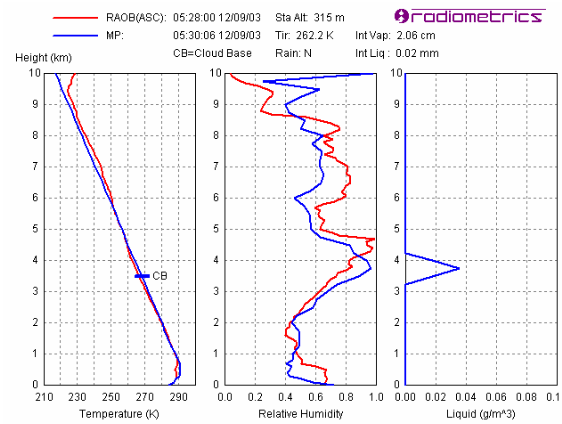

Fig. 5. The 0530 UTC radiometric retrieval (blue) and the 0528 UTC radiosonde sounding (red) are in reasonably good agreement.

Temperatures and relative humidities for both methods agree within several degrees K and 20% up to 9 km height. Relative humidity saturation is seen near 4 km height. The retrieved integrated vapor and liquid are 2.06 cm and 0.02 mm, and peak cloud liquid of 0.04 g/m^3 is seen at 3.75 km height.

Fig. 6 compares the retrieval at the time of maximum liquid density and integrated liquid with the most recent radiosonde sounding.

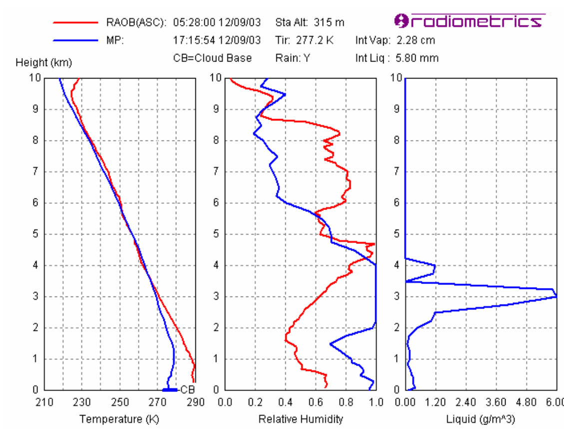

Fig. 6. Radiometric retrieval (blue) at the time of maximum retrieved liquid density and integrated liquid (1715 UTC) and the most recent (0528 UTC) radiosonde sounding (red).

A maximum rain rate of 3.2 mm/30-min was measured by the tipping bucket at 1720 UTC, 5 min after the maximum liquid retrieval. Boundary layer cooling by up to 15 C is seen in the retrieval in Fig. 6 along with 100% relative humidity from 2 to 4 km height, and 6.8 g/m^3 maximum liquid density at 3 km height.

The retrieval at 2324 UTC is compared to the most recent radiosonde sounding (at 0528 UTC) in Fig. 7.

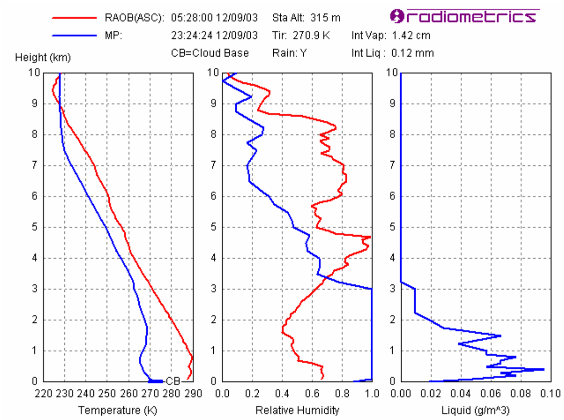

Fig. 7. The radiometric retrieval (blue) at 2324 UTC is compared with the most recent (0528 UTC) radiosonde (red). The retrieved fog layer extends from the surface to 3 km height with a maximum density of 0.09 g/m^3 at 300 m height.

During the 19 hour interval between radiosonde soundings, up to 25 C cooling occurred in the boundary layer, the remainder of the troposphere cooled by up to 10 C, and the tropopause descended by several km. By this time the retrieval shows boundary layer cooling up to 25 C at 800 m height, and 10 C cooling at 7.5 km height. The retrieval also shows fog, relative humidity saturation, and cloud liquid extending up to 3 km height, with 0.12 mm integrated liquid. The relative humidity profile showing saturated conditions to (or near) the surface is well supported by the cloud base height derived from the zenith infrared sensor and temperature profile. Cloud base height descends from 2 km at 2100 UTC to 0 to 200 m during hour 2300 UTC.

The retrieval and the radiosonde sounding at 2329 UTC are shown in Fig. 8. The radiosonde validates the temperature retrieval within several degrees C up to 6 km height and the relative humidity retrieval within 20% up to 5 km height. Retrievals in Fig.'s 7 and 8 show lifting of cloud base from the surface to 200 m height and cloud top descending from 3.25 to 2.25 km height during a 5-min interval. During this interval the integrated vapor decreases from 14.2 to 13.6 mm (14%) and the integrated liquid decreases from 0.12 to 0.11 mm (12%).

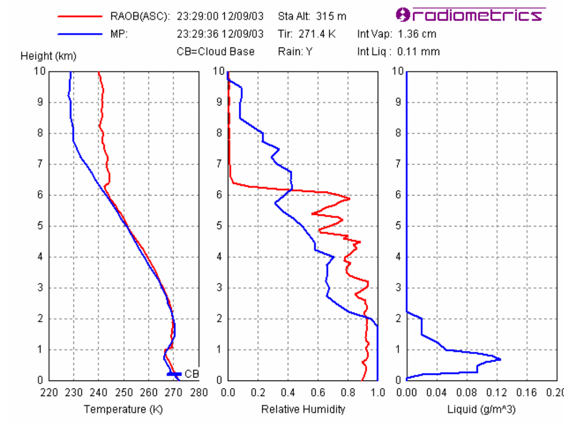

Fig. 8. The 2329 UTC radiosonde sounding (red) validates the 2329 UTC temperature and humidity retrievals (blue) within several degrees C up to 6 km height and within 20% up to 5 km height, respectively. The retrieved liquid reaches a maximum density of 0.12 g/m^3 at 800 m height.

4. CONCLUSIONS

Rain effect mitigation is effective in minimizing error resulting from accumulation of liquid water on a radiometer radome. As in other cases, the profiling radiometer returns a high level of detail in the evolution of temperature and humidity structure that cannot be recovered by twice-daily soundings. Hence the profiled temperature and relative humidity hold promise for improving local short term forecasting by providing much more frequent upper air observations. The capability for accurate observations during precipitation increases the research and operational potential for microwave radiometers.

5. REFERENCES

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