A CASE STUDY OF THERMODYNAMIC PROFILE RETRIEVAL USING A MICROWAVE RADIOMETER AT VERTICAL AND OFF-VERTICAL INCIDENCE

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1. INTRODUCTION

This study examines the characteristics of temperature and humidity profiles obtained via retrieval techniques using a Radiometrics 12-channel profiling microwave radiometer. The data collected are associated with a multi-year study of the development and dissipation of fog in the New York City area. The study is centered at a field site at Brookhaven National Laboratories (BNL) in central Long Island. The profiling radiometer (Fig. 1) provides 6 minute updates of temperature and moisture profiles from the surface up to 10km.

Figure 1 – The Microwave Profiling Radiometer at the Brookhaven National Labs site.

The microwave radiometer is a passive instrument that observes 12 frequencies of the microwave spectrum. Five of the frequencies are dominated by water vapor emissions and seven are dominated by molecular oxygen emissions. Forward modeling using the radiosonde data from the nearest radiosonde site and a neural network is used to derive the profiles. Surface and infrared data from a vertically pointing infrared sensor are also incorporated in the derivation of the profile (Ware et al. 2001).

While the microwave radiometer can produce profiles from vertically (zenith) pointing scans (method 1), it also has capability to produce vertical profiles from slant (off-zenith) scans ranging from 15° above horizontal on one side of the radiometer to 165° on the other. The off-zenith data are then combined using the neural network to come up with a composite (full-scan) profile (method 2). It has been theorized that this method would have the advantage of providing greater vertical resolution of both temperature and moisture in the lower layers of the atmosphere (Liljegren, 2004).

An alternative method combines the data taken from 15° to 90° to yield a profile from one 'side' of the radiometer (method 3). The same approach can be applied for the 90° to 165° profiles (method 4). This technique allows the radiometer to look at the temperature and moisture profiles 'upstream' and 'downstream' from the radiometer and detect gradients associated with fronts, boundaries or changes in airmasses.

This paper compares the 0000 UTC KOKX sounding (located adjacent to the radiometer on the BNL site) with the profile from the radiometer at that time and also looks at several off-zenith retrieval techniques during a cold front passage at BNL on November 29, 2003.

2. PROFILE ANALYSIS

2.1. KOKX Sounding Comparison

In order to assure that the radiometer is operating normally, a comparison of the 0000 UTC profiles on the 29th from both the radiometer and KOKX sounding was done. Fig. 2 shows the comparison of the temperature profiles using the four techniques described previously. Overall, the zenith scan (Fig. 2a) seems to fit the actual temperature sounding the best. The other three methods indicate a stronger inversion than the zenith scan, but they show a far bigger inversion than that actually present (Figs. 2b, 2c and 2d). Although all four methods detect the lower level inversion to some degree, all of them completely miss the mid-level inversion.

Fig. 3 compares the relative humidity for the radiometer versus the KOKX sounding. The comparison here is a sharp contrast to that for temperature. The zenith scan seems to do the best in the lowest 0.5 km, keeping more moisture in that layer before drying out (Fig. 3a). Conversely, Figs. 3b, 3c and 3d all dry out very rapidly in this layer. All four methods miss the moist and dry layers aloft and show little to no correlation above 0.5 km

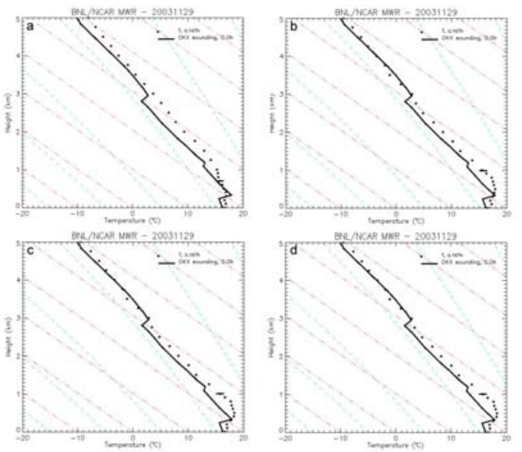

Figure 2 – A comparison of the radiosonde temperature data versus the microwave radiometer retrievals for the 0000UTC sounding from KOKX on 29 November, 2003. (a) shows the profile comparison using the zenith scan and (b) shows the profile using the full-scan combination. (c) shows the 15° to 90° scan (east-facing) combination and (d) shows the 90° to 165° scan (west-facing) combination.

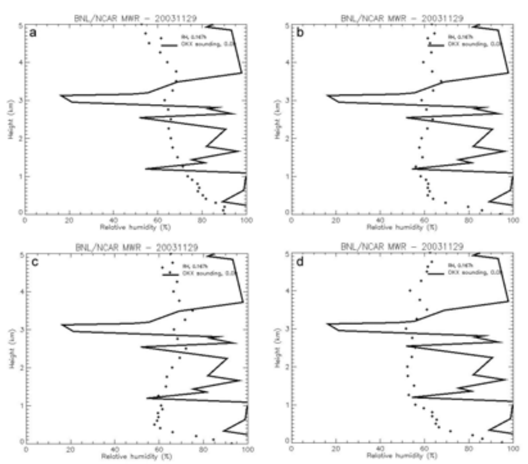

Figure 3 - A comparison of the radiosonde relative humidity data versus the microwave radiometer retrievals for the 0000UTC sounding from KOKX on 29 November, 2003. (a) shows the profile comparison using the zenith scan and (b) shows the profile using the full-scan combination. (c) shows the 15° to 90° scan (east-facing) combination and (d) shows the 90° to 165° scan (west-facing) combination.

2.2. Frontal Passage as Seen from the Microwave Radiometer.

At approximately 0400 UTC on November 29, 2003, the site at BNL experienced the passage of a cold front from the west. The cold front brought a drier and cooler airmass over the site. Fig. 4 shows the temperature time-series from 0000 UTC to 1200 UTC. The zenith profile method (Fig. 4a) detects the atmosphere cooling before the other three methods do. Method 3, which faces to the west (Fig. 4c), does see a cooling in the lower atmosphere before method 4, the east-facing method (Fig. 4d). However, the cooling is only on the order of a couple of degrees Celsius. Of the four methods, the zenith method again seems to do the best and catches the atmospheric cooling before the other three. It also does not detect the anomalous rapid cooling and warming around 0300 UTC that the other three methods detect, nor does it see the inversion jut above the surface the other three methods prominently show throughout the time-series plots.

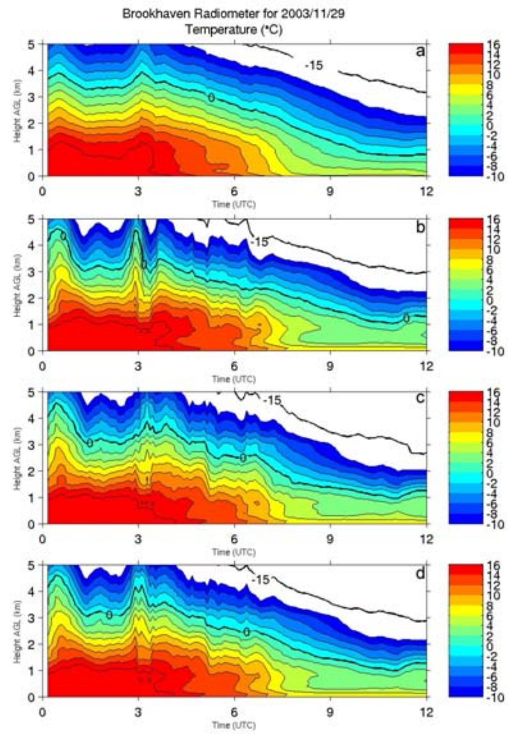

Figure 4 – The 0000 UTC to 1200 UTC 6-minute temperature profiles from the microwave radiometer. (a) shows the temperature plot from the zenith retrievals and (b) shows the full-scan retrievals. (c) shows the west-facing retrieval combination and (d) shows the east-facing combination.

Fig. 5 displays the relative humidity time series from the 6-minute radiometer retrievals. The four methods show little correlation to each other. Figs. 5b, 5c, and 5d show pockets of moist and dry air moving over the site that the zenith method never detects. While all four methods do agree on the atmosphere drying out around 2 km and higher at about 0600 UTC, there is almost no agreement between any of them before 0600 UTC and below 2 km.

3. CONCLUSIONS

While all four methods described above show varying changes in temperature and relative humidity, when looking at the sounding comparison, the zenith scan seems to match actual temperature soundings better than the elevation scans. The elevations scans tend to insert inversions erroneously

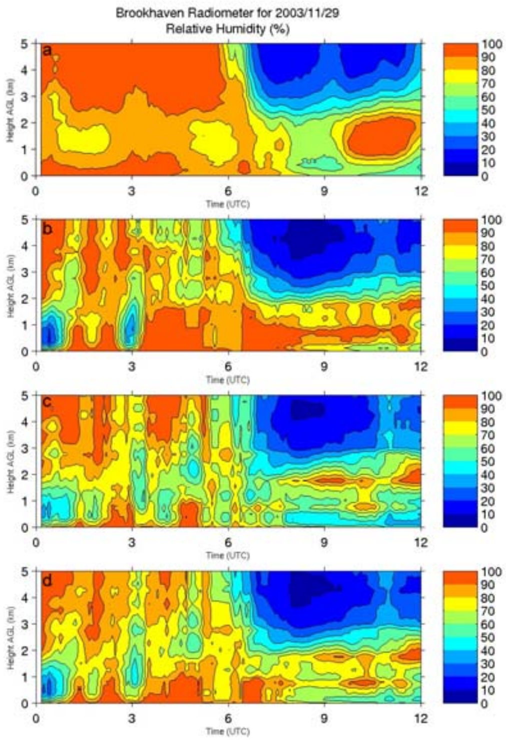

Figure 5 – The 0000 UTC to 1200 UTC 6-minute relative humidity profiles from the microwave radiometer. (a) shows the relative humidity plot from the zenith retrievals and (b) shows the full-scan retrievals. (c) shows the west-facing retrieval combination and (d) shows the east-facing combination.

in the sounding and all four methods miss the real inversion aloft. Additionally, in the time-series plots the elevation scans show features not seen by the zenith scans. These features are not obviously 'meteorological' in origin and, along with the sounding comparison results cited earlier, suggest that sidelobe and/or partial beam blockage effects may play a role in corrupting the lower elevation scans. While the elevation scans do indicate a weak signal of cooler air approaching from the west, the zenith scan shows the atmosphere cooling more quickly than the elevation scans.

The relative humidity field is much less representative than temperature in both the sounding comparison and the time-series plots. The elevation scans seem much more compromised in relative humidity than they do in temperature and the elevation scans show little to no correlation when compared against each other. Some of the possible reasons for these discrepancies could be beam blockage by trees at the site, minor miscalibrations in the K and V bands, and beam contamination from artifacts being detected in the side-lobes of the beam. More cases and research are needed to better understand the origins of the discrepancies. If it is determined that the elevation scan methods hold promise for improved vertical resolution profiles at lower levels, changes to the siting of the instrument would likely be necessary.

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5. REFERENCES

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