10.2 AN EVALUATION OF THE RADAR REFRACTIVITY RETRIEVAL DURING IHOP_2002

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1. INTRODUCTION

The International H_2O Project (IHOP_2002; Weckwerth et al. 2003) was designed to sample the three-dimensional time-varying moisture field to better understand convective processes. Numerous research and operational water vapor measuring systems and retrievals were operated in the U.S. Southern Great Plains from 13 May to 25 June 2002. This was done in combination with more traditional observations of wind and temperature. One of the new moisture retrieval algorithms, the radar refractivity retrieval (Fabry et al. 1997), was run on NCAR's S-Pol Doppler radar (Lutz et al. 1997).

This study will examine the representative horizontal scale and vertical depth of the radar refractivity retrievals.

2. BACKGROUND

The refractivity signal is derived from the difference in radar signal phase delay between two ground targets measured at a reference time exhibiting no refractivity gradients and a time of meteorological interest. This signal delay difference is due to atmospheric refractivity (N) variations which are related to changes in pressure, temperature, and water vapor by the following equation

$$N = 77.6\ {}^{P}/_{T} + 3.73 \times 10^{5}\ {}^{e}/_{T^2}, \qquad (1)$$

where P is pressure expressed in hPa, T is temperature in Kelvin, and e is the water vapor pressure in hPa. During the warm season, refractivity is most strongly influenced by changes in water vapor. During IHOP, a field of refractivity measurements was routinely obtained from the S-Pol radar in the Oklahoma panhandle. The nominal retrieval range was approximately 40 km but it extended 60 km toward the northwest due to the more numerous ground targets and more optimal slope of the land. The ground targets used for the retrieval were mostly towers, buildings, and power poles that were below 100 m, therefore the surface layer is suspected to be the level best represented by the refractivity. Spatial resolution should vary depending on the spacing of the ground targets, from the order of one to several km.

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3. INTERCOMPARISONS

The radar refractivity retrieval was compared to several different datasets—surface stations, AERIBAGO (Feltz et al. 2003), aircraft in-situ, and mobile mesonet (Straka et al. 1996)—to determine the representativeness of the retrieval. The location of each instrument plotted over the S-Pol refractivity field can be seen in Figure 1 (AERIBAGO is located at the Homestead site).

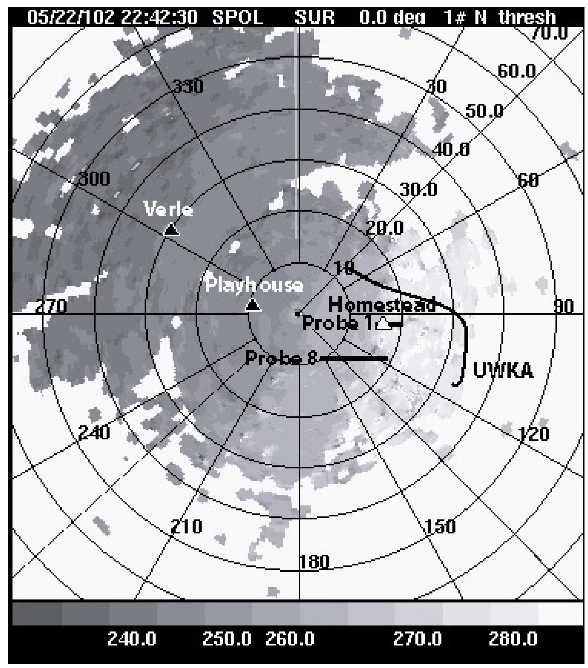

Figure 1a. Map of radar refractivity field at 2242 UTC on 22 May 2002 with locations of surface stations as well as aircraft and mobile probe tracks.

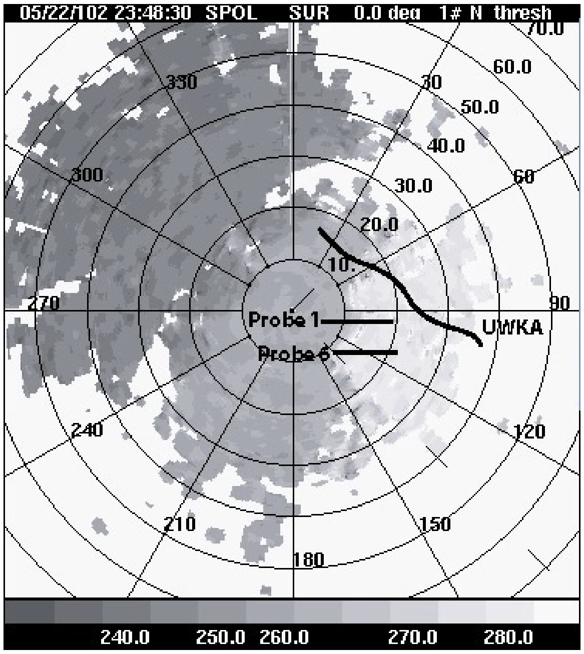

Figure 1b. Map of radar refractivity field at 2348 UTC, with locations marked as in 1a.

The refractivity retrieval was compared with data from different surface stations. The refractivity data from S-Pol shows excellent correlation (.98) with the refractivity computed from the Playhouse surface station (Figure 2), but shows a slight negative bias. The Verle surface station (Figure 3) also shows excellent correlation (0.99) with a slight negative bias. The Homestead surface station (Figure 4) shows a strong positive correlation (.92), but does not show a negative bias. The Homestead surface station was part of an ISS system, while the Verle and Playhouse surface stations were extra surface stations fabricated specifically for IHOP. We are unable to determine whether the bias exists with the S-Pol data or with the extra surface stations. Regardless, the radar refractivity retrieval shows excellent correlation with the refractivity computed from surface stations at ranges between 10 and 30 km.

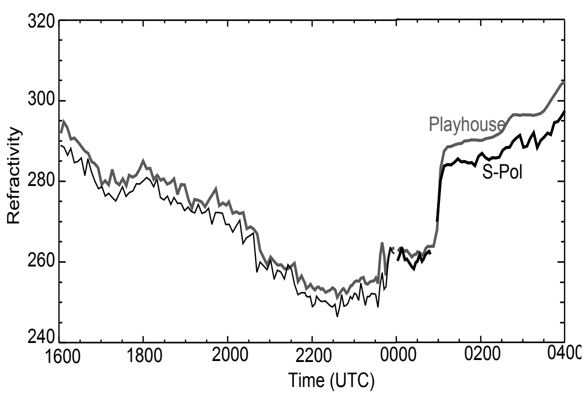

Fig. 2. 22-23 May 2002 intercomparison between S-Pol radar refractivity and refractivity calculated from Playhouse surface station data.

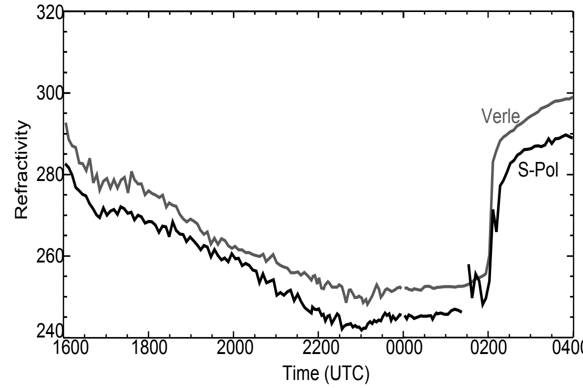

Fig. 3. Intercomparison between S-Pol radar refractivity and refractivity calculated from Verle surface station data.

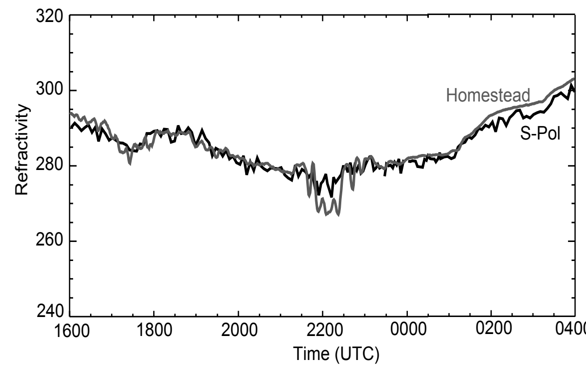

Fig. 4. Intercomparison between S-Pol radar refractivity and refractivity calculated from Homestead surface station data.

The second comparison done was with data from the AERIBAGO, an Atmospheric Emitted Radiance Interferometer (AERI), deployed within a Winnebago. AERIs measure downwelling infrared radiances and use them to retrieve temperature and moisture profiles. Figure 5 shows the trace of radar refractivity along with refractivity calculated from AERI averages at average heights of 175 m, 310 m, and 670 m above ground level (AGL) from 1600 UTC 22 May to 0400 UTC 23 May. While the magnitude of N should decrease with increasing height (because of the decrease in pressure), the correlation should not be adversely affected. Looking at the different vertical levels of the AERIBAGO data, there seems to be a distinct difference in the pattern above 220 m. At 220 m and below, correlation values are relatively high (.88-.90), but they fall off by 310 m (0.75). The layer between 220 m and 310 m seems to be a transition from high correlation values to lower ones (.90 at 220 m, 0.85 at 260 m, and 0.75 at 310 m). By 670 m the mixing ratio trace is very different from those at low levels as expected (0.42 correlation). This intercomparison suggests that radar refractivity is representative of the layer up to about 220 m AGL.

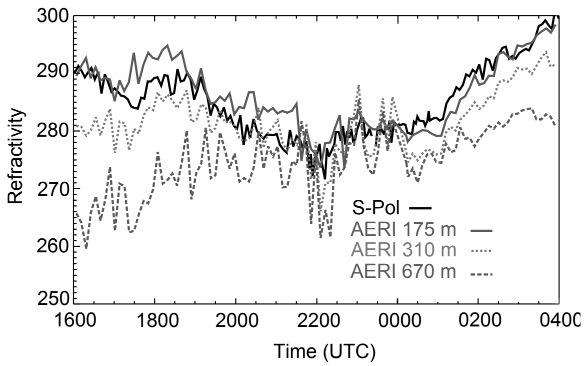

Fig. 5. Refractivity intercomparison between S-Pol radar refractivity and refractivity calculated from AERIBAGO at average heights of 175 m, 310 m, and 670 m AGL.

Another view of the vertical depth of the refractivity retrieval can be obtained from intercomparison with the University of Wyoming King Air (UWKA) in-situ data. The UWKA flew stacked flight legs on this day, flying approximately the same track at different heights. One set of stacked tracks (164 m, 358 m, 673 m, and 1475 m AGL) from 2158—2246 UTC had good agreement at the two lowest legs (correlations of 0.93 and 0.96, respectively), with a distinct drop in correlation at 673 m (not shown; correlation of 0.74). This set is again indicative that S-Pol refractivity is more representative of the low Atmospheric Boundary Layer (ABL). The second stacked track from 2322—2352 UTC, with legs at 167 m, 837 m, and 1494 m AGL, showed a drop in correlation with increasing height (0.88, 0.84, and 0.46, respectively).

Another question is the horizontal scale resolved by the radar refractivity. Looking at the lowest leg for each stacked track (Figures 6 and 7), it is apparent that while the radar refractivity captures the overall trend of the mixing ratio measured by the UWKA, the discontinuities are not nearly as sharp. The S-Pol refractivity smooths the gradient over a larger area.

To examine the spatial resolution further, data from the mobile mesonet are used. In Figure 8, S-Pol refractivity captures the gradient in refractivity in a similar resolution to that of mobile probe 6. In Figure 9, the S-Pol refractivity gradient is smoothed out over 2 km when compared to probe 1. In two other examples, S-Pol refractivity smooths out variations seen by the mobile probes over 3 km or more (Figures 10 and 11). Since spatial resolution of radar refractivity is somewhat dependent upon the number and spacing of ground targets, it is probable that some of the variability of horizontal resolution is location dependent, i.e., resolution is better at a location surrounded by more ground targets than it is at a location surrounded by fewer ground targets. However, since probe 8 and probe 6 were in roughly the same location and seem to have different resolutions, this is not the only factor. Another important factor is the smoothing of the phase data

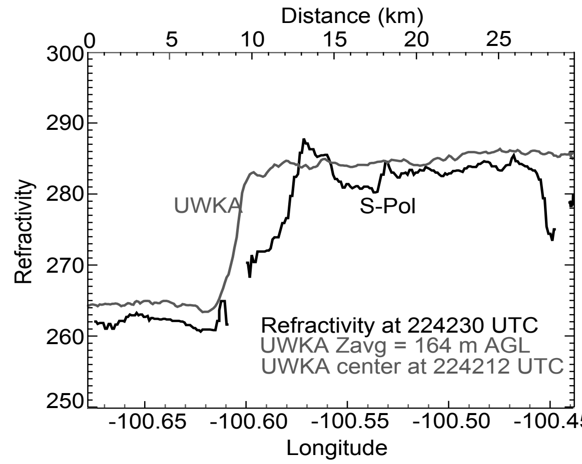

Fig. 6. Refractivity intercomparison between S-Pol radar refractivity and refractivity calculated from UWKA at 164 m AGL at 2242 UTC along track shown in Fig. 1a.

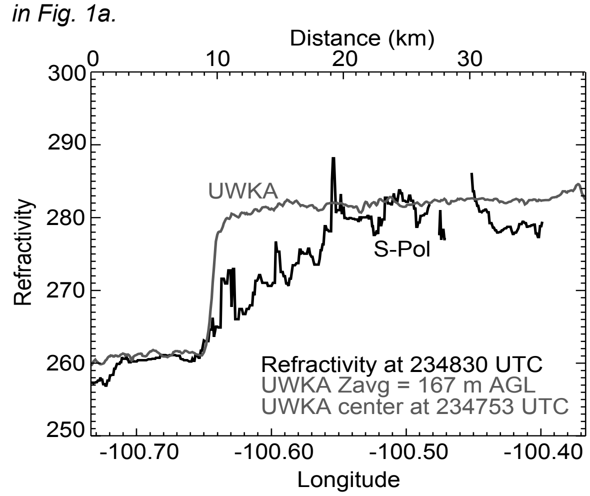

Fig. 7. Refractivity intercomparison between S-Pol radar refractivity and refractivity calculated from UWKA at 167 m AGL at 2348 UTC along track shown in Fig. 1b.

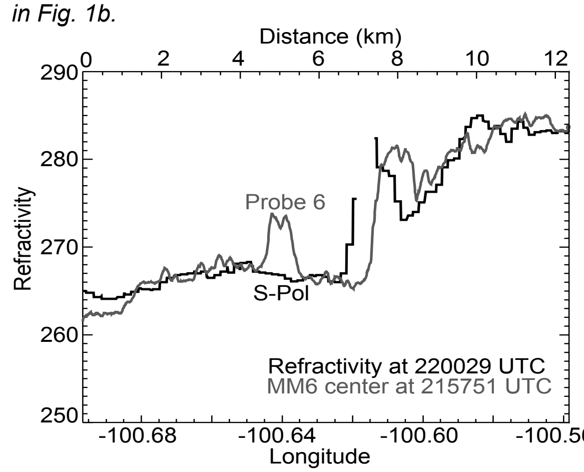

Fig. 8. Refractivity intercomparison between S-Pol radar refractivity and refractivity calculated from mobile mesonet probe 6 along track shown in Fig. 1b centered at 2158 UTC.

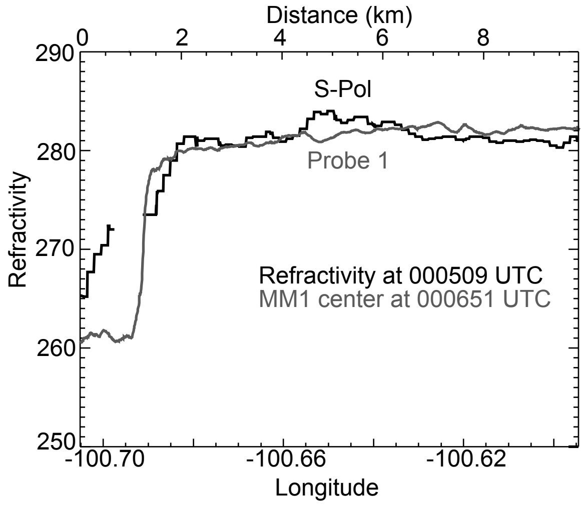

Fig. 9. Refractivity intercomparison between S-Pol radar refractivity and refractivity calculated from mobile mesonet probe 1 along track shown in Fig. 1b centered at 0006 UTC.

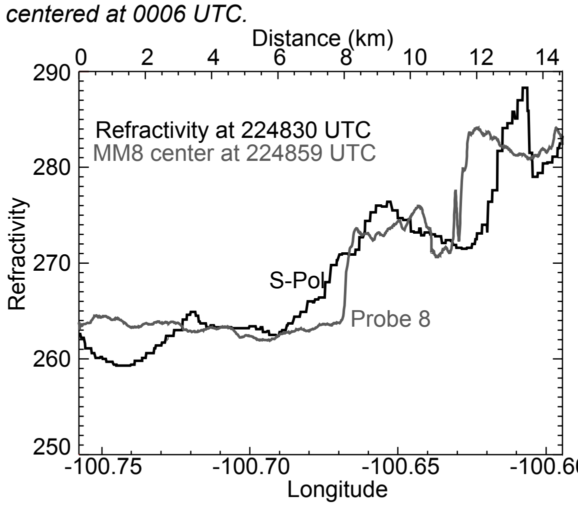

Fig. 10. Refractivity intercomparison between S-Pol radar refractivity and refractivity calculated from mobile mesonet probe 8 along track shown in Fig. 1b centered at 2232 UTC.

to remove noise. Since this value is set to 4 km, it is likely that cases of higher resolution are coincidental.

4. SUMMARY

Overall, radar refractivity shows excellent correlation with refractivity derived from surface measurements. There is a slight bias between radar refractivity and some surface stations, but it unknown whether this bias occurs in the radar refractivity, the surface stations, or both. Since many applications of radar refractivity will use gradients and temporal variations rather than absolute values, this is not considered a significant problem. The vertical depth represented by radar refractivity appears to be the low levels of the ABL. The specific height to which this extends may vary depending on the extent of vertical mixing and the homogeneity of the ABL. The horizontal scale of radar refractivity varies as well. It appears to be as high as 1 km at times, but at other times can be lower than 4 km. The appearance of resolution higher than 4 km may be coincidental, however, since the initial phase differences are smoothed over 4 km.

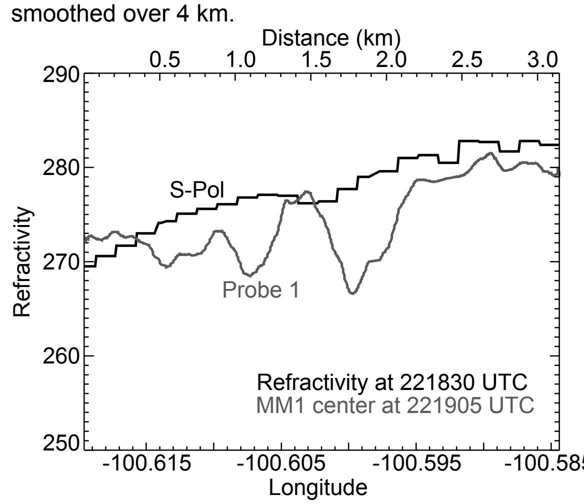

Fig. 11. Refractivity intercomparison between S-Pol radar refractivity and refractivity calculated from mobile mesonet probe 1 along track shown in Fig. 1a centered at 2219 UTC.

5. REFERENCES

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