16B.5 IMPROVING ABOVE-SURFACE WATER VAPOR ANALYSES USING SATELLITE AND RUC DATA

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1. INTRODUCTION

An accurate depiction of the pre-storm environment requires not only good estimates of surface temperature and dewpoint, but also information about temperature and water vapor profiles within and just above the boundary layer. Mixed-layer Convective Available Potential Energy (MLCAPE), for example, is sensitive to water vapor contents just above the surface. An overforecast of 925-mb dewpoint can result in an overestimate of convective instability and an underestimate of cap strength. We therefore seek the best possible analysis of low-level water vapor.

Current techniques, such as those used by the Storm Prediction Center (SPC), involve using observed surface temperature and dewpoint, and Rapid Update Cycle (RUC) analyses or 1-hour forecasts for profiles above the surface. Since raobs are typically launched only twice a day, errors in the above-surface temperature and dewpoint are likely to exist. Given the relatively dense surface observation network in the Central U. S., it's likely that accurate surface temperatures and dewpoints are paired with erroneous above-surface values, resulting in incorrect MLCAPE and MLCIN estimates.

In order to address this problem, we seek to first compare RUC analyses and 1-hour forecasts with observed RAOB values, to gain some idea of the average error and bias in the model. Next, we use a multiple regression technique to attempt to better "predict" the moisture values above the surface. For this study, we focus only on water vapor profiles and assume that the model temperature profile is reasonable. The ultimate goal is to also incorporate GOES data to better constrain the water vapor profile estimates, but as of the writing of this paper, that portion of the work has yet to be completed.

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2. DATA AND METHODOLOGY

Data from the newest version of the RUC-13 model was collected beginning on 24 June 2008 and continuing throughout the summer. Analyses from 12, 18, and 00 UTC were saved, as well as 1-hour forecasts from 11, 17, and 23 UTC (so that the valid times match up with raob launch times). Twenty-seven raob locations were selected across the central and eastern U.S., generally east of the Rockies and west of the Appalachians (see forthcoming figures for the raob locations). For each raob site, the nearest RUC grid point was located, and water vapor mixing ratio values from the surface to 700 mb (only the mandatory levels within this layer, i.e., surface, 925 mb, 850 mb, and 700 mb) were extracted from the RUC file for comparison with raobs. Data from 24 June – 6 September 2008 is available for the 0-hr analyses, and data from 30 July – 2 October 2008 is available for the 1-hr forecasts.

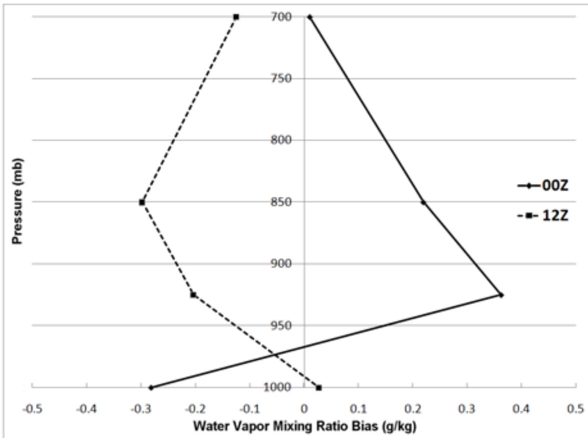
Regarding the raob data, we acknowledge that the water vapor measuring instrument is not perfect, but *some* data must be selected as "truth" with which to compare with the RUC output. The National Weather Service (NWS) is in the process of replacing all 102 supported radiosonde systems with newer instruments (manufactured by Sippican), so there's a possibility that biases may exist between the older and newer systems. Five of the 26 raobs used in this study still have the older equipment. This issue will be explored again later in the paper.

3. RUC/RAOB COMPARISON

Fig. 1 shows the mean low-level water vapor differences between all 26 raobs and RUC output. At 00Z, the RUC has a moist bias which is most pronounced at 925 mb, but is also evident at 850 mb, for both the 0-hr analyses and the 1-hr forecasts. Interestingly, this bias is slightly more pronounced in the analyses. For 12Z, the biases switch sign and have roughly the same magnitude (at least for the 0-hr analyses).

To investigate whether these biases vary geographically, RUC errors (for 00Z only) were computed and plotted for each of the 26 raob locations. Fig. 2a shows the northern group and Fig. 2b the southern group. Although impossible read, the scales on all plots in Fig. 2 are the same as that from Fig. 1a.

a)



b)

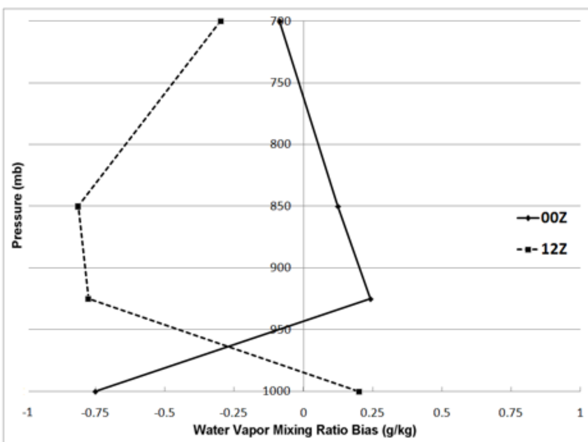


Figure 1. Mean difference between the water vapor mixing ratios at the surface, 925 mb, 850 mb, and 700 mb, from the 26 chosen raobs and the RUC 00Z and 12Z a) 0-hr analysis and b) 1-hr forecast (valid at 00Z and 12Z). Data for the 0-h analyses (a) is from 24 June – 6 September 2008. Data for the 1-hr forecasts (b) is from 30 July – 2 October 2008. The surface value is plotted at 1000 mb even though some station's surface pressures are lower.

In a great majority of the raob sites, there is a moist bias at 925 mb, with smaller biases at 850 mb and 700 mb. The one exception is Brownsville (Fig 2b, bottom), which interestingly is one of the four locations using the old raob equipment. The other four are Dodge City, Topeka, Green Bay, and International Falls.

The relative geographical coherence in 00Z biases suggests that applying a correction to the 925 mb mixing ratio, in particular, may improve the analyses. In practice, the same correction should not be applied everywhere, but instead the correction should depend on a particular location's proximity to a raob location. In this next section we choose a single location to illustrate how such a correction may be developed.

a)

b)

Figure 2. Same as Fig. 1a (including the horizontal and vertical scales), except for 00Z only and for each of the 26 individual raob locations. Each graph is approximately centered on the corresponding raob location. Stations whose surface pressures are less than 925 mb have their surface values plotted at 925 mb. Fig 2a shows the northern group, and Fig. 2b shows the southern group.

4. APPLICATION FOR NORMAN, OKLAHOMA

In Fig 2b, the Norman, Oklahoma, raob site shows the typical moist bias at 00Z, particularly at 925 mb. In this section, we arbitrarily choose KOUN to illustrate how a correction might be developed using the archived RUC and raob data.

The underlying assumption in performing this analysis is that we know accurately the surface dewpoint at every point, and that the low-level water vapor is positively correlated with the surface value. In other words, if the surface moisture increases, so does the 925 mb moisture. There are of course situations in which this is *not* the case, such as when the depth of the low-level moisture is very shallow, but statistically it's a good approximation. The correlation with the surface value is weaker at 850 mb, and nearly non-existent at 700 mb. Our statistics will illustrate this and take it into account.

Our goal is to obtain the coefficients in the following equation which minimize the mean absolute error:

$$r_p = A_1 r_{sfc} + A_2 r_{p\_RUC} + b, \qquad (1)$$

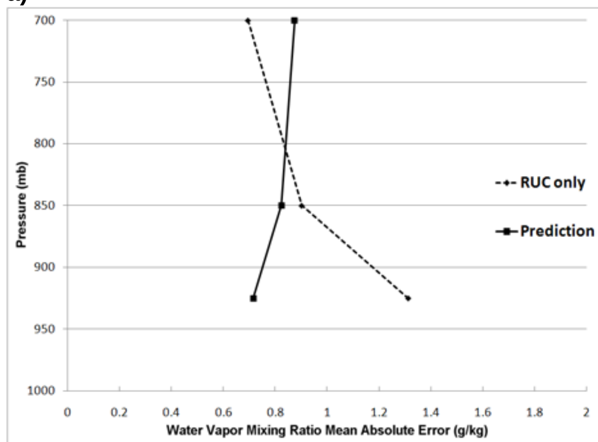
where r_p is the mixing ratio at some pressure *p*, r_{sfc} is the surface mixing ratio, r_{p_RUC} is the RUC forecast (or analyzed) mixing ratio at some pressure *p*, *b* is the intercept, and A_1 and A_2 are the regression coefficients. As explained above, we currently have a relatively limited amount of data, but nonetheless can obtain some meaningful results. An independent sample was obtained by selecting the odd days (i.e., June 25, 27, 29, etc.) to generate the coefficients, then testing the "predicted" mixing ratio using the even days. Thirty-five raobs (all at 00Z from KOUN) were therefore used in the regression. r_p and r_{sfc} were obtained from the raob data, and r_{p_RUC} from the RUC. Table 1 provides the resulting coefficients. As expected, the 700 mb water vapor mixing ratio is not correlated with the surface value, but that correlation increases at 850 mb and even further at 925 mb. Even though these values are not normalized, it is apparent that at 925 mb in particular the surface mixing ratio is as good a predictor for the 925 mb mixing ratio as the RUC analyzed 925 mb mixing ratio.

	A_1	A_2	b
700 mb	0.0028	0.801	1.015
850 mb	0.387	0.657	-2.040
925 mb	0.657	0.547	-4.570

Table 1. Coefficients obtained for Eq. 1 using data from the odd days (June 25-September 5, 2008) at 00Z from KOUN.

To test this prediction on the independent dataset, the data in Table 1 was used in Eq. 1 on the remaining (even) days at 00Z for KOUN, and the results are summarized in Fig. 3. Note that the prediction decreases the mean absolute error (MAE) from that of the RUC analysis significantly at 925 mb, very slightly at 825 mb, and actually increases the MAE at 700 mb (Fig. 3a). The moist bias at low levels is also significantly improved (Fig. 3b).

a)



b)

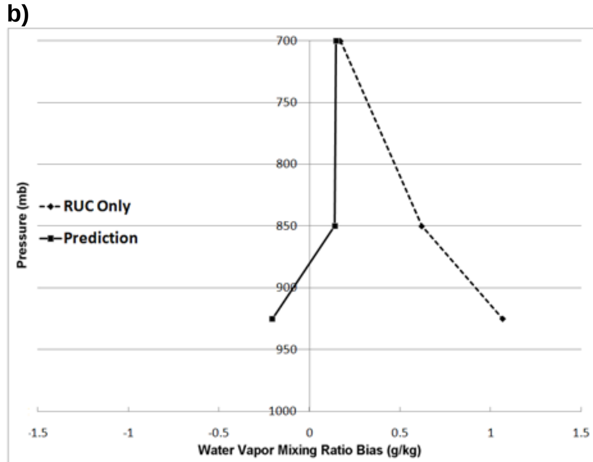
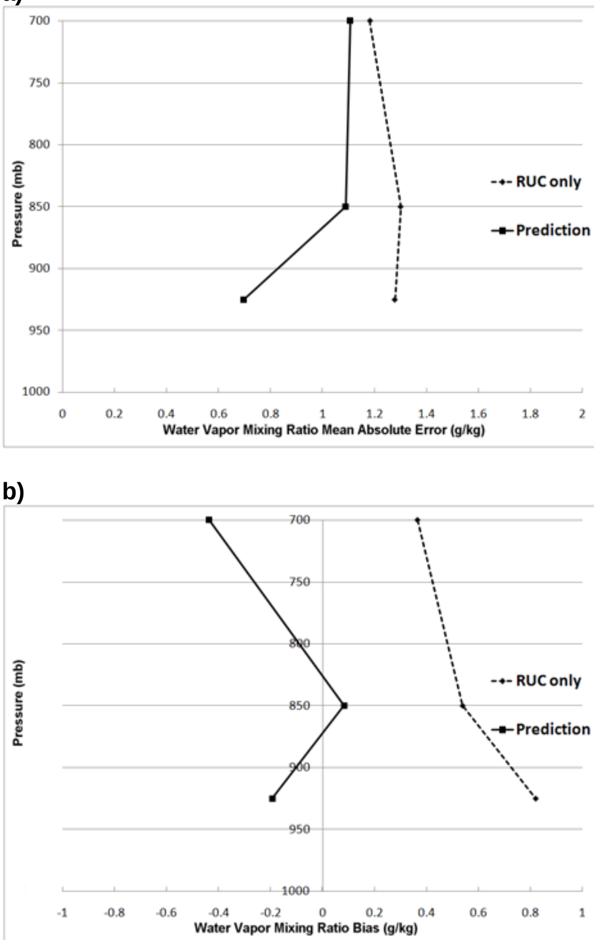


Figure 3. a) Water vapor mixing ratio mean absolute error (g/kg) at 00Z from KOUN at 925, 850, and 700 mb from the RUC analysis (dashed), and using the predictors in Table 1 in Eq. 1 for the independent sample of even days (solid). b) Same as a), except the total error (bias) is plotted on the x-axis.

The same analysis was then applied to the 1-hour RUC forecast valid from 23Z (valid at 00Z), and the results are given in Fig. 4. Compared to the analyses, the RUC 1-hour forecasts are actually slightly more accurate at 925 mb (for KOUN at least). Again, the prediction significantly improves the RUC-alone forecast, particularly at 925 mb, and also improves the bias.

a)



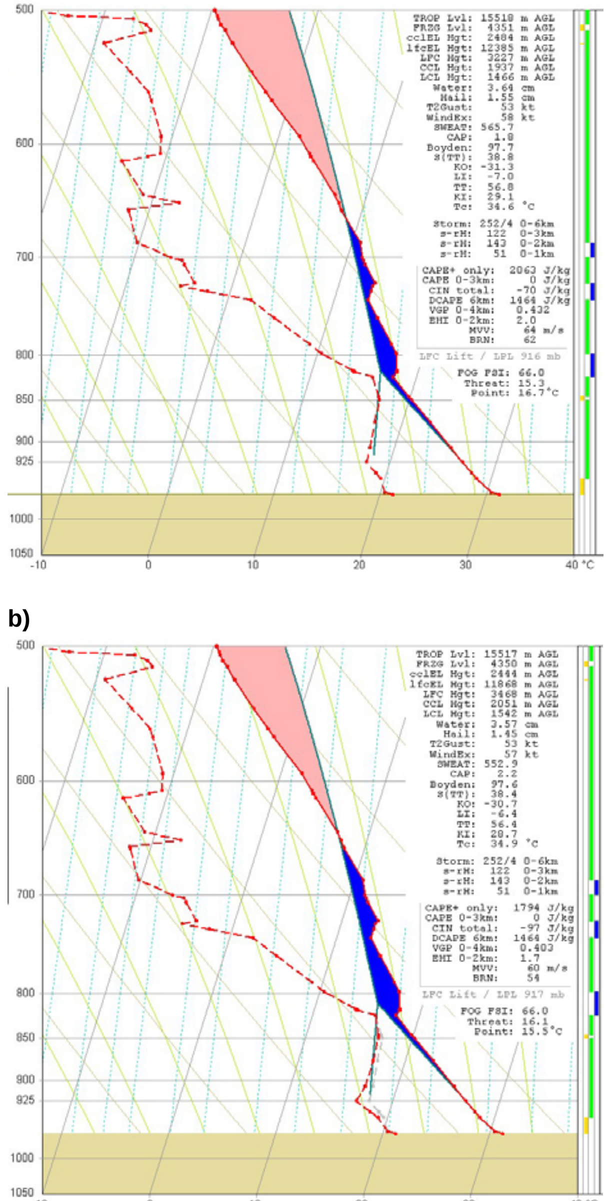
b)

Figure 4. Same as Fig. 3, except for the 23Z RUC 1-hour forecast valid at 00Z.

5. CONCLUSIONS AND FUTURE WORK

To get an idea of the impact of removing a ~1 g/kg moist bias at 925 mb and a ~0.5 g/kg moist bias at 850 mb (as is observed at KOUN in Fig. 3b), a day was chosen from May 2008 having a relatively unstable temperature profile, then the low-level dewpoint profile was modified. Fig. 5a shows the low-level sounding as observed (MLCAPE = 2063 J/kg, MLCIN = -70 J/kg, LCL = 1466 m), and Fig. 5b shows the sounding after modifying the low-level dewpoint profile (MLCAPE = 1794 J/kg, MLCIN = -97 J/kg, LCL = 1542 m). The seemingly negligible decrease in moisture above the surface but below 850 mb results in a nearly 300 J/kg drop in MLCAPE, a stronger cap, and a higher cloud base. Although not an enormous change, correcting errors of this magnitude could make an important difference on days with a strong cap which may or may not break.

a)



b)

Figure 5. a) Observed sounding (up to 500 mb) from KOUN from 27 May 2008 at 00 UTC, with a 100-mb mixed layer parcel trajectory also plotted. Blue areas indicate areas of negative CAPE (or inhibition), and pink corresponding to positive CAPE. Values for various parameters are also plotted. b) Same as a), except after modifying the low-level dewpoint profile by decreasing the 925 mb mixing ratio by 1 g/kg and the 850 mb mixing ratio by 0.5 g/kg.

Granted, the method proposed in this paper will not improve the 925 mb mixing ratio by 1 g/kg in every sounding, but any correction, no matter how small in magnitude, is worthwhile. This paper presents a work in progress and significantly more work is needed. Some unanswered questions include:

1) Coefficients are developed based on data from raob locations; how do we handle areas between raob locations?

2) Coefficients are developed based on data from raob times, i.e., 12Z and 00Z. How do we know what the coefficients should be at other times?

3) How do we handle days in which the moisture is *very* shallow and surface values are not correlated with 925 mb values?

Before addressing these issues, the next step is to include GOES satellite data. Specifically, certain bands (both imager and sounder) have weighting functions which peak in the lower troposphere and therefore provide some information about water vapor content. An example is the brightness temperature difference between the 10.7 and 12.0 μm imager bands; surface radiation is preferentially absorbed by lower tropospheric water vapor at 12.0 μm, so more moisture should result in a larger brightness temperature difference. To test this, we will identify the cloud-free days and add this difference as a new predictor term in Eq. 1. Our error statistics will then tell us whether or not the signal from satellite provides a significant improvement to the analysis. The ultimate goal of this work is to provide a mesoanalysis of MLCAPE, MLCIN, and LCL using corrected values of low-level water vapor.

6. ACKNOWLEDGEMENTS

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