An Examination of Model Analysis Vertical Profile Biases for Preconvective Heavy Rainfall Environments

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Advantage of Model Analysis Soundings

The primary advantage is to obtain a larger sample of heavy precipitation cases in a shorter period of time. The spatial and temporal scales are greatly reduced when considering model analysis soundings as viable options for proximity soundings. However, there are several critical criteria that must be considered when examining model analysis soundings:

1) Model analysis grids must be consistent with observed data if they are to serve as a diagnostic tool.

2) The model analysis grids must be available frequently in time so that the majority of heavy precipitation cases can be considered.

3) The model must have a relatively high horizontal and vertical resolution.

   a) High horizontal resolution will allow soundings to be chosen relatively close (spatially) to the event.

   b) High vertical resolution ensures the model will closely resemble the vertical resolution of current observational soundings.

Research Objective

The objective of the present study is to focus upon the vertical variability of the Rapid Update Cycle Version 2 and North American Regional Reanalysis model analysis soundings and how those variations change the magnitude of key parameters (moisture, instability, wind shear, etc) in preconvective heavy rainfall environments.

In this way, the present research will illustrate the viability of model analysis soundings for proximity sounding studies associated with heavy rainfall. Therefore, forecasters will have the opportunity to recognize the potential model biases in preconvective heavy rainfall environments.

Models and Cases Investigated

Rapid Update Cycle Version 2 (RUC-2)

Horizontal Resolution: 40 km

Vertical Resolution: 40 layers

North American Regional Reanalysis (NARR)

Horizontal Resolution: 32 km

Vertical Resolution: 45 layers

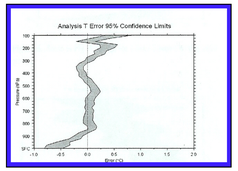
Cases:

There are 46 soundings from 32 cases where 24-h rainfall accumulations were greater than or equal to four inches. Observed and model analysis soundings were obtained for the same locations and time periods using proximity criteria illustrated on an adjacent poster. The observational data was subtracted from the model analysis data (equation below) to obtain difference values, which were plotted versus height (pressure).

Abs(model) - Abs(ob)

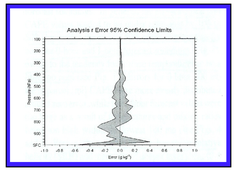
Previous Studies

Thompson et al. (2002; 21 Conf. SLS Preprint)



Using a 95% confidence interval, RUC-2 temperature errors are larger near the surface with a strong tendency for model analysis surface temperatures to be about 0.5 C too cool. Near 850 to 400 hPa there is very little error as the 95% confidence interval hovers near the zero error line.

The RUC-2 analysis mixing ratio errors were largest near the surface with an underestimate at the surface by approximately 0.3 g/kg and an overestimate directly above this region. The model also underestimates around 850 hPa before errors converge to the zero error line at higher levels.



Thompson et al. (2002; 21 Conf. SLS Preprint)

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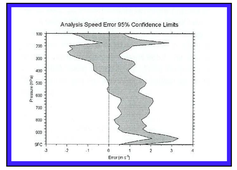
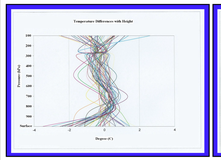
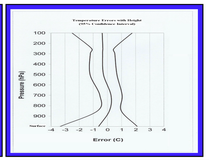


The RUC-2 analysis wind speed errors tend to be about 1 to 2 m/s too strong from the surface to 600 hPa. Above this level, the zero error line lies within the 95% confidence interval. This, along with the temperature and mixing ratio errors, illustrates that the RUC-2 model analysis has biases within the boundary layer.

RUC-2 Results

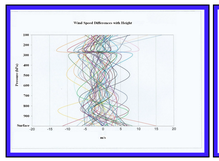


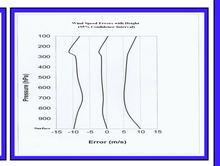


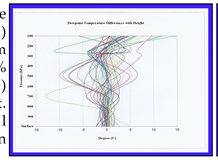
Above: RUC-2 temperature differences with height (left) illustrating all soundings from every four inch event; and 95% confidence interval (right) showing the errors with height. The 95% confidence interval error graph also shows the mean error with height (center line).

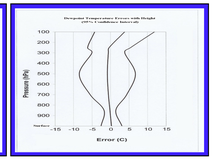
Below (left): Same as previous two figures, except for RUC-2 dewpoint temperature.

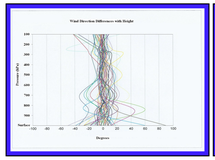
Below (right): Same as previous figures, except for RUC-2 wind direction.

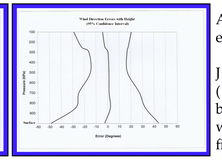








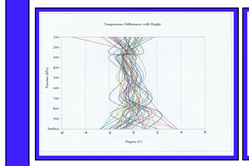


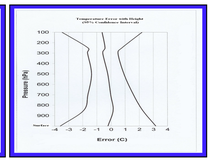


Above: Same as previous figures, except for RUC-2 wind speed.

Just as with Thompson et al. (2002), there appears to be boundary layer biases associated with the RUC-2 model analysis fields.

NARR Results

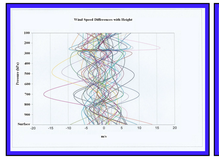


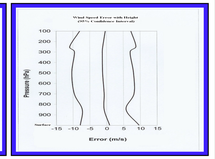


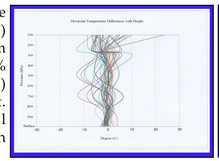
Above: NARR temperature differences with height (left) illustrating all soundings from every four inch event; and 95% confidence interval (right) showing the errors with height. The 95% confidence interval error graph also shows the mean error with height (center line).

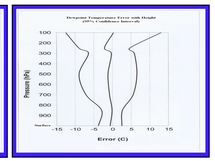
Below (left): Same as previous two figures, except for NARR dewpoint temperature.

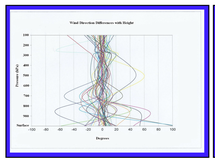
Below (right): Same as previous figures, except for NARR wind direction.

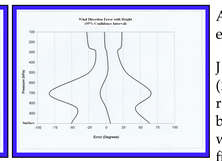












Above: Same as previous figures, except for NARR wind speed.

Just as with Thompson et al. (2002) and the previous RUC-2 results, there appears to be boundary layer biases associated with the NARR model analysis fields.

Summary and Conclusions

1) On average, RUC-2 analysis temperatures are slightly cooler at the surface and slightly warmer between 850 to 650 hPa than the observed sounding values. Beyond 650 hPa, temperatures are slightly underestimated throughout the remainder of the atmosphere.

2) On average, the RUC-2 analysis dewpoint temperatures closely resemble the observed values except a slight underestimation maximum near 500 hPa. Above 250 hPa, values are overestimated.

3) There is a wide range of values near the surface, but, on average, the RUC-2 analysis underestimates the wind direction at the surface and overestimates near 850 hPa. Above 850 hPa, values are near observed values until about 300 hPa where the model underestimates direction throughout the remainder of the atmosphere.

4) On average, RUC-2 analysis wind speeds are near observed values at the surface with a slight underestimation throughout the remainder of the atmosphere.

5) On average, NARR analysis values are nearly identical to the RUC-2 analysis values with the exception being at the surface. The NARR values are closer to observed values at the surface.

6) On average, NARR dewpoint temperatures show a slight cool bias near the surface before values approach the observed values near 850 hPa. Above 850 hPa, values are similar to the RUC-2 analysis values.

7) There is greater spread in wind direction values at the surface and 700 hPa associated with the NARR analysis dataset than the RUC-2 dataset. On average, the wind direction is overestimated at the surface and underestimated at 700 hPa. Above 500 hPa, values resemble those of the RUC-2 analysis values.

8) On average, NARR wind speed values closely resemble the RUC-2 analysis values except near the surface. Near the surface, NARR values are slightly overestimated.

Based on a limited sample size of 46 soundings in heavy rainfall environments, RUC-2 and NARR analysis soundings appear to be reasonably representative of observed soundings at the same locations. The small errors in temperature and dewpoint temperature are within instrumentation error associated with observed soundings. Therefore, RUC-2 and NARR analysis soundings may be suitable as surrogates for observed proximity soundings in heavy rainfall situations. However, large sample sizes will help reduce the error as shown with Thompson et al. (2002).

It is worth mentioning that due to the cool biases near the surface and warm bises near 850 hPa, surface-based CAPE is underestimated while CIN is overestimated. Also, vertical shear parameters that are very sensitive to variations in low-level winds will vary greatly. Values are underestimated using RUC-2 analysis soundings while wind shear parameter values are overestimated using the NARR analysis soundings.