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IMPROVED MOISTURE AND PBL INITIALIZATION IN THE RUC USING METAR DATA

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1. INTRODUCTION AND MOTIVATION

Hourly surface observations provided in meteorological aviation reports (METARs) are critical to short-range severe weather and aviation forecasting efforts. The Rapid Update Cycle (RUC, Benjamin et al. 2004a,b) uses these observations more completely (in horizontal coverage and in parameters measured) than other operational NWP models. However, even the operational RUC does not yet make maximum use of the information contained in these observations. A significant effort has been underway at FSL since early 2003 to improve this aspect of the RUC analysis. One portion of this effort, the inclusion of METAR cloud and visibility information, is described in another paper at this conference (Benjamin et al. 2004c, paper 9.13, Aviation Conference). Here, we describe a second part of the effort, a technique to use information from the background planetary boundary layer structure to infer information about the appropriate vertical correlation structure for the assimilation of the surface observations. This PBL-depth assimilation technique is currently being tested in experimental versions of the RUC model and is scheduled for implementation into the operational RUC in Fall 2004.

2. USE OF PBL DEPTH IN ASSIMILATION

The vertical correlation of surface parameter errors has long been a dilemma for assimilation of surface observations. While surface observations are relatively dense, there are almost no high-frequency observations of the vertical profile above the surface.

Until recently, the operational RUC analysis has assumed a relatively constant vertical correlation of background error from the surface upward. Other NCEP operational analyses have made similar assumptions to the extent that METAR data are assimilated.

A technique has been developed at FSL to use the background planetary boundary layer depth to provide an estimate of the depth over which the observation-minus-background values of temperature, moisture, and wind are likely to be applicable. Innovations (corrections to background forecast values) to θ_v (virtual potential temperature) and water vapor from METAR observations are then applied to some extent upward through a depth determined from the 1-h forecast PBL depth (limited to about ~200 hPa). This is accomplished by creating pseudo-innovations above the surface station into the estimated PBL. This assimilation technique is an attempt to infer conditions aloft in the boundary layer, as done subjectively by forecasters for many decades.

Previously, innovations from METAR observations were applied only to the lowest ~40 hPa. The reasoning for this change to the RUC analysis design is that the forecast errors indicated by METARs *are* actually representative of the background model error not just at the surface but through the estimated PBL depth. Without this PBL-based assimilation, analysis corrections from surface observations often are not retained during the

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subsequent model forecast. An example of the problem is illustrated in Figs. 1 and 2, a sounding from a RUC analysis showing an irregular discontinuity in the moisture profile near the surface.

Application of the PBL-based assimilation must be constrained because the background (1-h forecast) PBL depth may be quite incorrect. To prevent possible significant errors in this situation, some checks are included to guard against inappropriate application. If the observed METAR temperature (or θ_v equivalent) is more than 1 K colder than the background, the depth over which the observation is applied (pseudo-observations created) is reduced. If the observation is more than 4 K colder than the background, no pseudo-observations are created. The physical interpretation of this is that the RUC

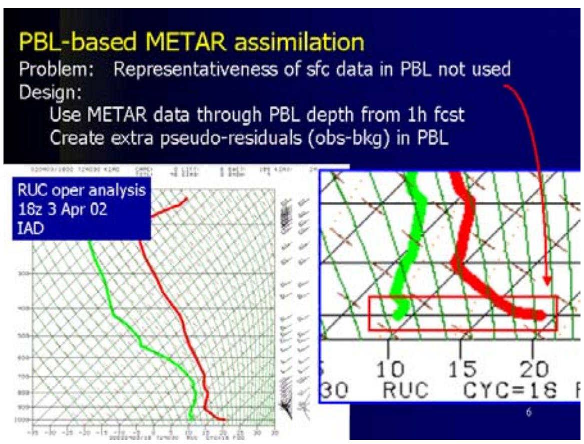

Fig. 1. Sounding illustrating RUC analysis problem without use of PBL depth.

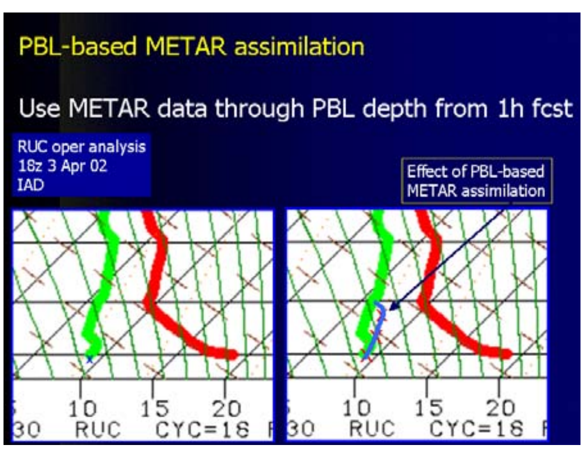

Fig 2. Sounding illustrating intended effect of PBL-based assimilation on moisture profile.

1-h forecast estimate of the PBL depth may be significantly too large (i.e., unforecast precipitation, cold pool, etc.) and so the treatment is designed to be similar to that of the current operational RUC (only lowest ~25-40 hPa near surface) in this condition.

3. RESULTS

The RUC PBL-based assimilation technique has been in real-time testing for over a year, showing an overall improvement in temperature and dewpoint forecast statistical accuracy, and improvements in convective available potential energy (CAPE) forecasts. The CAPE forecast improvement was very notable for the 10 November 2002 tornado outbreak case.

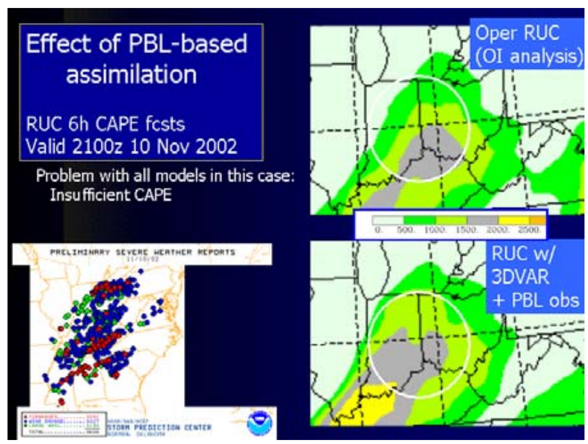

Fig. 3 CAPE forecasts (6-h projection) from RUC model valid 2100 UTC 10 November 2002. CAPE forecasts are shown for the operational RUC and from an experimental RUC using PBL-based METAR assimilation.

This case (shown in Fig. 3) clearly highlights the need for the PBL-based assimilation. A major tornado outbreak occurred this day with destructive tornadoes resulting in many fatalities as far north as Indiana and Ohio. Forecasters from the Storm Prediction Center and the National Weather Service Forecast Office in Cleveland, Ohio pointed out that the RUC analyses gave accurate values for CAPE and surface dewpoint, but that the RUC model forecasts resulted in inaccurate drying. The experiment shown in Fig. 3 indicates that the PBL-based assimilation lead to a considerable improvement in the 6-h CAPE forecast valid at 2100 UTC, especially in northern Indiana and northwestern Ohio.

4. FURTHER REVISIONS TO RUC ANALYSIS

Following extensive evaluations of operational and research versions of the RUC during Spring 2004, further revisions were developed to improve the robustness of the PBL-based assimilation technique. The magnitude of the moisture and temperature innovations was constrained to avoid the creation of unrealistically large analysis increments. These large increments can occur between observations or outside of data-dense regions (examples, northern Mexico and offshore ocean regions), when the influence of given observation extends across a significant gradient in the background field. Because the CAPE estimate is sensitive to small changes in moisture and temperature profiles, these temperature and moisture innovation constraints are very important for reducing erroneous maxima in the analyzed CAPE field.

In Figs 4, 5, and 6, example comparisons are shown for the operational RUC and a parallel RUC cycle with PBL-based assimilation and constrained moisture/temperature analysis. This comparison is extracted from a 2-month parallel cycle experiment conducted at NCEP in summer 2004. Analysis fields are shown for 0000 UTC 13 July 2004 for 2-m temperature (Fig. 4), 2-m dewpoint (Fig. 5), and most unstable CAPE (Fig. 6). Fields shown are from the operational RUC (a) and parallel RUC (b) cycles, as well as the difference field (c). This example is typical in that temperature, dewpoint, and CAPE values from the parallel RUC analyses (with the PBL-based assimilation and innovation limits) appear to be less noisy. This is especially apparent for the CAPE field over the western U.S. Generally, the difference fields for each variable indicate geographically where code redesign has resulted in improved analysis quality. For temperature (Fig. 4) and dewpoint (Fig. 5), less noisy analyses in the parallel RUC are apparent over the western U.S., offshore in coastal regions, and over Canada and Mexico where surface observations are less dense.

Results will be shown both for overall statistical improvement and other important case studies using this PBL-based technique for assimilation of METAR observations. This modification to the RUC analysis is scheduled for implementation into the operational RUC at NCEP in Fall 2004. It is also included in the 13-km RUC now in real-time testing at FSL and planned for implementation during the first half of 2005 (Benjamin et al. 2004d).

5. ACKNOWLEDGMENTS

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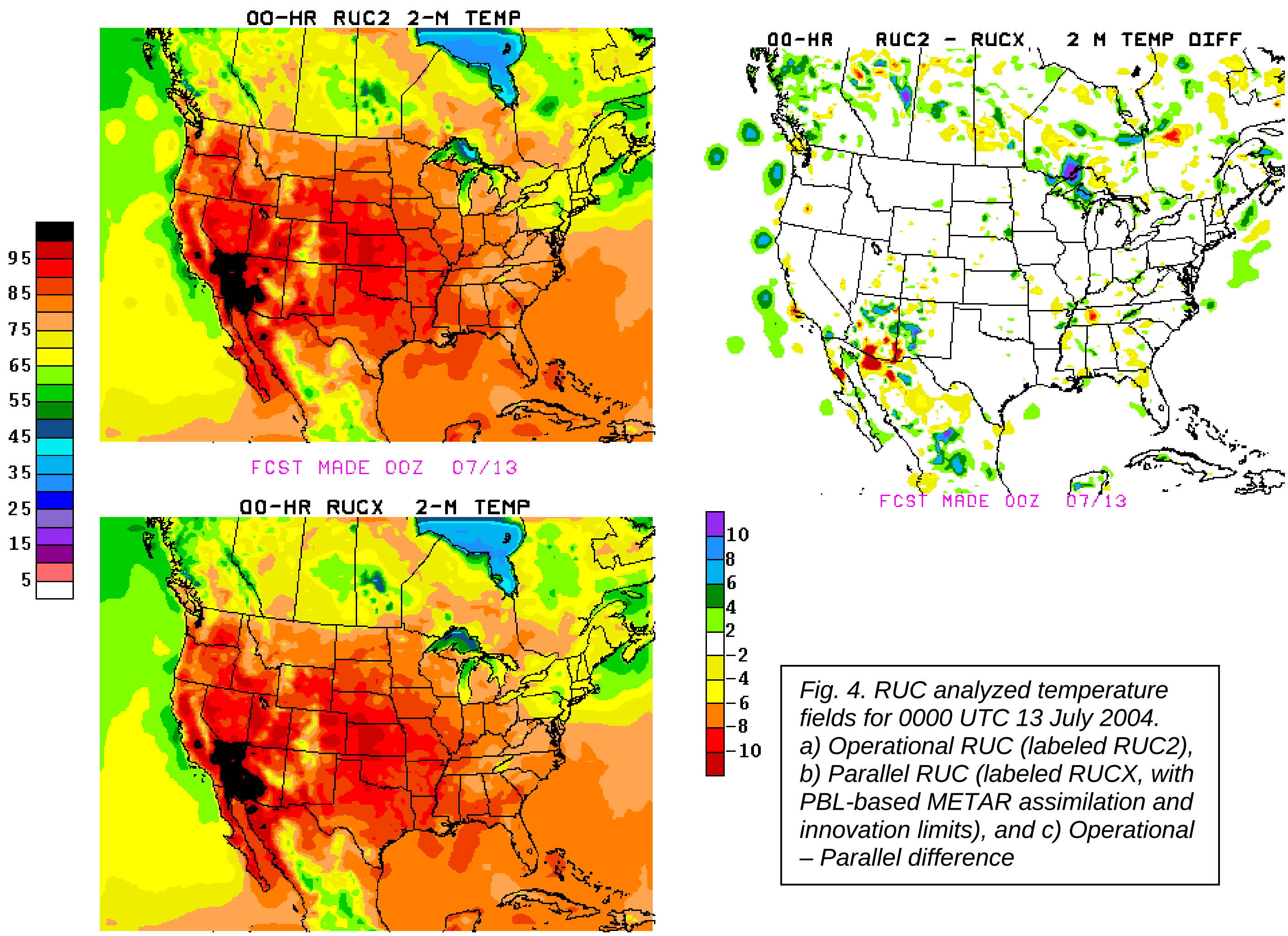
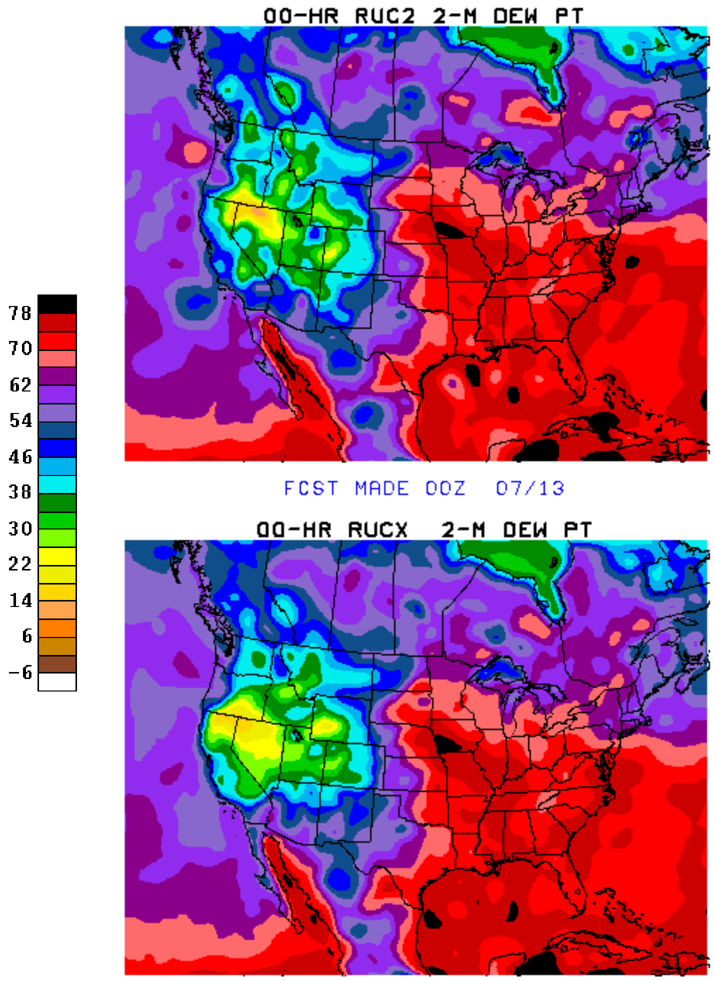


Fig. 4. RUC analyzed temperature fields for 0000 UTC 13 July 2004. a) Operational RUC (labeled RUC2), b) Parallel RUC (labeled RUCX, with PBL-based METAR assimilation and innovation limits), and c) Operational – Parallel difference



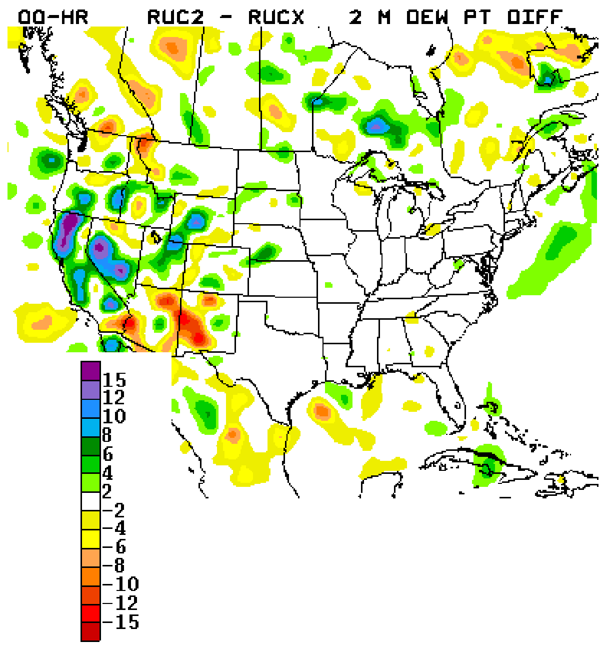


Fig. 5. RUC analyzed dewpoint fields for 0000 UTC 13 July 2004.
a) Operational RUC (labeled RUC2), b) Parallel RUC (labeled RUCX) with PBL-based METAR assimilation and innovation limits), and c) Operational – Parallel difference

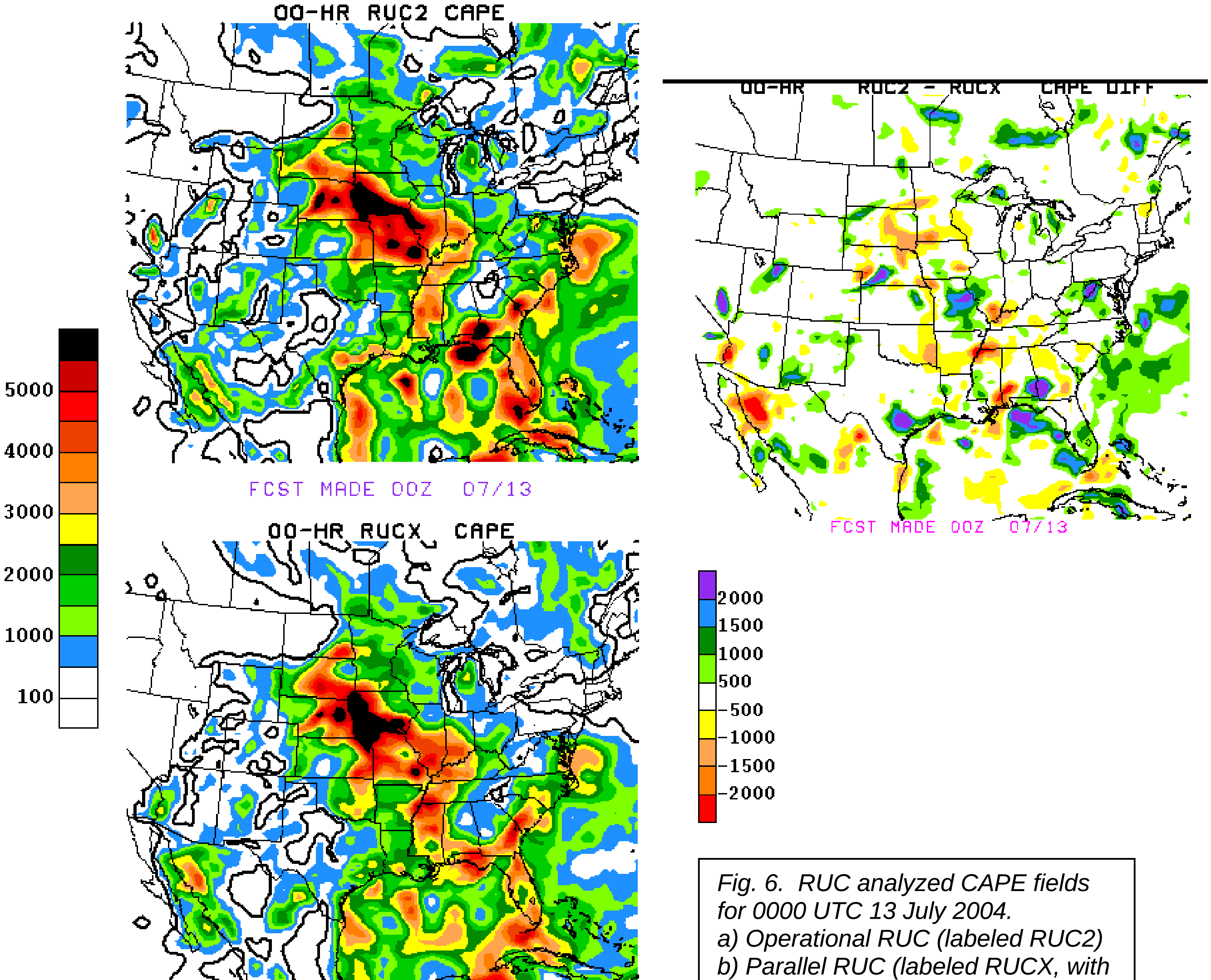


Fig. 6. RUC analyzed CAPE fields for 0000 UTC 13 July 2004.
a) Operational RUC (labeled RUC2)
b) Parallel RUC (labeled RUCX, with PBL-based METAR assimilation and innovation limts), and c) Operational – Parallel difference