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# ASSIMILATION OF SURFACE CLOUD, VISIBILITY, AND CURRENT WEATHER OBSERVATIONS IN THE RUC

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## 1. MOTIVATION AND INTRODUCTION

An important problem for short-range numerical prediction is initialization of cloud and hydrometeor fields. Forecasts of cloud, fog, ceiling/visibility (Herzegh et al. 2002), and stable and convective precipitation are dependent on accurate initial conditions for these fields.

Most mesoscale models now parameterize stable cloud processes with some type of bulk microphysics. The stable cloud microphysics parameterization used in the Rapid Update Cycle (RUC, Benjamin et al. 2003a) is explicitly mixed-phase, with prediction of mixing ratios of five different hydrometeor types (cloud water, ice, rain, snow, graupel), as described in section 5 of Benjamin et al. (2003b). The problem for cloud/hydrometeor assimilation is the mapping of disparate, one-sided (cloud decks apparent from space or the earth's surface with indeterminate depth) observations onto the 3-d multi-hydrometeor mixing ratio field.

The information sources for cloud/hydrometeor initialization include background short-range forecasts, satellite- and radar-based observations, and surface-based observations of cloud, visibility, and current weather. A pioneering effort in mesoscale cloud analysis using radar, satellite, and surface cloud observations but not a model background hydrometeor field was part of the LAPS analysis procedure (Albers et al. 1996). Koch et al. (1997) also describe a mesoscale cloud analysis technique.

The RUC became the first NCEP operational model to introduce modification of initial cloud fields in its data assimilation in 2002. A technique to clear and build clouds from the 3-d multi-hydrometeor (and water vapor) background 1-h forecast using GOES cloud-top pressure and temperature single-field-of-

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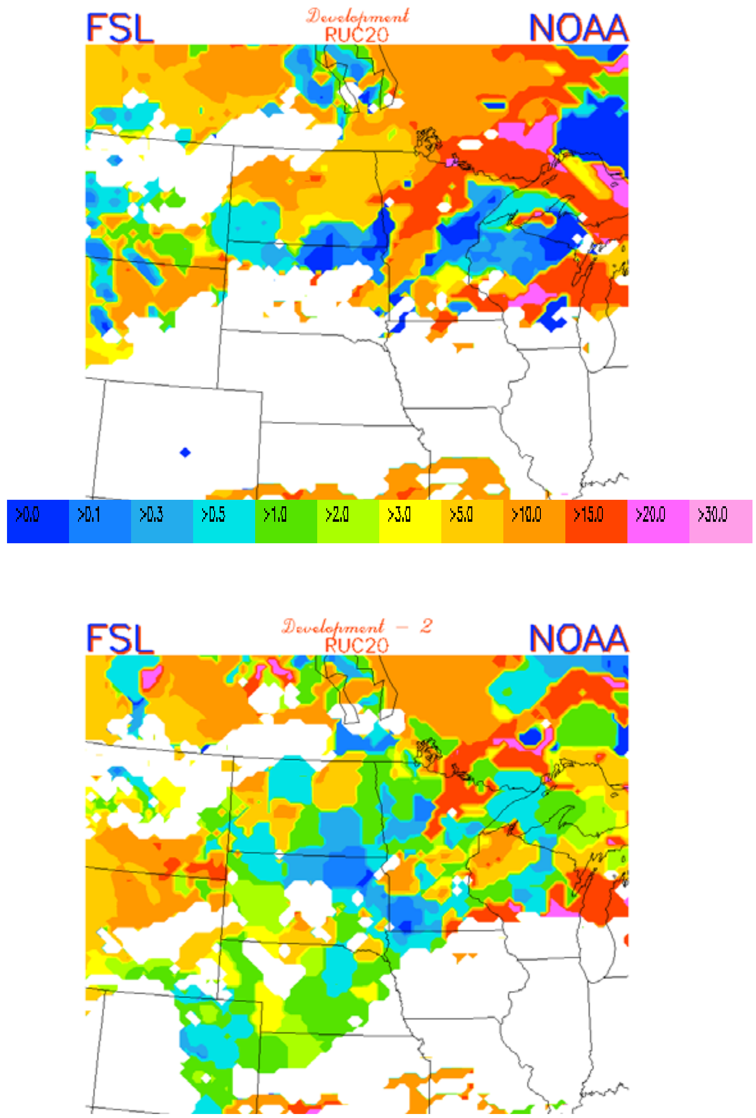


*Figure 1. Cloud base (ceiling) diagnosed from RUC 3-d hydrometeor fields for analyses without (top) and with (bottom) assimilation of surface cloud observations. Valid 1500 UTC 30 October 2003. Units – kft (1000s of feet) above ground level.*

view data was introduced into the RUC (Benjamin et al. 2003a) after extensive testing (Kim and Benjamin 2000, Benjamin et al. 2002). This technique included stability and boundary-layer dependencies to avoid problems with convective and marine clouds.

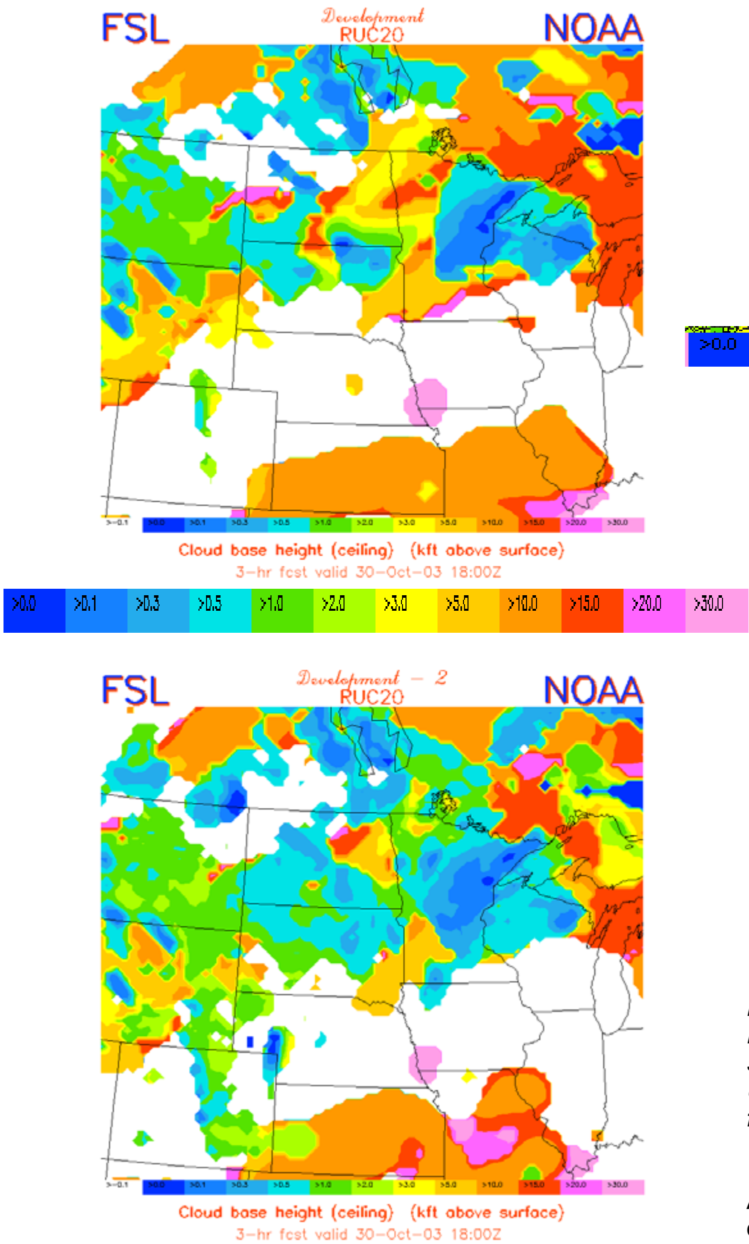


*Figure 2. Same as Fig. 1, but for 3-h forecasts without (a – top) and with (b – bottom) assimilation of surface-based cloud observations.*

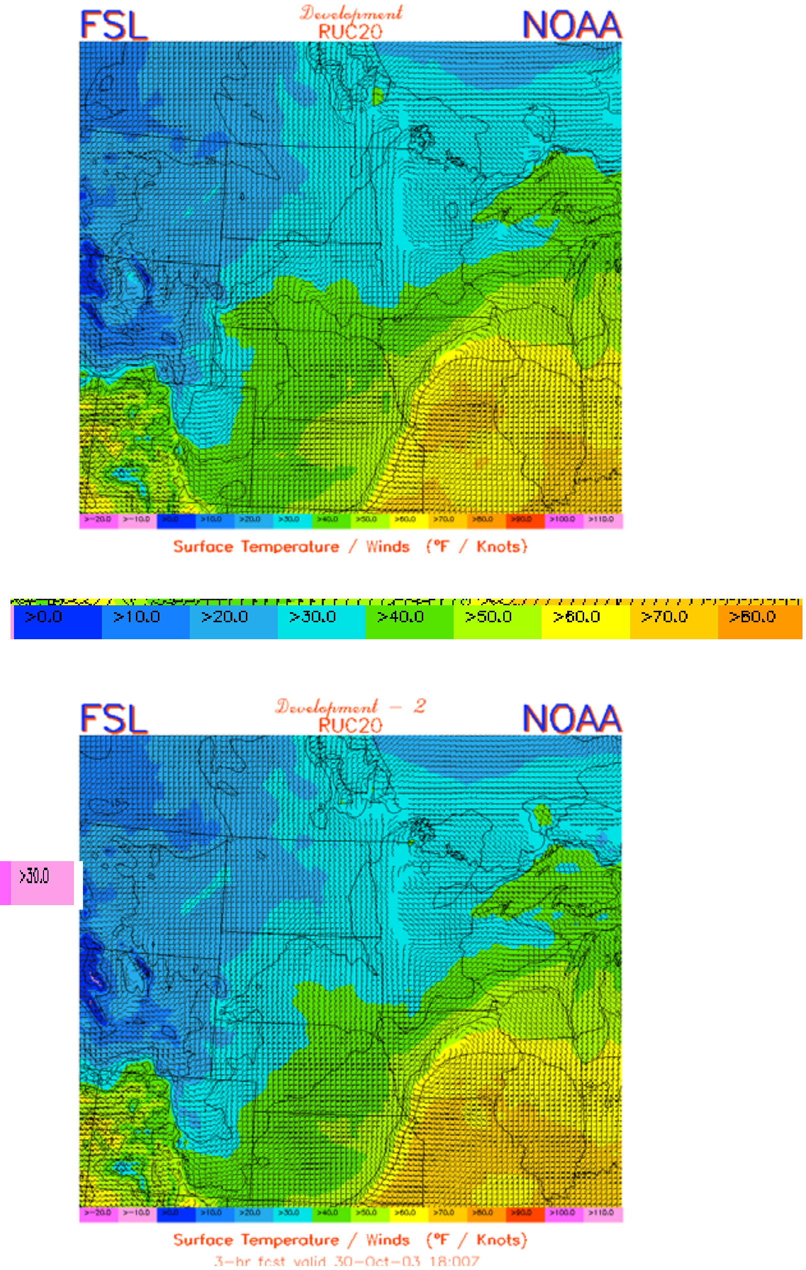


*Figure 3. 2-m (sfc) temperature 3-h forecasts from RUC cycles without (top) and with assimilation of surface-based cloud observations. Valid at 1800 UTC 30 October, same time as Fig.2, and initialized from cloud fields shown in Fig. 1.*

A preliminary technique has recently been developed to add assimilation of surface cloud observations to the cloud initialization used with the RUC. In this paper, we describe this technique, initial tests, and plans for implementation.

## 2. ASSIMILATION TECHNIQUE FOR SURFACE-BASED CLOUD OBSERVATIONS

The RUC assimilation of GOES cloud-top pressure and temperature (Benjamin et al. 2003a) is based on creating a 3-D gridded cloud logical field indicating volumes where it is known that clouds do not exist, where it is known that clouds do exist, and volumes where the presence of cloud is indeterminate. This approach can be extended to assimilation of surface-based cloud observations. For assimilation of either satellite-based or surface-based cloud observations, assumptions must be made about the depth of the cloud layer detected. For surface-based cloud observations, assumptions about the horizontal representativeness must also be made. In initial testing performed up to the writing of this paper, cloud depth of surface-based cloud observations is assumed as 300 m, and observations are assumed to be representative at up to 120 km in distance. These values can be refined in the future to be dependent on stability, the background relative humidity profile, and terrain dependencies.

Interconsistency with GOES cloud-top is enforced as follows: If GOES indicates that there is no cloud at a given horizontal point, any METAR observations indicating cloud are flagged and not used. Volumes up to a cloud base indicated by METARs are cleared, if there were any cloud or ice in the background 1-h forecast. A nearest neighbor technique for METARs with cloud observations is used, up to the current 120-km threshold.

## 3. INITIAL RESULTS

Cloud base, or ceiling, is diagnosed in the RUC by searching upward until a combined cloud water/ice hydrometeor mixing ratio exceeding $10^{-6}$ g/g is encountered. Fig. 1 depicts the ceiling from identical RUC analyses (CNTL, EXP) except that the second (EXP) adds the assimilation of surface-based cloud observations. In this case (30 October 2003), a surface front is extending southward and eastward through the central United States, with widespread low stratus decks in the post-frontal region. Fig. 1b, including assimilation of surface-based cloud observations, reflects the prevalence of this low cloud much more than the background 1-h forecast in this case., especially over Nebraska, Kansas, and eastern Colorado. Subsequent 3-h forecast of cloud ceiling (Fig. 2a,b) and 2-m temperature (Fig 3a,b) without and with assimilation of surface-based cloud observations indicates that there was some retention of the low-level clouds in the EXP forecast and a rather strong effect in reducing daytime heating in the post-frontal region, especially in western Nebraska and South Dakota.

## 4. PLANS

Further case study and ongoing cycle (retrospective and real-time) testing will be conducted for the technique described in this paper for assimilation of surface-based cloud observations into the RUC. The technique will be modified during this testing to include assimilation of visibility and current weather, both within the logical cloud variable. The local cloud variable will be subdivided into cloud versus hydrometeor components to allow for clearing or not clearing rain/snow hydrometeors from the cloud base to the surface based on the current weather observation. Most importantly, the assimilation for surface-based cloud observations will be combined with previously developed techniques for assimilation of radar reflectivity into the RUC hydrometeor fields (Benjamin et al. 2002).

A comprehensive RUC cloud/hydrometeor analysis including surface-based cloud observations and radar reflectivity assimilation will result in considerable improvement to RUC aviation-specific forecasts of ceiling and visibility (Herzegh et al. 2002), as well as in forecasts of clouds and precipitation important for all users. Implementation of this combined cloud/hydrometeor assimilation technique will be proposed for implementation into the operational RUC late in 2004.

## 5. ACKNOWLEDGMENTS

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