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ASSIMILATION OF METAR CLOUD AND VISIBILITY OBSERVATIONS IN THE RUC

Stanley G. Benjamin, Stephen S. Weygandt, John M. Brown, Tracy Lorraine Smith[1], Tanya Smirnova[2], William R. Moninger, Barry Schwartz, Edward J. Szoke[1], and Kevin Brundage[1]

NOAA Research – Forecast Systems Laboratory, Boulder, CO

[1]Affiliated with Cooperative Institute for Research in the Atmosphere, Colorado State Univ., Ft. Collins, CO
[2]Affiliated with Cooperative Institute for Research in Environmental Sciences, Univ. of Colorado, Boulder, CO

1. MOTIVATION AND INTRODUCTION

Aviation and other transportation users have an urgent need for considerable improvement in predictions of clouds, fog, ceiling/visibility, and stable and convective precipitation. Beyond a few hours, model-based predictions of these sensible weather elements are the main source for forecaster guidance. Accurate model predictions of these elements requires accurate specification of cloud and hydrometeor fields in model initial conditions.

Thus, an important problem for short-range numerical prediction is the initialization of cloud and hydrometeor fields. Clearly, satellite and radar data are important for specification of the three-dimensional cloud/hydrometeor field. Another important source of information that should be utilized is the sensible weather information (weather, clouds, ceiling, visibility) provided by surface METAR observations. Accordingly, a development effort is underway at FSL to include METAR cloud and visibility information into the Rapid Update Cycle (RUC, Benjamin et al. 2004a) analysis system. This work with the RUC is part of a larger FAA-sponsored effort to improve ceiling and visibility forecasts over the U.S. (Herzegh et al. 2004). The goals in assimilating METAR ceiling and visibility observations are:

- Force near-match of RUC hydrometeor fields to current ceiling/ visibility observations.
- Improve accuracy of RUC short-range predictions for ceiling, visibility, and precipitation.

* *Corresponding author address:* Stan Benjamin, NOAA/FSL, R/FS1, 325 Broadway, Boulder, CO 80305, stan.benjamin@noaa.gov

2. CURRENT OPERATIONAL RUC CLOUD ANALYSES

The RUC cycles at full-resolution five microphysical species (cloud water, cloud ice, and rain water, snow, and graupel) and has the capability for updating these fields from observations. A description of the RUC model parameterization for mixed-phase hydrometeors is in Benjamin et al. (2004b). In the operational RUC run at NCEP, GOES cloud-top data are used to update these fields yielding improved cloud initial conditions in the RUC (since 2002, described in Benjamin et al. 2004a). Each hour, the RUC cloud analysis utilizes the following sources of information as described:

- 1-h RUC explicit 3-D hydrometeor (cloud water, rain, ice, snow, graupel (forecast).
- GOES/NESDIS cloud top product (pressure and temperature) to build and clear clouds from 1-h forecast:
  - Building – add cloud water or ice, saturate water vapor.
  - Clearing – remove cloud water/ice, subsaturate.
  - Checks for convective/marine cloud situations.
- Radar reflectivity and lightning – used in FSL test versions of the RUC.

However, satellite data define only cloud tops, whereas cloud *base* (or ceiling) and visibility near the surface are more crucial for aviation (and other transportation) weather users.

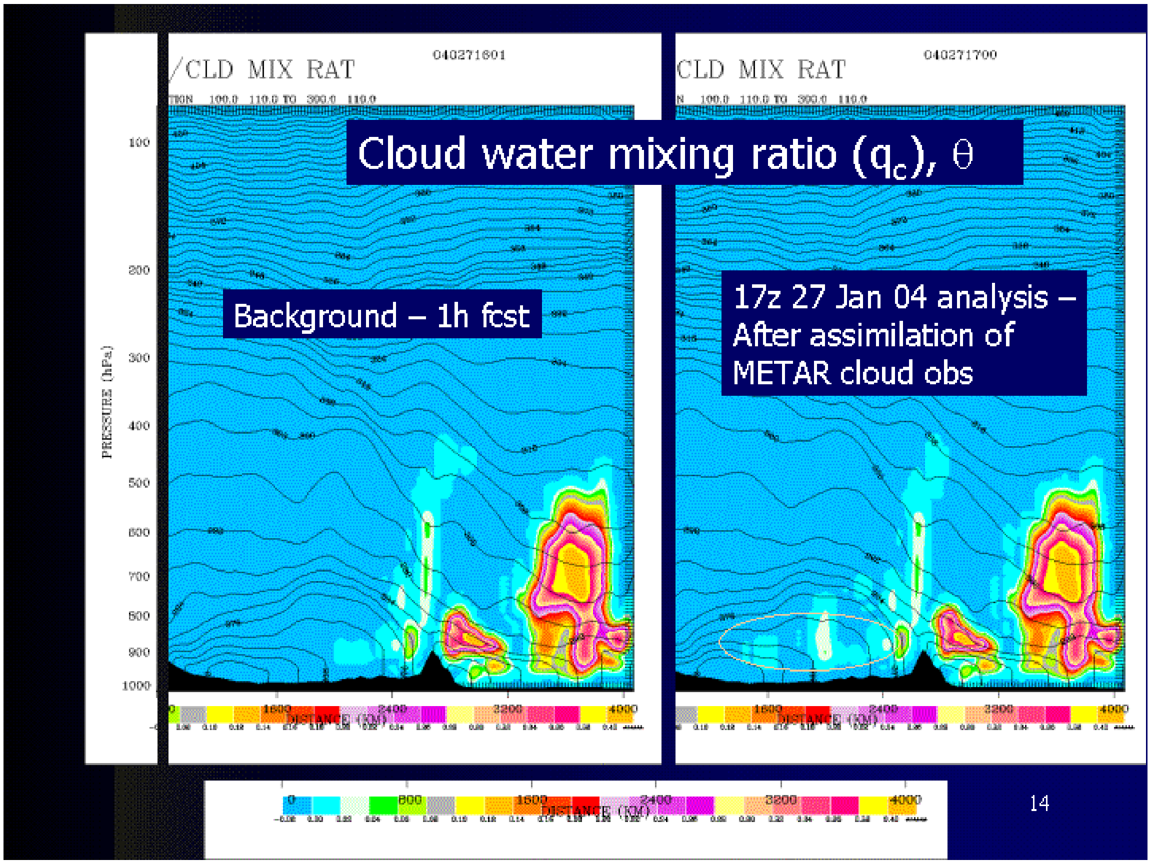

Figure 1. Cloud water mixing ratio (E-W cross section about 38°N, Appalachians evident about center) before (left) and after (right) assimilation of METAR cloud observations. Valid 1700 UTC 27 January 2004.

3. METHODOLOGY FOR ASSIMILATION OF METAR CLOUD/VISIBILITY OBSERVATIONS

The present assimilation technique for METAR cloud and visibility is to augment the pre-existing RUC cloud analysis technique, in which 1-h forecast (background) hydrometeor fields are modified using GOES cloud-top data. The assimilation of ceiling/visibility data allows clearing and building of cloud (hydrometeor) layers, generally in the lower troposphere, sometimes down to the surface. The RUC assimilation of GOES cloud-top pressure and temperature (Benjamin et al. 2004a) is based on the creation of a 3-D gridded cloud logical field indicating volumes where: 1) it is known that clouds do not exist, 2) it is known that clouds do exist, or 3) the presence of clouds is indeterminate. The same logical structure used for GOES cloud assimilation is used again with METAR observations, resulting in a more accurate 3-d hydrometeor yes/no/unknown field. Cloud layers are identified with BKN, OVC, or VV (vertical visibility) observations.

A cloud layer depth of 50 hPa is assumed unless the same METAR observation reports precipitation, in which the depth is set at 150 hPa. For surface-based cloud observations, assumptions about the horizontal representativeness must also be made. In initial tests performed up to the writing of this paper, surface-based cloud 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 elevation in the vicinity of the observation. METAR observations of clear conditions or ceiling levels higher than forecast are used to clear RUC analysis grid volumes.

For assimilation of either satellite-based or surface-based cloud observations, assumptions must be made about the depth of the cloud layer detected. An example of the METAR cloud visibility is shown in Fig. 1. Low-level stratus clouds with some embedded precipitation were evident in METAR observations over the Ohio Valley (west of the Appalachians in the cross section). With the assimilation of METAR ceiling data and incorporation of precipitation reported in the current weather field, the 3-D cloud water field is forced to represent the information present in these observations.

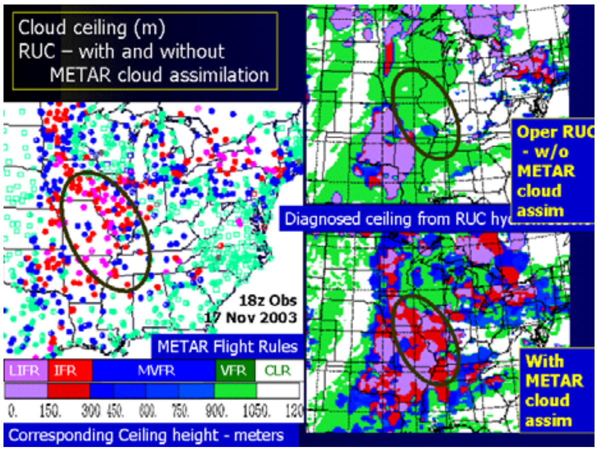

Figure 2. Improved fit of RUC initial cloud/hydrometeor fields to METAR obs after assimilation of ceiling observations. For analysis valid 1800 UTC 17 November 2003.

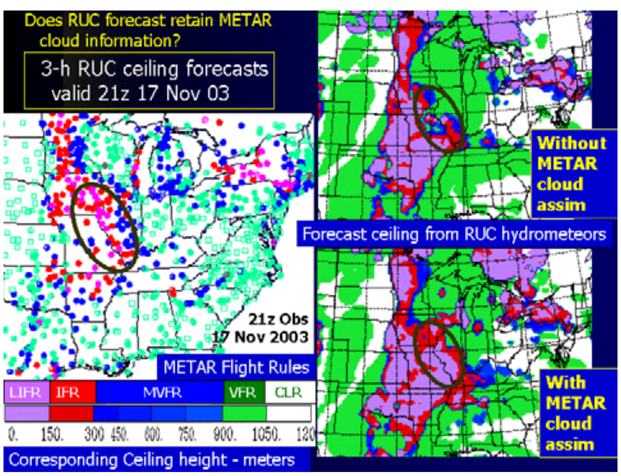

Figure 3. Same as Fig. 2, but for 3-h RUC forecasts valid at 2100 UTC 17 November.

An example showing a horizontal view of cloud fields with and without METAR cloud assimilation is now described. Fig. 2 shows aviation flight rules derived from individual METAR observations on the left (LIFR--limited instrument flight rules, IFR, MVFR, VFR, and clear) and RUC-analyzed flight rules on the right. Comparison of the RUC analysis that includes the METAR cloud assimilation (lower right panel) with the METAR-derived flight rules (left panel) clearly shows that RUC hydrometeor fields can be modified via assimilation to give a fairly consistent agreement with METAR observations valid at the same time. Without the METAR cloud assimilation (upper right panel), there is poor agreement with the METAR observations along the Missouri-Illinois border.

The resulting 3-h forecasts from versions of the RUC with and without METAR cloud assimilation are shown in Fig. 3. The cloud forecasts indicate improved skill resulting from METAR cloud assimilation along the Missouri-Illinois, where an area of LIFR conditions (ceiling less than 500 ft above ground level) occurred.

A second example is shown in Fig. 4, with a much more extensive improvement for 6-h forecasts with and without METAR cloud assimilation. The RUC forecast with METAR cloud assimilation (Dev) shows a much improved low ceiling forecast over a broad region from Pennsylvania southwestward to Texas along a frontal zone compared with the RUC forecast without the METAR cloud assimilation (Oper)

4. CONCLUSIONS

An initial technique for assimilating METAR cloud observations has been in testing since fall 2003, with a more recent addition of a related technique for assimilating visibility and current weather observations. Initial testing has included evaluating estimates of ceiling and visibility after converting METAR observations into 3D RUC prognostic variables, and then diagnosing ceiling and visibility back using translation algorithms (e.g., including extensions of the Stoelinga/Warner visibility estimation procedure).

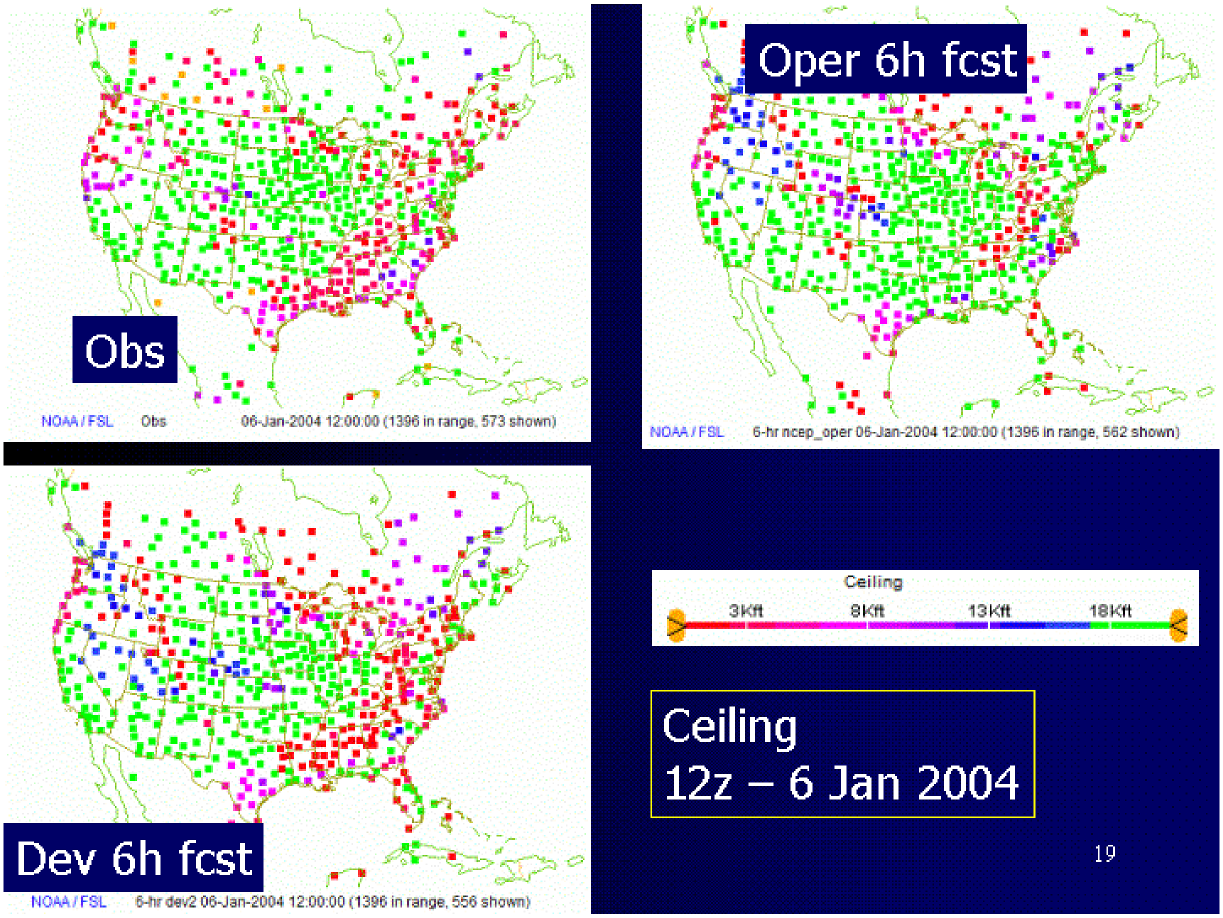

Fig. 4. Ceiling forecasts from RUC versions with (dev) and without (oper) METAR cloud assimilation. Observations also shown. All valid at 1200 UTC 6 January 2004

This testing has shown that the initial RUC technique is fairly good at incorporating ceiling and low cloud data into the RUC analysis. Since February 2004, a further technique with direct assimilation of visibility observations has also been added. This technique has been effective at modifying cloud/hydrometeor analyses, and will be reported on at the conference.

FSL is also testing a 13-km version of the RUC (Benjamin et al. 2004c), with implementation planned at NCEP in the first half of 2005. NCEP has been working to make cloud and visibility METAR reports available for data assimilation. An initial version of the METAR ceiling/visibility assimilation will be incorporated into the RUC13 implementation at NCEP, if observations are available by that time.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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