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CLOUD AND HYDROMETEOR ANALYSIS USING METAR, RADAR AND SATELLITE DATA WITHIN THE RUC/RAPID REFRESH MODEL

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1. Introduction

Aviation users have a strong need for accurate short-range forecasts of sensible weather parameters including clouds, fog, ceiling and visibility and precipitation. Model-based predictions of these parameters are the main source of guidance beyond a few hours and these predictions depend critically on the accurate initialization of cloud and hydrometeor fields. Thus, improving the initialization of these fields in mesoscale numerical models remains a key obstacle to better shore-range forecasts of surface sensible weather.

These cloud and hydrometeor fields are not well sampled by conventional observing systems and no single observing platform fully captures the needed information. To address this, observations from a variety of observing systems (radar, satellite, and surface reports) must be combined to yield a more comprehensive depiction of existing clouds and hydrometeors suitable for initializing microphysical variables in numerical models.

We describe herein a cloud analysis procedure developed for the Rapid Update Cycle (RUC) model and discuss ongoing and planned enhancements to it.

2. RUC Cloud Analysis Scheme

The RUC cycles 5 species of cloud (water and ice) and precipitation (rain, snow, graupel) hydrometeor fields, with the capability for updating these fields from observations. In the operational RUC run at NCEP, GOES cloud-top data and surface cloud, visibility and current weather information are used to update these fields to improve RUC cloud initial conditions (Benjamin et al. 2004). In the developmental RUC run at GSD, these data sources are complemented by 2D radar reflectivity and lightning data.

The RUC cloud analysis utilizes two 3D logical arrays to characterize information about clouds and precipitation. Recognizing the "one-way look" nature of many cloud observations, the logical array can possess values of YES, NO, or UNKNOWN to characterize the state of knowledge about clouds. Satellite data, for example, can indicate the existence of cloud top (the logical array would be set to YES in this region), but cannot provide information below this level (the logical array values would remain UNKNOWN below). When the satellite data indicated no clouds in the column, the entire column can be set to NO. For surface-based cloud observations, assumptions about the horizontal representative must be made before the logical arrays can be modified. Priority is given to satellite indications of no clouds in a column over METAR indications of cloudiness. Cloud and precipitation clearing and building (modifications of cloud/hydrometeor arrays) are then accomplished using the logical arrays. Additional details are given in Benjamin et al. (2002, 2004).

3. Planned RUC Cloud Analysis Upgrades

A significant limitation in the RUC cloud analysis is the use of a 2D radar reflectivity field. This precludes a full 3D characterization of the precipitation field. Work is underway to

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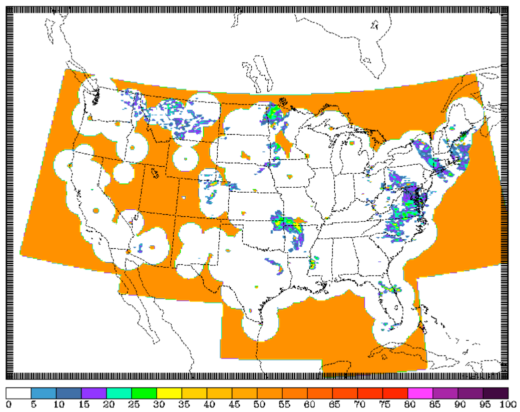

Fig. 1. Sample plot of merged NSSL radar reflectivity mosaic mapped to RUC 13-km grid. Plot shown is for z = 3.0 km ASL from 2000 UTC 24 May 2005. Orange shading indicates region of no radar data coverage within mosaic tile domain.

replace the 2D field with a 3D radar reflectivity mosaic provided by the National Severe Storms Laboratory (Zhang et al, 2004). Assembled from the WSR-88D network, this 21-level, 1-km horizontal resolution composite is transmitted to GSD as a series of 17 tiles covering the coterminous U.S. As can be seen in Fig.1, within the region covered by the assembled tiles (area within orange border) large areas of no radar data coverage exist (orange shading), especially over the Western U.S. Note that input from the Salt Lake City radar (KMTX) was missing from this particular file. This demarcation between no echo and no radar coverage is crucial for data assimilation purposes.

In addition to utilizing the radar reflectivity data to improve the RUC cloud analysis, we are examining techniques for using radar reflectivity derived latent heating fields to force the model dynamic fields during the RUC model digital filter initialization. In addition, work is underway to couple the closures in the RUC Grell-Devenyi cumulus parameterization to a radar-data based diagnosis of convective precipitation.

A second area of work related to the RUC cloud analysis will be conducted in conjunction with NASA Langley Research Center (LaRC). and involves testing the use of satellite-derived cloud properties. In particular, liquid water path and ice water path fields derived from GOES and Terra Aqua MODIS in real-time by LaRC (Minnis et al. 2004, 2005) will be assimilated into the RUC cloud analysis. The assimilation work will be preceded by an evaluation of current RUC hydrometeor analyses and forecasts and uncertainties in the LARC products relative to the other RUC cloud analysis inputs.

4. Transition to Rapid Refresh

The current RUC will to be replaced in late 2007 or 2008 by a new Rapid Refresh (RR) system now under development at the Global Systems Division (GSD, formerly the Forecast Systems Laboratory, FSL) of the Earth System Research Laboratory (ESRL) of NOAA. The RR represents a notable departure from the present RUC, entailing 3 major changes, which are summarized below. A more complete discussion can be found in Benjamin *et al* (2006).

1) The present domain covering the coterminous US will be expanded to cover all of North America, including continental Alaska, as well as most of the Caribbean Sea.

2) The forecast model will be a nonhydrostatic WRF core, either the WRF-NMM or WRF-ARW, in place of the current hydrostatic hybrid-vertical-coordinate RUC model. The present plan is to use an updated version of the NCAR microphysics, and, where possible, more advanced versions of other physics schemes now used in the current operational RUC13 (*e.g.*, the RUC land-surface scheme and the Grell-Devenyi ensemble convective scheme).

3) The existing RUC 3DVAR will be replaced by the Gridpoint Statistical Interpolation (GSI) 3dVAR scheme under development by the NCEP (National Centers for Environmental Prediction of the National Weather Service) and the Joint Center for Satellite Data Assimilation.

The GSD will be modifying the GSI to include feature known to be important for a rapid refresh application to aviation and other short-range forecast problems. The areas of modification include the treatment of surface observations and the cloud analysis. As part of this adaptation of the GSI, an upgraded version of the RUC cloud analysis procedure will be implemented to accommodate assimilation of satellite derived products, radar reflectivity and METAR cloud and present weather observations. These observations will be used to modify RR cloud and hydrometeors fields, which will be explicitly predicted and cycled hourly, just as they are in the RUC.

At the conference we will show test case results from cloud analyses run with the 2D and 3D reflectivity fields as well as with and without the surface cloud information.

5. Acknowledgements

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6. References

Benjamin, S.G., S.S. Weygandt, J.M. Brown, T.L. Smith, T.G. Smirnova, W.R.Moninger, B. Schwartz, E.J. Szoke, K. Brundage, 2004: Assimilation of METAR cloud and visibility observations in the RUC. 11th ARAM Conf. Hyannis, MA, Amer. Meteor. Soc.

Benjamin, S.G., D. Kim, and J.M. Brown, 2002: Cloud/hydrometeor initialization in the 20-km RUC with GOES and radar data. Preprints, 10th Conf. on Aviation, Range, and Aerospace Meteorology, Portland, OR, Amer. Meteor. Soc., 232-235.

Minnis, P., and co-authors, 2004: Real-time cloud, radiation, and aircraft icing parameters from GOES over the USA. 13th Conf. Sat. Ocean. And Meteor., Norfolk, VA, Amer. Meteor. Soc.

Minnis, P., J. Huang, B. Lin, Y. Yi, R. Arduini, T. Fan, J. Ayers, 2005: Advanced retrievals of ice water path in ice-over-water cloud systems. Submitted to *J. Geophys. Res.*

Zhang, J., K. Howard, C. Langston, S. Wang, and Y. Qin, 2004: Three- and four-dimensional high-resolution national radar mosiac. ERAD Proceedings.