THE STATUS OF THE REAL TIME MESOSCALE ANALYSIS SYSTEM AT NCEP

De Pondeca*, M.S.F.V., G. Manikin, D. F. Parrish, R. J. Purser, W.-S. Wu, G. DiMego, J. C. Derber, S. G. Benjamin, J. Horel, S. Lazarus, L. Anderson, B. Colman, and B. Mandt

* *Corresponding author address:* National Centers for Environmental Predictions, NCEP/NWS/NOAA, WWB, 5200 Auth Road, Camp Springs, Maryland 20746-4304, USA; email: Manuel.Pondeca@noaa.gov.

1. INTRODUCTION

The development of the 2DVar-based Real-Time Mesoscale Analysis (RTMA) system for the objective analysis of surface weather parameters is a joint effort between the National Centers for Environmental Predictions (NCEP) and the Earth System Research Laboratory (ESRL). The RTMA represents the first step of a comprehensive plan to develop an "Analysis of Record (AOR)." The latter is the best possible real-time and retrospective analyses of the atmosphere at high spatial and temporal resolution (Horel and Colman 2005). Such high quality analyses are desirable for a wide range of applications that include the creation and verification of gridded forecasts, coastal zone and fire management, dispersion modeling for the transport of hazardous materials, aviation and surface transportation management, and impact studies of climate change on the regional scale. The RTMA utilizes and enhances existing analysis capabilities at the National Weather Service (NWS) to generate objective analyses of surface observations on grids that match those of the National Digital Forecast Database (NDFD). The system was implemented operationally in the Fall of 2006. It represents a fast-track, proof-of-concept of the AOR program and establishes a benchmark for future AOR efforts. A parallel version of the RTMA was also initiated in the Fall of 2006 and used as a testbed for continued experimentation aimed at improving the quality of the analysis. As a result of the various experiments and evaluation that involved collaborators from the University of Utah, the Florida Institute of Technology, and some NWS regional offices, a major upgrade of the operational RTMA is expected for the Summer of 2007. In this paper, we give a general description of the RTMA and report on its status and ongoing developments.

2. RTMA DESCRIPTION

The RTMA consists mainly of the hourly 5km resolution 2DVar analysis of surface observations on NDFD grids. The system is presently configured only for the CONUS NDFD grid, but corresponding configurations for the Alaska, Hawaii, Puerto Rico, and Guam NDFD grids are to be introduced in the coming months. The main component of the RTMA is NCEP's Grid-point Statistical Interpolation (GSI) analysis system (Wu et al. 2002). This was originally a 3DVar system that was expanded to include a 2DVar capability for the analysis of surface observations. The RTMA uses the 13-km one-hour forecast from the Rapid Update Cycle (RUC) downscaled to the CONUS NDFD grid resolution as its first guess. It produces gridded analyzes of 2-m temperature, 2-m specific humidity, 10-m u and v-components of the wind, and surface pressure, and computes a diagnostic field of 2-m dew point temperature. Furthermore, it computes gridded estimates of analysis uncertainty for each analyzed field. An important characteristic of the RTMA-2DVar is the use of background error covariance functions that are mapped to a smoothed representation of the NDFD topography.

In addition to the 2DVar surface analysis, the RTMA also interpolates NCEP Stage-II precipitation and GOES sounder effective cloud amount to the CONUS NDFD grid.

3. THE RTMA FIRST GUESS

The downscaling of the RUC 13-km one-hour forecast fields to provide the first guess for the RTMA comprises three main steps: Horizontal interpolation to the higher resolution NDFD grid, vertical adjustment to reduce the interpolated fields to the NDFD topography, and coastline sharpening using a land-water indicator constructed from vegetation type (Benjamin et al. 2007). For the 10-m wind, Fig.1 displays an example of the original RUC 13-km field and the RTMA first guess over a portion of the CONUS NDFD grid. It is apparent from that figure that the downscaling accounts for a number of small scale features which are absent from the original 13-km field.

4. THE RTMA ANISOTROPIC BACKGROUND ERROR COVARIANCES

The RTMA uses the following subset of analysis variables from the GSI: stream-function, velocity potential, temperature, specific humidity normalized by the saturation value of the first guess, and surface pressure. The 2DVar is incremental and univariate, and the background error covariance models are of quasi-Guassian form. The covariance shapes of the RTMA are efficiently synthesized with the help of spatial recursive filters used in conjunction with the sequential line-filtering “triad” algorithm (Purser et al. 2003a,b and Purser 2005). Using a variant of the Riishøjgaard method (Riishøjgaard 1998), the structure functions are prescribed to display a controlled degree of correlation with the underlying smooth representation of the NDFD terrain. However, the degree of that correlation is different for each analysis variable. Specifically, it is moderately strong for temperature, specific humidity, and surface pressure, but very weak for stream function and velocity potential. An example of the terrain-following covariance is shown in Fig.2 for the 2-m temperature. The test point in that figure is located near the bottom of a mountain slope.

5. OBSERVATIONS AND QUALITY CONTROL

The Meteorological Assimilation Data Ingest System (MADIS) is the observation feed for the RTMA. Besides standard land synoptic, METAR, ship, buoy and C-MAN observations, the RTMA also assimilates high density observations from various Mesonets, satellite SSM/I wind speeds, and QuickSCAT ocean surface winds. The system assimilates observations that fall within a -12 min to +12 min time window centered around the analysis time. Figure 3 displays a representative map of the temperature observations used at a given assimilation time. In general, the mesonet observations account for about 80% of all mass observations and the METAR account for about 12%. The remaining observation types occur in varying percentage numbers from about 1% to about 3.5%. The heterogeneously distributed and sometimes unreliable mesonet observations pose a quality control challenge to the RTMA. This is particularly true of the mesonet winds which on average tend to exhibit a strong low speed bias primarily attributed to questionable anemometer siting strategies.

There are three layers of quality control in the RTMA-2DVar: (1) The MADIS quality control flags are honored; (2) additional gross-error checks are performed at the beginning of each outer loop of the minimization procedure; and (3) a dynamic “reject list” constructed from the most recent history of gross-error checks is used for the mass observations. However, for the mesonet winds, a list of trusted providers borrowed from the RUC is used instead. That list was constructed from long term statistics of winds speed differences (observed value minus RUC background equivalent) grouped by provider name. Unfortunately, more than 80% of the approximately 14000 mesonet wind observations fail the criteria for acceptability. In contrast, only about 10% of the mass mesonet observations are rejected. Work is underway to refine the methodology of the less restrictive “reject list” and make it applicable to the mesonet winds as well.

6. ANALYSIS UNCERTAINTY

The RTMA provides fields of analysis uncertainty for each analyzed variable. The method of computation is based on the well-known result that in incremental variational assimilation the analysis error covariance matrix coincides with the inverse of the Hessian matrix of the cost function (eg. Fisher and Courtier 1995).” For mathematical tractability and computational feasibility, the RTMA makes some drastic assumptions that lead to a point value estimate of the inverse of a “hypothetical” surrogate 1x1

Hessian at each observation location. With the help of the optimality condition of the variational problem, that point value is conveniently expressed in terms of the local value of the analysis increment, the innovation vector, and the observation error. Gridded fields of analysis uncertainty are then derived by performing a Cressman analysis of the square-root of the point estimates of the inverse Hessian. Fig.4 shows an example of the field of analysis uncertainty for the 2-m temperature over a portion of the CONUS NDFD grid.

7. ONGOING WORK

Additional RTMA-2DVar efforts are taking place in the following areas:

1. Attempt to estimate the analysis error variances using the connection between the bi-orthogonal system of gradient vectors of the pre-conditioned conjugate gradient method of the GSI and the Lanczos vectors used to solve large scale symmetric eigenvalue problems. The method is an adaptation of that described in Fisher and Courtier, 1995.

2. Use of a non-linear quality control for the observations.

3. Reformulation of the normalization method used for the recursive filter in order to allow for a time efficient assimilation when the covariance changes from one time to the other. In particular, this will enable the testing of alternate covariances that are mapped to the background potential temperature.

5. Setting-up of RTMA configurations for the Alaska, Hawaii, Puerto Rico, and Guam NDFD grids, whereby the first guess is provided by NCEP's North American Mesoscale Modeling System for the first three grids and by the Global Forecast System Model for the fourth grid.

6. Expansion of the list of analyzed variables to include, among others, minimum and maximum temperature, mean sea level pressure, and wave height.

7. Attempt to minimize the data latency issues at MADIS that prevent some mesonet observations from being available on time for assimilation by the RTMA.

8. USEFUL LINKS

Data from the operational and parallel RTMA are accessible via anonymous ftp:

ftp://ftp.emc.ncep.noaa.gov
(cd mmb/mmbpll/rtma)
(cd mmb/mmbpll/rtma/parallel) .

Results from the parallel RTMA evaluation can be found at the following website:

http://www.emc.ncep.noaa.gov/mmb/rtma/para/

SUMMARY

The Real Time Mesoscale Analysis is the first step toward the creation of an Analysis of Record, and consists of the 2DVar objective analysis of surface weather parameters and mapping of Stage-II precipitation and GOES sounder effective cloud amount to the CONUS NDFD grid. The system was implemented in the Fall of 2006 for the CONUS, and it is soon to be implemented for the Alaska, Hawaii, Puerto Rico, and Guam NDFD grids. The features that render the RTMA a useful analysis system to address the demand for high quality surface analysis in various applications include; (i) the use of a physically robust method for downscaling the RUC 13-km fields and provide the RTMA first guess, (ii) the use of a state-of-the art 2DVar with anisotropic background error covariances, and (iii) the assimilation of high density mesonet observations.

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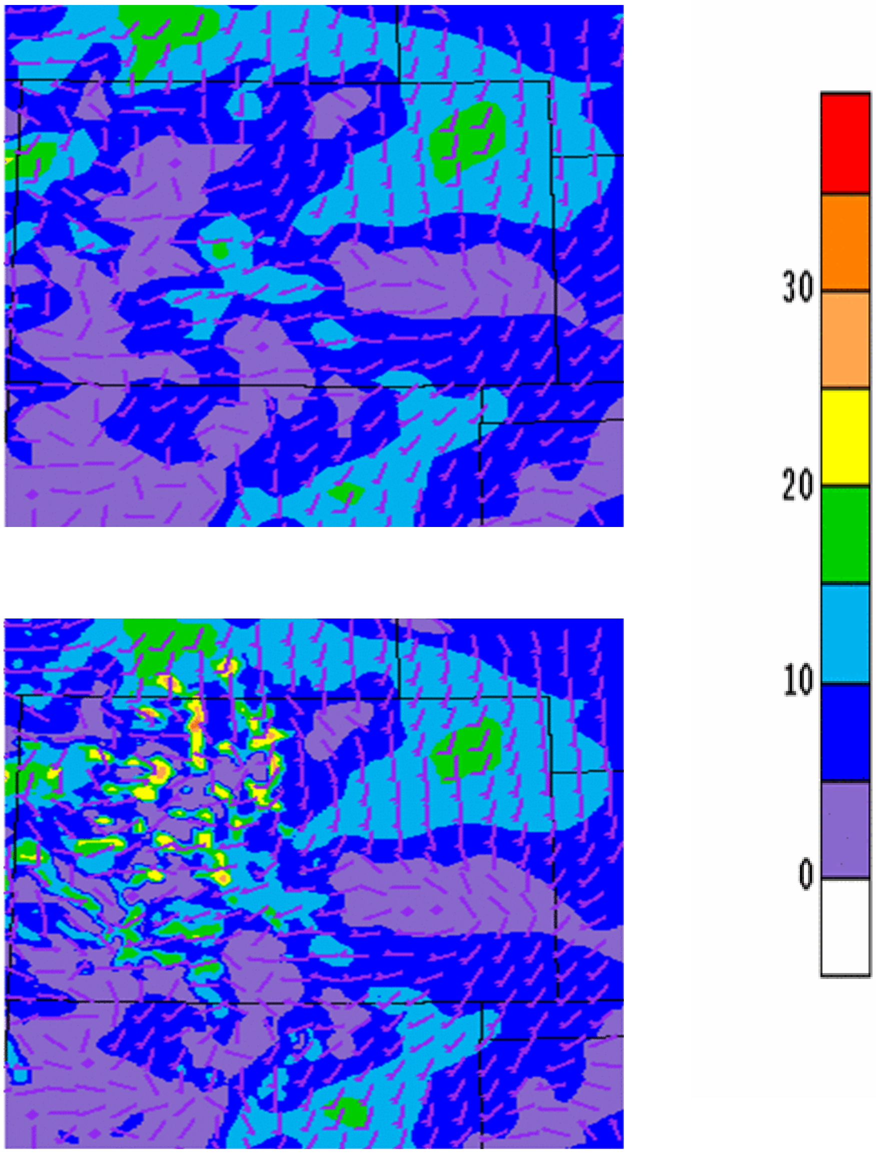

Fig.1: An example of the original 13-km RUC 10-m wind (upper panel) and its 5-km downscaled version (lower panel). Figure show only a portion of the CONUS NDFD. Values from color bar are in m/s.

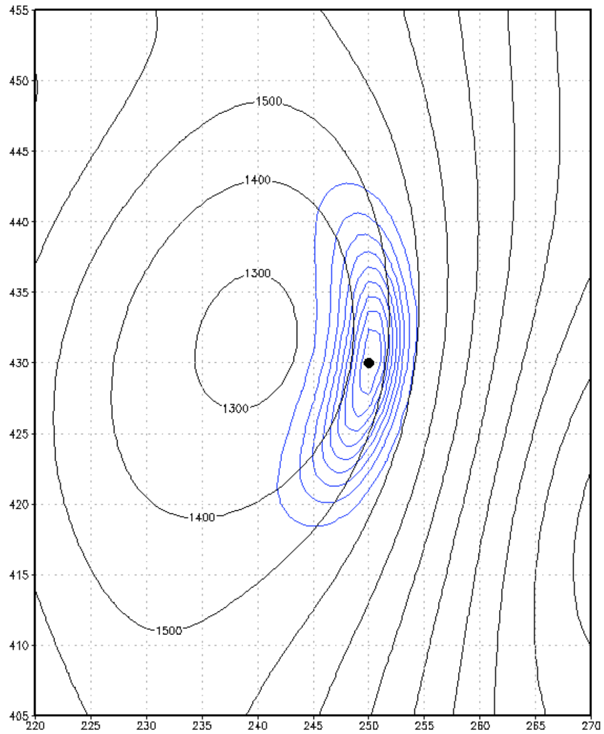

Fig.2: Example of the auto-correlation function for temperature (blue contours) for a test point located at grid unit coordinates x=250 and y=430. Black lines represent the smoothed NDFD terrain field.

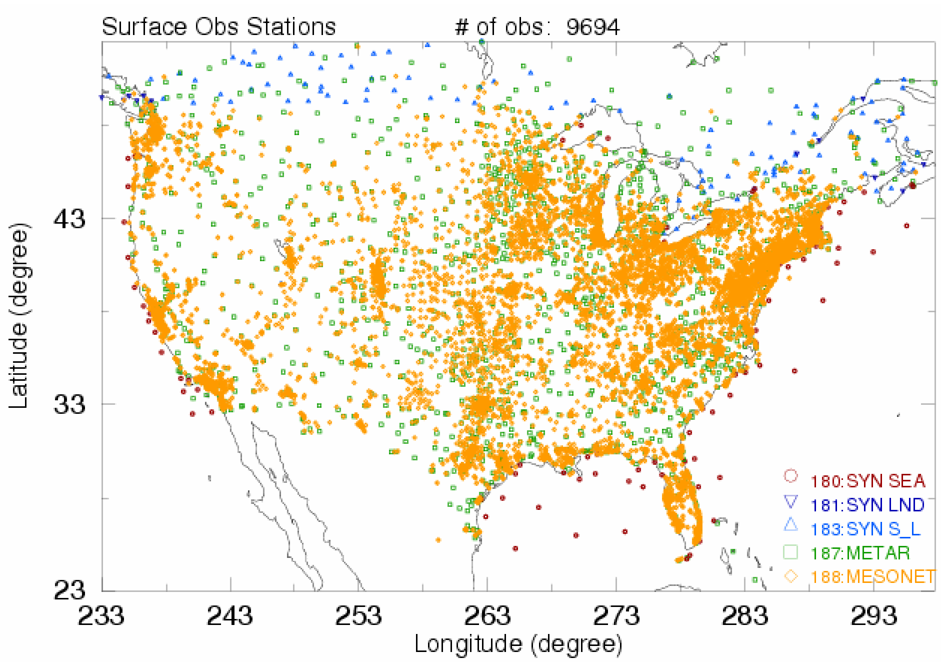

Fig.3: Representative map of the temperature observations used for a given RTMA analysis. Note the highly heterogeneous distribution of the mesonet data

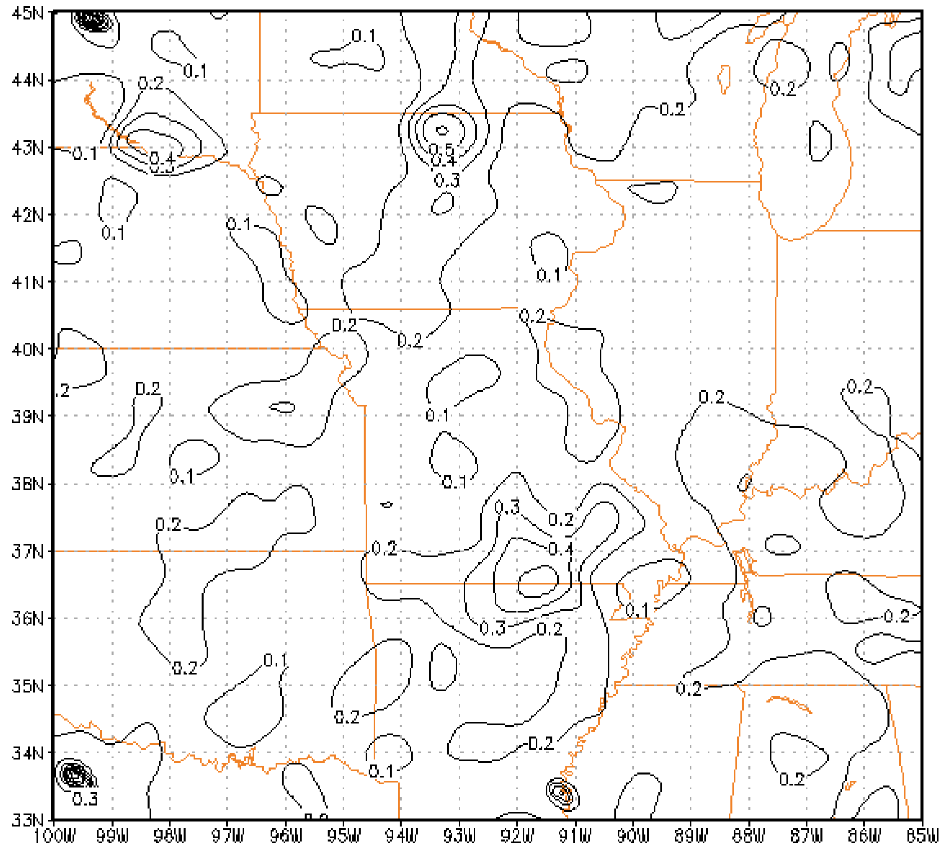

Fig.4: Example of the analysis error uncertainty for the 2-m temperature over a portion of the CONUS NDFD grid. Values are normalized by the square-root of the background error variance, which is assumed constant over the whole RTMA domain.