P2.7 A QUANTITATIVE EVALUATION ON THE PERFORMANCE OF A REAL-TIME MESOSCALE FDDA AND FORECASTING SYSTEM UNDER DIFFERENT SYNOPTIC SITUATIONS

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1. INTRODUCTION

A mesoscale weather analysis and forecasting system that employs Real-Time Four-Dimensional Data Assimilation (RT-FDDA) has been developed and operational since summer of 2000. The forecast system is built upon the Fifth Generation of the Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model (MM5). The triply nested model domain sits over the western United States and centers on the Dugway Proving Ground in Utah, where complex terrain and surface characteristics account for a variety of local forcing. The system utilizes a continuous data ingest mechanism to produce an analysis period using Newtonian relaxation, before a forecast period begins. The goal of the pre-forecast analysis period is to bring the model to a dynamically balanced state so as to reduce the time required for the spin-up process during the forecast period. A detailed description of the system can be found in this volume of preprints (Cram *et al*., 2001).

The RT-FDDA system is run in parallel to an operational real-time forecast system (referred to as OPN hereafter) that uses a one-time, static initialization at the beginning of the forecast [Davis *et al*., 1999]. Both systems are validated routinely against observations. Both sets (OPN and RT-FDDA) of verification statistics display significant fluctuations on the time scale of 3 to 5 days. Examples of this feature are shown in Figure 1, in which temperature bias at 1800 UTC (panel a) and 0000UTC (panel b) are plotted as a function of day in January 2001. The statistics are generated based on grid 3 solutions. It is also noted that the two sets of validation statistics are more diverged on some days than others. Assuming the quality of observational data holds steady, the synoptic situations could be reflected in the day-to-day fluctuations of statistics. Hence, the objectives of this study include (a) to identify how the performance of the forecast systems, in terms of verification statistics, are modulated by different synoptic scenarios, and (b) to identify the relative strength of the RT-FDDA forecast system to the regular cold-start operational system.

2. MODEL CONFIGURATION/PHYSICAL OPTIONS

The OPN system has undergone a series of changes and upgrade over the years since it became operational. See Davis *et al*. (1999) for detailed description of the original configuration. The current system preserves most of the configuration and physical options, with the most significant upgrade/changes being 1) first-guess background fields for the initial conditions coming from NCEP Eta model forecasts of finer resolution; 2) using the Oregon State University Land Surface Model (OSU LSM) for the calculation of substrate temperature and moisture (Chen and Dudhia, 2001). The coarse grid resolution is 30 km, with three finer grids at 10 km, 3.3 km, and 1.1 km resolution. The system produces two 36-hour forecasts that begin at 0600Z and 1200Z daily.

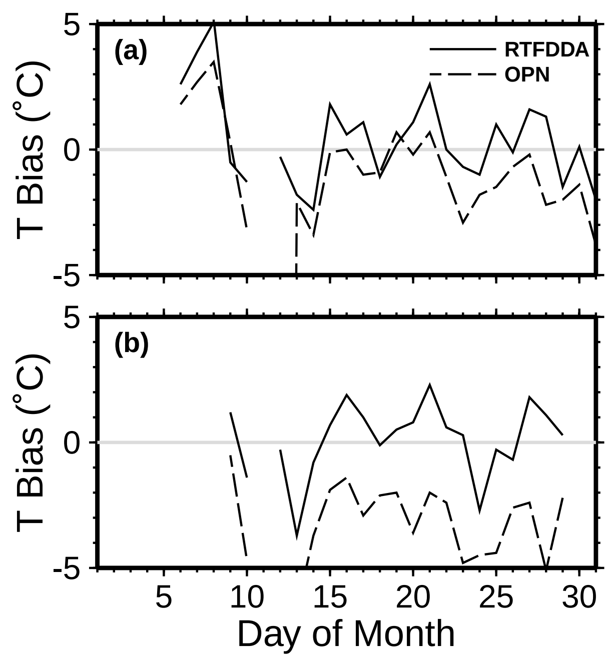

Fig. 1, Examples of temperature forecast bias fluctuating as a function of day in January 2001. Panel (a) shows verification results valid at 1800 UTC; whereas Panel (b) shows verification results valid at 0000 UTC. The solid lines represent the results from the RT-FDDA forecasts with beginning time valid at 1300 UTC; the dashed lines represent results from OPN forecasts.

The RT-FDDA system is configured to use mostly the same physical options as those adopted by the OPN system. The major difference, other than the dynamic initialization, is that the RT-FDDA system traded the sophisticated OSU LSM for computational efficiency. The domain/grid configuration is mostly the same as that for the OPN system, except the RT-FDDA system

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does not have a 1.1 km grid. The system originally used a simple multi-layer soil temperature scheme, known as the "slab" scheme. New additions to the simple soil model, including a soil moisture availability scheme and a snow scheme (Low-Nam *et al.*, 2001), were implemented in late march.

3. DATA AND METHOD

3.1 Observational Data

Observational data that come in through the ingest system undergo quality control procedures and are archived for both analysis and verification purposes. The preliminary results presented in this paper use surface observations only, which include measurements taken at different platforms and networks, including synoptic, METAR, mesonet, and special observations.

For comparison with observations, a procedure based on similarity theory is applied to the model output to generate surface temperature field valid at 2 m above ground, and surface wind field valid at 10 m above ground. In this paper, our focus is on surface temperature verification.

3.2 Forecast Cycle Selection

The design of the RT-FDDA system is such that each cycle is comprised of a "final" analysis period, followed by a "preliminary" period, and then a forecast period. All three periods are referred to using one cycle tag. For instance, 1100Z analysis has analyses from 0800 UTC through 1000 UTC; 1100Z preliminary period has analyses from 1100 UTC through 1300 UTC; and the 1100Z forecast period produces a forecast starting 1400 UTC. Again, see Cram *et al.* (2001) for a clearer picture.

To compare the two sets of statistics, both RT-FDDA and OPN forecasts are validated against common sets of observations. There are eight analysis-forecast cycles per day on the RT-FDDA system, whereas the OPN system has only two cycles daily, as stated above in Section 2. The 0600Z forecast cycles on the OPN system use Eta forecasts valid at 0600 UTC without the luxury of any observational data for initialization. Therefore, for a closer comparison with the RT-FDDA forecasts, only the 1200Z OPN forecasts are selected. Because of the way the RT-FDDA system is configured, none of the forecast cycles has the valid beginning time that exactly matches that of the OPN forecast cycles. Among the eight forecast cycles on the RT-FDDA system, we decide to use forecast cycles with beginning time valid at 1300 UTC and 1600 UTC for the following reasons: 1) the 1300 UTC beginning time is closest to the valid beginning time for the OPN forecasts at 1200Z; 2) the analysis cycles with valid starting time at 1100 UTC, which proceed to provide initial conditions for the forecast cycles with starting time valid at 1300 UTC, do not have rawinsondes for use in the analysis period; whereas the analysis cycles with starting time valid at 1400 UTC do use rawinsondes in the analysis, and subsequently provide initial conditions for the forecast cycles with starting time valid at 1600.

3.3 Categorization of Synoptic Situation

Currently the study focuses on three months from January through late March 2001, before the snow scheme and the moisture variability scheme were installed. The prevalent synoptic features in the western United States during these months can be categorized as following:

(a) TH: A transitional period, during which a surface high pressure system and/or upper-air ridges gradually moves into Utah from the west/northwest to replace either a low pressure system that moves out of the state to the east or a weak synoptic system with little large-scale forcing.

(b) H: Surface high pressure, in most cases, accompanied by upper-air ridges over Utah or adjacent states and most likely represents clear-sky conditions.

c) TL: A transitional period, during which a surface low and/or upper-air trough develops to the west or northwest of Utah, or a low-pressure system gradually moves into Utah from the west.

d) S: Winter storm system, caused either by a matured surface low pressure system over or near Utah, accompanied by upper-air troughs tilting to the west, or by a strong high pressure system in Canada or northern United States and brings in cold air to Utah. Snow and frontal system passing the state of Utah are commonly observed under these conditions.

(e) Q: As in "Quiet." Major synoptic systems are too far away from Utah to make an impact within 12 hours, which is the forecast length of the RT-FDDA system. This region is devoid of weather makers, and weak in large-scale forcing. There may be some small-scale, transient or fast moving disturbances.

The total number of cases in each category is listed in Table 1. Note that because of occasional system failure and, in rare cases, missing synoptic weather charts, the total number of cycles does not add up to total number of days from January through March.

Table 1, Number of cases associated with each synoptic situation category.

Category	TH	H	TL	S	Q
Count	16	14	6	11	17

4. VERIFICATION RESULTS

Figure 2 shows the temperature bias and root-mean-squared error (RMSE) for Category TH. The statistics are based on Grid 3 solutions. The RT-FDDA forecasts have biases mostly close to zero throughout the forecast cycles, although it appears to display some degree of diurnal variability, as evidenced by the two dips at 1600 and 0000 UTC (1000 and 1800 local time). The biases for the OPN system show increasing cold biases until around 1800 local time, and then recover slightly, as documented in Davis *et al.* (1999). The temperature RMSE's for the RT-FDDA system also hold mostly steady at about 2.5°C. A small peak at about 0000 UTC corresponds to the time when the bias is at its largest negative value. The RMSE's for the OPN system are consistently higher than those for the RT-FDDA system, with largest value also occurring around 0000 UTC.

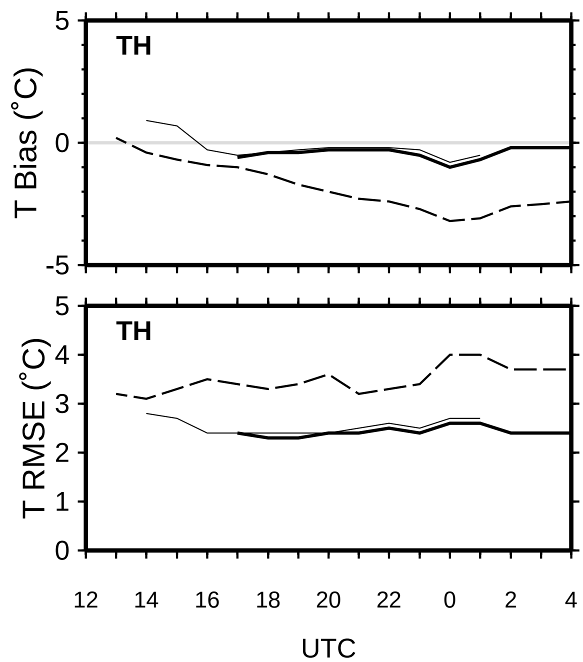

Fig. 2, Grid 3 temperature bias and RMSE for Category TH. Solid lines represent results from RT-FDDA system verification, while dashed lines are for the OPN system. Thin solid line is the result taken from the 1100Z forecast cycle, while thick solid line shows the results from the 1400Z forecast cycle.

Figure 3 shows the same as Figure 2, except for Category H. The biases for RT-FDDA system stay consistently at about –0.7°C, except for the period between 2200 UTC and 0100 UTC, when the cold bias reaches as low as 1°C. Similar to what is shown in Figure 2, the biases for RT-FDDA system appears to show diurnal variability, and the amplitude of fluctuation is larger compared to that for Category TH. The biases for the OPN system display a similar trend as that shown in Figure 2, except, in this case, the cold biases are much stronger, and the strongest cold bias occurs between 2100 UTC and 0000 UTC. The coldest bias for the OPN system in this category exceeds 5°C. The RMSE's for the RT-FDDA system stay mostly around 3°C throughout the forecast hours; whereas those for the OPN system display a huge hump between 1600 UTC and 0200 UTC, consistent with the large cold biases shown in the bias panel.

Figure 4 shows the same as Figure 2, except for Category TL. The temperature biases for the RT-FDDA system again show a small degree of fluctuation throughout the forecast period with slightly warm biases after sunrise until noon. The slightly cold biases turn into warm biases after sunset. The cold biases for the OPN system show similar pattern of increasing with time until 1800 local time. Although the RMSE's for the OPN system are mostly higher than those for the RT-FDDA system, they are much closer to RT-FDDA curves than what is shown in the previous two categories.

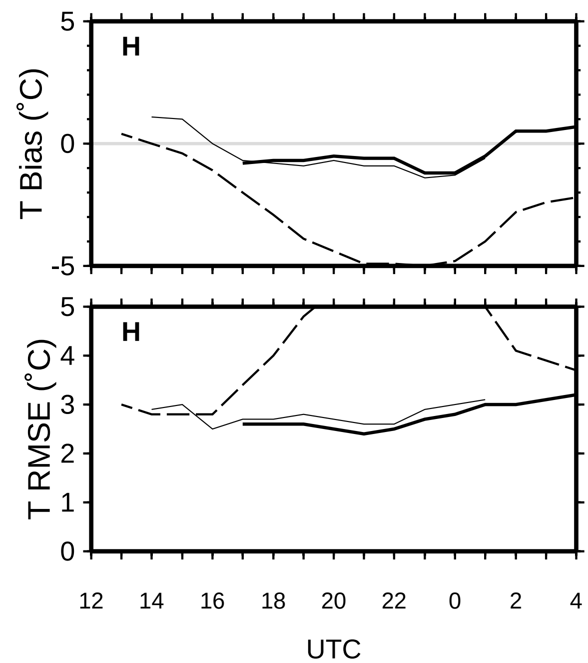

Fig. 3, Same as Fig. 2, except for Category H.

Figure 5 shows the same as Figure 2, except for Category S. There are several strikingly different features shown in this category, as compared to other categories. First, the OPN system has smaller bias and RMSE, compared to the RT-FDDA system. Second, the biases for RT-FDDA system show a significant jump after mid-morning, instead of the fluctuations of much smaller amplitude as shown in other categories. Third, the biases for the RT-FDDA system are now much larger than those for the OPN system during most part of the forecast period. Fourth, the biases for the OPN system show a departure from the trend (increasing cold biases right from the start) that has been shown consistently in other categories. The curve stays mostly close to zero until around 2200 UTC. The RT-FDDA system has significantly higher RMSE's between 1700 UTC and 0100 UTC. Note these features are particularly in contrast to what is shown in Fig. 3 for Category H. While the OPN system has unrealistic cooling under clear-sky conditions, the RT-FDDA system has unusual warming under winter storm conditions. But, recall that the collection of cases in this study ends before the snow scheme is installed. Preliminary examination of several winter storm cases in late March and early April suggests that the warm biases are corrected with the implementation of the snow scheme.

Figure 6 shows the same as Figure 2, except for Category Q. Compared to the OPN system, the RT-FDDA system again has smaller amplitudes in both bias and RMSE. However, a diurnal fluctuation is evident at least in the biases of the RT-FDDA system, similar to what is shown for Categories TH (Figure 2), H (Figure 3) and TL (Figure 4). The amplitude of the diurnal variability in this category is larger compared to those in the two transitional categories. Given the lack of large-scale forcing in this category, the RT-FDDA system seems to under-perform in terms of catching diurnal temperature variability.

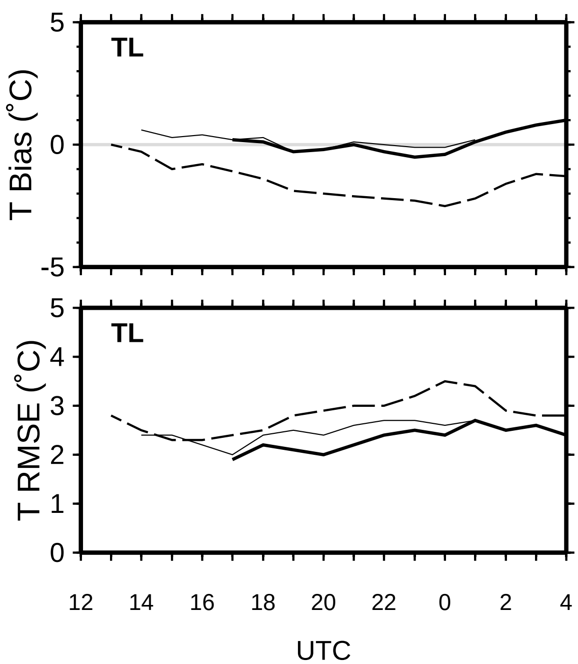

Fig. 4, Same as Fig. 2, except for Category TL.

5. SUMMARY AND DISCUSSION

The performance of a RT-FDDA weather analysis and forecasting system is quantitatively evaluated against surface temperature observations. The evaluation also includes an inter-comparison with the quantitative evaluation of the OPN (operational, cold-start) system. We examine the performance of these two systems under different synoptic situations. The purpose is to understand the strength/weakness of the RT-FDDA system relative to the OPN under a variety of synoptic scenarios during late winter and early spring.

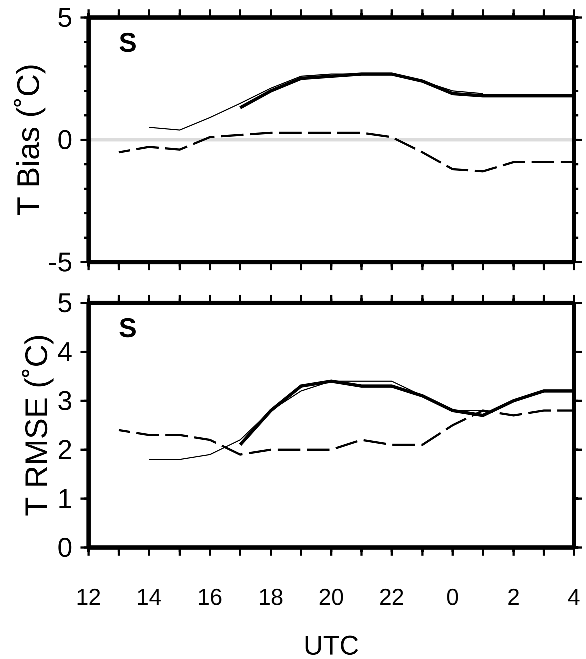

Fig. 5, Same as Fig. 2, except for Category S.

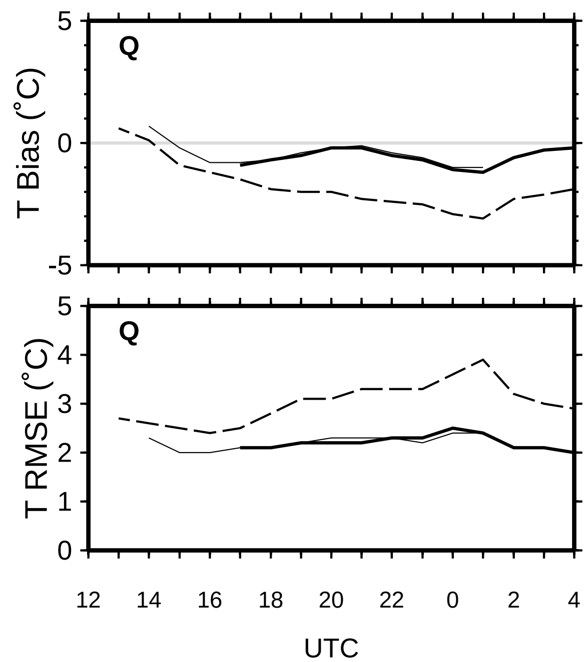

Fig. 6, Same as Fig. 2, except for Category Q.

In general, the RT-FDDA system clearly out-performs the OPN system in the surface temperature forecasts, except under the winter storm type of conditions. Under the conditions of strong high-pressure system over Utah, the RT-FDDA system has the largest advantage over the OPN system. Under the winter storm conditions, the RT-FDDA system shows large warm bias consistently, whereas the OPN system has small cold biases or close to zero biases. The original RT-FDDA system was implemented with a simple soil temperature scheme, and yet without a sophisticated snow scheme to handle snow accumulation/melting processes. This most likely accounts for the high warm biases under winter storm conditions. There is evidence that the high warm biases are eliminated after simple snow scheme and moisture variability were implemented.

Even though the temperature biases for the RT-FDDA system are mostly close to zero under most conditions (except winter storm), they do display some degree of diurnal variability. Under the conditions of minimal large-scale forcing, the diurnal fluctuation in temperature biases has the largest amplitude.

Our goals for the near future include: 1) expanding synoptic situation categories to include more types of large-scale forcing during spring and summer seasons; and 2) performing more in-depth analyses to identify what is responsible for the strength/weakness over the OPN system.

6. ACKNOWLEDGEMENT

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