# 2.3 ACCURACY OF RAPID UPDATE CYCLE LOW-LEVEL JET FORECASTS

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## 1. INTRODUCTION

A major contributor to the development of severe convection in the central United States is the maximum in winds that occurs in the lower troposphere commonly referred to as the low-level jet. The low-level jet is responsible for both transporting moisture northward from the Gulf of Mexico and creating cyclonic shear that fuels the development of severe storms during the late afternoon. As the jet intensifies at night, individual storms organize into mesoscale convective systems that are often responsible for heavy rainfall and flash flooding. Accurate forecasts from numerical prediction models of the timing and intensity of the low-level jet, and the vertical wind shear it creates are important to severe storm forecasters.

The Rapid Update Cycle (RUC) model, developed at the Forecast Systems Laboratory (FSL) and run operationally at the National Centers for Environmental Prediction (NCEP) provides forecasters with short-range predictions (1-12 h) of various sensible weather phenomena, updated on an hourly basis. The RUC model is unique in that it is updated with numerous asynoptic data sources from aircraft, wind profilers, satellite, and other data sources (Benjamin et al. 2004). Surface and upper-air verification of RUC forecasts have appeared in previous conference presentations (e.g., see Schwartz et al. 2000, Schwartz and Benjamin 2001 and 2002a. In addition, Schwartz and Benjamin (2002b) present a verification specific to convective weather forecasting regarding CAPE forecasts.

In this paper we present verification of lower-tropospheric RUC wind forecasts related to the low-level jet and the associated shear that accompanies this phenomena. In this paper, we verify RUC forecasts employing National Oceanic and Atmospheric Administration's (NOAA) wind profiler data (see http://www.profiler.noaa.gov).

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## 2. EXPERIMENT DESIGN

Forecasts from the 20-km operational version of the RUC on its native hybdrid coordinate surface and profiler data for eight 3-h initial times (00-, 03, …21 UTC) were extracted from FSL's data archive. Forecasts for 1-, 3-, 6-, and 12-h projections were obtained for 15 June - 31 August 2003. These dates were chosen because we also had data from five Kansas tall tower locations measuring winds at 50-, 80-, and 110-m for the same period supplied to us by the National Renewable Energy laboratory (NREL). This paper only presents the profiler results; if time permits we will show results of our verification at the Kansas sites at the conference.

Forecasts were interpolated both horizontally and vertically to eleven profiler locations (Table 1) and gate heights ranging from 500 m to 4000 m that have surface wind observations. Ten-m wind observations extracted from RUC surface files were used to match surface observations from the profilers. This enabled us to compute a 0 – 4 km shear and evaluate its accuracy. We realize that our choice of shear is somewhat arbitrary, but there is practical validity to computing a surface-based shear. Forecasters at NOAA's Storm Prediction Center (SPC) pay close attention to the 0 - 4 km shear when evaluating storm potential (Thompson et al 2003). In addition, we use the profiler observations (available hourly) to compare the forecasts to persistence for each forecast projection. Although FSL quality controls the profiler data, we performed an additional check to the profiler data. If any vector shear magnitude > 15 m $s^{-1}$ exists between adjoining 500-m profiler gate heights, both were removed and made unavailable to the vertical interpolation scheme. In some cases, our additional checking resulted in the profiler surface observation being flagged as bad and unavailable to be included in the verification.

## 3. RESULTS

Table 2 shows the wind speed bias (forecast – observed) and average vector error for 3-h forecasts at each profiler site averaged over all eight times of day. Results are presented for the surface), 4 km, and 0 - 4 km shear for both RUC (R0, R4km, and Rshr) and persistence (P0, P4km, and Pshr) forecasts. Only cases where the observed 0 – 4 km profile speed shear is > 5 m $s^{-1}$ are included. The sample sizes are different for each station because of the availability of surface data at the profiler sites, effects of quality control, and the occurrence of speed shear > 5 m $s^{1}$. Immediately evident is the apparent over and under forecasting for RUC forecasts at the surface and 4 km, respectively, resulting in an under forecasting of the 0 - 4 km speed shear. Our surface results agree almost exactly with those in the Thompson et al. 2003 study. However, our results at 4 km are different than those found by Thompson et al. (2003). In their rawinsonde verification of RUC derived soundings, a positive bias was reported up to 400 hPa. Their results might be different than what is found here because their sample includes derived soundings outside of the area that contains the eleven stations used in this study. In addition, they verification was against twice a day only soundings.

Persistence, on average, is more accurate than the RUC 3-h forecasts at the surface and for the shear. However, there are issues that we discuss later with comparing surface data to model data that might partially explain why the RUC loses to persistence at 3-h. Nevertheless, RUC 3-h forecasts are often better than persistence at 4 km. There is less of a difference between persistence and the RUC for the vector error indicating that the RUC directional component is closer (or better) than persistence.

Of more interest to forecasters are cases when there is a large directional shear component to the overall vector shear. Table 3 shows the same results for cases where the vector shear is > 1.5 times the speed shear. Sample sizes are small, and results should be viewed with caution. However, the difference between this table and the larger sample found in Table 2 indicates that although both RUC and persistence errors increased somewhat, persistence error increased more than the RUC error for the highly sheared cases. This indicates that the accuracy of the RUC forecasts is about the same in the highly sheared cases and that there are individual cases (e.g. frontal passages, trough passages, etc) where even very short-range (1-3 h) forecasts beat persistence. Generalized statistics often shroud the more interesting active weather days.

Figures 1a-b show the diurnal variability of the bias and vector error at Purcell, OK. The surface and shear speed bias maximizes at night with a secondary maxima in the late afternoon. Figures 2a-b show the biases and vector error for DeQueen, AR. The errors for both persistence and RUC forecasts are considerably less here than at Purcell. At DeQueen, the negative shear bias is more a result of the under forecasting of wind speeds aloft than the over forecasting found at the surface. At Purcell, the under forecasting of the speed shear is mostly due to the over forecasting of the surface wind speeds. The average vector error of the shear maximizes at about 0900 UTC at Purcell and varies very little at DeQueen.

Figures 3a-b and 4a-b show the distribution of the biases and vector errors by forecast projection for Haskell, OK and Vici, OK respectively. At about the 6-h forecast projection, the RUC forecasts at 4 km and for the shear become more accurate than persistence. Most interestingly, the 3-h surface bias at Vici is larger than forecasts of larger projection. Moreover, the RUC forecast accuracy deteriorates only slightly for forecasts out to 12-h. The same tendency of forecast accuracy decreasing only slightly with forecast projection is also evident at Haskell, OK (Fig. 4). The tendency for forecasts of longer duration to have similar skill was observed at all the stations (not shown) and was mentioned by Schwartz and Benjamin (2001).

## 4. DISCUSSION

Using NOAA network profilers to sample the low-level jet is somewhat problematic. On average, the height of the low-level jet lies between the surface and the first gate (500 m) sampled by the profilers. From a forecaster point of view, there is validity to computing a surface based shear profile in evaluating severe convection potential. In choosing the surface as a starting point, we realize we are under sampling the low-level jet at the expense of evaluating a more operationally relevant parameter for severe weather.

The results presented in this paper indicate that the RUC under forecasts the magnitude of the 0 – 4 km speed shear. However, forecasts appear to be just as accurate for events characterized by large directional shear (Table 3) as for all events combined (Table 2). The under forecasting of the 0 - 4 km speed shear at most profiler locations is almost directly related to the over forecasting of surface wind speeds. This might be at least partially explained by the warm RUC 2-m temperature bias that is most evident particularly at night (Benjamin et al. 2004, this preprint volume; also see Fig. 5). Corrections to the Planetary Boundary Layer (PBL) scheme used in the RUC are being made and are scheduled for implementation soon.

Using surface observations in verification raises interesting questions. For example, how representative of the storm environment is a single surface observation? How reliable are the surface observations taken at the profiler sites? Verification of model surface forecasts has always been difficult to perform because of very localized effects captured by the observations themselves that are not yet represented by the models. Without localized post processing of model surface forecasts (e.g. the Model Output Statistics [MOS] approach), it is unrealistic to expect short-range (1 - 3 h) model surface forecasts to compete with persistence of observations.

Therefore, forecasters that use the RUC to evaluate storm-shear environments, particularly those that are surface or near-surfaced based, should keep in mind the limitations associated with using surface data from any model. Obviously, the advantage of using the model forecasts is that it produces a forecast everywhere, not just at locations with observations. With improvements in the PBL scheme, we hope to correct a large portion of the surface wind speed bias to make the RUC surface forecasts more realistic.

## 4. REFERENCES

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*Table 1. NOAA network profiler data with surface data.*

| wmo | staion name | lat | lon | elv(m) |
|---|---|---|---|---|
| 74649 | Purcell, OK | 34.97 | -97.51 | 330 |
| 74630 | Vici, OK | 36.07 | -99.21 | 647 |
| 74647 | Lamont, OK | 36.69 | -97.48 | 306 |
| 74648 | Haskell, OK | 35.68 | -95.86 | 218 |
| 74541 | Haviland, KS | 37.65 | -99.11 | 647 |
| 74546 | Hillsboro, KS | 38.30 | -97.29 | 446 |
| 74752 | DeQueen, AR | 34.11 | -94.29 | 195 |
| 74735 | Jayton, TX | 33.01 | -100.98 | 707 |
| 74731 | Tucumcari, NM | 35.08 | -103.60 | 1240 |
| 74530 | Granada, CO | 37.77 | -102.17 | 1155 |
| 74629 | White Sands, NM | 32.40 | -106.34 | 1224 |

*Table 2: 3-h RUC forecasts (R) and persistence (P) wind speed bias (forecast - observed) and vector error ($ms^{-1}$) at the surface (0), 4000m(4km), and the 0-4 km shear (shr) for profiler sites during the 15 June – 31 August 2003 period. Observations eight times a day where observed speed shear > 5 $ms^{-1}$ are included.*

| | | | bias error | | | | |
|---|---|---|---|---|---|---|---|
| sta | R0 | P0 | R4km | P4km | Rshr | Pshr | num |
| 74649 | 1.88 | 0.09 | -0.62 | -0.48 | -2.50 | -0.57 | 272 |
| 74630 | 0.85 | 0.18 | -0.74 | -0.57 | -1.59 | -0.75 | 214 |
| 74647 | 0.68 | 0.11 | -0.43 | -0.50 | -1.11 | -0.62 | 225 |
| 74648 | 0.48 | 0.26 | -0.39 | -0.46 | -0.87 | -0.71 | 192 |
| 74541 | 1.32 | 0.31 | -0.64 | -0.58 | -1.96 | -0.90 | 181 |
| 74546 | 1.39 | 0.09 | -0.24 | -0.07 | -1.63 | -0.15 | 205 |
| 74752 | 0.42 | 0.03 | -1.00 | -0.52 | -1.42 | -0.55 | 218 |
| 74735 | 1.05 | 0.18 | -0.63 | -0.72 | -1.67 | -0.90 | 173 |
| 74731 | 1.38 | 0.25 | -1.04 | -1.07 | -2.42 | -1.31 | 189 |
| 74530 | 0.14 | 0.37 | -0.81 | -0.59 | -0.95 | -0.96 | 140 |
| 74629 | 1.13 | 0.38 | -0.42 | -0.69 | -1.55 | -1.06 | 218 |
| | | | vector error | | | | |
| 74649 | 2.31 | 1.10 | 3.00 | 3.60 | 2.22 | 2.19 | 272 |
| 74630 | 2.19 | 2.20 | 3.44 | 3.69 | 2.35 | 2.54 | 214 |
| 74647 | 2.05 | 2.06 | 3.09 | 3.90 | 2.31 | 2.45 | 225 |
| 74648 | 2.16 | 2.10 | 3.09 | 4.11 | 2.33 | 2.44 | 192 |
| 74541 | 2.31 | 2.03 | 3.35 | 3.57 | 2.37 | 2.33 | 181 |
| 74546 | 2.26 | 1.81 | 3.69 | 3.97 | 2.54 | 2.42 | 205 |
| 74752 | 1.35 | 1.08 | 3.49 | 3.90 | 2.18 | 2.35 | 218 |
| 74735 | 2.24 | 1.90 | 4.17 | 4.09 | 2.94 | 2.67 | 173 |
| 74731 | 2.38 | 2.23 | 3.99 | 4.09 | 2.77 | 2.68 | 189 |
| 74530 | 2.70 | 3.13 | 4.27 | 4.15 | 2.85 | 3.19 | 140 |
| 74629 | 2.89 | 2.36 | 3.72 | 3.62 | 2.87 | 2.58 | 218 |

*Table 3. Same as Table 2 except, for cases with large directional shear (observed speed shear > 5 ms$^{-1}$ and vector shear > 1.5 X speed shear).*

| sta | R0 | P0 | R4km | P4km | Rshr | Pshr | num |
|---|---|---|---|---|---|---|---|
| bias error | | | | | | | |
| 74649 | 1.54 | -0.68 | -0.68 | -0.39 | -2.24 | 0.28 | 34 |
| 74630 | 0.79 | -0.09 | -0.70 | -0.68 | -1.48 | -0.60 | 103 |
| 74647 | 0.23 | -0.42 | -0.99 | -0.29 | -1.22 | 0.13 | 69 |
| 74648 | -0.18 | 0.16 | -0.73 | -1.06 | -0.54 | -1.21 | 42 |
| 74541 | 1.02 | -0.03 | -0.87 | -0.40 | -1.89 | -0.37 | 60 |
| 74546 | 0.86 | -0.53 | -0.10 | 0.42 | -0.95 | 0.95 | 48 |
| 74752 | -0.26 | -0.59 | -1.52 | 0.50 | -1.27 | 1.09 | 9 |
| 74735 | 0.74 | -0.26 | -0.63 | -0.77 | -1.36 | -0.50 | 46 |
| 74731 | 0.84 | -0.32 | -0.87 | -1.19 | -1.72 | -0.88 | 55 |
| 74530 | -0.27 | 0.23 | -0.67 | -0.71 | -0.40 | -0.94 | 84 |
| 74629 | 1.50 | -0.30 | 0.12 | -0.08 | -1.40 | 0.21 | 43 |
| vector error | | | | | | | |
| 74649 | 2.51 | 1.65 | 3.24 | 4.07 | 2.39 | 2.66 | 34 |
| 74630 | 2.31 | 2.41 | 3.44 | 3.68 | 2.37 | 2.57 | 103 |
| 74647 | 2.45 | 2.73 | 3.56 | 4.59 | 2.91 | 2.93 | 69 |
| 74648 | 3.02 | 3.44 | 3.05 | 4.70 | 2.44 | 2.53 | 42 |
| 74541 | 2.36 | 2.15 | 3.30 | 3.42 | 2.63 | 2.37 | 60 |
| 74546 | 2.55 | 2.59 | 4.04 | 4.58 | 2.83 | 2.60 | 48 |
| 74752 | 1.83 | 1.57 | 4.07 | 3.29 | 2.01 | 2.00 | 9 |
| 74735 | 2.69 | 2.39 | 4.75 | 4.37 | 3.11 | 2.98 | 46 |
| 74731 | 2.20 | 2.51 | 4.19 | 3.87 | 2.99 | 2.69 | 55 |
| 74530 | 2.56 | 3.19 | 4.01 | 4.37 | 2.72 | 3.14 | 84 |
| 74629 | 3.24 | 2.66 | 3.81 | 3.50 | 2.60 | 2.64 | 43 |

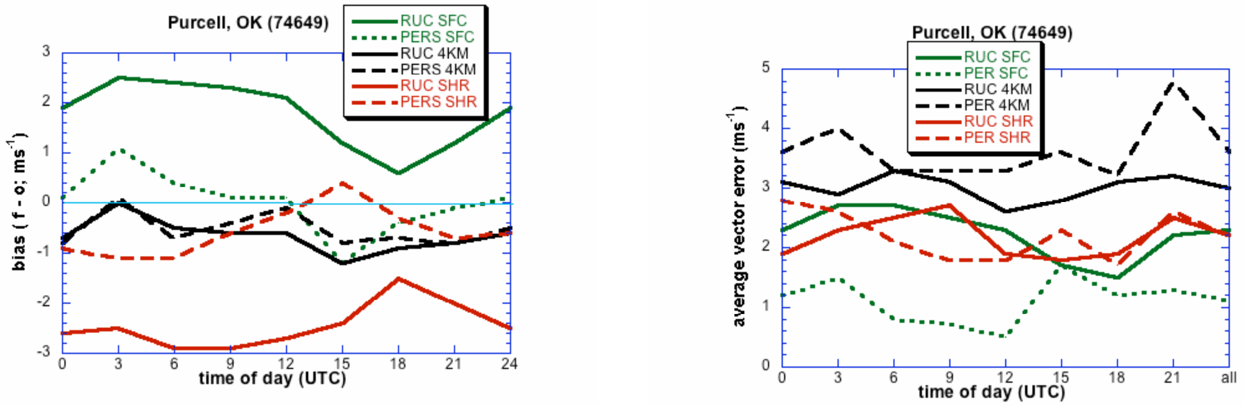

Fig 1. 3-h RUC and persistence forecast bias (a; forecast – observed); m s$^{-1}$) and average vector error (b; m s$^{-1}$ ) averaged over the 15 June – 31 August 2003 period. Results shown for the surface (SFC), 4 km (4km), and sfc – 4 km shear (shr) by time of day for Purcell, OK.

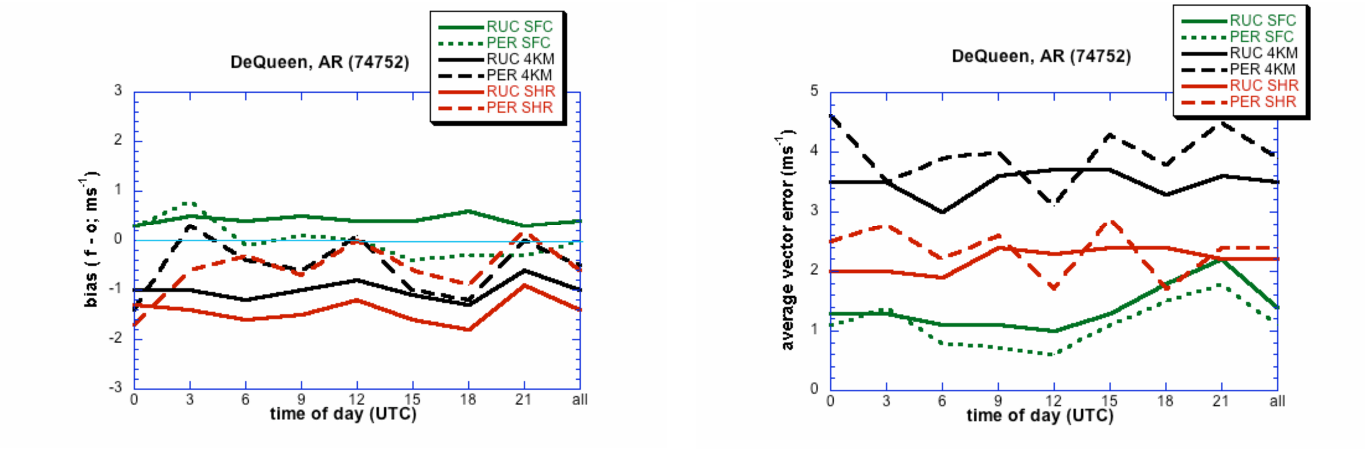

Fig. 2 Same as Fig. 1 except for DeQueen, AR.

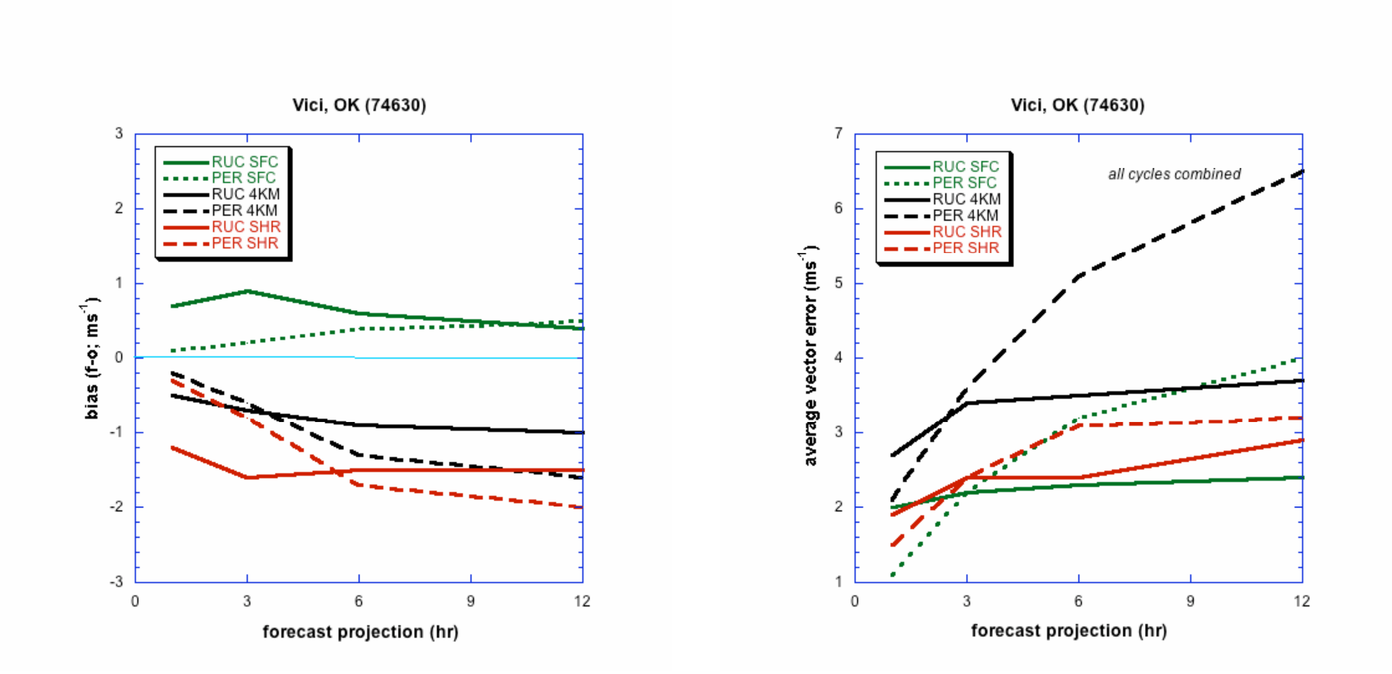

Fig. 3. Same as Fig. 1 except for distribution of forecast errors by 1-, 3-, 6-, and 12-h forecast projections for Vici, OK.

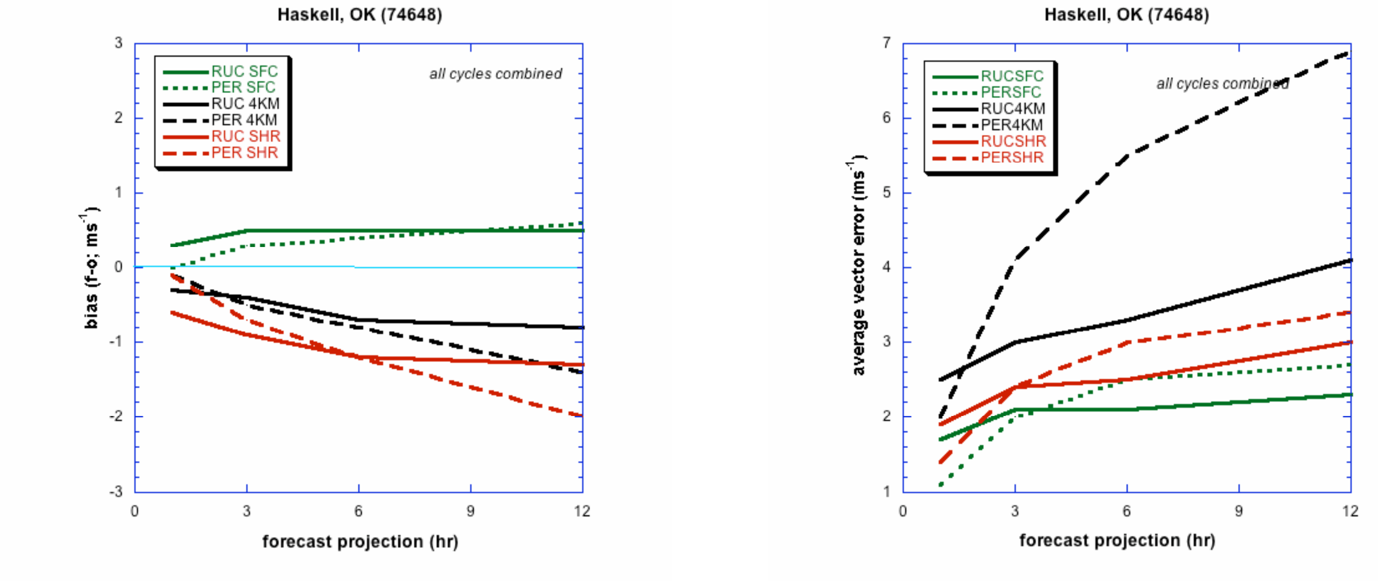

Fig. 4 Same as Fig. 3 except for Haskell, OK.

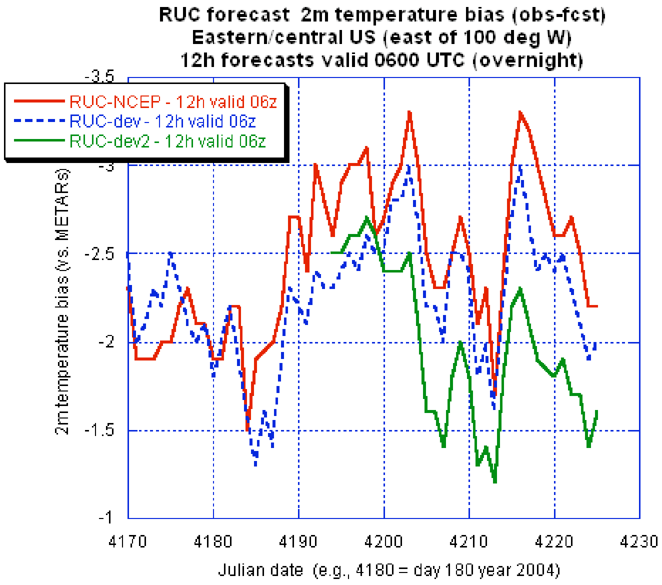

Fig. 5 Comparison of operational (NCEP RUC) and developmental versions (RUC dev and RUC dev2) 2-m temperature forecasts.