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EVALUATION OF ETA MODEL FORECASTS AS A BACKUP WEATHER SOURCE FOR CTAS*

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ABSTRACT

Knowledge of present and future winds and temperature is important for air traffic operations in general, but is crucial for Decision Support Tools (DSTs) that rely heavily on accurately predicting trajectories of aircraft. One such tool is the Center-TRACON Automation System (CTAS) developed by NASA Ames Research Center.

The Rapid Update Cycle (RUC) system is presently the principal source of weather information for CTAS.[1,2] RUC provides weather updates on an hourly basis on a nationwide grid with horizontal resolution of 40 km and vertical resolution of 25 mb in pressure.[3] However, a recent study of RUC data availability showed that the NWS and NOAA servers are subject to frequent service interruptions. Over a 210 day period (4/19/00-11/11/00), the availability of two NOAA and one NWS RUC server was monitored automatically. It was found that 60 days (29%) had periods of one hour or more where at least one server was out, with the longest outage lasting 13 hours on 9/21/00. In addition, there were 9 days (4%) for which all three servers were simultaneously unavailable, with the longest outage lasting 6 hours on 5/7/00. Moreover, even longer outages have been experienced with the RUC servers over the past several years.

RUC forecasts are provided for up to 12 hours, but these are not currently used in CTAS as back up sources (except that the 1 or 2 hour forecasts are used for the current winds to compensate for transmission delays in obtaining the RUC data). Since RUC outages have been experienced for longer than 12 hours, it is therefore necessary to back RUC up with another weather source providing long-range forecasts.

This paper examines the use of the Eta model forecasts as a back-up weather source for CTAS. A specific output of the Eta 32 km model, namely Grid 104, was selected for evaluation because its horizontal and vertical resolution, spatial extent and output parameters match most closely those of RUC.[4] While RUC forecasts for a maximum of 12 hours into the future, Eta does so for up to 60 hours. In the event that a RUC outage would occur, Eta data could be substituted. If Eta data also became unavailable, the last issued forecasts could allow CTAS to continue to function properly for up to 60 hours.

The approach used for evaluating the suitability of the Eta model and RUC forecasts was to compare them with the RUC analysis output or 0 hour forecast file, at the forecast time. Not surprisingly, it was found that the RUC model forecasts had lower wind magnitude errors out to 12 hours (the limit of the RUC forecasts) than the Eta model had. However, the wind magnitude error for the Eta model grew only from 9 ft/s at 12 hours (comparable with RUC) to 11 ft/s at 48 hours. We therefore conclude that RUC forecasts should be used for outages up to 12 hours and Eta model forecasts should be used for outages up to 60 hours.

METHODOLOGY

The comparison of RUC and Eta data was done for a typical ARTCC (Air Route Traffic Control Center), in this case the DFW Center (ZFW) airspace. In the vertical dimension, three altitude layers were examined: 7,500', 18,400' and 30,000'. The time period over which the comparison was made was a period of ten days, starting 9 June 2000.

Since the RUC and Eta model data is provided on different projection systems (Lambert Conformal vs. Polar Stereographic) and on different grids, the Eta data was first transformed onto the RUC grid using the following procedure.[5] Each RUC grid point was transformed into the Eta grid system and the surrounding Eta grid points determined. A linear interpolation was then done using the Eta weather products at the eight corners of the cube surrounding the RUC grid point. The resulting interpolated Eta model value was then used for the corresponding RUC grid point.

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Once the data were on the same grid, metrics were adopted for comparing weather data. For temperature, the metric was simply the scalar difference between the RUC analysis temperature and the RUC or Eta model forecast temperature. For winds, there are two possible metrics: vector difference and magnitude/direction difference as illustrated in Figure 1.

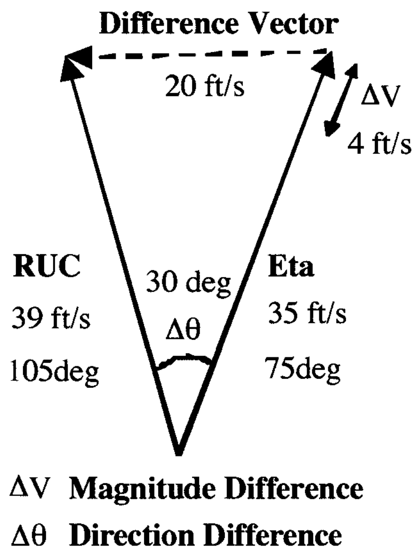

Figure 1. Metrics for comparing wind vectors.

The vector difference (shown by the dashed line in Figure 1) is often used as a wind error metric. However, this metric provides limited insight, since the orientation of the error vector varies greatly and the magnitude of the error vector is strongly influenced by the difference in direction between the two original vectors to be compared. For this study we chose the magnitude/direction metric ($\Delta V, \Delta\Theta$) as being more physically meaningful.

Finally, a selection must be made of the weather files to be compared. RUC outputs a set of forecasts on an hourly cycle, while Eta outputs a set of forecasts on a six hour cycle and while the longest RUC forecast is 12 hours, Eta forecasts as far as 60 hours into the future. Figure 2 shows the RUC and Eta cycles and the set of files generated at each update. The first file in each set is called the "analysis file" (abbreviated anl or r0 if for RUC and e0 if for Eta). This file represents the best knowledge of the weather at the analysis time after all the new measurements gathered during the previous cycle have been incorporated. The files following that are forecasts: a six-hour RUC forecast would be labeled r06 or simply r6 for RUC and e6 for Eta. A comparison between the RUC analysis file and an Eta 18-hour forecast would then be denoted by r0/e18 etc.

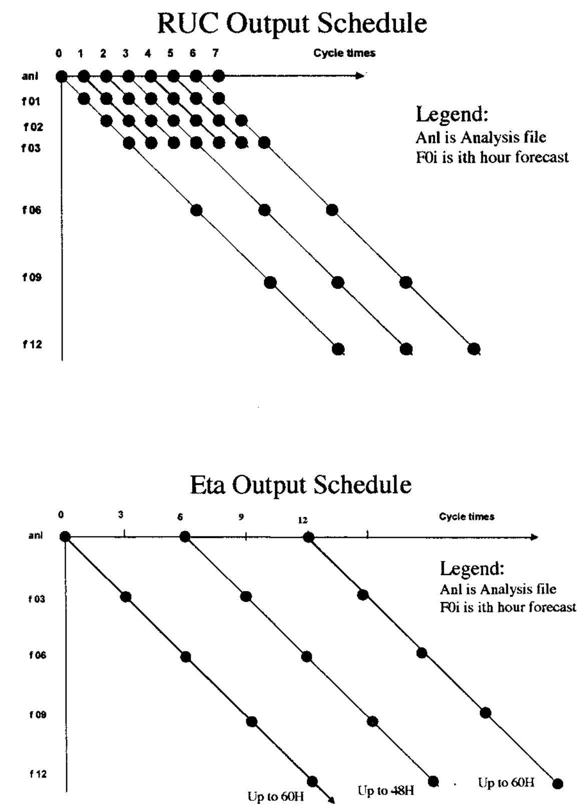

Figure 2. RUC and Eta model output schedules.

The comparisons that were made are first between the RUC and Eta analysis files, denoted r0/e0, for all sets output at the times corresponding to the Eta cycles (i.e. every 6 hours) for a period of 10 days. The 40 comparisons thus made were statistically analyzed separately and then combined for a global result in the end. Similarly, comparisons between RUC forecasts and a reference weather file, and Eta forecasts and the same reference file were made for the same 40 cycle times separately first and then the results were combined for a global result. The reference files were chosen to be the RUC analysis files that were generated at the time to which the forecasts were projected, i.e. a 12-hour forecast was compared with the r0 file generated 12 hours later. Although this seems to disadvantage Eta in a data quality comparison, it seemed justified by the fact that Eta is only a backup system to RUC and that RUC is the system normally in use. Finding an independent weather source (such as MDCRS readings etc) other than RUC or Eta to play the role of ground truth could be done but was beyond the scope of this study.

RESULTS

Figure 3 presents the results for the r0/e0, so-called "direct" data comparison. The x-axis is the index to the 40 Eta cycle updates and therefore the number of independent comparisons. The windows represent the results for comparison of temperature, wind strength and wind direction, averaged over the ZFW area and over the three selected altitudes.

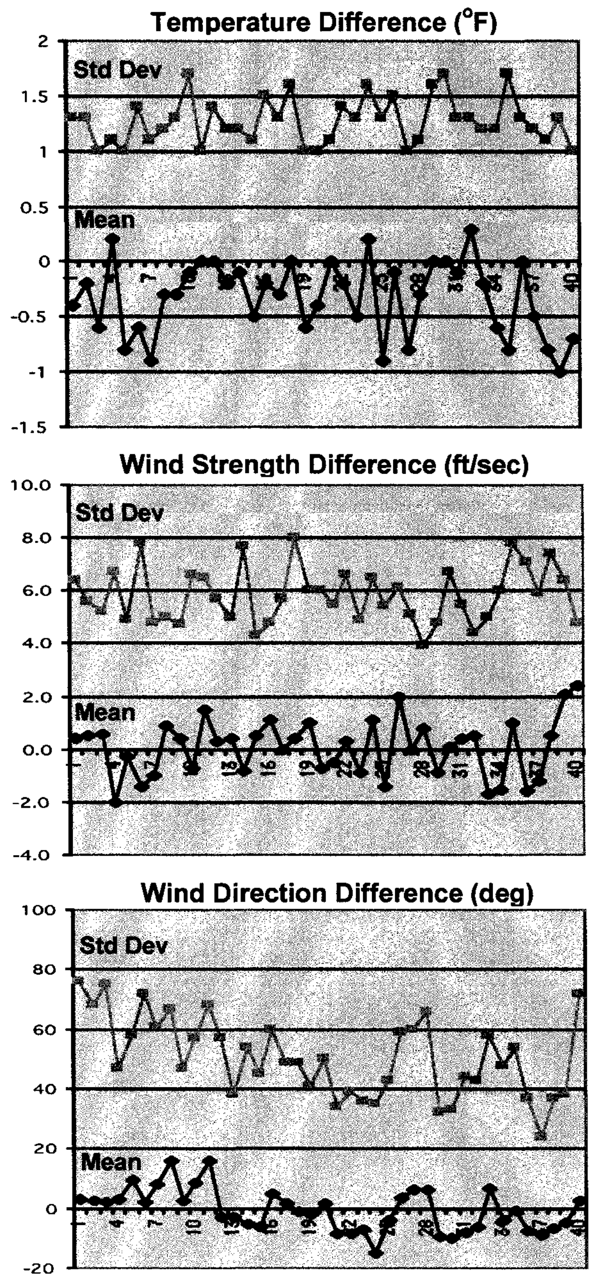

Figure 3. Direct RUC vs. Eta model comparison of temperature, wind strength and wind direction for 40 hourly updates (analysis cycles).

In order to better visualize what these results summarize we show in Figure 4 an overlay of the RUC and Eta wind fields at the altitude of 30,000ft (300mbar). One observes immediately that both systems present the same weather pattern, and that the wind strengths match well, but that there is a very discernible difference in wind direction. This seems to hold true for all comparisons made, whether among analysis files or forecasts. Wind strength varied from 5 ft/s in some parts to 45 ft/s in other parts, yet the average differences, returning to Figure 3, hover around zero, with a StD (standard deviation) of around 6ft/s for wind strength difference and a StD of about 1.25 degrees F in temperature difference. This seems to indicate that the differences between the RUC or Eta analysis files are small and that we are justified in taking either one (we choose RUC) as our reference when evaluating the RUC and Eta forecasts.

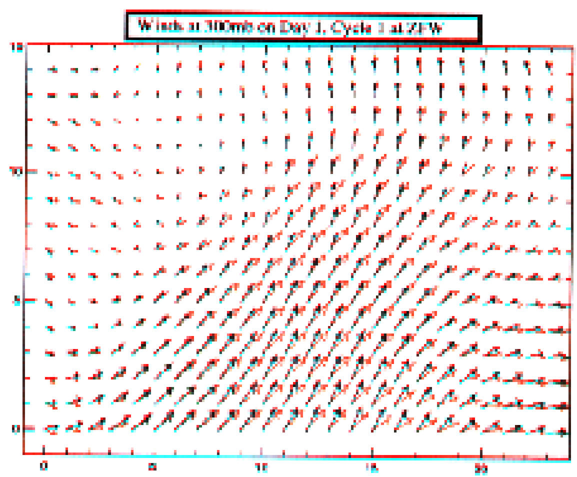

Figure 4. Overlay of RUC and Eta wind vectors.

The next comparisons are between RUC forecasts and the RUC analysis data, generated at the time to which is forecasted; and similarly between Eta forecasts and RUC analysis weather that materialized later at the appropriate time.

Figure 5 shows the results for the 12hour forecasts of the temperature: one curve for r0/r12 and another for r0/e12, with as x-axis the 40 Eta update times. In the first window we show the mean difference and in the second the StD of the temperature difference. In Figures 6 and 7 we show similar results for the wind strength and wind direction differences. A close look reveals that peaks and valleys in both curves match quite closely. This means that there were weather changes not predicted by either system, and that they erred in the similar ways.

Figure 8 shows means and StD for the comparison r0/e48, for the 48hour Eta forecast (no curve for RUC can be shown since RUC only forecasts for up to 12 hours).

Figures 9,10 and 11 summarize all these results averaged over all 40 updates. These new figures contain the mean and StD of differences r0/ri for 1,2,3,6 and 12 hours and r0/ej for 0,6,12,18...48 hours for the parameters temperature, wind strength and wind direction.

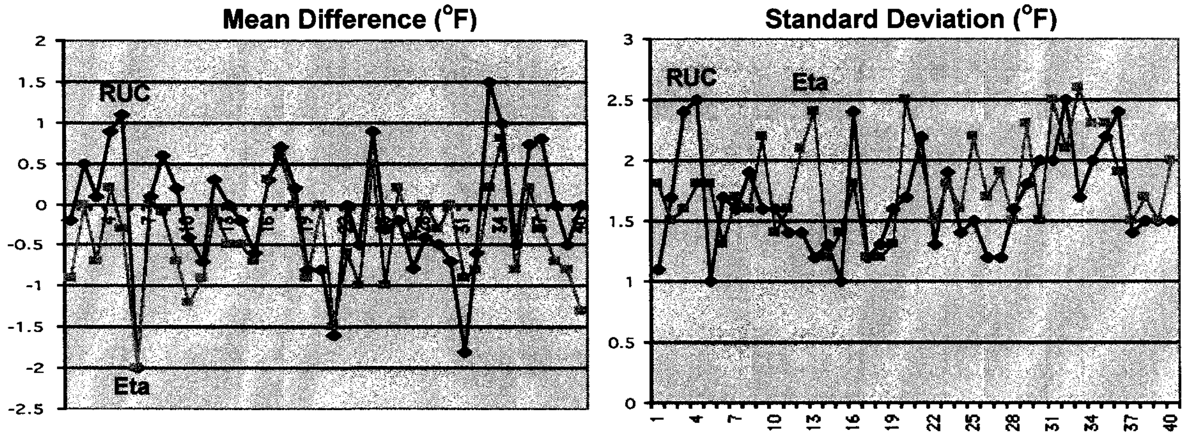

Figure 5: Comparison of 12-hour temperature predictions for RUC and Eta forecasts vs. RUC analysis data for 40 analysis cycles.

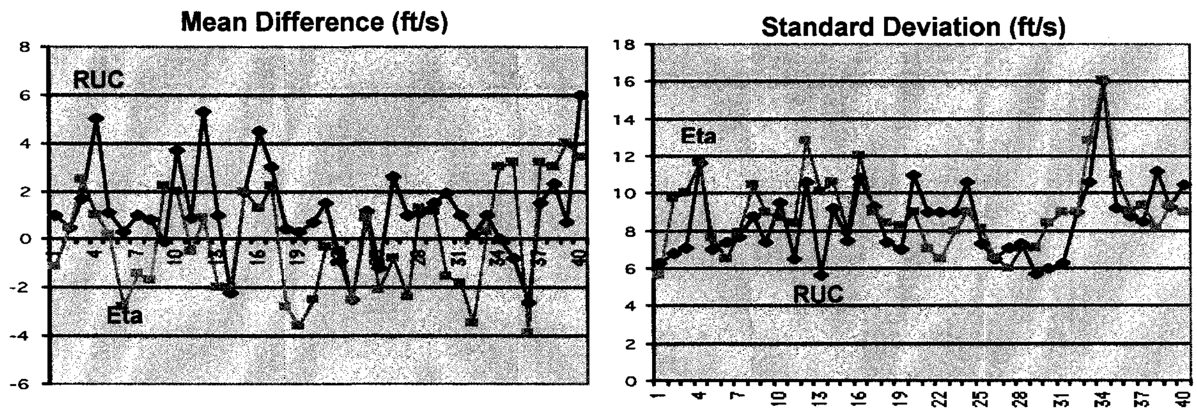

Figure 6: Comparison of 12-hour wind strength predictions for RUC and Eta forecasts vs. RUC analysis data for 40 analysis cycles.

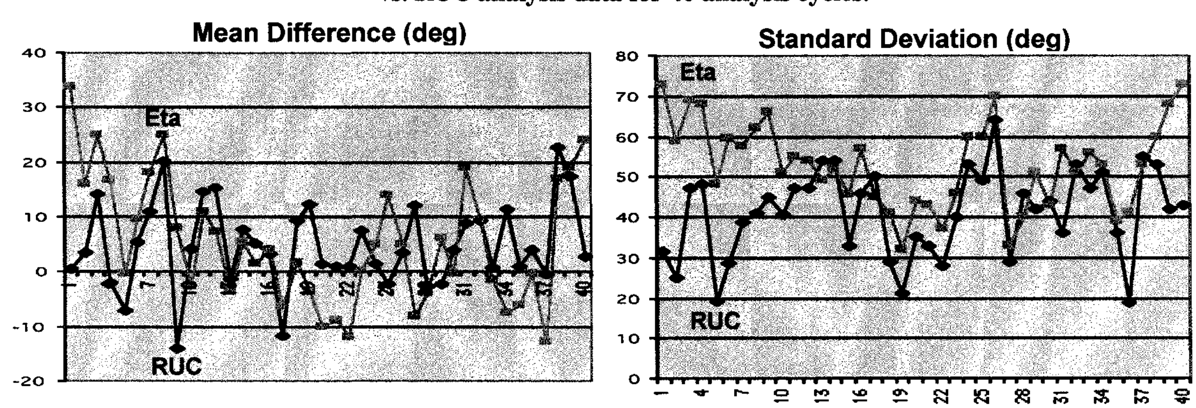

Figure 7: Comparison of 12-hour wind direction predictions for RUC and Eta forecasts vs. RUC analysis data for 40 analysis cycles.

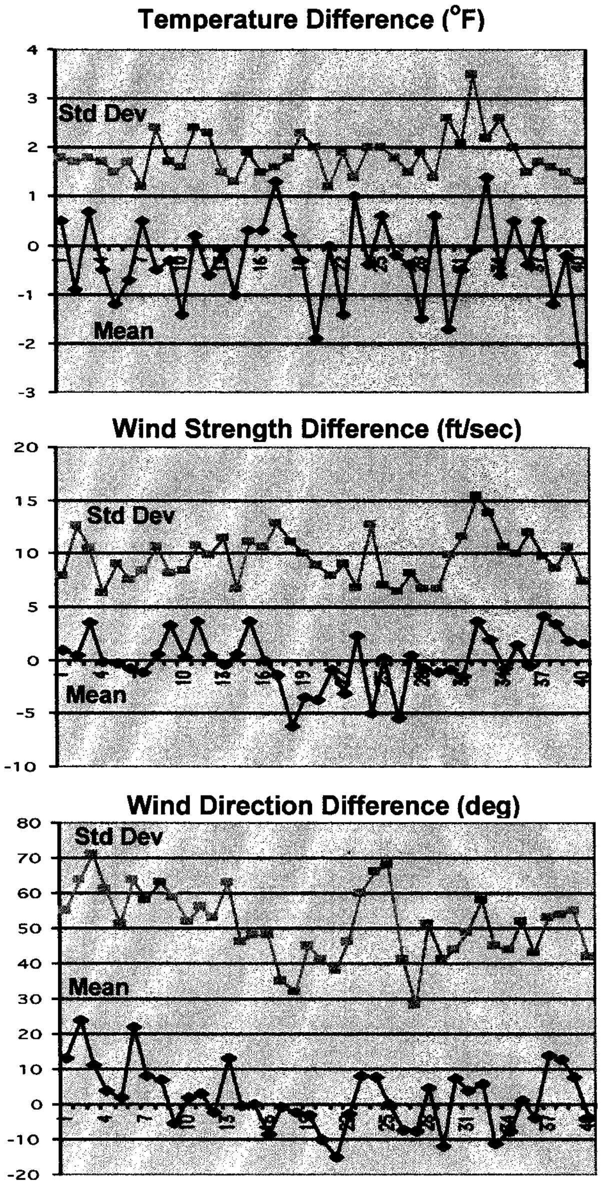

Figure 8: Evaluation of Data Quality of the 48-Hour Eta Forecasts

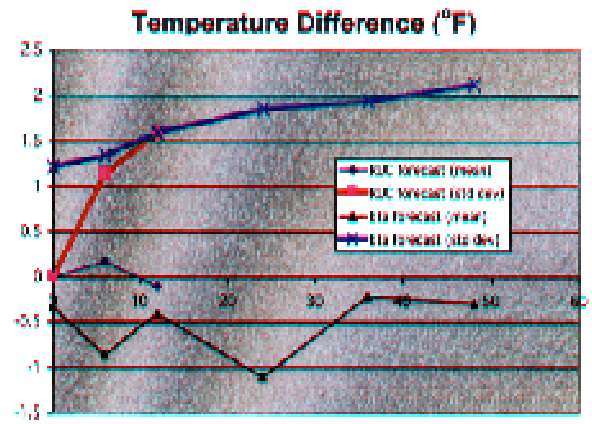

Figure 9: Summary of temperature differences for RUC and Eta forecasts vs. RUC analysis (°F).

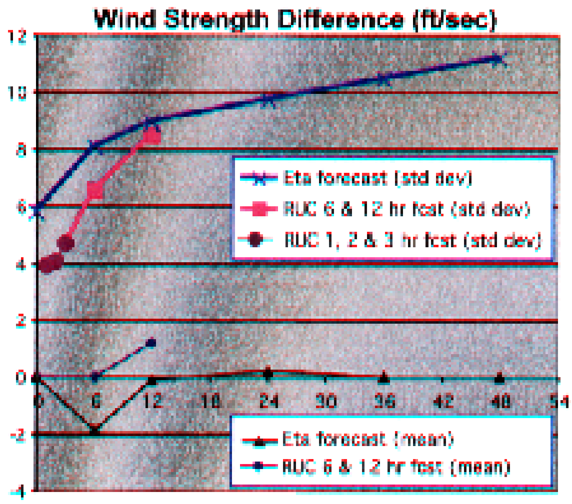

Figure 10: Summary of wind strength differences for RUC and Eta forecasts vs. RUC analysis (ft/s).

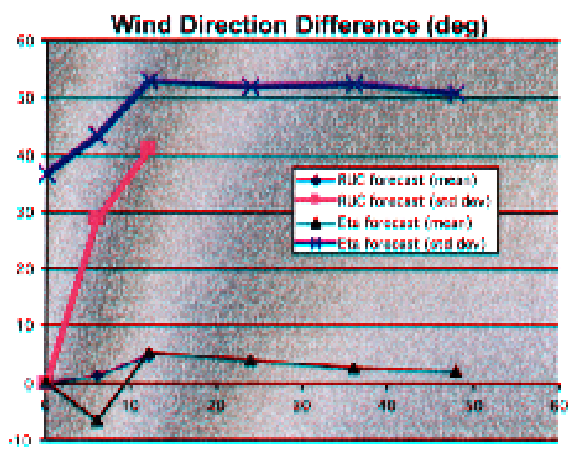

Figure 11. Summary of wind direction differences for RUC and Eta forecasts vs. RUC analysis (deg)

We observe that, based on the StD, one could state that RUC forecasts are marginally better than the comparable Eta forecasts for the same duration into the future up to 12 hours, at which point they are the same. But one can also see that 6 hour Eta forecasts are as good or better than 12hour RUC forecasts. The Eta forecasts maintain almost the same relative quality up to the maximum duration of 48hours tested (and by extension to the 60-hour duration available from Eta). Observe that the StD of temperature differences stays below 2 degree Fahrenheit for forecasts up to 48 hours, and StD of wind strength differences stay below 11ft/s (6.5knots) for even the maximum duration forecasts. The wind direction difference, although with mean about zero, has a StD of a steady 50 degrees. These and some more detailed observations form the basis for the proposed switching protocol when either RUC alone or both RUC and Eta data become unavailable

CONCLUSIONS

The purpose of this study was to verify the quality of the Eta forecasts and to propose a decision algorithm for switching from RUC to Eta in case of outages. First let us state that Eta forecast quality is not in doubt in view of the results presented in the previous paragraph. Next, the protocol for switching will be based on the presumed quality of the forecasts. For example, if access to both RUC and Eta is denied simultaneously, one should continue running CTAS with RUC forecasts as long as possible (from 9 to 12 hours, depending when in the RUC cycle the outage occurred). If RUC is interrupted, but not Eta, then one should switch at the next Eta update that would be at most 6 hours after the interrupt. There are some additional considerations: CTAS expects a new RUC weather file to be made available every hour. When interrupts occur it may be necessary to create hourly files by interpolating from two adjacent forecast files. This would be true for RUC after the third hour and is always true for Eta forecasts as is clear from Figure 2 showing the RUC and Eta output products. The complete algorithm depends on the exact time of start of the outage compared to the underlying RUC and Eta cycle time, but it is based on the presumed quality of RUC and Eta forecasts at any given time.

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