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TACKLING THE CHALLENGE OF NOWCASTING ELEVATED CONVECTION

Huaqing Cai*, Rita Roberts, Dan Megenhardt, Eric Nelson and Matthias Steiner

National Center for Atmospheric Research, Boulder, CO, 80307, USA

1. INTRODUCTION

Elevated thunderstorms are defined as a subset of thunderstorms which have their updraft roots based above the convective boundary layer. The most comprehensive studies to define, document and illustrate elevated thunderstorms in the United States were conducted by Colman (1990a and b). Elevated convection occurs most frequently during April and September and the majority (~ 60%) of elevated storms initiate at night. The importance of elevated convection becomes very clear in light of both numerical model simulations (Banacos et al. 2005) and observational studies (Wilson and Roberts 2006) coming to the same conclusion that elevated convection accounts for ~50% of all convective storms. However, both human forecasters and NWP models experience difficulties in successfully forecasting elevated convection. For example, the forecast skill scores for the Rapid Update Cycle (RUC) model exhibit a diurnal modulation with lowest scores during nighttime, which is an indication of poor forecast skills for elevated convection.

In view of the importance of elevated convection as well as the poor forecast skills by human forecasters and models for elevated convection, we have been exploring a new approach to forecasting elevated convection based on a conceptual understanding of the associated processes. The procedure builds upon a fuzzy logic technique using a variety of predictor fields based on both direct observations and derived fields from numerical weather prediction models. The fuzzy logic algorithm has been evaluated on a number of cases. Results so far are encouraging, which prompted us to initiate integration of the elevated convection into the NCAR Auto-Nowcast System (ANC) (Mueller et al. 2003) to complement its existing surface-based convection forecast capability.

2. METHODOLOGY

A through literature review was conducted regarding the mechanisms of elevated convection initiation (CI). A schematic depicting a typical elevated convection scenario north of a surface front is shown in Fig.1. The most favorable conditions for convection initiation in this scenario are found above the sloping frontal boundary where the LLJ (low level jet) impinges the frontal boundary. In contrast, near surface and north of surface front, the air is fairly stable. We aim to incorporate this conceptual model of elevated convection into the forecasting procedure taking advantage of all available datasets, from NWP model outputs to observations.

The technique we developed for forecasting elevated convection is similar to that used by the NCAR ANC. A block diagram illustrating the major components of the forecasting system is shown in Fig.2. A set of predictor fields has been identified based on a conceptual understanding of elevated convection. The predictor fields being evaluated here include: 1) 3D CAPE, 2) 3D CIN, 3) 3D convergence, 4) 3D frontal likelihood field, 5) averaged relative humidity, 6) vert sum interest, and 7) 200 mb divergence as proxy for Q vector convergence. Other fields such as cloud top cooling rate, theta-e advection, and total precipitable water vapor from GPS will be evaluated as well in the future. All predictor fields listed above are created using RUC forecasts. For details of the frontal likelihood and vert sum interest fields, the reader is referred to Mueller and Megenhardt (2003) and Trier et al. (2002).

The predictor fields are converted into likelihood interest fields using a membership function. For example, the membership function used for the 3D CAPE field is shown in Fig. 3. An example of the original CAPE field and its corresponding likelihood field at 1000 mb is shown in Fig. 4. After each predictor field is converted into a likelihood field, the combined likelihood field for elevated convection is obtained by summarizing each individual likelihood field according to its weight. Both the membership functions and the weights are tunable.

It should be pointed out that the original NCAR ANC was designed for forecasting surface-based convection. The ability to forecasting elevated convection will be a valuable addition to the current Auto-nowcast system, considering about half of convection is elevated in nature.

3. EXAMPLE CASE STUDIES

A typical elevated storm case, similar to the schematic shown in Fig.1, occurred on 23 September 2005 over the Illinois/Indiana region. A mesoscale convective system (MCS) developed ~ 150 km north of a surface cold front during nighttime (Fig. 5). The low level air north of front was stable with little CAPE and large CIN; while the air above the front at 825 mb showed modest CAPE and small CIN (Fig. 6), which is consistent with the conceptual model shown in Fig.1. The slope of the cold front can be clearly seen in Fig. 7, where high values of frontal-likelihood field indicate the position of the cold front.

The corresponding CAPE and CIN interest fields derived from predictor fields in Fig. 6 are shown in Fig.8. High interest values indicating high potential for elevated

* *Corresponding author address:* Huaqing Cai,
National Center for Atmospheric Research, Boulder, CO 80307; e-mail: caihq@ucar.edu

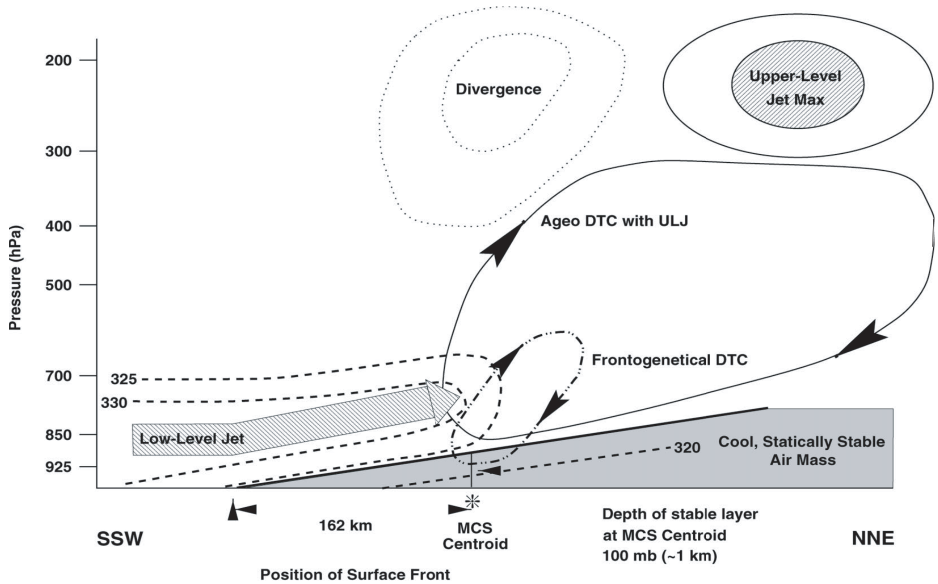

Fig. 1. Schematic cross-sectional view taken parallel to the LLJ across the frontal zone for a typical elevated convection scenario. Adapted from Moore et al. (2003).

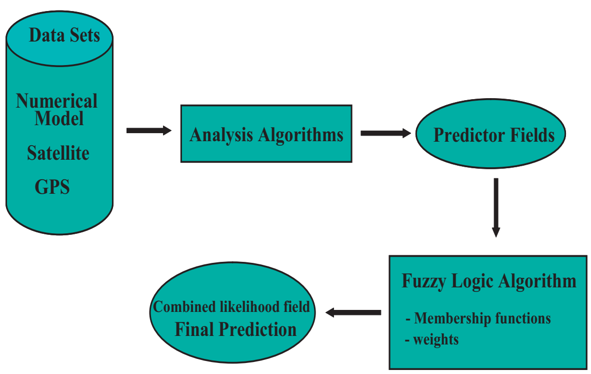

Fig. 2. Flow chart for the algorithm of forecasting elevated convection.

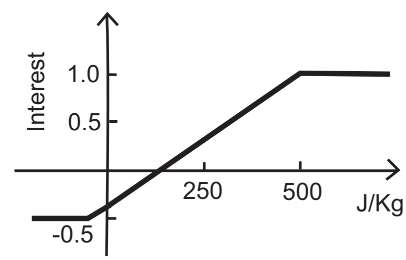

Fig. 3. Membership function for CAPE.

convection can be seen in the region where elevated storms developed 1-3 hr later (see Fig. 5b-d). The convergence interest field is shown in Fig. 9, which corroborates what Wilson and Roberts (2006) have found in their studies that most elevated storms were associated with convergence/ confluence signatures in RUC wind fields. The total interest field for elevated CI is shown in Fig. 10. The high interest values, which indicate high potential for elevated CI, correspond well with radar observations 1-3 hr later (see Fig. 5b-d).

More than 12 elevated convection cases from Illinois/ Indiana and Dallas region where NCAR ANC was running in 2006 were analyzed. Results similar to the case shown in this paper were obtained for typical elevated convection cases. However, performance may vary for other cases where the mechanism for elevated CI did not fit the simple conceptual model depicted by Fig. 1. More research is needed to identify the origin of convergence/confluence associated with elevated CI, ie., what mechanism produces the convergence that eventually trigger elevated CI?

4. SUMMARY AND FUTURE WORK

A fuzzy logic algorithm has been developed to forecast elevated convection based on conceptual understanding of the physical processes associated with it. Preliminary evaluations of the algorithm are promising and efforts are under way to implement the algorithm in the NCAR real time nowcasting system. Future research will focus on a better understanding of the mechanisms that trigger elevated convection.

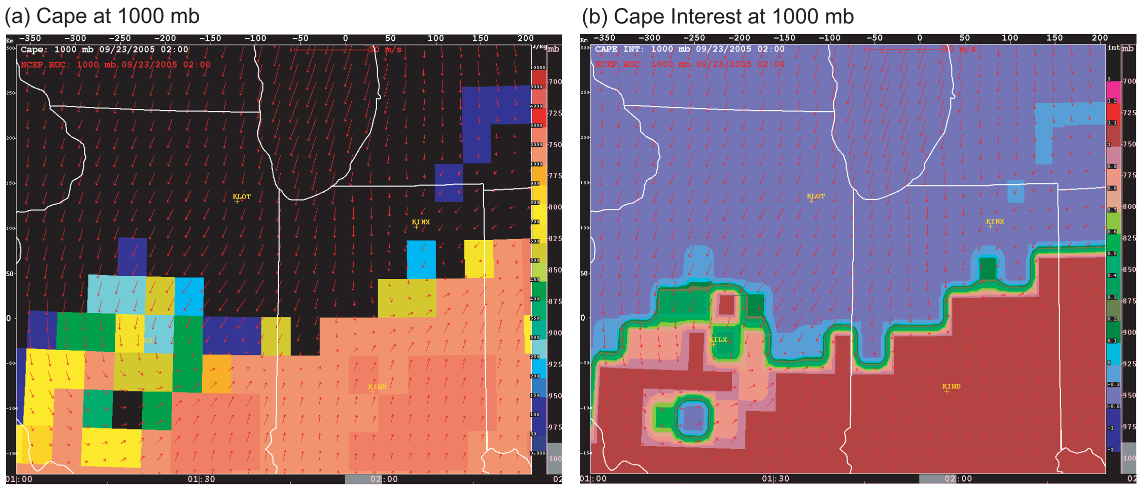

Fig. 4. An example of CAPE and its interest field at 1000 mb. RUC winds are shown as red arrows.

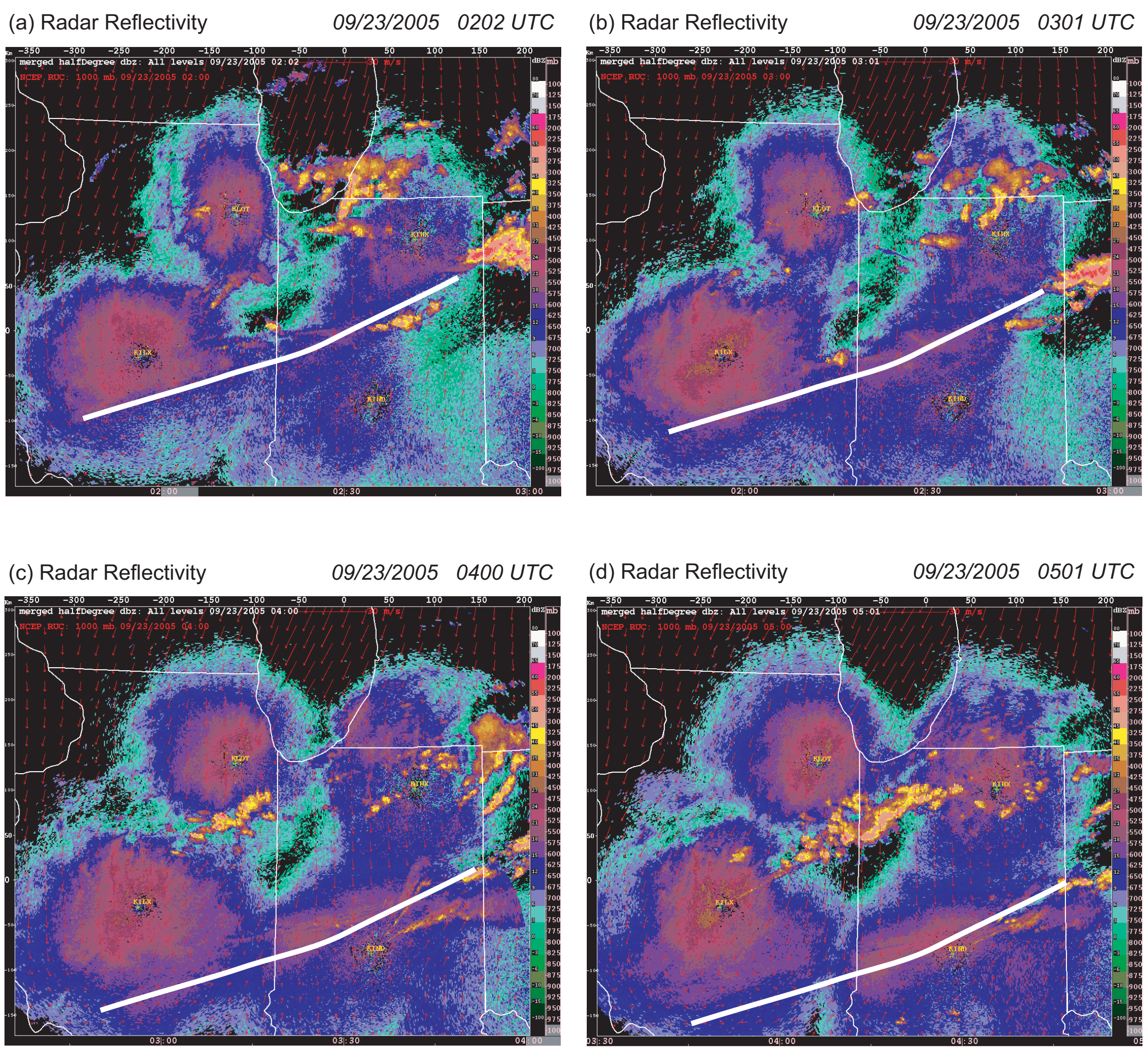

Fig. 5. Radar reflectivity showing a typical case of elevated convection north of a surface cold front on 23 September 2005. The thick white line represents the location of the cold front. RUC winds are shown as red arrows.

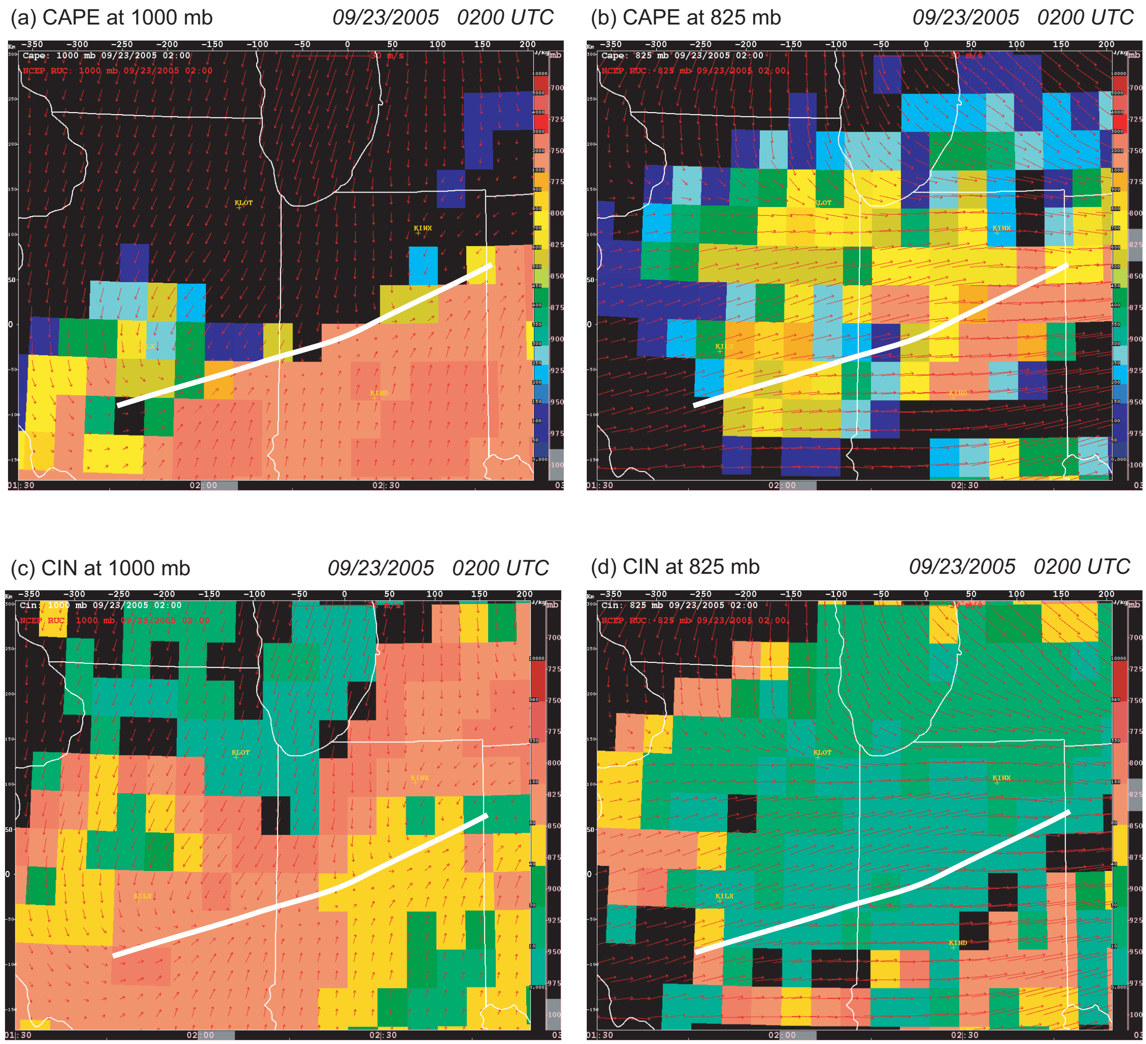

Fig. 6. CAPE and CIN fields at 1000 and 825 mb at 0200 UTC on 23 September 2005 (corresponding to Fig. 5a). The surface cold front is represented by the thick white line. RUC winds are shown as red arrows.

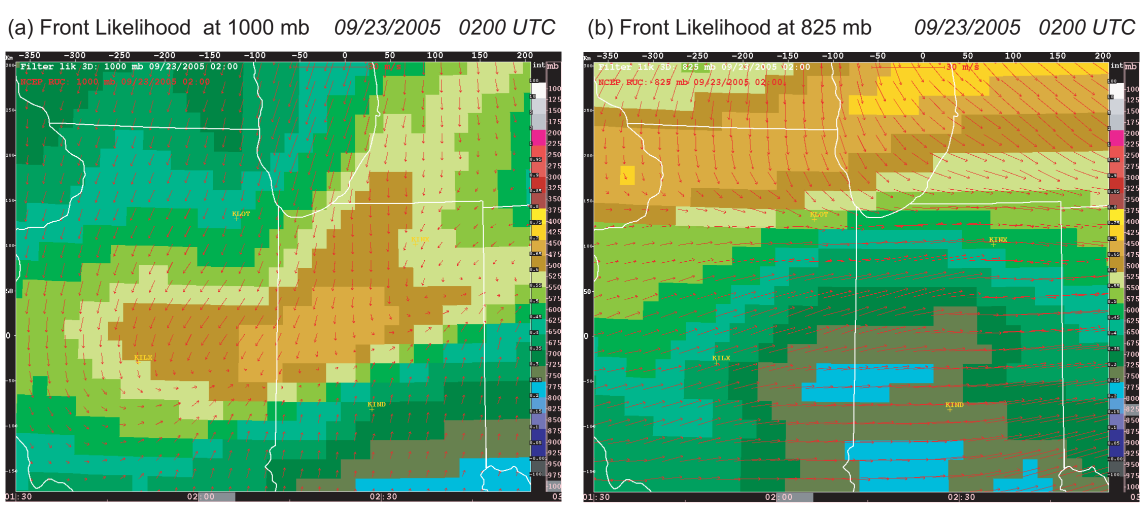

Fig. 7. Frontal likelihood fields showing the sloping cold front (corresponding to Fig. 5a). RUC winds are shown as red arrows.

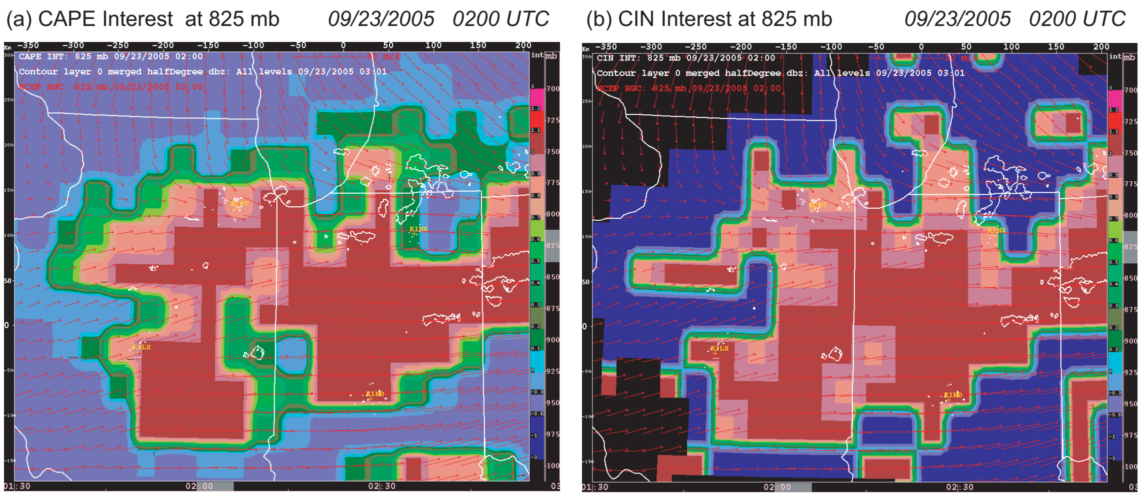

Fig. 8. CAPE and CIN interest fields for elevated convection at 825 mb at forecast issue time (0200 UTC). White contours represent 30 dBZ radar reflectivity at forecast valid time (0300 UTC). RUC winds are shown as red arrows.

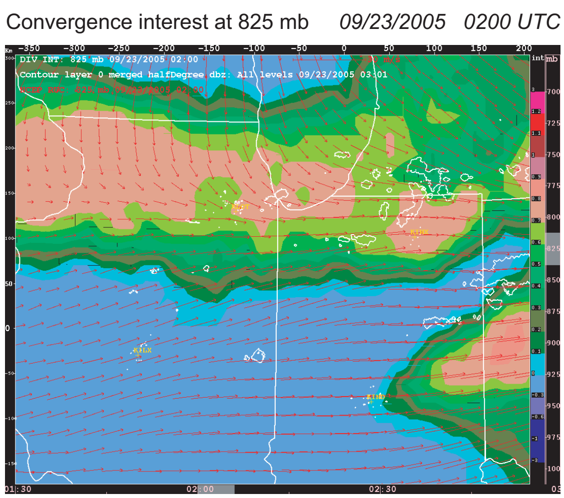

Fig. 9. Same as Fig. 8 except for convergence interest field.

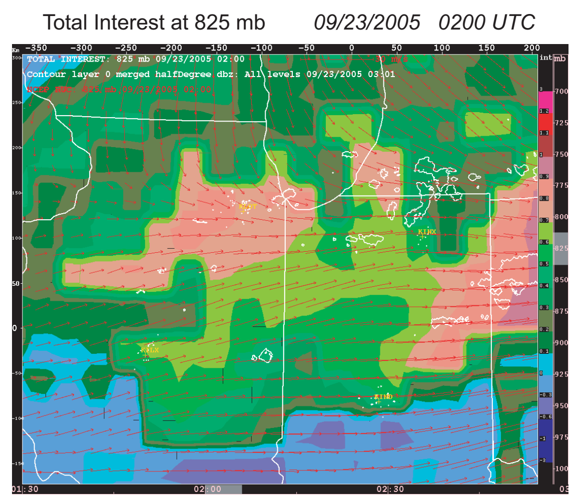

Fig. 10. Total interest field at 825 mb for elevated convection issued at 0200 UTC (valid at 0300 UTC) compared with 30 dBZ radar reflectivity at valid time. RUC winds are shown as red arrows.

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