Predictability of storm characteristics based on RUC environmental fields

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1.0 Introduction

The Federal Aviation Administration (FAA) systems currently plan and control for up to 5,000 aircraft a day over the CONUS. Currently the majority of traffic planning and control is handled manually. Methods and tools to aid decision makers in the control of air traffic are under development. There is a need and interest in including probability nowcast for convective weather into these systems.

The National Center for Atmospheric Research (NCAR) is developing methodologies to provide 1-2 hr probability nowcasts. The development and evaluation of these products are sponsored by the Federal Aviation Administration's (FAA) Aviation Weather Research (AWR) program as part of the Convective Weather Product Development Team. The Convective Weather Product Development Team consists of MIT Lincoln Laboratories (MIT/LL), National Severe Storms Laboratory (NSSL), National Weather Service's Aviation Weather Center (AWC), and NCAR.

In this paper correlations between storm characteristics (primarily life-time and size) as determined from national WSR-88D mosaics and synoptic forcing as determined by RUC are shown. The goal of this work is to differentiate and forecast long-lived storm systems from short-lived storms. Methodologies discussed here using a few case studies are implemented on our real-time system in order to compile statistics from the summer.

2.0 Data analysis

The Corridor Integrated Weather System (Evans et al., 2001) implemented and support by MIT/LL provided mosaics of the WSR-88D data for this study. Vertically Integrated Liquid water (VIL) mosaics at 5 min intervals are used. The domain covers much of the northeastern portion of the US extending from western Illinois to the east coast and Wisconsin down through Virginia.

A software program called *Thunderstorm Identification, Tracking, Analysis, and Nowcasting* (TITAN – Dixon and Weiner, 1993)) is used to determine storm characteristics. TITAN uses objects to track and characterize storms. Storms can merge and split from the main complex. Objects are defined in this study based on the 3.5 $kg\cdot m^{-2}$ isopleths of VIL (this is roughly equivalent to a 40 dBZ return in a convective storm). Reviewed storm characteristics include storm duration, maximum area coverage, growth-dissipation rate, and the initial position of the storm. The storm objects are required to be 30 km^2.

The RUC data are used to determine locations of large-scale forcing. A software package called *Frontal Likelihood* uses fuzzy logic to determine broad locations of large scale forcing based on the surface equivalent potential temperature gradient, convergence and vorticity fields.

Frontal Likelihood inputs the RUC hybrid hourly analysis fields. Three predictor fields are calculated, vorticity, convergence, and the gradient of equivalent potential temperature. The 5th sigma level are used for all three predictors. The vorticity and convergence fields are calculated using a 100 x 100 km square region. The theta-e gradient field is also calculated over 100 x 100 km square. Membership functions are applied to map the predictor fields to the likelihood of frontal forcing (likelihood fields). The dimensionless likelihood fields range from 0 to 1 and are meant to represent the relationship between the predictor fields and the existence of large-scale boundary-layer forcing. Values of 0 indicate no relationship and values of 1 indicate strong relationship or high likelihood. These likelihood fields are not equivalent to probability, high values of likelihood for a single predictor field may have very low probabilities. Membership functions and weights for the frontal likelihood field are given in Table 1. The likelihood fields are weighted and summed to produce a combined likelihood field. In order to smooth and remove discontinuities, the combined likelihood field is smoothed using a 480 km by 120 km elliptical filter.

Predictors	Value where likelihood set to one	Weight
Vorticity	6×10^{-5} sec^{-1}	0.25
Convergence	4×10^{-5} sec^{-1}	0.25
Gradient Theta-e	18 K	0.50

Table 1. Predictor fields for frontal likelihood

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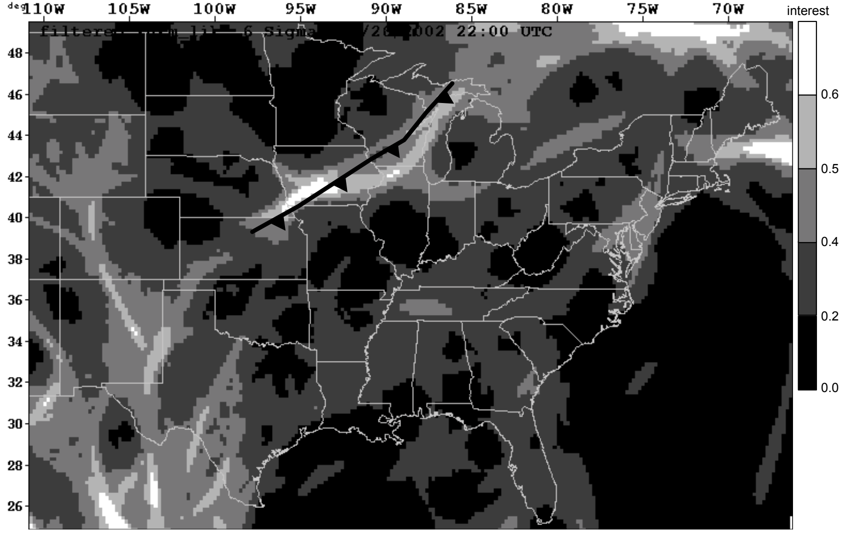
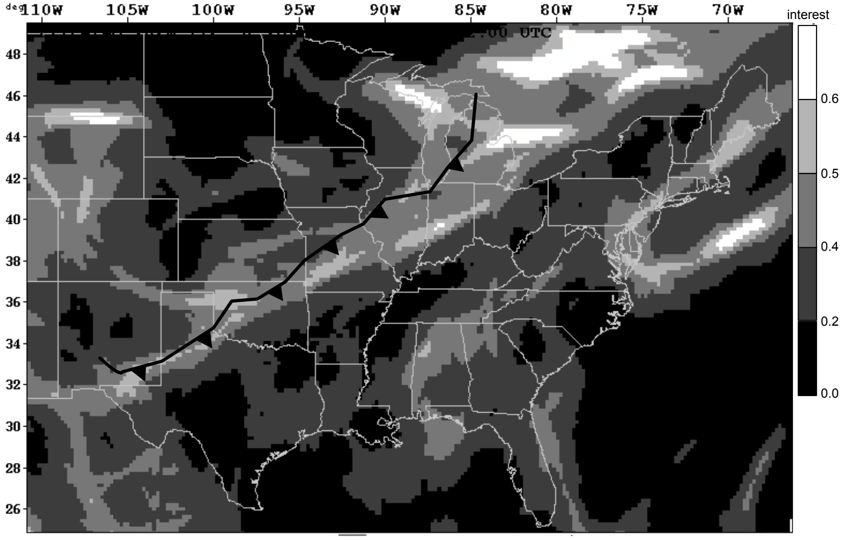
a) Jun 26, 02



b) Jul 22, 02



c) Aug 22, 02

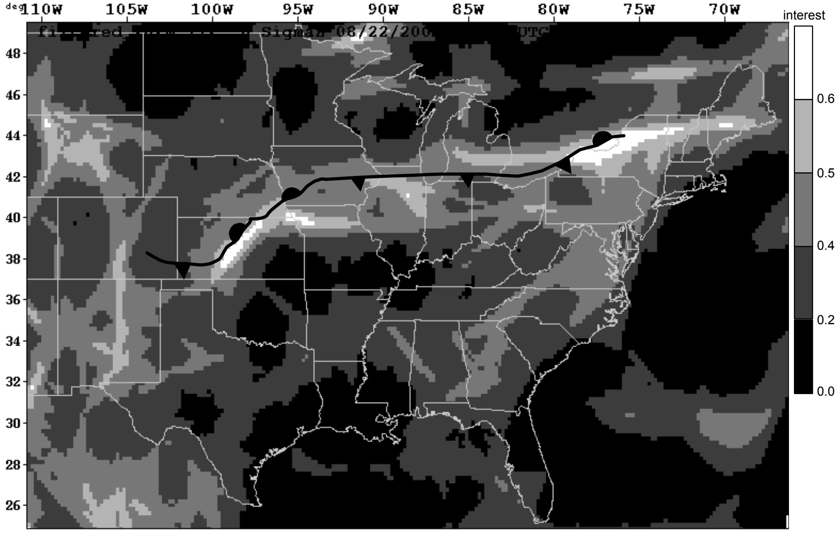


Figure 1. Data from Jun. 26 at 22Z, Jul. 22 at 22Z and Aug. 22 at 22Z are shown in Figs 1a, 1b and 1c. The frontal likelihood field (see text for explanation of field) is shown as shades of gray. Values of .5 to 1 show regions were fronts are likely to be located. The human analyzed front locations are overlaid.

The frontal likelihood field was reviewed daily during the summer of 2002. In general, the field did a good job of indicating the regions where fronts were analyzed. In many cases highest likelihood regions corresponded extremely well with frontal locations as indicated by National Weather Service (NWS). Example frontal fields are shown in Fig 1. The main frontal feature, as provided by the NWS, is overlaid. Frontal likelihood values of .5 to 1.0 do the best job of detecting the fronts while minimizing false detections.

Figure 2 shows correlations of storm duration to frontal likelihood for three cases; June 26 from 00Z to 23:59Z, July 22 from 15Z to 23:59Z, and Aug 22 from 15Z to 23:59Z. These days are used in the paper because they are all active storm days with long-lived convective systems. The values of frontal likelihood were assigned to storms based on their initial positions. Storms are divided based on their maximum area. The dark triangles in Fig. 2, indicate storms whose maximum area did not exceed 500 km^2, the gray squares are storms between 500-2,000 km^2 and the circles are storms >2,000 km^2. Maximum areas are based on the complex area so they comprise the sum of all storms in a given complex at a given time. Duration is based on the difference between the initial time a storm was detected to the time the storm complex dissipates.

On June 26th, the majority of the domain was in the warm sector. Afternoon surface flow was light southerly with maximum temperatures in the 80s and dewpoints equally high. Convection was prevalent throughout the domain. During the previous evening a Meso-scale Convective Complex (MCC) formed in association with a cold front to the west of the domain. During the evening it advected into the region and dissipated. Convection began to fire during the late morning (partially in association with the outflow from the MCC). Convection continued through out the domain into the following evening. At 22Z the cold front that had initiated the MCC the day before entered the domain from the west. Figure 2a shows the long durations of these complexes. Many of the storms that persisted for 600 min or more are from the same storm complex. The complex initiated in association with the cold front and moved east across the domain. Figure 2a shows that these long-lived storms tended to initiate in regions of higher frontal-likelihood values.

On both July 22nd and Aug. 22nd, a cold front extended through the middle of the domain. The majority of convection was associated with the front. On July 22nd there tended to be more warm sector convection during the afternoon. Figures 2b and 2c indicate that although storm complexes were not as long lived on these days as they were on June 26th, they still persisted for the majority of the afternoon. Similar to the June 26th case, small storms initiation was equally represented at all frontal likelihood values. However, the large systems tended to initiate in regions of high frontal likelihood.

3.0 Summary

This study represents an exploratory effort toward using environmental conditions from the RUC along with observations to nowcast convection. Information that can be obtained about the likelihood of a storms or storm complex to persist into the future can be used to help provide confidence values to extrapolation forecast and nowcast of storm growth/dissipation based on trending. Current efforts are toward including stability in the frontal likelihood field.

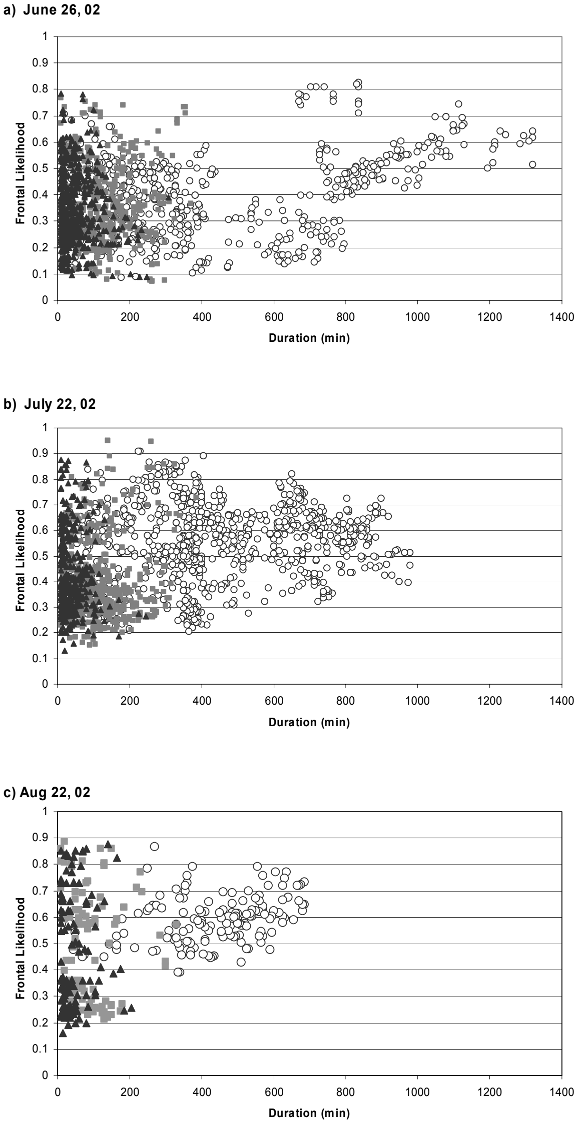


Figure2. Storm durations as a function of frontal likelihood. The values of frontal likelihood were assigned to storms based on their initial positions. The Dark triangles indicate storms whose maximum area did not exceed 500 km^2, the gray squares are storms between 500-2,000 km^2 and the circles are storms > 2,000 km^2.

4.0 References

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