P3R.2 NOWCASTING OF STORM DURATION

David M. Jankowski* and Neil I. Fox
University of Missouri - Columbia,
Columbia, Missouri, USA

1. INTRODUCTION

Storm duration is an oft-overlooked forecast that can be of great value to emergency services, outdoor event organizers, transportation officials and others. It can also be postulated that storm duration is a critical indicator of storm total precipitation and, therefore, flash flood potential. Collier and Fox (2003), and subsequently Hatter (2004), investigated the meteorological and hydrological components of flash flood events. In each case the findings indicated that, of the many factors required to identify threatening situations, storm velocity and duration were the least well understood and quantified.

As reported in a previous paper (Fox et al. 2005) an investigation was conducted of the relationship between the velocities of the centroid and the rear edge of storms and the resulting rainfall totals. This approach attempted to use a ‘storm duration factor’ (SDF) defined as $(v_c - v_r)/v_c v_r$, where v_c is the centroid velocity and v_r is that of the rear edge. The predicted duration (T) of the storm over a point at a distance D from the center of the storm is given by:

$$T = D\left(\frac{1}{v_r} - \frac{1}{v_c}\right) = D\frac{v_c - v_r}{v_c v_r} \qquad (1)$$

This approach makes the crude assumption that D >> ΔD, where ΔD is some measure of storm dimension. The results of the previous study suggest that this assumption leads to poor forecasts as the distance for which any forecast of convective rain is good must be relatively short, whereas storms that produce large amounts of precipitation are often relatively large.

This paper expands on the approach of the previous work by investigating whether storm total rainfall can be forecast over short periods using simple combinations of observed storm velocities and cell size.

2. STORM DURATION PREDICTION

In (1) only the magnitudes of the representative storm velocities are considered. In reality the propagation of the center and rear edge of the storm will most often proceed in different directions. For convenience the SDF ignores this. Practically, this is consistent with the concept of an objective measure of flash flood threat rather than an explicit precipitation forecast. This latter is problematic due to the requirement to forecast precipitation rate. Physically one would not expect the directions of these two vectors to diverge greatly, and given that the storm does have width, and will not move in a linear fashion, it seems reasonable to take the SDF as a good measure. However, this simplistic approach lacks any consideration of cell size.

The next step in the investigation was to redo the analyses accounting for cell size. This moves away from the range independent measure of SDF presented in equation (1), as it necessitates the use of the following formulation:

$$T = D\left(\frac{1 + \Delta D / D}{v_r} - \frac{1}{v_c}\right) \qquad (2)$$

This now depends on the relative distance of the area in question to the size of the storm cell. It therefore also makes sense to study this without reference to a fixed value of D, but to a fixed surface location (such as a rain gauge site). These modifications will form the basis of the next phase of these studies.

---

* *Corresponding author address:* David M. Jankowski, Univ. of Missouri - Columbia, Dept. of Soil, Environmental and Atmospheric Sciences, 302 ABNR Building, Columbia, MO 65211; e-mail: dmjf39@mizzou.edu.

3. DATA AND METHODOLOGY

For this study, radar data was examined from a number of events of different types and from a variety of areas. Level II Nexrad data was acquired from the NCDC archive and processed using WATADS. Using the available NSSL algorithm suite SCIT tracks and cell tables were used to assess the centroid velocity at each time step. One-hour rainfall accumulations for the hour subsequent to the scan analyzed were also available and used to correlate the SDF with points 25 and 50 km ahead of the storm center as well as at the location of the storm center (0 km).

The current storm-cell identification and tracking algorithm (SCIT) in the WSR-88D radar systems tracks the storm centroid. A linear least-squares method is used to determine movement using current and past mass-weighted centroid location (Johnson *et al*. 1998). In contrast to work that deals with the motion of MCCs (e.g., Corfidi et al. 1996; Chappell 1986; Collier and Fox 2003), the SCIT is concerned with the motion of the individual storm cells that make up the cluster. This is because severe weather is associated with individual cells, and the aim is to forecast the motion of these smaller areas where the severe weather threat is found. While the SCIT algorithm is very useful in determining the motion of severe weather events associated with individual cells (tornadoes, large hail) it is less useful when trying to forecast flash floods associated with an entire cluster of cells. Because the cells can be moving relatively quickly in comparison to the storm propagation as a whole, the cell motion predicted by the storm tracking algorithm can be misleading if one is trying to determine how long it will rain over a particular area. It would be more beneficial to take into account storm motion and propagation as a whole, rather than individual storm cell motions. Other short-period forecast systems (e.g. TITAN: Dixon and Wiener 1993) have similar approaches to storm tracking.

Data was taken from the San Antonio / Austin, TX (KEWX) radar for an extended period of rainfall events from 28 June – 9 July 2002. This comprised a whole series of discrete rainfall episodes which resulted from a variety of mechanisms and storm types. Some storms propagated onshore from the Gulf of Mexico, while others developed over the elevated topography west of the area and moved over the same region. The result was a series of heavy precipitation events over a number of days that produced a number of severe floods and flash floods. However, many of the storms did not, in themselves, produce floods, they did contribute to the overall persistence of the flood threat by maintaining soil moisture levels and river levels. Other cases used for the construction of the graph in figure 1 were taken from flash flood events in Missouri and Alabama detailed in Fox *et al*. (2005).

The rear edge velocity, v_r, is found by locating the trailing edge on subsequent scans. In order to reduce errors in diagnosed velocities the difference in position of the rear edge was found at 12-minute (for the 6-minute radar scan cycle) or 15-minute (for the 5-minute scan cycle) intervals. The trailing edge is found by tracing the diagnosed centroid velocity vector backwards until the observed reflectivity falls below a threshold value of 30 dBZ. Further details of the methodology can be found in Fox *et al.* (2005). Cell size (ΔD) is defined as the distance measured between the observed locations of the storm cell centroid and the rear edge location.

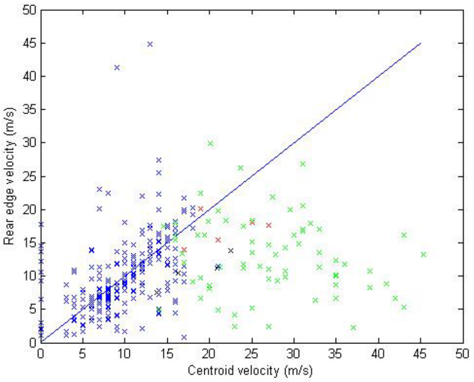

Figure 1: Comparison between centroid and rear edge velocities. Points depicted in blue are from the San Antonio case study, those in green are from the St. Louis and Kansas City cases, and those in red from the Huntsville radar. The solid line is that of equality.

4. RESULTS

4.1 Rear edge vs. centroid velocity

Comparisons of rear edge velocities and those of the centroid found by the SCIT algorithm are shown in the scatterplot in Figure 1. This is composed of 356 points, the majority of which (240) are from the extended San Antonio case. These data from the San

Antonio region are those for which the remainder of the analysis has been performed. While there are many points that lie close to the line of equality there are a significant number of points showing the rear edge propagating significantly more slowly than the centroid.

As was seen in the reflectivity imagery, and illustrated by the scattergram, the San Antonio cases (blue crosses) had storms that were mostly isolated cells that propagated without significant development. In these cases the cells had a fairly constant shape and the two velocities were similar. The data from the Missouri cases (green crosses) show a larger difference with a large number of the cells having much slower rear edge velocities. The data from the case in Alabama (red crosses) show a mixture of cells with slower rear edges and those that move at approximately the same speed as the centroid. Although the cells were similar to those seen in the Missouri cases there was enough separation between existing cells and those that developed to their rear that they are diagnosed as separate storms rather than continuously back-building single storms.

4.2 Comparisons with precipitation totals

In the previous work comparisons were made by preparing scattergraphs of one hour precipitation totals from the period subsequent to the velocity observations versus the measures of storm duration based on velocities alone. As this did not prove fruitful, for this paper the precipitation totals were compared to measures of storm duration based on a combination of velocity measures and storm size. The explicit forecast duration shown in (2) was compared to measures of duration based on the individual observed velocities:

$$T_r = D\left(\frac{1+\Delta D/D}{v_r}\right) \tag{3}$$

$$T_c = D\left(\frac{1+\Delta D/D}{v_c}\right) \tag{4}$$

In order to determine what measure of storm velocity provided the best indicator of future precipitation graphs were prepared that plotted T_c, T_r, and T against one-hour precipitation totals from the forecast time T = 0 to T + 60 minutes at distances of 0km and 25km ahead of the centroid location. These precipitation totals were determined from the radar-based 60 minute accumulations available in WATADS. A selection of these graphs are shown in figures 2, 3 and 4.

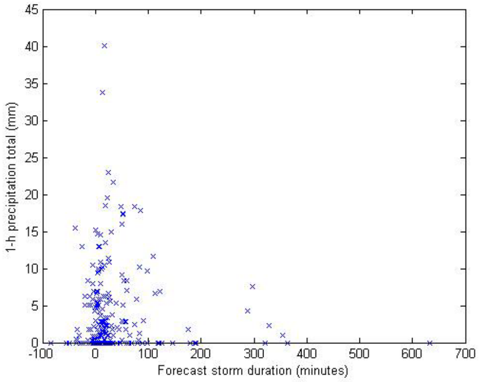

Figure 2: One-hour precipitation accumulation at 25km versus forecast storm duration.

.

Figure 2 shows the plot of the storm duration factor, defined in (1). This graph does not suggest that there is a reliable relationship between the parameters. This is in common with the other potential relationships between duration and precipitation total in which the duration is calculated as a function only of cell velocities (Fox *et al*. 2005). Despite the clustering of points close to the zero precipitation there is some sign in figure 2 that the precipitation accumulation increases with increasing SDF. There are clearly some duration forecasts that are excessive due to the observed slow motion of the rear edge. In these cases the development of dissipation of the storm is undoubtedly more significant than its duration over the forecast duration. Therefore there are a number of storms with forecast durations of hours that produce very little precipitation. The number of points clustered close together, and close to both axes, makes interpretation difficult. There is some sign that the precipitation accumulations increase with the values of each velocity measure.

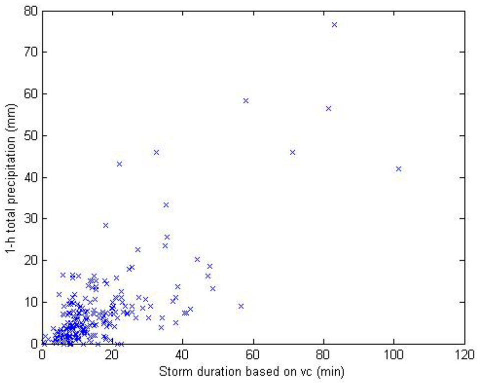

Figure 3: One-hour precipitation accumulation at storm location versus duration calculated using storm centroid velocity and cell size.

Figure 3 is a scatterplot of storm duration given by the formula in (4) versus observed precipitation for the following hour measured at the recorded location of the storm center at T=0. This graph shows the best correlation between a storm duration forecast and the resulting precipitation. This suggests that a duration forecast based on the centroid velocity and the cell size can provide a good indication of resultant precipitation for areas that are already being impacted by the storm. Of course, this is of limited, but not negligible, value as such a forecast can only ever be good for a very short period.

Figure 4 is a similar plot to that in figure 3 except that the forecast duration is based on the rear edge velocity and cell size. Although, once again, there is a clear relationship between the duration and the precipitation, but it is not as good as that found using the centroid velocity. This may be due to the lesser reliability of the measurement of the rear edge velocity which is not automated in the way that the calculation of centroid velocity is. An alternative explanation could be that the majority of the rain is provided by the high-reflectivity core that the centroid tracks or that the change in precipitation rate, due to cell decay, behind this area is greater and not accounted for in this forecast procedure.

One might also contend that the precipitation accumulation data used is unreliable as it is a pure radar product that may suffer from all the possible errors in radar retrieved rainfall estimates.

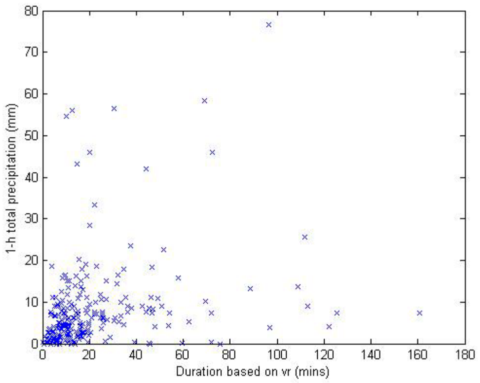

Figure 4: One-hour precipitation accumulation at storm location versus forecast storm duration based on rear edge velocity and cell size.

5. CONCLUSIONS AND NEXT STEPS

Although there clearly appears to be a difference between the diagnosed centroid motion and that of the rear edge there is little evidence that the simple use of the differential velocity provides a good prognostic indication of imminent rainfall totals.

There are a limited number of cases for which the precipitation totals have been recorded, and in the majority of these there is not a great difference between the centroid and rear edge velocities. The results suggest that there is a relationship between the storm precipitation and the duration based on observations of velocity and size of the storm cell. However, this relationship only appears valid for a small area around the current location of the storm.

Some of the problems in determining relationships may be due to the range of storm types incorporated into each graph. It may be that the analysis would be useful for some types of storms and not others. Therefore, the intention is to continue analyzing data and separate data by some objective assessment of storm type. It is also felt, at this time, that more data needs to be analyzed prior to the suggestion of a particular prognostic relationship.

The next step of this study will also involve the use of raingauge data. As a forecaster would most likely wish to predict the rainfall at a particular place of interest it makes sense to use such a fixed location as a reference point rather than an arbitrary distance ahead of the storm. For this kind of analysis a good raingauge site will be chosen. This will further facilitate an investigation into the appropriateness of the use of the radar derived rainfall totals that have been used in this study to date. The use of tipping bucket rain gauge data will also permit the comparison of rear edge velocity and precipitation end time as forecasted and observed.

ACKNOWLEDGEMENTS

This work was funded partly under a COMET Partners Project No. S04-44688 and by the University of Missouri Research Council.

REFERENCES

Chappell, D. F., 1986: Quasi-stationary convective events. *Mesoscale Meteorology and Forecasting*, P. S. Ray, Ed. Amer. Meteor. Soc., 124-131.

Collier, C.G. and N.I. Fox, 2003: Assessing the flooding susceptibility of river catchments to extreme rainfall in the United Kingdom. *Int. J. River Basin Man*. 1 (3).

Corfidi, S.F., J.H. Merritt, and J.M. Fritsch, 1996: Predicting the movement of mesoscale convective complexes. *Wea. Forecasting*, **11**, 41-46.

Dixon, M. and G. Weiner, 1993: TITAN: Thunderstorm Identification, Tracking Analysis and Nowcasting – A radar –based methodology. *J. Atmos. Oceanic. Technol*., **10**, 785-797.

Fox, N.I., D.M. Jankowki, E.A Hatter, and E.R. Heiberg, 2005: Forecasting storm duration. World Weather Research Programme Symposium on Nowcasting and Very Short Range Forecasting, Toulouse, France, 5-9 September 2005.

Hatter, E.A., 2004: Using Radar and Hydrologic Data to Improve Forecasts of Flash Floods in Missouri. MS Thesis, University of Missouri.

Johnson, J.T., P.L. MacKeen, A. Witt, E.D. Mitchell, G.J. Stumpf, M.D. Eilts, and K.W. Thomas, 1998: The storm cell identification and tracking algorithm: An enhanced WSR-88D algorithm. *Wea. Forecasting*, **13**, 263-276.