SAMPLING ISSUES ASSOCIATED WITH THE EVANSVILLE TORNADO AND OTHER NEARBY SUPERCELLS ON THE EARLY MORNING OF 6 NOVEMBER 2005: CHALLENGES TO OPERATIONAL FORECASTERS

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Patrick J. Spoden*, Ron Przybylinski**, Christine Wielgos*, & Rick Shanklin*

*NOAA / National Weather Service
Paducah, Kentucky

**NOAA / National Weather Service
St. Louis, Missouri

1. INTRODUCTION

During the late evening hours of 6 Nov 2005, clusters of HP supercells (Moller et al. 1990; Przybylinski 1988) moved across the Lower Ohio Valley and produced, among others, two F3 tornadoes in western Kentucky and southwest Indiana. These storms spawned the tornadoes within minutes of each other as a mid-upper level jet streak impacted the supercells. The F3 tornado which moved through the south side of the city of Evansville killed 24 people.

The dominate storm mode was not anticipated properly by the forecasters at either WFO Paducah or SPC. Forecasters knew the jet streak was going to enter Kentucky after midnight; however the implication of the jet streak was not fully anticipated. Forecasters expected the clusters of storms to become linear, even during the event, with wind damage becoming the dominate severe weather type. As discussed by Quoetone and Huckabee (1995), forecasters must be open to a multitude of possibilities, not just what was originally anticipated. The magnitude of the event affected all aspects of the operations. This idea was conveyed by Quoetone et al. (2001), when they discussed the May 3, 1999 tornado outbreak in Oklahoma.

This paper will briefly review the environment in which the HP supercells formed, followed by detailed analysis of the supercells. Two of these which produced the Evansville tornado and the Crittenden County tornado. Finally, we will discuss some insights into operational challenges that forecasters may face in a similar environment.

2. ENVIRONMENT

The storm environment on this day implied more of a damaging wind threat than a tornado threat. A broad trough was analyzed at 500 hPa over the northern and central U.S. At this level, a jet maximum, with wind speeds up to 31 m s^{-1}, was rounding the base of the trough. The 0000 UTC (all times hereafter in UTC) 6 November sounding (not shown) from Springfield (SGF), indicated fairly unidirectional flow was present although the 0-6 km shear was 28 m s^{-1}. The surface analysis from 0000 indicated a surface low over central Missouri, with a cold front arching southwestward back into northern Texas. Surface temperatures in the Lower Ohio Valley were ranging from 20 to 24 degrees C with surface dew points ranging from 13 to 15 degrees C. A broken line of storms were developing in the vicinity of the front at that time. LAPS 0-1 km helicity values averaged 220 m^2 s^{-2} over western Kentucky with MUCAPE values around 300 J kg^{-1}. The surface low deepened as it moved northeast to near Chicago, Illinois by 0600.

By 0600 the broken line of storms extended just ahead of the cold front from near KCMI to KMDH to just east of KJBR. A narrow tongue of higher surface dew points (16-17C) had advected north into western Kentucky and southwest Indiana by 0600 while surface temperatures were nearly steady. LAPS data from 0600 indicated that the region out ahead of the cold front continued to destabilize with 0-1 km MUCAPE values of 700-900 J kg^{-1}, which were centered along the Ohio River. LAPS 0-1 km helicity values had also increased to 350-450 m^2 s^{-2} by this time over the area of concern.

A 0700 LAPS sounding near Evansville (fig. 1) indicates nearly unidirectional shear, but quite a bit of speed shear through the column.

A jet streak at a height of 6 to 7.5 km was detected entering the Lower Ohio Valley by the VAD Wind Profilers (VWP) from KPAH and KVWX shortly after 0600. It is believed the nose of the jet streak impinged upon the supercell storms as tornadogenesis was occurring. Both the KPAH

Corresponding author address: Patrick J. Spoden, National Weather Service, 8250 KY HWY 3520, West Paducah, KY 42086;
e-mail: pat.spoden@noaa.gov

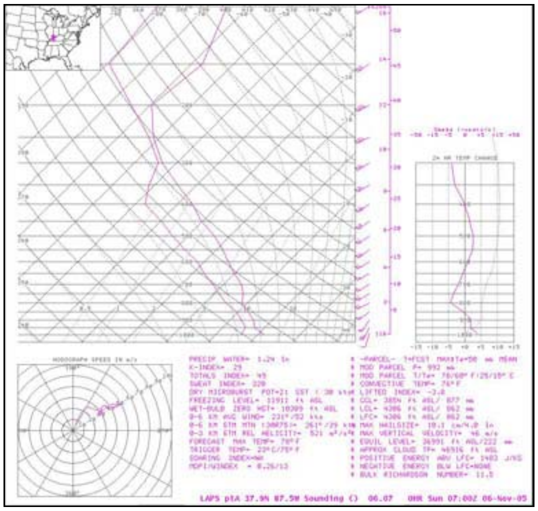

Figure 1 – 0700 LAPS sounding from near Evansville, IN

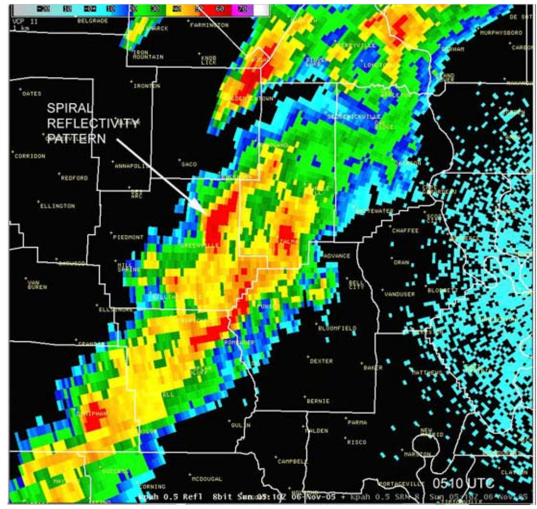

Figure 2 – 0.5 degree reflectivity from KPAH WSR-88D at 0510

and KVWX VWPs indicated a rapid increase of 7.7 to 10 m s^{-1} over a 30 minute time period between 0730 and 0800 (not shown) as the storms passed between the two radars.

3. EARLY STAGES OF THE EVANSVILLE STORM

The Evansville Indiana tornadic storm formed over Wayne County, Missouri or approximately 85 km west-southwest of Cape Girardeau, Missouri (KCGI) at approximately 0500. The overall reflectivity pattern appeared to resemble a broad comma-like structure – a variation of the High-Precipitation supercell family. The higher reflectivities at low levels revealed a 'spiral-like' reflectivity pattern at 0510 suggesting the presence of rotation within the storm (Fig. 2). Magnitudes of Vertical Integrated Liquid (VIL) at this time were meager (30 to 35 Kg m^{-2}) suggesting modest updrafts within the storm.

The first mesovortex was embedded within the western flank of the spiral structure over eastern Wayne County around 0510 from the WSR-88D at Paducah, Kentucky (PAH). The mesovortex showed weak rotational characteristics with maximum rotational velocities (Vr) at the 0.5 degree slice was 12 m s^{-1} while magnitudes at the 1.5 degree slice was 10 m s^{-1}. The depth of the first mesovortex reached 14.2 km while the core diameter was quite broad (11 km). As the storm moved east-northeast towards KCGI, new convective towers moving north were forming along the eastern flank of the storm as the broad spiral reflectivity pattern fragmented. A new smaller comma-shaped echo rapidly evolved 15 km west of KCGI after 0545 with the tail of the comma rapidly accelerating to the northeast.

Pence et al. (1998) and Przybylinski and Schmocker (2001) have shown that small comma-shaped reflectivity patterns which evolve in strong dynamic environments and during the transition or cool season have been associated with tornadic activity. The first mesovortex further strengthened and became more of a mid-level feature in the vicinity of the comma-head with the strongest rotation (16 m s^{-1}) identified near 4.0 km and weaker rotation above and below this level. VIL values only slightly increased from 30-35 to 35-40 Kg m-2. Even with the increased rotation and higher VIL, no severe weather was reported with this storm as it passed over the city of Cape Girardeau, MO.

As the Evansville storm crossed the Mississippi River into Union County, Illinois, the storm's overall reflectivity pattern evolved into another variation of the supercell theme. Such changes in the reflectivity pattern may be due to different structures in the vertical wind shear profiles over a given area. Burgess and Curran (1985) and Glass and Britt (2001) have shown that the vertical wind shear profiles can play a role in modifying the overall supercell reflectivity pattern (e.g. line to HP or HP to classic structures). At 0621, low-level reflectivity notches along the storm's forward flank were bounded by higher reflectivities aloft which signified the location of the storm's updraft region (Fig. 3).

Conversely, a region of very weak echo located along the storm's trailing flank marked the location of the storm's pronounced rear flank downdraft. A second mesovortex formed at 0606 northeast of the first circulation and moved across the central part of Union County, Illinois. This circulation rapidly became deep and revealed its strongest rotation between 2 and 3

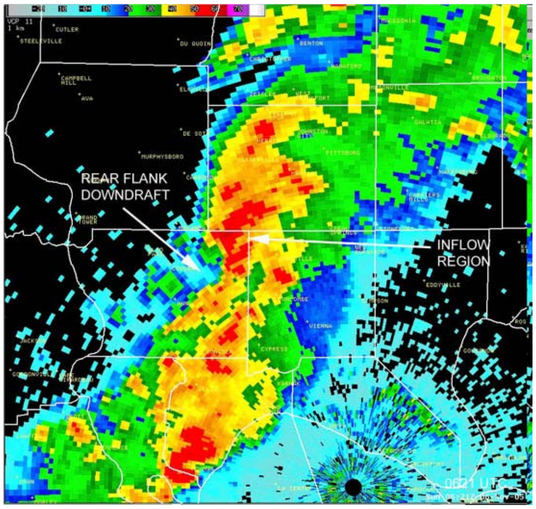

Figure 3 – 0.5 degree reflectivity from KPAH WSR-88D at 0621

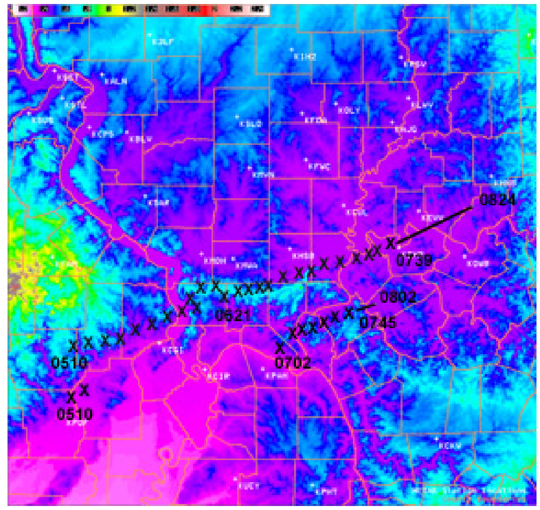

Figure 4 – topographic image and circulation tracks. The solid line indicates the tornado tracks.

km with Vr values reaching 20 m s^{-1}. Magnitudes of VIL further inched up to 45 – 50 Kg m^{-2}, however no severe weather was reported with the Evansville storm during this period. The second mesovortex weakened after 0616 over northeast Union County, while a new and third mesovortex formed 5 km to the south. This new vortex core developed along the southern flank of the HP storm as it moved into Johnson County (60 km northwest of Paducah, Kentucky (PAH). Mesovortex #3 rapidly became very deep at 0627 extending over 4 km with the strongest rotation (Vr 19 m s^{-1}) detected between 3 and 4 km.

4. THE EVANSVILLE STORM

At 0627 the 50 dBZ core dramatically increases in aerial coverage as the storm passes over a northern extension of Crowley's Ridge in southern Illinois. There is a rise of over 118 m within 5 miles from one of the valleys to the top of the ridge in northern Johnson County and a total rise of over 152 m from the Ohio River. It is unknown whether the topographical ridge actually played a role in the intensification of the storm. The HP storm exhibits an increase in rotation at this time as well as it enters southern Williamson County.

By 0637 Vr shear is about 16 m s^{-1} in the low levels and near 18 m s^{-1} in the upper levels. This rotation appears to descend to the lowest slice with a value of 18 m s^{-1} in Saline County by 0647, which is 68.5 km north of KPAH. The rotation was located in the southern flank, or "tail" of the large reflectivity structure. Between 0647 and 0702 the reflectivity returned to a more elongated structure, with a bow echo feature aloft. This bow echo appears to descend toward 1.5 degrees (approximately 2.5 km in height) during this time frame. A large WER exists partially on the southeast flank of the storm. This is partially due to the extreme storm speed of at least 31 m s^{-1}. Interestingly, the reflectivity on the 0.5 slice appears to split, or weaken, near the location of the circulation starting around 0637 and continues until about 0732. During the 0647 to 0702 time frame the circulation tightens and strengthens and produces two TVS signatures on the 0.5 slices at both 0657 and 0702 volume scans. No tornadoes were recorded during those times. See figure 4 for circulation tracks.

The KPAH radar was not the only radar sampling the circulation, which was located in Gallatin County in southeast Illinois at 0707. The KVWX radar, located in Owensville, Indiana was also able to sample the circulation. A comparison of the sampling by both radars can be seen in Figure 5. Both radars indicated Vr circulation strength of at least 20 m s^{-1} above 2 km. The storm was equidistant between KPAH and KVWX radars (approximately 80 km from each). The remainder of the discussion will utilize the KVWX radar.

During the 0707-0713 volume scan time, the lower portion of the circulation weakened and broadened, while the circulation remained strong (21-30 m s^{-1}) above 1.5 km. A BWER begins to form along the southern edge of the elongated storm and can be seen on two adjacent elevation slices (2.4 and 3.4 degrees) by 0720 while the strongest portion of the circulation begins to descend to near 1.5 km. The circulation continues to tighten and deepen so that by 0739 (fig. 6) the strength of the circulation reached 28 m s^{-1} through a majority of the depth of the storm, which by this time was 48 km south of the KVWX radar. A strong gate-to-gate signature (41 m s^{-1})

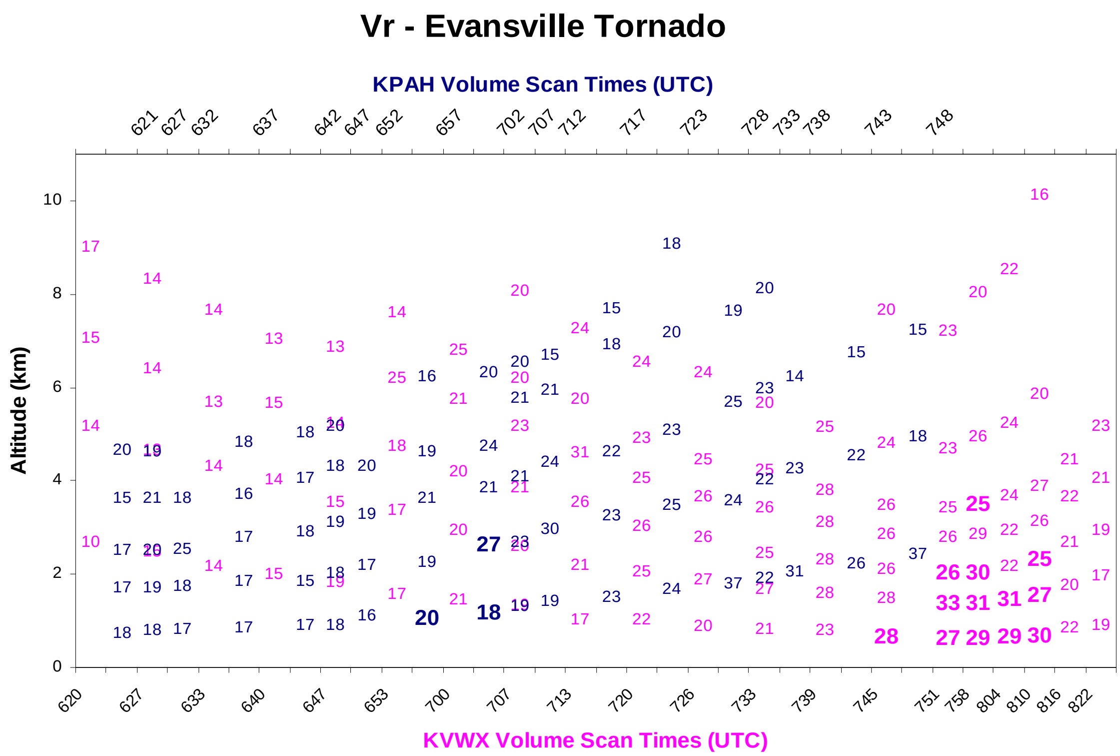

Figure 5- Vr plots from KPAH (blue) and KVWX (red). Bold numbers indicate that gate-to-gate shear >36 ms-1 within 102 km of either radar was present

was seen at 1.5 degrees. This was the last volume scan in which a BWER was detected

The tornado touched down at 0739 and began its 66 km long path from Kentucky into Indiana. By 0745, the TVS signature (49 m s^{-1}) descended to the 0.5 degree slice. Prior to tornado touchdown, no real-time reports of severe weather were received with this storm. Later reports indicated some minor wind damage in both Williamson and Gallatin Counties in southern Illinois.

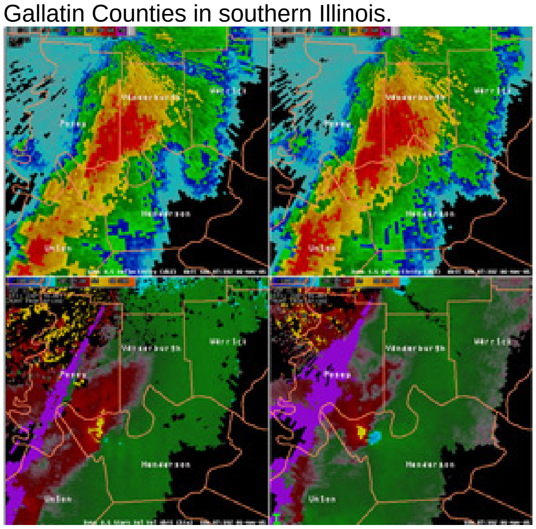

Figure 6 – 0.5 & 1.5 degree reflectivity and 8-bit SRM at 0739 from KVWX

5. CRITTENDEN COUNTY STORM

There were several HP supercells in the region that night. One other significant HP storm evolved out of an ill-defined line segment starting at 0712 in extreme southern Illinois. This storm was sampled by both the KPAH and KHPX WSR-88D radars throughout its lifetime.

Between 0702 and 0723, isolated cells developed just southeast of the main reflectivity cores and merged with the main structure. By 0723, the HP structure can be clearly seen with a comma-head feature and a tail extending southwest of the main reflectivity core. A small rear inflow notch can be seen above 2.5 km. By 0738, a forward flank notch develops on the east flank of the main precipitation area, however, the circulation remains embedded in the precipitation. The rear inflow notch continues its northeast path through the main reflectivity core during the next several volume scans and connects with the forward flank notch which results in a "cluttered" storm split which finally occurs between 0754 and 0808.

The strength of the circulation depended upon which radar was being used to sample the storm. The storm was moving northeast at 31 m s^{-1}, essentially along the radar beam from the KPAH WSR-88D. The KHPX WSR-88D was located to the southeast of the storm and the movement of the storm was essentially perpendicular to the radar beam. Figure 7 is a time-height diagram depicting Vr traces from both radars.

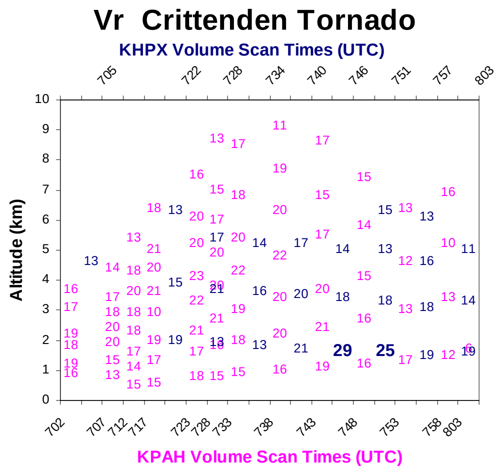

Figure 7 – Vr plot from both the KPAH (red) WSR-88D and the KPHX (blue) WSR-88D.). Bold numbers indicate that gate-to-gate shear >36 ms^{-1} within 102 km of either radar was present.

On the KPAH WSR-88D, the early stages of the circulation could be seen as early at 0702 above 1.3 km. By 0728 the rotation had increased in depth and intensity, reaching a value of 21 m s^{-1} near 2 km with a broader and weaker circulation of 15 m s^{-1} at the lowest slice. This circulation was located in the main precipitation area of the storm which at this time was about 53 km northeast of KPAH. The stronger rotation aloft descended to as low as 2 km by 0743, with a Vr of 21 m s^{-1}, while at the lowest slice (~1 km) the Vr was 19 m s-1 (maximum gate to gate shear was 27 m s^{-1}). After 0743, the circulation quickly broadened and weakened so that by 0758 the Vr on the 0.5 slice was only 12 m s^{-1} with the highest value in the storm at 6.9 km with a Vr of 16 m s^{-1}.

The KHPX WSR-88D depicted much stronger Vr values and almost doubled the gate-to-gate shears from the KPAH WSR-88D (fig. 8). Due to range obscured data, the circulation could best be seen starting at 0722. The value at the 0.5 degree slice (2 km) was 19 m s^{-1} with lower values higher up in the storm. The circulation varied in intensity through the 0734 volume scan when the 0.5 degree slice Vr was 13 m s^{-1} with a peak Vr of 16 m s^{-1} at 3.6 km. A dramatic increase occurred during the next 5 minutes. At 0746, an operator defined TVS was depicted at the 0.5 slice (1.7 km) with a gate-to-gate shear of 57 m s^{-1}. This operator identified TVS continued into the 0751 volume scan with a gate-to-gate shear value of 50 m s^{-1}. The subsequent volume scan showed a general broadening and weakening trend.

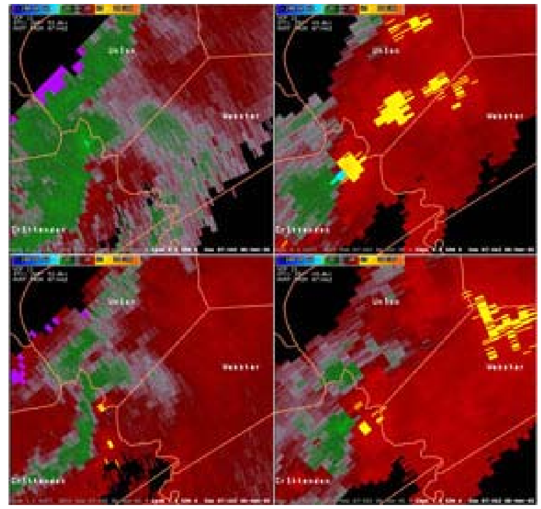

Figure 8 – Left 2 panels 0.5 and 1.5 degree SRM from KPAH (0748) with the right 2 panels 0.5 and 1.5 degree, respectively, SRM from KHPX (0746)

The tornado was on the ground from 0746 to 0802 for a path length of 18 km and reached F3 intensity.

6. OPERATIONAL CHALLENGES

There were several issues that impacted this event operationally. Most of these issues would be considered "lessons learned." We will attempt to briefly consider those in this section.

Communication is the top concern, both internally and externally. Internally, is everyone's situational awareness at the top level? Is the office fully staffed for an unforeseen ramp up of event level (i.e., minor event becomes a major event)? Is the information being conveyed properly to the people affected? Do severe weather statements contain new and precise information, or do they just rehash the warning? Reports are always important, but in the middle of the night, reports are limited. Forecasters have to rely on the radar and their instincts rather than confirmation of severe weather on the ground. In this event, the initial clusters of storms were expected to become linear and produce damaging winds. When the lines did not form, forecasters needed to notice this fact and be aware that the atmosphere had an even higher tornado potential than previously expected.

A careful review of the event revealed that forecasters should not abandon the use of 4 bit SRM data, but should in fact use that in conjunction with the 8 bit SRM. One might use the 4 bit data to locate the circulation and 8 bit to closer diagnose the intensity of the circulation. What color scales are chosen becomes imperative. The ability to properly see the shear is critical, and forecasters are recommended to use the Warning Event Simulator to test different color scales, some of which may need to change with the seasons. The extreme speed of the storms (at least 31 m s^{-1}) also posed challenges operationally. In the late spring and summer, it is normal practice to at WFO Paducah to warn for the next county when the storm is about half-way through the preceding county (due to small counties). However, with these kinds of speeds, one needs to warn several counties ahead. This may lead to higher false alarms, but longer lead times. Lastly, forecasters need to look at all of the radars available to them all of the time. The Crittenden County storm was sampled better by the KHPX radar, in which the radar beams were near perpendicular to the movement of the storm, than with the KPAH radar, in which the radar beams were parallel to the storm.

WFO Paducah's Situational Awareness Display allowed forecasters to see the extent of the damage in Evansville almost immediately. Although the fatalities where not known until the event was over, the knowledge that there was extensive damage and the high potential for fatalities affected each person differently. In events of this magnitude, some staff members may briefly lose touch with reality and become caught up in the moment. The Warning Coordinator needs to ensure that all forecasters working the warning positions are able to continue in their respective positions, or adjust warning operations if sufficient staffing exists.

7. CONCLUSIONS

This event was a challenge to forecast and thus a challenge to work operationally. The environments between tornadic supercells and damaging line segments are not far apart. Forecasters expected the broken line of storms to become more linear with time and produce mainly wind damage. When this did not occur, forecasters needed to adapt in real-time to issue timely warnings. The speed and sometimes rapid evolution of these types of storms affect the total area being warned and this will need to be addressed by all forecasters in the future polygon warning era, not just those whose county warning area contains small counties.

This event clearly shows the need to watch all available radars at all times. The Crittenden county storm appeared to be weaker when utilizing the KPAH WSR-88D, which was sampling the storm while it was moving along the beam. The KHPX radar sampled the same storm while it was moving perpendicular to the radar beam. The gate-to-gate shear on the 0.5 degree slice from KHPX was almost double the corresponding data from KPAH. Forecasters need to be aware of this potential, especially when there are no nearby radars.

8. THANKS

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7. REFERENCES

Burgess, D.W. and E. B. Curran, 1985: The relationship of storm type to environment in Oklahoma on 26 April 1984, Preprints, *14th Conf. on Severe Local Storms,* Amer. Meteor. Soc. 208-211

Glass, F. H. and M. F. Britt, 2001: The historic Missouri-Illinois High-Precipitation supercell of 10 April 2001. Preprints: *21st Conf. on Severe Local Storms.* San Antonio, TX

Moller, A. R., C. A. Doswell III, and R. Przybylinski, 1990: High-precipitation supercells: A conceptual model and documentation. Preprints, 16th Conference on Severe Local Storms, Kananaskis Park, Alta. Canada, Amer. Meteor. Soc., 52-57.

Pence, K. J., J.T. Bradshaw, and M. W. Rose, 1998: The central Alabama tornadoes of 6 March 1996. Preprints, *19th Conference on Severe Local Storms*, Minneapolis, MN, Amer. Meteor. Soc., 174-154

Przybylniski, R. W., 1988: Radar signatures with the 10 March 1986 tornado outbreak over Central Indiana. Preprints, 15th Conference on Severe Local Storms, Baltimore, MD, Amer. Meteor. Soc.,253-256

Przybylinski, R.W. and G.K. Schmocker, 2001: Characteristics of circulations associated with the 11 February 1999 tornado event over the Mid-Mississippi Valley Region. Preprints, *21th Conf. on Severe Local Storms.* San Antonio, TX

Quoetone E. M. and K. L. Huckabee, 1995: Anatomy of an effective warning: Event anticipation, data integration, feature recognition. Preprints, *14th Conference on Weather Analysis and Forecasting*, Amer. Meteor. Soc., Dallas TX pp 420-425

Quoetone E. M., D. L. Andra., W. F. Bunting, D., G. Jones, 2001: Impacts of Technology and Situation Awareness on Decision Making: Operational Observations from National Weather Service Warning Forecasters During the Historic May 3, 1999 Tornado Outbreak. Preprints*, Human Factors and Ergonomics Society 45th Annual Meeting,* Minneapolis MN, pp 419-423