P2.8 COMPARISON OF INFRASONIC DATA AND DOPPLER VELOCITY RADAR DATA: A CASE STUDY OF THE 16 JUNE 2004 TORNADIC SUPERCELL OVER THE SOUTHEAST COLORADO PLAINS

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1. INTRODUCTION

During the convective season of 2003, an infrasonic network (ISNET) was deployed across the central High Plains to assess the possibility of using infrasonic sound to detect rotation in supercell thunderstorms. A 1995 observation of infrasound from an infrasonic observatory co-located with the CHILL Doppler radar in northeast Colorado documented infrasound originating from the vicinity of rotation aloft, descending to the surface in the area of a tornado report. This observation led to a review of archived infrasound and radar data, identifying over 100 cases where the directions and times of infrasound signals matched documented observations of tornadoes. Subsequent field measurements through the summer of 2003 continued to indicate that infrasound could be useful in detecting rotation in supercell thunderstorms.

The ISNET currently consists of 3 sites across the High Plains. They are located at the NWS office in Pueblo CO, at the BAO site in Erie, Colorado and at the NWS office in Goodland, CO. During 16 June 2004, a supercell thunderstorm developed in Bent county, west of Lamar, Colorado and produced multiple tornadoes. This storm developed in a location which was sampled by both the ISNET and Doppler weather radars KPUX (northeast Pueblo county, CO) and KGLD (Goodland, KS). This case study will compare mesocyclone strength from KPUX and KGLD to the ISNET data during the life of this tornadic supercell storm.

2. ISNET BACKGROUND

Specific information on how the ISNET system works is described in an accompanying paper in this volume (Bedard et. al., 2004), and only a simplified description is given here. Figure 1 shows a typical data plot for the infrasound data which was measured at NWS Pueblo, Colorado. Data plotted in Figure 1 are correlation coefficients, with the Y axis being azimuth, the X axis being time (UTC). The correlation coefficient, R, is related to the signal to noise ratio, S/N, with a value of R = 0.5 corresponding to S/N = 1. In Figure 1, correlation coefficients < 0.5 are plotted in white, correlation coefficients between 0.5 and < 0.6 are plotted in yellow, while correlation coefficients >= 0.6 are plotted in red. Each data point in Figure 1 is the maximum correlation coefficient for a processing interval of 12.8 seconds. For each processing interval an array of four sensors is cross-correlated ("beam-steered"), covering all azimuth angles and phase speeds. Passband 1 in Figure 1 represents infrasound data measured in the 1.0 to 3.5 Hz band. This band is believed to indicative of tornadic activity.

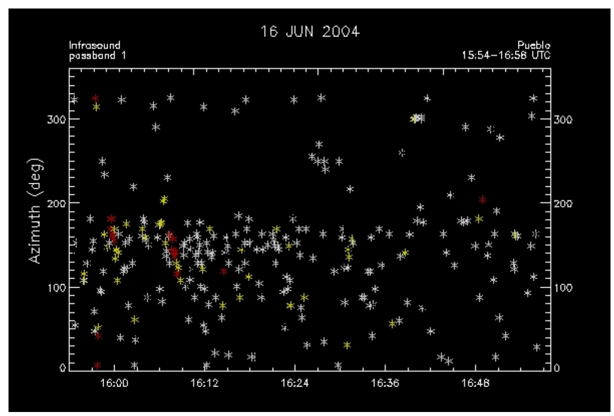

Figure 1. Plot of azimuth as a function of time of ISNET correlation coefficient data.

In a best case scenario, the correlation coefficients would be >= 0.5 (either yellow or red) and all of the data points would "line up" along an azimuth in the direction of the tornadic storm. The reader is encouraged to review figures 7 and 8 of Bedard et. al., 2004 (this volume) for examples of ISNET data detecting tornado activity.

In this paper, we compare infrasonic data (sound waves) to Doppler radar data (electro-magnetic waves). Obviously, meteorological targets detected by a Doppler radar arrive "instant-aneously" to the radar site, while the sound waves caused by a vortex can take many minutes to

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arrive at the ISNET site (dependent on the distance between the vortex and the ISNET site). In the figures below, the times of the radar signals and ISNET signals are the times of when the data arrived at each remote detection device, and no correction for the time of arrival of the ISNET data in the figures was made. It should be noted, however, in each figure, the time of travel of the sound waves between the source (tornadic supercell storm in Bent county, CO) and the location of the ISNET site is noted.

3. METHODOLOGY OF RADAR DATA

In order to compare storm rotation (Vr shear) to the infrasonic data (correlation coefficients), Storm relative velocity data from KPUX and KGLD was analyzed. Due to limitations of the current Warning Event Simulator, the legacy WSR-88D Doppler radar Vr shear values were used in this paper (It is hoped that true shear values will be available for the time of the conference as a WES upgrade is scheduled for late this summer). Shear in this study was calculated by measuring the maximum inbound and outbound velocity associated with the mesocyclone, and dividing this number by 2.

4. RESULTS

Meteorological conditions were favorable for rotating thunderstorms over southeast Colorado on 16 June 2004. Around 1900 UTC, a supercell thunderstorm developed over Bent County, Colorado, approximately 85 miles east-southeast (~110 degrees) of the Pueblo infrasonic network. This storm went on to produce 5 tornadoes, all of which were observed by experienced storm chasers, between 2058 UTC and 2248 UTC. In this section, we will compare the infrasonic data from the three ISNET sites to Vr shear, and the time of tornado occurrences between the times of 2000 UTC and 2300 UTC.

Figure 2 shows the KPUB ISNET data, Vr shear from KPUX and the time of tornado occurrences. In this figure, ISNET data was available from 2009 UTC to 2224 UTC. The tornadic supercell storm was located from 110-120 degrees from the KPUB ISNET site. The time delay between an infrasonic source caused by a vortex and it being detected at the KPUB ISNET site is approximately 7 minutes. During this entire period of time, moderate to strong rotation was indicated by the KPUX Doppler radar with the supercell storm in Bent county, CO. Four of the 5 tornadoes occurred during this time.

Except for the time periods around 2012 UTC and 2024 UTC, the ISNET data in Figure 2 did not show a well defined signal along the 110-120 degree azimuth. Correlation coefficients were typically below 0.5 during the entire time period. During the actual time of the tornadoes, no clear infrasonic signal was detected.

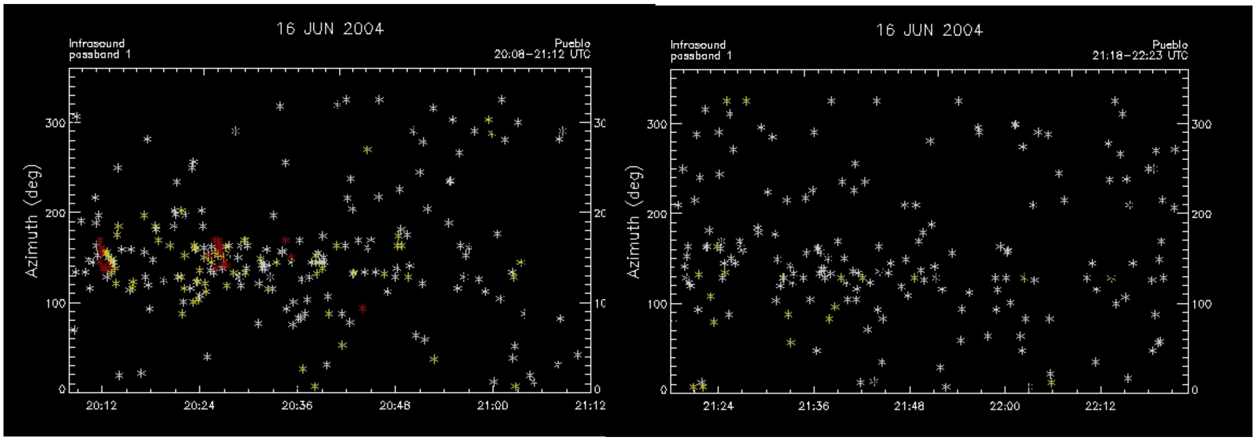
Figure 3 shows the KGLD ISNET data, Vr shear from KPUX and the time of tornado occurrences. In this figure, ISNET data was available from 2018 UTC to 2230 UTC. The tornadic supercell storm was located from 210-220 degrees from the KGLD ISNET site. The time delay between an infrasonic source caused by a vortex and it being detected at the KGLD ISNET site is approximately 11 minutes. During this entire period of time, moderate to strong rotation was indicated by the KPUX Doppler radar with the supercell storm in Bent county, CO. Four of the 5 tornadoes occurred during this time.

The ISNET data in Figure 3 did not show a well defined signal along the 210-220 degree azimuth. Correlation coefficients were typically below 0.5 during the entire time period. During the actual time of the tornadoes, no clear infrasonic signal was detected.

Figure 4 shows the BAO ISNET data, Vr shear from KPUX and the time of tornado occurrences. In this figure, ISNET data was available from 2148 UTC to 2254 UTC. The tornadic supercell storm was located from 145-155 degrees from the BAO ISNET site. The time delay between an infrasonic source caused by a vortex and it being detected at the BAO ISNET site is approximately 20 minutes. During this entire period of time, moderate to strong rotation was indicated by the KPUX and KGLD Doppler radars with the supercell storm in Bent county, CO. Four of the 5 tornadoes occurred during this time.

A strong infrasonic signal was being detected by the BAO site, especially between 2236 and 2254 UTC. However, this signal was being detected around the 250 degree azimuth, which is a direction pointing into the mountains. It is unknown what the ISNET system was detecting along this azimuth during this time period.

In the direction of the tornado activity, 145-155 degree azimuth, no well defined infrasonic signal was being detected at the BAO ISNET site during



3.4°	**43**	**38**	**43**	**45**	**40**	**43**	**40**	**40**	**43**	**43**	**26**	**43**	**45**	**43**	**40**	**45**	**48**	**38**	**38**	**48**	**48**	**48**	**48**	**xx**	**48**	**33**
2.4°	**36**	**31**	**43**	**43**	**31**	**45**	**31**	**xx**	**40**	**48**	**31**	**40**	**33**	**50**	**48**	**33**	**33**	**31**	**43**	**43**	**50**	**50**	**50**	**48**	**43**	**40**
1.5°	**26**	**31**	**45**	**43**	**31**	**38**	**7**	**31**	**36**	**31**	**31**	**36**	**33**	**36**	**29**	**33**	**43**	**43**	**38**	**43**	**50**	**50**	**50**	**50**	**35**	**26**
0.5°	**33**	**33**	**33**	**38**	**38**	**40**	**xx**	**40**	**xx**	**xx**	**xx**	**xx**	**33**	**50**	**xx**	**xx**	**xx**	**43**	**48**	**50**	**50**	**50**	**xx**	**50**	**43**	**40**
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Figure 2. Plot of azimuth as a function of time for the KPUB ISNET site from 2012 UTC to 2224 UTC. Below the plots are the KPUX shear values (in knots) at 3.4°, 2.4°, 1.5° and 0.5°."xx" represent missing radar velocity data (either range folded, dealiased or non observable data). The small "TT" are the time of tornado occurrences. During this time, the supercell storm producing the tornadoes was located ~115 degrees azimuth from the PUB ISNET site. It takes ~7 minutes for sound waves to travel from the site of the tornadic storm to the KPUB ISNET site.

the time of tornado activity.

5 CONCLUSION

In this case, the ISNET data for all three sites did not show high correlations along the azimuth in which the vortices (tornadoes) were occurring. It is believed the refractive properties of the atmosphere on this date were not favorable for near ground propagation of sound waves. More information regarding the strengths and weaknesses of the ISNET system can be found in R. Jones, et. al., 2004 (this volume).

It should be noted that another ISNET companion paper comparing tornado activity to ISNET data did find promising results. Please see Szoke et. al., this volume.

6 ACKNOWLEDGMENTS

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7 REFERENCES

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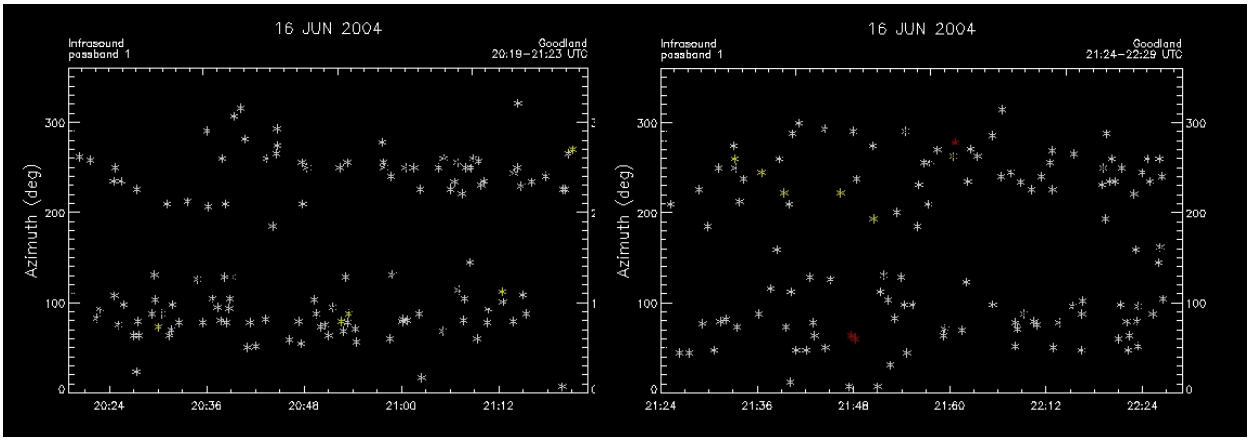

3.4°	**43**	**45**	**40**	**43**	**40**	**40**	**43**	**43**	**26**	**43**	**45**	**43**	**40**	**45**	**48**	**38**	**38**	**48**	**48**	**48**	**48**	**xx**	**48**	**33**	**25**
2.4°	**43**	**43**	**31**	**45**	**31**	**xx**	**40**	**48**	**31**	**40**	**33**	**50**	**48**	**33**	**33**	**31**	**43**	**43**	**50**	**50**	**50**	**48**	**43**	**40**	**26**
1.5°	**45**	**43**	**31**	**38**	**7**	**31**	**36**	**31**	**31**	**36**	**33**	**36**	**29**	**33**	**43**	**43**	**38**	**43**	**50**	**50**	**50**	**50**	**35**	**26**	**30**
0.5°	**33**	**38**	**38**	**40**	**xx**	**40**	**xx**	**xx**	**xx**	**xx**	**33**	**50**	**xx**	**xx**	**xx**	**43**	**48**	**50**	**50**	**50**	**xx**	**50**	**43**	**40**	**30**

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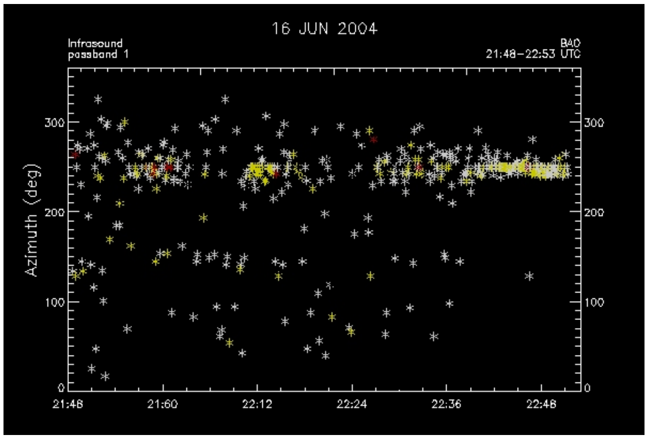
Figure 3. Plot of azimuth as a function of time for the KGLD ISNET site from 2018 UTC to 2230 UTC. Below the plots are the KPUX shear values (in knots) at 3.4°, 2.4°, 1.5° and 0.5°."xx" represent missing radar velocity data (either range folded, dealiased or non observable data). The small "TT" are the time of tornado occurrences. During this time, the supercell storm producing the tornadoes was located ~215 degrees azimuth from the KGLD ISNET site. It takes ~11 minutes for sound waves to travel from the site of the tornadic storm to the KGLD ISNET site.



3.4º	**38**	**48**	**48**	**48**	**48**	**xx**	**48**	**33**	**25**				
2.4º	**43**	**43**	**50**	**50**	**50**	**48**	**43**	**40**	**26**				
1.5º	**38**	**43**	**50**	**50**	**50**	**50**	**35**	**26**	**30**				
0.5º	**48**	**50**	**50**	**50**	**xx**	**50**	**43**	**40**	**30**	**38**	**33**	**45**	**50**

TTT ***TTT*** ***TTTT*** ***TTTTTTT***

Time (utc) => 21:48 22:00 22:12 22:24 22:36 22:48

Figure 4. Plot of azimuth as a function of time for the BAO ISNET site from 2148 UTC to 2254 UTC (ISNET data from BAO was not available prior to 2148 UTC) . Below the plot are the KPUX shear values (in knots) at 3.4º, 2.4º, 1.5º and 0.5º. The last 4 shear values at 0.5º are from WSR-88D KGLD as data from KPUX was not available. Only the lowest radar slice was available from KGLD. "xx" represent missing radar velocity data (either range folded, dealiased or non observable data). The small "TT" are the time of tornado occurrences. During this time, the supercell storm producing the tornadoes was located ~150 degrees azimuth from the BAO ISNET site. It takes ~20 minutes for sound waves to travel from the site of the tornadic storm to the BAO ISNET site.