A Challenging Tornado Event on the Weather Event Simulator

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Introduction

On the afternoon of 25 July 2004 a small area of thunderstorms moved across south central Montana producing marginally severe sized hail and sub severe wind gusts. The exception was one storm that intensified and became a right mover with supercell characteristics, including a hook. As the storm crossed a highway running through a rural area, a tornado (as indicated by storm surveys), developed causing considerable damage to a few mobile homes that were not properly anchored to the ground. The tornado then apparently dissipated as the storm continued to intensify. The storm maintained supercell characteristics for over 45 minutes, however additional tornadoes or damage were not reported.

The meteorological environment in which the storm and tornado developed in was not typical of supercell tornadoes, as observational and model data suggest CAPE values were under 500 J/kg with minimal CAPE below 3 km and surface dewpoint spreads greater than 30 F (Rasmussen and Blanchard 1998; Rasmussen 2003; Thompson et al. 2003). Since this was such a challenging case due to rapid thunderstorm development and tornadogenesis in a somewhat benign environment for supercells, meteorologists at WFO Billings went through this case on the WES. The simulation focused on gaining a grasp of the near storm environment by picking up on subtle clues to help anticipate rapid storm development and the tornado potential. This paper will briefly discuss some of the subtle clues that may have led to the tornado.

Meteorological Conditions and Thunderstorm Evolution

An upper level high that was centered over Colorado on 23-24 July 2003 shifted slightly east on the 25th (figure 1). In this environment, middle and upper level moisture wrapping around the high helped produced isolated, pulsing thunderstorms that brought a few reports of marginally severe sized hail on the 23rd and 24th. Late on the 24th a weak cold front pushed through the eastern half of Montana and Wyoming, causing low level flow to become easterly. Meanwhile westerly flow continued aloft. The result was an increase in shear below 700mb, however instability was low as a result of the low level cooler air behind the front. Some showers and thunderstorms moved northeast through northern Wyoming and southern Montana overnight on the 24th and through part of the morning on the 25th, possibly producing low level boundaries that lingered over the area through the afternoon. Weak short wave forcing moving north out of northwest Wyoming, hinted at in the water vapor imagery, was the primary large scale lifting mechanism of the day (figure 1).

A modified ACARS sounding from 1926Z on the 25th indicated very little CAPE, with storm tops under 35 kft, although lifting from the higher terrain does show greater instability. Figure 2 shows the sounding modified by surface observations from Billings (3570 feet) and Pryor Mountain RAWS (6612 feet) just south of Billings as the convection was developing (the tornado occurred around 4000 feet). A RUC sounding initialized at 1800Z showed slightly cooler temperatures around 700mb and stronger shear than the ACARS sounding, but still indicated low CAPE values (figure 3). The initialized 00Z RUC sounding, just prior to the greater storm development, maintained the fairly low CAPE values but also kept the fairly strong shear (figure 4). Like the ACARS sounding, the KBLX 88D VAD Wind Profile indicated the RUC was likely excessive with the shear, but not considerably bad.

Radar analysis and surface observations between 2330Z and 0022Z, just prior to the strongest convection, shows several low level boundaries present over south central Montana. The most obvious boundaries, as shown in figure 5, are fairly common terrain-induced convergent boundaries along the Yellowstone River near Billings (boundary A in figure 5) and along the Clarks Fork of the Yellowstone (boundary B in figure 5). Two additional nearly stationary boundaries may also be present south of Billings (boundary C and D in figure 5) due to convection earlier in the morning. These lines of enhanced returns could also be due to horizontal rolls. Either way, those lines appear to be regions of persistent enhanced lift and likely enhanced low level shear. Satellite imagery does not show these boundaries due to cirrus cloud cover and very little visible cumulus underneath.

As the batch of thunderstorms west of Billings around 0022Z moved into boundary B, storm development took place on the southern flank where low level convergence appears to be most intense via surface and radar observations (figure 5). Around 0045Z, one storm took on supercell characteristics with a pronounced rear flank downdraft (RFD) and storm top of 40 to 45 kft as it moved along boundary C (figure 6). About the same time there appears to be a region of lower returns moving south just ahead of the storm (denoted by the black line in figure 6). This region could be a result of several factors such as subsidence and clearing ahead of the storm, a result of outflow from convection to the north, or from the forward flank downdraft.

Another important consideration for the tornado formation may be the lack of stability associated with the RFD. The Pryor Mountain RAWS shows a temperature of 65 with a dew point of 56 just after the RFD passage, which indicates neutral instability behind the RFD per the ACARS sounding. It is possible the tornado was able to form in association with the RFD since there was not much stability behind the RFD (figure 6).

Between 0102Z and 0108Z, the tornado formed near the Yellowstone County line along boundary C. The time of the tornado coincides closely with the arrival of the southward moving boundary into the area shown in figure 6. Only weak rotation was indicated by the 8 bit velocity and SRM with little to no gate to gate shear. Figure 7 shows the 0.5 and 1.5 SRM and 8 bit reflectivity around the time of the tornado. Point A in figure 7 denotes the location where storm surveys indicate tornado damage and point B in figure 7 shows where straight line wind damage appears to have occurred (figure 8).

Discussion

Providing ample lead time for a tornado warning in this type of event is especially difficult due to the rapid development of the storm and lack of significant velocity signatures. A first glance at the meteorological conditions prior to the convection did not reveal much of a severe weather threat other than pulse type storms due to low CAPE values and weak forcing. However, close scrutiny of the radar and surface observations did reveal low level boundaries would provide increased forcing and locally stronger low level shear. This was particularly the case just south of Billings where strong low level convergence was implied. Thus, when storms moved into that region, intensification with more sustained updrafts were likely. Once the one storm began to intensify, the proximity of this storm to pre-existing boundaries (boundary C in figure 4) and strong storm inflow suggested the storm would maintain its strength for an extended period of time, unlike all other storms earlier in the day.

Predicting the rapid change in storm characteristic and especially the tornado development was less obvious than predicting the storm intensification. However, numerous journal articles such as Atkins et al. (1999) and Markowski et al. (1998) have shown the importance of low level boundaries in storm morphology and tornado occurrence. In most years, there are several storms a year in WFO Billings CWA that take on supercell characteristics with a well defined RFD and hook that do not produce tornadoes. Issuing a tornado warning on every one of those storms would lead to a high false alarm rate. However as this case shows, having a greater tendency to issue tornado warnings on similar storms that are in more favorable environments as defined in the meso-analysis severe weather guide by Pete Wolf and on storms intensifying along boundaries should help identify storms with the greatest potential of producing a tornado.

References

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Thompson, Richard L., Edwards, Roger, Hart, John A., Elmore, Kimberly L., Markowski, Paul. 2003: Close Proximity Soundings within Supercell Environments Obtained from the Rapid Update Cycle. Wea. Forecasting: Vol. 18, No. 6, pp. 1243-1261

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Figure 1

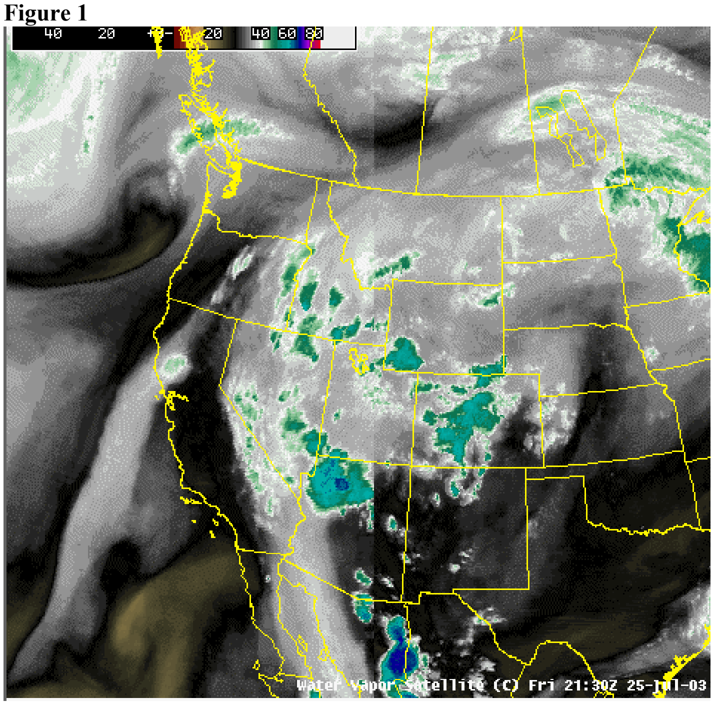


Figure 2

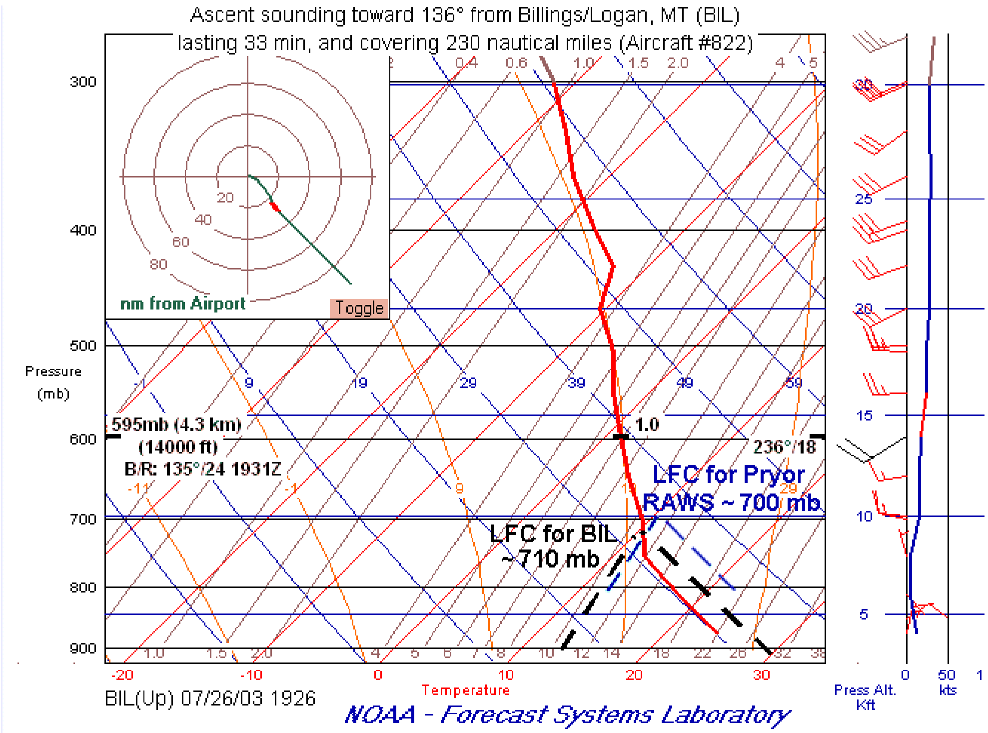


Figure 3

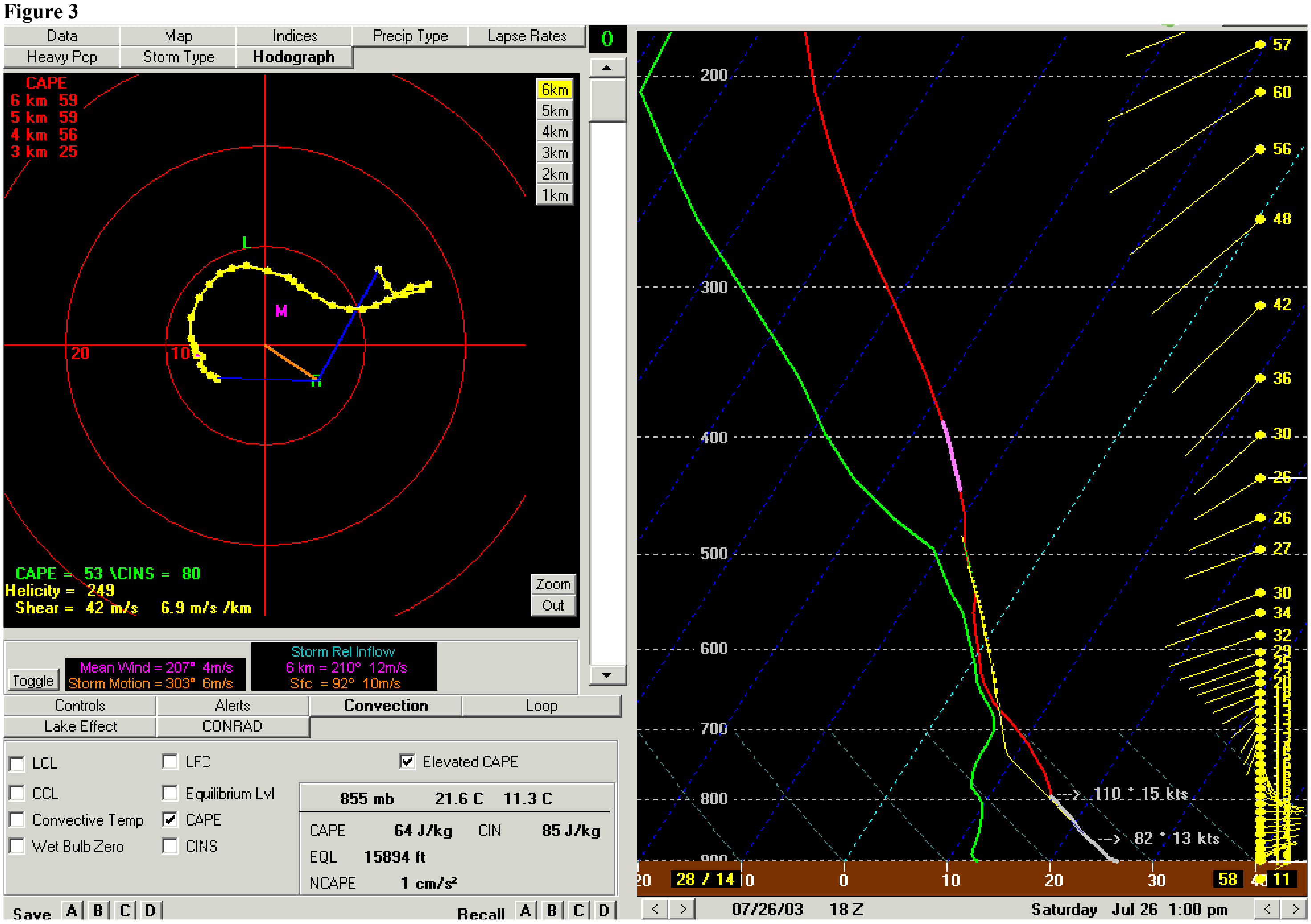


Figure 4

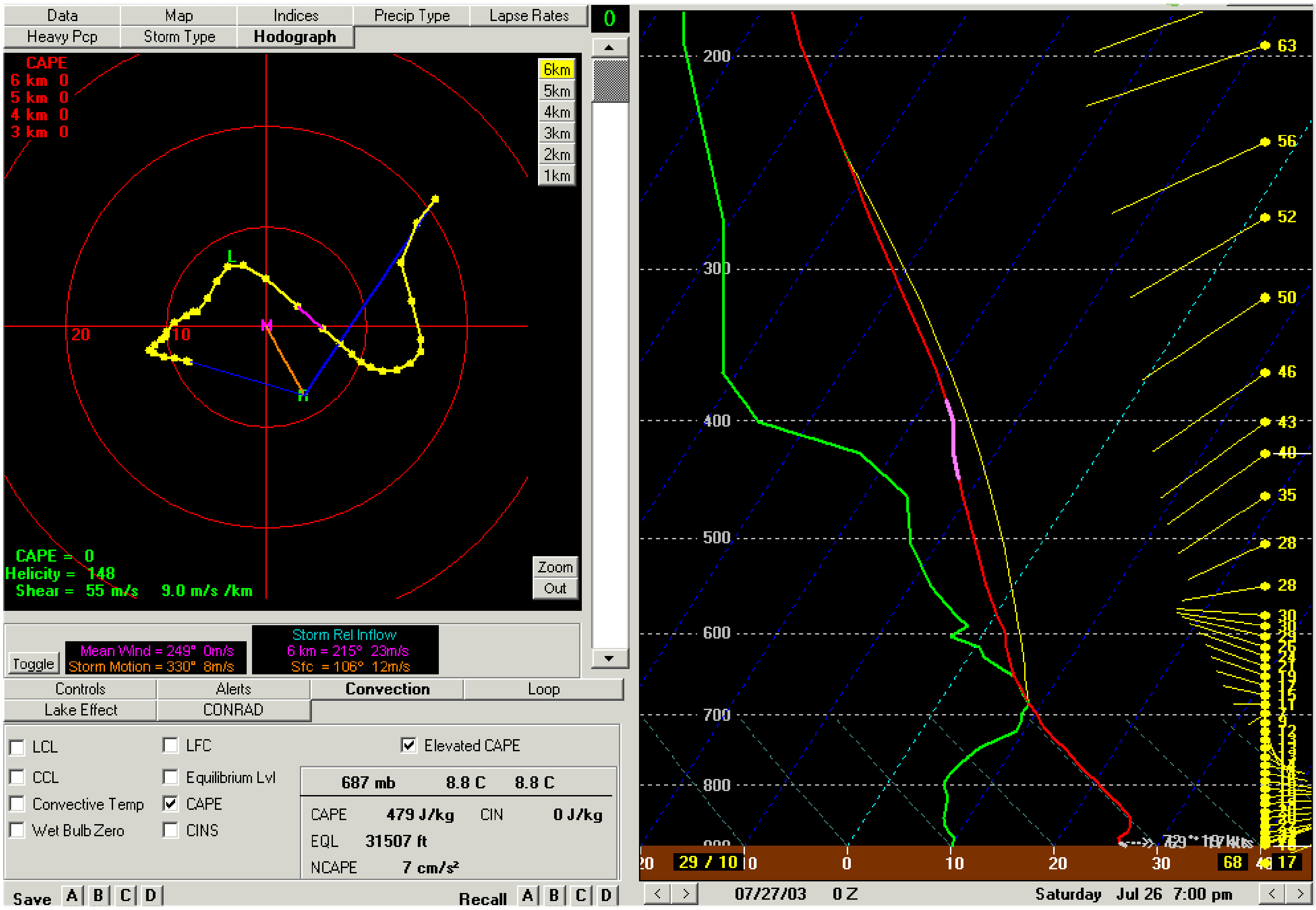


Figure 5

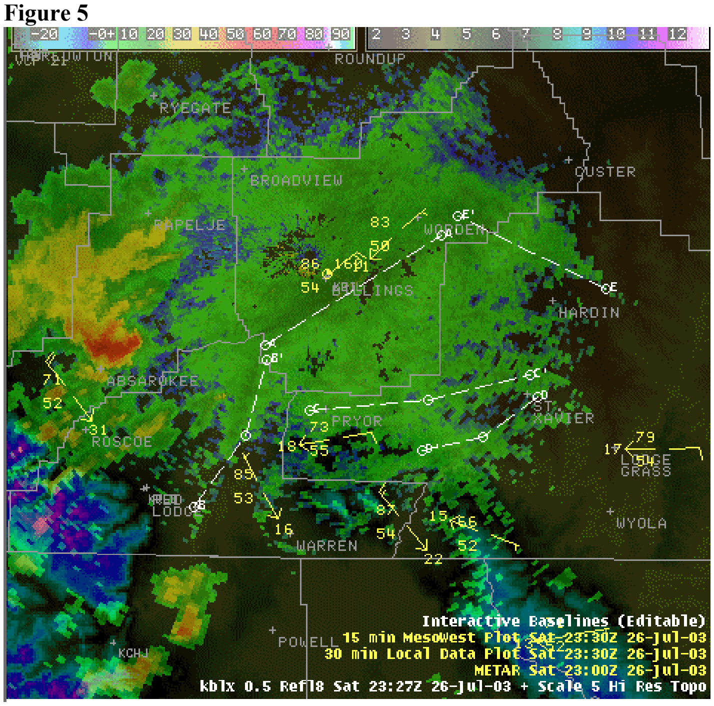


Figure 6

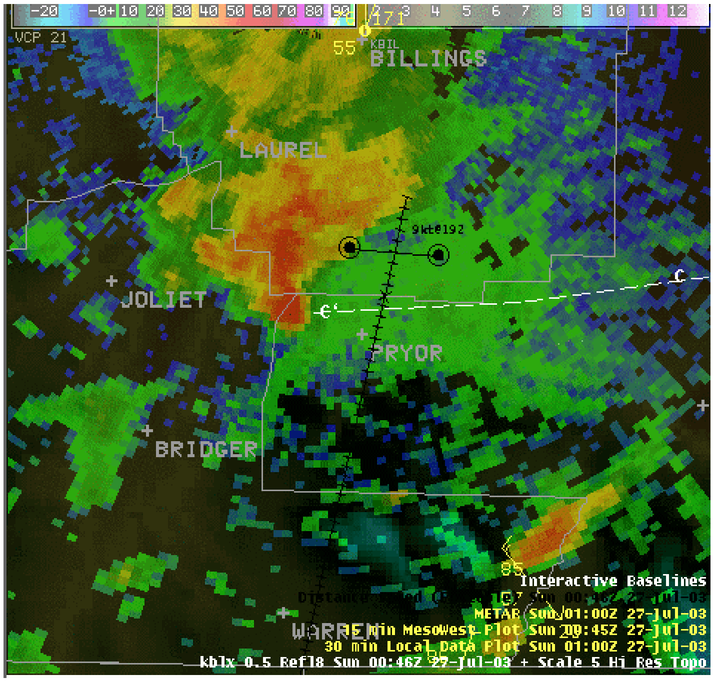
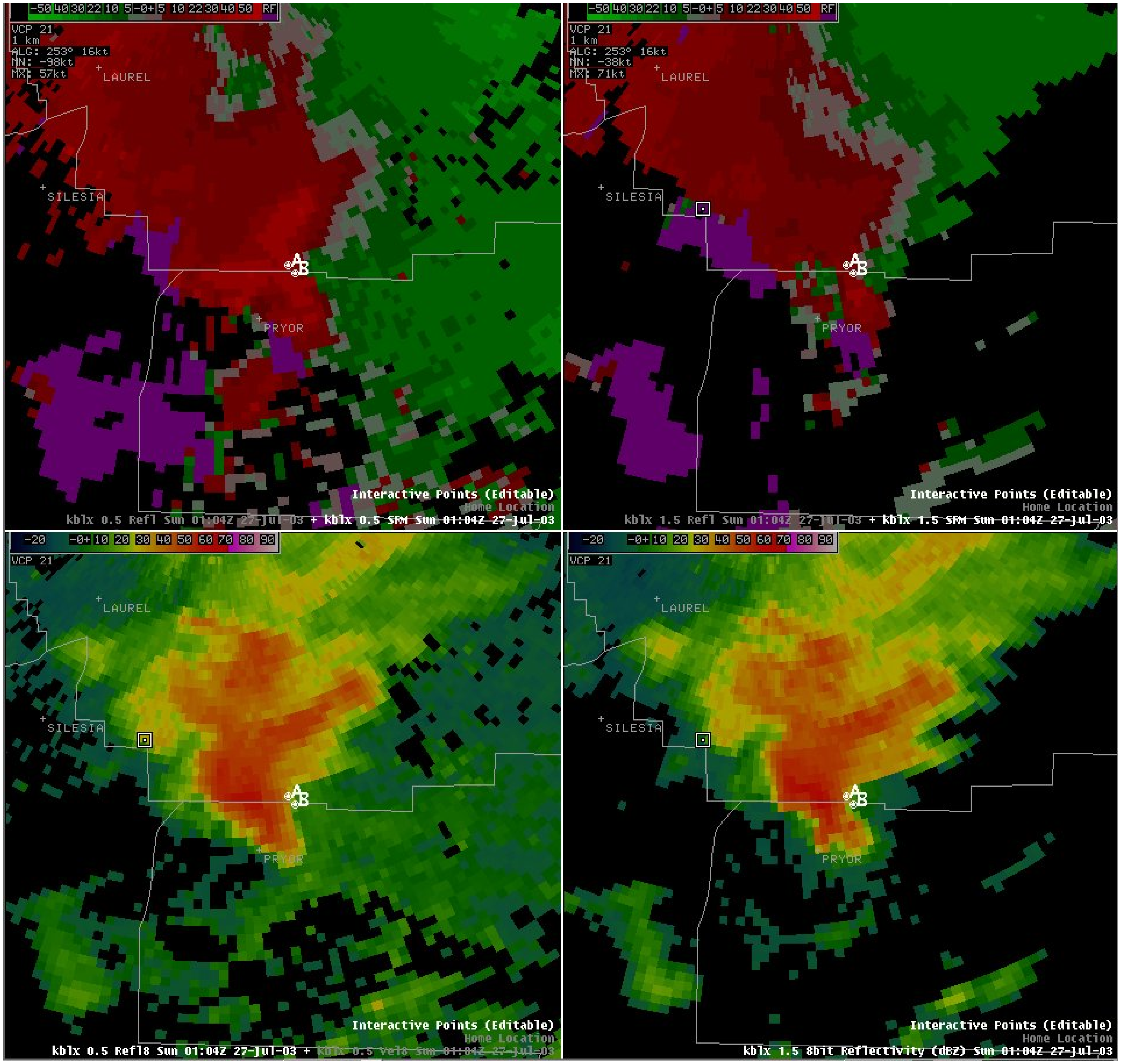

VCP 21
BILLINGS
LAUREL
JOLIET
PRYOR
BRIDGER
WARREN
9kt@192
Interactive Baselines
METAR Sun 01:00Z 27-Jul-03
15 min MesoWest Plot Sun 00:45Z 27-Jul-03
30 min Local Data Plot Sun 01:00Z 27-Jul-03
kblx 0.5 Refl8 Sun 00:46Z 27-Jul-03 + Scale 5 Hi Res Topo

Figure 7


VCP 21
1 km
ALG: 253° 16kt
NN: -98kt
MX: 57kt
LAUREL
SILESIA
PRYOR
Interactive Points (Editable)
Home Location
kblx 0.5 Refl Sun 01:04Z 27-Jul-03 + kblx 0.5 SRM Sun 01:04Z 27-Jul-03
VCP 21
1 km
ALG: 253° 16kt
NN: -38kt
MX: 71kt
LAUREL
SILESIA
PRYOR
Interactive Points (Editable)
Home Location
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VCP 21
LAUREL
SILESIA
PRYOR
Interactive Points (Editable)
Home Location
kblx 0.5 Refl8 Sun 01:04Z 27-Jul-03 + kblx 0.5 Vel8 Sun 01:04Z 27-Jul-03
VCP 21
LAUREL
SILESIA
PRYOR
Interactive Points (Editable)
Home Location
kblx 1.5 8bit Reflectivity (dBZ) Sun 01:04Z 27-Jul-03

Figure 8

Figure 8. Tornado damage to a poorly anchored mobile home. The horse trailor in the background was apparently moved a few hundred feet without touching the ground.