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A Post Mortem Examination of the 26 June 1996 Splitting-Cell Thunderstorm in Western Montana

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Introduction

This Technical Attachment (TA) provides a closer look at a splitting-cell thunderstorm which occurred on 26 June 1996, along the east slopes of the Continental Divide region of Montana (see Fig. 1). Splitting-cell thunderstorm events are somewhat of a rarity in this region.

General Climatology of the East Slopes of the Continental Divide Region of Montana for the Month of June

June is normally the wettest month of the year for the east slopes of the Continental Divide region in Montana. Average precipitation ranges from 1.91 to 3.01 inches in this region during the month of June (Climatological Data Annual Summary, Montana, 1995). The predominate airmass is one of moist and unstable characteristics, primarily induced by a prevailing moist, southwesterly upper-level flow from the Pacific Ocean. A quasi-stationary surface low-pressure pattern over southern Montana creates upslope conditions in the east slopes region. Coupling of the upslope conditions and moist upper-level southwest flow, creates a robust environment for thunderstorm formation.

Description of the Storm Environment

On 26 June 1996, a deep geopotential low was situated along the California coastline (Fig. 2). Strong southwesterly flow transported Pacific moisture to western Montana throughout the day. The right rear quadrant of a 46 ms^{-1} jet maxima was positioned over the east slopes region that afternoon (see Fig. 2). Surface low pressure (at 2100 UTC) along the Montana - Wyoming border was producing weak upslope conditions in the east slopes region (Fig. 3), at the time the thunderstorm under investigation was forming.

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Environmental stability was very weak, with Convective Available Potential Energy (CAPE) and Lifted Index (LI) values (extrapolated from the 0000 UTC Great Falls sounding) in excess of 2600 Jkg^{-1} and -8 °C, respectively. This magnitude of CAPE would translate to a maximum possible updraft strength of 72 ms^{-1}, using $w_{max} = (2CAPE)^{-2}$. However, Weisman and Klemp (1986) point out that water loading, perturbed vertical pressure gradients, and mixing effects reduce these estimates by roughly 50 percent. Employing this 50 percent reduction yields a maximum possible updraft of about 36 ms^{-1}.

A radar derived hodograph, using the Radar Coded Message (RCM), created for 2144 UTC (just prior to cell-split of the storm under investigation), shows primarily speed shear (a fairly straight line hodograph) in the vertical above the planetary boundary layer (see Fig. 4), with a storm relative helicity value of 90 m^2s^{-2}. When the hodograph is more or less a straight line, the most likely development within this moderate to large range of shears is splitting-cell thunderstorms (e.g., Doswell 1991; Weisman and Klemp 1986), with the main updraft splitting into two quasi-steady state storms moving to the right and left of the environmental wind. The right- and left-moving updrafts rotate cyclonically and anticyclonically, respectively.

Radar Perspective of the Storm

The initial thunderstorm began its rapidly-developing life cycle near 2130 UTC 26 June 1996, 38 km southwest of Great Falls. By 2154 UTC, the storm exhibited splitting-cell characteristics (see Fig. 5). The storm was moving from the southwest at 4 ms^{-1}. Five volume scans later (2219 UTC), it was clearly evident that the initial storm had split into two distinct cells, with one moving to the right and the other moving to the left of the mean environmental wind (see Fig. 6).

A. Right-Moving Cell

An appendage appeared on the south side of the right-moving cell (rightmost echo core on Fig. 6) and is believed to be an artifact of the forward flanking line (FFL). The Great Falls radar (KTFX) did detect a Tornadic Vortex Signature (TVS) at the 1.5 degree elevation slice at 2214 UTC, but close inspection (by forecasters on duty during the event) of the base velocity products at several elevation slices did not reveal substantial circulation patterns. The appendage seen on the base reflectivity product disappeared on the next volume scan as well. Based on these analyses, forecasters on duty chose not to issue a tornado warning.

At 2224 UTC the right-moving cell began developing strong cyclonic circulation; a 18 ms^{-1} rotational velocity 56 km from the KTFX Radar Data Acquisition unit (RDA). Using the Norman, Oklahoma Operational Support Facility (OSF) mesocyclone recognition criteria (Andra et al., 1994), this indicates that the rotation meets the moderate mesocyclone criteria. Two volume scans later the cyclonic rotation had decreased slightly in magnitude. Because of the persistence of this radar feature and its consistency in the vertical, a tornado warning was issued at 2233 UTC. From 2234 UTC - 2238 UTC the rotational velocity increased to 28 ms^{-1} 45 km from the KTFX RDA, indicative of a strong mesocyclone (off the scale of the mesocyclone recognition criteria chart). By 2243 UTC the strong mesocyclone signature (on velocity products) had disintegrated, however, the tornado warning was allowed to remain in effect for another 30 minutes.

Unfortunately the Great Falls office was not able to obtain ground-truth confirmation of a tornado. Science and Operations Officer (SOO) David Bernhardt conducted a site survey of the area affected by this tornadic event on 27 June 1996. The area is comprised of primarily pasture land with few structures, trees or power lines. This caused difficulty in determining whether a tornado actually occurred. Severe weather spotters in the vicinity witnessed no condensation funnel, even though surface dewpoint temperatures were near 16 °C; very high for this part of Montana. Dave Bernhardt surmised that at the very least there were strong winds (near 44 ms^{-1}) during the event, based on damage of fences and grain crops.

One of the interesting things about this event was that neither cell was dominate, i.e., they both maintained a very coherent structure for nearly the same amount of time. Normally it is the right-moving cell which tends to become the dominate cell .

B. Left-Moving Cell

The left moving cell traversed a path nearly straight north throughout its life span (see Fig. 7). It was clear from the radar velocity products that this storm had coherent anticyclonic rotation (see Fig. 8). Interestingly the left-moving cell exhibited a structure that Houze et al. (1993) dubbed a false-hook left mover (see Fig.6). A true hook, which should occur on the north side of the storm, rather than on the south side, gives the storm an appearance contradictory to that of a hypothetical mirror image of a classic right-moving thunderstorm.

As Houze et al. (1993) explained, in this false-hook configuration the hook-echo appendage wraps around the west side of the storms downdraft, whereas in a hypothetical mirror image of a classic right mover it would wrap around the west side of the updraft. Figure 9 shows the conceptualization of the low-level kinematic and radar reflectivity patterns of the false-hook left mover (compare to the reflectivity pattern seen in the left-mover in Fig. 6).

Both cells had dissipated by 0030 UTC 27 June 1996, and did have a history of producing hail in the 19 - 45 mm range (well above the National Weather Service severe thunderstorm criteria). As mentioned earlier in this text, neither cell was dominate throughout their life spans.

Summary

This TA has taken a closer look at a classic splitting-cell thunderstorm that occurred in the east slope of the Continental Divide region of Montana. This storm and the storm environment exhibited many of the characteristics seen in splitting-cell thunderstorms seen in many parts of the central United States.

Acknowledgments

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Weisman M. L., and J. B. Klemp, 1986: Characteristics of isolated convective storms (Chap. 15). *Mesoscale Meteorology and Forecasting* (P. Ray, ed.), Amer. Meteor. Soc., Boston, 331-358.

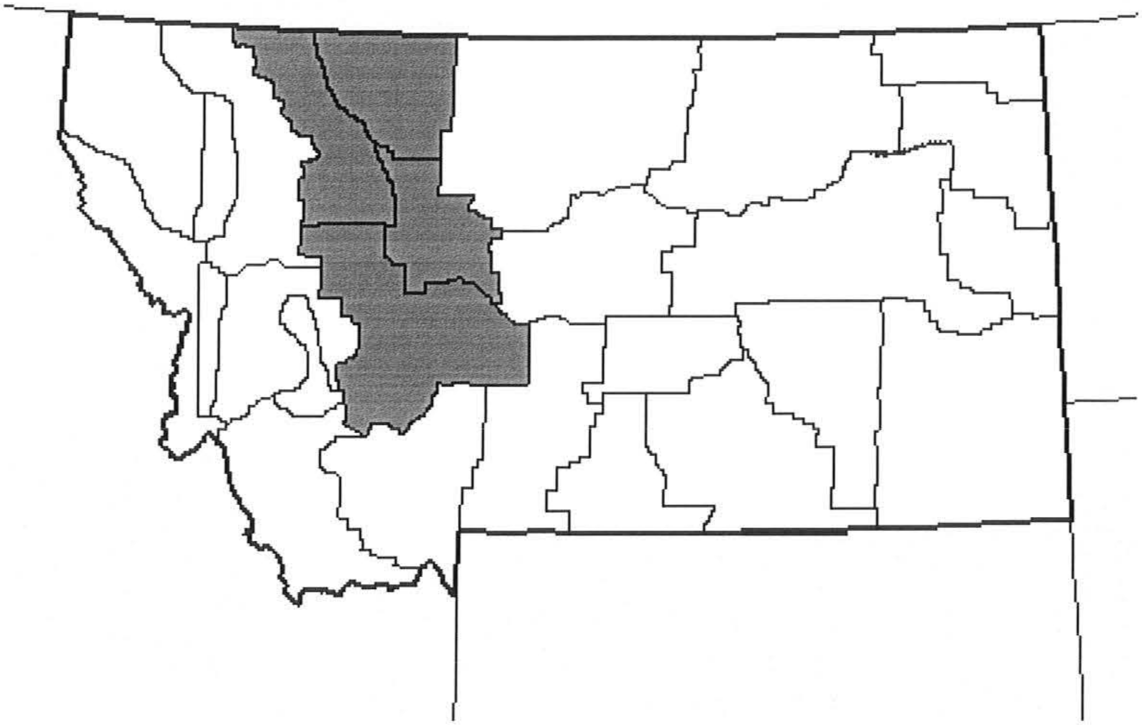

Figure 1. East slopes of the Continental Divide region of Montana (shaded area). Thin jagged lines outline the new forecast zone configuration which will become effective sometime in the fall of 1996.

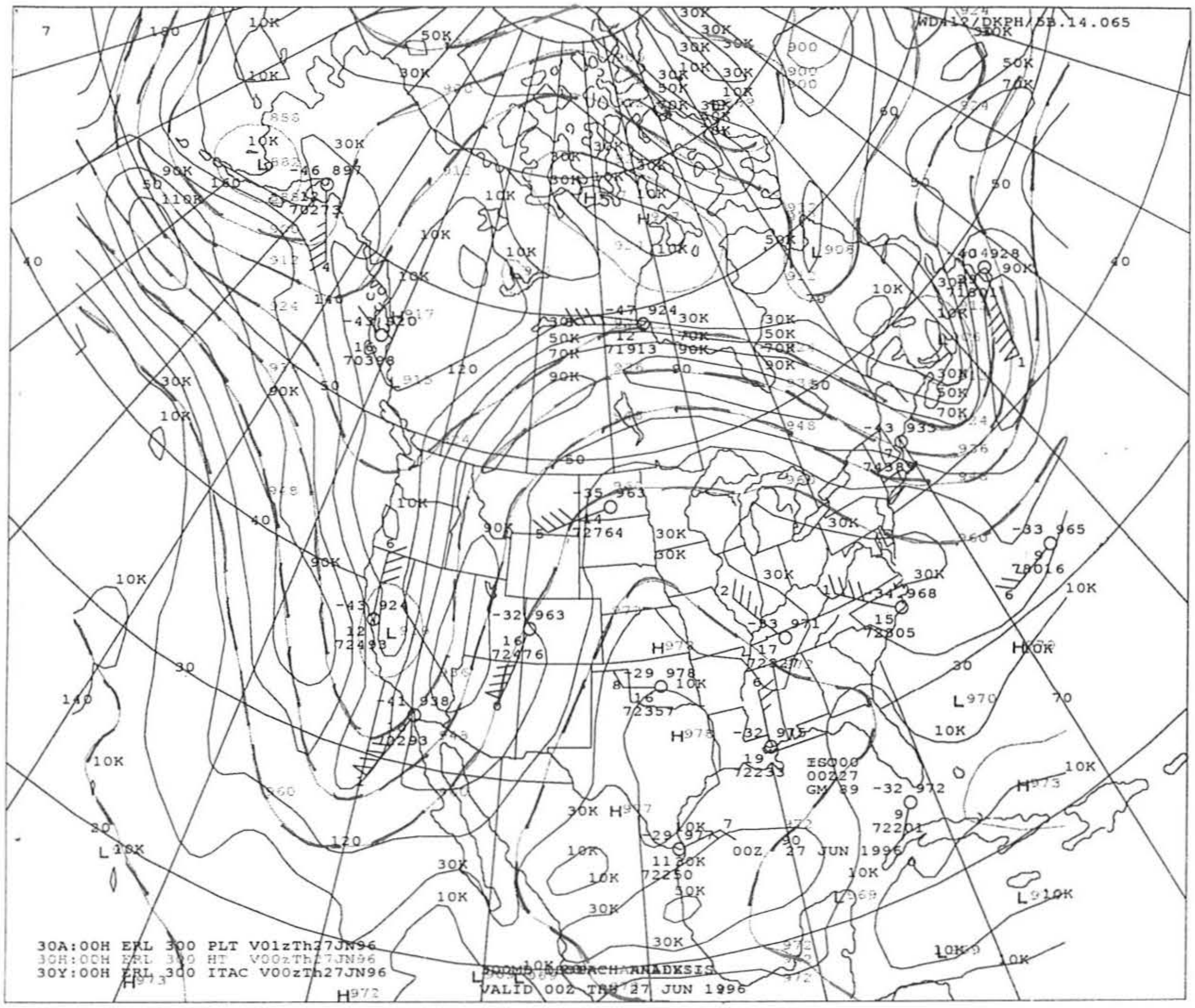

Figure 2a. 27 June 1996 0000 UTC plots of 300 mb isohypsic surfaces in meters (dashed lines), and isotachs in kt (solid lines).

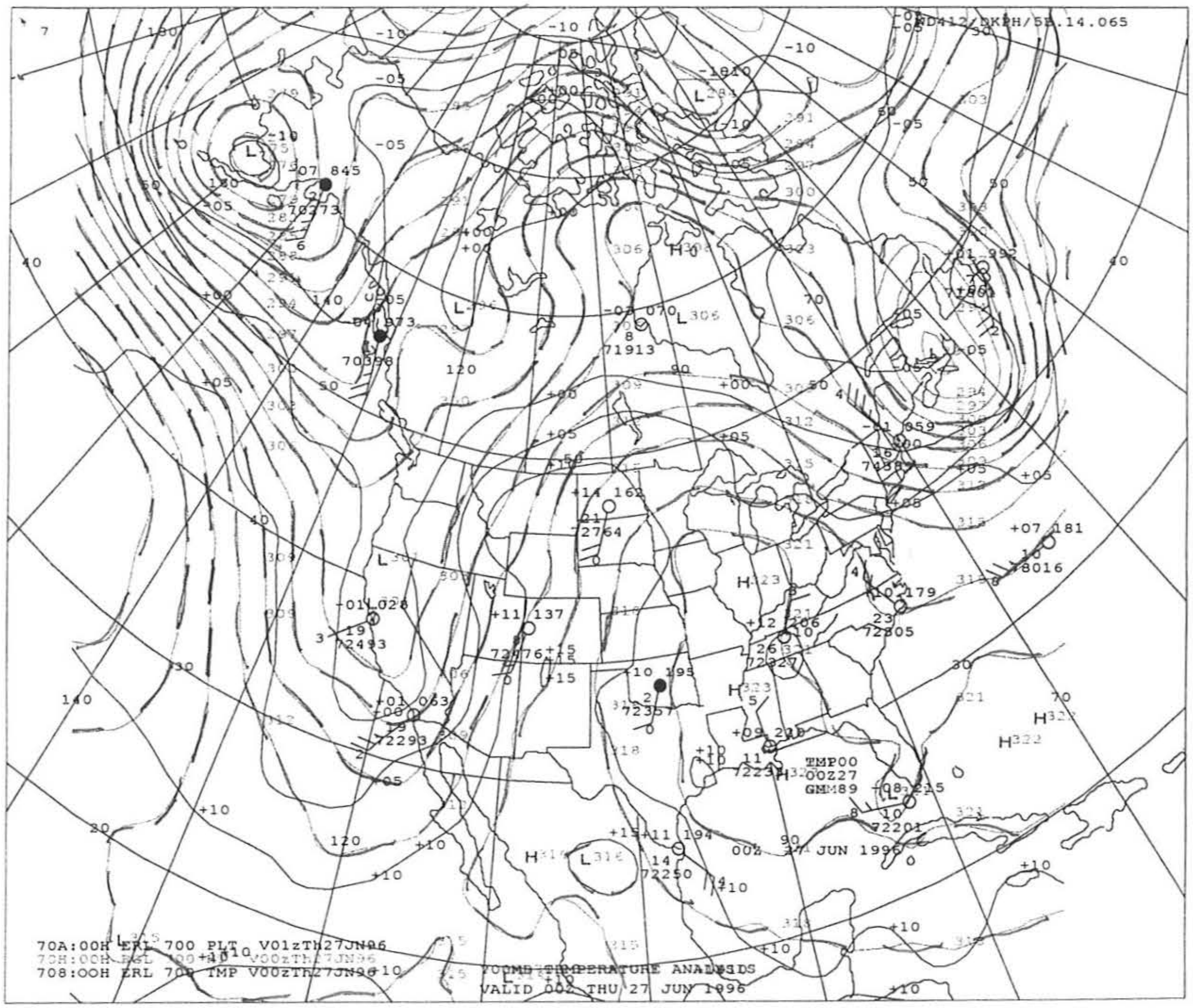

Figure 2b. 700 mb isohypsic surfaces in meters (dashed lines), and isotherms in degrees Centigrade (solid lines).

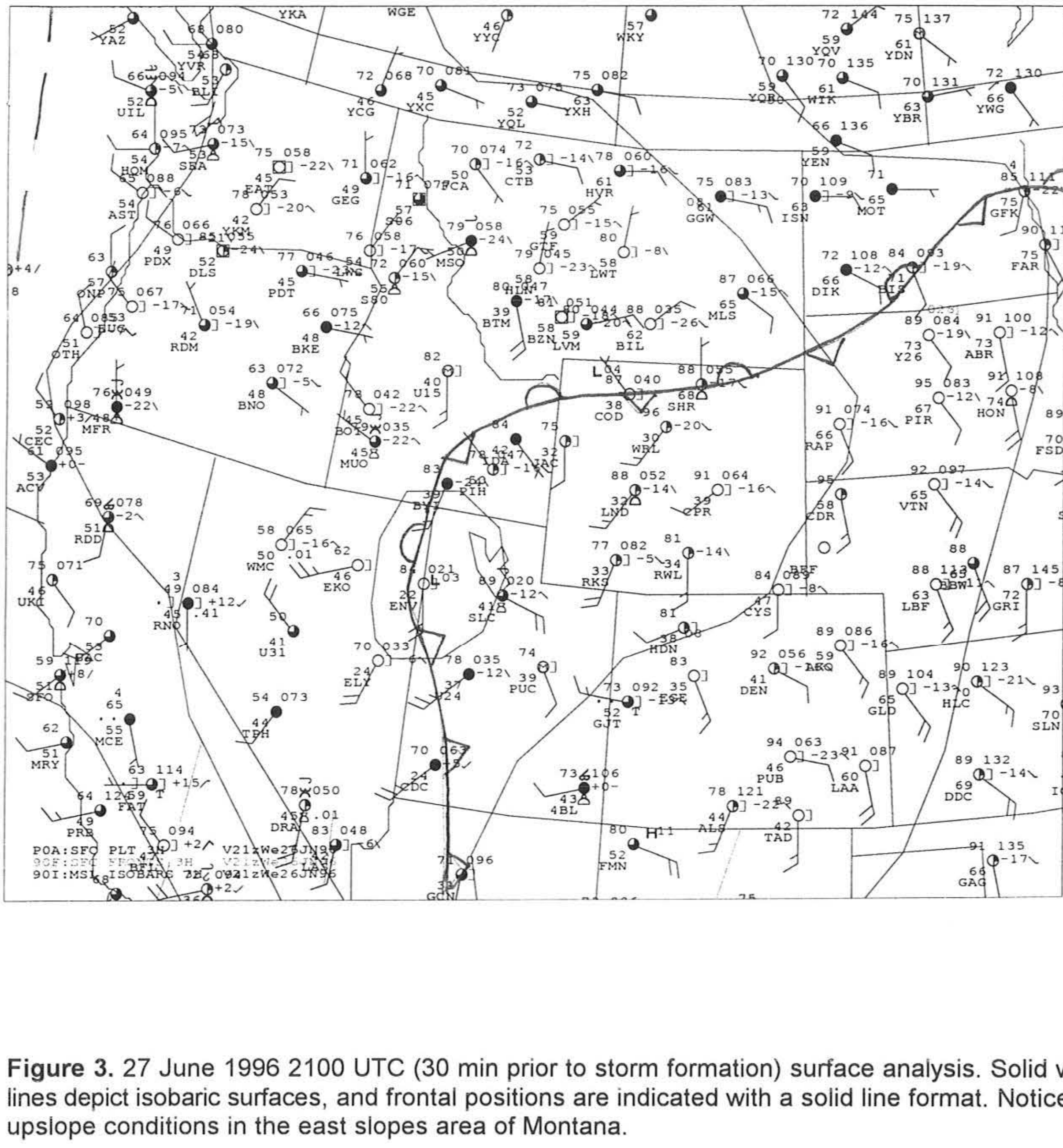

Figure 3. 27 June 1996 2100 UTC (30 min prior to storm formation) surface analysis. Solid wavy lines depict isobaric surfaces, and frontal positions are indicated with a solid line format. Notice the upslope conditions in the east slopes area of Montana.

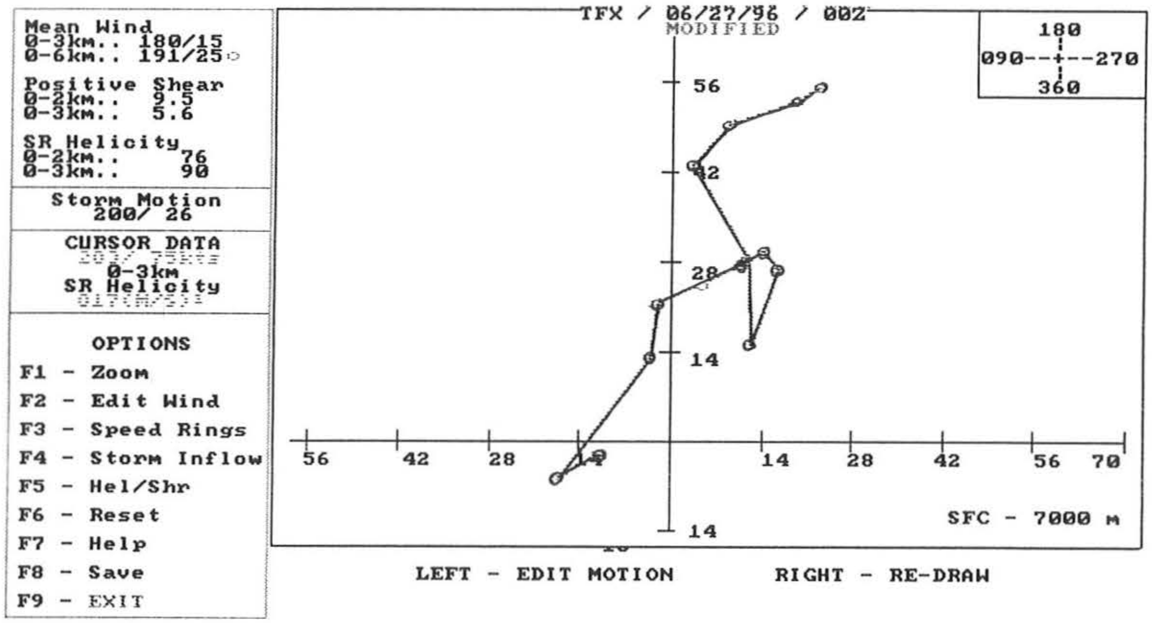

Figure 4. Radar derived hodograph at 2144 UTC; just prior to cell-splitting of the thunderstorm under investigation.

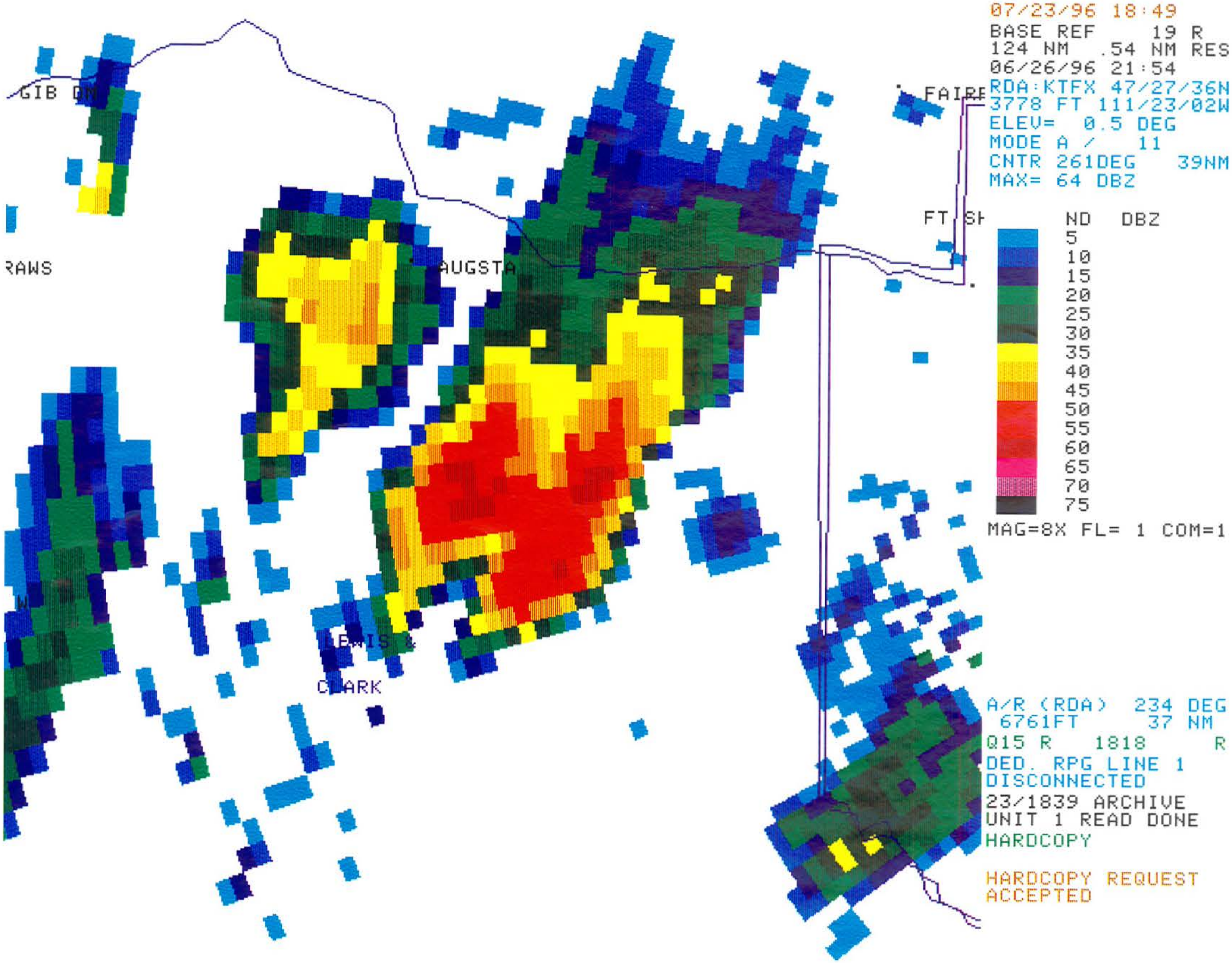

Figure 5. Great Falls radar (KTFX) base reflectivity image (0.5 degree slice) at 2154 UTC, showing evidence of cell-splitting characteristics. Great Falls is located on the right-hand side of the figure (outside the domain of the image).

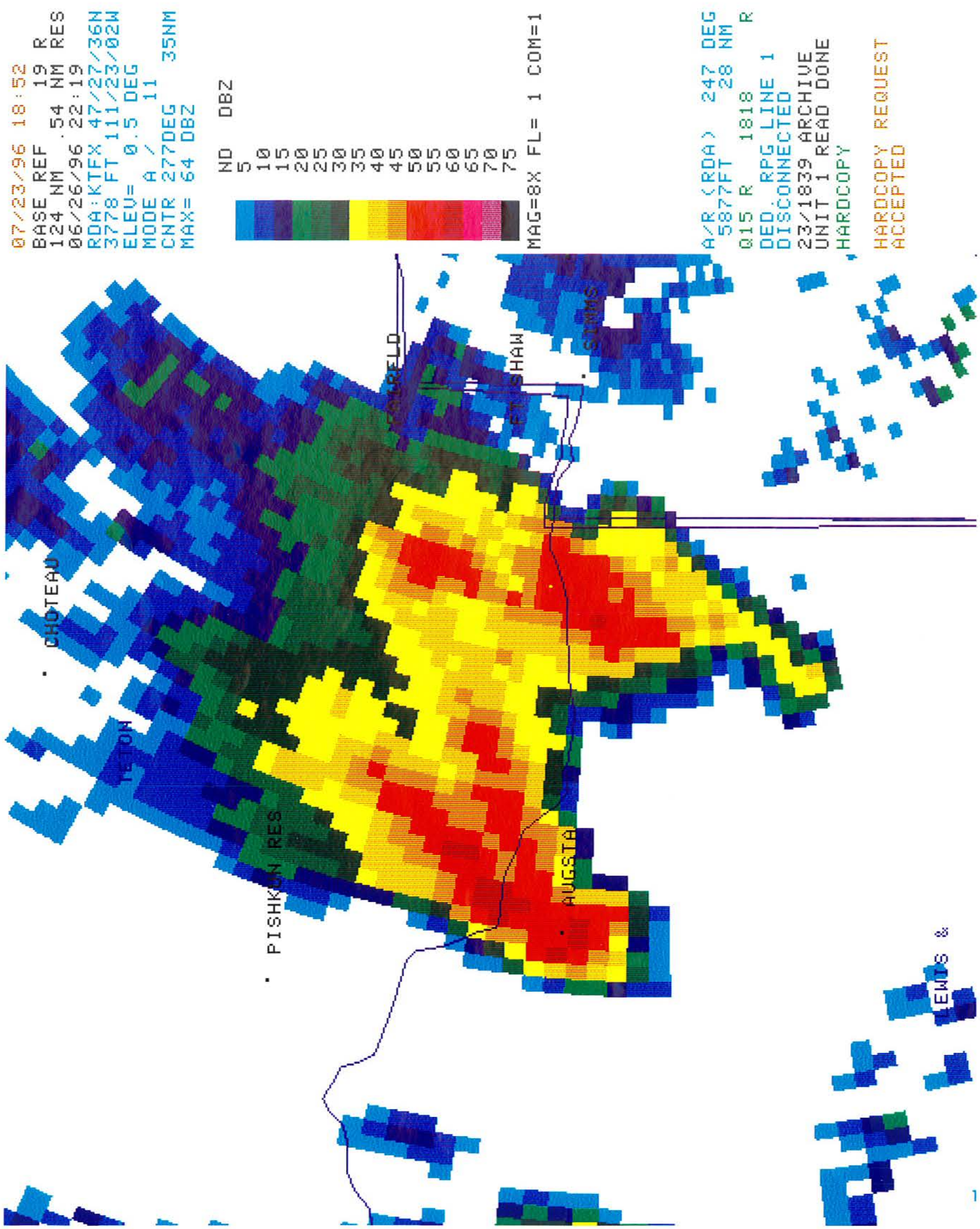

Figure 6. KTFX (0.5 degree) base reflectivity image at 2219 UTC, clearly exhibiting cell-split of the parent storm. The storm center had moved 26 km to the northeast of its position at 2154 UTC.

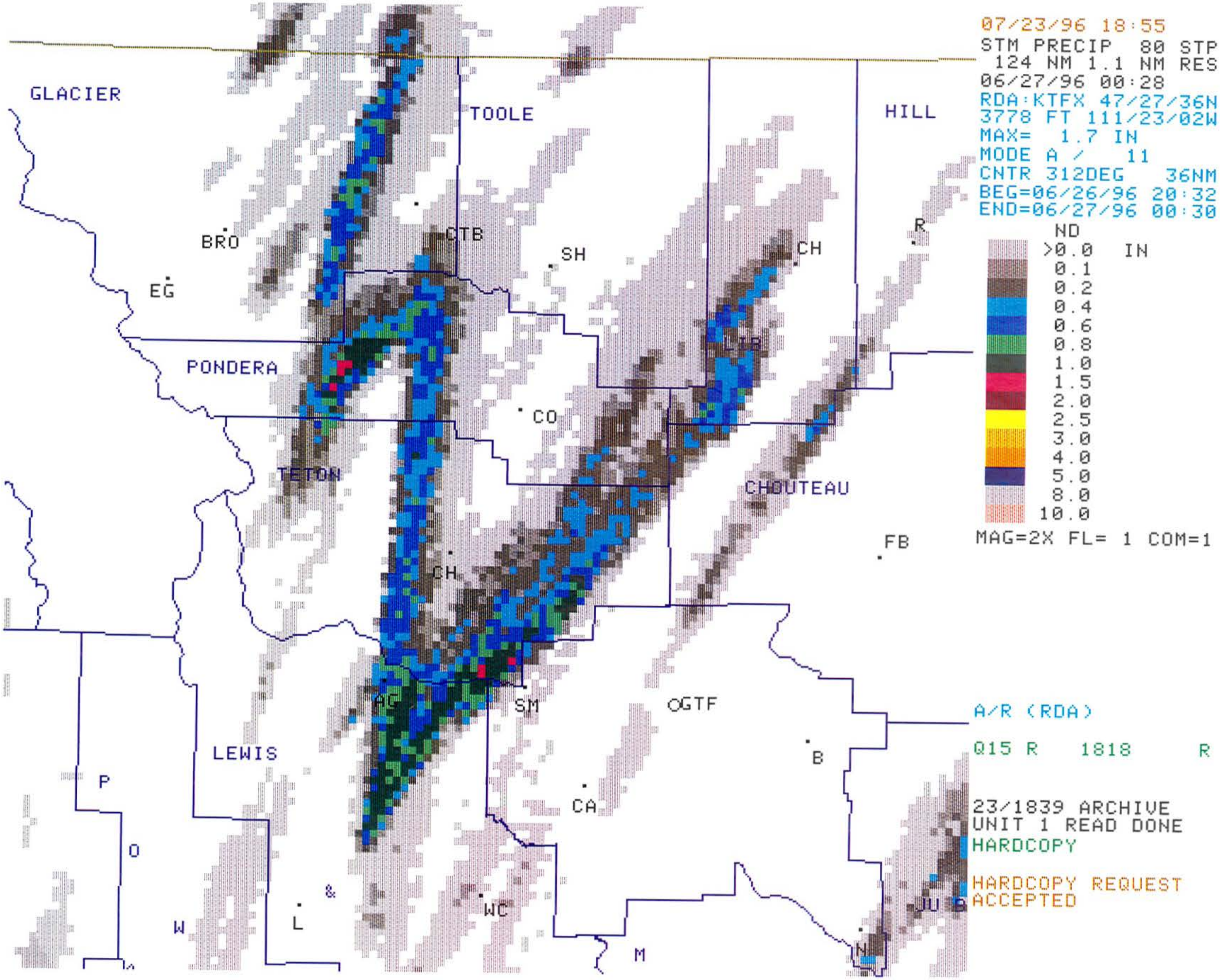

Figure 7. KTFX Storm Total Precipitation (STP) at 0028 UTC 27 June 1996, displaying the storm tracks of the left and right moving cells (big 'V' in center of figure). Notice the distinct northerly path of the left moving cell.

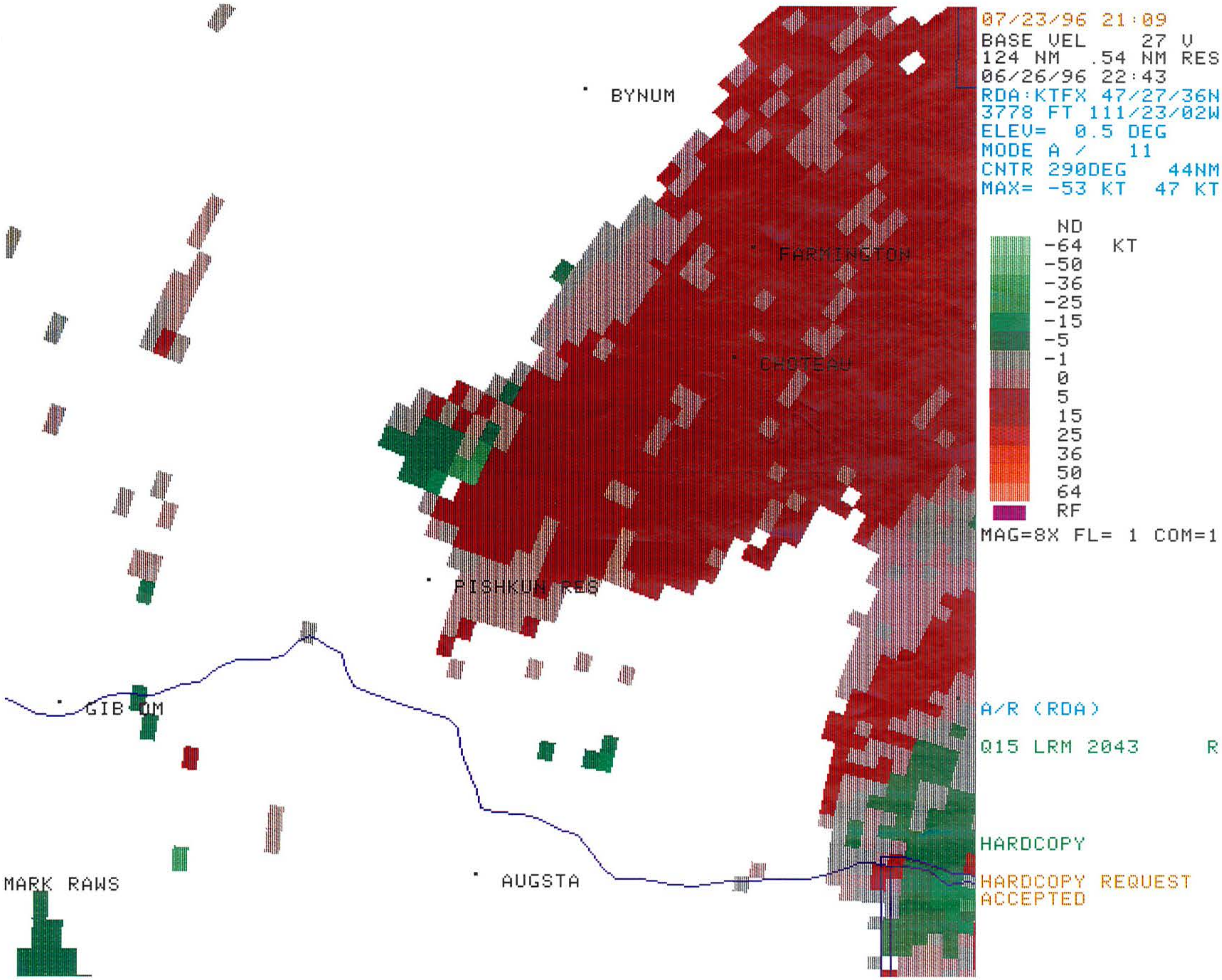

Figure 8. KTFX (0.5 degree slice) of base velocity showing the anticyclonic rotation of the left-moving cell (center of the figure).

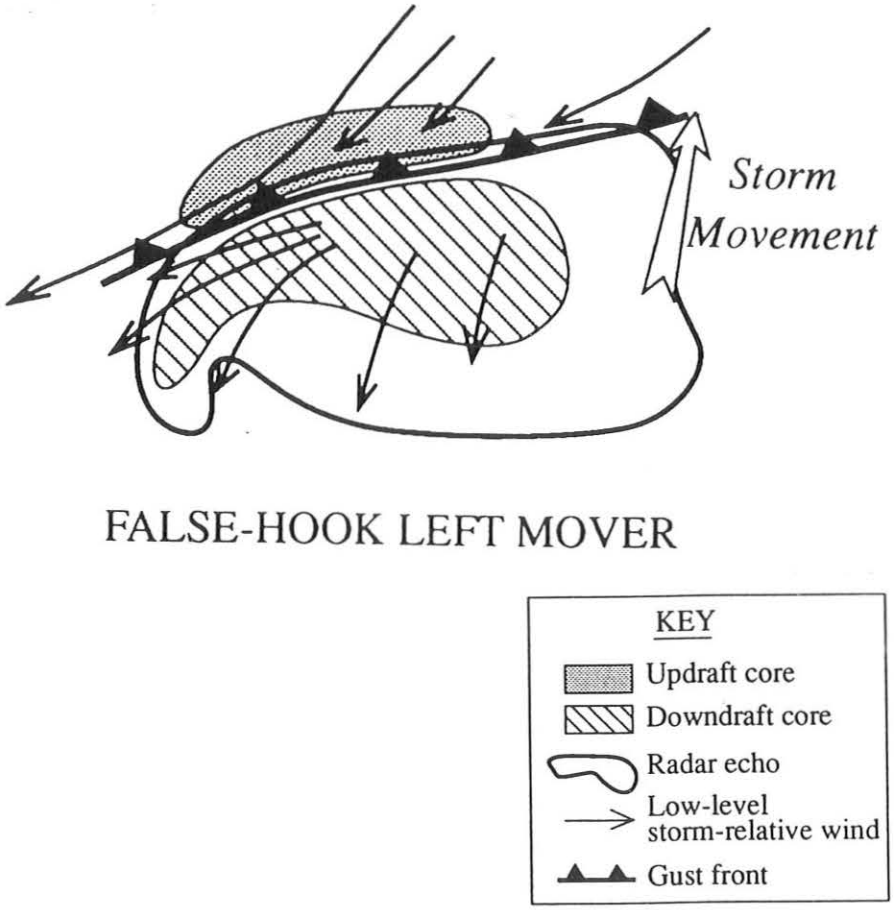

Figure 9. Idealization of the low-level kinematic and radar reflectivity patterns of the false-hook left-moving thunderstorm (From Houze, *et al.* 1993, adapted from Lemon and Doswell, 1979).