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EXAMINATION OF MESOCYCLONE CORE EVOLUTION OF A NOCTURNAL SUPERCELL THUNDERSTORM IN CENTRAL OREGON

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Introduction

On the night of 30 May 30 1997, a thunderstorm developed over central Oregon, and intensified as it moved northeast into north-central Oregon. This thunderstorm began showing supercell characteristics after midnight producing large hail (up to 1.75") early on the morning of 31 May. The location in which this supercell developed and the path it took has been a favored area for strong convective development in the past. Since the modernization of the National Weather Service and the installation of the WSR-88D across the Pacific Northwest, it has been observed that thunderstorms exhibit supercell characteristics more frequently then previously thought. However, nocturnal supercells are rare in Washington and Oregon. This Technical Attachment (TA) provides a closer look at the synoptic and thermodynamic conditions of the 31 May nocturnal supercell; as well as, the WSR-88D evaluation of mesocyclonic core evolution within the storm.

Description of Synoptic Conditions

On 31 May 1997, 0000 UTC, a broad 500 mb low was centered between 45N-50N latitude and 157W-138W longitude with the associated trough axis extending south between 140W-135W long. The upper-level low tracked northeast the next 12 hours with weaker short-wave troughs moving across the Pacific Northwest during this period (Fig. 1). This 500 mb pattern was similar to the common synoptic pattern (negative tilt pattern) for significant severe weather episodes in the Pacific Northwest explained by Evenson and Johns (1995). The only difference was the trough axis was farther west than the cases identified in the Evenson and Johns study. A short-wave moved across Oregon the night of 30 May. In the southwest upper-level flow, strong 500 mb vorticity advection moved over Oregon between 0300-0900 UTC. The 31 May 0000 UTC Eta 6 hour forecast, has the area of best Positive Vorticity Advection over central Oregon (Fig. 2). Strong divergence of the total wind is evident between 400-300 mb on the cross section in (Fig. 3). Furthermore, a convergence/divergence couplet exists with convergence below 500 mb. The cross section was taken roughly along the path of the supercell and the line plotted on the figure (approx. 45.5N, 120.4W) is through north-central Oregon. A surface cold front located near 130W longitude at 0000 UTC 31 May moved east to the coast by 1200 UTC. At 0600 UTC, a surface low was positioned over central Oregon and significant low-level moisture had pooled into this area. The elevated dew points ranged from the mid 50s to lower 60s (Fig. 4). Lastly, an 850 mb theta-e ridge moved across eastern Oregon between 0000-1200 UTC 31 May.

Thermodynamic Situation

The evening of 30 May, the atmosphere was highly unstable. The 31 May 0300 UTC Eta 10 km (Eta10) model, indicated a -10K to -24K theta-e decrease with height from 850 mb to 500 mb over central Oregon (Fig. 5). The Convective Available Potential Energy (CAPE) plot from the 0300 UTC Eta10 showed a maximum through central Oregon of 1350 J/kg to 1950 J/kg (Fig. 6). Model forecast CAPE did decrease through the remainder of the night and early morning, most likely from the loss of solar heating. However, atmospheric buoyancy was still evident because max CAPE values for central Oregon remained around 600 J/kg through 1200 UTC. A hodograph derived from Remote Automated Weather Stations (RAWS) and Pendleton Doppler radar (KPDT) 88D, VAD Wind Profile (VWP), shows some speed shear in the vertical with strong directional shear (Fig. 7). The velocity vectors are plotted every 1/2 km to a height of 7 km. Using storm motion from the radar, the storm relative helicity in the lowest 3 km was calculated by the Sharp program as 345 m^2/s^2. This helicity value was classified as a strong mesocyclone environment according to Davies-Jones (1990). Furthermore, when the hodograph is clockwise turning, the most likely supercell movement is to the right of the mean wind.

Mesocyclone Core Evolution

The initial development of a thunderstorm's updraft is a gradual process with the storm evolving through the organizing and maturing stages over the course of a couple of hours before eventually dissipating. However, Klemp (1987) illustrated in a conceptual model (Fig. 8a) that mesocyclone core evolution can take place towards the end of a thunderstorms mature stage. This process is accomplished by the rear-flank downdraft wrapping around the initial updraft, thus cutting off the moist low-level inflow to the updraft. This forms an occlusion between the front and rear-flank frontal features. A new updraft then forms rapidly at the triple point of the frontal occlusion in a region rich with streamwise vorticity (Fig. 8b). In such a rich environment, the organizing stage of new updraft cores are rapid and quickens the cyclonic rotation of the newly forming updraft. This organizing stage can end in as little as ten minutes before evolving into the mature stage. The mature stage also tends to be shorter then normal because successive rear-flank downdrafts tend to occur sooner. The cut off updrafts then move away from the newly forming updraft along the frontal occlusion, entering the dissipating stage and dropping the remainder of their precipitation. This mesocyclonic core evolution process can take place repeatedly as long as the environment remains undisturbed or until downdrafts completely cut off the low-level inflow.

The Event

Shortly after midnight on 31 May, the Pendleton Doppler radar (KPDT) began to detect the developing thunderstorm along the east slopes of the Oregon Cascades 120nm southwest of the radar. Between 0700 and 0800 UTC, the thunderstorm continued intensifying and moving northeast over Jefferson County in central Oregon. Cell movement continued with the mean wind of 220 degrees at around 30 knots. By 0804 UTC, reflectivity cross section and four-panel data showed a single cell thunderstorm with a pronounced weak echo region on the southeast flank of the storm. Storm Relative Velocities (SRV) indicated consistent mesocyclonic rotational velocities of moderate magnitude and a storm top divergence greater then 80 knots. Radar algorithms indicated possible severe hail of 2 inches in diameter, a Vertical Integrated Liquid value of 59 (kg/m^2) and maximum reflectivity of 65 dBZ.

Between 0815 and 0830 UTC, the thunderstorm underwent a transformation that appeared to indicate the storm had split. Reflectivity data at 0829 UTC (Fig. 9) showed two distinct cores with a new updraft having developed on the southeast flank and the cross section showing a Bounded Weak Echo Region (BWER) associated with the new updraft. However, upon further evaluation of the 0834 and 0849 UTC SRV data (Fig.10), it was clear that both cells maintained a cyclonic circulation. This indicated that it was not a splitting supercell since the left moving cell would have exhibited an anti-cyclonic circulation following a split. The radar identified a 3-D correlated shear at 0834 UTC associated with the rapidly forming updraft in the rich streamwise vorticity inflow. Composite reflectivity at both times showed a distinct hook appendage on the southwest flank of the new cell (Fig. 10, quadrant 4). The movement of the new updraft and each successive updraft that would form over the next couple of hours would be 10-20 degrees to the right of the previously mentioned mean wind.

In a mesocyclonic core evolution event, each successive core evolution takes place quicker since the updrafts reach the mature stage faster than normal, resulting in faster development of rear-flank downdrafts (Klemp 1987). SRV 1.5 degree data from 0844 to 0849 UTC (Fig. 11, quadrant 1 and 2) show an increase of inbound velocities on the southwest flank of the updraft. This indicates the intensification of a rear-flank downdraft as the precursor to the current updraft becoming cutoff. By 0859 UTC, SRV data (Fig. 11, quadrant 3 and 4) show that the rear-flank downdraft has decreased having wrapped around the updraft and three cyclonic circulations are now evident. The reflectivity data at the 0859 UTC (Fig. 12) also verifies that another updraft has become cutoff as three distinct echo tops can now be seen in the higher slices of the four panel. In addition, a BWER, hook echo and radar identified mesocyclone are associated with the new rapidly forming updraft at the triple point of the surface occlusion. The mesocyclonic rotational velocities of the new updraft indicated moderate to strong circulation.

SRV data from 0859 to 0919 UTC, 1.5 degree (Fig. 13, quadrant 1-4) again show an increase of inbound velocities on the back side of the main updraft signifying the development of more rear-flank downdrafts. Another updraft would become cutoff by

0914 UTC as another updraft formed rapidly and the radar identified yet another mesocyclone. However, from this point, on further SRV data showed that the thunderstorm became dominated by continuous rear-flank downdrafts. This was also evident in the reflectivity data as distinct notch developed in the backside of the reflectivity core (Fig. 14). Studies have shown that this notch is caused by rear-flank downdrafts evaporating cloud water droplets, thus producing cloud-free air, or a clear slot (Klemp). Successive SRV and reflectivity data from 0924 to 0949 UTC showed that the mesocyclone circulations in the lowest three elevation angles decreased and the storm entered into the dissipating stage. The thunderstorm reached its peak shortly after passing Condon and continued on towards Ione where hail up to one and three-quarter inches was reported, and radar estimated rainfall rates were around one inch per hour. The thunderstorm stopped exhibiting supercell characteristics after passing Ione and began moving along with the mean wind into southern Washington.

Conclusion

The three-hour precipitation data (Fig. 15) illustrate the repetitive nature of this mesocyclone core evolution event. The movement to the right of the mean wind becomes evident in the precipitation field after the first core evolution took place over southeast Wasco County. However, even more evident are the fingers of precipitation on the northwest side of the precipitation field. These were produced by the updrafts that became cutoff and moved back along the surface occlusion while dropping their precipitation. It is clear that several updrafts were cutoff during this event. The early updrafts that were cut off produced the most precipitation while the later updrafts produced less. This is most likely due to the quickened development of an updraft and subsequent rapid formation of the rear-flank downdraft, cutting off the updraft (Klemp) and allowing less intensification.

This TA demonstrates that with significant synoptic forcing and atmospheric instability, even nocturnal supercells are possible in the Pacific Northwest. It also takes a look at the mesocyclonic core evolution that took place as this supercell evolved. Mesocyclonic core evolution has been shown (Klemp) to be responsible for production of reoccurring tornadic activity in a supercell. However, possibly due to the remote location of this thunderstorm and the time of night, no tornadic activity was reported. In addition, due to the thunderstorms distance from the radar, SRV data was inconclusive in determining whether any tornadic activity took place.

References

Davies-Jones, R., D. W. Burgess, and M. Foster, 1990: *Test of helicity as a tornado forecast parameter.* American Meteorological Society, 588-592.

Evenson, E.C. and R.H. Johns, 1995: Climatological and synoptic aspects of severe weather development in the northwestern United States. *Wea. and Forecasting*, **9**, 265-278.

Klemp, J. B. 1987: Dynamics of tornadic thunderstorms. *Annual Reviews Fluid Mechanical*, **19**, 369-402.

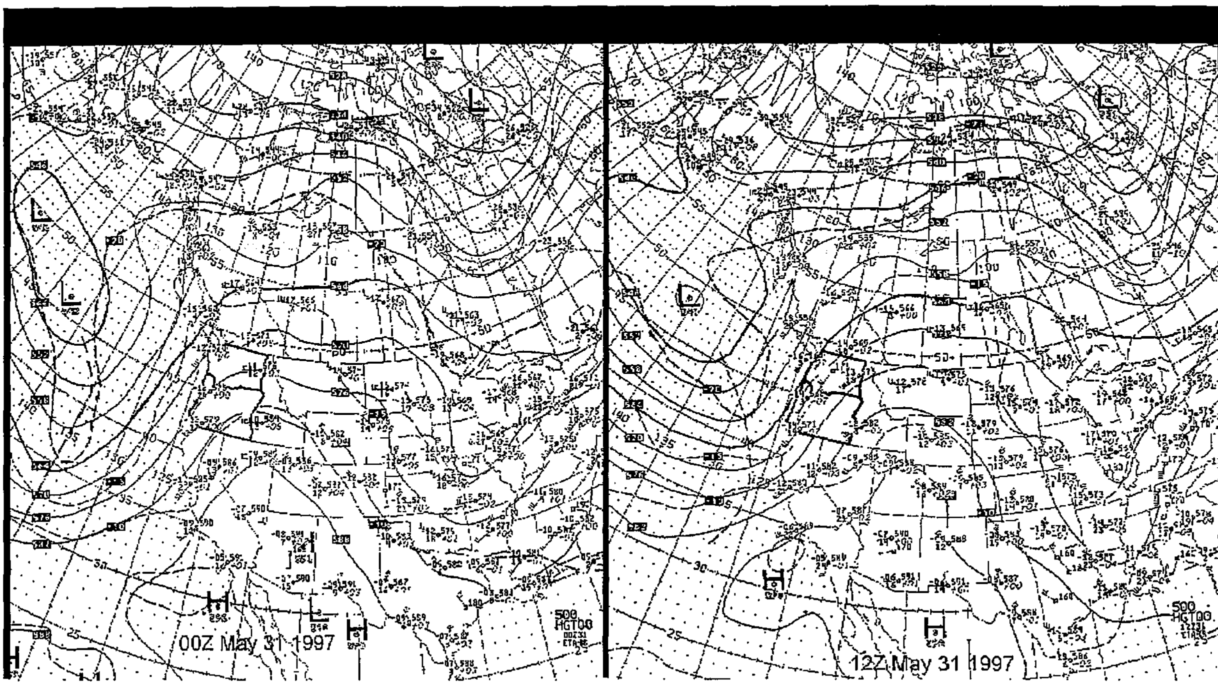


Figure 1: 500 mb analysis from May 31 1997 0000 UTC and 1200 UTC.

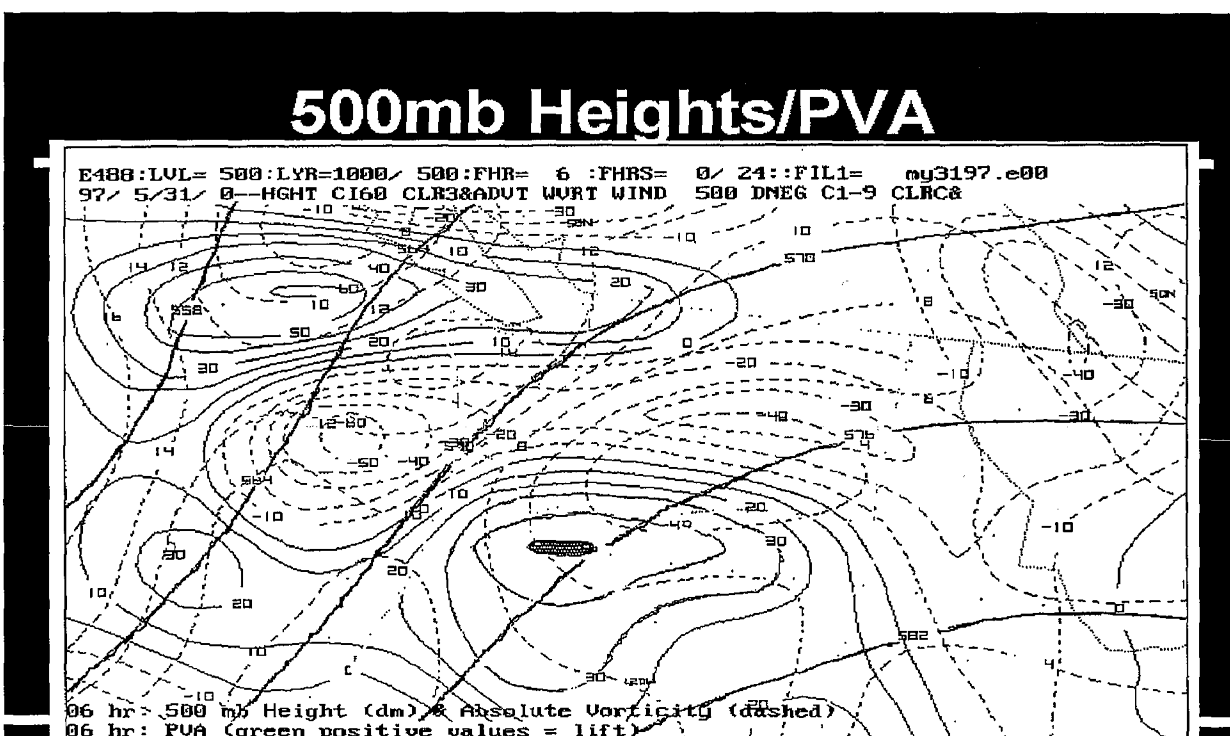
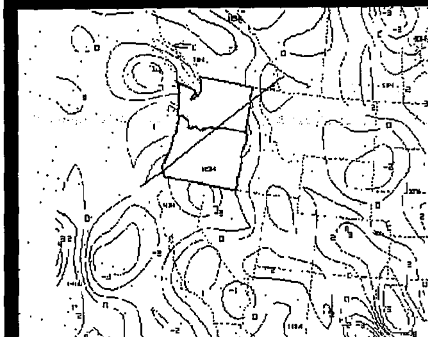


Figure 2: Positive Vorticity Advection (Green) forecast valid May 31 1997 0600 UTC.

Cross-Section (Valid 06Z)



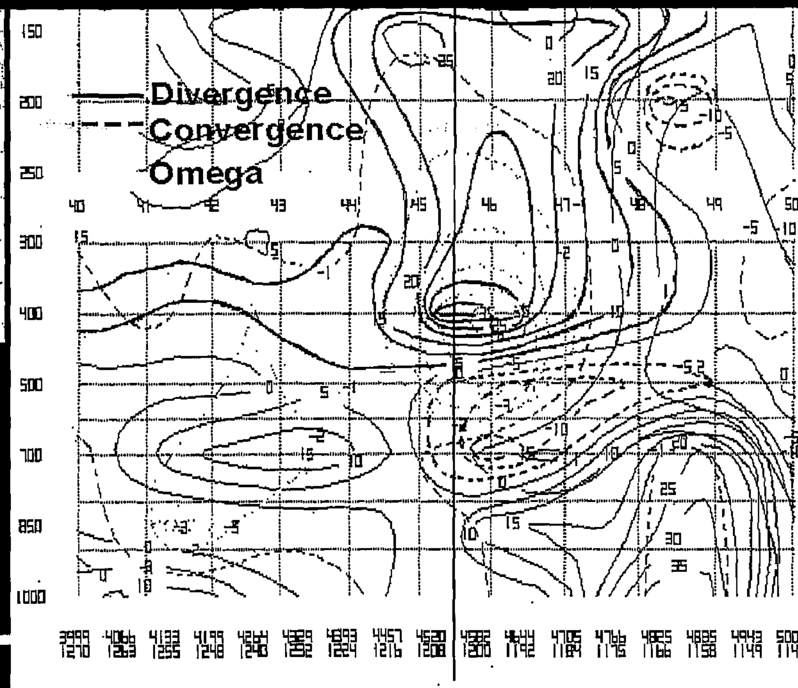


Figure 3: Cross section from May 31 1997 0000 UTC ETA valid at 0600 UTC May 31. The path of the cross section can be seen in a). The solid red line is divergence and the dashed blue line is convergence. The dashed green line is omega or the area of best synoptic lift.

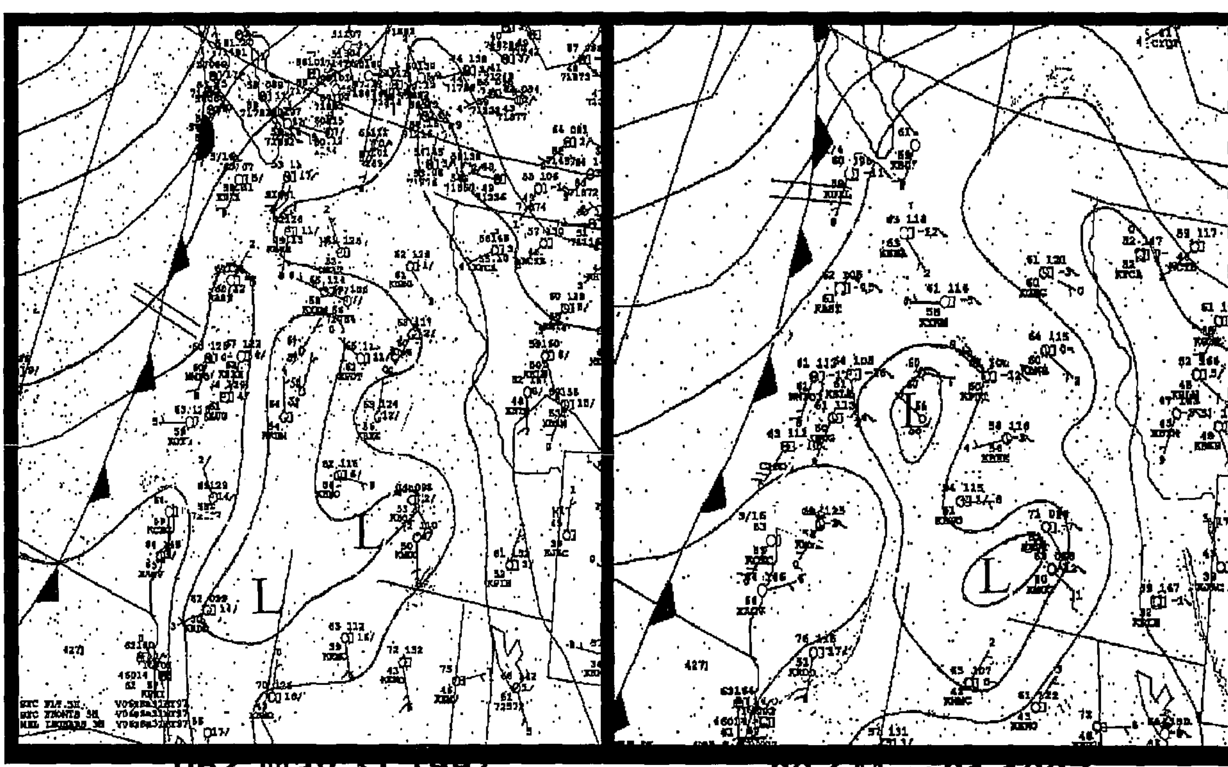


Figure 4: Surface analysis for May 31 1997 0600 and 0900 UTC

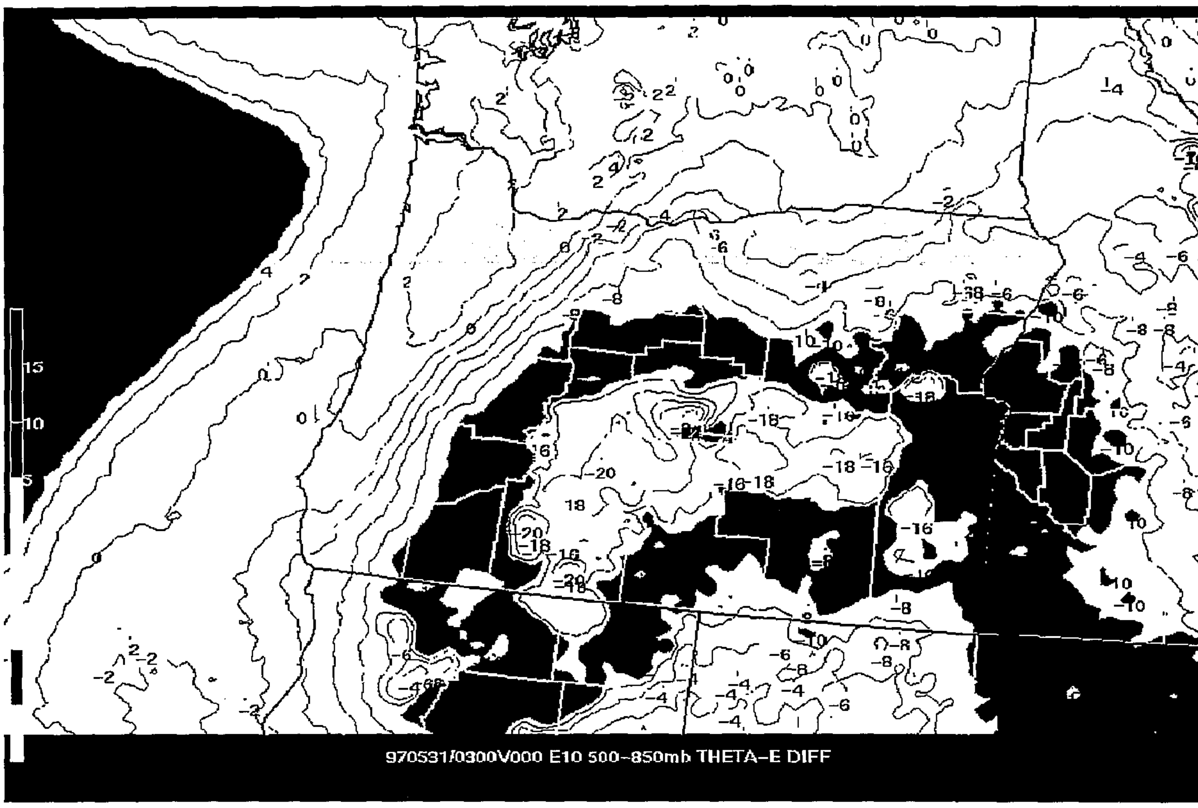


Figure 5: Theta-e decrease with height in 850 mb to 500 mb layer for May 31 1997 0300 UTC. The red area corresponds to -10K to -18K and the purple is -18K to -24K.

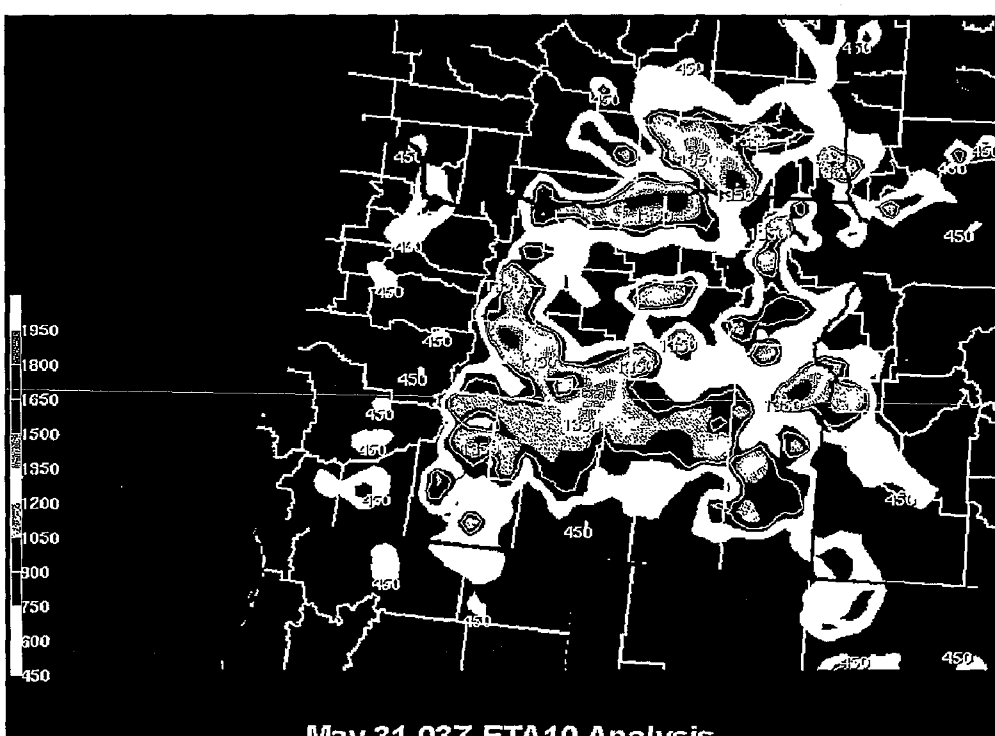


Figure 6: High Cape values along the east slopes of the Cascades

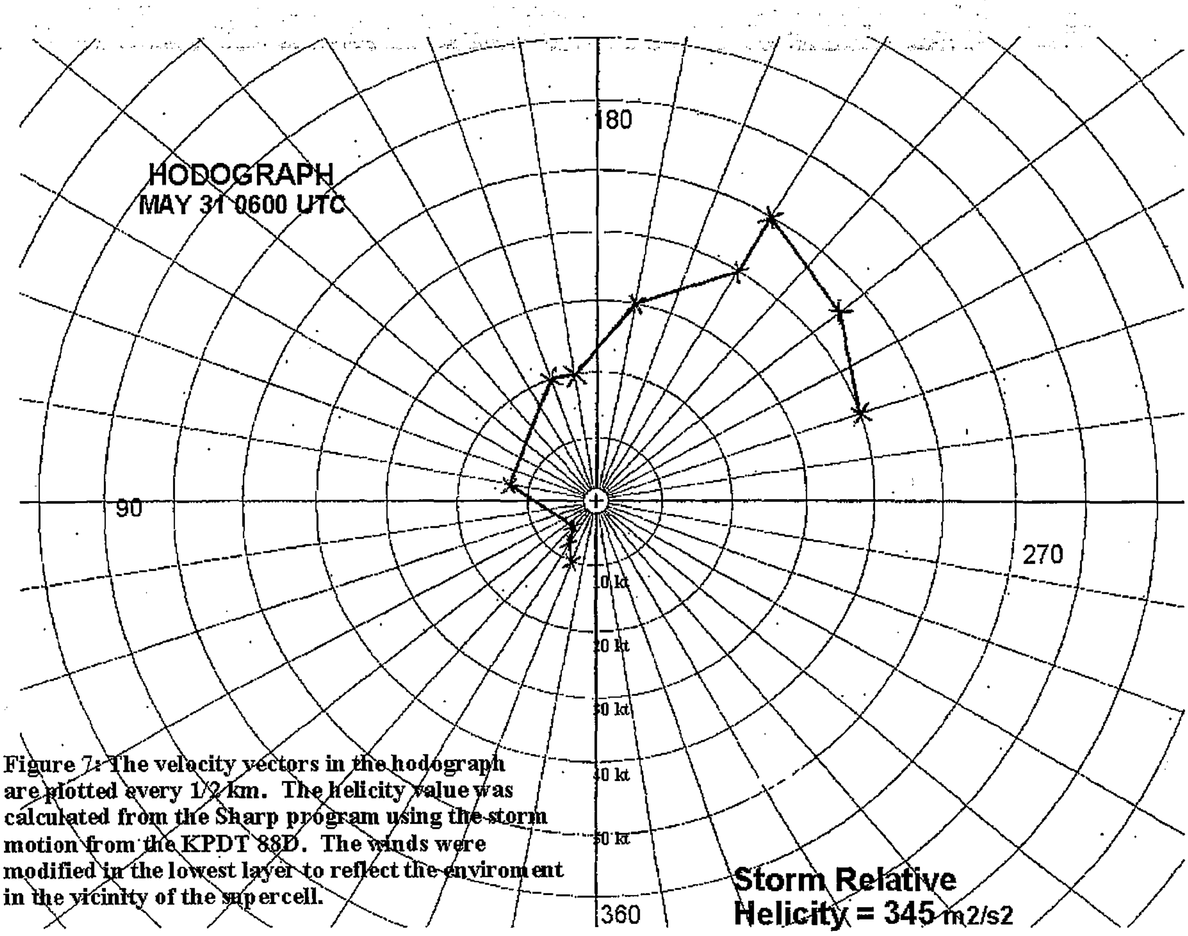


Figure 7: The velocity vectors in the hodograph are plotted every 1/2 km. The helicity value was calculated from the Sharp program using the storm motion from the KPDT 88D. The winds were modified in the lowest layer to reflect the enviroment in the vicinity of the supercell.

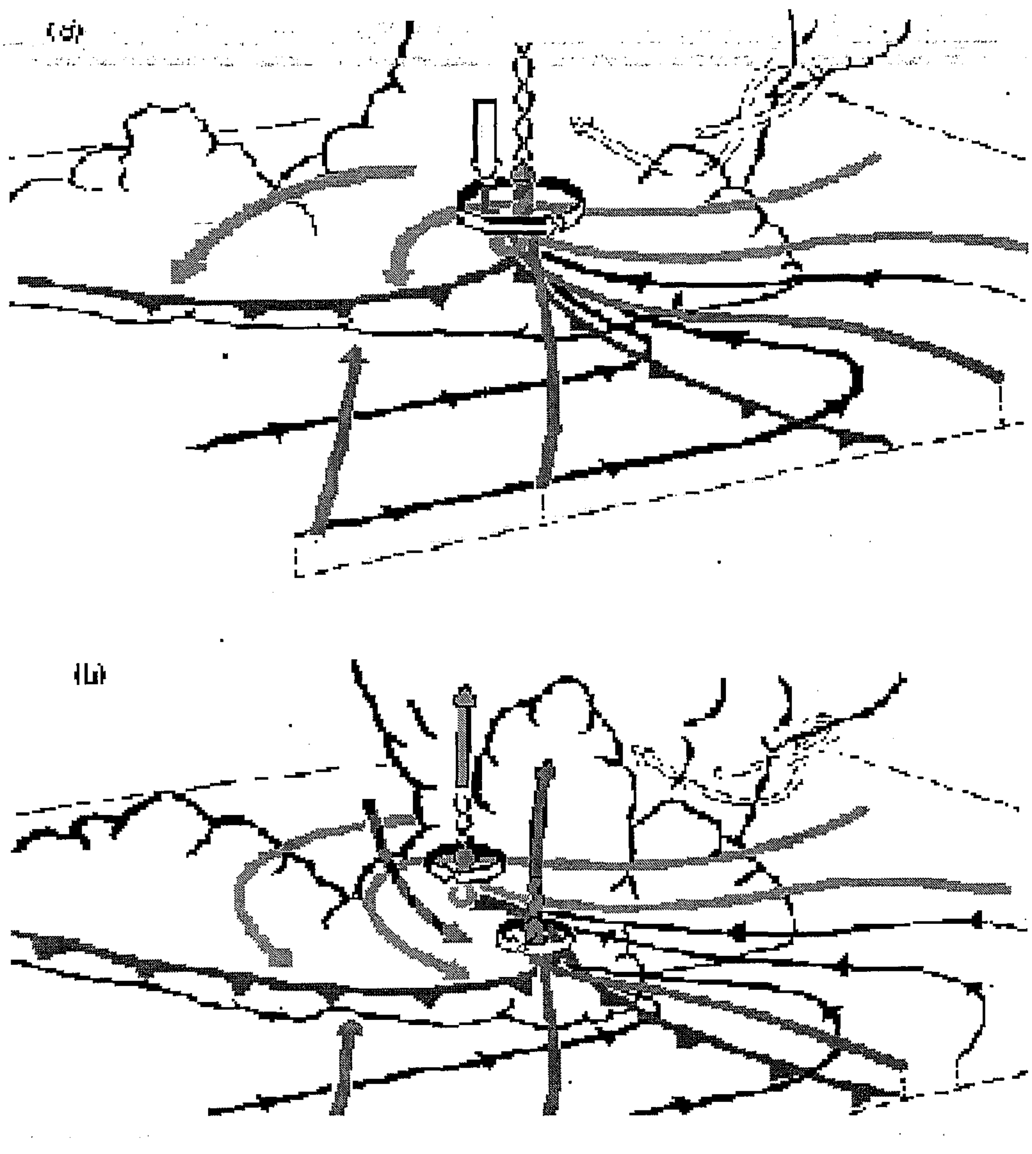


Figure 8: Klemp's diagram depicting Mesocyclone Core Evolution. Southeast view (a) of thunderstorm with low-level inflow and updraft development prior to the formation of the rear-flank downdraft. About 10 minutes later (b) the rear-flank downdraft (red and black striped arrow) has intensified cutting off the initial updraft. A new updraft forms at the triple point of the frontal occusion. Frontal features are dark blue, vortex lines are black, low-level inflows in light blue and red.

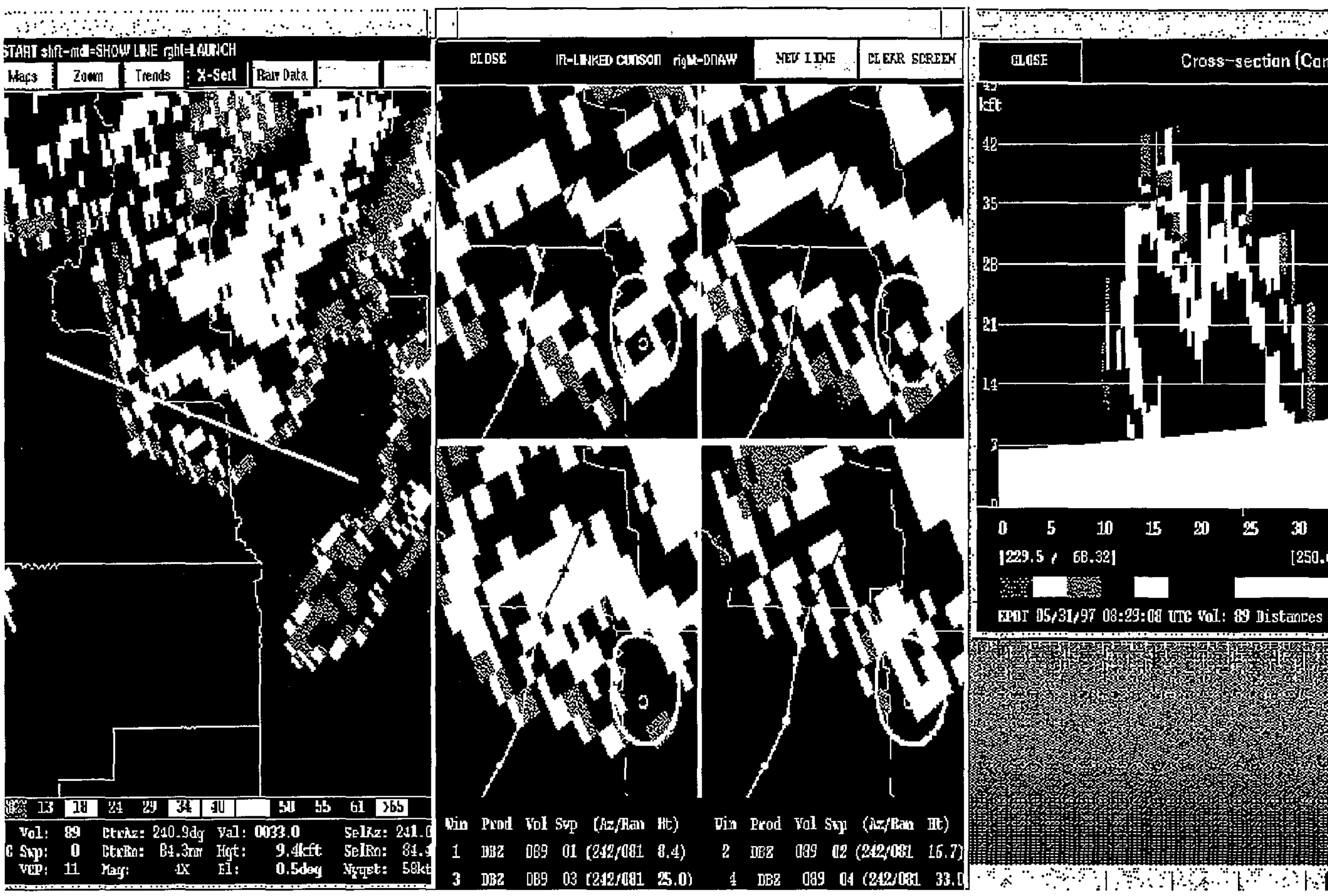
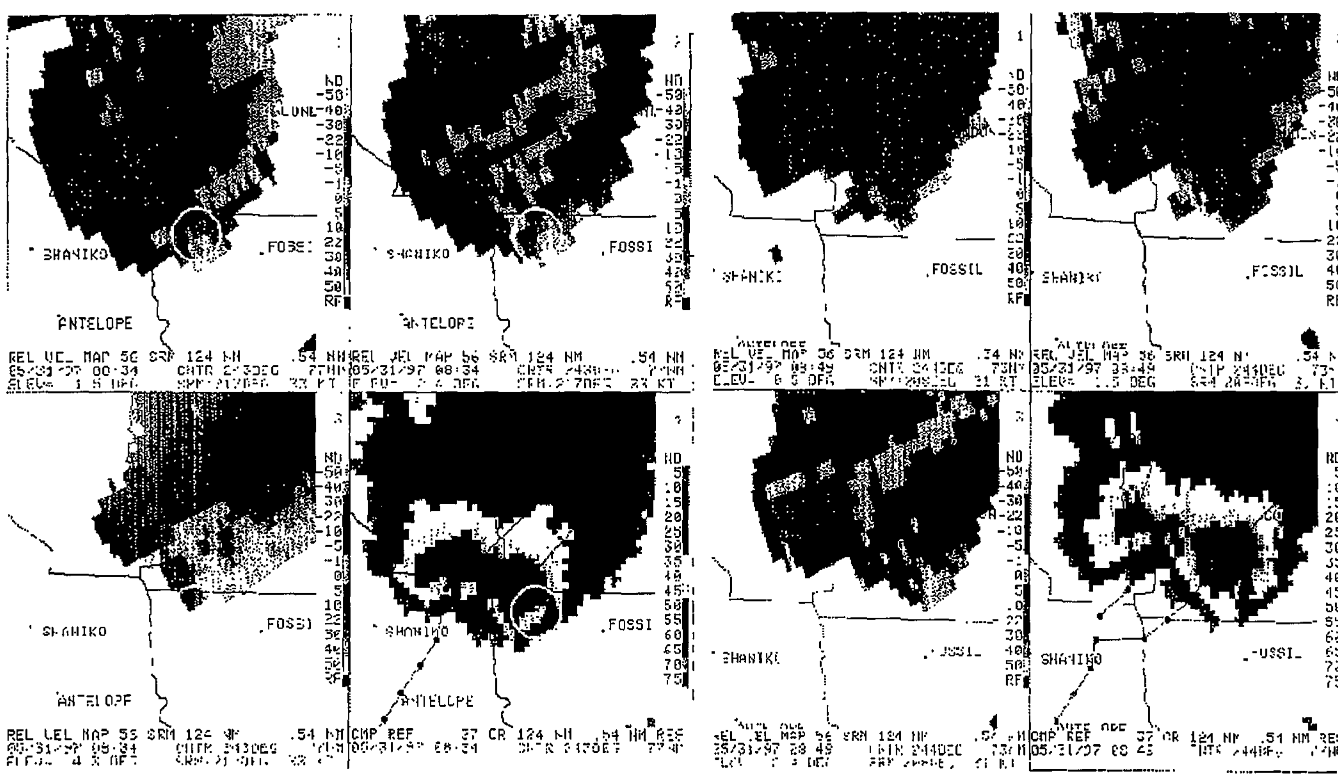


Figure 9: Reflectivity data at 0829 UTC showed that the first updraft had become cut off with a new updraft having formed on the southeast flank. Good overhang can be seen in the 4-panel indicated by the white dot and circle. A bounded Weak Echo region is visible in the composite reflectivity cross section as well as two distinct reflectivity cores.

Figure 10: Storm Relative Velocities at 0834 and 0849 UTC showing two cyclonic rotaions following the first mesocyclonic rotation that took place over southeast Wasco County, just wast of Shaniko. The new updraft developing to the west of Fossil has a 3-D correlated shear at 0834 UTC. Also evident at both times is a hook echo on the southwest flank of the new updraft.



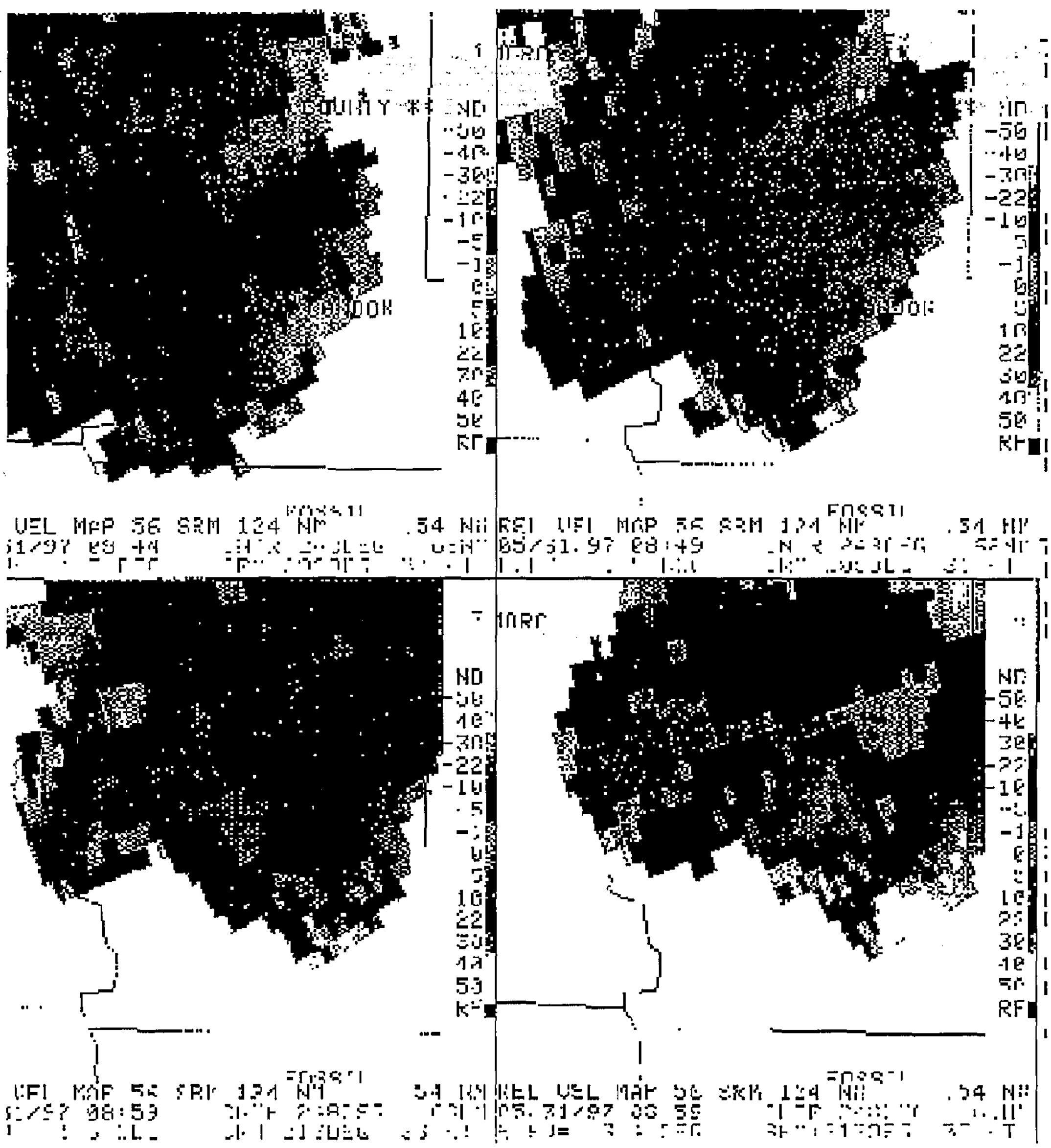


Figure 11: A time sequence of 1.5 degree Storm Relative Velocities from 0844 to 0859 showing an increase of rear-flank downdrafts seen as inbound velocities at 0849 UTC. By 0859 UTC (quadrants 3 & 4) three cyclonic circulations are evident at both the 1.5 and 3.4 elevation. This indicates that another mesocyclonic evolution has taken place.

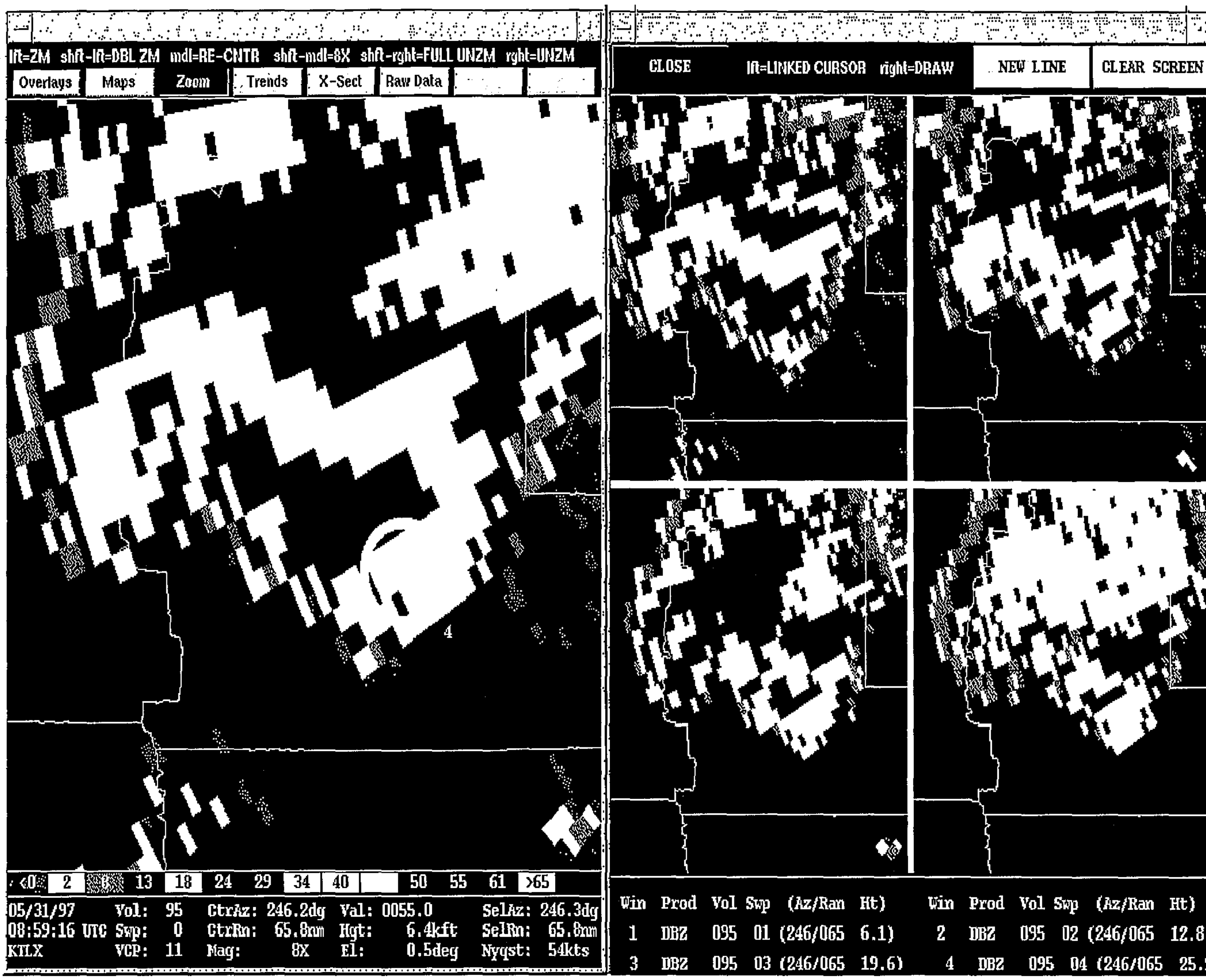


Figure 12: 0859 UTC reflectivity data also confirms that another updraft has been cutoff with three distinct reflectiviy cores seen in the four-panel. Also visible is a radar identified mesocyclone circulation associated with the new updraft forming in the streamwise vorticity rich inflow region. A Bounded Weak Echo Region (BWER) and hook echo are also distinctly evident.

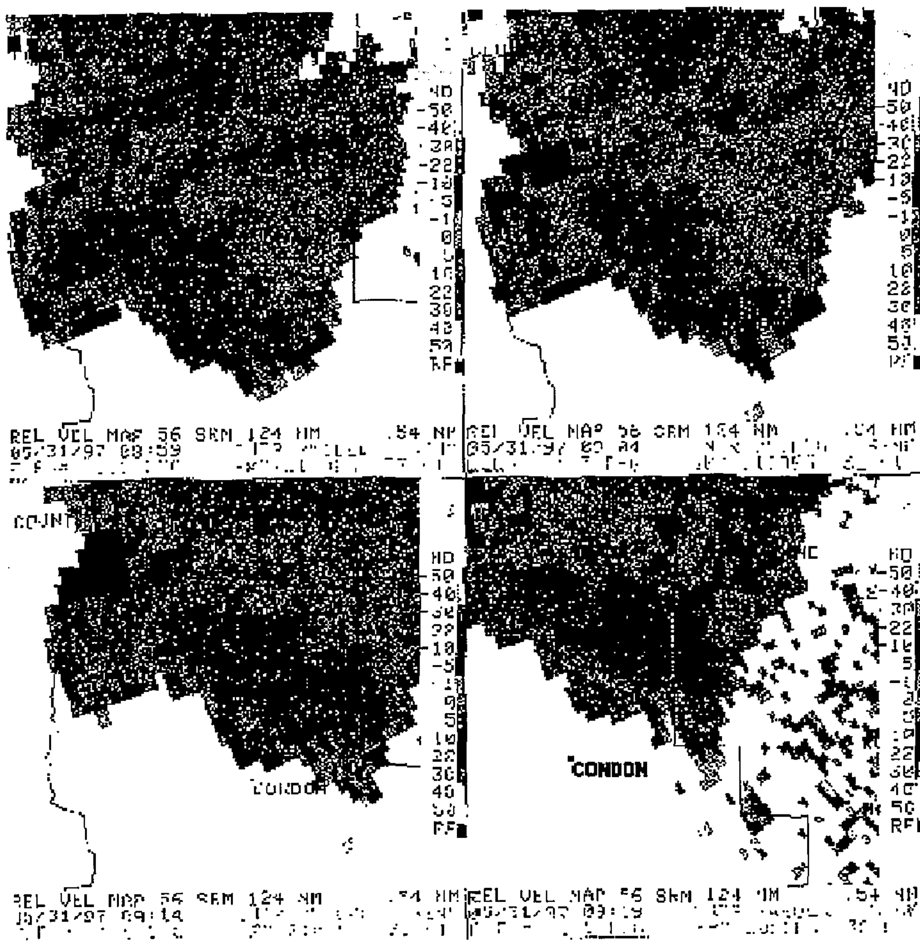


Figure 13: A time sequence of 1.5 degree Storm Relative Velocities from 0859 to 0919 UTC again shows an increase of inbound velocities associated with the development of more rear-flank downdrafts as the thunderstorm passes Condon, Oregon roughly 60 nm southwest of the radar. Reflectivity data confirmed that another updraft was cutoff at 0859 UTC and the radar identified another rapid updraft development. However, from this point further SRV data showed that the rear-flank downdrafts beacme the dominating feature of the thunderstorm and permanently cutting off the thunderstorm's inflow.

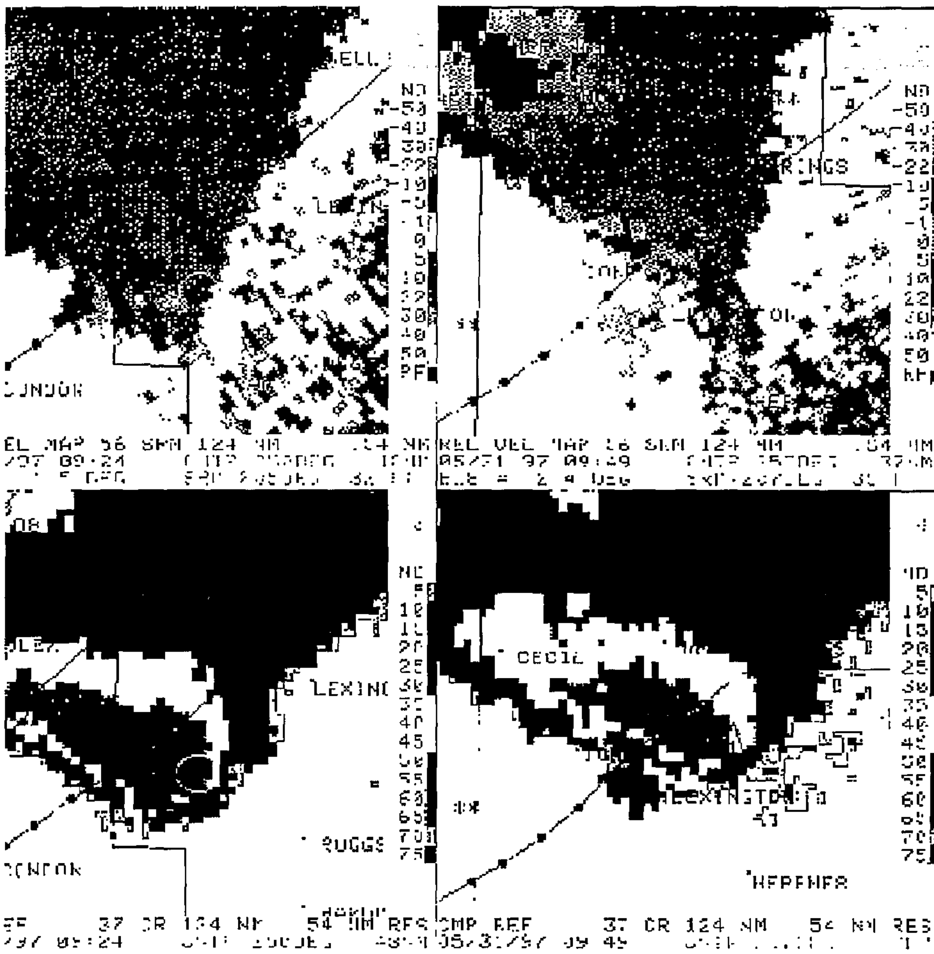


Figure 14: A notch developed on the backside of the reflectivity data by 0949 UTC. This correlated well with the increase of rear-flank downdrafts seen as inbound velocities in the Storm Relative Velocitiy data (qaudrant 1 & 2) that began dominating the storm as it approached Ione. By 0949 UTC the thunderstorm was located 40nm southwest of the radar near the town of Ione where 1.75" hail was reported during the storm's dissipating stage.