

DRAMATIC EXAMPLES OF THUNDERSTORM TOP WARMING RELATED TO DOWNBURSTS

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ABSTRACT

Examples of rapid thunderstorm top warming as observed in satellite infrared imagery are related to the occurrence of straightline or downburst wind damage at the surface. The events were observed over the southern United States in early May 1984. Two types of warming patterns were observed: (1) small, circular dark areas embedded within the anvil, and (2) a wedge-shaped darkening area near the upwind portion of the anvil. Both occurred to the rear of the coldest IR tops and locations of surface wind damage. Evaporative cooling is believed to have been a contributor in the latter case.

During the first 10 days in May 1984, a series of devastating severe weather outbreaks occurred over the southeastern U.S. There were numerous reports of tornadoes, large hail, and straightline or downburst winds. Extensive damage and some loss of life was reported. What made these severe storms especially dangerous was that many persisted through the night into the early morning hours.

During this period there were several instances of rapid thunderstorm top warming observed in infrared (IR) satellite imagery. These warmings occurred near the times of damaging downburst winds at the surface. Fujita (2) first noticed that warming of thunderstorm anvil tops in IR data was strongly related to downbursts and in some cases, tornadoes. The warming was noted to occur near the core of ovalshaped anvils and just upwind from the downburst and the coldest IR tops. In wedge-shaped anvil tops which form in strong vertical shear, the warming is often downwind from the downburst area in an elongated band or trench. The latter is comparable to the Enhanced-V signature, a feature which has been found to be correlated with severe weather (3).

Anvil top warming is often difficult to observe because the half-hourly or hourly interval between IR pictures does not correspond to the period of rising and falling in the thunderstorm tops. In some cases, the IR enhancement curve simply does not have the proper grey-scale resolution in the temperature range of the anvil tops. In the examples shown here, however, the thunderstorm top features closely coincided with the times and optimum temperature ranges of operational IR satellite images.

The first event occurred from 0120 to 0200 GMT on May 3. A huge thunderstorm system similar in

appearance to a Mesoscale Convective Complex (MCC) (4) engulfed the State of Arkansas as shown by the GOES-East view enhanced with the MB curve in figure 1. The MB curve has excellent resolution in the -64°C to -80°C temperature range. By 0200, a nearly circular dark hole appeared near the center of the anvil top in east-central Arkansas (arrow)

indicating that significant warming had just occurred. By comparing the observed grey-scale difference with the enhancement curve temperature scale on the picture, the warming was estimated to be about 10°C . This warming is equivalent to a descent of about 1 km. Fifteen minutes earlier (0145), wind damage was reported near Dewitt, Arkansas (shown by the small circle). A mobile home was overturned, resulting in a fatality, and another home was pushed off its foundation. The extent of the damage suggests a downburst of F1 scale (maximum winds 73-112 mph). The F scale, although originally used to evaluate tornado intensity, can also be used for downbursts (2). Most downbursts (79%) have an intensity of F1. The National Weather Service radar summary at 0235 (figure 2) showed a pronounced "bow" echo (the boomerang-shaped line), a feature often associated with the occurrence of downbursts (2). Further minor damage occurred as the storm continued into northern Mississippi.

A similar event happened on the night of May 7-8 when severe thunderstorms occurred in a wide area from east Texas to Georgia. Figure 3 shows the severe weather reports for portions of the Gulf States for the period 0000 GMT to 0400 GMT on May 8. By 0100 GMT, the extent of the thunderstorm system was evident (figure 4). Several tornadoes, hail, and wind damage had recently occurred over Northern Louisiana and northern Mississippi. A small dark hole (A) appeared in the center of the anvil over northern Mississippi. About the time of this picture, winds gusted to 42 knots at Greenwood, MS (GWO) just to the south of this spot.

At 0130 GMT the hole had enlarged considerably (A in figure 5) while another area of warming was present along the eastern border between Louisiana and Arkansas (B in figure 5). A line echo wave pattern (LEWP) first detected at 0030 GMT had by this time advanced to western Mississippi (figure 6). Maximum radar tops were reported at 57,000 ft near the apex of the LEWP. No specific severe weather reports could be related to these features at this time.

By 0200 GMT, a darkening "slot" had pushed eastward to the Mississippi River (B in figure 7). The

coldest enhanced portion of the anvil in this area by now had formed an S-shaped back edge (C in figures 7 and 8). Within 30 minutes after this time, there were several reports of severe wind damage from Yazoo City to Greenwood, MS (GWO). Damage reports indicating roofs blown off a number of houses suggest a downburst intensity of F1 and possibly F2 (113-157 mph). To the north, a large cell appeared to develop in the midst of the warm hole previously observed (A in figure 7). Radar at Centreville, Alabama, reported the top of this cell to be 57,000 ft with a possible hook echo on the southwest side.

By 0230 GMT, another large hole appeared in northeast Mississippi (A in figure) and about 25 minutes later, wind damage was reported near Columbus, MS (CBM) just to the east of the hole. Winds at the Columbus airport gusted to 42 kt at 0230 GMT. The warm slot continued to become better defined to the southwest (B in figure 8). Related minor wind damage was reported at GWO and Jackson, MS, airport reported wind gusts to 34 kt.

At 0300 GMT, (figure 9) these features had progressed eastward and became somewhat less distinct. Later reports of wind damage in northern Alabama however, could be related to observable warm features in the cloud tops.

The western edge of the coldest IR tops ahead of the warm slot described above formed a comma-shaped pattern similar to that associated with a synoptic scale vorticity maximum. Since the slot in a comma cloud relates to the location of the jet stream (5), this suggests that either a wind maximum at mid or upper levels interacted with the upwind edge of the storm, or a horizontal acceleration occurred in the flow. The latter concept was proposed by Fujita to explain the severe downburst event in northern Wisconsin on July 4, 1977. The acceleration was thought to have "pulled" the anvil down to the rear of the storm, as shown schematically in figure 10. This would result in the warming observed in satellite images. After the downburst weakened, a deceleration occurred, producing a bulge to the rear of the storm and some cooling of the anvil at that location.

One possible cause of the acceleration noted above is evaporative cooling. Evaporative cooling in the subcloud region is believed to have been an important factor in many downburst episodes during the JAWS (Joint Airport Weather Studies) project in 1982 (6). Evaporative cooling creates an increase in the negative buoyancy of thunderstorm downdrafts, resulting in a downward acceleration. For a moving thunderstorm, the downdraft also has a horizontal component with respect to the ground in the direction of motion (e.g., ref. 7), which will also increase. Such an acceleration in one portion of a thunderstorm line is a possible cause of the characteristic shape of the bow echo.

The 500-mb analysis for 00 GMT May 8 (figure 11) showed a relatively strong 50-kt wind at Longview (GGG) in northeast Texas. More importantly, air upstream from the convection at GGG and Lake Charles (LCH) was very dry (dewpoint depression greater than 30°C). The Lake Charles

radiosonde (not shown) showed that the dry air extended through a deep layer from 500 mb to below 700 mb. Evaporative cooling was thus a likely contributor to the strong downdraft winds in west central Mississippi.

We have seen examples of two types of thunderstorm top warming which corresponded to surface wind damage caused mainly by downbursts. Nearly circular holes appeared in the cores of the huge anvils while a slot-like warm intrusion was evident at the western edge of the convection in one case.

Identification of satellite-observed features such as those described here usually does not provide sufficient lead time for public or aviation warning for the initial severe weather events. Since the severe weather tends to be recurrent for large persistent thunderstorm systems, however, an indicator of further wind damage in the path of the storm would be provided.

ACKNOWLEDGMENTS

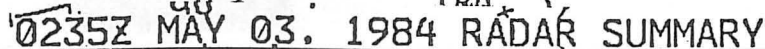
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FOOTNOTE AND REFERENCES

1. The author received the B.S. degree in meteorology from Penn State and the M.S. from the University of Wisconsin. He has served as a weather officer in the Air Force and has been a research meteorologist at the University of Wyoming as well as in his current position. Operational experience includes National Weather Service forecasting assignments at Seattle and Washington, D.C.
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GOES-East image enhanced with MB curve at 0130 and 0200 GMT May 3, 1984. Gray-scale to temperature conversion for MB curve is shown at top.



National Weather Service radar summary for
0235 GMT May 3, 1984.

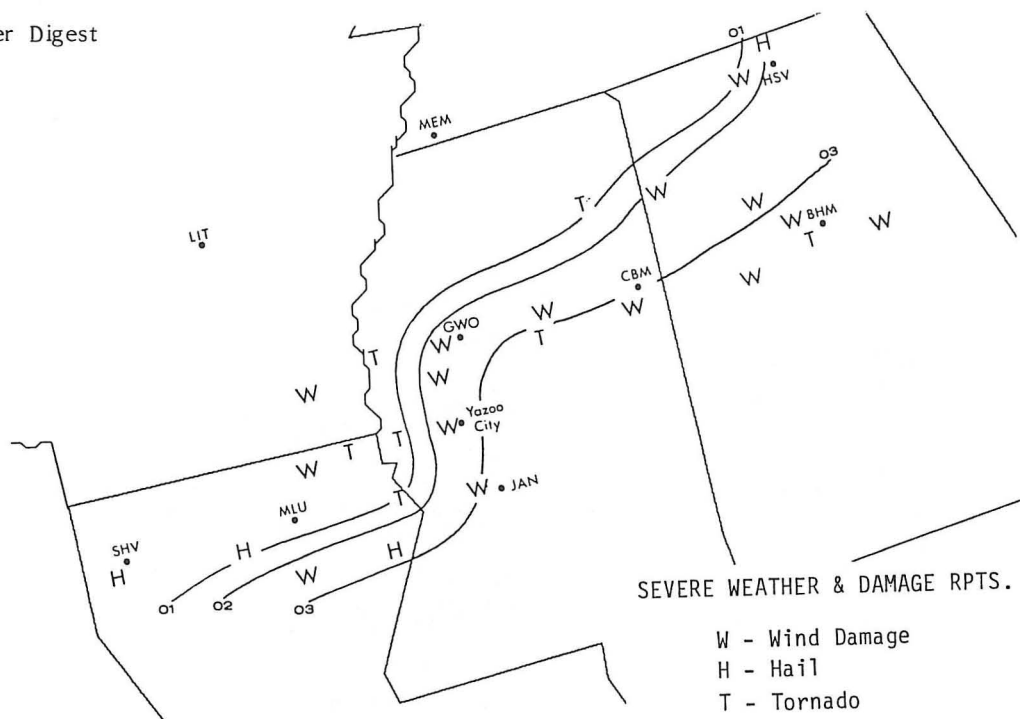


Figure 3.
Severe weather reports for the period 0000 to 0400 GMT on May 8, 1984. Solid lines are isochrones in GMT.

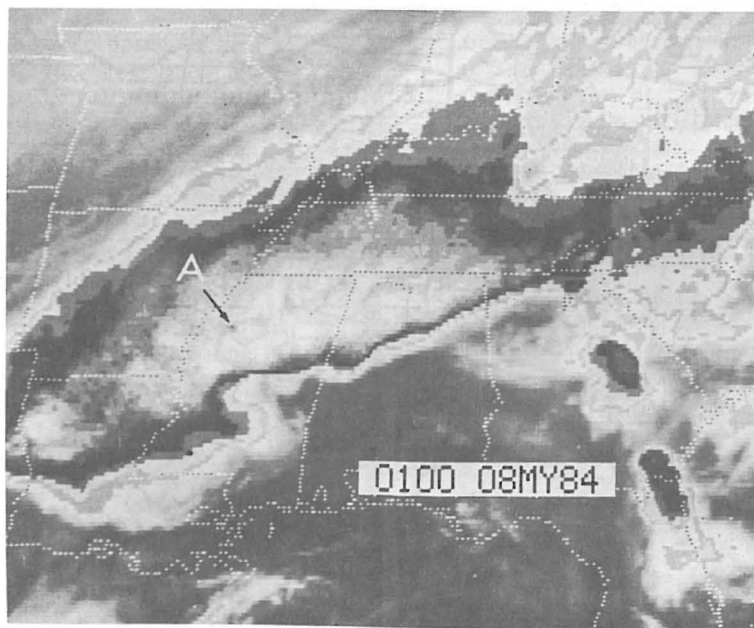


Figure 4. GOES-East image enhanced with MB curve for 0100 GMT May 8, 1984.

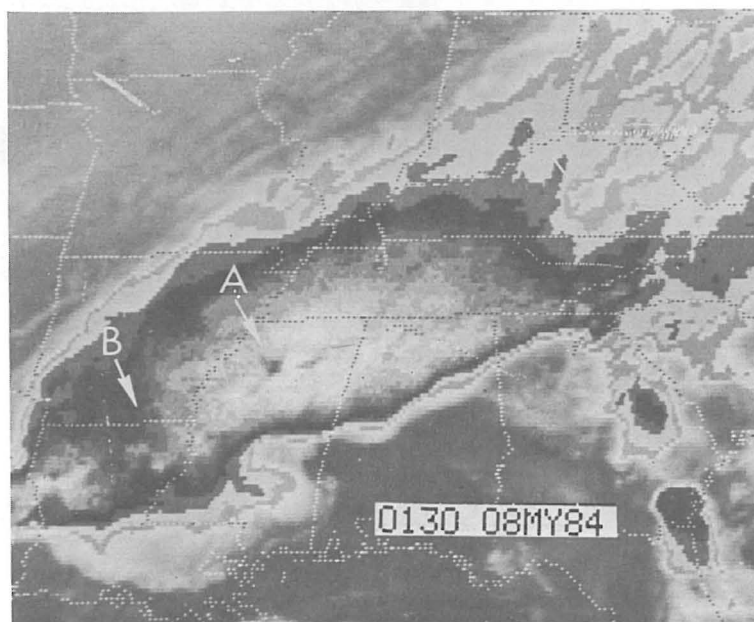


Figure 5. Same as Fig. 4 at 0130 GMT

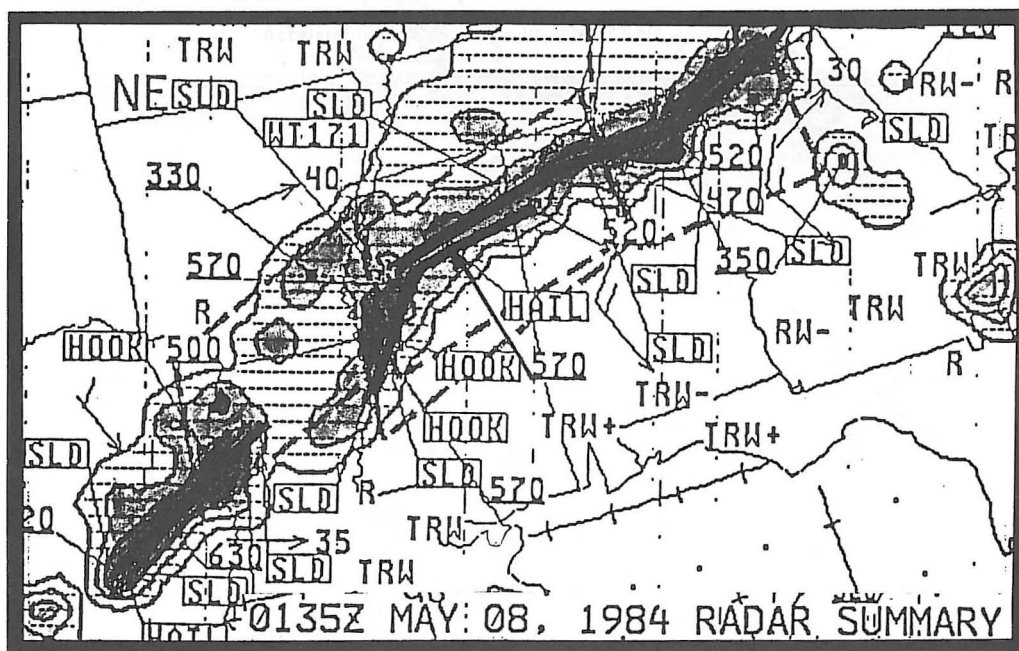


Figure 6. NWS radar summary at 0135 GMT.

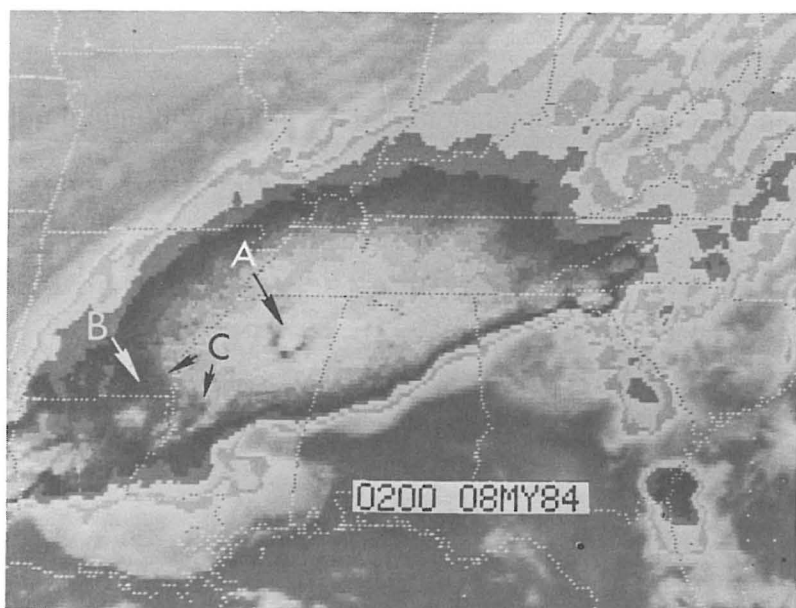


Figure 7. Same as Fig. 4 at 0200 GMT.

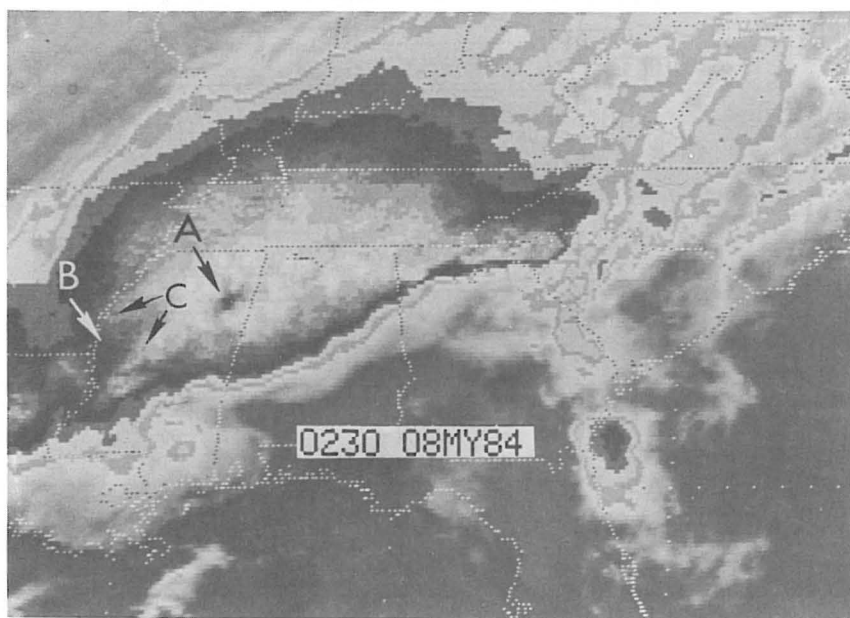


Figure 8. Same as Fig. 4 at 0230 GMT.

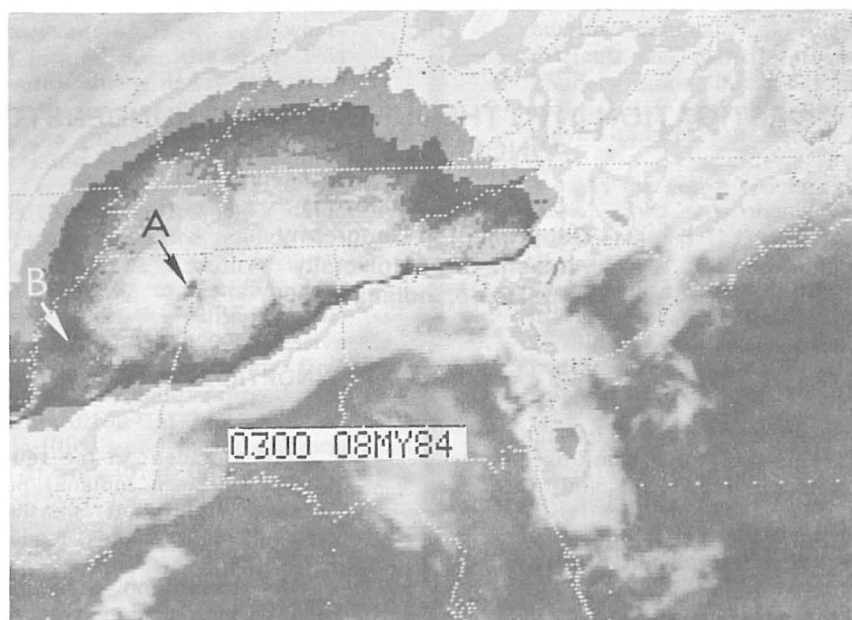


Figure 9. Same as Fig. 4 at 0300 GMT.

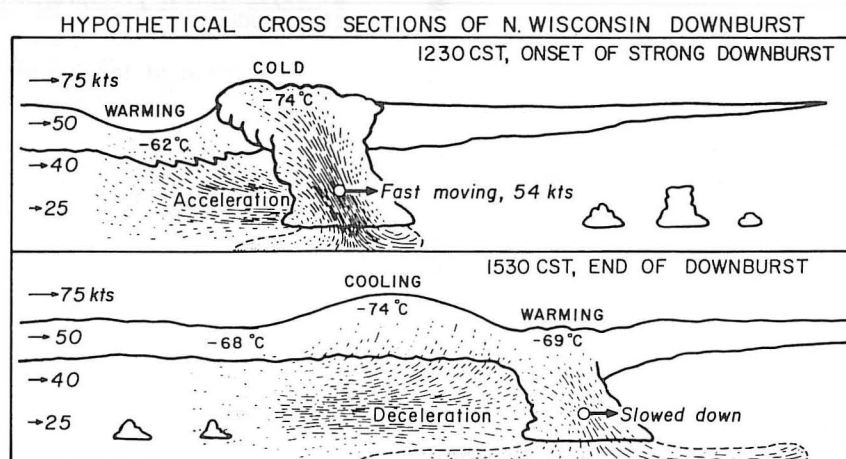


Figure 10.
Hypothetical cross sections of northern Wisconsin downburst at 1230 CST and 1530 CST July 4, 1977 (From Fujita, 1978).

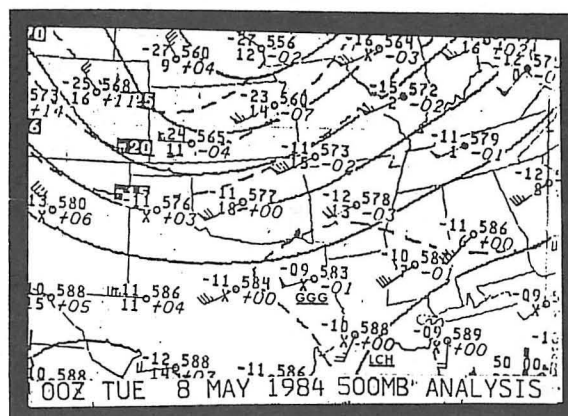


Figure 11. 500-mb analysis at 00 GMT May 8, 1984.