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Using WSR-88D Radar Data and 30-second Interval GOES Satellite Imagery to Examine Apparent Thunderstorm-top Rotation Observed on May 31, 1996

by
Brian Motta
CSU/CIRA/FIRSTT[1]*
and
John Weaver
NOAA/NESDIS/CIRA[1]
Colorado State University, Fort Collins, Colorado

1. INTRODUCTION.

Previous studies utilizing Doppler radar velocity data (Lemon, et al., 1982 and Rotzoll, et al., 1983) have shown that supercell thunderstorms can have significant rotation very near storm top. Satellite studies based on single images have also found indications of this rotation in visible imagery (Adler, et al., 1981), and a study by Anderson (1982) shows apparent cyclonic rotation at storm top in wind vectors derived from sequential satellite imagery. As part of the National Weather Service FIRSTT[1] initiative, a supercell outbreak over Kansas and Colorado is being examined using a combination of WSR-88D radar data, and special 30-second interval GOES-8 satellite imagery. The storm of interest to this paper produced apparent storm top rotation coincident with a series of F1 tornadoes. The storm occurred near Ness City, Kansas which is located within 75 km of the Dodge City, Kansas WSR-88D radar. The data were synthesized to determine whether or not the rotation observed at anvil level was connected to the storm's mesocyclone.

2. DATA SOURCES.

The radar data used for comparisons came from the Dodge City, Kansas WSR-88D Doppler radar operated by the National Weather Service. Satellite imagery measurements discussed in this paper were based on imagery from the Geostationary Operational Environmental Satellite, GOES-8. Trajectories were constructed by following cloud elements on 30-second to 4-minute interval visible imagery whose resolution at satellite sub-point is about 1 km.

3. THE NESS CITY STORM.

Severe thunderstorms formed along an east-west oriented mesoscale outflow boundary in

[1] Key to affiliations: CSU - Colorado State University; CIRA - Cooperative Institute for Research in the Atmosphere; FIRSTT - Focus on Integrated Remote Sensing Technology and Training; NOAA National Oceanic and Atmospheric Administration; NESDIS - National Environmental Satellite, Data, and Information Service.

* Corresponding author address: Brian Motta, CSU/CIRA, Fort Collins, CO 80523-1375; e-mail: motta@terra.cira.colostate.edu

central Kansas -- a boundary that had been left behind by a large overnight squall line in Nebraska. All of the storms were severe, but one storm near Ness City, Kansas produced a series of F1 tornadoes over a 25 mile path length. The tornadic activity began at 2307 UTC and continued until just after 2345 UTC. Tornadoes were observed and video-taped by several qualified storm spotters.

When the authors first viewed the 30-second interval satellite imagery in animation, there seemed little doubt that there was significant rotation at the top of the Ness City storm. This observation seemed particularly significant because the WSR-88D data from Dodge City, Kansas indicated a very strong circulation at lower- and mid-level elevations at the time the tornado was occurring. Thus, it seemed possible that we were seeing a case of a very deep mesocyclone-- one extending all the way to storm top. This turned out not to be the case.

88D radar base velocity data measured 60 ms^{-1} shear in the lower two tilts which we interpret to be low-level rotation which extended in height to about 4 km. The diameter of this circulation was approximately 15 km. Nearer to storm top we found weaker broader-based shear. The diameter increased significantly above 4 km with the circulation diameter approaching 40 km in the horizontal at a height of 12 km.

In an effort to establish the apparent connection between in-storm and storm top rotation, we first tried to quantify the satellite-observed rotation. This was done by constructing a storm relative "loop" (wherein a motion vector of 240 at 22 ms^{-1} was removed) and tracing the trajectories of cloud elements which seemed to be involved in the circulation. The time period studied was from 2254 UTC through 2315 UTC which included the time of the initial F1 tornado touchdown. The sometimes difficult task of tracking the same cloud element from image to image was made simpler by the special collection schedule.

The authors were unable to find any verificable closed circulations using cloud element tracings. Many trajectories were identified which indicated strong southwesterly flow. A few elements were identified which were moving very slowly back TOWARD the southwest in a storm-relative sense (i.e., actually moving toward the northeast at a slower storm-relative speed than the mean flow speed). These elements were located near the center of the long axis of the anvil and may have been associated with slower-moving, stratospheric cirrus. In any case, we found several instances of moderately strong, 180-degree shear, but were unable to find any curved trajectories indicative of rotation. We were not even able to find any cloud elements traveling orthogonal to the mean flow.

The perception and interpretation of motion by an observer is often incorrect. Many times, a person will fit pattern-to-motion in an attempt to quickly diagnose and understand a situation. In fact, elements that seem to move together systematically generally tend to become perceptually grouped by a human observer (Wertheimer, 1937). Cutting and Proffitt (1981) argued that object-relative versus observer-relative motions have vastly different perceptual significances. Observer-relative motion specifies where an object is and how it is moving; object-relative motion specifies what an object is. By constructing our storm-relative loop, we attempt to better understand the nature of the "object" -- here, the apparent circulation at storm top. Cutting and Proffitt (1982) also showed that the human visual observation/interpretation system tends to minimize relative motions. When interpreting a set of motions as a single object, humans normally tend to turn relative shears into circulations. Thus, careful measurement is important when trying to interpret such situations on sequential imagery.

4. CONCLUDING REMARKS.

Anvil top rotation has been the subject of much discussion in recent years. In this case, an apparent storm top rotation turned out to not be a circulation at all, but rather a shear which the human observation/interpretation system tended to interpret (incorrectly) as a closed circulation. This was confirmed with trajectory tracings on visible imagery as well as with proximity WSR-88D data.

However, there may be more to the issue than simply that of interpretation. Even if a mesocyclone were intense enough to cause rotation in a thunderstorm's anvil top, the transport of a circulation to that height would take some time. There is no evidence to suggest that such an event would precede, rather than follow, the appearance of a tornado, nor whether such circulations are always associated with tornadic mesocyclones. Thus, the nowcasting value is, at this point, unknown.

Future research should be directed toward discovering if, and how often, in-storm circulations extend to cloud top, whether such extensions can reach into the strongly divergent region of the anvil, and when in the severe weather cycle this extension occurs. There are several ways actual rotations might occur at cloud top; a) mesocyclonic circulations reaching the anvil intact, b) eddies at anvil top level induced by blocking of the upper flow near the overshooting top, and c) misinterpretation of anvil shear. Once some of these basic questions are sorted out, nowcasting value can be assessed.

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