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A WATER VAPOR IMAGE FEATURE RELATED TO SEVERE THUNDERSTORMS

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The 6.7μm channel water vapor (WV) images from GOES have been generally used as a tool for synoptic scale weather analysis since their availability in the early 1980's. However, WV images do have mesoscale applications as well. The availability of hourly WV images starting in late 1987 has permitted the monitoring of changes in mid and upper level moisture in the environment of convective storms. For example, increasing image brightness may be an indication of vertical motion due to an upper level trough or jet streak, resulting in enhanced potential for thunderstorm development (Rodgers and Griffith, 1989). Other mesoscale uses of WV imagery are summarized by Beckman (1987).

A convective-scale characteristic has recently been observed in WV images which seems to indicate a high probability of severe thunderstorms. The feature is a narrow dark zone which envelopes the upstream edge of the cold cirrus anvil of a thunderstorm cell, or cluster. This dark zone usually has a "C" or "V" shape, but may also be observed as a small circular or oval pattern. An example, shown in Figure 1, was associated with a severe thunderstorm over north central Nebraska on the morning of June 28, 1989. A dark band, estimated to be 15-20 nm wide, lies along the southern edge of the bright white region denoting the thunderstorm system.

A study of water vapor imagery during the Spring and early Summer of 1989 has revealed 150 examples of this signature on 43 days. The main source of imagery for this study was facsimile prints of the 9 CC3 standard sector, an operational product on the GOES-Tap system. Hourly animated imagery was also viewed on the VAS Data Utilization Center (VDUC) display system located at Camp Springs, Maryland. The latter was found to be superior in identifying the dark regions because of an enhancement scheme which highlights subtle features much better than the CC3 prints. An important requirement in the study was determining that the dark zone did not exist prior to the formation of convection, and thus occurred as a result of the convection.

Of the 150 examples observed, 103 (69%) were associated with severe thunderstorms, based on preliminary severe weather reports from the National Severe Storms Forecast Center in Kansas City. Of those for which no severe weather was reported, most occurred either late at night or in sparsely populated areas. A breakdown of the associated severe weather (Table 1) shows that large hail was the predominant weather type by far, occurring in 87 events (84% of the 103 severe storms). For the June 28 case shown in Figure 1, one inch diameter hail was reported.

TABLE 1
Severe Weather Events with WV Dark Zone

Large Hail	87	(84%)
Tornadoes	29	(28%)
Winds damage	18	(17%)
Gusts >50 kt	13	(13%)

The geographic distribution of this WV signature showed a maximum in the central United States. Only 18 occurrences (12%) were observed east of the Mississippi River. This is not surprising, in light of the normally higher frequency of severe weather in the Great Plains.

One of the environmental conditions required for the observation of the dark band feature is the near absence of cirrostratus in the vicinity of convection. The cirrostratus tends to obscure any darkening which may occur, because of its persistence and opacity. On the other hand, in situations where extremely dry air aloft is present, the dark zones are rarely observed, probably due to the lack of sufficient contrast in the images. A minor adjustment to the operational enhancement curve, or an adjustment of contrast on video display systems should improve this situation. since it is a small scale feature, it is best observed when the standard WV sectors are enlarged, such as in the sub-sector mode on the Satellite Weather Information System (SWIS).

The cause of the thunderstorm dark zones, while still open to conjecture, is believed to be sinking along the upstream edge of the anvil cirrus. This effect should be most pronounced with a combination of: (1) moderate to strong upper level flow and (2) a strong, sustained thunderstorm updraft which tends to block the environmental flow and force compensating subsidence. Since the stable tropopause presents an obstacle to rising motion, the approaching air tends to sink as it converges with the anvil outflow. Some warm, dry stratospheric air is possibly forced to sink also. The result is both warming and a net loss of moisture in the air column, leading to darkening in the WV images. Conceptual models of airflow in the environment of strong supercell thunderstorms (e.g., Lemon and Doswell, 1979) suggest that mid to high level sinking on the upwind side ma initiate the "rear-flank downdraft" (Figure 2).

Another example occurred with an outbreak of severe storms over east Texas and southeast Oklahoma on the afternoon of April 28, 1989, shown in Figure 3. The WV image at 2300 UTC showed that considerable deep convection was present. At 0000 UTC, April 29, dark zones were observed on the western edge of cells in north central Texas and southeast Oklahoma (arrows). Starting at 0020 UTC, a tremendous hailstorm occurred

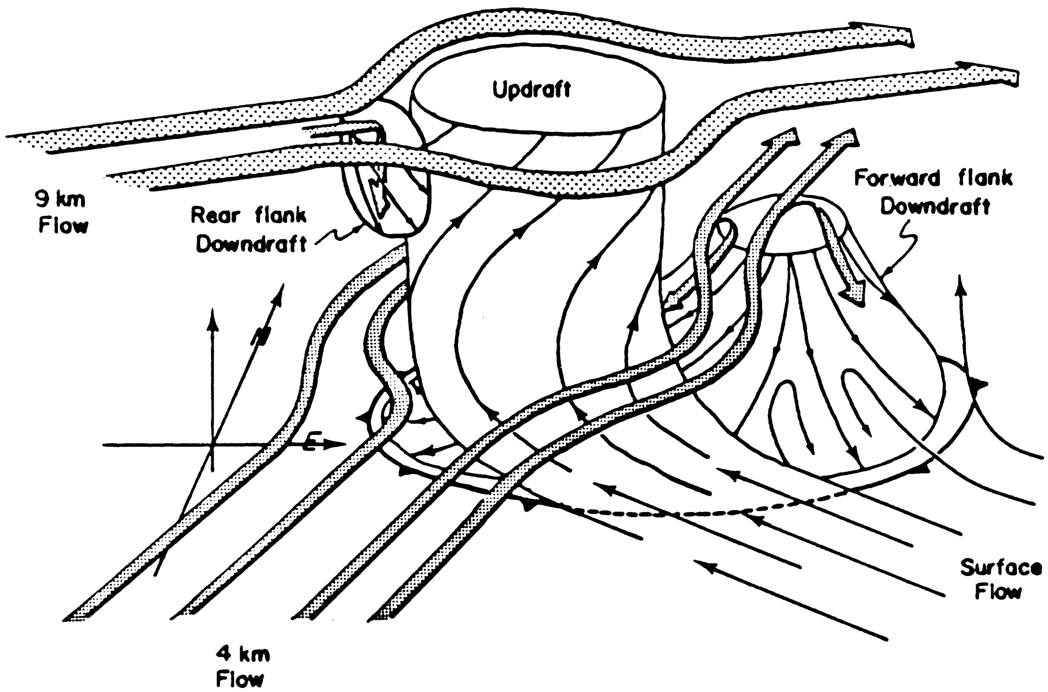

Figure 2. Three dimensional model of airflow during the early stages of a supercell thunderstorm (from Lemon and Doswell, 1979).

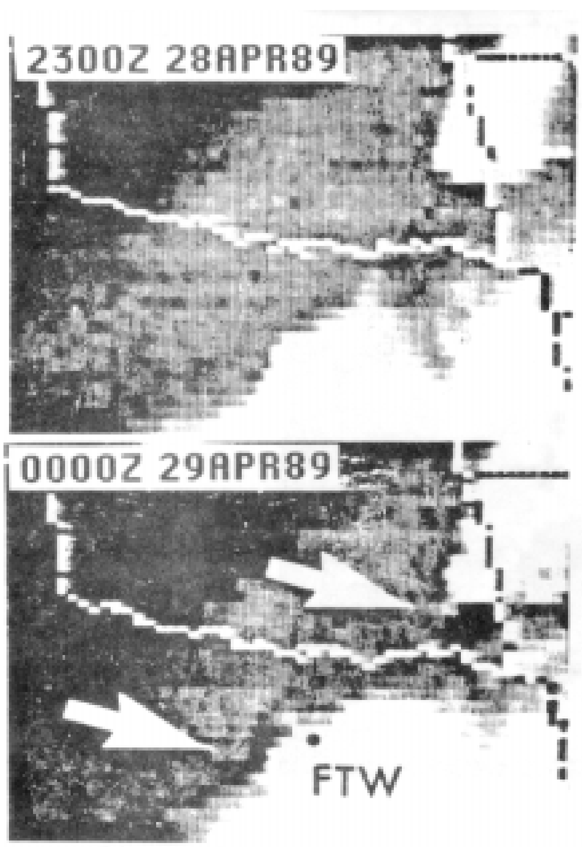

Figure 3. GOES WV images at 2300 UTC 28 April (top) and 0000 UTC April 29, 1989 (bottom).

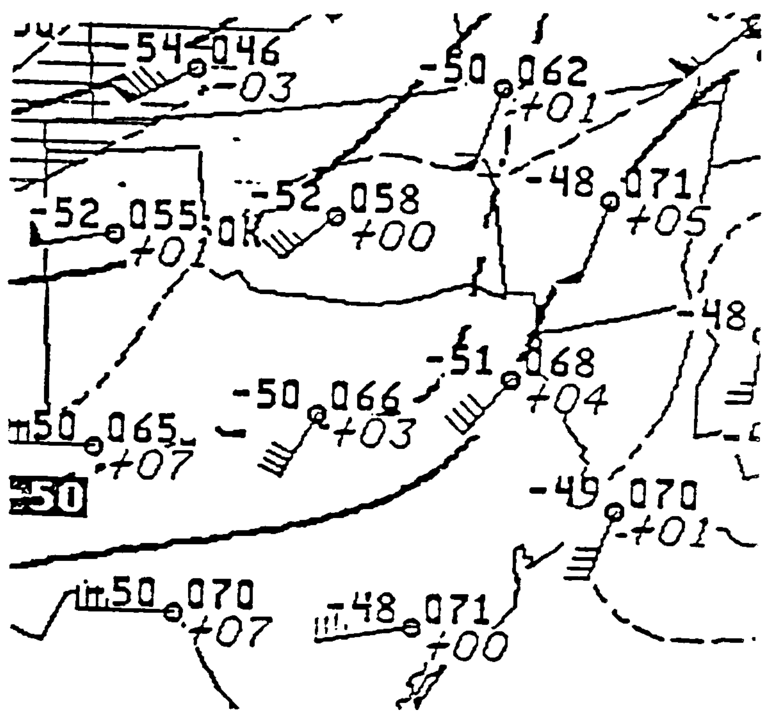

Figure 4. NMC 250 mb April analysis at 0000 UTC, April 29, 1989.

near Ft. Worth, Texas. Hailstones ranged from 1 inch in diameter to near softball size, and some damage was reported. At about the same time, hail of more modest size (1 inch) occurred in southeast Oklahoma. While in this particular event, some lead time was present between the detection of the WV signature and the severe weather, in many other situations it was not possible to determine. The delayed transmission of WV images on the GOES-Tap system is another negative factor. The 250 mb analysis for this time (Figure 4) indicated that westerly winds of 35-50 kt over west Texas became strongly diffluent over east Texas due to the blocking effect of the storms.

Our ability to monitor the environment of severe thunderstorms is expected to improve with the higher resolution and more frequent WV imagery from GOES I-M satellites in the 1990's. In the meantime, the hourly GOES WV imagery may serve as another analytical tool in the detection of severe storm activity.

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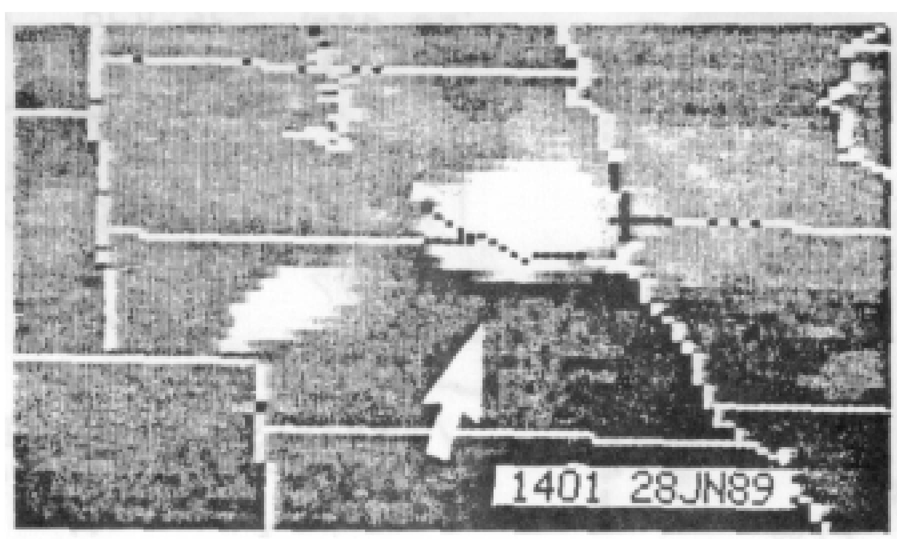

Figure 1. Water vapor image from GOES-7 at 1400 UTC, June 28, 1989.