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NOWCASTING DURING THE 10 APRIL 1979 TORNADO OUTBREAK: A SATELLITE PERSPECTIVE

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1. INTRODUCTION

On the afternoon and evening of 10 April 1979, northwest Texas and southwest Oklahoma experienced an intense outbreak of severe thunderstorm weather which included downbursts, extremely large hail and several destructive tornadoes. For a discussion of the synoptic-scale weather pattern associated with this outbreak see Alberty et al (1979). The outbreak was particularly significant in that a few of the largest tornadoes occurred in densely populated areas such as Vernon, Texas, Wichita Falls, Texas, and Lawton, Oklahoma. For a complete damage description see Alberty et al (1980).

Under normal circumstances, meteorological data for the period would have been limited to routine radiosonde data, hourly surface observations, half-hourly satellite photos, radar data and reports of severe weather in progress. However, 10 April was a special severe weather research day for Project SESAME (Alberty et al, 1979). Radiosondes were being released at 3-hourly intervals at sub-synoptically spaced sites across the central plains, GOES satellite data were being taken at 3-minute intervals, and several Doppler radars were in operation in Oklahoma. Additionally, tornado filming crews were located in northwest Texas. Although few of these special data could be processed in real-time to assist forecasters on 10 April, they still provide a means to clarify events observed via more conventional sources. In particular high frequency satellite imagery reveals features only surmised through other sources. The following study suggests several ways that satellite data could be used to simplify the short-term forecast problem.

2. CASE STUDY

Data for this paper were studied in approximate 3-hour time segments to coincide with the SESAME RAOB release intervals; i.e., mid-morning, noon and mid-afternoon.

2.1 Early to Mid-Morning

Figure 1 shows a mid-morning (0856 CST) visible satellite image and significant surface features. By the time of this analysis an occluded front stretched southward from a low in Colorado into the Texas panhandle. For most of the morning a large portion of central Texas was capped by a layer of low stratus. Special sounding data revealed the reason for the persistence of the stratus deck: except very near the surface the stratus region was characterized by a deep stable layer extending to near 700 mb.

On the previous day, a cold front had pushed southward through Oklahoma and Texas to the Gulf of Mexico. The front had cooled the surface significantly in Oklahoma, but had modified considerably further south. By the morning of the 10th, warm, moist air was moving northward along the surface through Texas. Surface analysis at 0700 CST found 60^{o}F dewpoints as far north as central Texas, versus Oklahoma dewpoints in the 30's and 40's. The warm front was difficult to locate early in the day. However, from a forecast point of view, the significant boundary was the zone of strongest upward vertical motion. Since cloud lines often form along these zones, satellite data were helpful in this analysis. On visible satellite photos the "front" showed up as a rather broad band of enhanced cloudiness. Infrared data showed a line of slightly colder clouds coincided with this enhanced region. It is along that line, separating cooler, drier air in Oklahoma from warm moist air in Texas, that a "warm front" was tentatively placed.

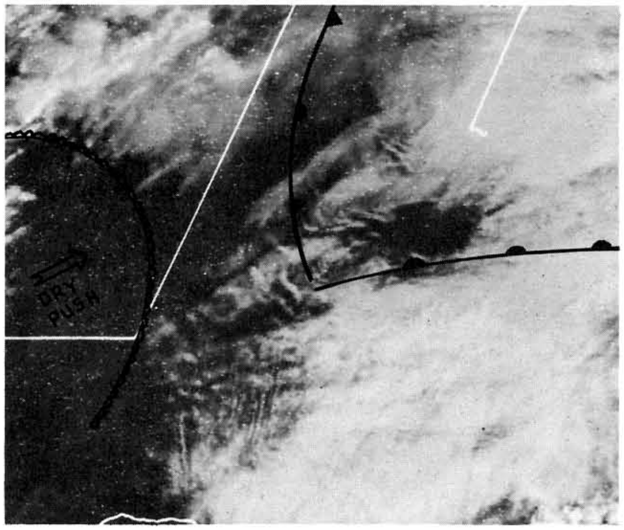

Figure 1. Satellite photo from 0856 CST, 10 April 1979 with significant surface features added. Symbols are conventional.

For the purpose of this study a distinction is made between the terms "dryline" and "dryline surge". Dryline refers to the normal, diurnal eastward progression of surface dry air due to heating and mixing (Schaeffer, 1974). The "dryline surge" refers to the eastward progression of dry air due to both heating and dynamic processes (McGinley and Sasaki, 1975). On the analysis shown in figure 1, the dryline surge (labeled 'dry push') is outlined by the scalloped curve. The feature was identified by surface data and its position adjusted using satellite imagery showed its movement was from the west-southwest at about 30 kts.

By mid-morning the stage has been set. Several preferred areas for convective development have been identified: a dryline surge, an occluded front and an ill-defined warm front. At a velocity of 30 kts the dryline surge should reach the Lubbock, Texas area by 1200 CST.

2.2 Mid-Morning to Noon

Between 0900-1200 CST, the features discussed above remained identifiable on satellite pictures. Three important events happened just before noon. First, along the warm front near the Red River, a line of moderately strong thunderstorms (≥ 50 dbz) had formed. These cells were moving from 200° at 40 kts. Second, thunderstorm development began both along the dryline surge and the occluded front. The onset of convection at these two widely separated locations was not unrelated. The activity in western Texas occurred as the shortwave trough aloft entered that region. The storms along the Red River were due to warm air advection occurring in response to the approaching system aloft. The third important pre-noon event was the development of an organized line of clouds near Abileen along the western edge of a weak ridge of high pressure.

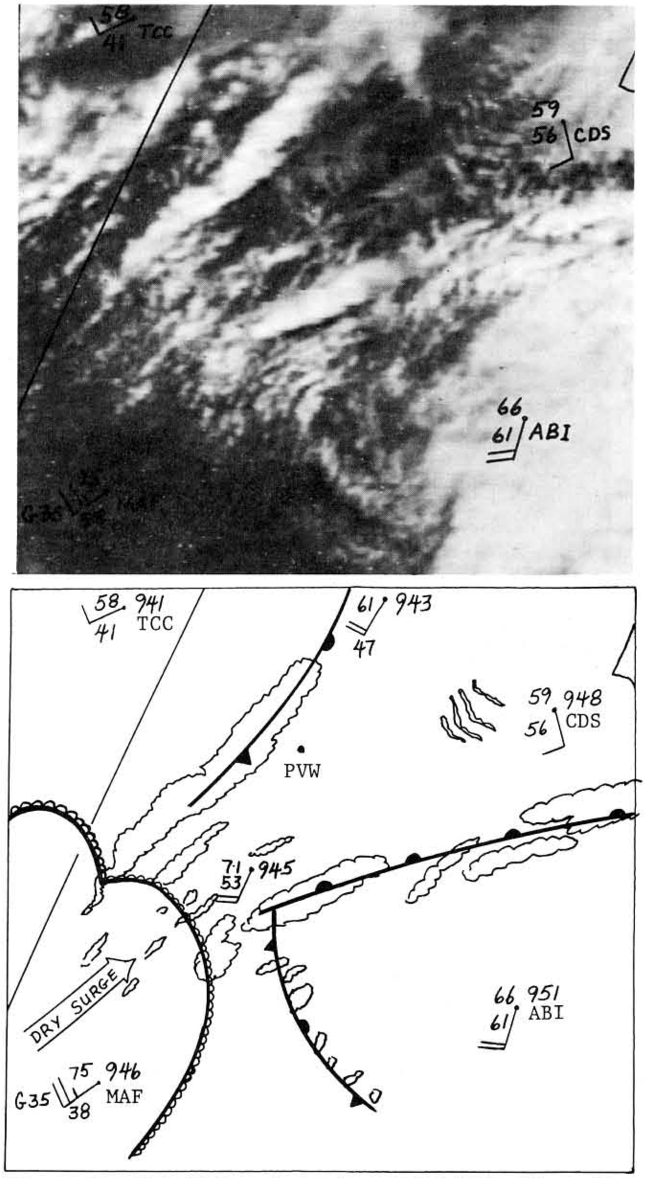

Figure 2. Satellite photo from 1152 CST, 10 April 1979 with significant surface features and cloud pattern outlined below.

This western edge of the small, high pressure area is outlined by the north-south curved line of clouds west of Abileen. This feature is analysed as a mesoscale stationary front for lack of a better designation. Figure 3 shows one possible cause for this meso-front: differential heating due to the cloudy (stratus region) versus clear region to its west. By noon some of the clouds along this mesofront had already grown relatively large and were producing small anvils. However, satellite movie loops from 3-minute interval imagery reveal that as small storms formed on this line, they quickly moved east and dissipated.

Figure 2 is the 1152 CST visual satellite photo which shows the convection that had begun in western Texas. One line of storms was building along the occluded front, and, according to Amarillo radar, moving from 210° at 32 kts. Another line of storms had formed along the western extension of the warm front. That line extended eastward from the dryline/warm front/mesofront intersection near Lubbock. Satellite data showed these storms to be moving from about 230°. Only the storms at this intersection point continued to strengthen and grow.

The forecaster's emphasis at this point should be focused on these three storm areas. First, the storms along the occluded front. They are moving north, northeastward toward much colder and drier air. If there is going to be severe weather it must happen soon. Second, the same may be said of the moderately strong storms on the warm front along the Red River, since they are also moving into a much more stable air. Thirdly, however, circumstances are different for the storms near Lubbock. That activity is evolving at the dryline surge, warm front, mesofront intersection and is moving along the warm frontal zone. Thus, this activity is traveling toward the "ripest" air available (see figure 4 and discussion on the next page).

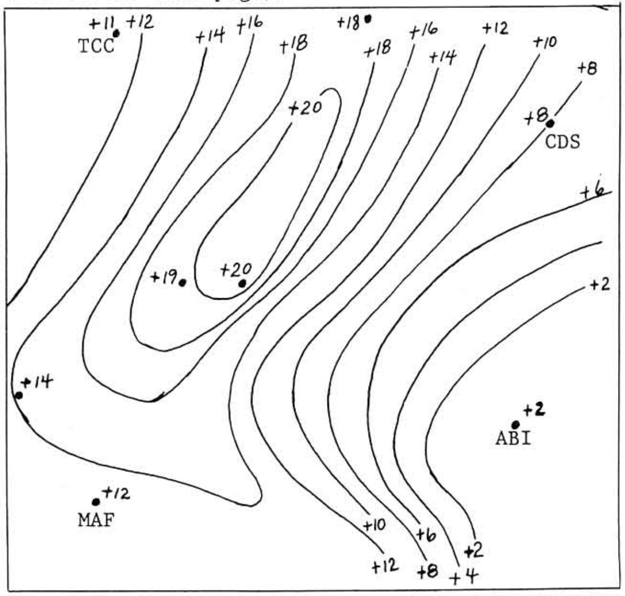

Figure 3. Surface temperature change between 0900 CST and 1200 CST for region shown in figure 2. Temperature change is analyzed in increments of 2°F.

2.3 Noon to Mid-Afternoon

During the early afternoon all three areas discussed above developed severe weather. Along the occluded front 1½" hail occurred southeast of Amarillo and a small tornado was reported east of Plain View (1338 CST--no damage). Along the warm front near the Red River two reports were received around noon of 1" diameter hail in northern Texas. These were the last severe weather reports received in association with those two storm areas.

The storms traveling east-northeastward from the Lubbock vicinity were the most active and had the majority of the severe weather for this day. As pointed out earlier, the latter storms were strongest, since they were moving into the most potentially unstable air mass. The potential instability is strongly implied by temperatures and dewpoints in this region. Additionally, calculations of static energy (Darkow, 1968) which are shown in figure 4 confirm this.

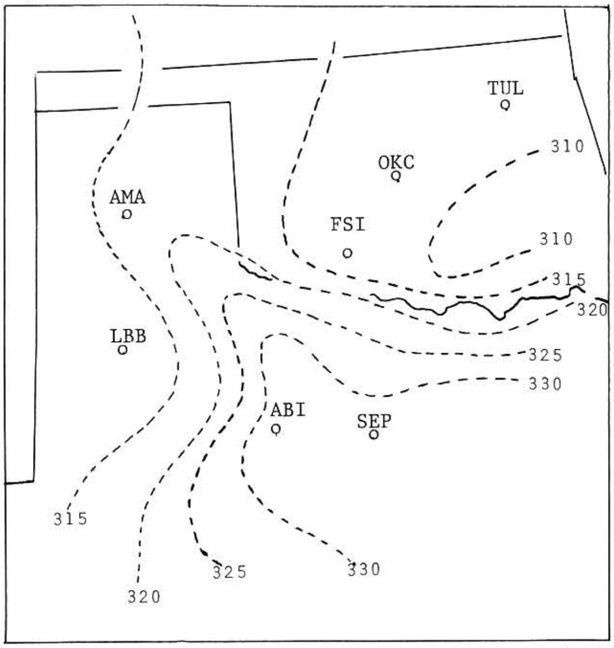

Figure 4. Surface static energy ($E=C_pT+gz+L_oW$) for 2100Z on 10 April 1979 expressed in Joules gm^{-1}.

Figure 5a is the 1526 CST visible satellite image with surface features in figure 5b. There are two storms of particular interest at this time, marked S1 and S2. Five tornadoes were associated with storm S1. The first touched down near Foard City, Texas at 1505 CST; the last lifted off the ground just east of Lawton, Oklahoma shortly after 1715 CST. The second tornado in the series of five caused 11 deaths and F4 damage (Fujita, 1971) in Vernon, Texas, while the fifth brought 3 deaths and F3 damage in Lawton, Oklahoma. A single 64 mile track tornado occurred in conjunction with storm S2. In its path scattered F2 damage occurred; however, it did manage to nearly destroy the airport at Granfield, Oklahoma.

Storm S1 formed at 1900 CST at the intersection point of the dryline surge, and mesofront (hereafter this intersection will be referred to as the trigger point). What might be considered surprising, is that storm S2 also formed at the trigger point (at 2030 CST). The path of the trigger point furnishes an explanation for the north-south offset in storm location (figure 6). The diagram shows the path with time of the trigger point traced using 3-minute interval high-resolution satellite photos.

A third severe thunderstorm (S3 in figure 7) formed later (2230 CST) at this same point. Again, the storm track was slightly south of the previous one (storm S2). Comparison of the resulting set of the three damage tracks from those storms (Alberty et al, 1980) shows that the bulk of the severe weather was generally limited to a small area associated with the three storms formed at the trigger point.

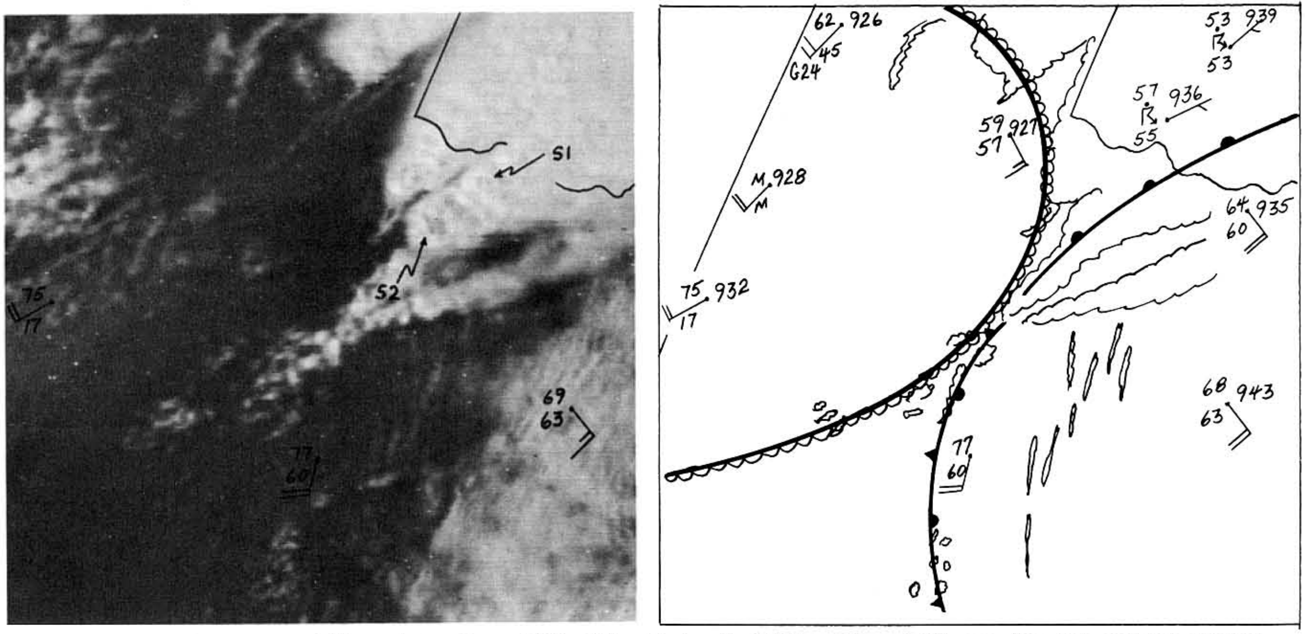

Figure 5. a) Visual satellite photo from 2126 CST, 10 April 1979. S1 and S2 are the two severe storms referenced in text. b) Surface features at 2100 CST for the region shown in a. Symbols are conventional.

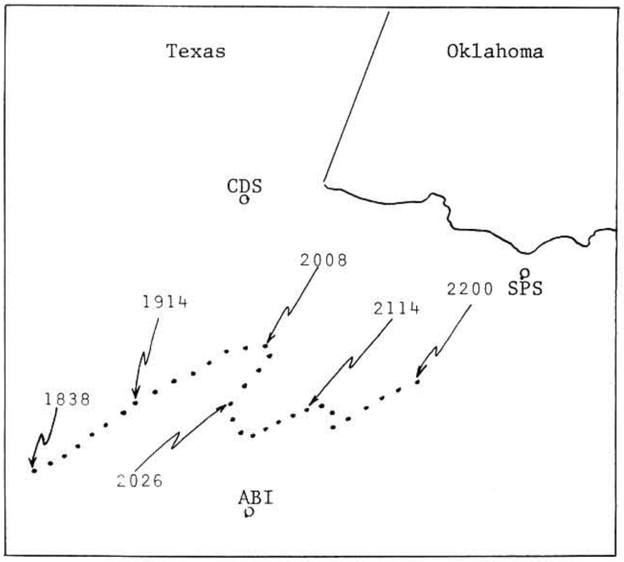

Figure 6. Propagation of the dryline/warm front/ mesofront intersection. Times indicated are in central Standard Time.

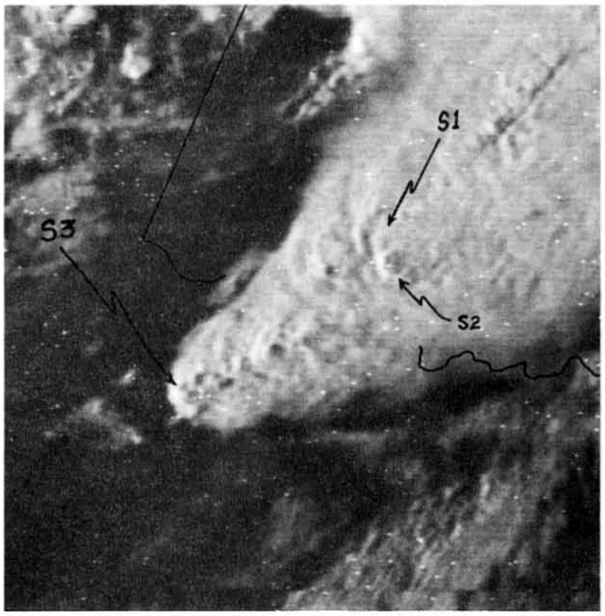

Figure 7. Satellite photo taken at 2308 CST, showing the location of tornadic storms S1, S2 and S3. All 3 had tornado activity at this time, with S1 entering Lawton, Oklahoma and S3 Northeast of Seymour, Texas.

3. CONCLUDING REMARKS

A major tornado outbreak occurred on 10 April 1979. Indications from morning, synoptic-scale forecast data were that nearly the entire south central plains region was threatened. As shown in the preceding discussion, mesoscale forecast information, derived from combining special satellite surface and upper air data could be used to drastically reduce the primary threat area quite early in the day (say by 1230 CST).

Severe thunderstorms nearly always form along low-level convergence boundaries (i.e., warm fronts, cold fronts, arc lines, etc). These boundaries are typically identifiable in photos taken from satellite. In this case study, it was shown how three mesoscale storm regions were responsible for all the severe weather reported. All three regions were identifiable using satellite data. The occluded front was positioned using both surface observations and satellite imagery. In case of the warm front, satellite data significantly helped position the boundary for analysis. The mesofront, an extremely important boundary for storm development upon its interaction with the dryline surge, was revealed only with satellite imagery. It was shown that all of the destructive tornadic thunderstorms formed at this point.

One of the single most useful tools that should be developed for assisting forecasters is routinely available displays of satellite imagery with conventional data overlays. The research community would also benefit by being able to see, using satellite data, what environmental factors separate the severe from the non-severe storm.

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