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Satellite

INVESTIGATION INTO THE JUNE 10, 1984 THUNDERSTORM VINCENNES, INDIANA

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ABSTRACT

On June 10, 1984, a thunderstorm of unusual severity produced heavy precipitation in a small area centered on Vincennes, Indiana. Sequential analysis of the development of the storm using satellite imagery and radar data indicates its origin as part of a weak cold front. The active storm cell resulted from the merging of two active cells. Full explanation of the event draws upon examination of prevailing synoptic conditions following the weakening of a blocking High.

INTRODUCTION

At midnight, Sunday, June 10, 1984, the United States was bisected by a long, narrow cold front. This front extended from a Low in northern Wisconsin and stretched southwest to the Texas Panhandle. This area of disturbed weather was the principle parameter in the development of a major thunderstorm that evening in Vincennes, Indiana. The isolated precipitation pattern associated with a highly unusual storm path warrents further investigation.

SATELLITE BACKGROUND

Satellite images dated June 9 clearly show a well-developed frontal system. Figure 1, taken from GOES-E, shows the development of the storm over time. At midnight CDT (0500 GMT on the 10th), the cold front with associated thunderstorms extends from central Wisconsin to northern Texas. The front was beginning to weaken, although a rather large band of moderate to intense thunderstorms remains from central Missouri to north Texas. By 9 am (1401 GMT) the area of thunderstorms had decreased in size. As sometimes happens when a thunderstorm complex begins to spread out, it loses strength and breaks into two separate but smaller complexes (1501 GMT). The northern area (centered over Chanute, KS) continues as an area of moderate thunderstorm activity.

SYNOPTIC SETTING

As is evident in the 1601 GMT image, Vincennes (in southwestern Indiana) has not experienced any type of significant weather. However, several variables might suggest trouble in the near future.

As is common in summer, the Azores-Bermuda High has increased in strength and has begun to block approaching frontal systems. This resulted in a prolonged period of dry weather in much of the eastern United States during the summer of 1984. Terre Haute, IN (55 miles north of Vincennes) went 24 days without precipitation (May 28 through June 21, including June 10).

The State of Indiana on this date was between the blocking Bermuda High and the cold front advancing from the plains. Pressures had fallen slightly during this period as the 1020.0 millibar line moved from Nashville, TN, on the 9th to about 100 miles east on the 10th. The high-pressure center slowed the front, as it travelled only 140 miles in the 24-hour period.

Another variable that could have alerted the Vincennes area of the approaching storm was the 500-mb wind pattern. The 500-mb height contour map of June 10th shows a dominent south-soutwest flow into Indiana. With wind speeds approaching 50 mph at this level, moisture from the Gulf of Mexico could help develop thunderstorms (3).

4. STORM MOVEMENT

As noted previously, thunderstorms were occurring in southeastern Kansas. Within 1 hour, a new storm had begun to form in western Missouri (1701 GMT). At 1 pm (1801 GMT) the former storm had dissipated and the new storm moved to central Missouri. At this time, the cold front was not evident in the satellite imagery. Only this one storm remained. Thin clouds are covering western Indiana as clear skies move into northern Illinois.

Three hours later (2100 GMT) the thunderstorm has increased in overall size. By now clear skies have moved into much of northern Indiana. At 5 pm (2200 GMT) the storm has entered Illinois, just south of St. Louis. Also, the storm appears to have two separate centers. Clear skies are now only 30 miles northwest of Vincennes. At 6:30 pm (2300 GMT) the storm has regrouped and appears to be over Mt. Vernon, Il. At

this time the sky is clear only 15 miles north of the city of Vincennes. However, a small, east-west-oriented cloud band had formed over the city. This cloud band corresponds well with the newly developed radar echoes discussed in the next section. By 7 pm (0000 GMT) a very faint line appears on the infrared image. This line connects the large thunderstorm in Illinois with the clouds in Indiana. The 7:30 pm visible picture (0030 GMT) clearly defines a cloud line stretching from Vincennes to the cloud tops approximately 50-60 miles to the west-southwest. At this time the cloud was beginning to develop more over Vincennes while losing strength in Illinois. This is very reminiscent of earlier images of successive cell development. However, instead of the first storm dissipating, it appears as though it merged with the new storm. The 8:00 pm (0100 GMT) image shows the large weaker storm in Illinois and the new strong storm over Vincennes. At 8:30 (0130 GMT) a single thunderstorm is centered over the study area. By 9:30 (0230 GMT) the storm has begun to diminish in intensity and by 10 pm (0300 GMT) it has dissipiated.

5. RADAR ANALYSIS

A series of National Weather Service radar images from Evansville, IN, are shown in Figure 2. Vincennes is approximately 40 miles north of Evansville, as is evident on the 0230 GMT radar overlay. At 6:27 pm (2327 GMT) the heavy thunderstorm over Mt. Vernon and the cell over Vincennes have maximum cloud tops of 40,000 ft. The cells were moving to the northeast at only 10 mph. The NWS classified these as very strong thunderstorms with very heavy precipitation estimated. By 7:30 pm (0026 GMT) the cells have formed one line of stroms, with tops ranging from 40,000 ft about 45 miles SW of Vincennes (at the rear of the storm) to 45,000 ft at Vincennes. The storm continues to move northeastward at 15 mph.

By 8:30 pm (0128 GMT) the thunderstorm had decreased in coverage to an area 30 miles long by 8 miles wide. However, it had increased in intensity. The maximum cloud tops over Vincennes were now approaching 50,000 ft. By now the NWS had rated the thunderstorm "intense," with continued heavy precipitation. The cell was now moving northeastward at 25 mph. By 9:30 pm (0230 GMT) the cloud tops had decreased to 26,000 ft and the classification was only light rain showers decreasing in intensity. As shown in the final satellite image, by 10 pm the storm had dissipiated to just mid-level clouds.

6. CLOUD DEVELOPMENT

Satellite images have shown a rapid movement of an intense thunderstorm from western Missouri to eastern Illinois. This storm developed just east of a storm complex in eastern Kansas at 1601 GMT and progressed to central Illinois by 2330 GMT. This storm travelled approximately 275 miles in this 7 1/2 hour span, or an average of 36 mph.

Convective storms commonly develop along the outflow boundary of other thunderstorms. It is difficult to identify this process from satellite imagery alone, but the successive movement of the storm being examined suggests the this mechanism played an important part in this particular episode.

As the storm reaches central Illinois it seems to slow. Two new thundershowers developed to the east-northeast (2330 GMT). When this occurred in Kansas, the first storm died and a new storm developed. However, this time the storms seem to merge. The 0000 GMT satellite image showed a line forming between the areas. An interesting occurrance is that the major part of the storm skipped from the Mt. Vernon area to Vincennes. As seen at 0030 GMT the heaviest extent of the storm was over Vincennes, even though the larger (aerial) storm was in Illinois. By 0130 GMT, the storms had merged into one.

Merging of cells is not a new idea. Byers and Braham (2) presented the first arguments for cell mergers. They list four means of creating a favorable environment for new convective growth:

1) Cold outflow air underrunning and lifting neighboring warm air;

2) Mixing of saturated air entrained from the parent cell;

3) Addition of moisture to neighboring air by precipitation falling from an overhanging canopy created by the parent cell;

4) Local areas of surface convergence or upper-level divergence causing spontaneous generation of downdrafts.

The merging of three cells over Vincennes undoubtably is connected to one or more of the mechanisms. However, it would be extremely difficult to predict a specific area where the storms would merge.

7. PRECIPITATION PATTERN

The widespread cold anvils shown on the satellite images are deceiving in the sense that the actual rainfall is confined to a much smaller area. Because of this, one of the most interesting aspects of this storm was its rainfall pattern.

Observations from the surrounding area indicate an unusual occurrance (Figure 3). Whereas Vincennes received a tremendous amount of precipitation, totals from NWS observers in surrounding areas were light. To the west, Lawrenceville (10 miles) received .01 inch, and Olney (32 miles) did not report any measurable amount. To the east, Washington (20 miles) received only .01 inch and Monroe City (9

miles south-southeast) received .1 inch. This tends to prove that the storm formed and dissipiated over the Vincennes area, since the movement of the storm was east-west.

Latitudinally, Palestine and Oaktown, IN (23 and 13 miles to the northwest and northeast, respectively) reported no precipitation. Also, the Purdue Agricultural Experiment Station (3 miles north) reported .09 inch. To the south, Mt. Carmetl (22 miles) received only a trace. Therefore, the storm seemed to have a very small north-south component of movement. rainfall was confined to a very local area.

Figure 4 allows a more detailed study on the immediate Vincennes area. Vincennes is a small town of about 4 miles by 4 miles. Within the city boundaries, various amounts of precipitation are indicated, thus showing how isolated the storm was. On the far southwest side, no rainfall fell. Along the river on the west side of the city (the Vincennes Water and Sewage Plant) 1.89 inches fell. 3.00 inches of rain was reported in the southeast part of the city. The city core (the Vincennes Sun-Commercial Newspaper) reported 2.52 inches. The heaviest rainfall was centered on the northern boundary. 4.50 inches fell along the northern limits at Public Service Indiana, while an extreme measurement of 5.50 inches was reported around the city loop. Sources of rainfall data not mentioned are from private homes.

8. DAMAGE REPORT

A storm of this intensity can cause considerable damage. The storm was centered just to the east of the cloverleaf (city loop). A small creek, approximately 5 feet deep and 5 feet wide, covering 3 square miles of drainage (including the cloverleaf) was filled to capacity in a very short time by the heavy rains. Because of the heavy rainfall, the runoff could not pass through the highway culverts, thus leading to flooding. The northbound lane of Highway 41 (the principal north-south highway in western Indiana) was covered by over 1 foot of water, flooding many cars. This road was closed for over 2 hours before the water receded. Flood water also came close to damaging homes. The Civil Defense had to act quickly to sandbag neighboring houses to keep water from causing major damage. Other damage to Vincennes homes occurred by lightning strikes in the immediate area.

Public Service Indiana, the Street Department, and the Water and Sewage Department all reported damage. A power transmission line between two substations was damaged, with 475 PSI customers without electricity for part of the night. The local street department spent all night trying to clear roads that were blocked by fallen trees and debris from flood water. Possibly the greatest damage was incurred by the Water and Sewage Department. The Bruceville Lift Station (east of the cloverleaf) was totally destroyed in the storm. Estimated damage to this department alone was over $9000.

9. EXTREMES

Undoubtably this was not a typical Indiana storm. Apart from the longevity of the original storm system, the development of successive storms as it entered Indiana, and the merging of these storms, this system is unique. A fact to remember when considering these phenomena is that the National Weathe Service forecast for June 10 did not call for precipitation in the Vincennes area. Furthermore, the NWS did not issue any watches or warnings during the study period.

One interesting observation is to analyse the all-time maximum precipitation amounts. Considering that data for the Vincennes area is not available, close proximity cities from Indiana and Illinois must be utilized. In Indianapolis, the maximum precipitation amount recorded in any 24-hour period in June is 3.80 inches. For South Bend, the maximum for 24 hours in June is 4.70 inches. In Illinois, the maximums for Chicago and Springfield are 4.58 and 4.73, respectively. Considering reports indicate at least 4.50 inches fell, with one report of 5.50 inches, it is easy to see that this storm was very unusual. It has been estimated that this raincell exceeded the 50-year rainfall amount for this part of Indiana.

This storm also has unusual characteristics of precipitation amounts and temperature changes. Although the rainfall amount does not compare with the all-time extremes of 31 inches in 4.5 hours in Pennsylvania (1942) or the 12 inches in 42 minutes in Missouri (1947), it still ranks as quite an acheivement to receive over 5 inches in 2 hours in an extremely small area.

The temperature in Vincennes reached a high of 91 degrees at 4 pm, it dropped to 87 at 6 pm, and it remained at 87 until the storm arrived. At this time it dropped to 64 degrees, or a 23 degree drop in only 15 minutes. The temperature began to rise soon afterwards, and it had reached 73 degrees by midnight. The 23 degree drop does not compare with the 62 degree drop in 7 hours in Missouri (1911) or the 62 degree rise in 2 minutes in South Dakota (1943), but it is remarkable.

10. CONCLUSIONS

The thunderstorm cell that struck Vincennes on June 10, 1984, was truly unusual. Although atmospheric conditions favored some type of activity that day, no one expected a storm this intense. Hopefully, improved interpretation of satellite imagery and radar pictures can prevent major damage from the sudden impact of such a storm in the future.

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FOOTNOTES AND REFERENCES

1. Mr. Binkley, a Graduate Assistant in the Department of Geography at Indiana State University, is completing work for the M.S. degree. He received the A.S. in Meteorology from Western Kentucky University and the B.S. in Geography from the University of Utah. He will be a Ph.D. candidate in the fall working in the field of synoptic climatology.

2. Byers, H.R., and R.R. Braham, Jr., 1949: The Thunderstorm. U.S. Govt. Printing Office, Washington, D.C., 287 pp.

3. National Oceanic and Atmospheric Administration, 1984: Daily Weather Maps. National Environmental Satellite, Data, and Information Service, U.S. Government Printing Office, Washington, D.C.

4. Wilhlemson, R.B. and C.S. Chen, 1982: A Simulation to the Development of Successive Cells Along a Cold Outflow Boundary. J. Atm. Sci., 39, pp. 1466-1483.

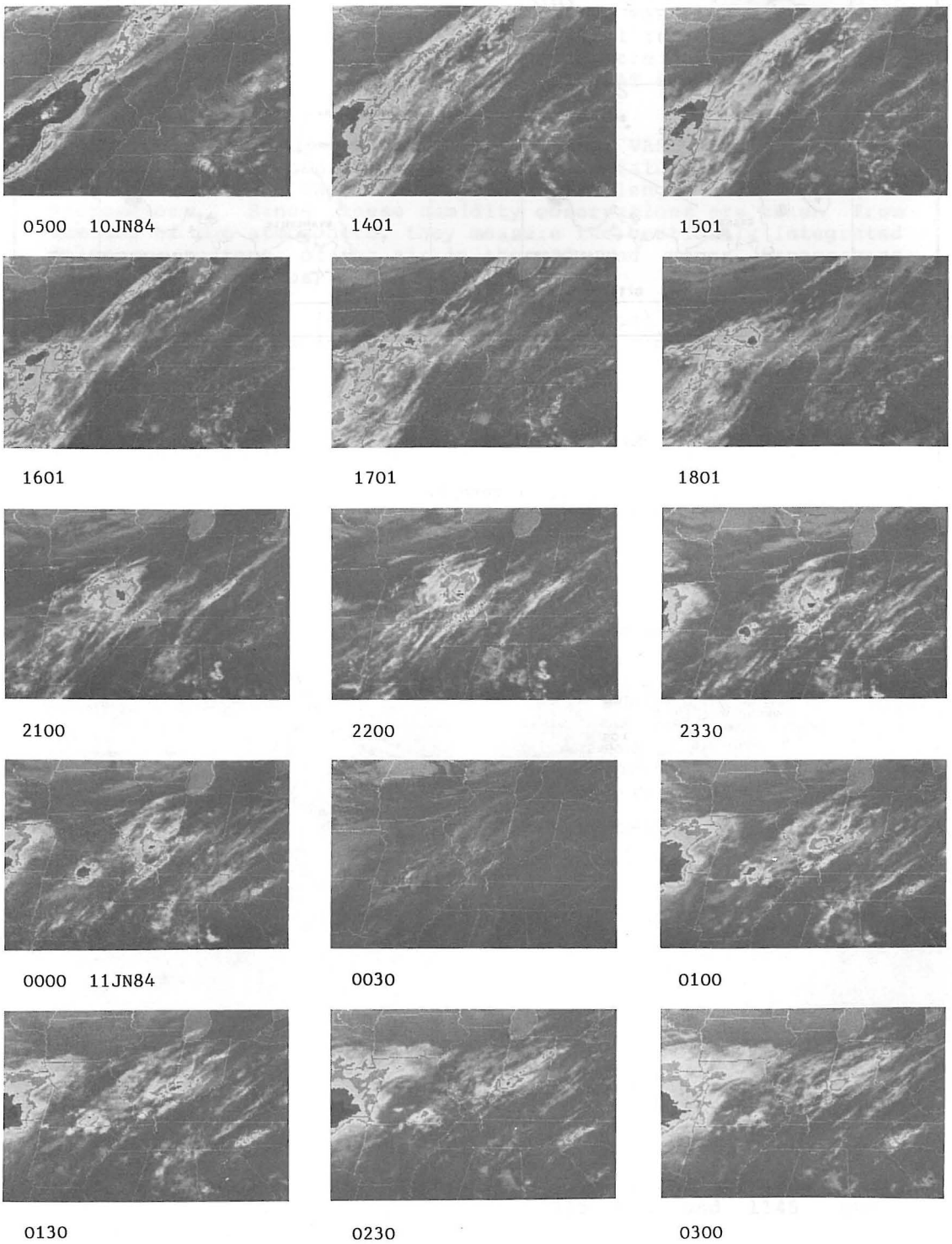

Figure 1.

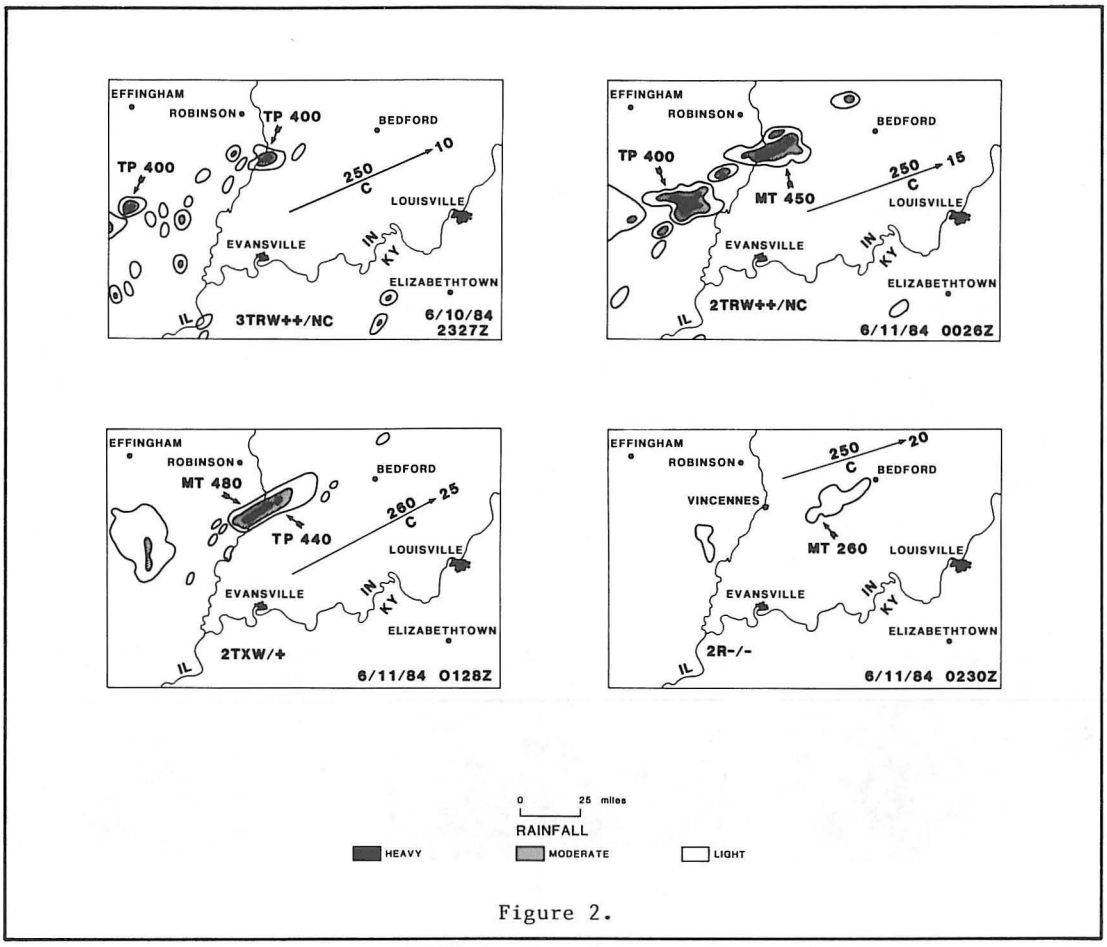

Figure 2.

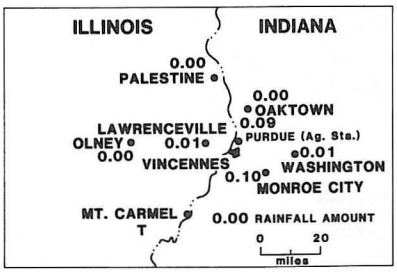

Figure 3.

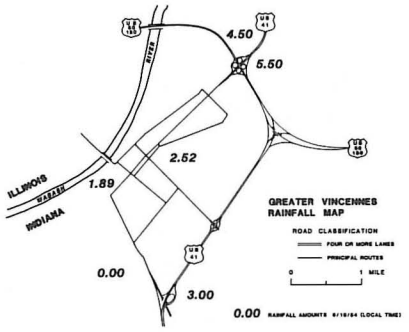

Figure 4.