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THE CHEYENNE TORNADO: A METSAT CASE STUDY

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MARCH 27,1980

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FOR THE COMMANDER

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This Technical Note describes the Meteorological Satellite (METSAT imagery, of the thunderstorm outbreak, which produced the Cheyenne, Wyoming tornado. It discusses METSAT Imagery signatures for severe weather and the application of METSAT Imagery in providing weather support to certain Air Force operations.

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1. Introduction.

At 2135Z on 16 July 1979 a tornado struck Cheyenne, Wyoming (Figure 1). The funnel cloud developed over Francis E. Warren AFB, proceeded along the northern boundary of the base and continued eastward into Cheyenne. It caused one fatality and over $40 million damage in the civilian community (Ostby and Wilson, 1980). Damage to Air National Guard C-130s at the Cheyenne Airport totaled several million dollars, (Figure 2).

One problem in forecasting such an occurrence is the lack of surface observations and radar data in the sparsely populated regions of the west. Satellite data covers a continuum of space, and the resolution of GOES imagery allows mesoscale analysis. GOES satellite imagery is not dependent upon surface reporting stations or location of radars. These data are available at 30 minute intervals to units with GOES or WSFO taps. An analysis of the available GOES imagery from the afternoon of 16 July suggests a technique for predicting the occurrence of severe convective weather.

Figure 2. Wyoming ANG C-130 damaged by the Tornado (Photo courtesy Capt J. James OL-A, 9 WS, F. E. Warren AFB, WY).

2. Synoptic Situation.

There was a high potential for severe convective weather over the high plains of southeastern Wyoming and northeastern Colorado on 16 July 1979. A shortwave trough with weak to moderate PVA was evident at 500mb. A 90kt westerly jet at 200mb was over the area, providing a venting mechanism for deep convection. There was strong thickness advection in the low levels, as well as high moisture content. The atmosphere was conditionally unstable. Since no sounding was available over Cheyenne, the exact vertical thermal structure is unknown. Analysis of surrounding soundings, however, indicates that a layer of warm dry air overlaid a cool moist layer near the surface. This is a convectively unstable situation with the potential for explosive overturning. All the ingredients for severe weather were present.

Since we began forecasting severe weather we have faced this limitation: We can forecast areas of severe weather potential with considerable skill, but we are unable to forecast the time and place of occurrence, until the thunderstorms develop and can then be tracked by radar. We are unable to forecast tornado occurrence until one is sighted, or a radar signature is observed. Then extrapolation of movement is used to predict the path of the storm. Most base weather stations within Air Weather Service will not issue a warning for severe convective weather elements until their signatures are displayed upon a radar or until reported by observation. The warning lead time is dependent, therefore, on how far upstream in time and space the severe weather signatures or elements are observed. Therefore, on days such as July 16, even though there may be great potential for severe convective weather, point warnings are often not issued until the first occurrence of a severe weather element.

3. GOES Imagery.

At 1646Z the satellite imagery (Figure 3) showed the first cumulus development, near Casper, to the north of the Cheyenne area. The 1746Z GOES picture (Figure 4) showed the first thunderstorm developing southwest of Laramie. Some small cumulus can be seen developing over the Laramie Mountains between Laramie and Cheyenne. By 1846Z (Figure 5) a mature thunderstorm cell was located over Cheyenne with a second mature cell just to the west. Two small cells in the building stage were located to the north. The National Weather Service observation at the Cheyenne Airport included thunder from 1826Z to 1829Z. By 1946Z (Figure 6) a line of thunderstorm cells extended from just south of the Colorado border to the area just south of Laramie, then northeastward to Kimball, Nebraska. Cells were also developing north-to-south along the ridgeline of the easternmost ranges of the Rockies. A large cluster of these cells developed from the west-to-southwest of Laramie. This was the first indication of organization of the cells into mesoscale convective systems. Note also the two cloud clusters at point C and the small cell at point D.

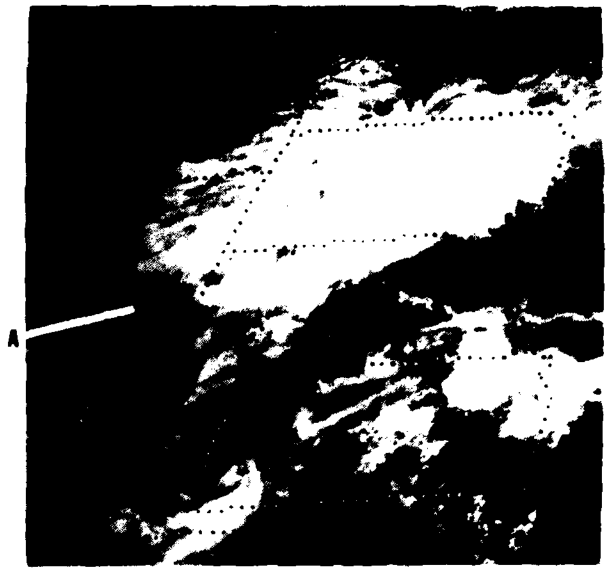
The picture for 2016Z (Figure 7) shows the two large cells at C have remained nearly stationary but have become better organized. The small cell at point D has not grown appreciably but has moved rapidly to the northeast. The line to the southeast has remained stationary. The area of cells to the southwest of Laramie continued to grow. A recapitulation of events at this point would indicate that mesoscale cloud systems have grown and become organized while remaining quasi-stationary, except for the somewhat intriguing movement of the one cell labelled D.

Figure 8 shows the situation at 2046Z. Cell D has developed dramatically into a mature thunderstorm. Cells C1 and C2 have remained stationary while the line of cells (A) have moved to the southeast. The cloud mass southwest of Laramie, now shows two large distinct cells B1 and B2. B2 is beginning to merge with C1 and C2. The variation in movement between the cells would seem to indicate the convective interaction has developed into a mesoscale circulation system which dominated the environment of northeastern Colorado, southeastern Wyoming and the Nebraska panhandle.

The 2116Z imagery (Figure 9) shows a dramatic departure. There are now four dominant cells in the region. Two have persisted for several hours and have obviously reached quasi-steady-state supercell status. These are cell D which has continued to move eastward and cell A which has grown "fatter" and has lost its line appearance. Cells B2, C1 and C2 have merged and are now labelled merely C. Cells A and B are beginning to merge, just to the west of Cheyenne. Practically the entire area between Casper, Wyoming and Denver, Colorado east to the Nebraska border is covered by these four thunderstorm clusters.

By 2146Z (Figure 10) cells A and B have fully merged and C and D have begun to merge. The merged A and B cells extend east and west of Cheyenne. Figures 11, 12 and 13 show that by 2246Z the cells all have merged into one large group.

Figure 3. SMS - 2 Visual imagery at 1646Z shows first cumulus development near Casper (A).



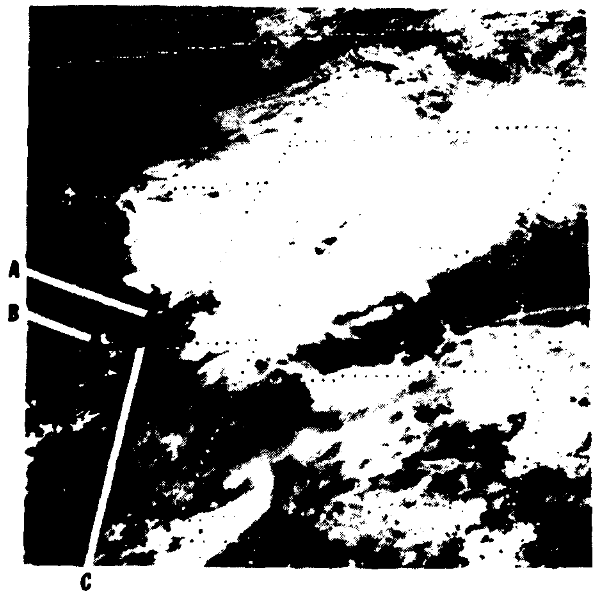


Figure 4. SMS - 2 Visual imagery at 1746Z. The development near Casper (A) is dissipating. Thunderstorms have developed southwest of Laramie (B). Smaller cells have begun building over the Laramie mountains (C).

Figure 5. SMS - 2 Visual imagery at 1846Z. A thunderstorm cell is over Cheyenne (A). There is considerable thunderstorm development over the Laramie mountains (B). Two small cells are beginning to develop north of Laramie (C).

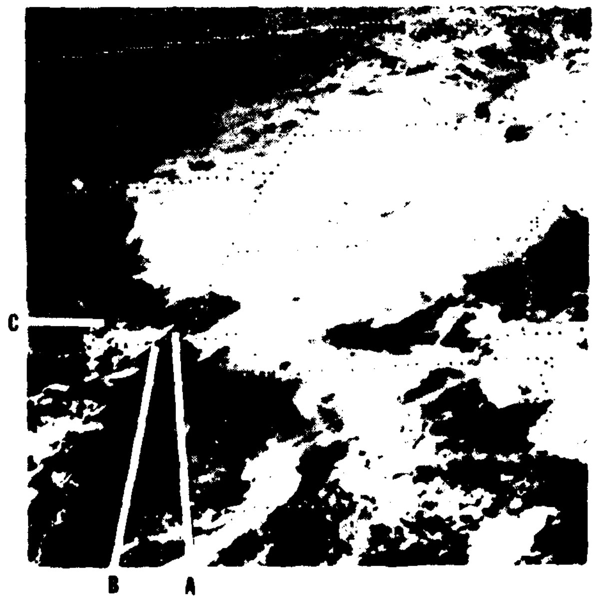


Figure 6. SMS - 2 Visual imagery at 1946Z. The thunderstorms have organized into a line from the Colorado border to Kimball, Nebraska (A). Another cluster of cells is growing over the eastern slope of the Rockies (B). The two small cells (C) from the last picture have grown into cloud clusters. Another small cell has begun development (D).

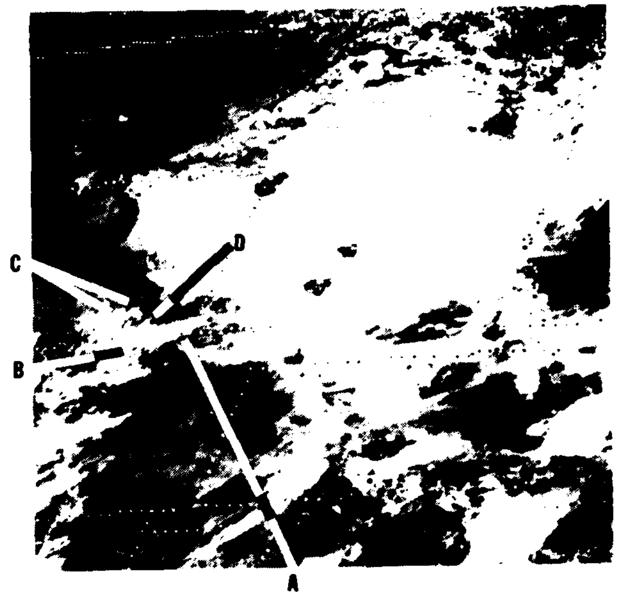


Figure 7. SMS - 2 Visual imagery at 2016Z. The line of thunderstorms (A) has remained nearly stationary, as has the cluster of cells over the mountains (B). The two clusters (C1 and C2) have changed little in 30 minutes. Note, however, the rapid movement of cell D.

Figure 8. SMS - 2 Visual imagery at 2046Z. Line A has moved slightly southeastward. Area B seems to have differentiated into two areas of cells (B1 and B2). B2 is beginning to merge with C1 and C2. Note the dramatic development of cell D.

Figure 9. SMS - 2 Visual Imagery at 2116Z. Cells B2, C1 and C2 have merged and are now designated C. Cell B1 is designated B. The line A now has a circular appearance, and with cell D have reached super cell status. Cell A and cell B appear to be merging, just to the west of the Cheyenne area.

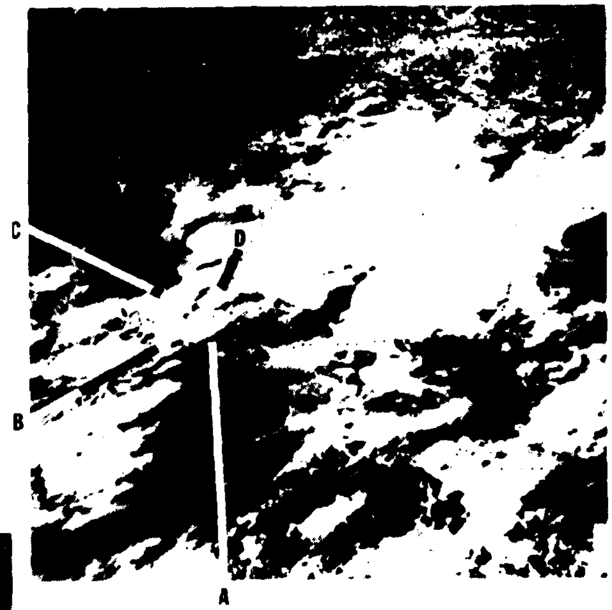


Figure 10. SMS - 2 Visual Imagery at [illegible]Z. [illegible] minutes after the tornadic occurrence, cells A and B have completely merged over the Cheyenne area. Cells C and D have [illegible].

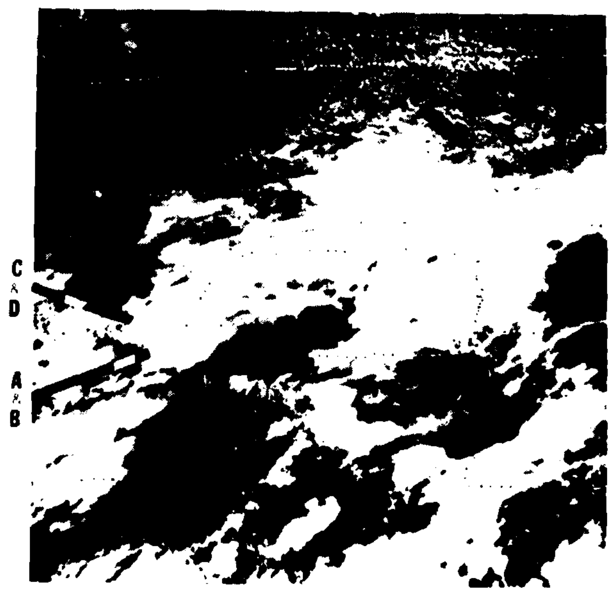


Figure 11. SMS - 2 Visual Imagery at [illegible]. Cells C and D have merged.

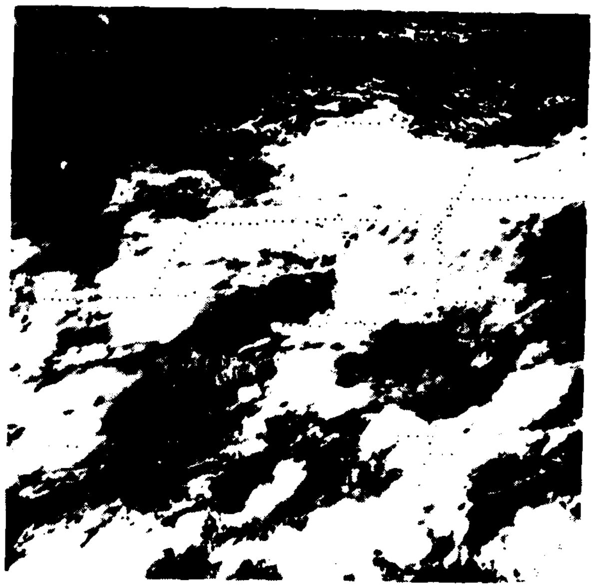


Figure 12. SMS - 2 Visual imagery at 2246Z. The two large cells appear to be merging.

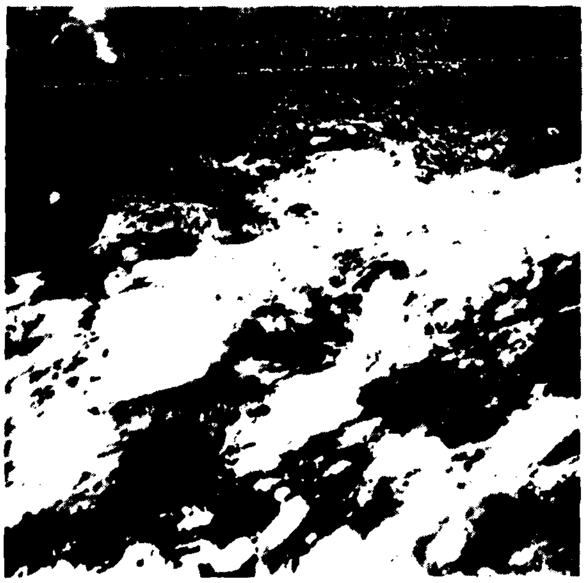


Figure 13. SMS - 2 Visual imagery at 2346Z. The entire area is covered with thunderstorm cirrus shields.

4. METSAT Imagery Tornado Signature.

The relationship between merging cells on radar displays and the occurrence of tornadoes have been discussed (e.g. The Ft. Rucker Tornado (Miller, 1972)). A limitation of satellite imagery is that the precipitation cells cannot be located, only the cloud tops are visible. Even so, close analysis of these data indicate that two large thunderstorms merged over the Cheyenne area at the time of the tornado occurrence. Furthermore, the imagery indicates the interaction of the cells during the development of this large convective system. Purdom (1979) demonstrated the primary importance of convective scale interaction in the evolution of deep convection.

This indicates that careful analysis and met watch of these GOES data by a trained forecaster could have provided strong indication of severe thunderstorm activity more than an hour before the tornado occurrence. Furthermore, 19 minutes before tornado occurrence, there was indication of merging cells; a tornado "signature".

5. Need For GOES Imagery.

Radar data would provide a much more complete analysis of such occurrence. METSAT imagery is not a substitute for radar. Rather, the two systems are complementary. Purdom (1979) states:

> "Rapid interval satellite imagery combined with radar data must be the basis for short term forecasting (nowcasting) of convection. This is because they are the only meteorological observing systems that can monitor the convective scale interactions that are so vital in the maintenance of deep convective activity".

For units which have no radar, yet are tasked to provide weather warning support, a GOES Tap will go a long way to "close the gap" in mesoscale analysis. Given this met watch tool, forecasters can closely monitor the data for signs of developing convection, cell and system movement, and signs of severity (rapid cell movement, high cloud tops from infrared imagery, merging cells, etc.). The ability to forecast the time of occurrence and degree of severity of the severe convective weather elements will not be as great as with a radar, so warnings will have to be more general with a resultant increase of timing error and [illegible] intensity error. This is still preferable to a decrease in warning lead time.

6. Conclusion.

A review of GOES imagery from [illegible] indicates that a merging thunderstorm mechanism was responsible for the Cheyenne tornado. This leads to the conclusion that merging cells in METSAT imagery [illegible] a tornado signature for severe weather forecasting [illegible]. This [illegible] yet more evidence of the need for GOES Taps at [illegible].

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