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INFRARED, STEREO-HEIGHT, CLOUD-MOTION, AND RADAR-ECHO ANALYSIS OF SESAME-DAY THUNDERSTORMS

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1. INTRODUCTION

The SESAME-day thunderstorms in northern Oklahoma on 2 May 1979 induced a variety of wind effects on the ground. These windstorms were one mesocyclone, five tornadoes, several suction vortices, and four downbursts. In the context of Fujita's (1981) planetary scales, these windstorms covered meso, miso, and moso scales.

The top of the thunderstorms were photographed in the rapid-scan mode by both GOES West and East as stereo pairs, permitting us to perform stereo-height computations by using the techniques by Hasler (1981) and Fujita (1982).

2. AERIAL SURVEY AND MAPPING OF 10 WINDSTORMS

The latest map of the 10 windstorms on 2 May 1979 presented in Fig.1 was produced by Fujita based on the aerial survey and photography by Stiegler a few days after the storms.

The Orienta tornado(F2) left behind a 47km (29 mi) long swath which was narrow and intermittent at places. The Lahoma tornado(F4), preceded by the Cleo Springs tornado(F0), ended in the open field to the northeast of Meno, being taken over by a mesocyclone circulation which intensified at six locations, C_1, C_2,.......(Fig.2).

There were three suction-vortex marks (No.1, 2, and 3) inside the windfield of the mesocyclone, 3 to 5 km (2 to 3 mi) in diameter. However, there were no sign of tornado in the immediate vicinity of these vortex marks, suggesting that these suction vortices developed inside the mesocyclone without a tornado in it. Suction vortex No.1 was 14 m in diameter (Fig.3), No.2 was 22 m in diameter (Fig.4), and No.3 left behind a 5 m wide swath (Fig.5).

The first and the second Marshall tornadoes were less than 10 km in length and rated as F3 and F2, respectively.

The Coyle downburst was characterized by a distinct diverging flow with cyclonic curvature typical of a twisting downburst. Another twisting downburst was located to the west of Vance AFB where the nesocyclone dissipated.

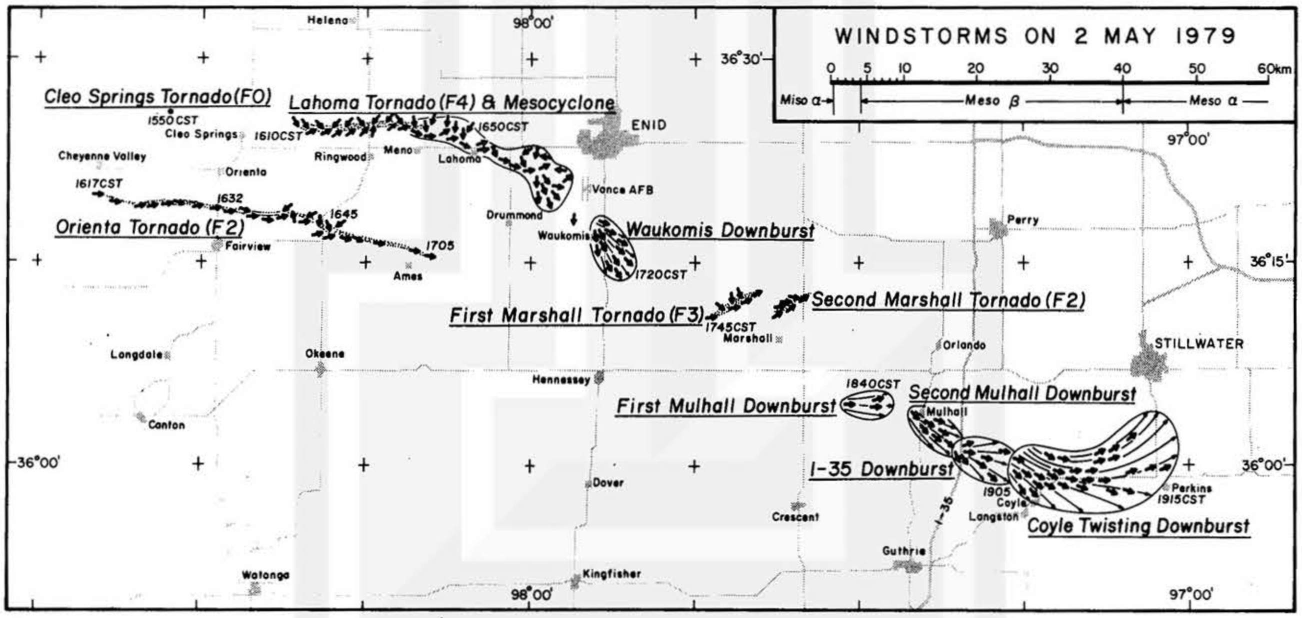

Fig.1 Damage map of the 10 windstorms on 2 May 1979. Short arrows indicate the directions of uprooted trees, debris streaks, etc. Four tornadoes were characterized by convergent swirling patterns while five downbursts, by divergent flow patterns which are either straight or curved. For definition of downbursts and related winds, refer to Fujita (1981). This map was completed based on the post-storm aerial survey and phtographs by Stiegler of SMRP.

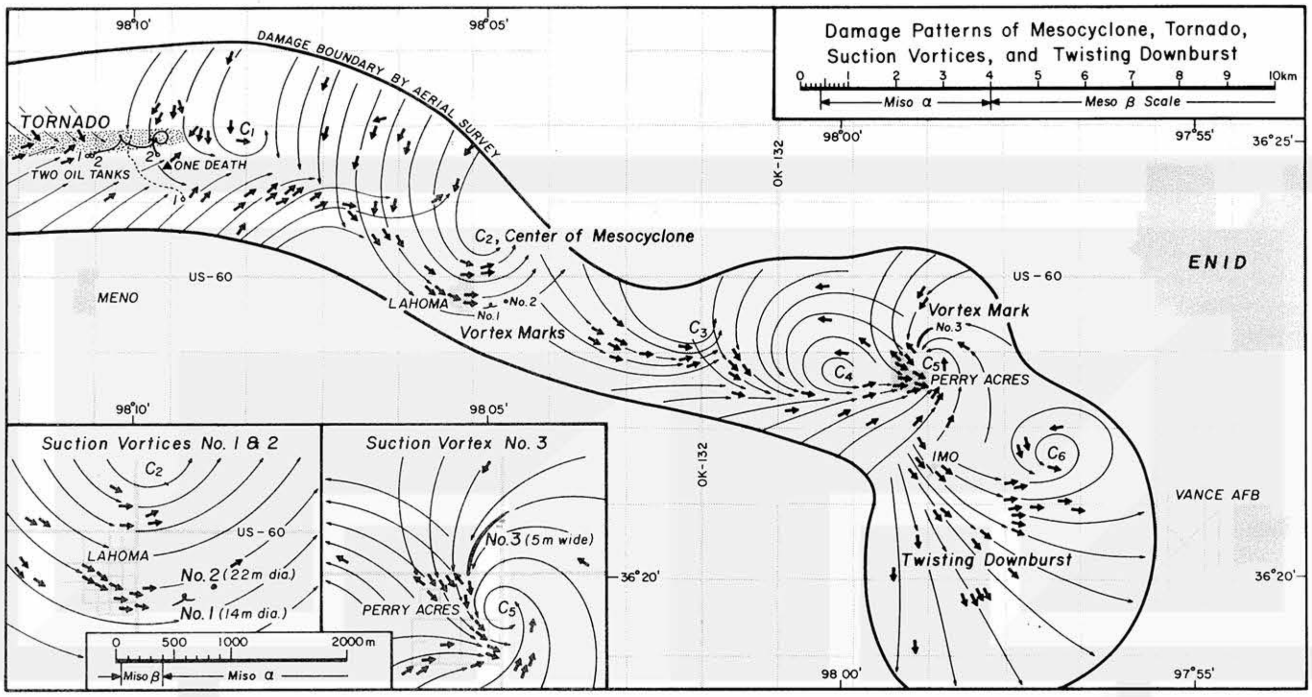

Fig.2 An enlarged map of the Lahoma tornado/mesocyclone which ended just to the west of Vance AFB. Three vortex marks were found inside the mesocyclone without a tornado in it.

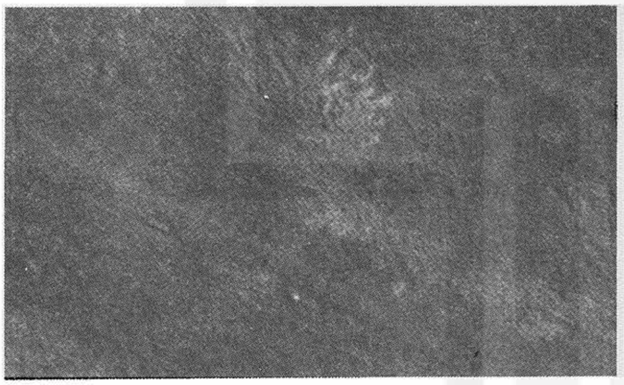

Fig.3 Ground mark of suction vortex No.1

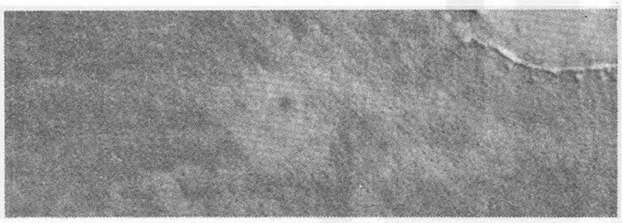

Fig.4 Ground mark of suction vortex No.2

Fig.5 Ground mark of suction vortex No.3

3. IR TEMPERATURE OF TWO SUPERCELLS

The eastern and the western hooks (Fig.6), accompanied by Orienta and Lahoma tornadoes, are located on the southwest ends of the supercells photographed with 0.5° elevation angle.

Rectified isotherms in °C reveals that the top of the western supercell is cold, -70°C while the eastern supercell was located where the IR temperature increases significantly toward the northeast. A cold, -70°C area is seen 20 km to the south of the eastern supercell (Fig.7).

Is there error in IR temperature mapping ? What is the influence of the slanted IFOV of the IR sensor ? How much time lag in the sensor response do we expect ? The current answers to above questions do not explain the basic difference in the temperature fields atop these two supercells.

The major difference appears to be the relative positions of two supercells: the one is located on the downwind side of the other. Wind aloft at 11 km MSL was 109 kt from WSW.

It is seen that the IR temperature field is characterized by a mesoscale horseshoe-shaped ridge of cold temperature. IR temperature inside the horseshoe is warm, often identified as the V-shaped wake (V wake) in enhanced IR imagery. The western supercell is located on the west (UPWIND) side of the horseshoe while the eastern supercell, on the east (WAKE) side.

4. STRATOSPHERIC CIRRUS: CAUSE OF THE WARM WAKE

Is the anvil top inside the V-wake area depressed as implied by the warm IR temperature ? In answering to this question, the heights of various spots, either bright or dark, were computed stereoscopically.

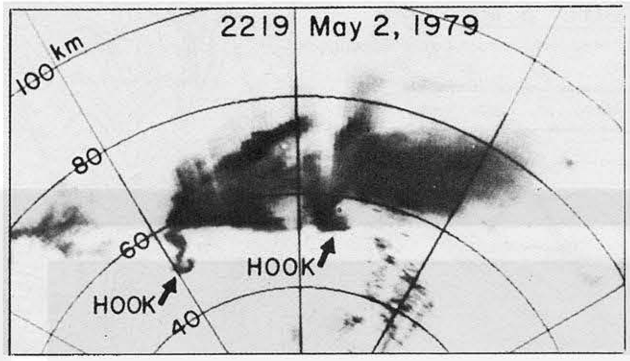

Fig.6 Reflectivity of two hook-echo thunderstorms depicted by NCAR's CP-3. At this time, the Orienta tornado, inside the western hook, was developing in form of a sequence of suction vortices while the Lahoma tornado had touched down a few minutes earlier inside the eastern hook which was approaching to the north of Ringwood.

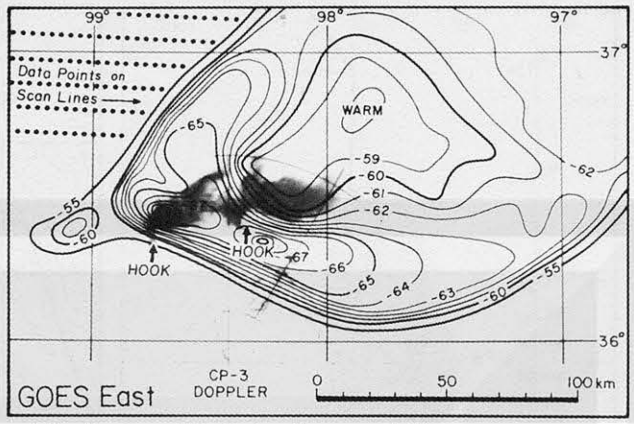

Fig.7 Rectified isotherms of IR temperature from GOES East at 2217GMT (1617CST). The western thunderstorm is located where the IR temperature is coldest while the western thunderstorm, where the gradient of the IR temperature is largest.

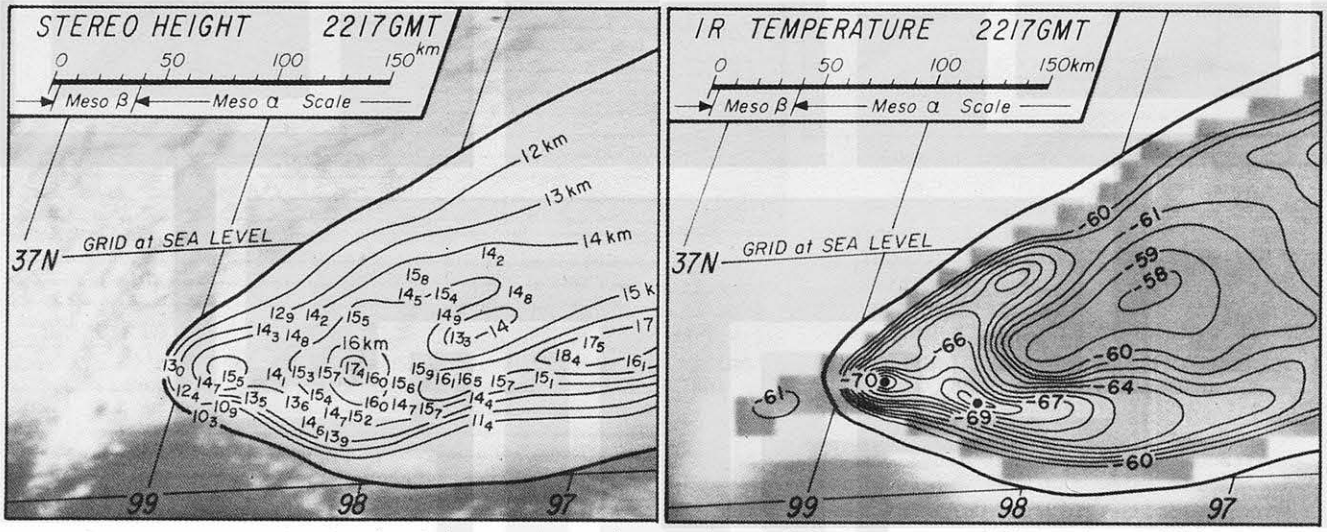

Fig.8 LEFT: Stereo height (in km) superimposed upon the visible imagery at 2217GMT 2 May 1979. RIGHT: IR isotherms (in °C) superimposed upon the enhanced IR imagery at the same time. These pictures reveal that the IR temperatures are warm and stereo heights are high inside the horseshoe wake. On the upwind side of the wake, however, the higher the stereo height, the cloder the IR temperature.

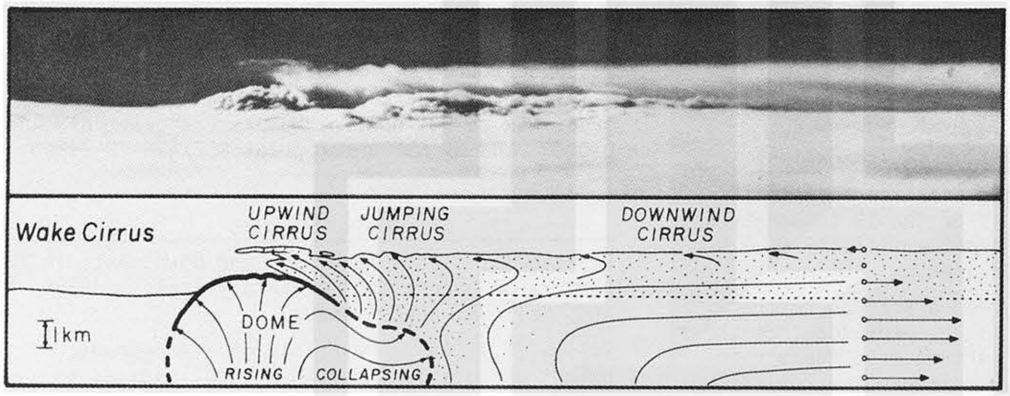

Fig.9 A horizontal view of overshooting tops and their wake region seen from a research Lear Jet at 13.7 km (45,000') over southern Texas. The wake region is covered with the "wake cirrus" which contaminates the radiant emittance of cold overshooting domes.

Stereo heights plotted on the visible imagery in Fig.8 LEFT reveal that there are distinct 15.5 km and 17.4 km tops at the locations of the western and the eastern supercells, respectively.

The IR temperature field in Fig.8 RIGHT was contoured at 1°C intervals on the enhanced IR imagery in the identical scale and projection, allowing us to interpret the stereo heights in relation to the warm V wake. It will be found that the radiometric temperature in the wake region is quite different from that of the dome area on the upwind side of the horseshoe ridge.

In an attempt to explain the nature of the wake region, which is warm but stereoscopically high, over 5,000 semi-horizontal pictures taken during the Lear Jet Experiment (1971 through 1978) by the University of Chicago under NASA grant were examined, knowing what to look for now.

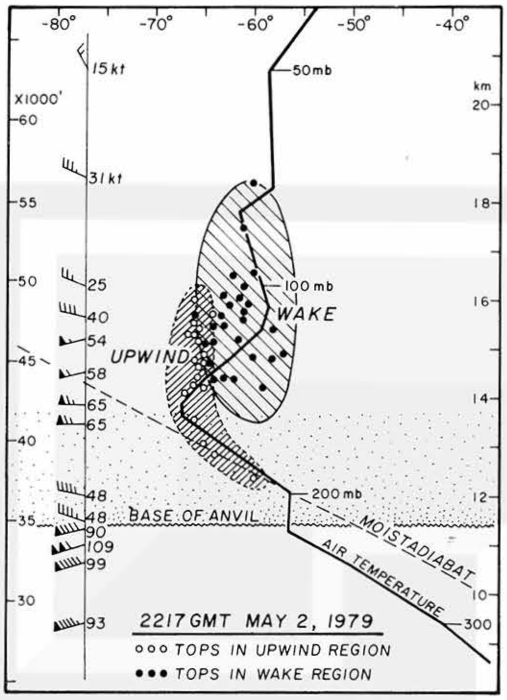

Fig.10 IR temperature of the cloud tops, both high spots and low spots, in Fig.8 plotted as a function of their stereoscopic heights. Oklahoma City sounding at 2400GMT is shown with a heavy line. This diagram shows that cloud-top temperature is 10 to 15°C (WPWIND) and 15 to 25°C (WAKE) warmer than that of the moist adiabat.

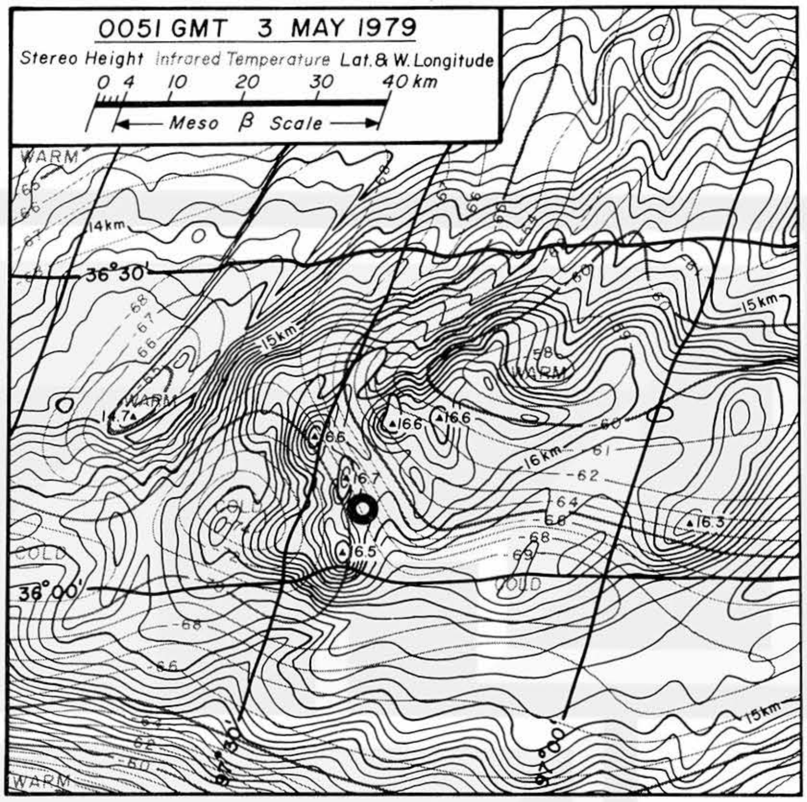

Fig.11 A detailed cloud-top topography depicted by contour lines at 100 m intervals. IR isotherms at 1°C intervals show that the cloud-top temperature increases from -74°C (16.2 km top) on the upwind side to -58°C (15.1 to 16.3 km top) in the wake region. A small cirrus streak with a 14.7 km top is several degrees warmer than its environment.

Although we did not pay a serious attention during and after the Lear Jet Experiment, now we found numerous pictures of cirrus clouds which extend downwind (and also upwind) from the region of overshooting domes rising and collapsing violently. The cirrus cloud, now called "stratospheric cirrus" is located in the lowermost stratosphere, 1 to 4 km above the anvil top, extending 100 to 300 km downwind often covering the tops of the overshooting domes on the upwind side (Fig.9).

5. CLOUD-HEIGHT ESTIMATE FROM IR TEMPERATURE

It has been the standard practice to estimate cloud heights on the basis of the IR temperature when cloud tops with apparent emissivity of 1.0 covers the IFOV or larger area.

This research will now add a serious restrictive condition that "........, provided that the severe thunderstorm top is free from the stratospheric cirrus often located above the top of severe-storm-producing thunderstorms".

The height-temperature diagram in Fig.10 shows that the cloud-top temperature is 10 to 25°C warmer than that of the moist adiabat of the undiluted parcel.

Figure 11 reveals more dramatically the correspondence (or non-correspondence) between the cloud-top topography and the IR temperature field especially in the wake region. The stereoscopic contouring was made possible by Hasler's (1981) stereo pair, stereo-height computations, and the lunar mapping techniques. The secont Mulhall downburst in Fig.1 was in pregress at the location of the doughnut circle in the figure.

Acknowledgements:

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