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A DETAILED ANALYSIS OF THE SAN MARCOS, TEXAS TORNADO INDUCED BY HURRICANE "ALLEN" ON 10 AUGUST, 1980

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1. INTRODUCTION

Many studies on hurricane-spawned tornadoes have focused on the relationship of tornado occurrence to the parent hurricane. However, studies concerning the characteristics of the tornadoes themselves are virtually non-existent. Little is known as to the potential type (single-vortex vs. multi-vortex), strength (maximum windspeed), length, width, direction and duration of hurricane-spawned tornadoes. It is generally accepted that most hurricane tornadoes are weak and short-lived; as a result, few have been surveyed. And, since some hurricanes can produce numerous tornadoes (e.g. 109 in Hurricane Beulah), there has been skepticism that some hurricane tornadoes may not be real.

During the past decade, Fujita and members of SMRP (Satellite and Mesometeorology Research Project) at the University of Chicago have conducted aerial and ground surveys of land-falling hurricanes to investigate their mesoscale wind effects and possible tornadoes (see Fujita 1980). The most recent survey immediately followed the passage of Hurricane Allen through southern Texas. Results of the survey presented herein, provide some of the best information to date on the potential of hurricane-spawned tornadoes.

2. TORNADOES OF HURRICANE ALLEN

As Hurricane Allen made land-fall and decayed from August 9-11, 1980, it produced a total of 29 tornadoes in a 45 hour period (see Fig. 1). In Fig. 2, positions of the tornadoes are plotted relative to the hurricane center. A problem in such an analysis is that tornadoes can not be reported everywhere at all times in land-falling hurricanes. Since much of Allen extended over Mexico and water during the land-fall period, contours of the percent of U.S. land area give a measure of the probability that a tornado would be reported at a given location. The figure shows most tornadoes to have occurred in the right front quadrant, concurring with studies of other hurricanes by Novlan and Gray (1974), Pearson and Sadowski (1965), and Smith (1965).

Analysis of the hurricane structure during land-fall was conducted by combining radar pictures from Brownsville, Galveston and Hondo and superimposing them on surface analyses. Five times were analized at 6 hour intervals from 1200 CST Aug. 9 to 1200 CST Aug. 10. The last analysis, shown in Fig. 3, was centered on the period when Allen was most actively producing tornadoes. A corresponding IR satellite image in Fig. 4 shows an expanding cloud system as Allen decayed.

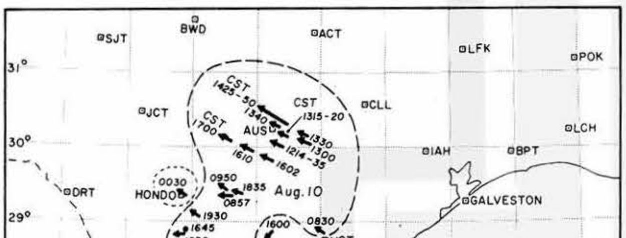

Figure 1. The path of Hurricane Allen and the distribution of tornadoes. Arrows indicate direction.

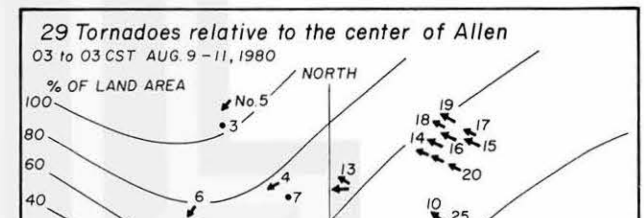

Figure 2. Positions of tornadoes relative to the hurricane center. Tornadoes are numbered chronologically. For definitions of scales Meso α, Meso β, etc. see Fujita (1981).

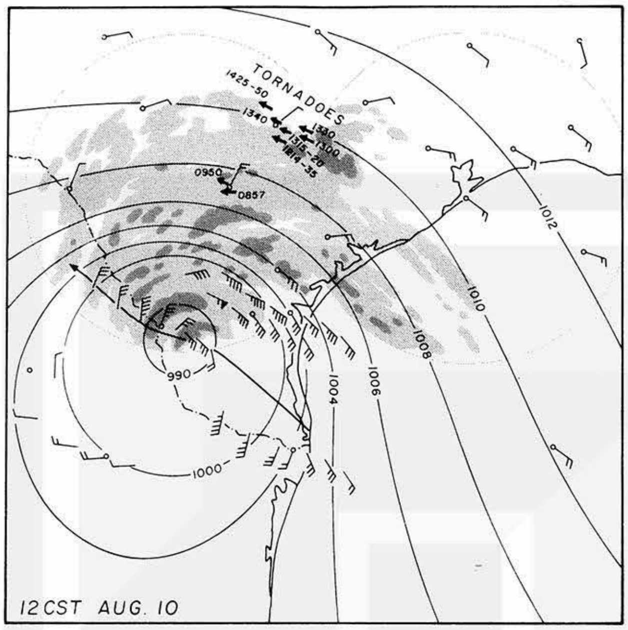

Figure 3. Radar and surface analysis of Allen at 1200 CST of Aug. 10. Eight tornadoes were induced far to the north of the hurricane center.

Most of the 29 tornadoes were investigated during aerial surveys conducted on Aug. 12 and 13, 1980. The survey results reinforce the assumption that most hurricane tornadoes are weak and short-lived. For some, no damage path could be found whatsoever. Others, especially those within the area of hurricane force winds, had paths which were non-distinguishable from the surrounding hurricane wind damage. Only 2 of the 29 tornadoes were found to be of any significance: 1. the Austin Tornado reaching F2 strength as it destroyed $50 million worth of aircraft at the municipal airport, and 2. the San Marcos Tornado discussed in this paper.

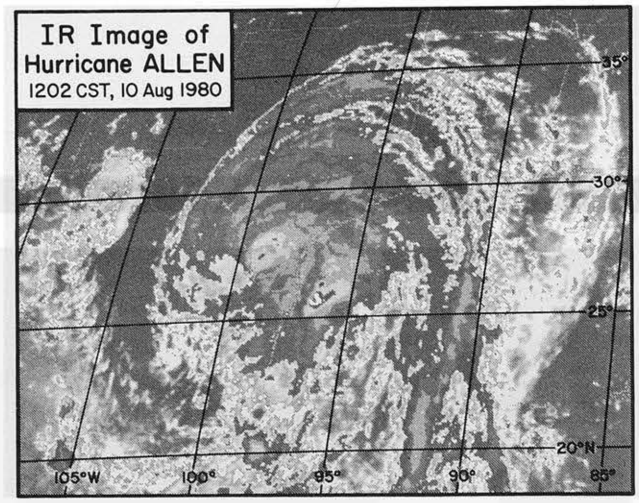

Figure 4. Infra-red satellite image of Allen corresponding to Fig. 3.

3. THE SAN MARCOS TORNADO

The San Marcos Tornado began at 1602 CST on Aug. 10 about 10 km to the east of the city and moved from ESE to WNW, an unusual direction when compared with non-hurricane tornadoes (see inset Fig. 5). As the tornado intensified it moved through a field of hay bales shown in Figs. 6 and 7. Hay from the disrupted bales was strewn into drift marks demonstrating trajectories of the hay as it was caught up in the tornado and its environmental winds. Much of the hay was collected into a confluence line marking the edge of the core to the right of its motion. The drift marks were found to extend as far as 140 m from the confluence line. The estimated 80 to 90 m diameter core is believed to have been a single vortex as otherwise the hay should have been collected into cycloidal swaths. Upon exiting the field the tornado scored a direct hit on a high-tension tower

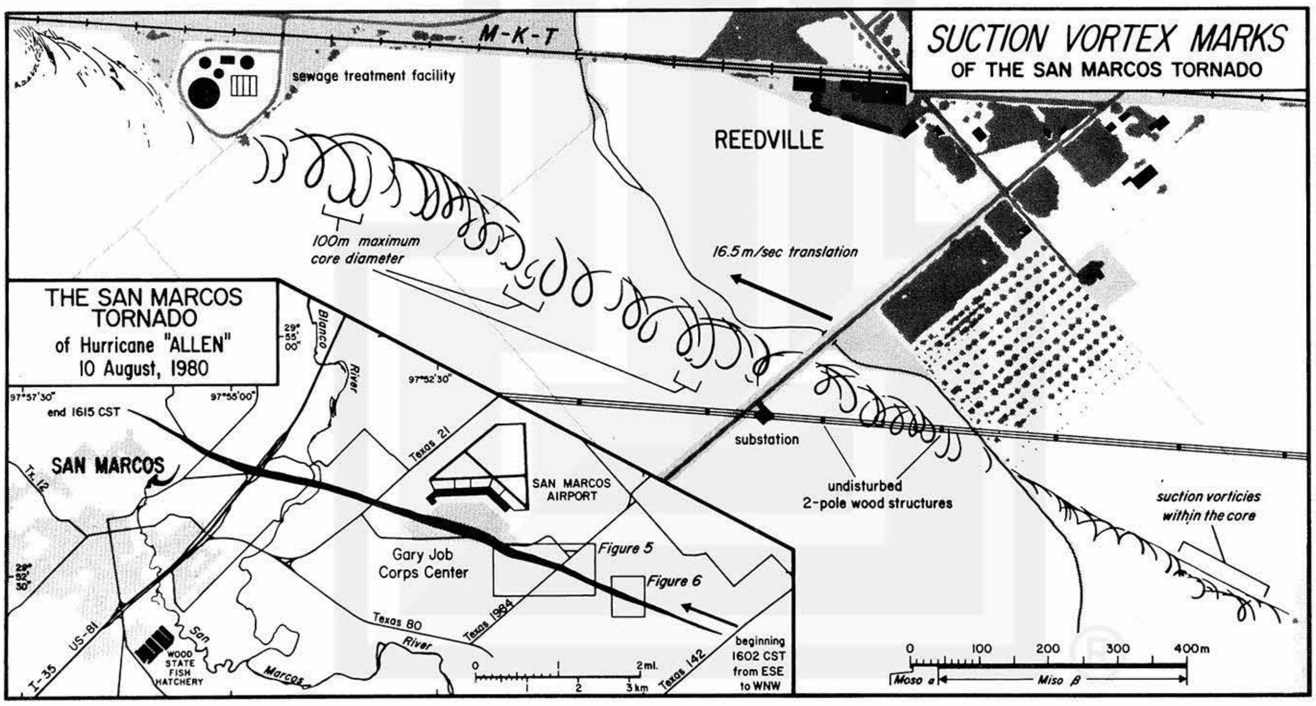

Figure 5. Detailed map of the San Marcos suction vortex marks. Inset: The damage path of the San Marcos Tornado.

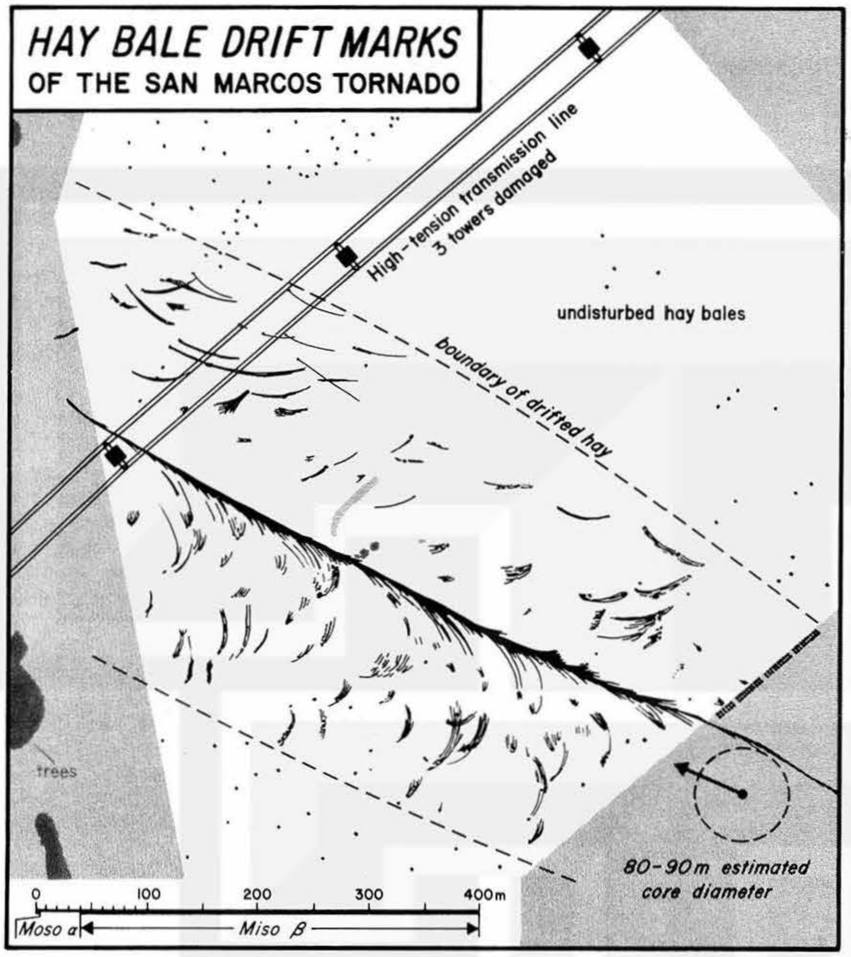

Figure 6. Detailed map of drifted hay bales depicting debris trajectories in the environmental windflow as well as within the tornado. Confluence line marks the right edge of the tornado core.

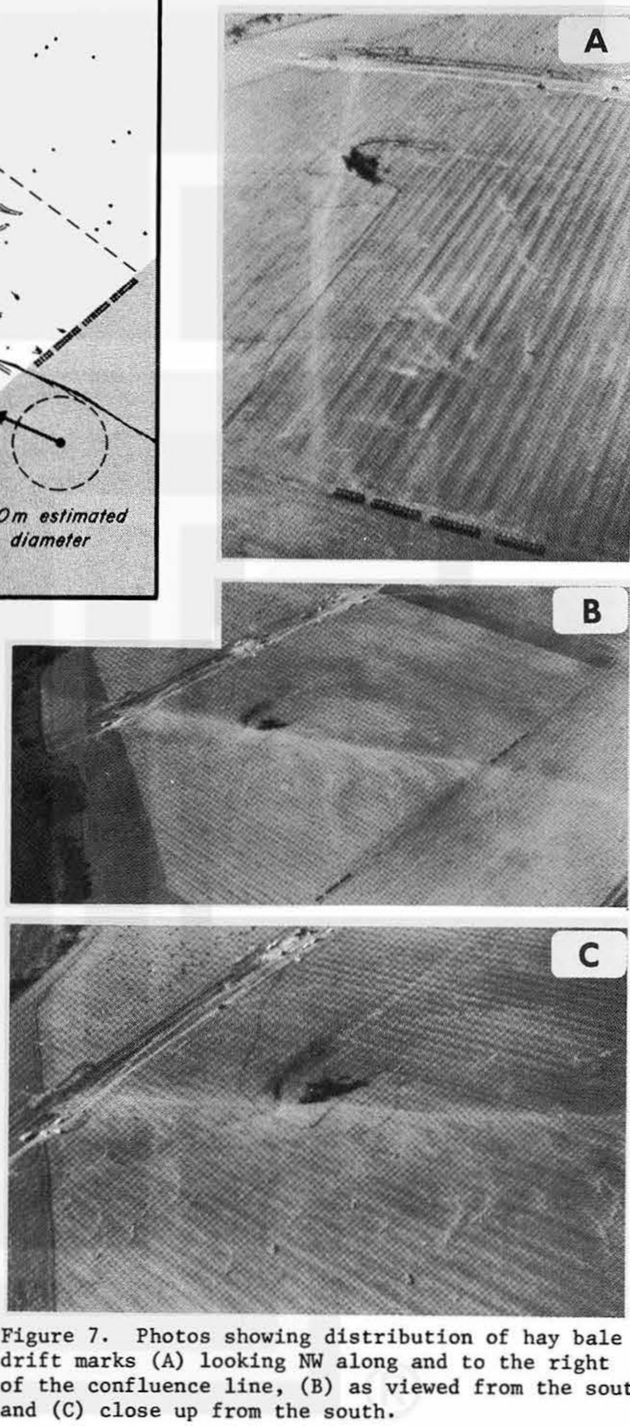

Figure 7. Photos showing distribution of hay bale drift marks (A) looking NW along and to the right of the confluence line, (B) as viewed from the south, and (C) close up from the south.

causing two other towers to the NE along the power line to be damaged.

As the tornado continued it began to form suction vorticies as exhibited by the swath and looping marks shown in Figs. 5 and 8. The possibility of suction vorticies occurring in the Fairfax Co. Tornado of Tropical Storm David was suggested by Hoadley (1981), however this is the first confiming evidence of suction vorticies in a hurricane-spawned tornado. Fujita (1976) classified suction vorticies into several categories, the most common being orbital (moving around the edge of the core). However, some of the first swaths of the San Marcos Tornado were found to have orbited within the core leaving swaths which were displaced from a confluence line marking the maximum rotational wind at the right edge of the tornado core. From other swaths the core was estimated to reach a maximum diameter of 100 m.

A tornado maximum windspeed was estimated from the looping marks using a method described by Fujita et. al. (1970) and used by Agee et. al. (1977). A 16.5 m/sec translation U, determined from the radar echo motion, was added to the rotation V, determined as 2.5 U based on the ratio of loop width to core diameter, resulting in a windspeed without suction vortex rotation of 58 m/sec. Forbes (1978) calculated the mean rotation of a suction vortex in the Parker Tornado to be 39 m/sec. If we add a conservative estimate of suction vortex rotation to the San Marcos Tornado, say 20 m/sec, we obtain a maximum F3 windspeed of 78 m/sec or about 175 mph.

The remainder of the damage path was characterized by F2 or weaker damage until it ended at 1615 CST at the northern edge of San Marcos. The total

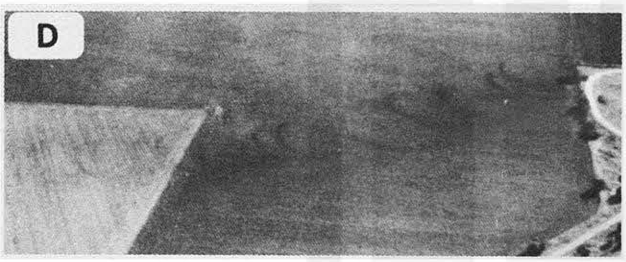

Figure 8. Photos of suction vortex marks (A) from their initiation to Texas 1984, viewed from NE, (B) within the core, viewed close up from SW, (C) crossing Texas 1984, looking NW along the direction of motion, and (D) looking SW at the termination of the swaths where the core diameter is estimated to be a maximum of 100 m.

path length was 12.5 km or about 7.75 miles. One unusual feature of structural damage in the later stage of the tornado was the removal of pickets from a fence near I-35 while the remainder of the fence was left standing (Fig. 9).

4. CONCLUSIONS

Most of the tornadoes spawned by Hurricane Allen were weak and short-lived, while a small percentage were found to have characteristics of strong mid-western tornadoes. It has been shown that a hurricane-spawned tornado may produce suction vorticies and have windspeeds of F3 intensity. While probability is low, the possibility of strong hurricane tornadoes exists; and as such, further investigation of future hurricane tornadoes is highly recommended.

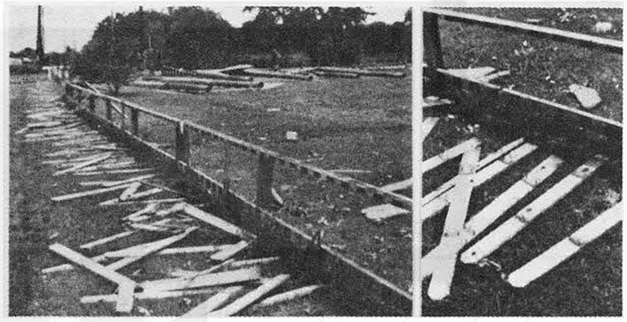

Figure 9. Pickets removed from fence by F2 tornadic winds near I-35.

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