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MESOSCALE DAMAGE PATTERNS OF HURRICANE FREDERIC IN RELATION TO ENHANCED SMS IMAGERY

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1. INTRODUCTION

On the evening of September 12, 1979, Hurricane Frederic landed east of Pascagoula, Mississippi and moved northward causing considerable damage to portions of Alabama, Florida, and Mississippi. In response to a call from Peter Black of the National Hurricane and Experimental Meteorology Lab (NHEML) a team from the University of Chicago embarked on several trips to the devastated areas in order to investigate the wind effects that are characteristic of hurricanes. Of particular interest was the F-scale assessment of hurricane versus tornado damage. Supplemented data into the structure of the storm was provided by radar and satellite imagery.

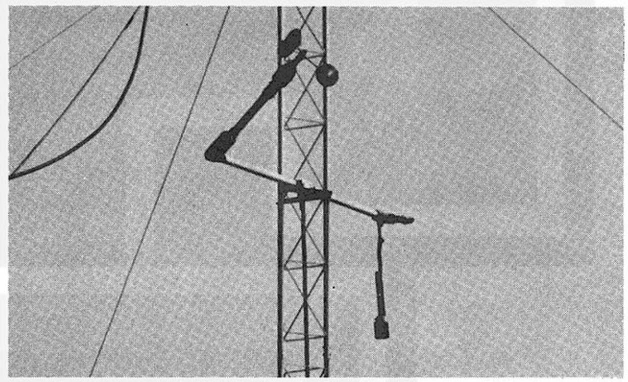

Figure 1. The anemometer at the Ingalls Shipbuilding Yard. The wind vane was broken and the 3-cup anemometer tilted toward the south.

Table 1. List of the peak gust recorded on September 12 and 13, 1979 in the hurricane damaged area. The two or three letter code after the site name is the abbreviation used to mark the location on the overall mapping (see Figure 2)

Site	Peak Gust	Date	Time	Height AGL
Dauphin Is. Bridge (BR)	145 mph	12th	1939, 1942 CST	70 to 100 ft
Dauphin Is. Sea Lab (SL)	138 mph	12th	unknown	30 ft
Ingalls Shipbuilding (SY)	128 mph	12th	2152 CST	26 ft
Mobile Civil Defense (CD)	109 mph	12th	2244 CST	70 ft (estimated)
Mobile NWS (MOB)	97 mph	12th	2143, 2207 CST	20 ft
Pensacola NWS (PNS)	78 mph	12th	1944, 2111 CST	22 ft
Meridian NWS (MEI)	69 mph	13th	0225, 0339, 0402 CST	20 ft

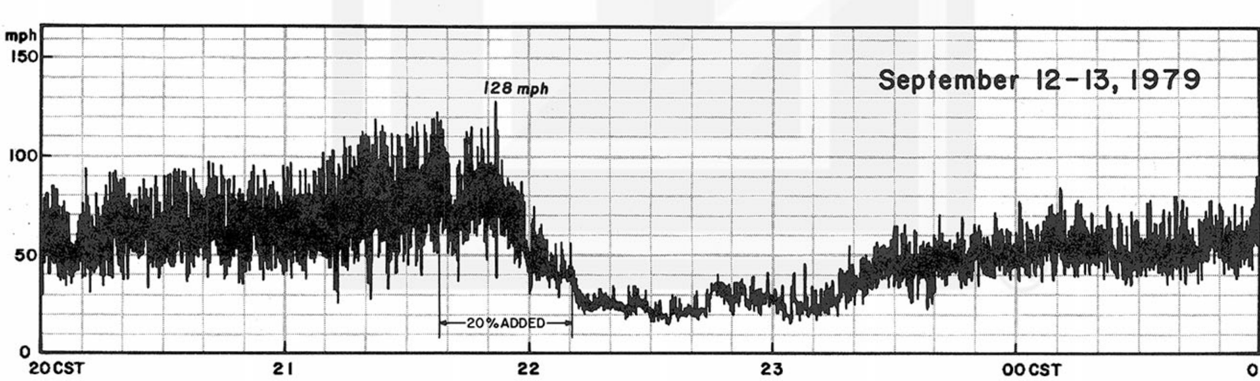

Figure 2. Wind trace obtained from the Ingalls Shipbuilding Yard. Note the windspeed correction applied between 2138 CST to 2210 CST. The 128 mph peak windspeed is associated with the inner eye.

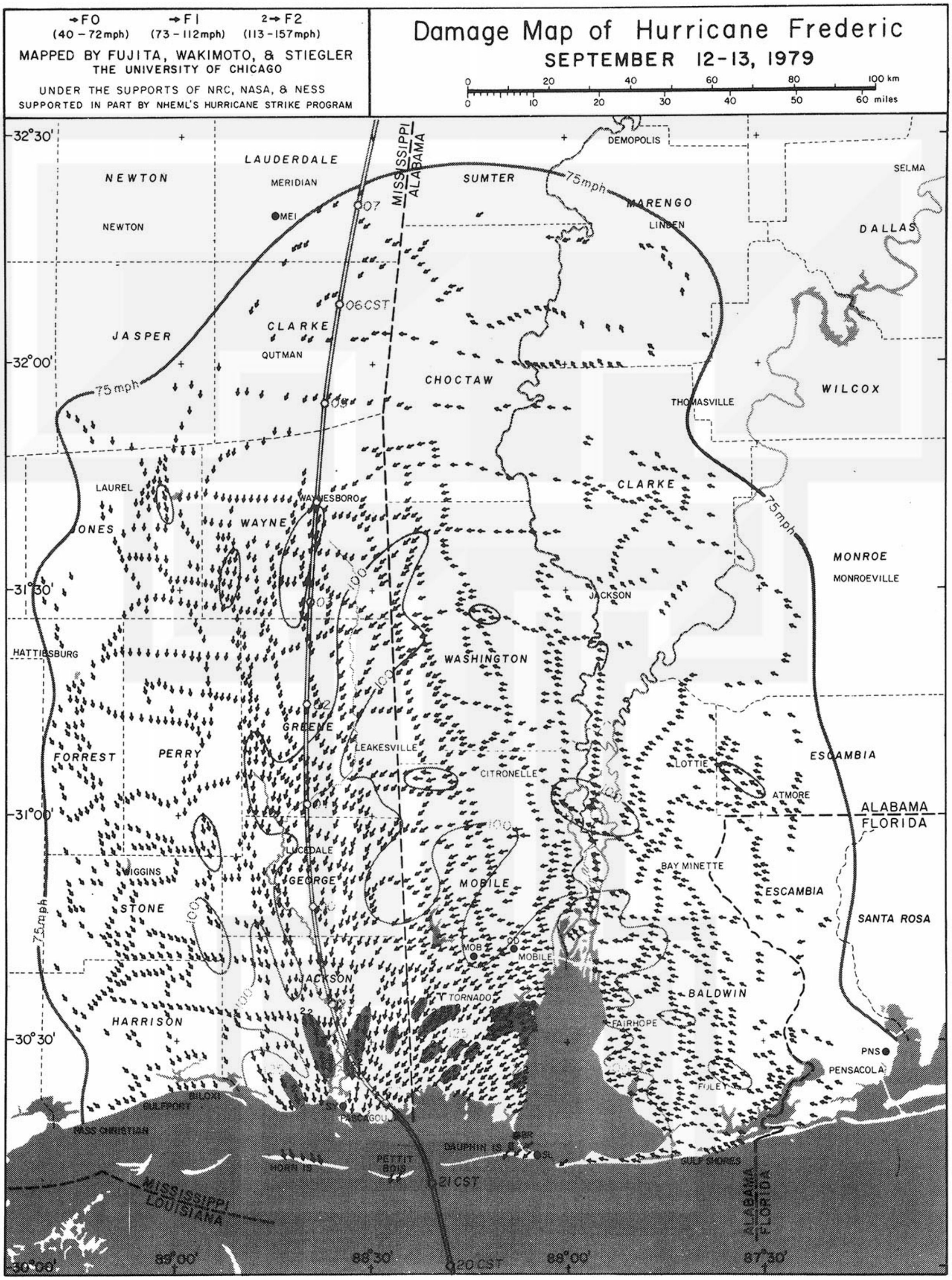

Figure 3. F-scale analysis of Hurricane Frederic. The arrows represent vectors of the tree and structural damage. See the above legend for the windspeed classification. The path of the storm's center is shown by the double line. Color copies of this map are available at the conference.

2. RECORDED WINDSPEEDS

Several windspeed traces were recovered after the storm which indicated the peak gust recorded at several locations in the damaged area. (see Table 1)

Of the seven recorded traces in Table 1, only the one from the Ingalls Shipbuilding Yard recorded the passage of the hurricane's eye. The anemometer was mounted on a 10-ft tower atop the flat roof of a fire station/hospital building.

The wind-direction sensor became inoperative at 2107 CST while the windspeeds continued to be recorded. Post storm inspection of the site revealed that the wind vane had been blown off and the 3-cup anemometer had tilted 49 degrees towards the south from its original, vertical position (see Figure 1). Unfortunately, no one witnessed how and when these sensors were disturbed during the storm.

Under the assumption that a tilted anemometer rotates slower than a vertical one, for winds that are nearly parallel to the direction of tilt of the anemometer (i.e. north or south winds), 20 percent of the wind speed was added to the original values to compensate for the tilt. The onset of the tilt was chosen to be at 2138 CST when peak gusts, which had increased gradually, suddenly began decreasing rapidly. During this time the estimated wind direction was from the north.

As the wind speed decreased in the eye, the wind direction shifted from north to west. If it is assumed that the anemometer cups rotate normally in westerly winds, no correction need be applied after 2210 CST (see Figure 2).

3. DAMAGE SURVEY

In response to a telephone request by Peter Black of NHEML, the authors made several aerial surveys with low-flying Cessnas. The breakdown of the surveys is as follows:

September 19, 20: Fujita and Wakimoto used two Cessna 172s based at Pensacola, Florida for aerial mapping and photography of the damage.

September 27, 28, 29: Wakimoto and Stiegler made both ground and aerial surveys based at Jackson, Mississippi.

November 13, 14: Wakimoto and Stiegler visited Dauphin Island, the wind-recording sites, and other areas of specific damage on the ground to investigate wind effects.

About 1,500 damage vectors, each identified with an F-scale category, were plotted on U.S.G.S. topographic maps of 1:250,000 scale.

In addition, five rolls of color transparencies photographed by NHEML and copied by the Johnson Space Center at Houston (JSC), were used to add about 500 damage vectors.

Two additional rolls of infrared (IR) color transparencies, photographed by the U.S. Forest Service at Atlanta and copied by JSC, were also used to add and confirm damage vectors.

The resultant damage map is shown in Figure 3. The center of Hurricane Frederic passed directly between Pettit Bois and Dauphin Island as it headed for the coast. The anemometer on the Dauphin Island bridge (BR), was located 14 miles to the east of the center, just outside the eye.

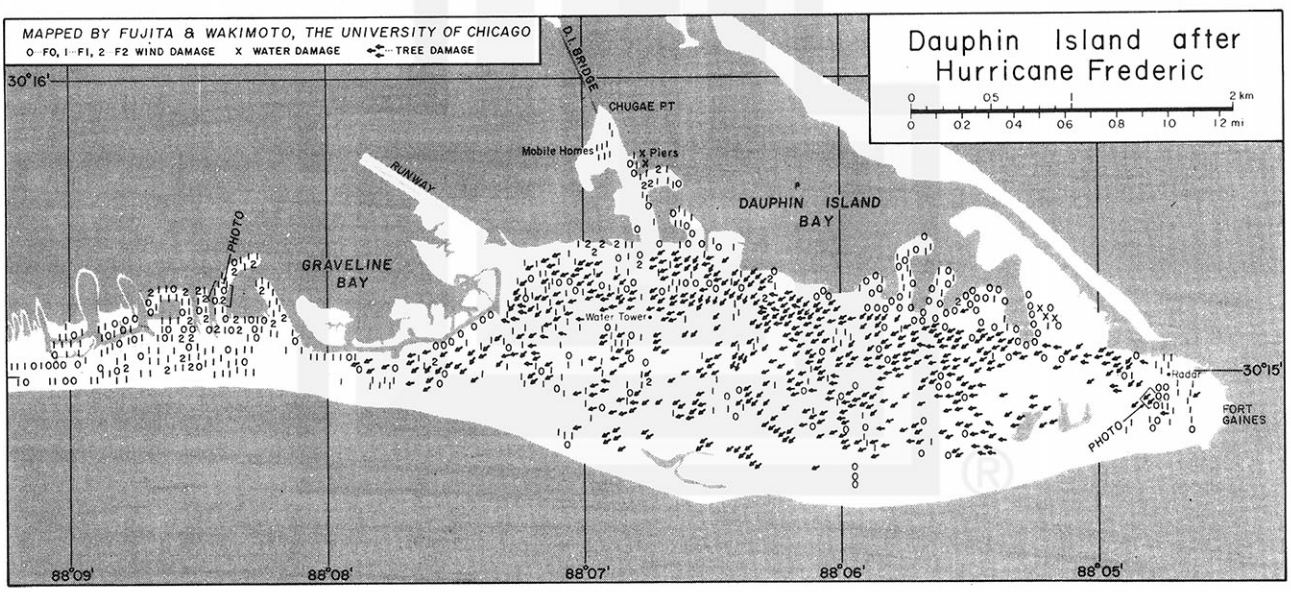

Figure 4. Dauphin Island map.

The wind at the Ingalls Shipbuilding Yard (SY) began decreasing at 2152 CST, approximately the time when the hurricane turned toward the northwest. The SY anemometer was then about 8 miles to the west of the hurricane center. The diameter of the eye was estimated to be about 15 miles.

The damage map in Figure 3 includes isolines of the F-scale wind speeds contoured with 75, 100, and 125 mph speeds. The areas where the wind speed was 125 mph or greater are shaded dark.

4. SPECIFIC DAMAGE

In order to assess the wind effect caused by hurricanes, specific damaged areas were inspected closely both from the air and from the ground. A tornado, 8 miles southwest of the Mobile airport, was confirmed.

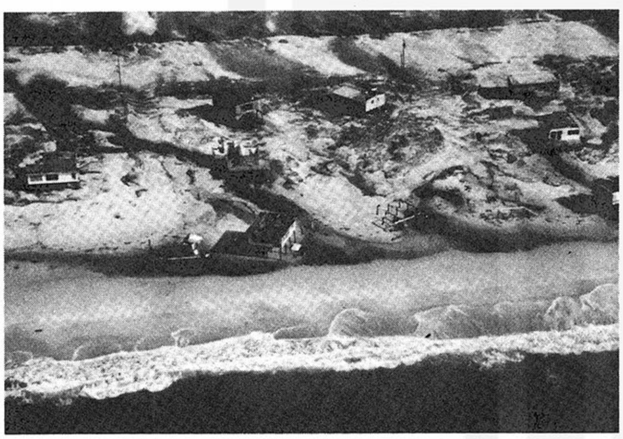

Figure 5A. Aerial photo of beach houses along the south shore of Dauphin Island after the storm.

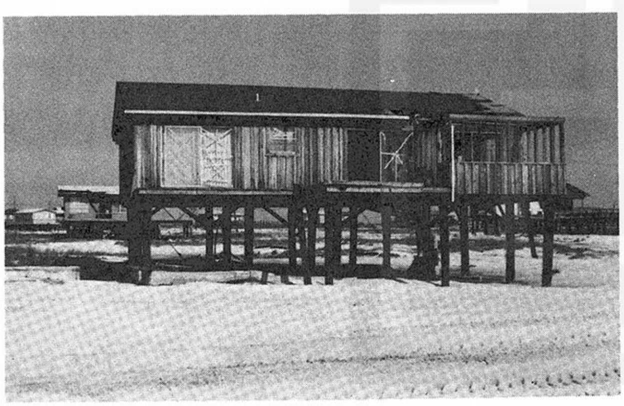

Figure 5B. Typical elevated beach house on Dauphin Island.

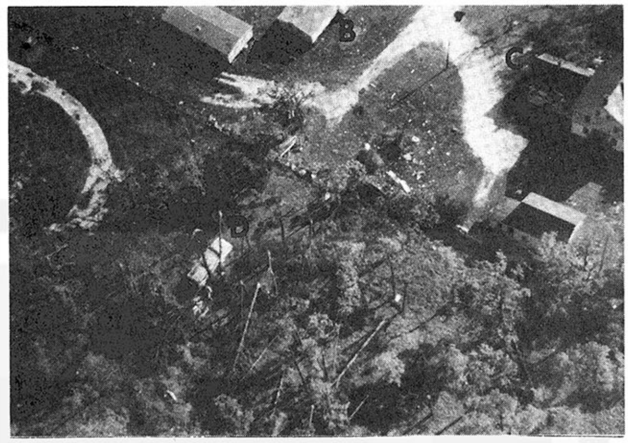

Figure 6A. Aerial view of damage near the Dauphin Island Sea Lab.

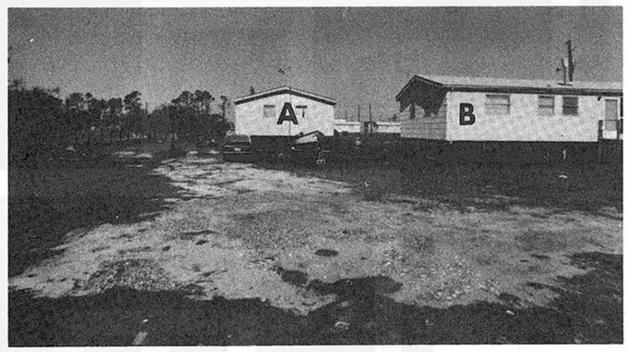

Figure 6B. Ground photo of houses shown in Figure 6A.

4.1 DAUPHIN ISLAND

Aerial photos by Fujita and by NHEML and a ground survey by Wakimoto and Stiegler were the basis for assessing the wind damage on Dauphin Island (see Figure 4).

A. BEACH ON THE GULF

Numerous summer and year round houses are located along the shore line south of the island. Most of these houses escaped water damage because of the building code established after Hurricane Camile of 1969, which stated that the floor must be 10 feet above the mean high water level (see Figures 5A and 5B).

Wind effects on the beach houses were minimal, and were rated from aerial surveys as being F0 or F1. If there were no recorded wind traces from the Dauphin Island Sea Lab and bridge, the estimated wind speeds based on the damage would have been less than 100 mph.

B. SEA LAB AREA

The Sea Lab is located near the east end of the island. Some of the frame houses in this area are no stronger than those typically seen in the suburbs of northern cities.

Many of these frame houses did not appear to be damaged when seen from the air. Figure 6A, looking northeast, shows barrack-like houses labeled A and B. These houses, as seen from the ground (see Figure 6B), are built on posts 3 to 4 feet high. Building C is a two story frame house which received minor roof damage. The roof of the small trailer labeled point D was dented by snapped pine trees.

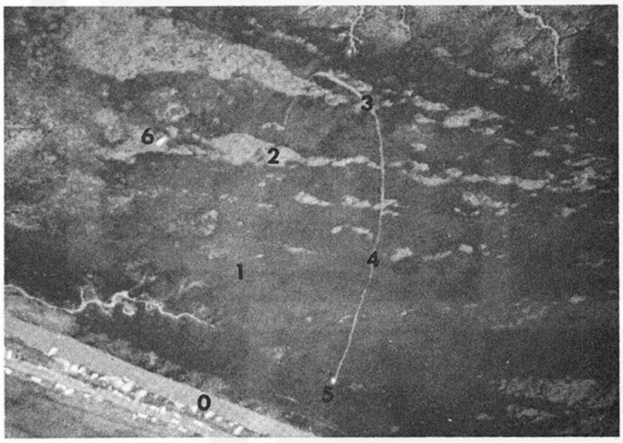

Figure 7A. Aerial photo depicting a trail of damaged grass left by a boat.

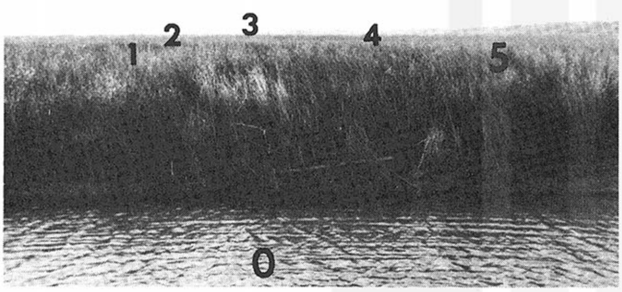

Figure 7B. Ground photo taken at '0' of Figure 7A looking across the canel.

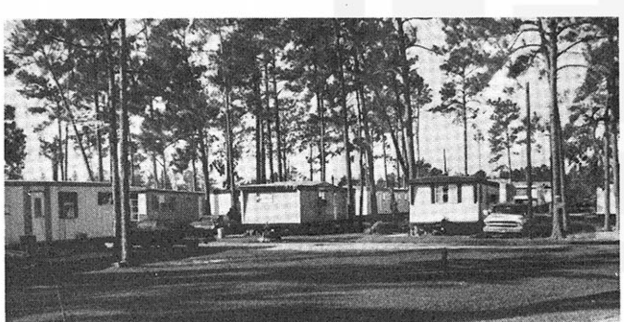

Figure 8. The trailer park sheltered by tall pines shown in Figures 9A and 9B.

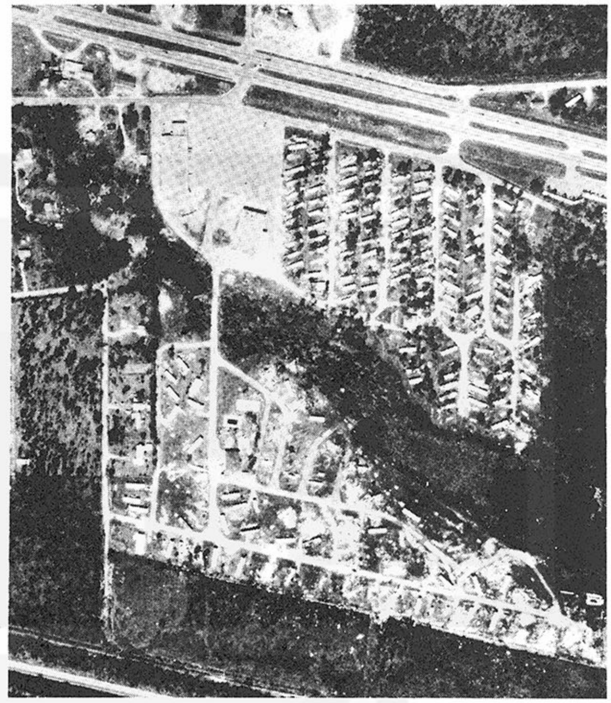

Figure 9A. NHEML photo of two trailer parks.

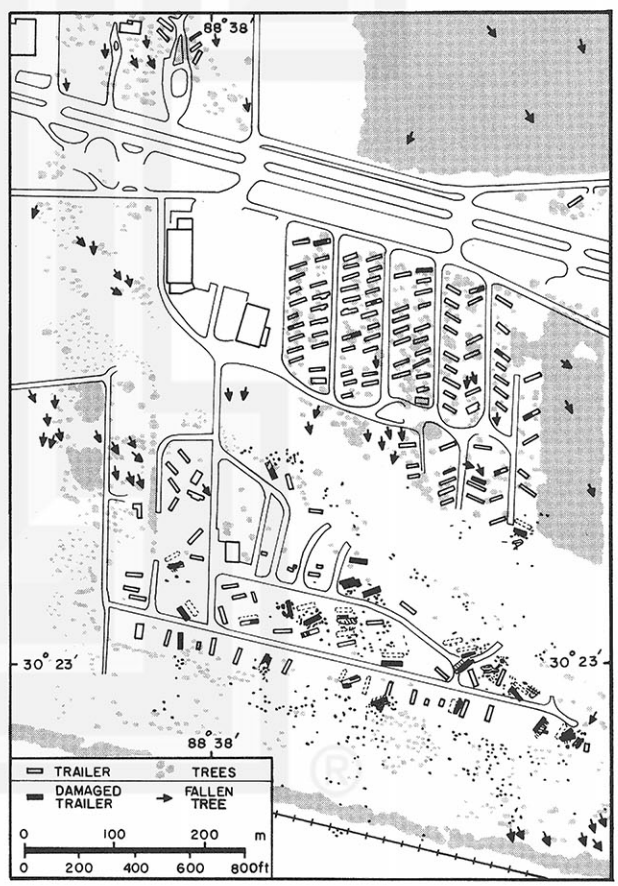

Figure 9B. A mapping of the damaged trailer parks shown in Figure 9A.

4.2 A BOAT WHICH MADE A U-TURN

From a canal north of the Dauphin Island bridge, a boat was picked up by a combination of the high tide and wind. It was probably pushed, while afloat, towards the west-southwest (see Figure 7A) from '0' to '1' to '2'. As the water level subsided the boat began damaging the grass from '2' to '3' (see Figures 7A and 7B). Then the wind direction reversed, pushing the boat back to near its original location. After leaving a U-turn mark on the grass, the boat came to rest at '5'.

4.3 WIND-BREAK EFFECT ON TRAILER PARKS

A number of trailer parks were affected by the hurricane-force winds. In almost all cases, however, the mobile homes surrounded by tall pine trees (see Figure 8) received much less damage than those in open areas.

Figures 9A and 9B is an example of two trailer parks, 5 miles to the west of Pascagoula, where the gusts were estimated to be 100 mph from the north. In the northern trailer park which is surrounded by tall pines, practically all the mobile homes were untouched by the winds.

In the southern trailer park which is in an open area, none of the trees were tall enough to act as an effective wind break to shield the mobile homes from the strong gusts.

5. F-SCALE ESTIMATION OF WINDSPEEDS

The F-scale proposed by Fujita in 1971 was originally intended to estimate the windspeeds of hurricanes and tornadoes, based on the resultant damage. However, since there are basic characteristic differences between hurricanes and tornadoes, the damage associated with each is different for a given peak windspeed, and therefore the F-scale cannot be applied equally to both storms. These differences are summarized below:

Hurricane

A. The level of the peak windspeed is high above the ground with a relatively deep boundary layer. As a result, trees and structures exhibit shielding effects.

B. Peak winds are associated with descending motion. Thus, roof damage is less than expected.

Tornado

A. The height of the peak wind speed is near the ground with a shallow boundary layer. As a result, trees and structures exhibit little or no shielding effects.

B. Peak winds are associated with ascending motion. Thus, roof damage is greater than expected.

The wind break effect has been discussed in 4.3 (see Figures 9A and 9B). The F-scale distribution of mobile home damage in Figure 10 reveals that the mean F-scale was F0.65 (61 mph) for the mobile homes protected by tall pine trees, and F1.15 (79 mph) for those in the open area. This result implies that on the average, pine trees reduced the peak surface windspeeds by 18 mph.

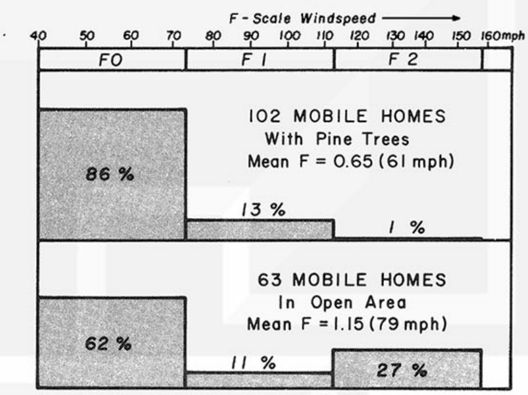

Figure 10. F-scale distribution of the mobile home damage seen in Figures 9A and 9B.

Dauphin Island provided an excellent example of estimating peak windspeeds based on hurricane damage. An F-scale assessment of 775 frame houses on the island was made from the air (see Figure 3). The resulting breakdown by scale is: 37% F0, 56% F1, and 7% F2.

The weighted average F scale is F1.20, which corresponds to an 81 mph windspeed (see Figure 11). In contrast, Table 1 shows peak windspeeds of 145 mph and 138 mph were recorded at the Dauphin Island Bridge and Sea Lab respectively.

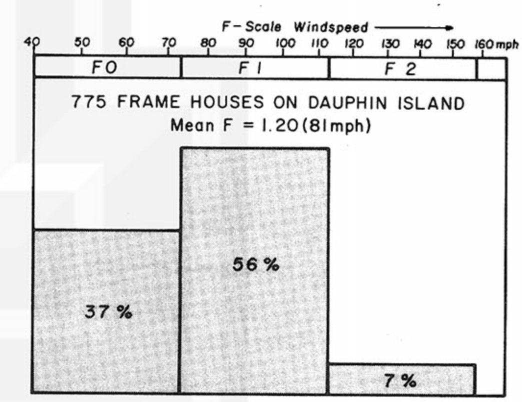

Figure 11. F-scale distribution of frame houses on Dauphin Island.

6. RADAR AND SATELLITE IMAGERY

In an attempt to study the structure of the hurricane, radar echoes were superimposed upon GOES/SMS infrared images. During the storm period these pictures were taken every 30 minutes, excluding 2230, 2300, and 2330 CST.

Figures 12, 13, and 14 show the patterns of the precipitation echoes and IR temperature as the hurricane center moved northward between Dauphin Island and Pettit Bois Island and subsequently landed to the east of Pascagoula.

By 0000 CST, the hurricane had lost much of its symmetry, being characterized by cold cloud tops over the central core (see Figures 15 and 16).

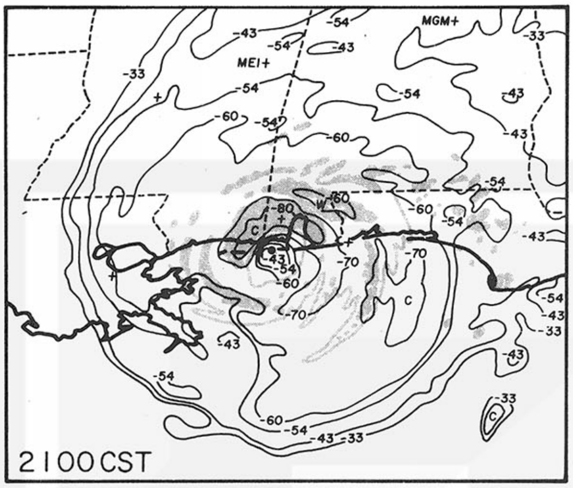

Figure 12. Infrared temperatures superimposed on radar echoes for 2100 CST.

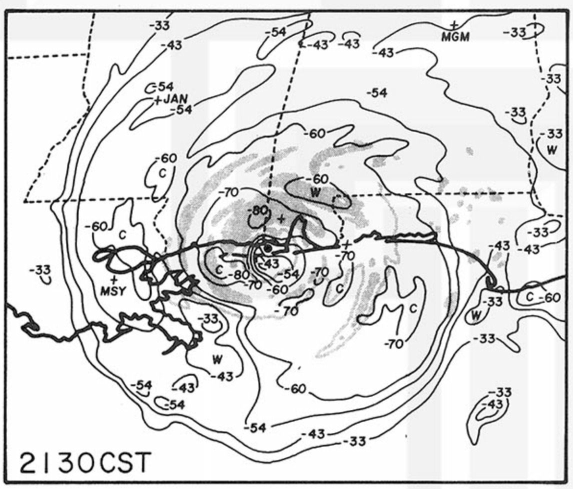

Figure 13. Infrared temperatures superimposed on radar echoes for 2130 CST.

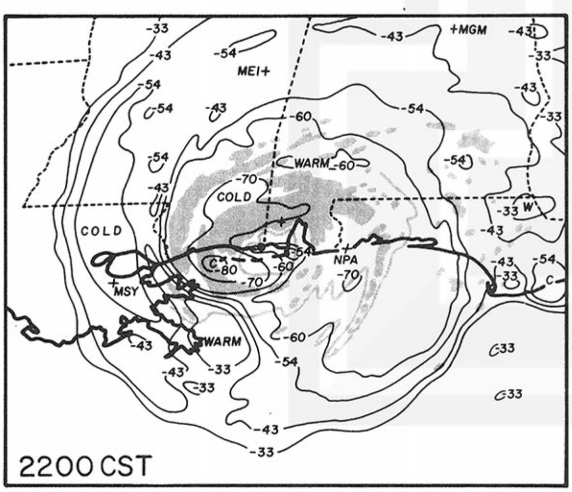

Figure 14. Infrared temperatures superimposed on radar echoes for 2200 CST.

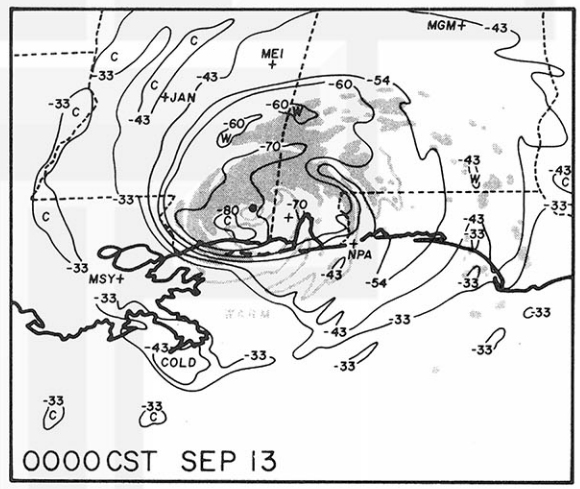

Figure 15. Infrared temperatures superimposed on radar echoes for 0000 CST.

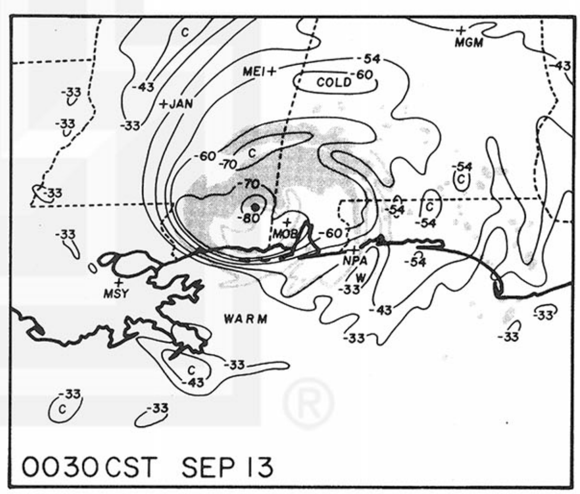

Figure 16. Infrared temperatures superimposed on radar echoes for 0030 CST.

7. MOTION OF RADAR ECHOES

As the hurricane moved inland it became increasingly difficult to determine the circulation center. To overcome this difficulty, echo-motion vectors were computed from successive radar pictures. The results shown in Figures 17 and 18 depict a changeover of the circulation center from an axi-symmetric center to an instantaneous center of rotation. The former denotes the center of circulation when the storm's translational motion is removed, and the latter is the center, around which the hurricane winds circulate at a given instance. The latter is always located on the left-hand side of the former so that the center shifts during the transition stage to the left of its original location when viewed towards the direction of motion.

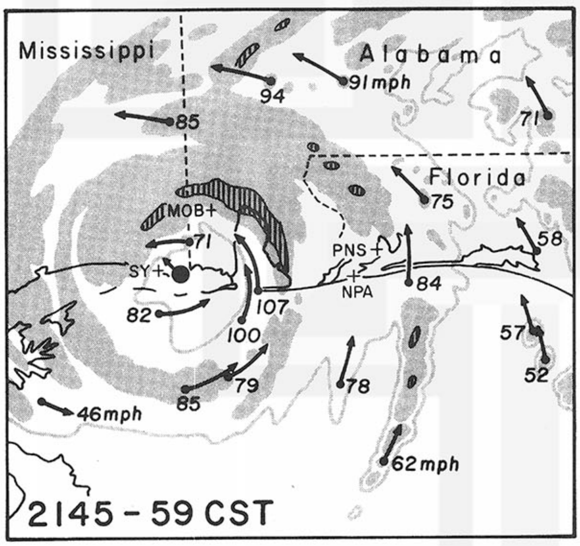

Figure 17. Precipitation echo motion vectors derived from successive radar pictures (2145-2159 CST).

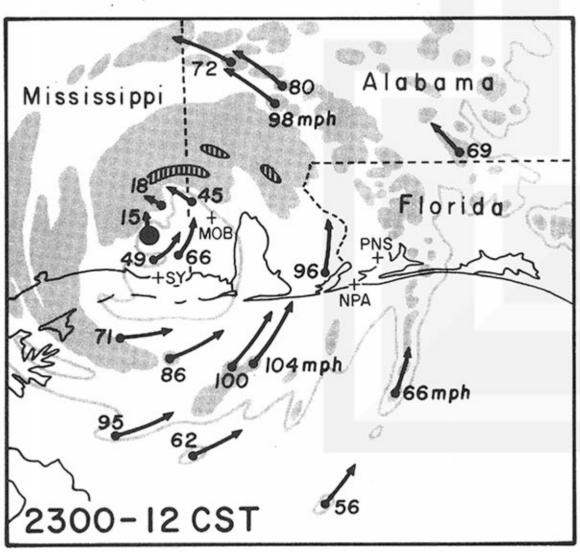

Figure 18. Precipitation echo motion vectors derived from successive radar pictures (2300-2312 CST).

8. CONCLUSIONS

Preliminary results reported herein reveal that the F-scale damage patterns show not only mesoscale features but also those related to the shielding effects of trees and the grouping effect of structures. The scatter in estimating the damage scale was plus or minus one F-scale.

It has been shown the discrepancies in the recorded windspeed and the estimated windspeed from the F-scale were caused by differing damage mechanisms of hurricane and tornado winds.

The structure of Hurricane Frederic changed from an axi-symmetric center to an instantaneous center when it landed near Pascagoula.

It is recommended that the damage, by both wind and water, of major hurricanes be investigated in detail. The investigation should include:

1. Aerial photography with 9"x9" color transparencies.
2. Damage-vector mapping and local photography using Cessna 172 or 182.
3. Ground survey of wind and water effects.

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