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Use of Enhanced ATS Pictures for Gulf-Storm Researches

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Abstract

Hurricanes cause severe damage along the Gulf Coast almost annually. Since two intense hurricanes, Camille and Celia, resulted in severe damage, it became necessary to predict possible damage based on satellite pictures long before ground-based radar is capable of detecting hurricane structure. Presented in this paper is an example of enhanced satellite picture and the extent of hurricane damage assessed by the damaging wind scale proposed by Fujita.

1. INTRODUCTION

Applications Technology Satellites (ATS) located 22,500 miles above the equator have been taking pictures of the earth at frequent intervals. Since the orbital period of ATS is selected to be the sidereal rotation period of the earth, it is feasible to monitor development of storms continuously during sun-lit hours. An operational satellite SMS/GOES to be launched late in 1973 will carry an infrared sensor, permitting us to monitor severe storms 24 hours a day.

To make the most use of satellite data, pictures can be enhanced so as to depict detailed structure of storms for their prediction and subsequent disaster preparedness.

It is the purpose of this paper to review potential values of geostationary satellite data and to present a method of storm damage assessment based on the F-scale damage categories.

References and illustrations at end of paper.

2. VALUES OF GEOSTATIONARY SATELLITES IN MONITORING GULF STORMS

ATS III, located above the equator south of the United States, is sending pictures back to the earth for every 10 to 30 minutes, depending upon storm situations. These pictures have been put together operationally into time-lapse movies by National Hurricane Center at Miami, National Severe Storms Forecast Center at Kansas City, and National Environmental Satellite Service at Suitland, Md. Basic research on the operational application of satellite data has been conducted by SMRP, Satellite and Mesometeorology Research Project, at the University of Chicago in an attempt to solve problems of storm identification and prediction.

Shown in Fig. 1 is a picture of hurricane Camille shortly before her landing near Gulfport, Miss., causing tremendous wind and water damage. As has been well known, the top of a hurricane is covered with a thick cirrus shield which often appears to be a white disc in satellite pictures. Taking place beneath this white disc are high winds and waves coupled with heavy precipitation, resulting sometimes in practically zero visibility.

Thanks for the development of geostationary satellites capable of looking down upon the earth to scan cloud patterns with 2.5-mile resolution at the subpoint. We can now trace back all hurricanes to their spawning ground which may be in the Caribbean or the Atlantic or even in West Africa. The eggs of potential hurricanes can thus be monitored all-the-way to their hatching ground.

3. PICTURE ENHANCEMENT TO KNOW MORE ABOUT THE STORM STRUCTURE

As a storm grows into a full-size hurricane, Mother Nature tries to hide the internal structure by spreading cirrus clouds on top of the storm's active area. This is why ordinary satellite pictures such as in Fig. 1 are not good enough to determine the storm structure.

Recent investigation of the brightness values transmitted from ATS revealed that a cirrus shield is not uniformly bright, despite its appearance as a white disc. An example of the brightness change across the top of Camille in Fig. 1 is presented in Fig. 2. Relatively flat top of the brightness corresponds to the area of the hurricane top. Note that the range of the brightness fluctuation is appreciable, suggesting that a new image of hurricane top can be produced simply by enhancing the brightest portions inside the white disc.

Shown in Fig. 3 is the view of the same Camille picture produced by enhancing the brightest clouds. Careful examination of this picture reveals the existence of double eye characterized by two concentric rings of eye-wall circulation. This is a typical feature of intense hurricanes such as Camille of 1969.

A number of movies were made from enhanced picture sequences to illustrate the possibility of hurricane-intensity assessment based on ATS pictures.

4. SURVEY OF HURRICANE DAMAGE BASED ON F-SCALE DAMAGE CATEGORIES

Fujita (1971) proposed a scale of damaging wind, which is comparable to Beaufort Force but covers wide ranges of damaging wind including tornadoes. Fig. 4 was prepared to show the connection of Beaufort force, Fujita scale, and Mach number. As shown in the figure, F 1 corresponds to B 12 or the beginning of hurricane wind speed, and F 12 to Mach 1, the speed of sound. The downward extension of F scale defines the range of F 0 scale with a wind speed range between 40 and 72 miles per hour which could cause light damage.

There are no reasons to believe that the full range of F 1 to F 12 is necessary to express categories of damage because it is unlikely that F 4 (207-260 mph) or higher winds exist within hurricanes. There are reasons to believe that practically all tornadoes are characterized by F 5 or smaller categories.

The following damage specifications were made for the purpose of quick assessment of damage caused by hurricanes. It should be pointed out that hurricane-associated tornadoes frequently reported in gulf states are localized but they could be more intense than their parent hurricanes.

<u>FUJITA SCALE DAMAGE SPECIFICATIONS</u>

(F 0) 40-72 mph, LIGHT DAMAGE
Some damage to chimneys and TV antennae; breaks twigs off trees; pushes over shallow rooted trees.

(F 1) 73-112 mph, MODERATE DAMAGE
Peels surface off roofs; windows broken; light trailer houses pushed or overturned; some trees uprooted or snapped; moving automobiles pushed off the road. 73 mph is the beginning of hurricane wind speed.

(F 2) 113-157 mph, CONSIDERABLE DAMAGE - Roofs torn off frame houses leaving strong upright walls; weak buildings in rural areas demolished; trailer houses destroyed; large trees snapped or uprooted; railroad boxcars pushed over; light object missiles generated; cars blown off highway.

(F 3) 158-206 mph, SEVERE DAMAGE Roofs and some walls torn off frame houses; some rural buildings completely demolished; trains overturned; steel-framed hangar-warehouse type structures torn; cars lifted off the ground; most trees in a forest uprooted, snapped, or leveled.

(F 4) 207-260 mph, DEVASTATING DAMAGE - Whole frame houses leveled, leaving piles of debris; steel structures badly damaged; trees debarked by small flying debris; cars and trains thrown some distances or rolled considerable distances; large missiles generated.

Presented in Fig. 5 are photographs of typical F 1 through F 4 damage. Most hurricane damage along the Gulf Coast will be F 1, F 2, and possibly F 3.

5. HURRICANE CAMILLE OF AUGUST, 1969

To determine the horizontal extent of hurricane Camille damage, an extensive aerial survey was made by flying over the entire area affected by the storm. Both direction of maximum wind and F-scale damage were determined along the flight track (see Fig. 6). The area of most severe damage caused by F 2.5 or stronger wind is stippled. Against our expectation that a hurricane will weaken very quickly after landing, F 2.5 damage area extended inland more than 30 miles, suggesting that tight hurricane circulation was maintained through such a long distance.

It is of interest to find pockets of F 2 areas within the F 1 region. This implies that hurricane damage is rather streaky in the direction of the maximum gusty winds. To determine the scale and the extent of such small damage areas, it is necessary to undertake more complete areal mapping than the fly-by-day type of areal survey.

6. HURRICANE CELIA OF AUGUST, 1970

A high-resolution damage mapping became feasible when a NASA Earth Resources plane based at Houston was sent to Corpus Christi for photographic missions. The city received severe damage by hurricane Celia on August 3, 1970. A large number of vertical color pictures were taken by using aerial photogrammetric cameras. Pictures covered the entire city of Corpus Christi with a resolution even to identify parking lanes.

Through painstaking effort, damaged houses and trees in the entire city were stressed in F-scale categories, obtaining finally the F-scale damage pattern of Fig. 7. Numerous damage streaks, as long as 2 to 3 miles, are seen in the figure. Some are straight but ones with anticyclonic curvature are also seen, especially in the south side of the city. Dr. R. H. Simpson (1970), director of National Hurricane Center expressed his view that these streaks are characterized by straight-line wind showing no indication of rotating flow such as expected within tornadoes. Dr. Simpson flew over the entire city immediately after the storm by helicopter for a detailed inspection of the damage.

At the present time, we are unable to explain the cause of such streaks except that gusty winds from the westerly direction came from the area of heavy rain on the south side of the eye wall. Detailed analysis of Celia including this peculiar damage will appear in a paper by Fujita, Simpson, and Gentry (1972).

7. CONCLUSIONS

How can geostationary satellites help the prediction of hurricane damage? This is a very good question that should be answered as a part of the conclusions of this paper.

If a hurricane is a simple axial-symmetric vortex drifting down the large-scale flow around the North Atlantic high, the storm's wind fields can be expressed by a vector sum of the hurricane circulation and the velocity of the large scale flow. In reality, however, a hurricane hides beneath its cirrus shield a large number of convective systems each of which is characterized by a concentrated rain area. Investigation of enhanced pictures clearly shows that most of the highly convective areas can be depicted through proper enhancement. We know that these convective systems contribute to the asymmetry of the hurricane circulation and asymmetric circulation results in more asymmetric distribution of convective systems.

It is, therefore, necessary to know the patterns of local convection within a hurricane in order to predict the direction of strongest winds caused by a landing hurricane. In the case of Camille, very strong off-shore winds resulted in extremely high storm surge. But Celia was a different lady; she was accompanied by strong winds from inland which resulted in insignificant storm surge.

After SMS/GOES goes into operation within a couple of years, our system of monitoring hurricanes will be improved significantly. We also hope that other severe storms such as squall lines and hailstorms can be monitored during their entire life history so that an advanced warning can be transmitted to coastal residents each time a disaster potential is suspected.

References

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Fujita, T. T., R. H. Simpson, and R. C. Gentry, (1972): Detailed Analysis of Hurricane Celia of August 1970. Unpublished manuscript to be published shortly.

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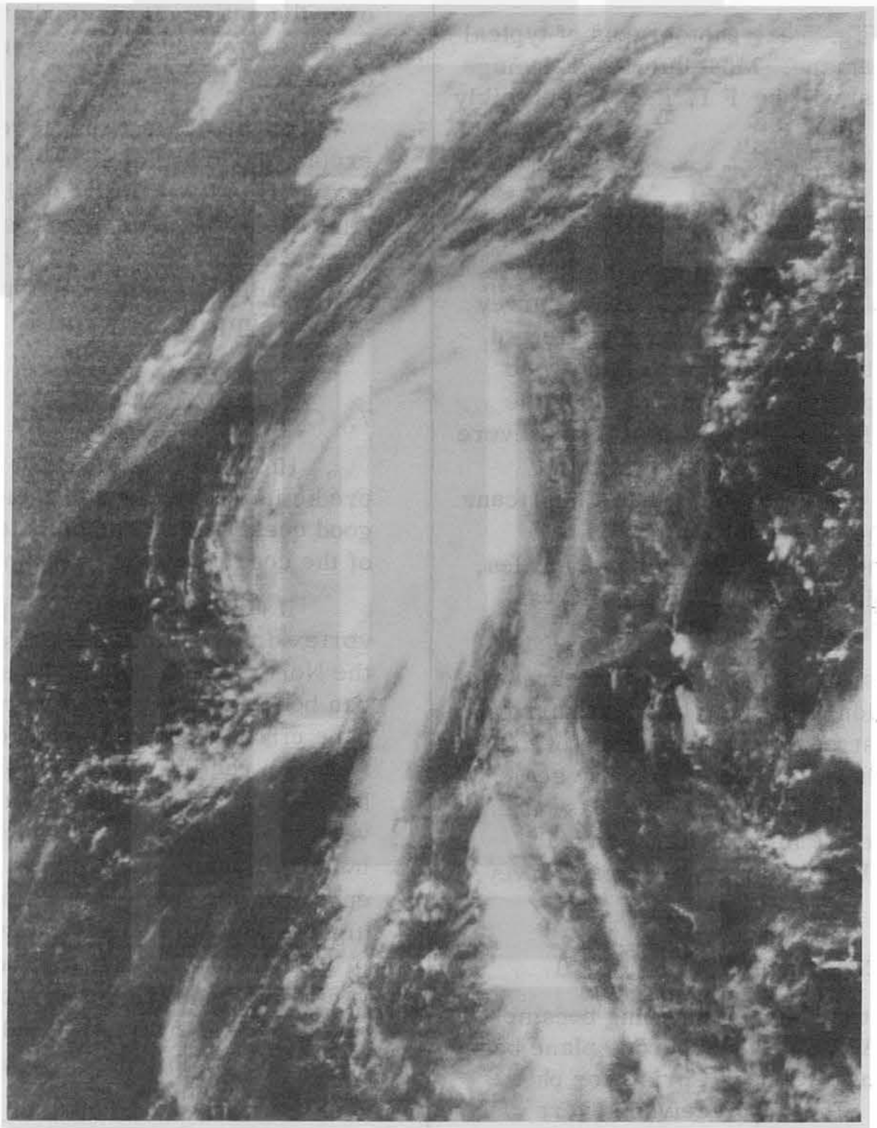

Fig. 1 - ATS view of Hurricane Camille on Aug. 17, 1969, shortly before her landing near Gulfport, Miss. (Courtesy of NASA)

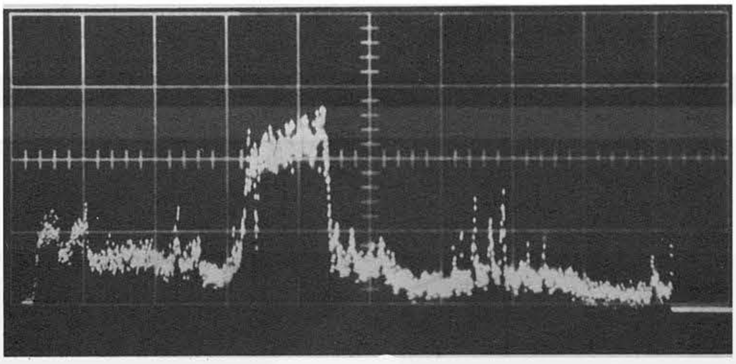

Fig. 2 - Change in brigthness values across the cirrus shield. Note that brightness varies up and down within the white hurricane top. (Courtesy of NASA)

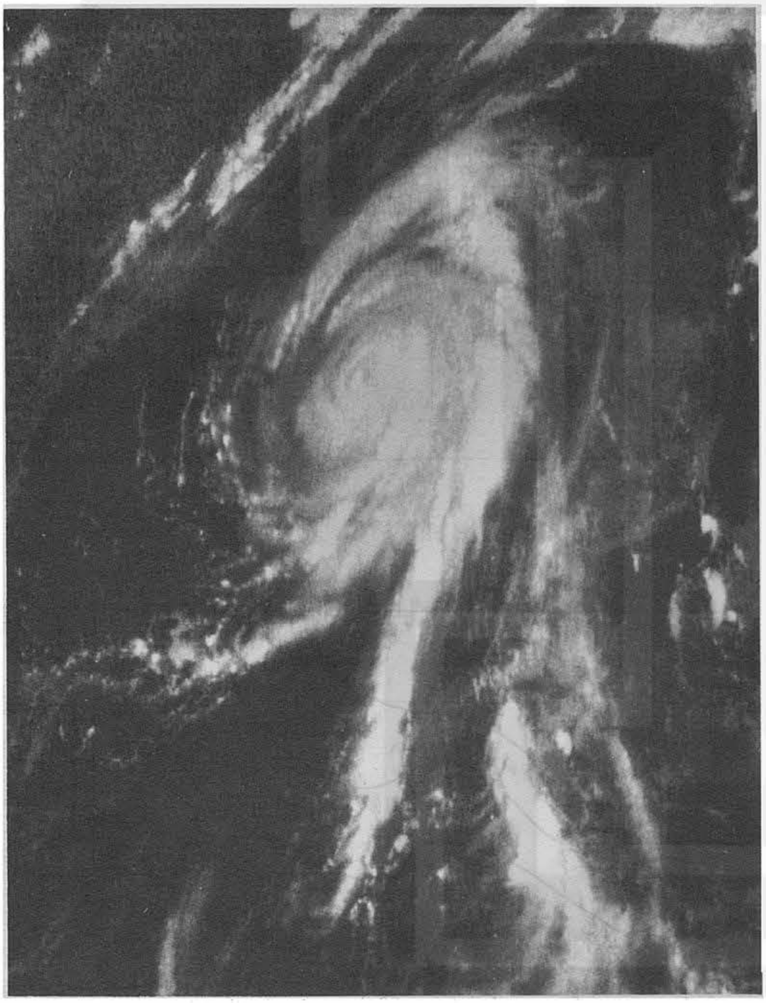

Fig. 3 - Enhanced view of Hurricane Camille to show double-eye structure and thick convective clouds inside the cirrus shield. (Courtesy of NASA)

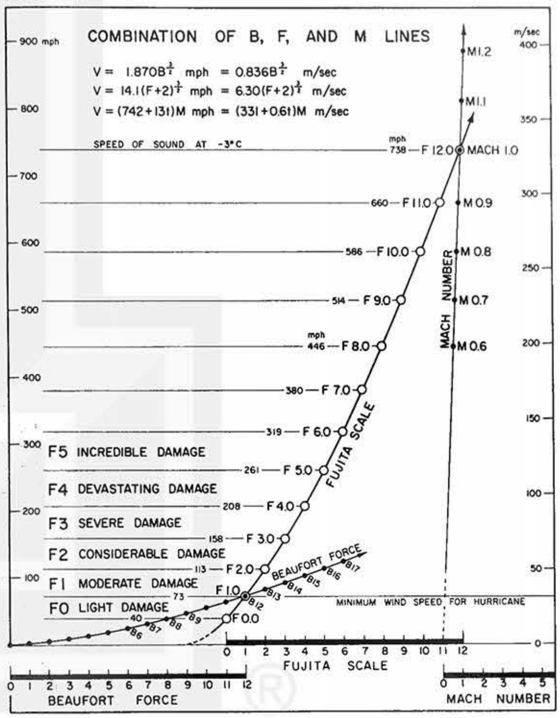

Fig. 4 - Connection of three scales expressing various ranges of wind speed (from Fujita, 1971).

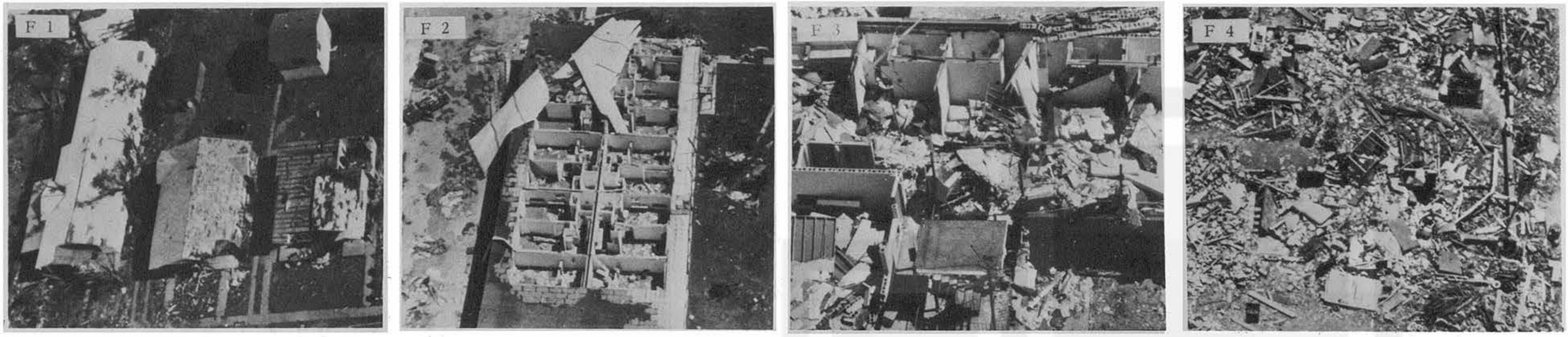

Fig. 5 - Typical damage by F 1 through F 4 wind within tornadoes (from Fujita, 1971).

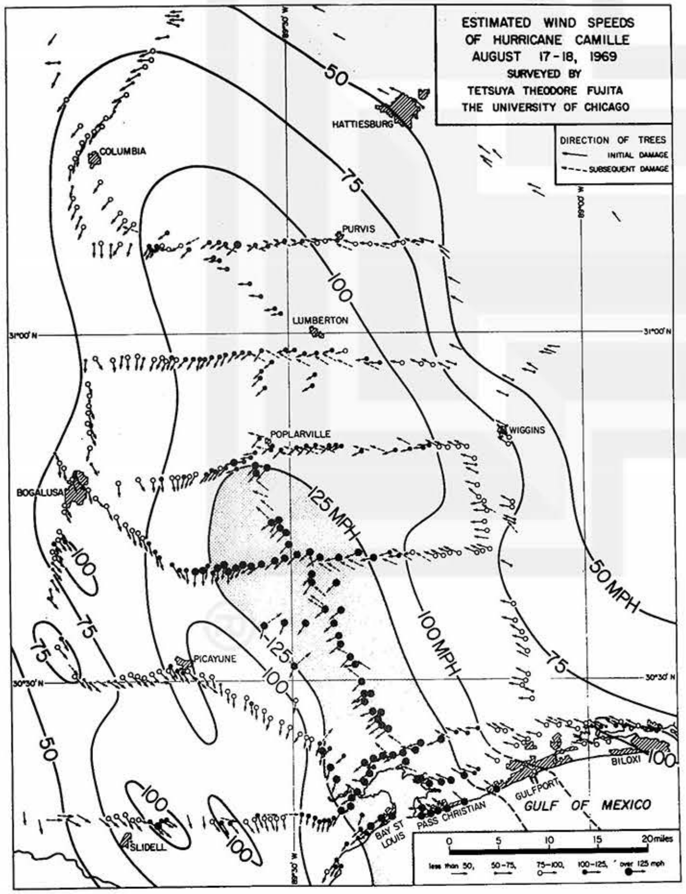

Fig. 6 - F-scale damage map of Hurricane Camille, Aug., 1969. Damage scale and wind direction was mapped from Cessna (from Fujita, Simpson and Gentry, 1972).

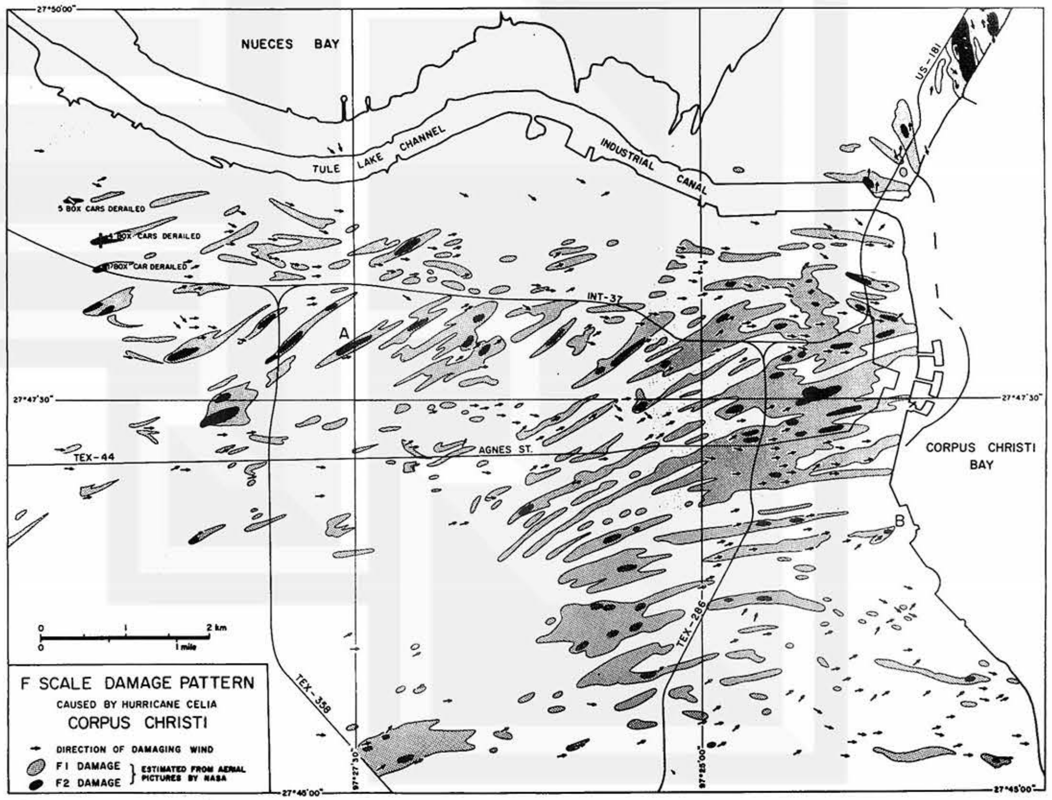

Fig. 7 - Damage streak produced by Hurricane Celia of Aug., 1970, in the city of Corpus Christi (from Fujita, Simpson and Gentry, 1972).