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MESOSCALE STRUCTURE OF HURRICANE ALICIA

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Abstract

The meteorological life-history of Hurricane Alicia is illustrated and discussed. Examples are presented to verify the merits of hurricane monitoring via aircraft, satellite and radar observations. Particular attention is focused on the damage incurred during landfall. Aerial and ground surveys were performed to assess the damage, using F scale to arrive at a windfield with estimated windspeed. The damage distribution and windfield are presented in a map, along with the path of Alicia's eye and/or circulation center. The geographical and storm-relative distributions of 22 tornadoes spawned by Alicia is also shown. Finally, a sample of damage photos demonstrating the hurricane's destructive impact are included.

1. PATH OF ALICIA

When Hurricane Alicia entered Texas from the Gulf of Mexico on August 18, 1983, it was the first hurricane to make landfall in the continental U.S. since Hurricane Allen struck southern Texas on August 10, 1980, a period of three years. Alicia was also one of the costliest hurricanes in Texas history, causing widespread damage to a large portion of southeast Texas, including coastal areas near Galveston and the entire Houston area.

Most hurricanes in the Gulf of Mexico either form in or enter the gulf on easterly waves, pressure troughs that are imbedded in the easterly, trade winds that originate near the coast of Africa just north of the equator. Alicia was different in that it formed from the remnants of a westerly-flow, cold front, only 175 miles south of New Orleans. As the westerly flow aloft retreated northward, the remaining surface, low-pressure area came under the influence of an easterly flow and became a tropical depression about midday on August 15th. By the end of the day, the system had become Tropical Storm Alicia (see Figure 1).

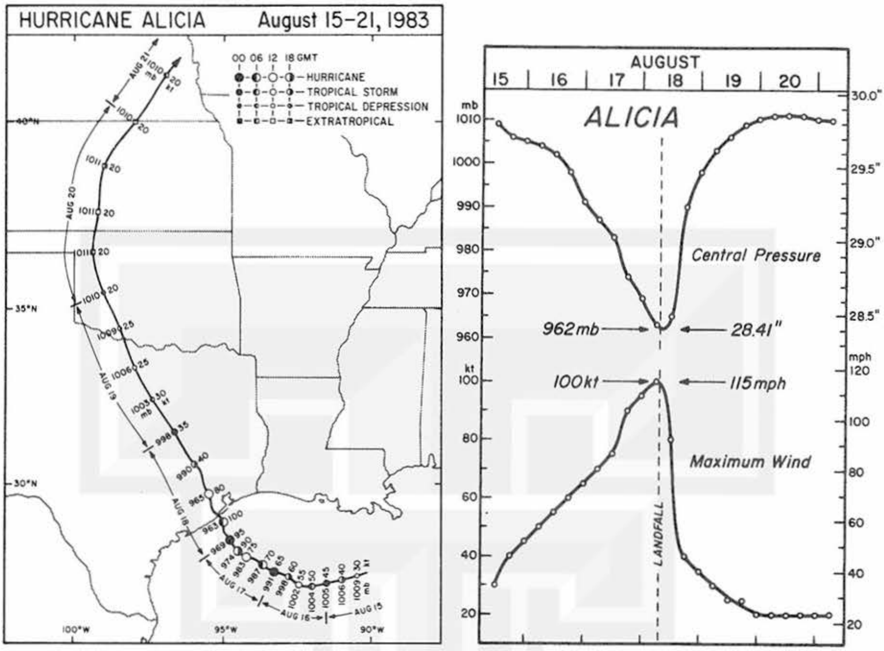


Figure 1. The path (left), and the central pressure and maximum wind (right) of Hurricane Alicia during its 6-day life. Note that the storm developed rapidly prior to landfall.

Alicia's initial progress westward was very slow, allowing sufficient time to gather moisture and intensify over the warm gulf waters. Alicia attained hurricane status (estimated winds of 65 knots or greater) at 0000GMT on August 17th, and began turning northwest toward the Galveston-Houston area shortly thereafter. Landfall occurred over the west end of Galveston Island at approximately 0730GMT on August 18th. At that time, Alicia had reached a minimum central pressure of 962 millibars (28.41" Hg), and its maximum sustained winds of 100 knots (115 mph).

Unlike most hurricanes, Alicia did not rapidly weaken after landfall. Alicia had maintained hurricane force winds even as its eye passed over western Houston, more than 60 miles (about 100 km) inland and 6 hours after landfall. As the hurricane eventually weakened, it moved northwestward through Texas and was finally downgraded to the extratropical stage in western Oklahoma. Then moving northward, Alicia made a final turn northeastward before becoming disorganized in eastern Nebraska.

2. AIRCRAFT, SATELLITE AND RADAR OBSERVATIONS

Throughout its life, Alicia was closely monitored by aircraft, weather satellites, and all operational and research, weather radar within observational range. The NOAA/RFC aircraft made several passes through the hurricane during the landfall period, at a 5000 ft. MSL flight level. The collected wind data was adjusted in position according to Alicia's translational motion (both direction and distance) to form a composite windfield for a single moment in time (see Figure 2). Figure 3 illustrates the windspeed data in a radial profile, taken from a penetration flight through Alicia's eye just prior to landfall. Note that the windspeed dropped to near zero within the eye.

Weather satellites allowed the earliest detection of Alicia's formation over the Gulf of Mexico. Its cloud structure and development were made evident in both visible and infrared imagery. Figure 4 shows both types imagery, taken from the NOAA 7, polar-orbiting satellite at 1345 GMT on August 16th. Alicia was a tropical storm at this time, and 36 hours away from landfall. The dark regions over the clouds in the infrared photo mark the coldest, and therefore highest, cloud tops. This indicates areas of strong, vertical motion within the clouds, and the likeliest areas for strong surface winds. Note that no eye is yet apparent in the visible photo.

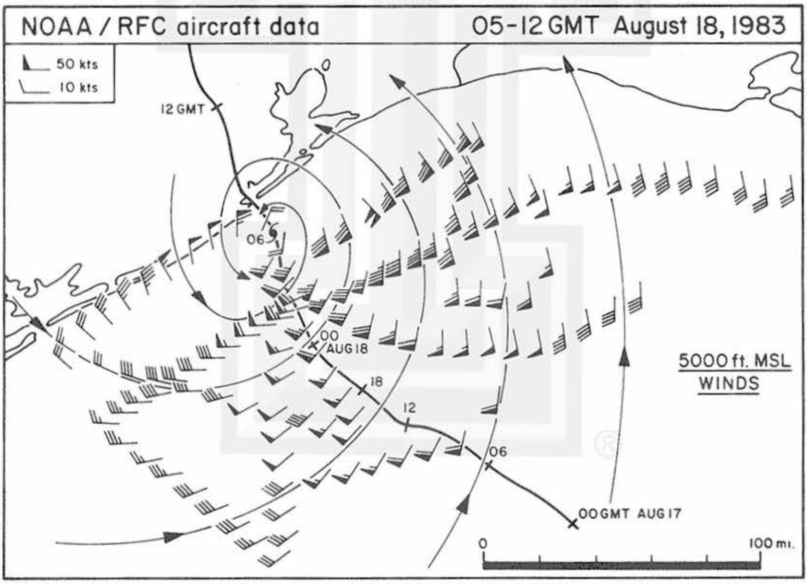


Figure 2. Streamline analysis of Alicia's winds as recorded by NOAA/RFC penetration aircraft at a 5000 ft. MSL flight level. The figure is a composite of several fly-throughs conducted over a 5-hour period, with data adjusted to Alicia's 0600 GMT, August 18th position.

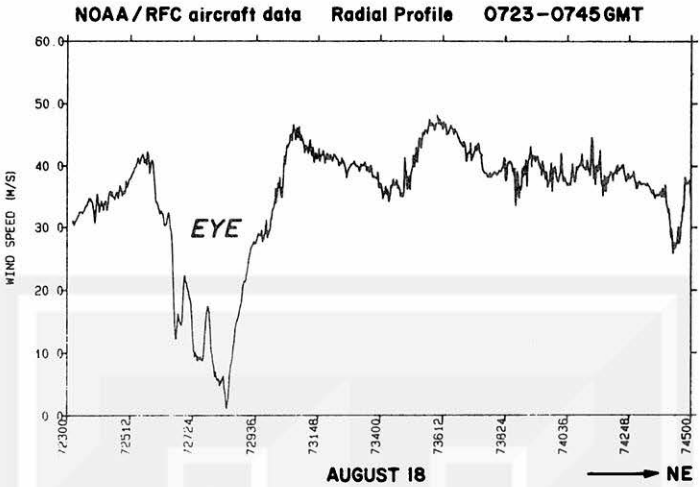


Figure 3. A radial profile of 5000 ft. MSL winds vs. time during a 22-minute period of a penetration flight through the eye of Alicia. ---NOAA/RFC aircraft data and analysis courtesy of Peter G. Black and Howard A. Friedman, AOML/Hurricane Research Division.

In Figure 5, an SMS/GOES East, visible photo shows Alicia with a small but well-defined eye on August 17th, about 14 hours prior to landfall. However, the primary tool for tracking Alicia's eye was weather radar. The weather radar indicates areas of precipitation, with light to heavy intensity shown by six gradations of grey, white and black in a repeated pattern. Figure 6 shows Alicia as detected by the NWS radar at Galveston, about 5 1/2 hours prior to landfall. It shows the hurricane as having a "double eye" (concentric precipitation rings), an uncommon feature that Alicia exhibited prior to and shortly after landfall.

3. DAMAGE MAP AND ESTIMATED SURFACE WINDSPEED

Shortly after Alicia's demise, aerial and ground surveys were conducted by Stiegler on August 21-25, 1983 to determine the extent, degree and general distribution of wind-induced damage. Fallen trees and debris from structural damage were used to obtain vectors representing the intensity and direction of the peak winds. The vectors were mapped with respect to geography as depicted by the red arrows in Figure 7. Note that due to problems inherent to field survey (cost and time restrictions), the mapped vectors cannot be taken as all-inclusive.

The relationship between surveyed damage and estimated windspeed was established by means of the F scale, a system that was proposed for tornado and hurricane damage by Fujita in 1971, and has since become widely accepted (see key, upper right of Figure 7). Windspeed analysis was performed, and peak gusts over land were estimated to be in excess of 125 mph in some areas. The area affected by winds of 75 mph or great-

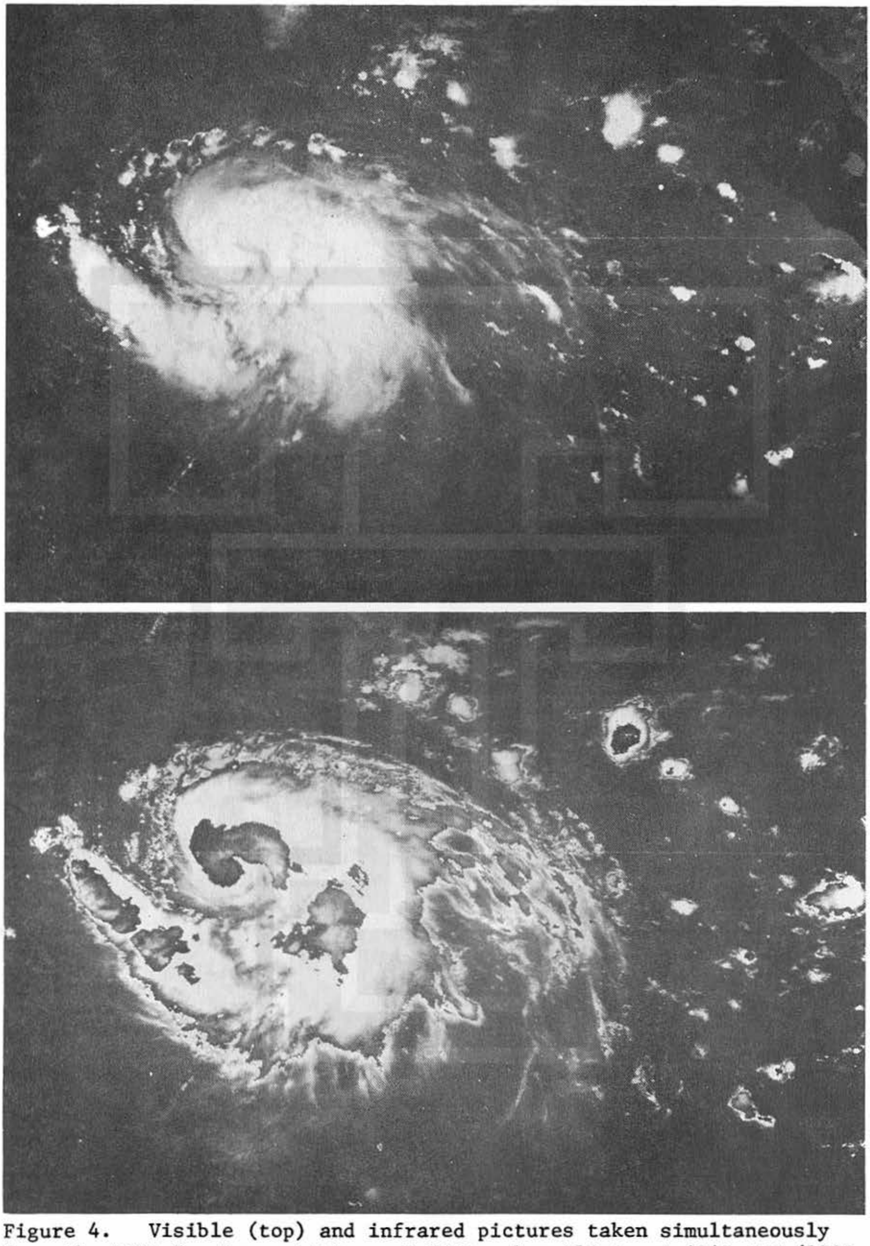


Figure 4. Visible (top) and infrared pictures taken simultaneously from the NOAA 7 polar-orbiting satellite show Alicia at 1745 CST (1345 GMT) on August 16th. Note that Florida and Cuba can be seen in the early morning light on the right edge of the visible photo. ---Photos supplied by Linwood F. Whitney, Jr., NESDIS.

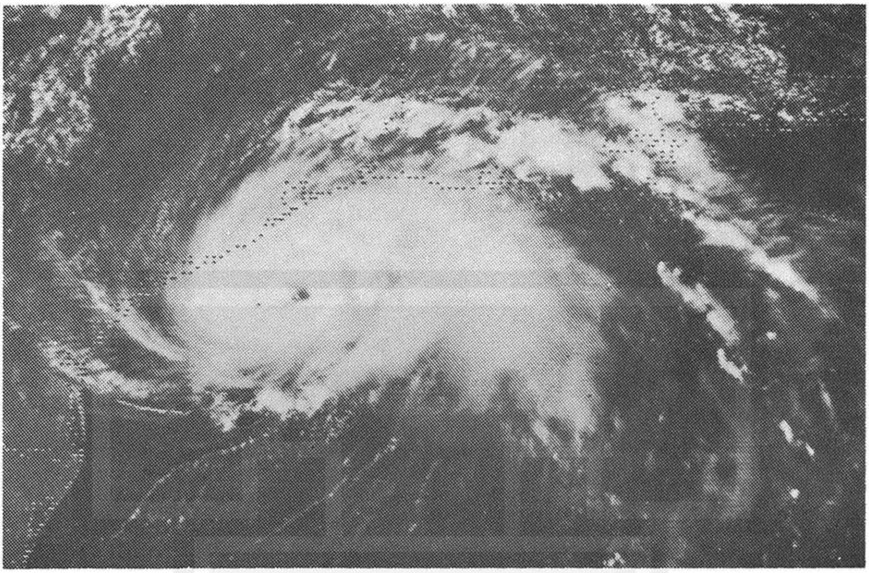


Figure 5. GOES East satellite, visible image taken at 1131 CST (1731 GMT), August 17th. ---Photo supplied by NHC.

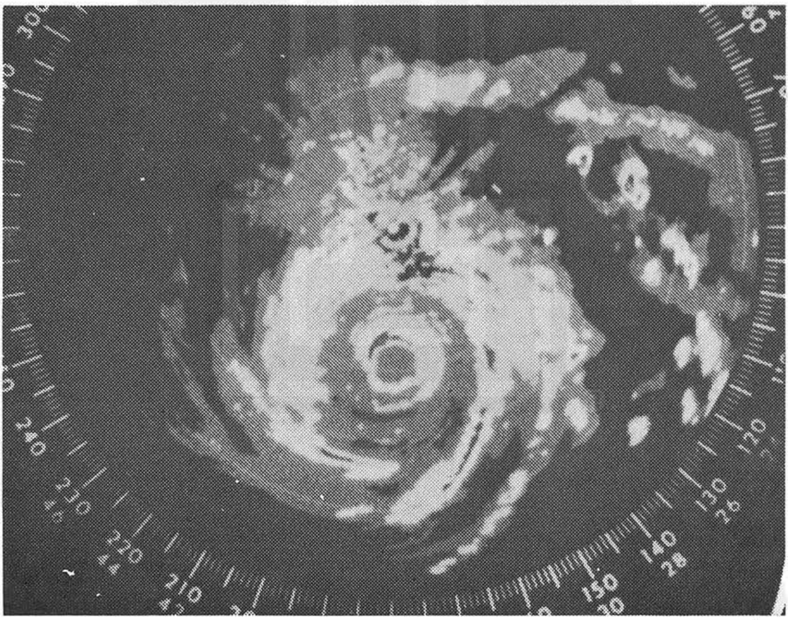


Figure 6. Alicia as depicted by Galveston NWS radar at 2000 CST on August 17th (0200 GMT, August 18th). ---Photo from NCDC.

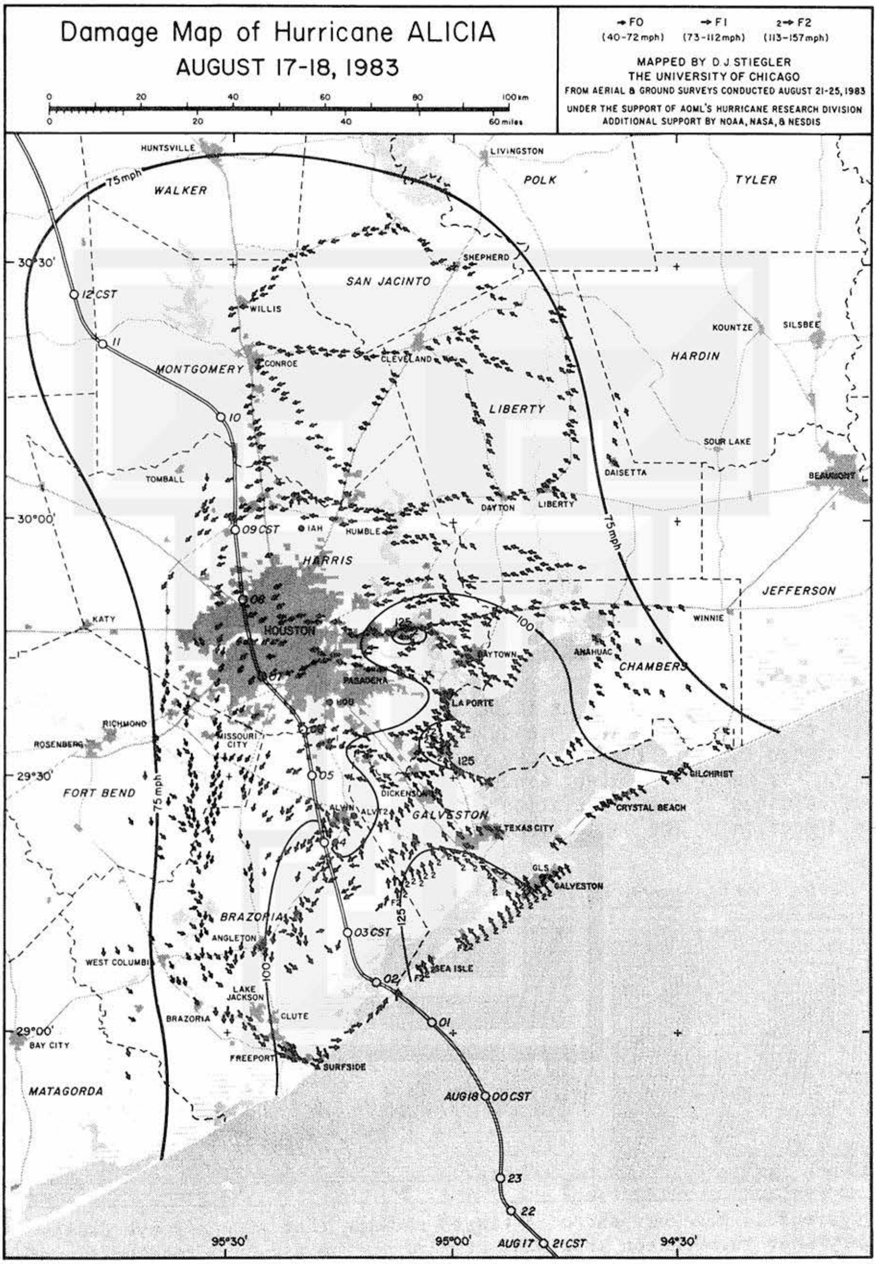


Figure 7. Damage map of Hurricane Alicia as derived from aerial and ground surveys conducted August 21-25, 1983.

er was about 100 miles wide along the coast, and reached as far as 110 miles inland. The entire area approximately equalled 6,000 square miles.

As would be expected, winds were higher to the right of the eye's path, a factor resulting from the hurricane's translational motion. If one assumes that a hurricane has a symetrical windfield when it is stationary, then a translational motion will increase windspeeds to the right of the path and reduce those to the left, a difference equalling twice the translational speed.

The overall pattern of the vectors show the cyclonic windflow of the storm, with a few discontinuities allowing for time variability and imbedded mesoscale phenomena. The possibility of a downburst (a localized thunderstorm downdraft that produces damaging surface winds) is apparent in the difluent pattern of vectors within the 125 mph zone on the west edge of Trinity Bay, just south of LaPorte. However, the possibility also exists that the higher winds could have resulted from the air having been driven over the long fetch of the near-frictionless surface of Trinity Bay.

The path and hourly position of Alicia's eye was determined using microfilm from the NWS radars at Galveston, Texas and Lake Charles, Louisiana, along with supplemental data from the Texas A & M radar at College Station, Texas. One exception was a 3-hour portion of the path near Alvin, between Houston and the Gulf Coast. Since Alicia's eye was especially large during this period, and the circulation center of a hurricane does not necessarily coincide with the center of the eye, wind and pressure data from the National Weather Service office east of Alvin (ALVT2) and damage vectors were used to uncover the true course of Alicia's circulation center as it passed Alvin. The 45-minute, level portion at the bottom of the pressure trace (see Figure 8) and the reduced windspeed indicate that the eye passed over the Alvin NWSO as was detected by radar. However, since the winds did not totally calm, the path was adjusted to the circulation center as depicted by the radical change in direction of the damage vectors to the west of Alvin.

Barograph and Gust Recorder Traces from Alvin, Texas WSO during Hurricane ALICIA

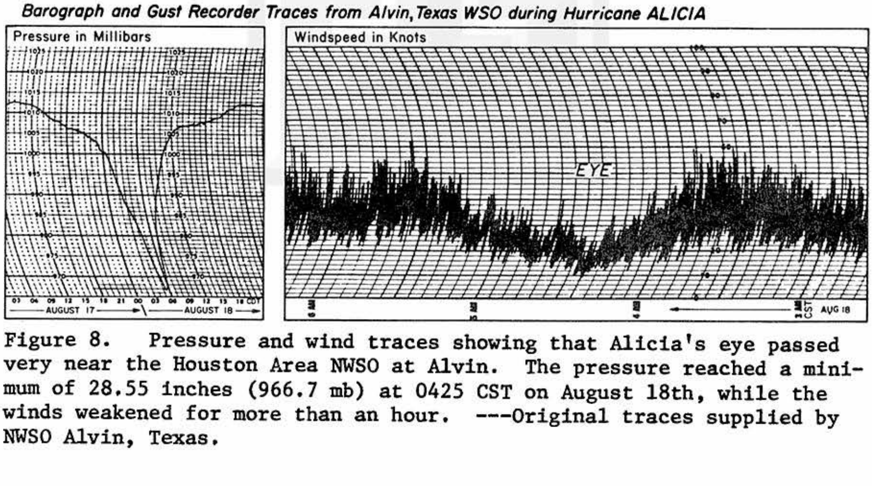


Figure 8. Pressure and wind traces showing that Alicia's eye passed very near the Houston Area NWSO at Alvin. The pressure reached a minimum of 28.55 inches (966.7 mb) at 0425 CST on August 18th, while the winds weakened for more than an hour. ---Original traces supplied by NWSO Alvin, Texas.

4. ALICIA-INDUCED TORNADOES

Hurricane Alicia produced 22 tornadoes during a 22-hour period from 2110 CST on August 17th to 1920 CST on August 18th. Of the 22 tornadoes, mapped by geographical location and storm relative position in Figure 9, only one was rated F2 in intensity, another was F1, and the remaining 20 were all rated F0. The fact that most of these tornadoes were weak and short-lived made their damage paths nondiscernible from the widespread hurricane-wind damage. Numerous reported tornado locations were inspected during aerial surveys, and no evidence of their existence could be found. This leaves some doubt as to their actual occurrence. The strongest and most credible tornado occurred at Corsicana, Texas, far to the north of the other tornadoes, in an area where hurricane wind damage was minimal at best.

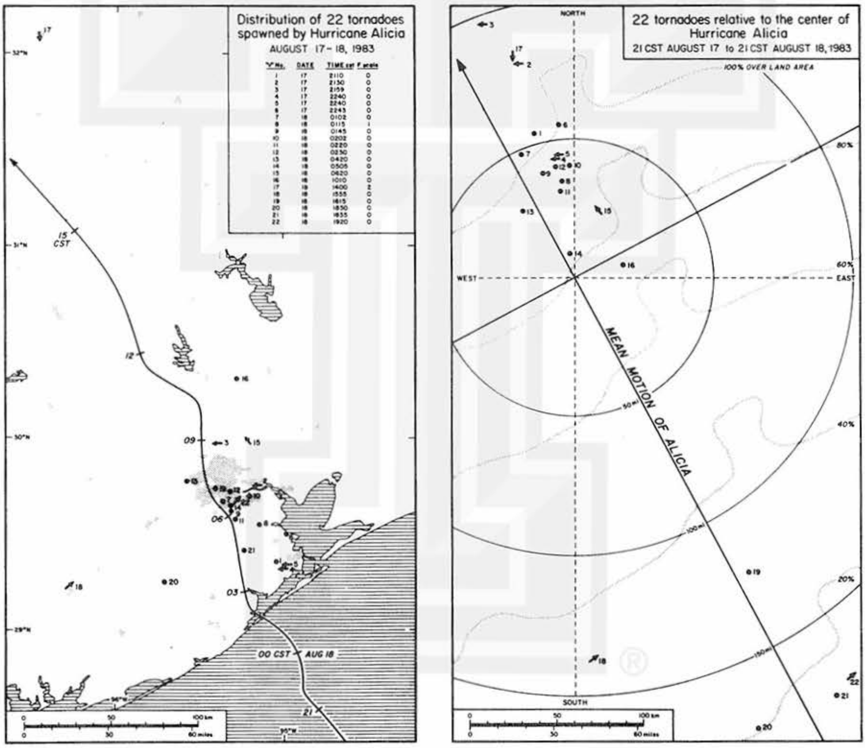


Figure 9. Mappings of 22 tornadoes spawned by Alicia in less than 24 hours during landfall. The tornadoes, numbered chronologically, are shown both by geographic location (left) and storm relative position (right). Grey lines in the right map represent the percent of the time period that that portion of Alicia was over land. ---Data from NWSFOs at San Antonio and Fort Worth, Texas. Mappings by University of Chicago.

The tornadoes were not evenly distributed geographically. A cluster of 8 were reported over southern portions of Houston, while one, as mentioned, occurred far to the north. However, from a storm relative point of view, most of the tornadoes were grouped in the right front quadrant of the storm, a pattern that coincides with previous hurricanes. Only the last 5 tornadoes, chronologically, occurred on a trailing squall line, far to the rear of the hurricane after it was well inland.

5. AERIAL AND GROUND PHOTOGRAPHY OF DAMAGE

Presented on the following pages are photos that chronicle Hurricane Alicia's destructive force. The first series of photos, Figures 10 to 15, were taken by Barbara White and Al Wootten on Galveston Island as Alicia made landfall. The two weather enthusiasts made a special trip from Florida to ride out the storm and record Alicia's destructive fury as it happened. The remaining damage photos were taken during aerial and ground surveys after Alicia's passage. They are only a sample of the many photos that were used to complete and refine the damage map in Figure 7. When viewing the photos, one should keep in mind that as the damage was assessed using the F scale, particular attention was paid to the type of structure damaged, and what type of destructive force caused the damage. Most of the engineered structures (hotels, major business buildings, skyscrapers, etc.) fared well through Alicia's passage. Many of the non-engineered structues (homes, roadside businesses, mobile homes, barns, etc.) were severely damaged or totally destroyed. Also, much of the damage immediately along the coast and bay area resulted from storm surge as well as the wind.

6. CONCLUSIONS

It has been shown that, through aircraft, satellite and radar monitoring, an accurate life-history of a hurricane such as Alicia can be obtained. However, Alicia-produced damage, as revealed by detailed, aerial and ground surveys, has provided added insight into the hurricane's effects and structure during landfall. Conversely, the knowledge gained of Alicia's effects and structure can now be used to make improvements in building design and construction that will reduce the damage potential of future hurricanes.

Generally, Alicia was found to be a hurricane of moderate size and intensity. The hurricane was similar to others in its overall windflow pattern, type and intensity of damage, and the storm-relative distribution and intensity of its tornadoes. It was different in that it had an unusual origination, exhibited a "double eye", was slow to weaken after landfall, and produced an incredible amount of damage that was widespread over a major metropolitan area.

In closing, the life-history of Alicia, as compared to other hurricanes, has demonstrated that each hurricane is unique. For this reason it is important that future, landfalling hurricanes be closely studied to gain an increased understanding of their meteorological, engineering, ecological and sociological impact.

Acknowledgment

The research presented in this paper was supported by NOAA/NHEML under contract NA80RA-C-00081, by NOAA/NESDIS under grant NA80AAD00001, and by NASA under grant NGR14-001-008.

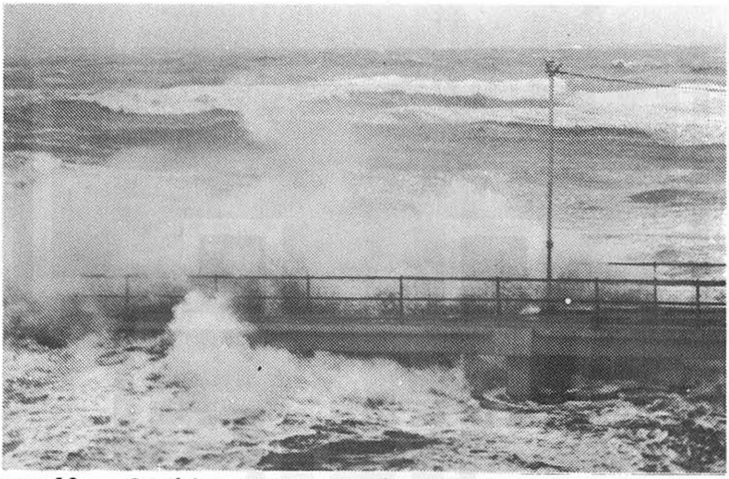


Figure 10. Crashing waves over the fishing pier of the Flagship Hotel taken at 1245 CST on August 17th.

Figure 11. Strong gales blowing water over a fishing pier just north of the Flagship Hotel. Photo taken at 1830 CST, August 17th.

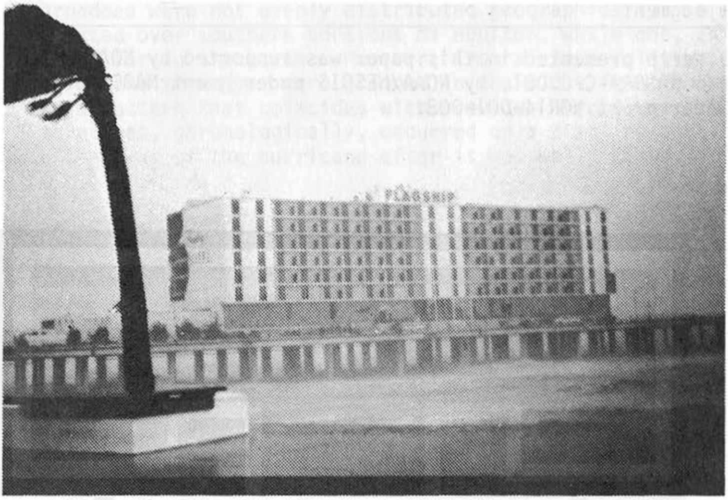


Figure 12. The Flagship Hotel at 0630 CST on August 18th after a nightlong battle with Alicia resulted in part of its exterior wall being blown off.

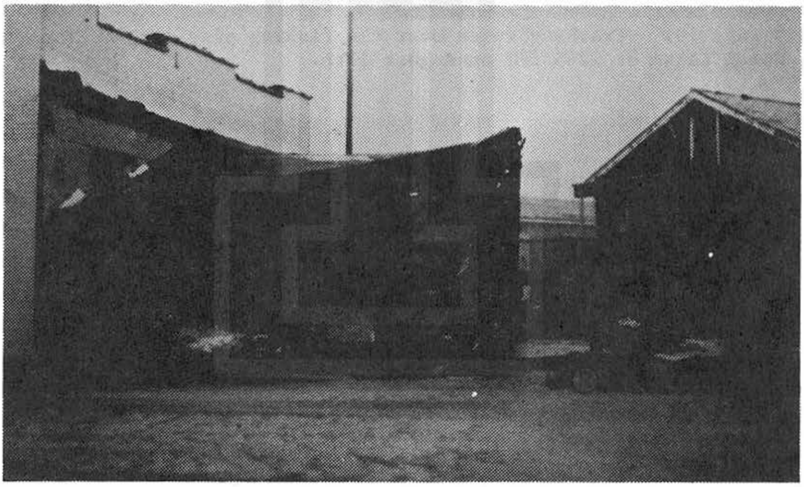


Figure 13. A man attempts to walk in intense wind and rain past a damaged building along Seawall Boulevard, immediately paralleling the shore. Time: 0700 CST, August 18th.

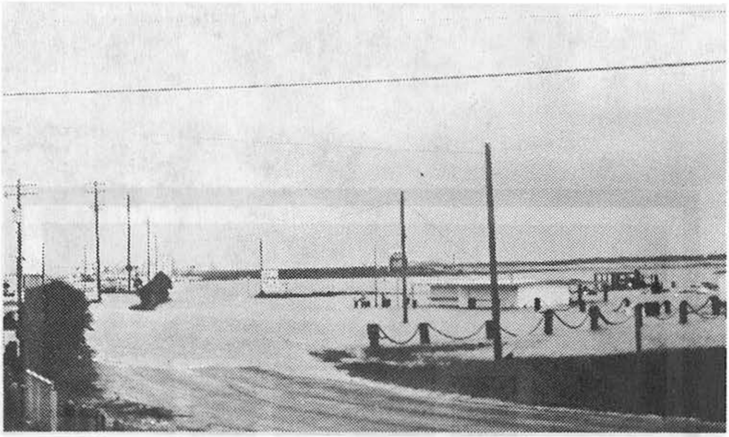


Figure 14. A bait and tackle shop engulfed in tidal flooding before the storm at 1100 CST on August 17th. The shop was completely washed away by the following morning.

Figure 15. A trailer park, built on the beach below a protective seawall, was totally demolished by the storm surge. Time: 0725 CST, August 18th.

Figure 16. Trailer damage near Jamaica Beach.

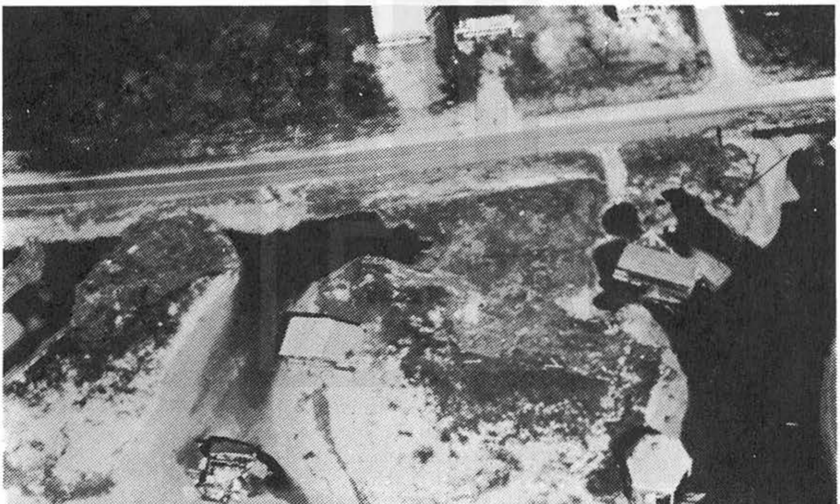


Figure 17. Beach erosion east of Surfside caused by the storm surge. ---Both photos above courtesy of Joseph Golden, NOAA/ERL.

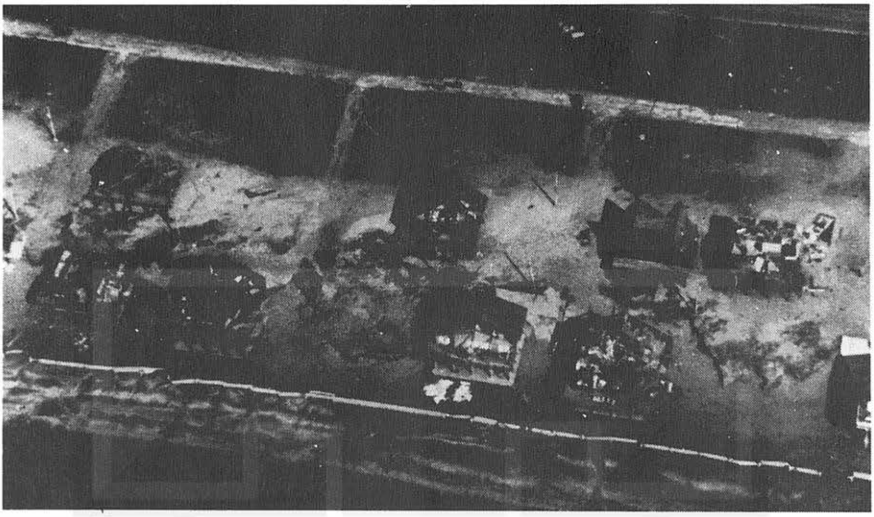


Figure 18. Beachfront homes at Sea Isle, many with roofs blown off and walls collapsed. Although most beach homes on Galveston Island were protected against the storm surge by having been built on stilts, many still succumbed to Alicia's winds.

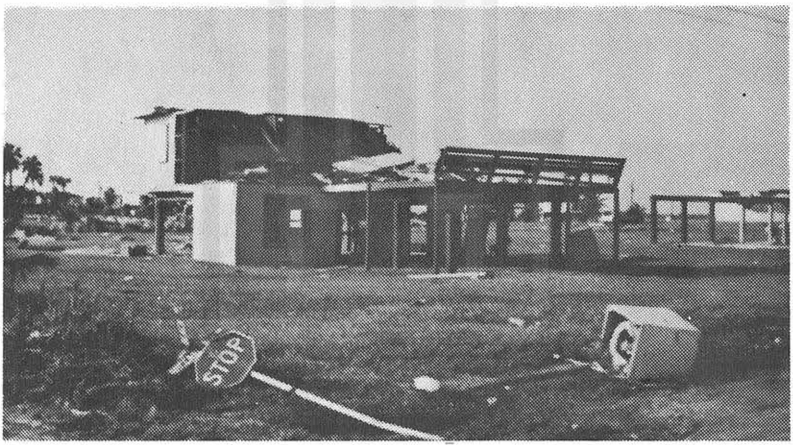


Figure 19. A wind-destroyed home at Jamaica Beach, about 11 miles southwest of Galveston.

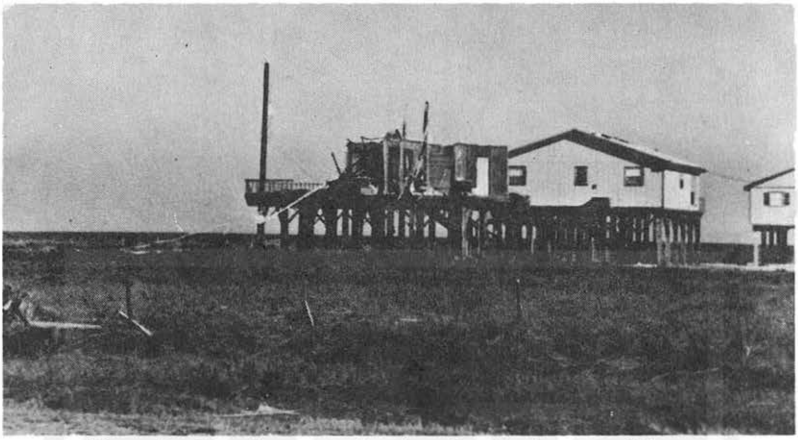


Figure 20. Another home at Jamaica Beach that was blown apart, while an adjacent home of the same design and construction appears untouched.

Figure 21. A beachfront home at Pirates' Beach, about 8 miles southwest of Galveston.

Figure 22. Storm surge erosion of a roadway on the inland side of Seawall Boulevard in Galveston.

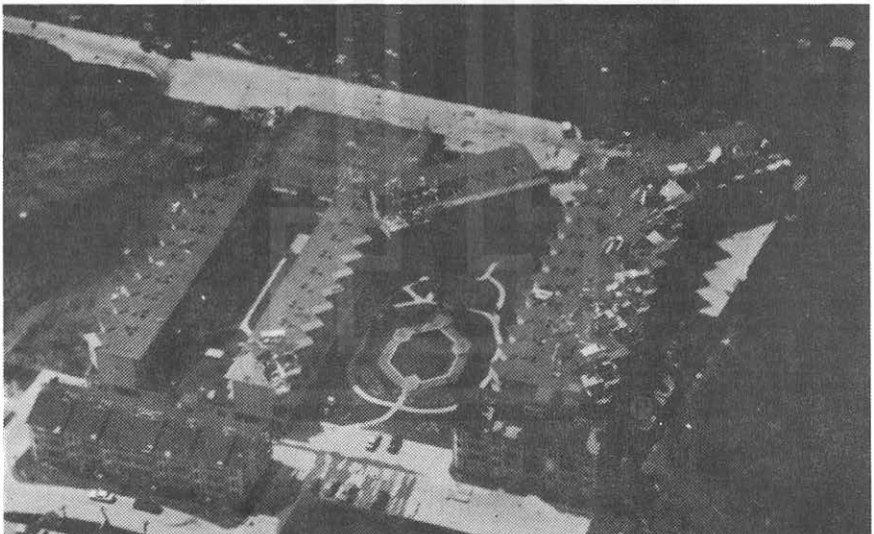
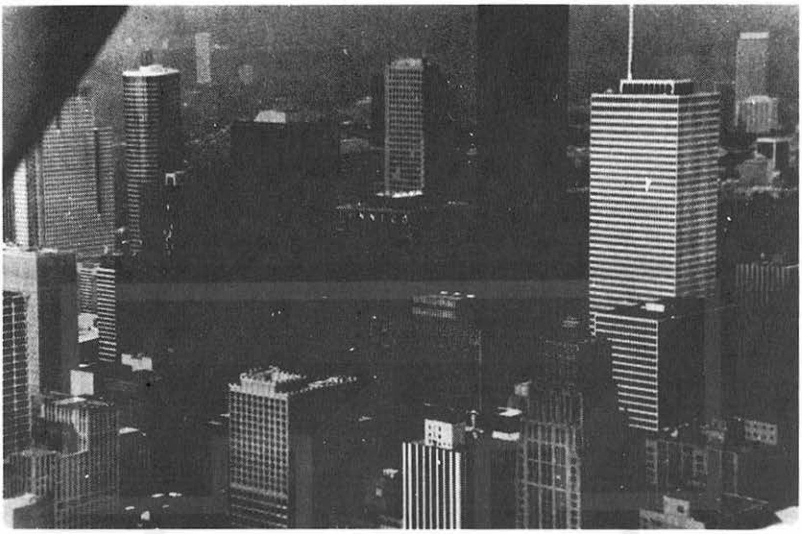
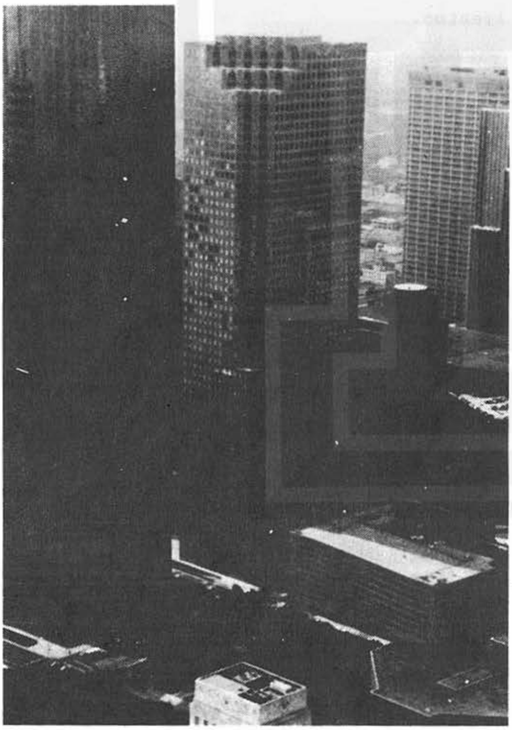


Figure 23. Roofing torn by the wind from a hotel in Galveston.





Figures 24 & 25. The sky-scrapers of downtown Houston with numerous windows boarded up. It is likely that the majority of the broken panes were caused by the impact of flying debris.

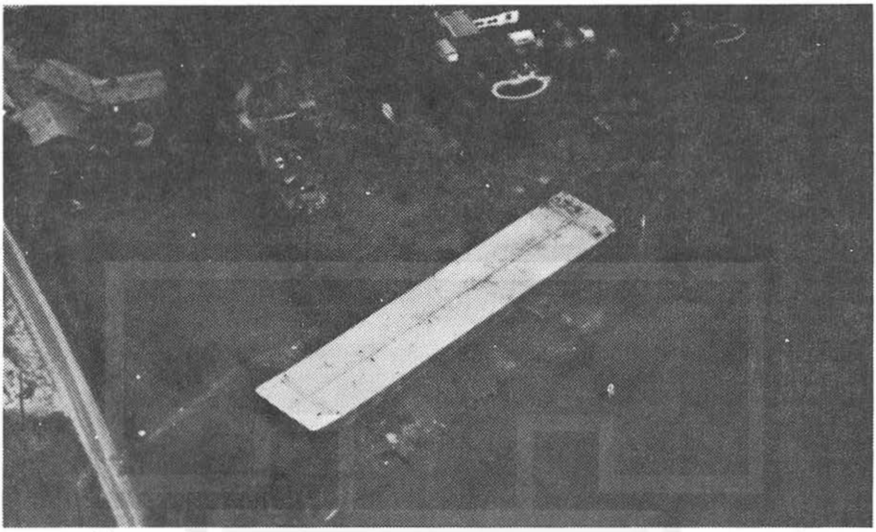


Figure 26. A barge washed ashore by the storm surge near Channelview, 15 miles east of Houston, was found to be occupying someone's back yard.

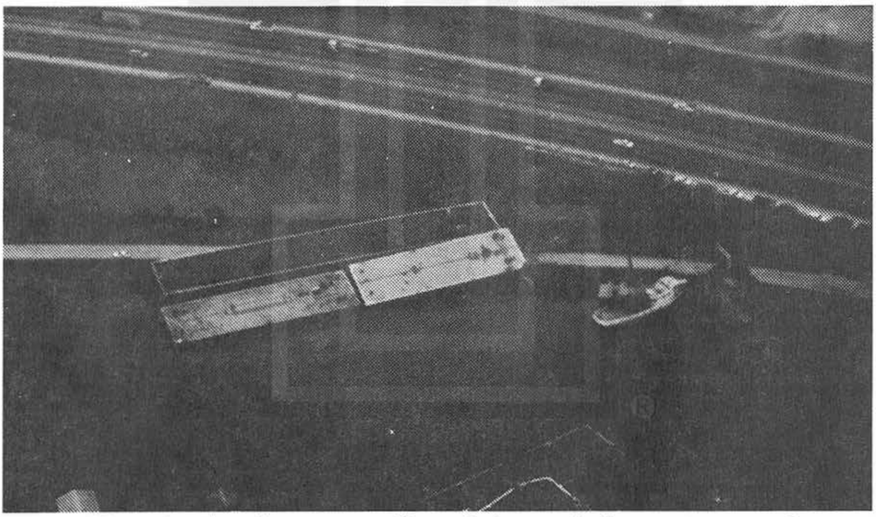


Figure 27. Another barge near Channelview washed up onto a road paralleling Interstate 10.

---All photos in Figures 18 through 27 by Duane J. Stiegler, University of Chicago.