

TORNADOES ASSOCIATED WITH HURRICANE BEULAH ON SEPTEMBER 19-23, 1967

ROBERT ORTON

ESSA State Climatologist for Texas, Austin, Tex.

ABSTRACT

One hundred fifteen tornadoes are known to have occurred in association with hurricane Beulah. The total was far greater than the number reported with any previous North Atlantic tropical cyclone in history. The spatial distribution of the tornadoes with reference to the hurricane center was examined, and it is shown that the best relationships on location of the hurricane-tornado within the parent cyclone are obtained with respect to true azimuth and are superior to those obtained using an orientation from a heading along the tropical cyclone track. With few exceptions, the tornadoes associated with hurricane Beulah occurred outside the area of known hurricane-force winds. The period of the day, the orientation of the Texas coastline in relation to the hurricane's path, and the length of time Beulah lingered near the coast may have contributed to the record number of occurrences of hurricane-tornadoes.

1. INTRODUCTION

This paper discusses the distribution of tornadoes associated with hurricane Beulah. Interest in such an analysis was intensified by the realization that the number of tornadoes accompanying this particular hurricane was considerably greater than the number reported with any previous North Atlantic tropical cyclone in history. Tannehill (1956) noted that there were few authentic records of tornadoes or violent local storms of tornadic nature occurring within a hurricane. Tornadoes were reported as occurring at Charleston, S.C., in 1811 and 1814. Malkin and Galway (1953) presented data showing only 24 reported tornadoes over a 141-yr period ending in 1962. *Technical Paper No. 20* (Wolford 1960) lists 84 tornado occurrences with hurricanes from 1916 to 1957. A tabulation by Smith (1965) shows that a total of 98 hurricane-tornadoes were produced during the period from hurricane Connie in August 1955 to hurricane Carla in September 1961. Of the hurricanes producing tornadoes during this period, the average number of tornadoes per hurricane is nine. Hurricanes Audrey in 1957 and Carla in 1961 spawned 23 and 26 tornadoes, respectively. No new hurricane-tornado occurrences were recorded in 1962 or 1963. Pearson and Sadowski (1965) reported on the occurrence of 39 tornadoes associated with the four hurricanes that struck the United States during 1964. Of the 1964 hurricanes, Isbell on October 12-16 spawned the greatest number of tornadoes—a total of 13. Three tropical cyclones entered the U.S. mainland in 1965 (U.S. Weather Bureau 1965). Of these, hurricane Betsy spawned six tornadoes, while no tornadoes were reported with the other two, which were of less than hurricane intensity. A total of nine tornadoes were reported accompanying hurricane Alma, the only tropical cyclone whose center crossed the U.S. coastline in 1966 (Environmental Science Services Administration 1966). The center of hurricane Inez passed very near the southern Florida coast in 1966;

however, no tornadoes were reported. Thus, prior to 1967, the greatest number of tornadoes reported as occurring in association with North Atlantic tropical cyclones was 26, spawned by hurricane Carla in 1961.

One hundred fifteen tornadoes and one waterspout are known to have occurred in association with hurricane Beulah. All occurrences were in Texas (figs. 1 and 2). There were no tornadoes reported in association with hurricane Doria, which also occurred in 1967 (Environmental Science Services Administration 1967), while a total of 24 tornadoes were reported accompanying tropical cyclones that crossed the U.S. coastline in 1968 (Environmental Science Services Administration 1968). Of the five tropical cyclones that entered the U.S. mainland in 1968, there were no tornadoes reported with either hurricane Brenda or hurricane Dolly; three tornadoes accompanied hurricane Abby; two accompanied hurricane Gladys; and 19 accompanied tropical storm Candy, which crossed the Texas coastline in June 1968. An increasing awareness of severe local storms by the general public and by the news media in the past 15 yr most likely has resulted in an increase in the number of reports of hurricane-tornadoes compared to prior years; nevertheless, the tornado-genic characteristics of hurricane Beulah are rather outstanding.

2. DATA

The actual number of tornado occurrences cannot be ascertained at present. The ESSA State Climatologist, whose duty it is to report the occurrences of these phenomena for publication in *Storm Data*,¹ or any other investigator must accept a “best estimate” of the number of tornado occurrences based on all tornado “reports” available to him, and when possible, on personal investigations at the scene of the storm path and damage characteristics. Most importantly, the investigator must rely on his pro-

¹ Published monthly by the Environmental Science Service Administration, Environmental Data Service, Asheville, N.C.

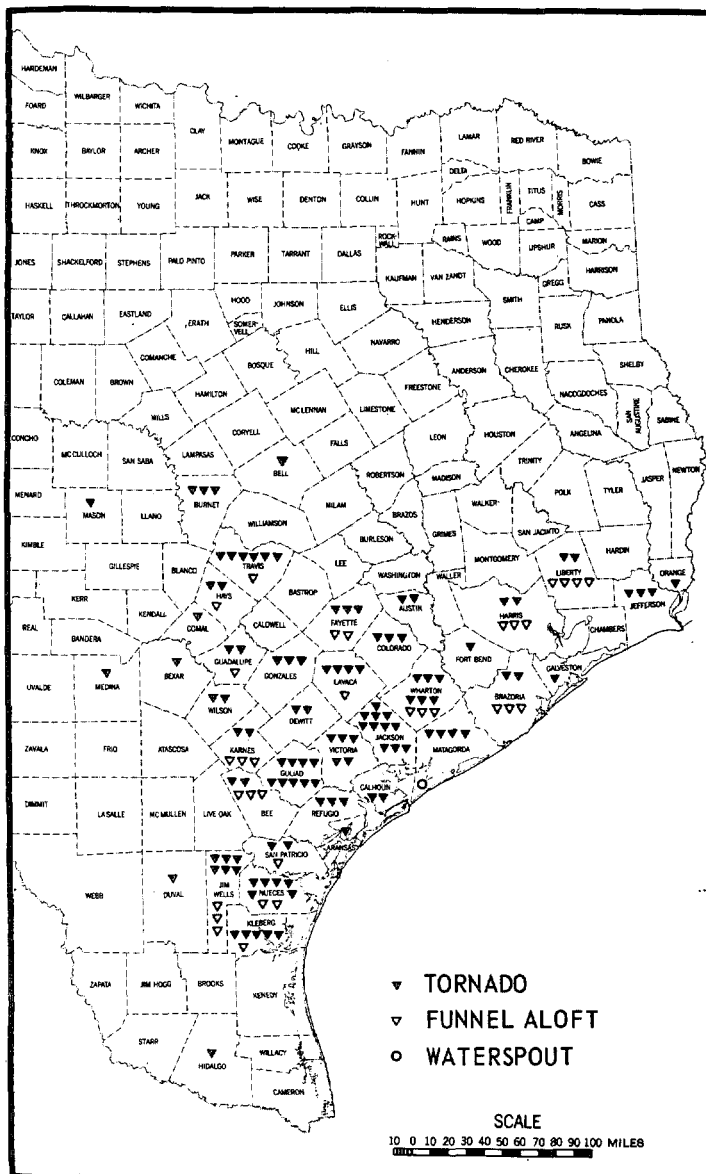


FIGURE 1.—The 115 Texas tornadoes and one waterspout spawned by hurricane Beulah on Sept. 19–23, 1967. The symbols indicate the counties in which the storm occurred rather than exact locations.

fessional judgment in interpreting correctly the evidence at hand. This includes eliminating duplicate reports and rejecting others that do not indicate clearly the storm to be tornadic in character.

The number of tornadoes (115) attributed to hurricane Beulah plus one waterspout were determined from a thorough review of all storm reports collected by ESSA Weather Bureau Offices in the area affected by hurricane Beulah,² by examining 156 *Hurricane Report* questionnaires returned to the ESSA State Climatologist's office at Austin, Tex., by persons in the affected area, and by scanning more than 700 newspaper clippings pertaining to

² Reports transmitted on the ESSA Weather Bureau Rarep and Warning Coordination System teletypewriter circuit.

hurricane Beulah for descriptive evidence of tornado occurrence.

The daily September totals of tornadoes associated with hurricane Beulah are: the 19th, 5; 20th, 67; 21st, 21; 22d, 21; and 23d, 1.

Of these, 79 occurred in the morning and 35 in the afternoon; for one tornado occurrence, the period of the day was not known.

The location of each tornado, the time of occurrence when known, and other pertinent data concerning these storms are on file at the ESSA State Climatologist's office.

3. DISTRIBUTION

According to Hill et al. (1966), the best relationships on location within the parent cyclone are obtained with respect to true azimuth and are superior to those obtained using an orientation from a heading along the tropical cyclone track. The orientation of tornadoes with respect to the center of hurricane Beulah supports such a conclusion remarkably well. Figure 3 shows the orientation of 91 tornadoes with respect to the path of hurricane movement. The frequencies of occurrence within both the left rear and the right rear quadrants are considerably higher than those reported in the earlier studies of 93 hurricane-tornadoes by Smith (1965) and of the 39 tornadoes by Pearson and Sadowski (1965). The explanation lies simply in the unique path taken by Beulah across Texas. Hurricane Beulah curved cyclonically in a "horse-shoe" path after moving inland, resulting in a path that turned toward low latitude and the Mexican Desert. In the previous studies, which included the hurricanes of 1955–1962 and 1964, all hurricanes moved along a path that either continued toward higher latitude or curved anticyclonically toward the coast. The paths of most hurricanes did both. Of the 91 tornadoes plotted in figure 3 (the number whose exact time of occurrence was known), all 44 occurrences from 0000 on the 19th to 1800 CST on the 20th were in the right front quadrant. The direction of hurricane path during this time was between 304° and 339° . During the next 6 hr (1800 on the 20th to 0000 CST on the 21st), Beulah took a more westerly course (286°), and all five tornado occurrences were in the right rear quadrant. For the following 6 hr (0000–0600 CST) with the hurricane moving in a direction of 266° , all three tornado occurrences continued to lie in the right rear quadrant. Between 0600 and 1200 CST on the 21st, Beulah took a south-southwest heading of 210° . In this 6-hr period, only two of the 13 occurrences were in the right rear quadrant while 11 were in the left rear quadrant. All subsequent tornado occurrences, a total of 26, were in the two rear quadrants of the hurricane. During this period of 1200 on the 21st to 1800 CST on the 23d, the direction of hurricane movement was 211° to 240° . The last official position of hurricane Beulah released in the Weather Bureau advisories was $26^\circ 00'$ N. latitude and $100^\circ 00'$ W. longitude at 0600 CST on the 22d. Consequently, the orientation of all 21 tornadoes that oc-

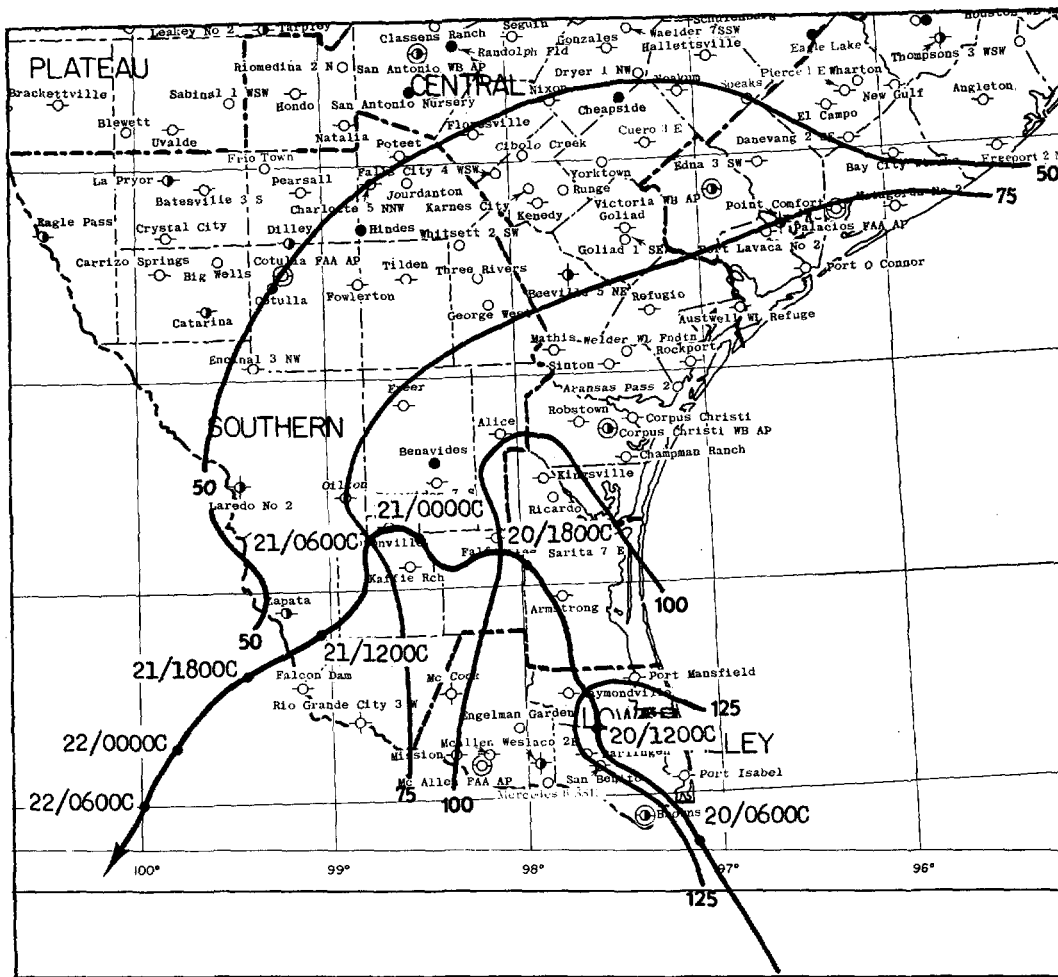


FIGURE 2.—Track of hurricane Beulah over Texas on Sept. 20–21, 1967. Isotachs show distribution of maximum winds (peak gusts) in miles per hour.

curred *after* 0600 CST on the 22d was based on the direction of hurricane path (211°) during the previous 6-hr period from 0000–0600 CST. Since the circulation of hurricane Beulah was disrupted by the mountains near Monterrey, Mexico, the assumption of a 211° heading after 0600 CST on the 22d appears reasonable. Such a heading would route the storm's center within about 6 mi of Monterrey. Tornado data are not available from northern Mexico; consequently, it cannot be stated that there were no tornadoes within the front quadrants of the hurricane after it turned westward. However, it is significant that the unusually large outbreak of tornadoes along the Texas coastal plain during the earlier part of the storm's history did not continue westward across southern Texas as the hurricane made its horseshoe turn.

When the 91 tornado occurrences were plotted with respect to true azimuth, all but a very few lay within the right front quadrant (fig. 4). This emphasizes the fact that, while the hurricane path took a most significant change in direction away from the coast, tornadoes continued to occur on the Gulf Coast Plain in much the same area as before.

The distribution of tornado frequency as hurricane Beulah moved from the sea to inland areas is shown in figure 5. Smith (1965), in his study of hurricane-tornadoes during the period 1955–1962, noted three frequency peaks of tornado outbreaks: 1) when the hurricane center was 275 mi at sea, 2) near the coastline, and 3) 375 mi inland. In the case of Beulah, there were few tornadoes while the center was offshore; but the number increased significantly when the center moved inland. A secondary peak in tornado frequency occurred when the hurricane center was more than 150 mi inland. The center of hurricane Beulah moved inland near the mouth of the Rio Grande at about 6:00 a.m. CST on the 20th. The hurricane turned northward with the center remaining within 30 n.mi. of the coastline for the next 12 hr. The direction of movement at this period of the storm's history, a slight anticyclonic curvature toward the coastline, was not unlike the paths of the 1955–1962 hurricanes studied by Smith (1965), which may account for the similarity of peak frequencies near the coast. The period of the day (0600–1800 CST), the orientation of the Texas coastline northeast of the storm center, and the length of time hurricane Beulah lingered

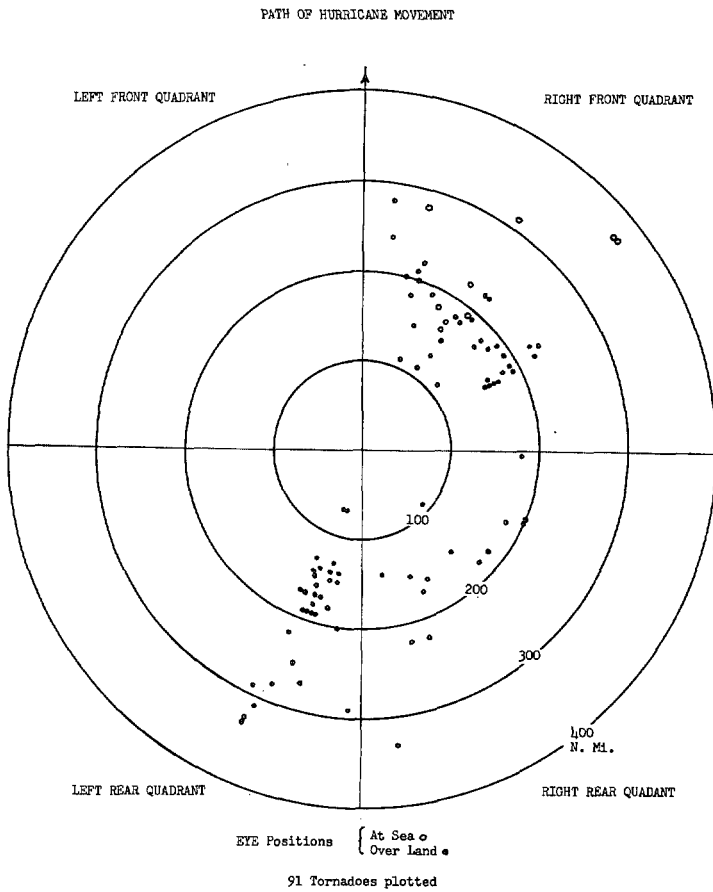


FIGURE 3.—Location of tornadoes with reference to center and direction of hurricane movement.

near the coast may have contributed to the record number of tornado occurrences.

The secondary peak in tornado frequency occurred after the center of hurricane Beulah had reached a position of 26°00' N. latitude and 100°00' W. longitude, about 30 statute miles northeast of Monterrey, Mexico. The storm center arrived at this point at 0600 cstr on the 22d. Since this was the last hurricane position used in determining tornado distances from the storm center, the secondary peak of tornado frequency is described more accurately as occurring beyond 150 n.mi. rather than between 150 and 175 n.mi. When the last few tornadoes occurred, the disorganized storm center may have been around 200 n.mi. distant from the Mexican coast. Here again, the period of the day and geographical features may have contributed to the occurrence of a secondary peak tornado frequency beyond 150 n.mi. Only two tornadoes occurred between 1800 on the 21st and 0600 cstr on the 22d. A total of 19 tornadoes occurred in the following 12-hr "daytime" period 0600–1800 cstr; then, only one tornado occurred in the succeeding "nighttime" period 1800–0600 cstr. This second large outbreak of tornadoes, when the hurricane center was a considerable distance from the coastline, occurred in the Texas Coast Bend area, northeast of Falfurrias and Benavides and south of Refugio. Other

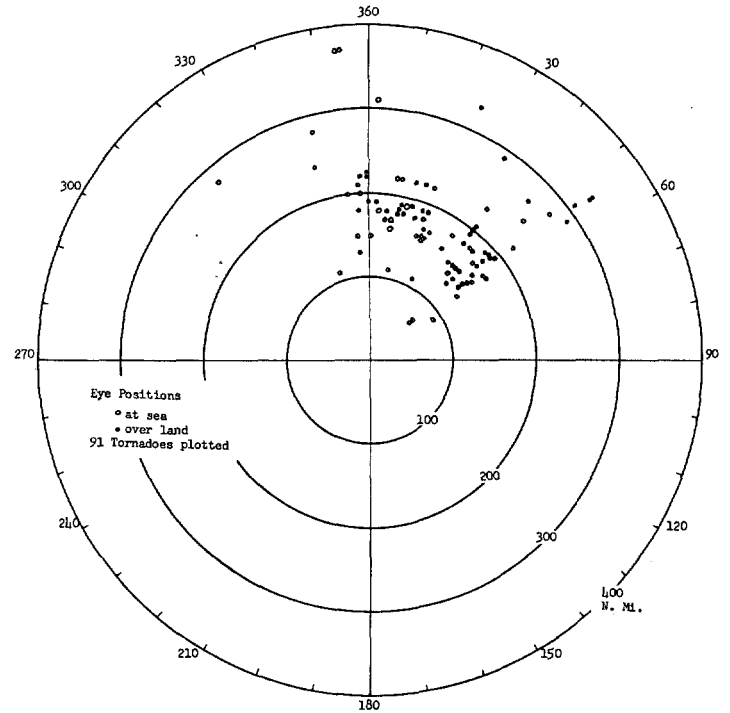


FIGURE 4.—Location of tornadoes with reference to hurricane center and azimuth angle.

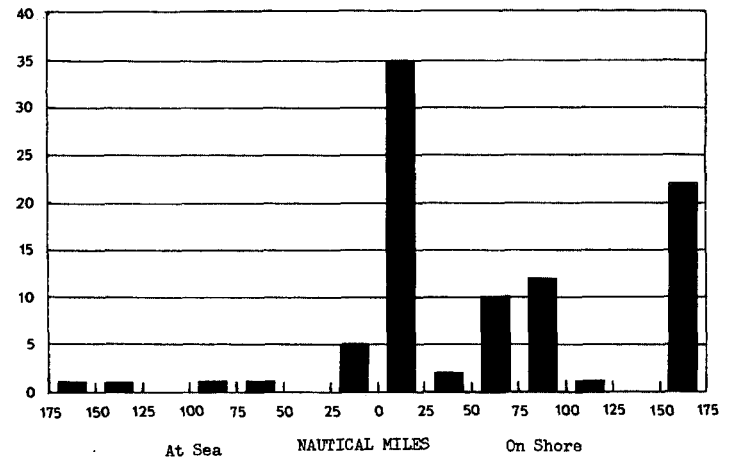


FIGURE 5.—Tornado frequencies (91 occurrences from a total of 115 tornadoes) with respect to the distance of the hurricane center from the coastline (point zero).

tornadoes may have occurred in the sparsely settled ranch country south of Falfurrias and Kingsville; but they either escaped detection or were not reported. However, tornadoes did not occur as far south as the Rio Grande Valley, as they would not have gone unnoticed in this more heavily populated area. It is not known whether or not tornadoes occurred in northern Mexico.

The time of day most favored by hurricane Beulah's tornadoes is shown in figure 6. Of the 91 tornadoes whose exact time of occurrence was known, 73 (80 percent)

occurred between the hours of 0300 and 1500 cst. This is remarkably near the 82 percent frequency of occurrence that Smith (1965) found for the same time interval in his study of the 1955-1962 hurricane-tornadoes. Pearson and Sadowski (1965) noted that the 39 hurricane-tornadoes that occurred in 1964 showed a decided preference for the afternoon hours. (Our conclusion, however, varied

from this.) In 1964, peak frequency occurred between 1500 and 1800 (EST or CST, according to the time zone of location of the associated hurricane). In the case of Beulah, 29 tornadoes are known to have occurred between the hours of 0900 and 1200 cst.

4. TORNADOES AND HURRICANE-FORCE WINDS

With two exceptions, the tornadoes associated with hurricane Beulah occurred outside the area of known hurricane-force winds (74 mi hr⁻¹), as determined from surface measurements. Of the 91 tornadoes whose exact times of occurrence were known, 21 occurred during the period 0600-1200 cst on the 20th. Only one of these, near Kingsville, occurred within the area of hurricane-force winds (fig. 7). At Kingsville during this 6-hr period, the highest sustained wind speed was estimated at 90 mi hr⁻¹ (0900-1000 cst); and the peak gust, also estimated, was 108 mi hr⁻¹ (1000-1100 cst). Most of the tornado occurrences during this particular period were in the vicinity of Palacios and Victoria, Tex., where maximum observed wind speeds were 25 to 30 mi hr⁻¹ and a peak gust of 46 mi hr⁻¹ was recorded. Not illustrated in the figures is the position of the other tornado that occurred near Rockport on the 20th between 1800 and 2359 cst where

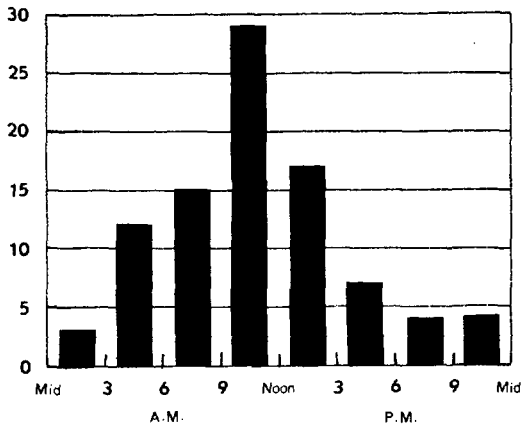


FIGURE 6.—Tornado frequencies (91 occurrences from a total of 115 tornadoes) with reference to time of day (CST).

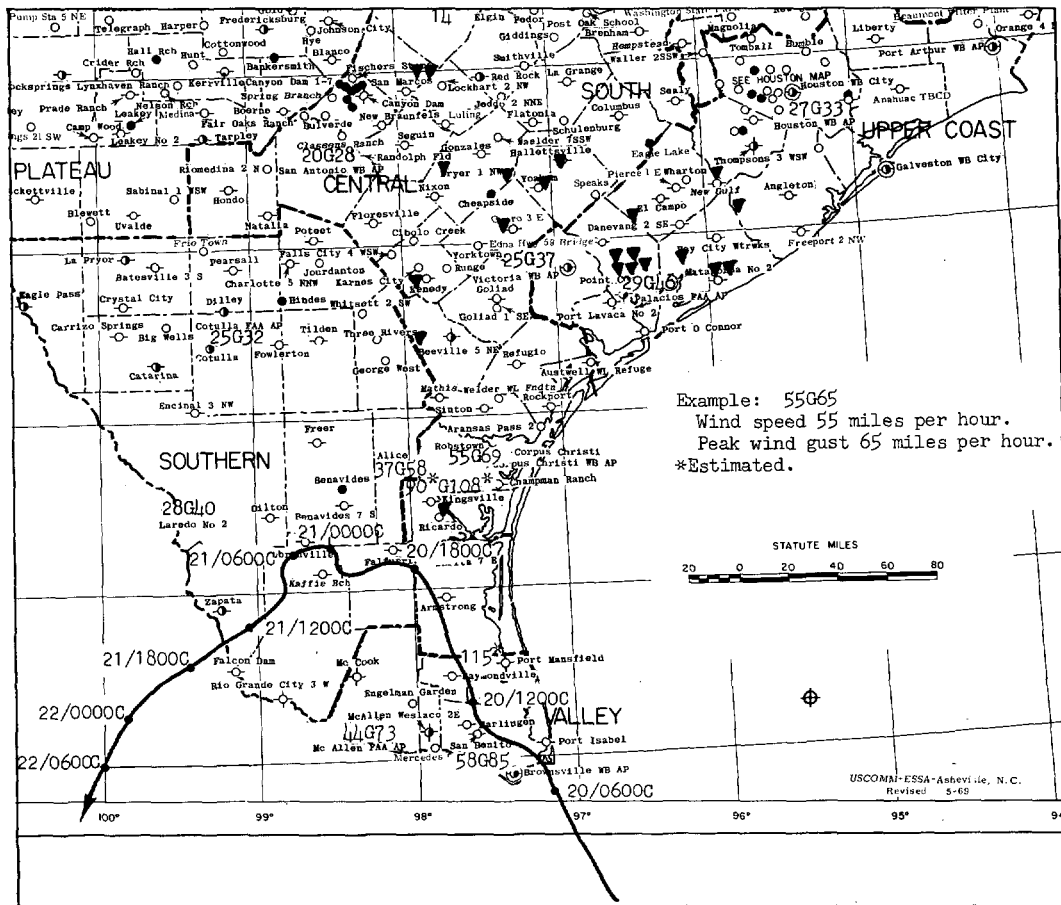


FIGURE 7.—Maximum surface wind speed and tornado occurrences on Sept. 20, 1967, at 0600-1200 cst.

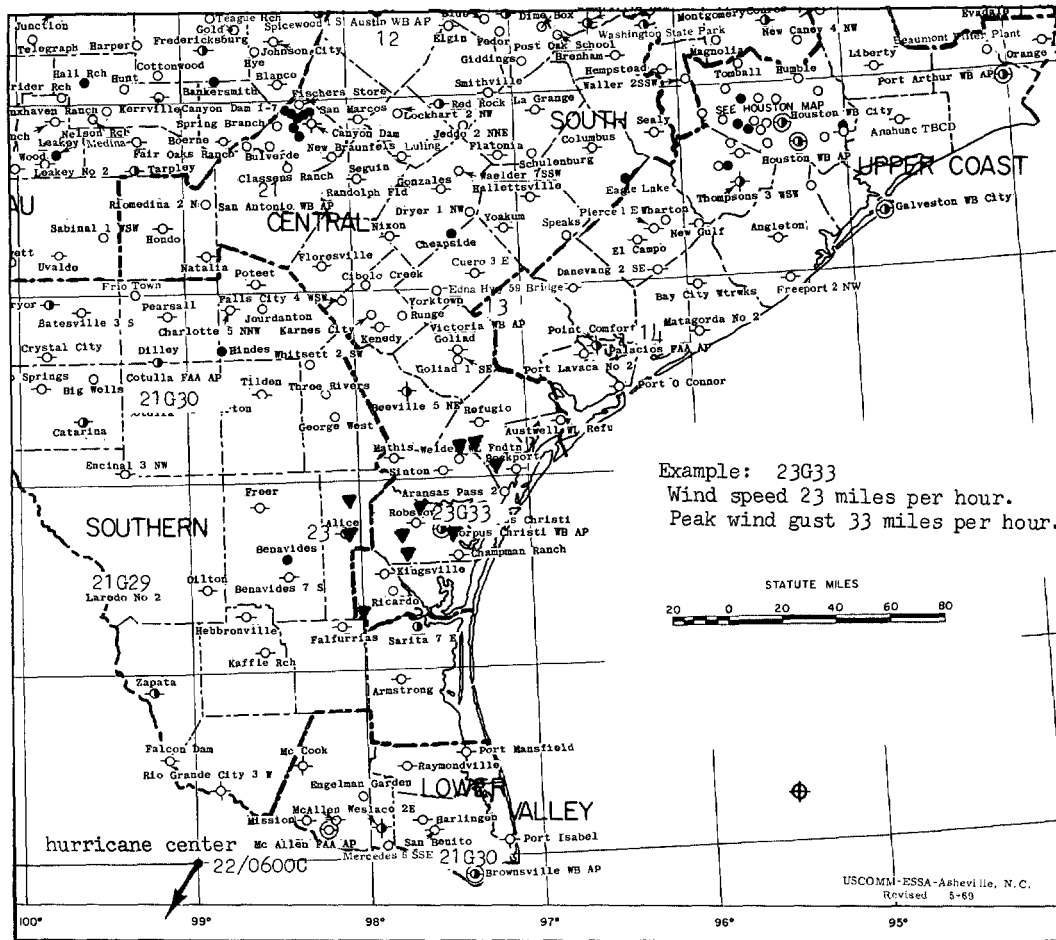


FIGURE 8.—Maximum surface wind speed and tornado occurrences on Sept. 22, 1967, at 0600–1200 cst.

the highest sustained wind speed during the period was estimated at 58 mi hr⁻¹ and a peak gust estimated at 81 mi hr⁻¹ occurred. Thus, only two of the 91 tornadoes considered occurred within the area of hurricane-force surface winds.

Figures 8 and 9 show the maximum measured surface wind speeds in southern Texas during the secondary peak in tornado frequency that occurred between 0600 and 1800 cst on September 22. By 0600 cst on the 22d, the hurricane center had reached a position about 30 statute miles northeast of Monterrey, Mexico.

5. TORNADO CASUALTIES AND DAMAGE

Thirteen persons died, and 37 others were injured as a result of hurricane Beulah. Five of these deaths (38 percent) and 34 of the injuries (92 percent) were caused by tornadoes. Total property damage resulting from tornadoes was estimated at \$1,939,200, approximately 2 percent of the total property damage caused by the hurricane. The greatest destruction occurred at Sweet Home, a community of 360 persons in Lavaca County where four persons were killed, six persons were injured, and property loss was estimated at \$750,000.

6. CONCLUSION

The number of tornadoes (115) that accompanied hurricane Beulah was far greater than the number reported with any previous North Atlantic tropical cyclone in history. Without question, a portion of the increase in hurricane-tornado frequency within the past 15 yr can be attributed to better communications and public interest. The best relationships on location of the hurricane-tornado within the parent cyclone are obtained with respect to true azimuth and are superior to those obtained using an orientation from a heading along the tropical cyclone track. With only two exceptions, the tornadoes associated with hurricane Beulah occurred outside the area of known hurricane-force winds, as determined from surface measurements. The period of the day, the orientation of the Texas coastline in relation to the hurricane's path, and the length of the time Beulah lingered near the coast may have contributed to the record number of occurrences of hurricane-tornadoes.

The total damage to property resulting from tornadoes spawned by hurricane Beulah was small compared to the tremendous loss from all causes; however, the number of casualties inflicted by the hurricane-tornadoes was most significant.

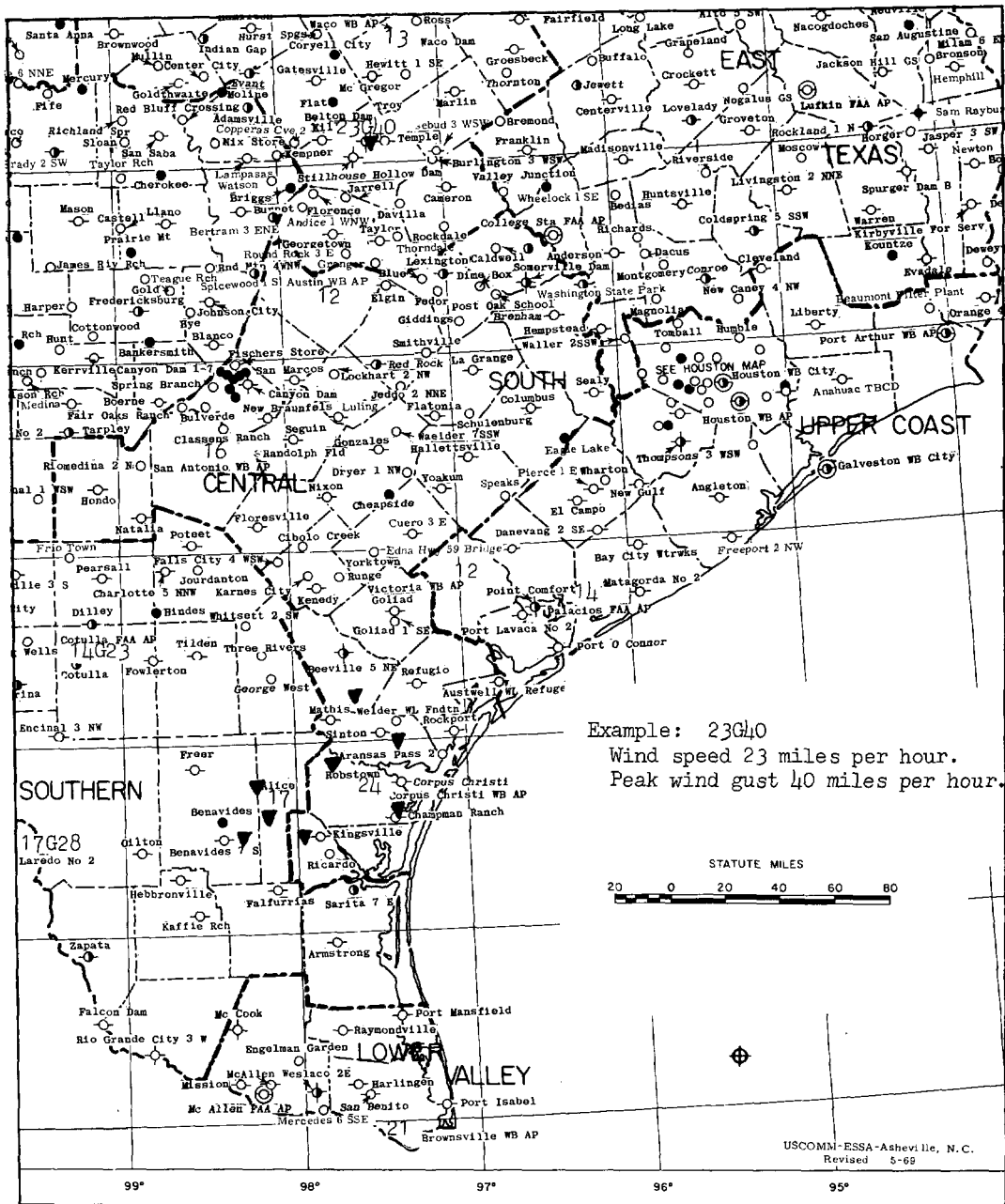


FIGURE 9.—Maximum surface wind speed and tornado occurrences on Sept. 22, 1967, at 1200-1800 CST.

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