

Relationship of central pressure of hurricane Esther (1961) and the sea surface temperature field

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(Manuscript received September 6, 1962)

ABSTRACT

In this report variations of central pressure of hurricane Esther are related to the sea surface temperature patterns along its track. There appears to exist a distinct relationship between central pressure variations, wall cloud intensity, and hurricane intensity to the temperature of the water over which it passes. The storm's central pressure appears to deepen over warm water and fill over cooler water.

Introduction

A relationship has been known to exist between the sea and hurricanes; however, little is known concerning the exact nature of this relationship. Lack of sufficient sea surface temperature (SST) data in the immediate vicinity of hurricanes has prevented microanalyses of the SST field. Such analyses are now possible if available data are used on a composite basis (2-4 weeks).

Fisher (1957) has constructed daily SST charts with limited success. Construction of detailed daily SST charts is difficult without a knowledge of the general sea surface temperature pattern.

Extensive work by Gibson (1962) on SST reveals new concepts of oceanographic analyses. Gibson shows that construction of 10-day composite charts with definable temperature patterns is possible. The author (1962) has shown that the SST pattern in a given area remains remarkably stable over a period of a month, and that annual changes are quite conservative, although absolute temperature values show variations.

The present study, in an attempt to approach the problem in a manner similar to that used by Fisher, utilizes much more detail in the SST field, and reveals that variations of hurricane intensity are apparently directly related to the SST field. One must assume that the

hurricane remains tropical in nature and is not influenced by frontal activity or major extratropical troughs. Consideration of the SST field in the hurricane path, even after recurvature had taken place in the middle latitudes, was possible. Although this paper illustrates a study of only one hurricane (Esther), the SST-hurricane intensity relationship is believed to be real and to apply to many other hurricanes if the above assumptions are made.

Data source and evaluation

Data used for construction of the SST charts shown in Figs. 1 through 3 were obtained from synoptic ship reports for the period 20 August through 15 September 1961. The temperature values are all injection readings. Since injection intakes are located at various depths, some deviations from actual surface temperatures are probably present in the data. A comparison of injection temperatures and bucket temperature readings in a survey conducted in July 1961 shows the former to average 1° to 2°F higher than the latter. Additional errors may result from faulty transmission, coding, or in position reporting. Despite these errors, which constitute about 18 percent of the data, construction of an empirical SST chart containing a high degree of reliability is still possible through detailed analyses.

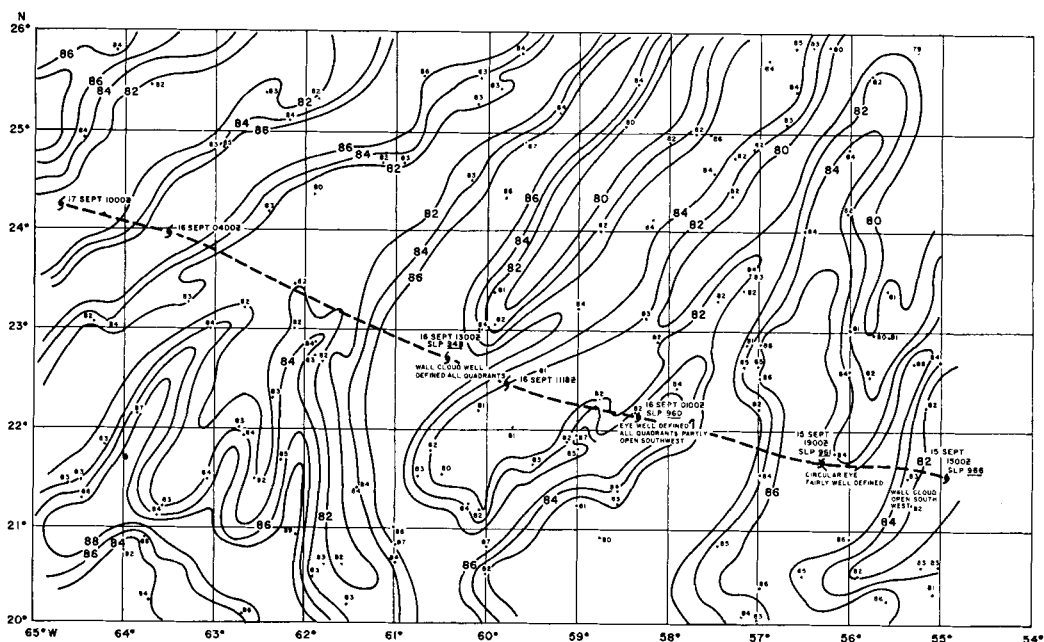


Fig. 1. Sea surface temperature pattern 20 August–15 September 1961.

Much of the data for this study is obtained along major shipping lanes; however, areas of sparse daily reports are covered adequately by combining data for 3-week periods. Use of 3-week composite charts eliminates some errors by virtue of mass coverage.

Oceanography and analyses

Fluctuation of the central pressure of hurricane Esther (9–26 September 1961) and of the SST field along her track was examined in this study. There appears to be no marked changes caused by the SST field in the track of hurricane Esther; however, micro-oscillations along the track may be attributed to variations of central pressure which are related to the SST field.

A 3-week composite chart was used to depict the SST pattern immediately prior to the passage of hurricane Esther. Abundance of data in this chart eliminated much of the subjectivity in the analyses. As mentioned previously, investigation of SST analyses has shown that the SST pattern is remarkably stable despite its complexity, hence, it is feasible to use data accumulated over periods of 3 or more weeks.

Data for the 7-day periods were plotted in different colors in order to determine possible temperature variations between various tongues of water. Since maximum heating of the subtropical ocean takes place by September, little change could be noted in the absolute temperature value of the various water bands during each 7-day period between 20 August and 15 September.

Figs. 1 to 3 show SST patterns constructed from injection temperature data. The large number of warm and cool bands of water is notable. These bands are well defined even in tropical latitudes and appear to be fairly uniform in width. South of 23° N, orientation of the water bands appears to be north-northwest south-southeast. North of 23° N, orientation is more northeast-southwest. Surface temperature gradients of 5° to 7°F differentiated the various water bands even in the tropical latitudes. Temperatures in the warm water ranged from 84° to 88°F; temperatures in the cool water ranged from 78° to 82°F. Immediately north of the Gulf Stream, temperatures of 68° to 72°F were observed in the colder North Atlantic waters.

Relation of the vertical structure of the ocean

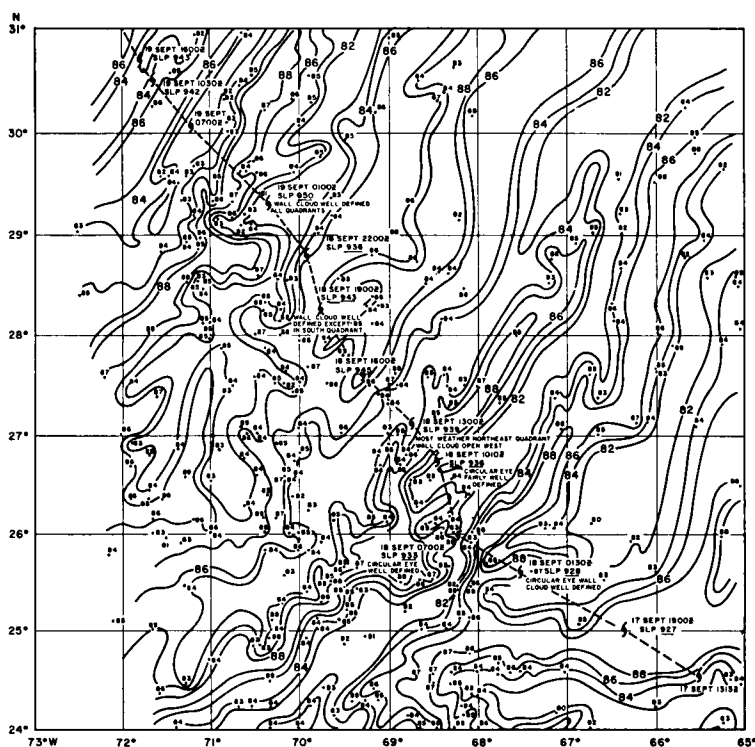


Fig. 2. Sea surface temperature pattern 20 August–15 September 1961.

to the various water bands for this particular time of year is interesting. Numerous bathythermograms indicate that warm water bands are generally isothermal between the surface and depths of 90 to 150 feet. The cooler water bands show temperature decreases of 3° to 8°F in the upper 100-foot layer. This thermal structure indicates the potential energy available in the SST pattern. Hence, as a hurricane passes over the cooler water bands their temperatures drop 2° to 4°F . The warmer bands should experience smaller temperature decreases. Accordingly, the SST curve (Fig. 4) is probably higher than indicated over cool water bands.

Hurricane Esther

Hurricane Esther formed in the eastern Atlantic on 9 September 1961. On 11 September, the satellite Tiros III showed the vortex to be near 15°N , 38°W . The hurricane followed a west-northwest to northwest course until 19 September when recurvature began. This hurricane served as an excellent subject for this

investigation, not only because of its well-defined tropical characteristics, but also because of the vast amount of aerial reconnaissance data obtained. Dropsonde information was utilized to relate the fluctuation of central pressure to the SST field.

Fig. 4, a comparison of SST values and central pressure variations computed from dropsonde data, reveals remarkable agreement between the two curves when hurricane Esther was north of 20°N and west of 50°W . This graph shows an apparent relationship which is, of course, a function of the speed of the hurricane and its track relative to the various water masses. Owing to sparsity of temperature and dropsonde data, comparisons could not be made east and south of this point. Figs. 1 through 3 show the track of hurricane Esther superimposed on the empirical SST pattern just prior to her passage. Note that as the track passed through the various bands of water, the central pressure of the storm responded as follows: (1) the relative change of central pressure is unique in that the storm seems to fill

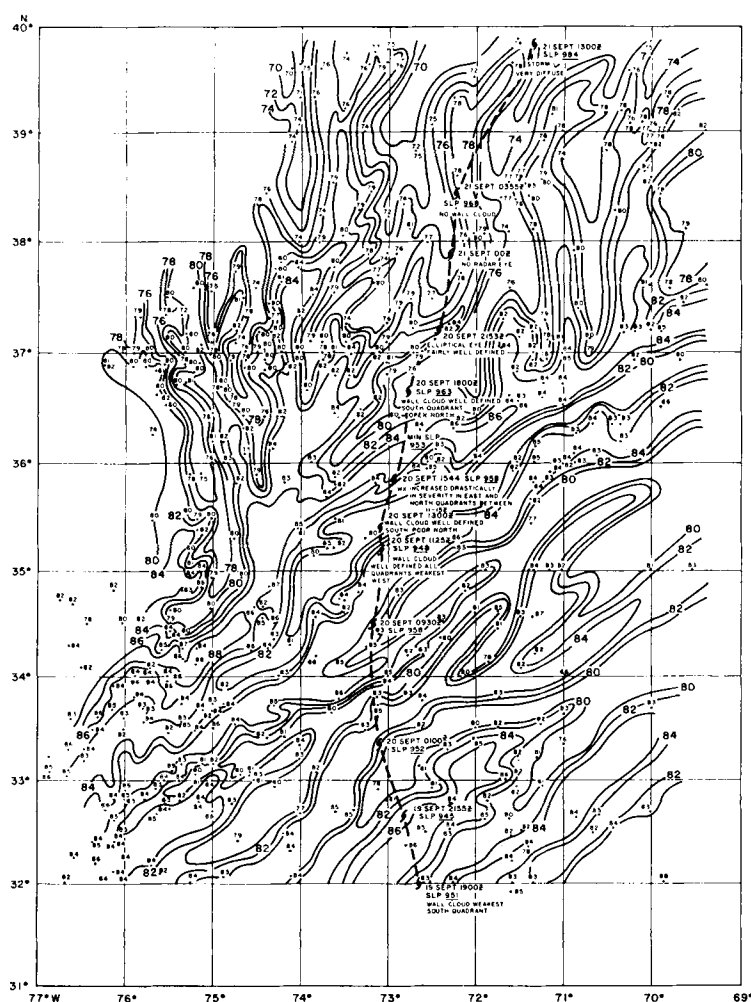


Fig. 3. Sea surface temperature pattern 20 August–15 September 1961.

while over the cooler water, and (2) the central pressure appears to deepen over the warmer water.

The maximum intensity concurred with a rather broad warm band of water averaging 88°F on 17 September as shown in Fig. 2. Also shown are the track of the hurricane from 25° to 32° N and the various bands of water through which it passed.

Relation of the wall cloud intensity to the SST field is also interesting. It appears that the wall cloud of Esther was well defined over the warmer water, but was somewhat weaker over the cooler water. Increase of temperature gradients between the various water bands can

be observed in Fig. 3. Large fluctuations of central pressure correspond directly to increased temperature gradients. Sudden changes of central pressure are apparently related to changes of sea surface temperature. Strong and weak quadrants of the wall cloud showed a remarkable relationship to the warm and cool water bands.

On 20 September, between 1100Z and 1500Z, reconnaissance aircraft observed that the severity of Esther increased drastically in the north semicircle when the hurricane passed into the Gulf Stream where the sea surface temperature increased from 80° to 86°F. At this time the south semicircle of the storm was relatively

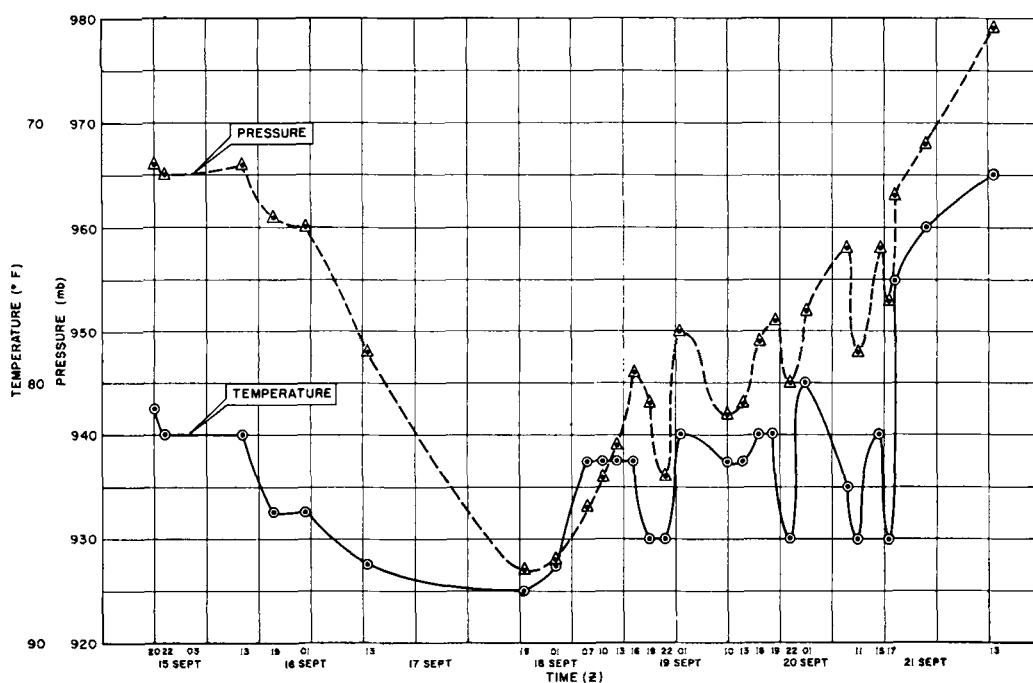


Fig. 4. Central pressure versus temperature.

weak over 80°F water. The central pressure correspondingly dropped 5 mb (958 to 953 mb). At 1845Z the eye of Esther was over cooler water (76°F) north of the Gulf Stream while the south semicircle was positioned over the Gulf Stream. At this time aircraft reconnaissance indicated that the wall cloud was well defined in the south semicircle and open in the north semicircle. The central pressure filled from 953 mb to 963 mb. This rapid intensification and filling occurred within a few hours, reflecting the rapid changes of hurricane structure with respect to changes in the surface environment. As hurricane Esther moved northward over cooler water, filling continued. At 1300Z on 21 September the central pressure was 978 mb, while the sea surface temperature had decreased to 72°F. The curves (Fig. 4) clearly illustrate rapid increases of central pressure with rapid decreases of sea surface temperature. It was impossible to correlate central pressures to sea surface temperatures while Esther performed a loop off the mid-Atlantic coast.

A correlation coefficient of 0.7 was calculated

from the curves in Fig. 4 for the ΔP and the ΔT relationship at the time of each dropsonde. This coefficient would have been higher had the mixing effect of the cooler water bands been taken into account. However, data (SST) are not necessary in the immediate vicinity of the hurricane to permit a study of the pressure-SST field, if a detailed SST analysis of the environment just prior to the hurricane's passage is available.

Conclusions

The major portion of this study stresses the relationship between central pressure and SST values. This relationship also holds after recurvature, if the assumptions in this study are considered.

Fig. 4 clearly illustrates spontaneous response of hurricane central pressure to the SST field. Intensity of the wall cloud also shows an apparent relationship of its structure to the SST field. When the entire area of the wall cloud is over warm water (greater than 82°F), all quadrants of the storm appear to be well

defined. When one or more quadrants lie over cooler water (less than 82°F), intensity of the wall cloud apparently decreases. This continual fluctuation of central pressure plus variations in the hurricane's wall cloud structure may be reasons which contribute to the cycloidal character of many hurricane tracks.

There is no indication that the path of a hurricane coincides with areas of warm water; however, hurricane intensity is apparently directly related to temperature of the water over which it passes.

A major contribution to this microstudy has been the concept of SST analyses developed by Gibson. Although analyses of the composite SST pattern were made as objectively as possible, some subjectivity is involved when data are sparse.

As Fisher indicates, there is a direct relationship between warm water and certain physical properties of the atmosphere above the ocean. As indicated by this study, the sea definitely acts as a source of available energy of both sensible and latent heat.

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