The Annual Variability of Tropical Cyclone Activity in the North Atlantic - Caribbean Sea - Gulf of Mexico Basin

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Abstract

The annual variability of tropical cyclone activity in the north Atlantic - Caribbean Sea - Gulf of Mexico basin is quite large. Ten hurricanes formed here in 1969, two in 1982, but none in 1914. How does one account for such a variability? Is there an objective method to forecast the status of the next hurricane season?

Certain environmental conditions have long been recognized as necessary for an area of disturbed weather to become a tropical cyclone. These are:

1. Warm sea surface temperature (greater than 27 degree Celsius).
2. The disturbed area must be far enough away from the equator (>5 degree latitude) so that Coriolis force converts inflow into cyclonic spiralling (Lighthill, 1992).
3. An unstable atmosphere (the environmental lapse rate of the lower troposphere must exceed the moist adiabatic lapse rate) (Figure 1).
4. An absence of strong wind shear in the vertical.
5. An area of mass overflow in the upper atmosphere high above the surface disturbance (200 mb high pressure system above the surface disturbance) (Figure 2).

Though these conditions (local) are a common feature of the tropical oceans in each hurricane season (June 1st to November 30th), yet tropical cyclone activity varies from season to season. To explain this variation, researchers have been studying the influences of certain global and regional factors. This discussion evaluates five predictive factors recognized by researchers at Colorado State University as being statistically related to seasonal variations of tropical cyclone activity (Gray, 1993). They are:

1. The Stratospheric Quasi-Biennial Oscillation.
2. The El Nino Southern Oscillation.
3. African rainfall.
4. Surface pressure gradient in certain areas of West Africa
5. Caribbean Basin Sea Level Pressure Anomaly and upper tropospheric (200 mb) Zonal Wind Anomaly.

Introduction

The World Meteorological Organization (WMO) defines a tropical cyclone as a non-frontal cyclone of synoptic scale, developing over tropical or sub-tropical waters and having definite organized surface circulation

A hurricane (HRCN) is a warm-core tropical cyclone in which the maximum average surface wind (one-minute mean) is 118 km/h or greater.

A tropical storm (TS) is a well organized warm-core tropical cyclone in which the maximum average surface wind (one-minute mean) is in the range 63-117 km/h inclusive.

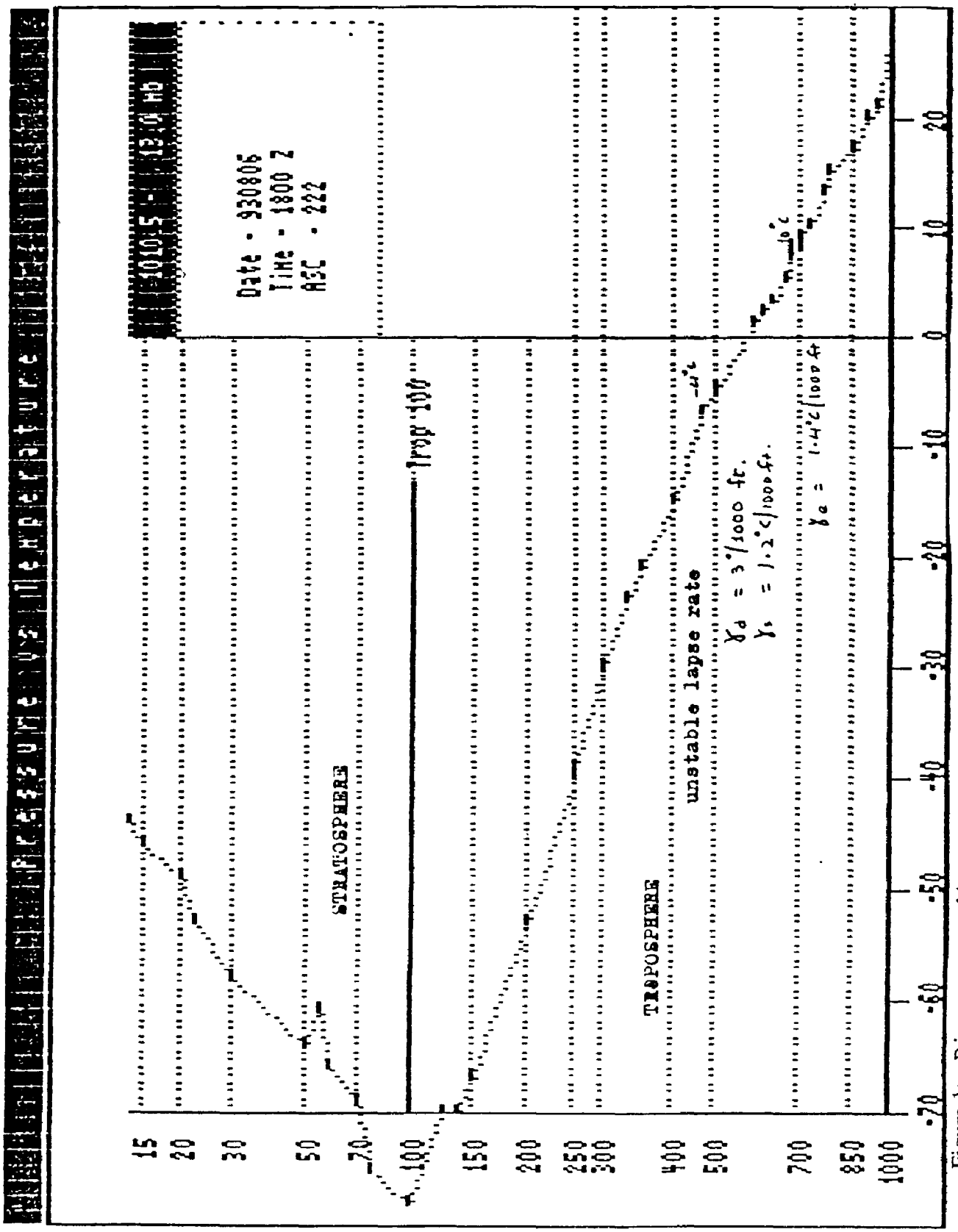

Figure 1: Piarco sounding 6 Aug. 1993 1800 GMT.
(TS Bret Warning in effect for Trinidad and Tobago).

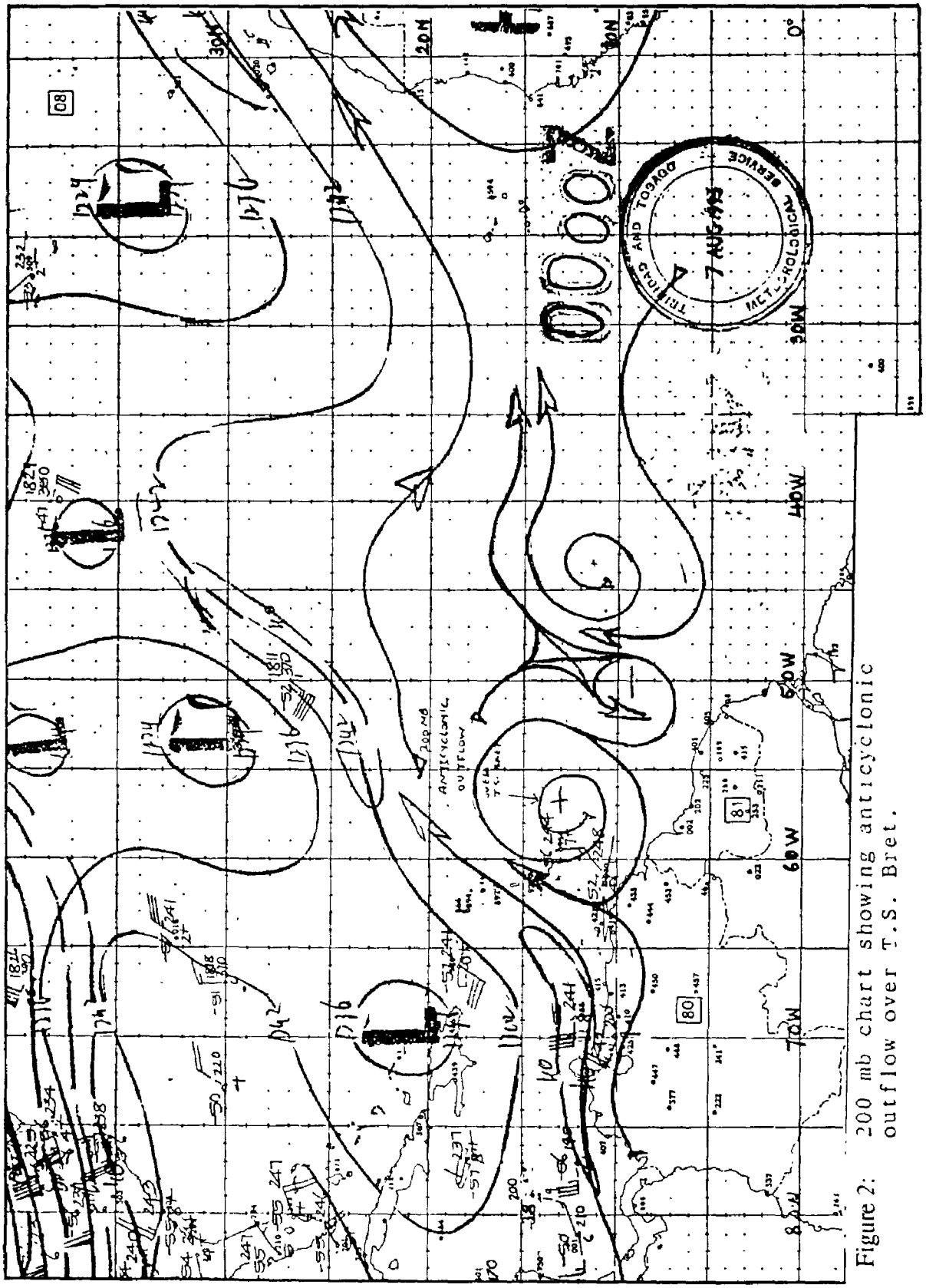

Figure 2: 200 mb chart showing anticyclonic outflow over T.S. Bret.

A tropical depression (TD) is a tropical cyclone in which the maximum average surface wind (one-minute mean) is 62 km/h or less.

Tropical cyclones bring death and destruction to many tropical and sub-tropical regions around the world, including the West Indies. Figure 3 shows the tracks of 1993 tropical cyclones (to date - October 10) in the North Atlantic - Caribbean Sea - Gulf of Mexico Basin. TS Bret's visit on August 7, as well as Figure 4, which shows tropical cyclones passing within 75 nautical miles of Trinidad during the last 100 years, or so (Neumann, 1987), confirms that Trinidad and Tobago must prepare itself against the disasters of destrucive winds, storm surges, massive flooding and landslides that accompany tropical cyclones. Figures 5 and 6 demonstrate the menacing presence of TS Bret approaching Trinidad and Tobago.

On average, 9 tropical cyclones (tropical storms and hurricanes) form per season in the North Atlantic - Carbbean Sea - Gulf of Mexico Basin. In any particular year the number might be greater or smaller depending upon the following factors identified by eminent researcher Prof. William Gray at Colorado State University:

1.The Stratospheric Quasi-Biennial Oscillation.
2. The El Nino Southern Oscillation.
3. African rainfall
4. Surface pressure gradient in certain areas of West Africa
5. Caribean Basin Sea Level Pressure Anomaly and upper tropospheric (200 mb) Zonal Wind Anomaly.

The Stratospheric Quasi-Biennial Oscillation (QBO)

A major reversal of wind direction occurs in the tropical lower stratosphere, easterly winds changing to westerlies, and vice versa (Krishnamurti, 1979). The period of oscillation is quite irregular, varying between 21 and 30 months (Burton, 1991). Figure 7 exhibits this QBO for Piarco, Trinidad, for the period February 1986 to February 1993. Tropical cyclone activity was found to be generally enhanced when the 30 mb winds were westerlies and suppressed when they were easterlies (Burton, 1991). Less vertical wind shear (favouring tropical cyclone formation) results with the westerly phase.

The El Nino Southern Oscillation (ENSO)

El Nino refers to the anomously warm sea surface temperature off the Ecuador-Peru coast. During an El Nino year (which occurs, on average, every 3 to 5 years), tropical cyclone activity in the North Atlantic - Caribbean Sea - Gulf of Mexico Basin is suppressed. Enhancement occurs in non-El Nino years with cold sea surface temperatures. These differences relate to changes of upper tropospheric (200 mb) westerly winds over the North Atlantic. Westerly wind shear (which inhibits tropical cyclone development) increases during El Nino seasons.

El Nino events are intimately connected to a long-term sea level pressure seesaw over the Indo-Pacific Ocean of the Southern Hemisphere (the Southern Oscillation). The phenomenon is thus referred to as the El Nino Southern Oscillation (ENSO).

African Rainfall (AR)

North Atlantic tropical cyclone activity is generally increased during those seasons when the Western Sahel region of West Africa received above average rainfall the previous late summer and fall. Prolonged drought here has been known to correlate with El Nino events and with low tropical cyclone activity.

Surface Pressure Gradient in West Africa

North Atlantic tropical cyclone activity is generally enhanced during those seasons when the pressure gradient across West Africa is such as to permit a moist (rain bearing) southerly airflow over West Africa. This occurs when pressure values over the Niger - east Mali

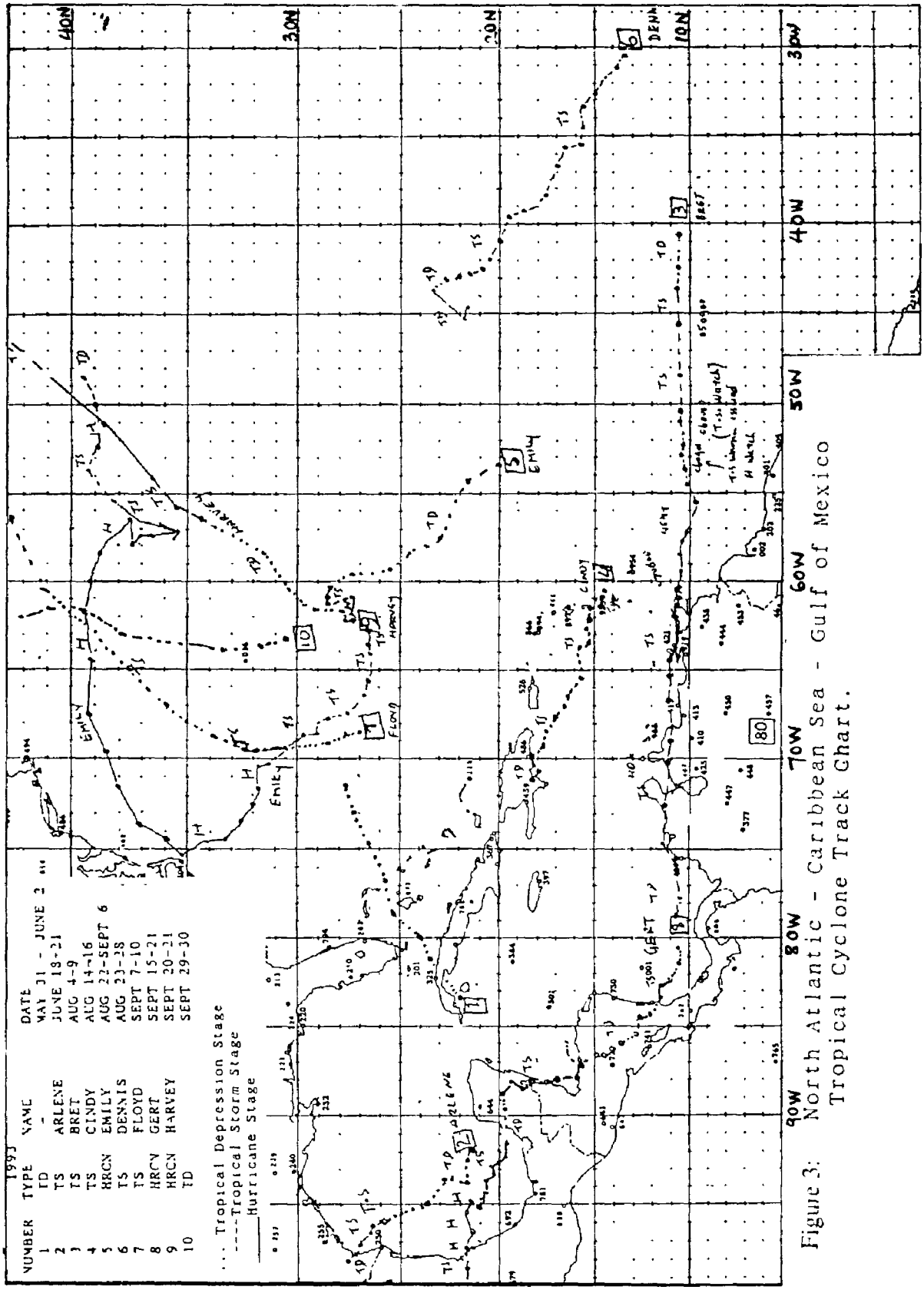

Figure 3: North Atlantic - Caribbean Sea - Gulf of Mexico Tropical Cyclone Track Chart.

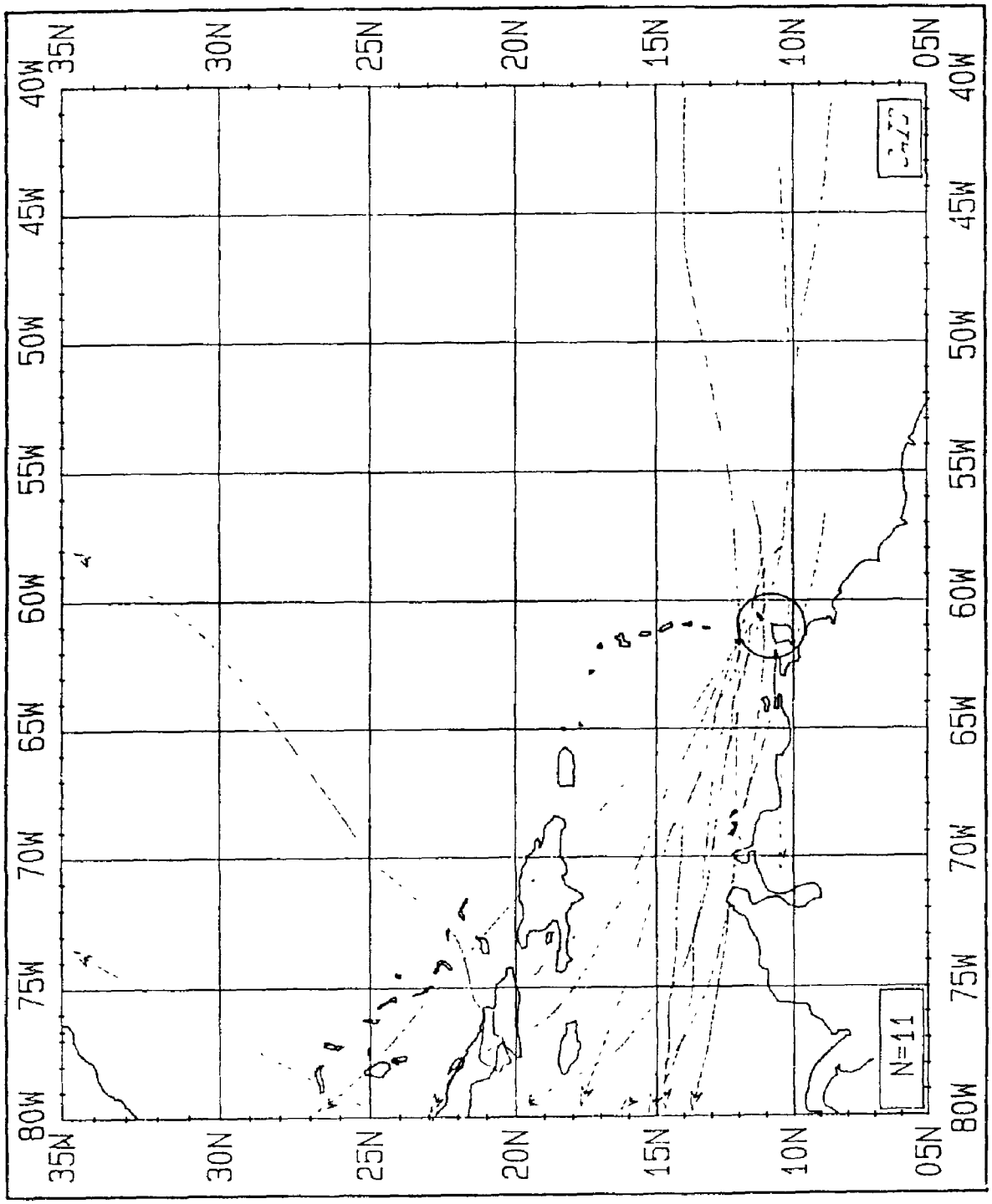

Figure 4: TROPICAL CYCLONES PASSING WITHIN 75 N.MI. OF TRINIDAD, 1886-1987

CHART 2

(SITE LOCATION MOVED TO 10.8N, 61.0W)

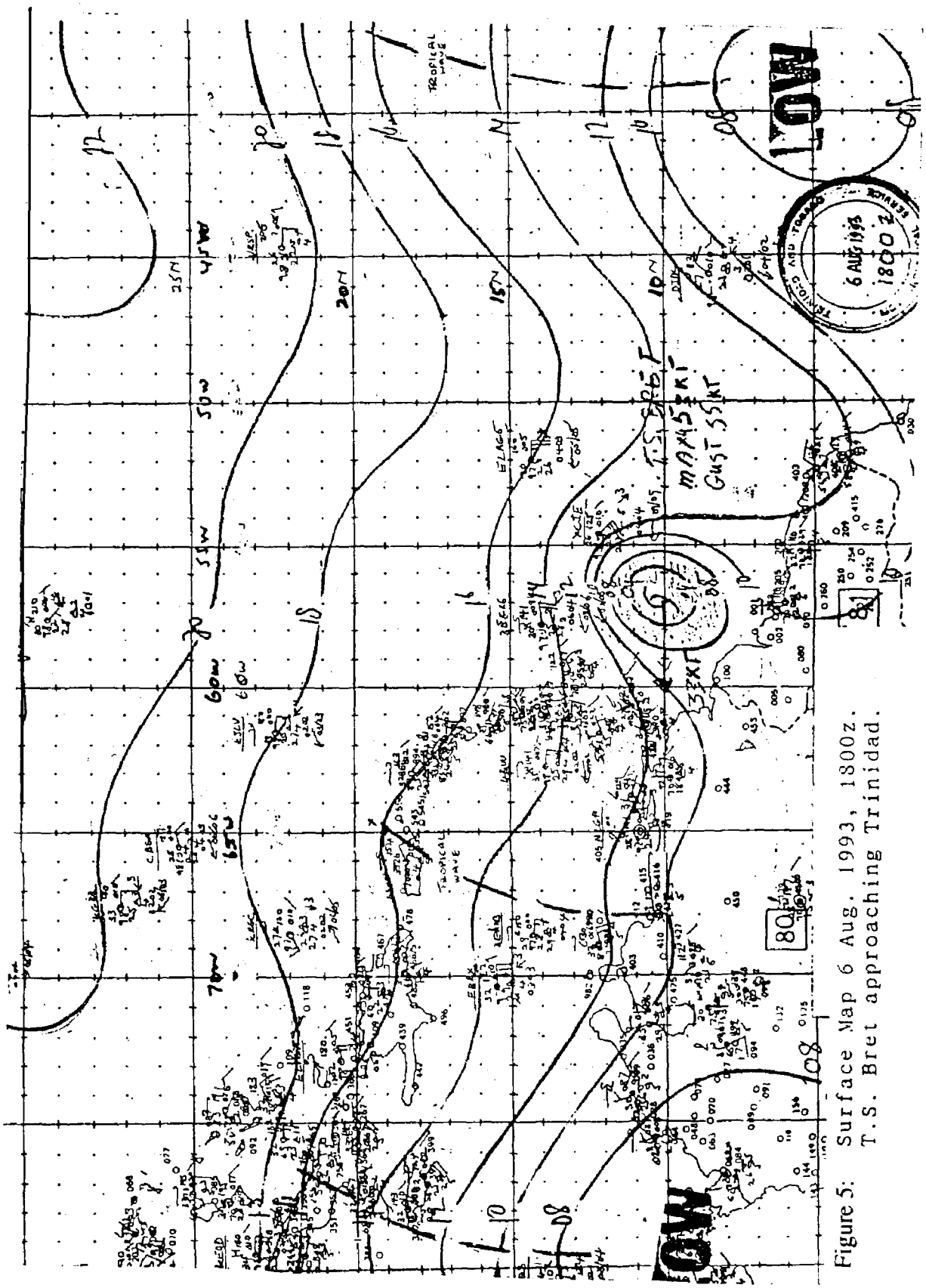

Figure 5: Surface Map 6 Aug. 1993, 1800z.
T.S. Bret approaching Trinidad.