# Atlantic Tropical Systems of 1976

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ABSTRACT

The 1976 hurricane season produced 111 "tropical systems," of which 23 acquired the closed circulation of a depression. Over half of these (68) originated over the African Continent. These are the most African systems observed since our annual summary began in 1968. African seedlings initiated four of the eight named Atlantic storms, and all but one of the fourteen East Pacific storms.

## 1. Introduction

This is the ninth consecutive year a seasonal tropical disturbance summary has been completed. The general philosophy of the counting method was outlined in previous articles by Simpson *et al.* (1968, 1969).

Last year Hebert (1976) speculated the tropics may be returning to normal, and this trend continued this past summer. For example, Lawrence (1977) found that mid-season sea temperatures were near normal over the breeding grounds of Atlantic hurricanes. The vertical shear of the horizontal wind was also generally less over the tropics than observed for the past four years. However, even though several factors pointed toward a normalcy, including the number of named storms, there were some highly anomalous features that produced a very unusual season.

Lawrence (1977) noted the following unique events:

1) This was only the second time this century there were no named storms in the Caribbean or Gulf of Mexico.

2) Emmy and Frances both recurved toward the east at very low latitudes. This was a response to the development of a large baroclinic cyclone north of Emmy that moved eastward and became quasi-stationary over the Azores. The combination of this cyclone with Emmy and Frances produced extremely low negative anomalies in the height pattern over the central Atlantic that persisted from late August to mid-September.

In addition, negative height anomalies off the west coast of California in September and October caused the recurvature of three hurricanes and one tropical storm onto the west coast of Mexico.

Meteorologically, the 1976 hurricane season might properly be designated as the "summer without a September." The onset of an early winter with strong cold fronts sweeping southeastward from the United States and penetrating deep into the tropics in late September and October abruptly ended the threat of a serious U. S. hurricane. Once again there was an absence of a classical September super-hurricane that is typically initiated by an African disturbance over the tropical Atlantic east of the Antilles.

## 2. Census of 1976 tropical systems

The systems observed during the 1976 hurricane season are given in Table 1, and results for several categories are summarized in Table 2 and Fig. 1. Table 1 describes the history of the 111 systems, giving the dates when they passed three key stations: Dakar, Senegal, Barbados and San Andres Island. The table also lists the spawning date of seedlings that formed and weakened along the intertropical convergence zone (ITCZ) in the Atlantic, and the dates of formation of subtropical cyclones or depressions over the Gulf of Mexico and the Atlantic north of latitude 20°N. The Atlantic and Eastern Pacific storms that were initiated by Atlantic seedlings are listed in the last four columns.

Table 2 summarizes the systems according to type and geographical area of formation. The numbers in parentheses indicate systems that were counted in a weaker stage of development. For example, Emmy, Frances and eight depressions that formed in the tropical Atlantic south of latitude 20°N were initiated by African waves. Once again we see that nearly half of the systems were wave perturbations in the trades whose origin was over Africa. This observation has been true every year we have completed the survey, and stresses the importance of Africa as a seed-bed for Atlantic disturbances.

Fig. 1 tabulates the total number of systems passing Dakar, Barbados and San Andres Island as well as the number that maintained their identity while traversing the Atlantic and Caribbean. Statistics are also presented on the seedlings that developed within four geographical areas: the Gulf of Mexico, the Caribbean Sea, and the subtropical and tropical Atlantic, where latitude 20°N

TABLE 1. Summary of the tropical systems of 1976.*

| Dakar passage | Nature | Formed in Atlantic | Date weakened Atlantic | Date Barbados passage | Nature | Weakened Caribbean | Formed Caribbean | San Andres passage | Nature | Formed Gulf of Mexico | Formed North Atlantic | Atlantic depression | Atlantic storm | Pacific depression | Pacific storm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5/1 | | May 5 | ITCZ | 5/6 | | | | | | | | | |
| | | | | | | | 5/6 | May 7 | ITCZ | | | | | | |
| | | 5/3 | | May 8 | ITCZ | | | May 12 | ITCZ | | | | | | |
| | | 5/8 | 5/10 | | | | | | | | | | | | |
| | | 5/9 | | May 15 | Wave | | | May 18 | Wave | | | | | | |
| | | | | | | | | | | 5/21 | | STC A | | | |
| | | 5/12 | | May 18 | Wave | | | May 22 | Wave | | | | | # 1 | |
| | | 5/13 | 5/15 | | | | | | | | | | | | |
| May 15 | Wave | | | May 23 | Wave | 5/23 | | | | | | | | | |
| | | | | | | | 5/25 | May 26 | ITCZ | | | | | | |
| | | 5/21 | | May 25 | Wave | 5/27 | | | | | | | | | |
| May 19 | Wave | | | May 27 | Wave | | | May 30 | Wave | | | | | # 2 | Annette |
| | | 5/27 | | May 30 | Wave | | | June 2 | Wave | | | | | | |
| May 26 | Wave | | | June 2 | Wave | | | June 6 | Wave | | | | | | |
| May 29 | Wave | | | June 4 | Wave | | | June 9 | Wave | | | | | | |
| June 1 | Wave | | 6/3 | | | | | | | | | | | | |
| | | | | | | | | | | | 6/7 | # 2 | | | |
| | | | | | | | | | | 6/11 | | # 3 | | | |
| June 3 | Wave | | | June 10 | Wave | | | June 14 | Wave | | | | | | |
| June 6 | Wave | | | June 12 | Wave | | | June 16 | Wave | | | | | | |
| June 8 | Wave | | | June 14 | Wave | | | June 18 | Wave | | | | | # 3 | Bonny |
| | | 6/12 | 6/15 | | | | | | | | | | | | |
| June 14 | Wave | | | June 22 | Wave | | | June 25 | Wave | | | | | # 4 | |
| June 17 | Wave | | 6/19 | | | | | | | | | | | | |
| | | 6/24 | | June 25 | Wave | | | June 28 | Wave | | | | | | |
| June 21 | Wave | | | June 26 | Wave | 6/27 | | | | | | | | | |
| June 23 | Wave | | | June 28 | Wave | | | July 2 | Wave | | | | | | |
| June 26 | Wave | | | July 1 | Wave | | | July 4 | Wave | | | | | | |
| June 28 | Wave | | | July 4 | Wave | | | July 7 | Wave | | | | | | |
| June 29 | Wave | | | July 5 | Wave | | | July 8 | Wave | | | | | # 5 | Celeste |
| | | | | | | | | | | | 7/6 | # 4 | | | |
| July 2 | Wave | | | July 7 | Wave | | | July 10 | Wave | | | | | | |
| | | 7/7 | | July 8 | Wave | 7/9 | | | | | | | | | |
| July 5 | Wave | | | July 9 | Wave | | | July 12 | Wave | | | | | # 6 | Diane |
| | | 7/8 | | July 11 | Wave | 7/12 | | | | | | | | | |
| July 7 | | | | July 13 | Wave | | | July 16 | Wave | | | | | # 8 | Fernanda |
| | | | | | | | 7/17 | July 18 | ITCZ | | | | | # 7 | Estelle |

* Dep. indicates depression.

TABLE 1 (*continued*)

| Dakar passage | Nature | Formed in Atlantic | Date weakened Atlantic | Date Barbados passage | Nature | Weakened Caribbean | Formed Caribbean | San Andres passage | Nature | Formed Gulf of Mexico | Formed North Atlantic | Atlantic depression | Atlantic storm | Pacific depression | Pacific storm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| July 11 | Wave | | | July 17 | Wave | | | July 21 | Wave | | | | | | |
| | | | | | | | | | | | 7/20 | # 5 | | | |
| July 13 | Wave | | | July 20 | Wave | | | July 23 | Wave | | | | | | |
| | | 7/21 | | July 23 | Wave | | | July 26 | Wave | | | | | | |
| July 17 | Wave | | | July 24 | Wave | | | July 27 | Wave | | | | | #11 | |
| July 20 | Wave | | | July 27 | Wave | | | July 30 | Wave | | | | | # 9 | Gwen |
| | | 7/26 | | July 28 | ITCZ | | | Aug. 1 | ITCZ | | | | | | |
| July 22 | Wave | | | July 29 | Wave | | | Aug. 2 | Wave | | | # 6 | | #10 | Hyacinth |
| July 24 | Wave | | | July 30 | Wave | | | Aug. 3 | Wave | | | | | | |
| | | | | | | | | | | | 7/29 | STC B | Anna | | |
| July 26 | Wave | | | Aug. 2 | Wave | | | Aug. 5 | Wave | | | # 8 | Belle | | |
| July 29 | Wave | | | Aug. 4 | Wave | | | Aug. 8 | Wave | | | | | #12 | |
| July 31 | Wave | | | Aug. 7 | Wave | | | Aug. 11 | Wave | | | | | | |
| Aug. 2 | ITCZ | | 8/3 | | | | | | | | | | | | |
| Aug. 3 | Wave | | | Aug. 9 | Wave | | | Aug. 12 | Wave | | | | | | |
| | | | | | | | 8/14 | Aug. 15 | ITCZ | | | | | | |
| | | 8/12 | | Aug. 13 | Wave | | | Aug. 17 | Wave | | | | | | |
| Aug. 7 | Wave | | | Aug. 14 | Wave | | | Aug. 18 | Wave | | | | | | |
| | | | | | | | | | | | 8/18 | # 9 | Candice | | |
| | | | | | | | | | | 8/18 | | #10 | Dottie | | |
| Aug. 10 | Wave | | | Aug. 16 | Wave | | | Aug. 20 | Wave | | | | | | |
| Aug. 13 | Wave | | | Aug. 19 | Wave | | | Aug. 21 | Wave | | | | | #13 | Iva |
| Aug. 16 | Wave | | | Aug. 23 | Storm | | | Aug. 27 | Wave | | | #11 | Emmy | #14 | Joanne |
| Aug. 18 | Wave | | | Aug. 25 | Wave | | | Aug. 29 | Wave | | | | | | |
| Aug. 20 | Wave | | | Aug. 26 | Wave | | | Aug. 30 | Wave | | | | | | |
| Aug. 22 | Wave | | | Aug. 27 | Wave | 8/28 | | | | | | | | | |
| Aug. 23 | Wave | | | Aug. 29 | Wave | | | Sep. 2 | Wave | | | | | #15 | Kathleen |
| Aug. 25 | Wave | | | Aug. 30 | Storm | 8/31 | | | | | | #12 | Frances | | |
| Aug. 28 | ITCZ | | | Sep. 3 | Wave | | | Sep. 6 | Wave | | | | | | |
| Aug. 30 | Wave | | 8/31 | | | | | | | | | | | | |
| | | | | | | | | | | | 9/4 | #13 | | | |
| | | | | | | | | | | 9/5 | | #14 | | | |
| | | 9/3 | | Sep. 5 | Wave | | | Sep. 9 | Wave | | | | | | |
| Sep. 1 | Wave | | | Sep. 7 | Wave | | | Sep. 10 | Wave | | | | | | |
| | | | | | | | 9/10 | Sep. 13 | ITCZ | | | | | | |
| | | | | | | | | | | 9/13 | | STC C | | | |
| Sep. 4 | Wave | | | Sep. 10 | Wave | | | Sep. 14 | Wave | | | | | | |
| | | 9/5 | 9/8 | | | | | | | | | | | | |

TABLE 1 (*continued*)

| Dakar passage | Nature | Formed in Atlantic | Date weakened Atlantic | Date Barbados passage | Nature | Weakened Caribbean | Formed Caribbean | San Andres passage | Nature | Formed Gulf of Mexico | Formed North Atlantic | Atlantic depression | Atlantic storm | Pacific depression | Pacific storm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep. 8 | Wave | | | Sep. 14 | Wave | | | Sep. 18 | Wave | | | | | | |
| Sep. 10 | ITCZ | | | Sep. 18 | Wave | | | Sep. 21 | Wave | | | | | #16 | Liza |
| | | | | | | | | | | 9/22 | | #17 | | | |
| Sep. 13 | ITCZ | | | Sep. 20 | Wave | | | Sep. 23 | Wave | | | | | | |
| Sep. 15 | Wave | | 9/16 | | | | | | | | | | | | |
| Sep. 16 | Wave | | | Sep. 22 | Wave | | | Sep. 26 | Wave | | | | | #17 | Madeline |
| | | 9/24 | | Sep. 25 | Storm | | | Sep. 29 | Wave | | | #19 | Gloria | | |
| Sep. 19 | Wave | | | Sep. 28 | Wave | | | Oct. 3 | Wave | | | #16 | | | |
| | | 9/22 | 9/25 | | | | | | | | | | | | |
| Sep. 24 | Wave | | | Oct. 1 | Wave | | | Oct. 6 | Wave | | | | | | |
| Sep. 25 | Wave | | 9/28 | | | | | | | | | | | | |
| Sep. 27 | Wave | | | Oct. 5 | Wave | | | Oct. 8 | Wave | | | | | | |
| Sep. 29 | Wave | | | Oct. 7 | Dep. | 9/12 | | | | | | #20 | | | |
| | | | | | | | 10/11 | Oct. 13 | ITCZ | | | | | | |
| Oct. 2 | ITCZ | | | Oct. 10 | Wave | | | Oct. 15 | Wave | | | | | #18 | Naomi |
| Oct. 3 | Wave | | 10/5 | | | | | | | | | | | | |
| Oct. 5 | Wave | | 10/15 | | | | | | | | | #21 | | | |
| Oct. 10 | Wave | | | Oct. 17 | Wave | | | Oct. 22 | Wave | | | | | | |
| | | 10/15 | | Oct. 20 | Wave | | | Oct. 26 | Wave | | | | | | |
| Oct. 13 | Wave | | | Oct. 23 | Storm | 10/24 | | | | | | #22 | Holly | | |
| Oct. 16 | Wave | | | Oct. 27 | Wave | 10/29 | | | | | | | | | |
| Oct. 19 | Wave | | | Oct. 29 | Wave | 10/31 | | | | | | | | | |
| Oct. 21 | Wave | | 10/23 | | | | | | | | | | | | |
| | | | | | | | | | | | 10/31 | #23 | | | |
| | | | | | | | 11/4 | Nov. 5 | Wave | | | | | | |
| Oct. 26 | Wave | | | Nov. 4 | Wave | | | Nov. 9 | Wave | | | | | | |
| Oct. 29 | Wave | | 11/3 | | | | | | | | | | | | |
| | | 11/6 | | Nov. 8 | ITCZ | | | Nov. 12 | ITCZ | | | | | | |
| Nov. 6 | Wave | | | Nov. 12 | Wave | | | Nov. 16 | Wave | | | | | | |
| | | | | | | | 11/18 | Nov. 18 | ITCZ | | | | | | |
| | | 11/13 | | Nov. 17 | Wave | 11/18 | | | | | | | | | |
| Nov. 12 | ITCZ | | | Nov. 21 | ITCZ | | | Nov. 25 | Wave | | | | | | |
| Nov. 16 | Wave | | | Nov. 24 | Wave | 11/25 | | | | | | | | | |
| Nov. 18 | Wave | | 11/19 | | | | | | | | | | | | |
| Nov. 20 | Wave | | 11/23 | | | | | | | | | | | | |
| Nov. 25 | Wave | | 11/30 | | | | | | | | | | | | |

TABLE 2. Summary of 1976 tropical systems according to type and geographical area of formation. The numbers in parentheses indicate systems that were counted in a weaker stage.

| | Africa | Tropical Atlantic | Sub-tropical Atlantic | Caribbean | Gulf of Mexico | Total |
|---|---|---|---|---|---|---|
| Waves | 62 | 13 | 0 | 1 | 0 | 76 |
| ITCZ | 6 | 9 | 0 | 7 | 0 | 22 |
| Depression | 0 | (8) | 7 (1) | 0 | 6 | 13 (9) |
| Named storms | 0 | (2) | (5) | 0 | (1) | (8) |
| Subtropical storms | 0 | 0 | (1) | 0 | (2) | (3) |
| | 68 | 22 (10) | 7 (7) | 8 | 6 (3) | 111 (20) |

has been used as a dividing line. Of the 68 African systems, 55 were tracked to the Caribbean and 45 all the way to the Pacific Ocean. Over the tropical Atlantic, 22 disturbances formed with 17 eventually passing through the Antilles. Another five were identified along the ITCZ and followed for at least 48 h before dissipating. A total of 72 systems crossed the Antilles (55 from Africa plus 17 that formed in the Atlantic) of which 58 maintained their identity while traversing the Caribbean. The eight disturbances that formed over the Caribbean added to the number from the Antilles resulted in 66 seedlings entering Central America.

One unusual aspect of the 1976 season was the early appearance of a well-defined African wave that moved by Dakar on 15 May. The first African system of the season does not generally occur until late May or early June when the easterly subtropical jet becomes established across tropical Africa in the upper troposphere.

The depression tracks for the months May through October are shown in Fig. 2. The first depression of the season developed in May along an old baroclinic zone in the Gulf of Mexico. This system strengthened and was designated a subtropical storm on the 23rd. Lawrence (1977) describes the history of this storm. The last depression of the year formed on an old front northeast of Puerto Rico on 31 October, and persisted 4 days before weakening.

Most of the depressions in 1976 formed along the lower tropospheric baroclinic zones over the subtropical Atlantic, and did not threaten the United States. Only two reached the U. S. coast and neither offered a serious problem. Both formed over the Northern Gulf of Mexico and approached the Gulf states in September.

Apart from the depressions that strengthened into named storms, only one other was noteworthy enough to warrant special comment. The depression that was spawned by an African wave in the central Atlantic on 3 October caused some concern in the Antilles. Fortunately, strengthening never occurred, and the system moved through the Islands with a very weak circulation. The depression turned toward the north in the central Caribbean and weakened over Hispaniola. Heavy rains were reported over parts of Hispaniola, but there were no reports of serious flooding or damage.

Fig. 3 summarizes the source of Eastern Pacific named storms. All but one of the storms were initiated by African disturbances. This is the most Pacific storms initiated by African disturbances since we began keeping records in 1968. African systems certainly controlled hurricane activity in the Eastern Pacific in 1976.

### 3. Comparison with other years

Table 3 compares the tropical systems in 1976 with averages determined over the previous eight years within several categories. The totals in most categories in 1976 were slightly higher than the previous eight-year average but compared very closely with the numbers in 1975.

Frank (1974) introduced a simple parameter that seems to be useful in describing the overall character of the hurricane season. This is computed by forming the

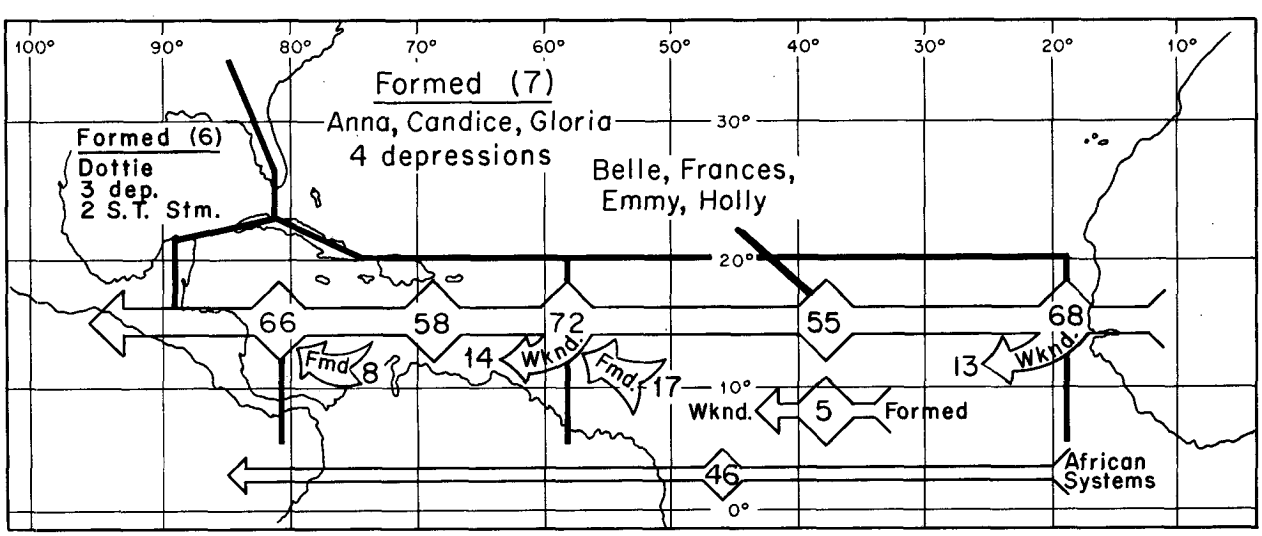


FIG. 1. Summary of tropical disturbances that passed three key stations (Dakar, Barbados, San Andres) in 1976 and those maintaining their identity while crossing the Atlantic and Caribbean.

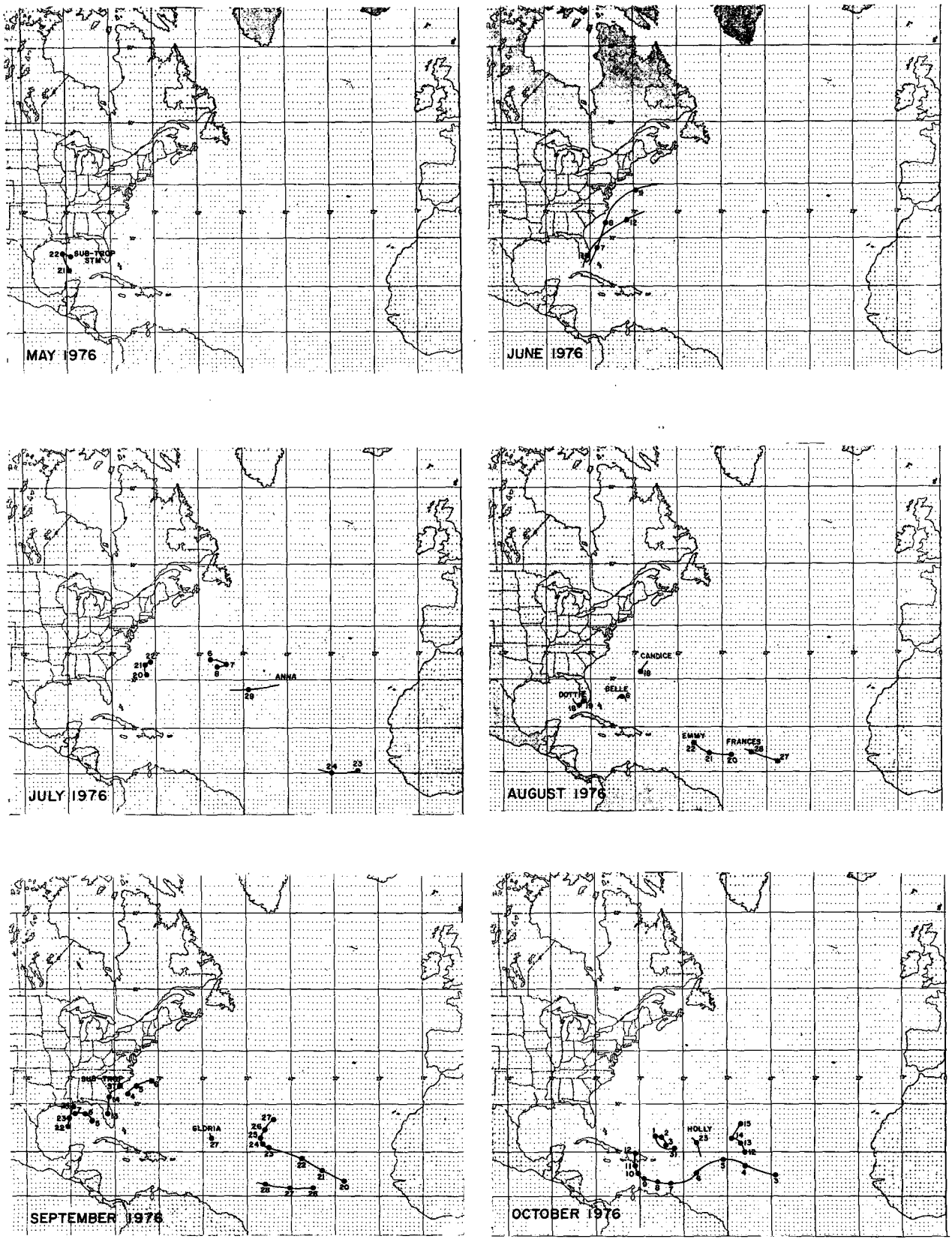


FIG. 2. Tracks of 1976 depressions.

TABLE 3. Results of 1976 compared with the previous eight years.

| | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 8-year average | 1976 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total systems (All types) | 107 | 105 | 85 | 103 | 113 | 95 | 96 | 113 | 102 | 111 |
| Dakar systems | 57 | 58 | 54 | 56 | 57 | 56 | 52 | 61 | 56 | 68 |
| Barbados systems | 59 | 44 | 53 | 56 | 56 | 58 | 58 | 69 | 57 | 72 |
| San Andres systems | 40 | 43 | 45 | 58 | 49 | 54 | 52 | 64 | 51 | 66 |
| Depressions* | 22 | 34 | 26 | 23 | 24 | 24 | 25 | 28 | 26 | 23 |
| Named storms | 7 | 13 | 7 | 12 | 4 | 7 | 7 | 8 | 8 | 8 |
| Subtropical storms | | | | | 4 | 1 | 4 | 2 | | 3 |

* This is the total number of depressions while Table 4 refers to depressions during the hurricane season only (June through November).

ratio of the number of depressions of tropical origin to the total number of depressions. The 1976 value has been added to Fig. 4, and we observed a continuation of the regime that has persisted for the past five years. Low values of this ratio indicate a high number of baroclinic depressions and we have observed this to be associated with anomalous baroclinic conditions over the tropics.

The story of the 1976 hurricane season is well summarized in Table 4, in which we see that over half of the depressions (12) were initiated by baroclinic seedlings. In the table, the 1976 results can be compared with the averages for the past nine years; however, a more meaningful comparison can be made by dividing the past nine years into two periods. The years from 1967 to 1970 were characterized by normal storm activity, while a quiet period has been observed during the period 1971 to 1975. Even though there is little difference in the total number of depressions, there is a very significant difference in the character of the disturbances that initiated the depressions. During the four-year normal period, two-thirds to three-fourths of the depressions were spawned by tropical-type seedlings, and subtropical cyclones were not very common. But during the last five years over half of the depressions were initiated by baroclinic disturbances, and subtropical cyclones/subtropical storms were much more frequent. The character of a hurricane season is directly related to the amount of activity in the subtropical latitudes.

Another perspective of the season is shown in Table 5 which compares the monthly incidents of depressions with the past nine-year averages. From this table one might conclude 1976 was a very normal year because the numbers each month are very close to the longer period averages. However, as we have already seen, the nature of a hurricane season depends upon the character of the depressions and named storms as well as the total numbers.

In the final analysis, one must conclude the 1976 hurricane season was quieter than normal and the lull in both the number and severity of hurricanes, currently being enjoyed by interests in the Atlantic, has now persisted for six years.

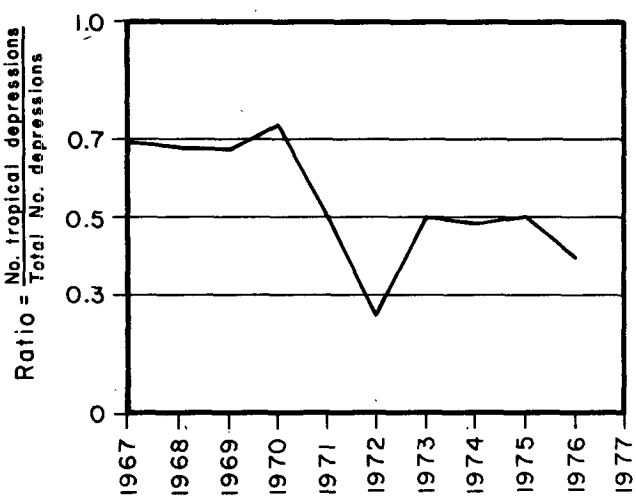


FIG. 3. Summary of the type of seedlings that initiated east Pacific storms in 1976.

TABLE 4. Summary of the type of seedling that initiated Atlantic named storms and depressions during 1976 compared with annual averages from previous years.

| Year | Tropical: African systems | Tropical: Disturbances | Baroclinic: Upper troposphere | Baroclinic: Lower troposphere | Totals |
|---|---|---|---|---|---|
| | Named storms | | | | |
| 1976 | 4 | 0 | 3 | 1 | 8 |
| Average 1967–75 | 4.0 | 2.0 | 1.0 | 1.0 | 8.0 |
| Average 1967–70 | 4.0 | 3.0 | 1.0 | 1.0 | 9.0 |
| Average 1971–75 | 4.0 | 1.0 | 1.0 | 2.0 | 8.0 |
| | Depressions* | | | | |
| 1976 | 10 | 0 | 3 | 9 | 22 |
| Average 1967–75 | 10.0 | 4.0 | 4.0 | 6.0 | 24.0 |
| Average 1967–70 | 13.0 | 5.0 | 3.0 | 4.0 | 25.0 |
| Average 1971–75 | 8.0 | 3.0 | 4.0 | 8.0 | 23.0 |

* Only the depressions that occurred from June through November.

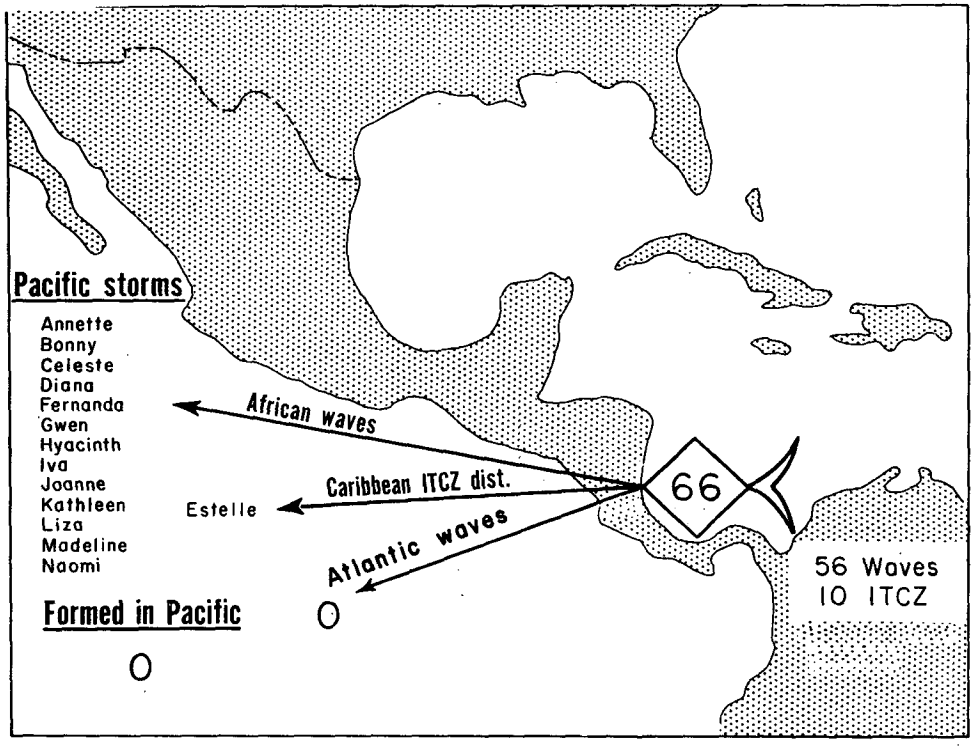


FIG. 4. Ratio of the number of depressions of tropical origin to the total number of depressions, 1967–76.

TABLE 5. Number of depressions that formed each month compared with monthly averages determined over the 9-year period 1967 through 1975.

| | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0 | 1 | 2 | 4 | 5 | 7 | 4 | 0 | 0 | 23 |
| Average 1967–75 | 1.0 | 1.0 | 2.5 | 3.5 | 5.5 | 7.5 | 4.0 | 1.0 | 1.0 | 26 |

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