Atlantic Hurricane Season of 1973

PAUL J. HEBERT AND NEIL L. FRANK

National Hurricane Center, National Weather Service, NOAA, Miami, Fla. 33124

(Manuscript received 28 January 1974)

ABSTRACT

The general overview of the 1973 hurricane season in the North Atlantic is presented together with detailed accounts of all named tropical storms.

1. General summary

The tropical Atlantic remained relatively quiet in 1973 as hostile atmospheric conditions continued to discourage storm development. The current lull in storm activity began in 1970 with the development of strong upper-tropospheric westerlies over the Caribbean and the appearance of abnormally cool sea-surface temperatures between Africa and the Antilles. For the third time in the past four years both the number and intensity of tropical cyclones in the Atlantic were below normal. Seven tropical cyclones were given names and four attained hurricane strength. The past 30-year averages are nine and six respectively.

This was the first year since 1962 that a hurricane did not cross the United States coastline; therefore, damages and loss of life in the United States were the lowest since 1963 and 1968, respectively. Delia claimed 5 lives and caused $18 million in damages in Texas and Louisiana. For all areas of the Atlantic, Caribbean, and Gulf of Mexico, 16 lives were lost and damage estimates were less than $20 million. Statistics for the 1973 season are presented in Table 1.

The tracks of the 1973 named storms are shown in Fig. 1. During the past few years the National Hurricane Center has attempted to differentiate between pure tropical storms and those of mixed character, which have been designated subtropical cyclones (Simpson, 1973). Fran and Gilda both possessed subtropical features during a portion of their existence and one other small subtropical cyclone developed and was labeled Alfa. The tracks of the subtropical portions of these storms are shown in Fig. 2.

One of the most significant characteristics of the last three hurricane seasons has been the lack of storm development in the central and eastern Atlantic. Apparently, this is not because of a reduction in the number of opportunities. Frank and Hebert (1973) found that the number of disturbances emerging from Africa was exactly normal, and that 1973 produced an abundance of hurricane seedlings. Why the lack in storm activity? Even though the exact reason cannot be specified, it is possible to look at anomalies of several environmental parameters that are at least consistent with inactivity.

In 1972 the large-scale flow over the tropical Atlantic was more baroclinic than normal. This pattern persisted in 1973. One way of measuring the magnitude of this effect is to examine the vertical shear of the horizontal wind from the upper to the lower troposphere. Fig. 3 shows the mean vertical shear (Simpson, 1970) over the primary development areas during the peak of the 1973 hurricane season, and Fig. 4 depicts the changes

TABLE 1. Summary of North Atlantic tropical cyclone statistics, 1973. (H) indicates hurricane and T, tropical storm.

No.	Name	Dates	Maximum sustained wind (kt)	Lowest Pressure (mb)	U. S. damage ($ millions)	Deaths
1)	Alice (H)	July 1–6	80	986		
2)	Brenda (H)	Aug. 18–22	70	977		Mexico, 10
3)	Christine (T)	Aug. 25–Sep. 4	62	996		Puerto Rico, 1
4)	Delia (T)	Sep. 1–7	60	986	18.0*	U. S., 5
5)	Ellen (H)	Sep. 14–23	120	962		
6)	Fran (H)	Oct. 8–13	70	978		
7)	Gilda (T)	Oct. 16–29	50	994	†	

* 15 million dollars of this amount was crop damage resulting from heavy rains with Delia and a tropical depression which affected the same area five days later.

† An undetermined amount of beach erosion was caused mainly by the subtropical storm which developed from Gilda.

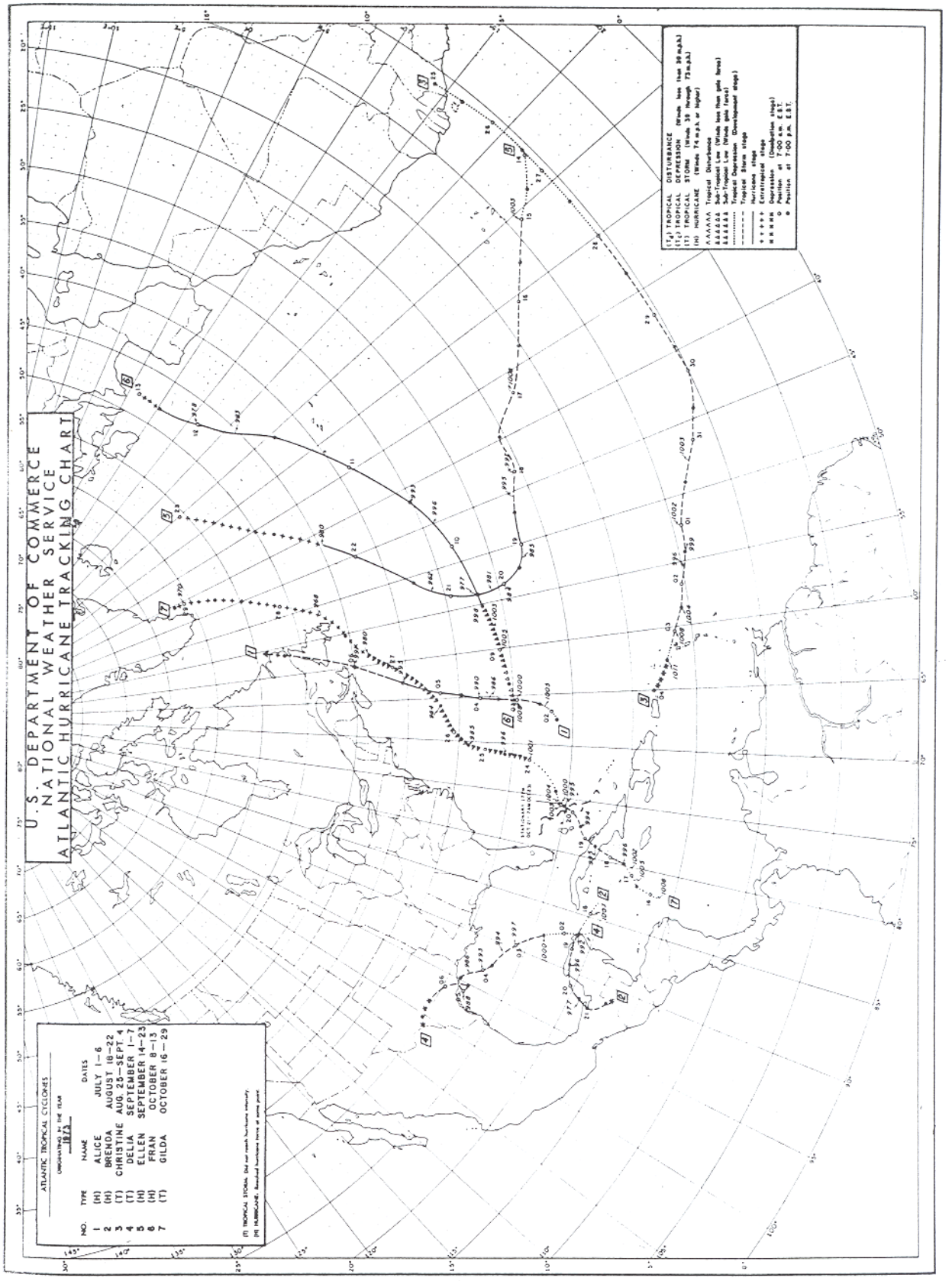

FIG. 1. Tracks of Atlantic tropical storms and hurricanes of 1973.

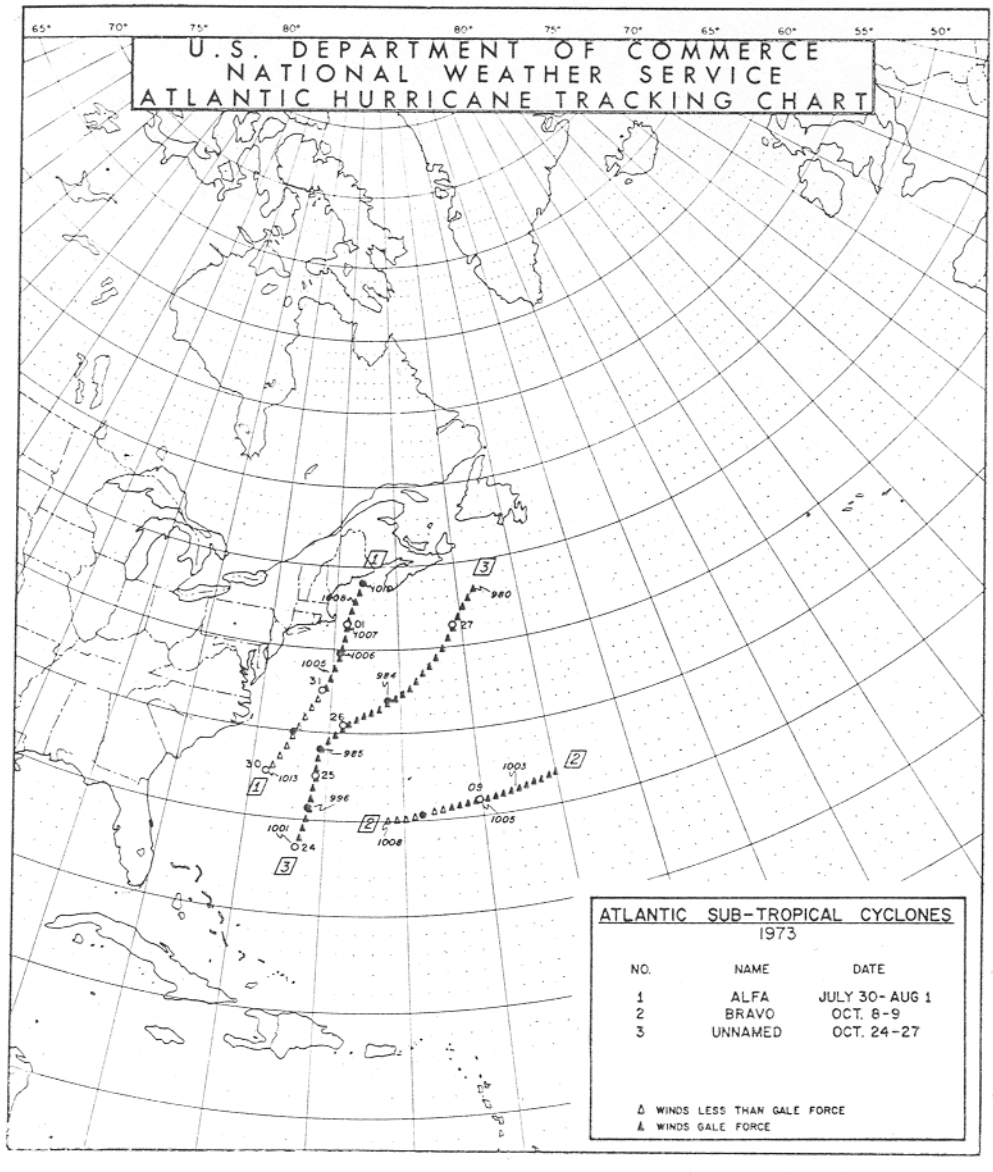

FIG. 2. Tracks of Atlantic subtropical storms of 1973.

from 1972. Little change is noted in the magnitude of the shear except over the western Caribbean where two storms and one strong depression developed during this period in 1973. The stronger than normal shears indicated unusually cool temperatures aloft continuing over the tropics.

Another parameter that is important is the temperature of the sea. Fig. 5 shows the mean sea-surface temperature anomalies for the period from 15 August to 15 September, and Fig. 6 shows the changes from 1972. The anomalously low sea-surface temperatures (SST) of 1972, which extended from the Lesser Antilles to Africa, gave some indications of returning to normal in 1973, but remained marginally near Palmén's threshold value for development (Palmén, 1948).

In spite of the fact that storm development was below normal, several noteworthy firsts were observed during the 1973 hurricane season. Alice was the first July hurricane to threaten Bermuda, and Brenda was the first hurricane of record to affect the southeastern coastal sections of Campeche Bay while moving onshore. Delia was the first storm to make two landfalls over the same coastal location, and the evolution of Gilda from a tropical storm to a severe subtropical cyclone was the first such event documented.

Detailed accounts of individual storms follow.

2. Individual storms

a. Hurricane Alice, 1–6 July

Alice was the first hurricane or tropical storm of record to ever develop or pass near Bermuda in July.

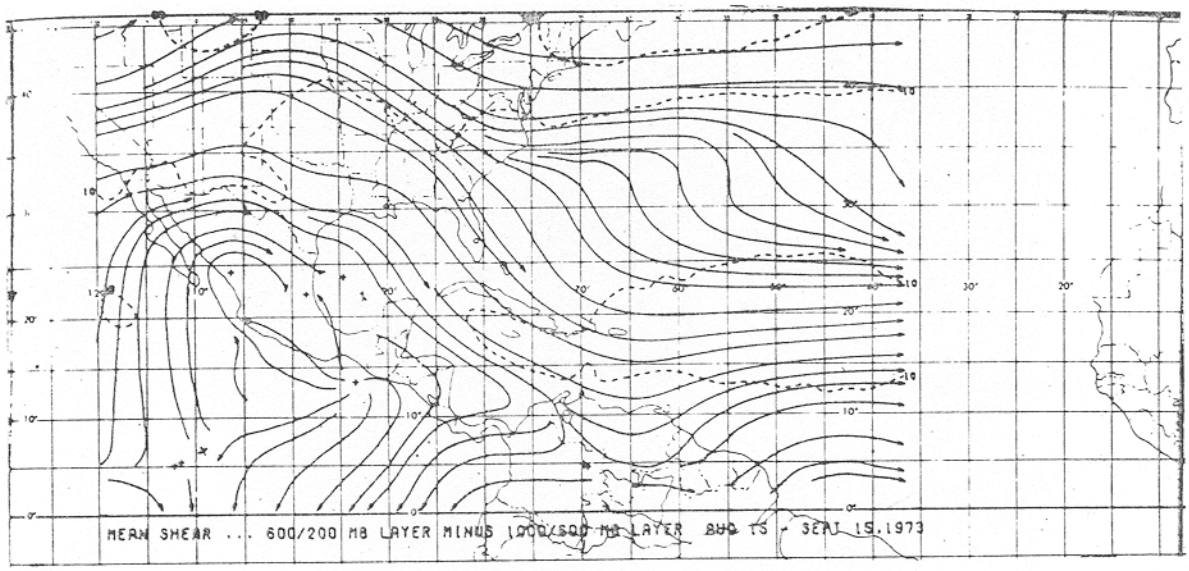

FIG. 3. NHCtropospheric mean wind shear field (600–200 mb upper mean minus the 1000–600 mb lower mean) for the period 15 August–15 September 1973.

The interaction of merging convective cloud systems of an easterly wave and a weak middle-tropospheric trough moving eastward from Florida produced a weak circulation northeast of the central Bahamas late on 28 June, but the first evidence of a well-defined circulation came on the 30th when ship reports located a low near 26N, 69W.

The development process during the initial stages appeared to be drawing more on baroclinic energy than on the latent heat releases of the convection. Satellite pictures showed the low-level cyclonic cloud banding separated from the dense, convective cloudiness to the east. This type of cloud presentation is usually associated with strong upper westerlies and this impedes tropical storm development. Environmental conditions surrounding the depression gradually became more favorable, as vertical shears over and near the depression slowly decreased, allowing the low-level cyclonic circulation to gradually merge with the convective energy source to the east.

Winds approached gale force on 1 July and reconnaissance aircraft consistently reported winds in excess of tropical storm force on the 2nd, when the system was named. A persistent ridge of high pressure to the east steered Alice n a northward course at 10 kt during the next 48 hours. As the high level flow pattern

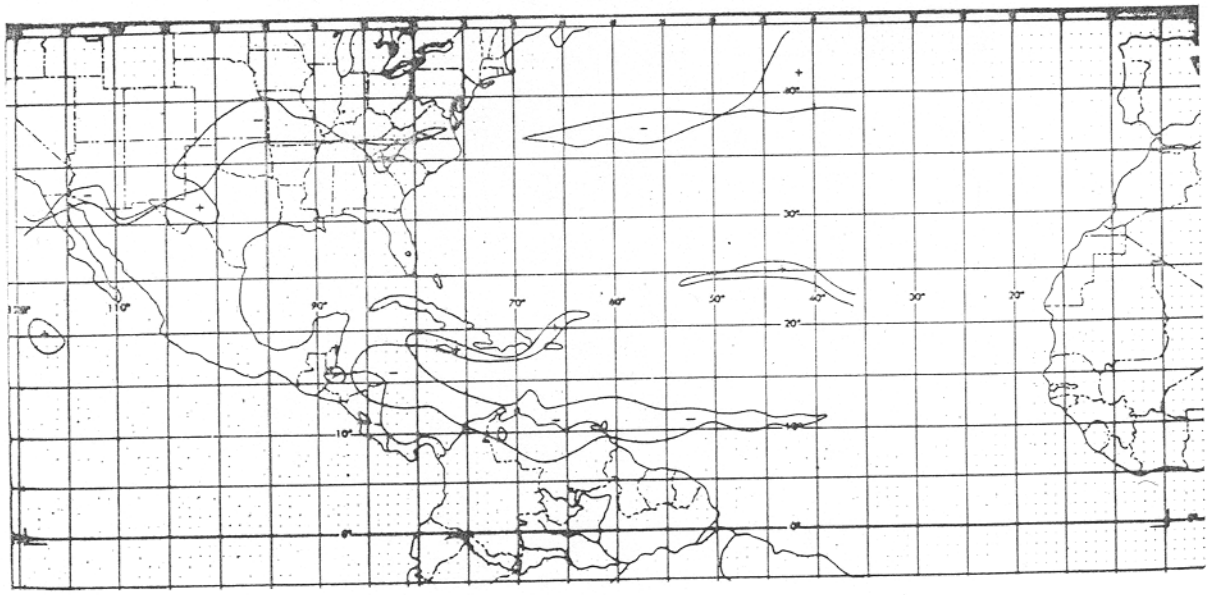

FIG. 4. Change of the 10-kt mean wind shear isotach of Fig. 3 from the same period in 1972.

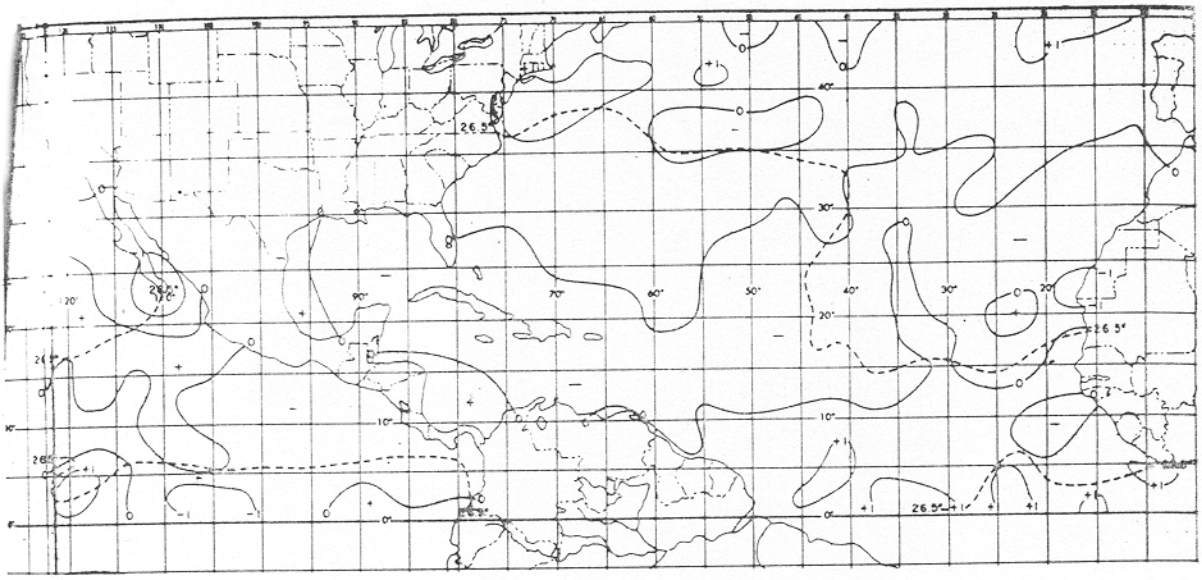

FIG. 5. Sea surface temperature (SST) anomalies (°C) for the period 15 August–15 September 1973. The 26.5C isotherm (dashed line) indicates the Palmén threshold for hurricane development (Palmén, 1948).

became more favorable for outflow the storm continued to deepen and Alice became a hurricane on the morning of the 3rd. Reconnaissance aircraft found sustained 700-mb flight level winds of 70 kt and satellite pictures revealed a well-defined eye. Eighteen hours later the lowest central pressure of 986 mb was recorded by a reconnaissance aircraft as the radar set at Bermuda indicated the eyewall of the hurricane was brushing the western tip of the island.

The lowest pressure reported from Bermuda was 995 mb at 0630 GMT 4 July. The maximum sustained surface wind was 43 kt, while gusts reached 57 kt. Sustained winds reached 65 kt with gusts to 77 kt atop a 100-ft tower on the island. Rainfall from the hurricane totalled 4.54 inches.

Alice accelerated northward when a middle tropospheric trough moved into the North Atlantic States. Winds decreased to less than hurricane force late on the 5th, and the system was in the process of losing its tropical character as it crossed the southwest coast of Newfoundland around 1700 GMT 6 July.

Sable Island, near 44N, 60W, measured surface winds of 40 kt with gusts to 57 kt as the center passed 20 mi to the west about 1000 GMT 6 July, but winds of gale force were not observed over Newfoundland.

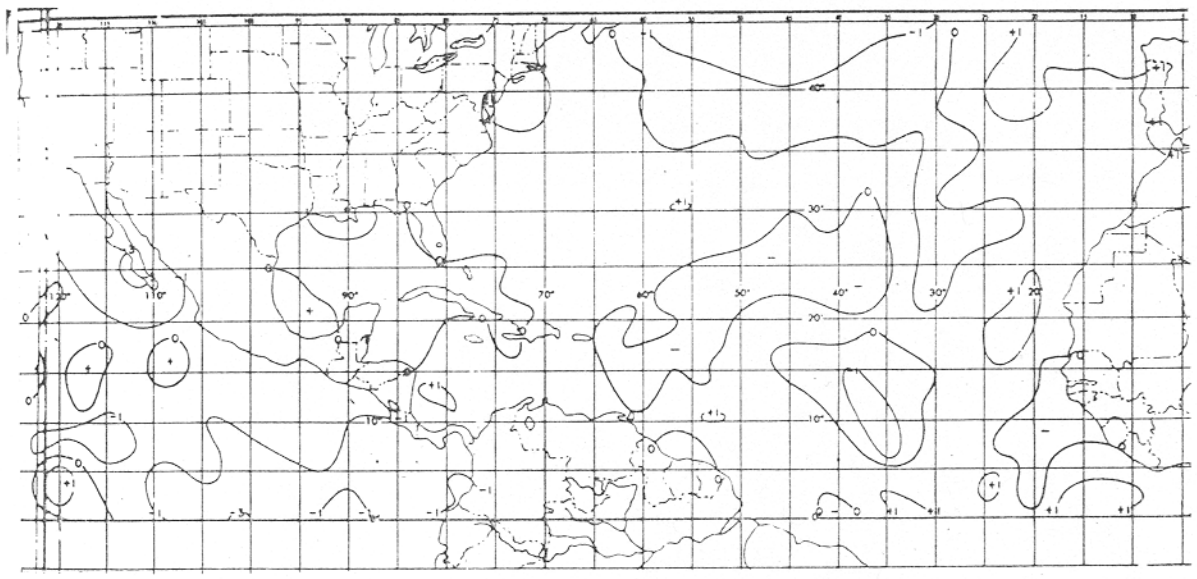

FIG. 6. Changes in the SST anomalies of Fig. 5 from the same period in 1972.

No casualties or significant damage have been attributed to Alice.

b. Hurricane Brenda, 18–22 August

The disturbance which eventually developed into Brenda moved westward off the African coast south of Dakar, Senegal, on 9 August. The disturbance weakened after leaving the coast, moving across the Atlantic as an inverted-V tropical wave. The first signs of development occurred on the 13th when a large area of showers and thunderstorms developed over the Lesser Antilles. This area of disturbed weather became more concentrated as the system moved to the western Caribbean during the next three days. A sharp amplitude upper and middle tropospheric trough had preceded the convection by about 300 mi. East-northeast winds of 40 to 60 kt at middle tropospheric levels were reported by several stations in advance of the trough. Satellite pictures on the 17th revealed the convection had consolidated into a concentrated, nearly circular pattern, and the 850-mb wind at Kingston, Jamaica, shifted to southeasterly 55 kt at 1200 GMT. Thickness values indicated the system was quite warm, and Grand Cayman gave evidence of strong convection by recording over four inches of rain on the 17th.

A ship near 21N, 84W reported 45 kt southeast winds and 18-ft seas that evening, suggesting that a low center was developing. A NOAA-2 infrared satellite photograph at 0117 GMT 18 August also suggested formation of a low center. The next morning a ship just south of Cape San Antonio, Cuba, reported winds shifting from northeasterly 50 to 60 kt to southeasterly 45 kt accompanied by 20-ft seas. A reconnaissance aircraft reported winds nearing hurricane force during the afternoon, and the central pressure dropped to 992 mb shortly before the center moved inland 30 mi north of Cozumel, Mexico, during the early evening.

The center passed directly over Merida 24 hours later, and was turned southwestward into the Bay of Campeche on the 20th by a strong ridge of high pressure building over Texas and Mexico. Rapid intensification occurred after the center moved offshore. ATS-3 satellite pictures revealed an eye at midday, and a reconnaissance aircraft reported a central pressure of 977 mb and maximum sustained winds of 70 kt about 0000 GMT 21 August. At the same time an unidentified ship north of the center reported hurricane force winds of 65 kt from the northeast, one of two ship observations of hurricane force winds during the 1973 hurricane season. It is likely that further intensification took place prior to landfall 30 mi west of Carmen early on the morning of the 21st. Rapid weakening occurred over land, and the system was downgraded to a depression by 0000 GMT 22 August.

The turn of Brenda to the southwest and south was very unusual for an August storm. Brenda was the first hurricane of record to affect the southeast coastal sections of Campeche Bay by moving onshore from the Gulf of Mexico. The only other tropical cyclones of storm intensity to move ashore in the Carmen-Campeche area occurred in May 1933, and October 1922 and 1936.

Carmen reported the highest sustained wind by a land station—45 kt with gusts to 50 kt, but hurricane force winds undoubtedly occurred near the center. Gusts to gale force were observed as far west as Vera Cruz. Earlier, Cozumel and Merida had experienced winds of minimal gale force.

Ten persons were killed in coastal towns as widespread tidal flooding occurred from Vera Cruz to Campeche. The town of Campeche was 80% flooded, the worst in 25 years. The hurricane destroyed 50% of the houses in coastal municipalities of the state of Tabasco, leaving 2000 persons homeless. Another 2000 persons lost their homes in Carmen.

The press mistakenly associated widespread damage over large portions of Mexico with Brenda. Prior to the arrival of this storm, a prolonged three-month rainy period had caused considerable flooding damage over central Mexico, and this damage was enhanced by an earthquake along the southeast Mexican coast west of Brenda's landfall.

The Greek freighter *Yucatan* was crippled by Brenda when caught by the unexpected turn to the south. In addition, Brenda terminated the almost-completed Acali Raft Experiment of human endurance, which had departed from the Canary Islands on 12 May.

c. Tropical storm Christine, 25 August–4 September

The disturbance which produced Christine left the west Africa coast as a strong depression on 25 August. Unlike many African disturbances which produce tropical storms, its passage 300 mi to the south of Dakar, Senegal, was barely reflected in the latter's upper air soundings.

Satellite pictures on the morning of the 28th indicated the system was probably of minimal tropical storm strength and later that day the German cargo ship *Steinfels* reported winds of 30 to 35 kt veering from NE to S, while passing some distance east of the center. Except for the ephemeral Ginger of 1967, Christine became the first tropical storm since 1966 to form as far east as longitude 30W. The first advisory on Christine was not issued until late on the 30th when a reconnaissance flight found a surface pressure of 1007 mb and sustained surface winds of 45 kt about 1000 miles east of Trinidad.

The storm reached maximum strength on 2 September when reconnaissance aircraft obtained the lowest central pressure of 996-mb and 700-mb maximum sustained winds of 62 kt from the east. With the storm located 300 mi east of Guadeloupe, gale warnings and a hurricane watch were issued at noon AST on the 2nd for the northern Leeward Islands of Guadeloupe,

Desirade, Antigua, and Barbuda. Later in the day, gale warnings were extended southward to Dominica.

As has been the case several times in recent years, the storm began to weaken steadily as it approached the Leeward Islands, and was of less than tropical storm strength when it reached Antigua at midday on the 3rd. Satellite pictures that day indicated a strong vertical shear of the horizontal wind over the storm, and as a consequence the low-level circulation separated from the convective system of the storm. The depression degenerated into an easterly wave while approaching Puerto Rico and finally lost its identity under an upper cold low north of Hispaniola on the 6th.

Heavy thundersqualls moved into the Leeward Islands early on the 4th and spread westward to Puerto Rico later that day. Wind gusts to 49 kt occurred at San Juan during the late morning, causing minor damage over eastern Puerto Rico. One person died when electrocuted by a fallen power line. Heavy rains up to 9½ inches in southeastern Puerto Rico caused minor flooding. Similar conditions likely prevailed over the Virgin and northern Leeward Islands, but detailed information is lacking.

d. Tropical storm Delia, 1–7 September

Delia was the only tropical storm or hurricane of 1973 to cross the U. S. coastline, but it did so twice. The storm made a loop back over the water shortly after moving ashore in the Galveston-Freeport area during the evening of the 4th, and moved onshore again in the same area 24 hours later. The Galveston-Freeport area thus becomes the first coastal section of the United States ever to have two landfalls with the same storm. The two landfalls of hurricane Easy in the Cedar Key-Tampa area in 1950 were somewhat further apart.

Delia was triggered by a tropical wave that developed over the central Caribbean on 27 August. This disturbance moved west-northwest during the next three days, and phased with an upper tropospheric cold low which had moved from north of Hispaniola to the eastern Gulf of Mexico.

ATS-3 satellite pictures on the 30th and 31st showed a gradual increase in convection with evidence of cyclonic banding. Surface observations on the 31st indicated a weak cyclonic circulation over the Gulf of Honduras. The depression drifted northward along the east coast of the Yucatan Peninsula on 1 September with satellite pictures showing the convective area becoming more concentrated and circular. The depression moved northwest into the Gulf of Mexico during the night and by the afternoon of the 2nd, a reconnaissance aircraft found a central pressure of 1000 mb and 45 kt winds about 150 mi north of the Yucatan Peninsula, promulgating the first advisory on Delia.

Slow intensification took place during the next 24 hours as Delia continued northwest at 13 kt. However, large scale baroclinic changes hostile to hurricane development began to dominate the Gulf of Mexico. A large scale cyclonic circulation developed in the middle troposphere, and there was evidence of a surface low in the Bay of Campeche to the south of Delia on the 3rd. These changes reduced the low level mass inflow and restricted significant strengthening of the tropical circulation. Together with passing anticyclones to the north they also contributed to two tight loops in the northwestern Gulf of Mexico before the storm moved inland on the 6th and weakened rapidly. The remains of the storm turned west-southwest and dissipated over the mountains of northern Mexico on the 7th.

Reconnaissance aircraft measured maximum sustained winds of 60 kt on the 3rd and 4th, and reported squalls well above hurricane strength on the 4th and 5th. However, Delia never developed the classic wall cloud of a hurricane, and sustained winds remained just below hurricane force. The lowest pressure of 986 mb was reported by reconnaissance aircraft just prior to the first landfall on the 4th.

Gales of 40 to 45 kt occurred from Freeport to Galveston with gusts of 50 to 60 kt. The maximum recorded sustained wind of 40 kt and gusts to 59 kt occurred at Galveston on the 4th. The lowest pressure recorded by a land station was 992 mb at Freeport early on the 6th. At least 8 tornadoes were reported in Louisiana and Mississippi on the 4th and 5th, causing 4 injuries but no significant damage. Additional meteorological data is given in Table 2.

Tides of 4 to 6 ft MSL in Galveston Bay caused flooding of the Baytown area and an estimated $3 million in losses for homeowners. Coastal industrial and marine interests suffered only minor losses from Delia.

Significant damage to crops estimated at $3 million resulted from 8- to 10-inch rains over southeastern Texas and southwestern Louisiana. These losses were augmented when a strong tropical depression moved into the same area five days later and became nearly stationary, producing up to 15 inches of additional rainfall along the Texas coast. The destruction of the rice crop blown down earlier by Delia raised total crop losses to an estimated $15 million. The crop was ready for harvest and salvageable prior to the rains associated with the second depression. However, there was considerable benefit to inland agricultural interests, as the weakening storm brought needed moisture to pasturelands.

There were 5 deaths associated with Delia in the Houston-Galveston area—two drownings in flooded culverts, one heart attack while boarding up, and two automobile fatalities on rain-slicked streets.

Gale warnings and a hurricane watch were issued at 11 a.m. CDT 3 September for the Louisiana coast east of Lake Charles to the mouth of the Mississippi River. They were extended westward to Palacios, Texas, at 5 p.m. CDT as the storm turned more to the west,

TABLE 2. Tropical storm Delia, 1–7 September 1973, meteorological data.

Station	Date	Pressure (mb) Low	Pressure (mb) Time†	Wind (kt) Fastest mile	Wind (kt) Time†	Wind (kt) Gusts	Wind (kt) Time†	Tide (ft) Highest MSL	Tide (ft) Time†	Rainfall (inches) Storm total	Rainfall (inches) Dates
Louisiana											
Cameron CG	5			NE 30	4/1000	NE 40	4/1000	5.2‡	0220		
Lake Charles WSO	4	1001.0	1550	E 26	1645	E 35	1530			9.99	3–6
Southwest Pass	5			SE 40	0300						
Texas											
Austin WSO	6	995.3	0930	NW 32	5/2013	NW 43	5/2013				
Baytown	6							5.6	0400		
Corpus Christi WSO	5	1001.4	0357	NW 36	1427	NW 41	1404	2.6	4/1100		
Freeport CG	6	992.2	0000	NNE 35	4/1500	NNE 56	4/1500	4.5	5/0000	4.07	
Galveston WSO	4	994.2	1700 and 6/0000	NE 40	1256	NE 59	1300			2.60	
Galveston Oil Rig 25 SSE	4			NE 45	1200	SE 48	5/2200				
Houston WSO	6	993.9	0253	E 30	0355	E 48	0402			5.04	4–6
Matagorda	5	993.6	0100			NW 43*	0130	3.6		7.40	
Palacios	5	993.9	0100	NW 40				4.0		6.04	
Port Aransas CG	5			WNW 32	0600						
Port O'Connor CG	5			NNW 38	0300						
Sabine CG	5			SE 45	2200	SE 50	2200	4.3	4/1500		
Sargent	5	993.9	0000			NW 35*		4.5		10.93	

† Central Standard Time.
‡ Above mean low water.
* Estimated.

and discontinued east of Morgan City at 11 p.m. CDT as the threat diminished. Gale warnings had to be extended to Baffin Bay south of Corpus Christi at 8 a.m. CDT on the 5th as Delia looped southwestward. Observed winds along the coast indicate that warnings were adequate.

e. Hurricane Ellen, 14–23 September

Ellen was the second tropical cyclone of the 1973 season to reach storm intensity in the far eastern Atlantic and eventually became the most intense hurricane of the season. NOAA's Research Flight Facility reconnaissance aircraft measured a minimum central pressure of 962 mb and maximum sustained winds of 120 kt at 1500 ft on the 21st.

Ellen formed from an African disturbance. The cloud system moved off the coast on 13 September and formed a depression about 300 mi south of the Cape Verde Islands on the 14th. Twenty-four hours later the French naval vessel *Garonne* passed through the system and reported a minimum pressure of 1003 mb with 40 kt southerly squalls. Because of the sparsity of conclusive data, the first advisory on Ellen was not issued until the 17th. On that day reconnaissance aircraft found a minimum pressure of 1008 mb and 50-kt surface winds near 22N, 36W.

The storm had moved steadily northwestward at 17 kt after leaving the Cape Verdes. During that time satellite pictures showed the convective cloud mass becoming progressively elongated north-northwest to south-southeast, suggesting that the storm was being influenced by a weak trough of low pressure between two high pressure cells within the Azores-Bermuda ridge. This trough interacted with a trough passing in the westerlies on the 17th. As the latter continued eastward the westernmost high pressure cell near 30N, 50W strengthened, turning Ellen westward.

Satellite pictures on the morning of the 18th showed a more circular convective cloud system and a diffuse eye, and by late afternoon reconnaissance aircraft found a central pressure of 995 mb and 700-mb flight-level winds of 60 kt. Ellen strengthened to hurricane force that evening and on the 19th a reconnaissance aircraft measured a 985-mb central pressure, 700-mb flight level winds of 75 kt, and a temperature rise of 8C in the eye. The hurricane turned sharply towards the northwest late on the 19th in response to a weak trough moving northeastward from the Bahamas. Rapid intensification to maximum strength took place on the 21st as the hurricane accelerated northeastward ahead of a deepening upper trough moving off the east coast of the U. S. Ellen reached a forward speed of 50 kt on the 22nd before becoming extratropical when the hurricane merged with a frontal zone about 650 mi east of Newfoundland.

No casualties or major damage to shipping has been attributed to Ellen.

f. Hurricane Fran, 8–13 October

A convective cloud system located north of Hispaniola on 1 October gave birth to subtropical cyclone Bravo, which in turn matured and transformed into

hurricane Fran. The shower activity was associated with a midtropospheric trough which had been moving westward across the Atlantic during the preceding week, and may have originated in Africa. The system interacted with a weak mid-tropospheric trough near the U. S. coast, producing a surface trough from southeastern Florida northeastward on the 4th.

Ship reports of light west winds just east of Florida on the 5th suggested that a weak circulation was developing. Satellite pictures showed increasing organization of the convective pattern during the next 3 days as the system drifted eastward. Ship reports indicated a 1008-mb low pressure center near 30N, 67W on the morning of the 8th and a reconnaissance aircraft found 35-kt surface winds during the late afternoon.

In the meantime, a cold front had moved southward over the western Atlantic and merged with the developing depression. Ship reports indicated that nontropical air was entering the depression's circulation from the north, and when winds attained storm strength the low was designated subtropical cyclone Bravo. On the next day, however, a reconnaissance flight found hurricane force winds 15 mi from the center and a warm core at 700 mb; thus Bravo was re-classified as hurricane Fran.

Under the influence of a deep surface low in the westerlies, the hurricane accelerated to a forward speed reaching 35 kt by the 11th, passing about 30 mi north of the islands of Flores and Corvo in the Azores. Ship reports and satellite pictures indicated that Fran maintained tropical character until merging with a cold front and becoming extratropical about 300 mi off the French coast late on the 12th.

Southerly surface winds of 35 to 45 kt were reported at 1200 and 1800 GMT on the 11th in the Azores but the maximum winds experienced in the Islands are not known. One of the two ship observations of hurricane force winds during 1973 had been received from the Belgian cargo ship *Frubel Oceania* 24 hours earlier, when it was buffeted by 65-kt southwest winds near 32N, 49W. The maximum sustained wind measured by reconnaissance aircraft during the storm was 70 kt on the 11th at 1500 ft.

The lowest central pressure measured by reconnaissance aircraft was 993 mb on the 10th, when the hurricane was midway between Bermuda and the Azores. The central pressure in Fran continued to fall after the storm passed the Azores. The French cargo ship *Cetra Columba* reported 981 mb and southerly winds of 35 kt 30 mi east of the center on the 12th. At the same time the German cargo ship *Stephanitor* reported 982 mb and westerly gales to 60 kt 125 mi southwest of the center. From these two ship reports the lowest central pressure during Fran's life was calculated to be 978 mb.

Thus far, no casualties or significant damage has been attributed to Fran.

g. Tropical storm Gilda, 16–29 October

The development of Gilda seemed to be at least partially influenced by a disturbance which left the African coast on 3 October. It reached the eastern Caribbean on the 10th, and developed a large convective system from Hispaniola southwestward to Panama by the 13th. The convection became better organized and more concentrated over the northwestern Caribbean on the 15th, as a large 200 mb anticyclone developed just south of Jamaica, changing to anticyclonic the rather strong, cyclonic vertical shears which had persisted over that area during the preceding week.

A diffuse tropical depression finally formed northeast of Cape Gracias, Nicaragua, late on the 15th. The depression drifted northeastward and continued to strengthen, and late on the 17th a reconnaissance flight found a central pressure of 996 mb. The depression developed into tropical storm Gilda just 60 mi east of Grand Cayman.

Initially, Gilda appeared to present the first serious threat of a hurricane to southeast Florida since Gladys of 1968. National Meteorological Center (NMC) prognostic charts for the next 72 hours indicated lower and higher level steering currents would become rather delicately balanced, leaving indeterminate whether the net effect would be to steer Gilda slightly west or slightly east of due north.

Middle and upper level steering currents prevailed, and the storm moved north-northeast at 6 kt for 48 hours and even more slowly northeast during the next 24 hours. The storm showed little change in strength during this time. Reconnaissance aircraft found the lowest central pressure of 994 mb and the maximum sustained winds of 50 kt during the tropical portion of Gilda's life when the storm was centered off the southern tip of Andros Island on the 19th.

The high level anticyclone remained south of Jamaica as the storm moved northward and came under the negative influence of increasing vertical shears. Satellite pictures on the morning of the 19th showed the convective cloud system separating from the low level circulation, and by the 21st the two were almost completely detached. Slow weakening took place until Gilda was downgraded to a depression at noon EDT on the 22nd. As the storm weakened, low-level steering forces became more dominant, and rising surface pressures around the center stalled it about 60 mi east of Harbour Island late on the 21st.

The storm did not affect Cuba significantly. The lowest sea level pressure reported over the island was 995 mb in Camaguey Province, while the mountain station of Gran Piedra, located well east of the center in Oriente Province, reported the highest sustained wind of 50 kt. Moron, near the north coast just east of the storm's path, reported a six-hourly rainfall of 6.13 inches before the center passed.

While total monetary losses in the central Bahamas were small, the storm proved to be a personal disaster

for most of the farmers on Exuma, Eleuthera, Cat, Long, south Andros, and Harbour Islands and adjacent cays. Most of the losses were caused by the prolonged high tides and heavy rains. Several U. S. Navy automatic weather stations on the east coast of Andros Island reported wind gusts in excess of 50 kt on 19 October. The highest gust was 65 kt at Golden Cay around midday.

After remaining stationary for 36 hours, tropical depression Gilda came under the influence of a cold, upper trough digging southward over the Carolinas on the 23rd, and began moving northeastward and deepening. Synoptic and reconnaissance reports on the morning of the 24th indicated the depression was being transformed into a large, vigorous subtropical cyclone, as the cold air associated with the Carolinas trough provided a baroclinic acceleration of Gilda's circulation. The transformation was completed by the afternoon of the 25th when the huge, severe storm packing sustained winds near 60 kt and a central pressure of 985 mb passed midway between Hatteras and Bermuda. Thus, Gilda became the first tropical storm of record to pass through a subtropical stage en route to becoming extratropical. At one time the circulation of the storm covered the western Atlantic from New England to the Bahamas and eastward beyond Bermuda.

The storm turned northeastward away from the U. S. on the 26th and became extratropical just southeast of Sable Island, Nova Scotia, on the 27th. The central pressure dropped to 968 mb as the low passed just east of Cape Race, Newfoundland, on the 28th, but the stabilizing influence of the colder waters prevented any further increase in surface wind strength. The system that was once Gilda became quasi-stationary off the southeast coast of Greenland on the 29th and gradually filled.

The U. S. Coast Guard Cutter *Taney* (Ocean Station Vessel "H"), located near 38N, 71W, endured gales for 54 hours and 50-kt winds for 24 hours. Seas rose to a peak of 28 ft during the evening of the 25th and early morning of the 26th. Several other ships reported 50 kt gales and seas 20 ft or more on the 25–26th. Sable Island reported northerly gusts to 64 kt on the 27th as polar surface air was drawn into the storm's circulation.

The pounding surf combined with normal high tides for this period to produce minor beach erosion, and caused beachfront property damage from Hatteras to Palm Beach. The most notable damage was along the Florida east coast from Daytona Beach to Hollywood, where rough seas persisted for more than 72 hours.

While such a major storm must have caused some marine losses by damaging cargo, total monetary losses during Gilda's life appear to be small. No casualties have been reported.

Gale warnings were issued from Fort Lauderdale to North Key Largo at 6 a.m. EDT on the 19th, when it appeared Gilda would move close to the southeast Florida coast. Gale warnings were also issued from Cape Hatteras, N. C., to Manasquan, N. J., at noon EDT and extended to Merrimac River, Mass., at 6 p.m. EDT on the 25th during the subtropical portion of Gilda. Gales were observed from Cape Hatteras to New Jersey.

Tropical storm advisories were issued on Gilda during the subtropical stage, even though forecasters recognized the inconsistency at the time. There were two factors pertinent to the decision—first, the wish to avoid confusion by maintaining continuity with previous forecast releases; and second, the possibility that the storm would again become more tropical in nature.

h. Other strong systems.

In addition to the named tropical cyclones there were three other significant systems during 1973.

A weak subtropical cyclone developed about 200 mi southeast of Cape Hatteras on 30 July. It was designated subtropical cyclone Alfa on the 31st when reconnaissance aircraft found sustained 40-kt surface winds and a central pressure of 1005 mb. This system weakened on 1 August before reaching the east coast of Maine.

The depression that developed in the northwestern Caribbean Sea on 6 September within a low pressure trough extending south and southeast from Delia was of little consequence until it became stationary in the Freeport, Texas, area on the 10th. The heavy rains associated with it caused most of the losses attributed to Delia. The depression strengthened to near storm strength on the 12th as it moved briefly over the coastal waters south of Galveston, but weakened as it moved east northeast through southern Louisiana.

A strong depression developed in the southwestern Caribbean Sea on 17 November, and may have briefly attained tropical storm strength on the 18th before weakening under the influence of increasing westerly shears which destroyed the convective system.

Acknowledgments. Portions of the individual storm accounts were taken from preliminary reports prepared at the National Hurricane Center by Messrs. G. B. Clark, J. R. Hope, J. M. Pelissier, and A. C. Pike, and by R. McKee and H. Hoose of the New Orleans and San Juan hurricane warning offices respectively. Graphics were supplied by D. Martin and C. True, and the manuscript was typed by M. Samet.

REFERENCES

Frank, Neil L., and Paul J. Hebert, 1974: Atlantic tropical systems of 1973. *Mon. Wea. Rev.*, **102**, 290–295.

Palmén, Erik H., 1948: On the formation and structure of tropical hurricanes. *Geophysica*, 3, 26–38.

Simpson, R. H., 1973: The neutercane—Small hybrid cyclone. Paper presented at the Eighth Technical Conference on Hurricanes and Tropical Meteorology, Key Biscayne, Miami, Fla.

——, 1970: A reassessment of the hurricane prediction problem. ESSA Tech. Memo, WBTM SR-50, 16 pp.

Atlantic Tropical Systems of 1973

NEIL L. FRANK AND PAUL J. HEBERT

National Hurricane Center, National Weather Service, NOAA, Miami, Fla. 33124

(Manuscript received 28 January 1974)

ABSTRACT

The 1973 hurricane season featured 95 "tropical systems" of which 24 acquired the closed circulation of a depression. Atlantic "seedlings" were responsible for the seven named storms in the Atlantic and seven of the twelve East Pacific storms. Fifty-six of the systems originated over Africa.

1. Introduction

The lull in storm activity that has been evident over the Atlantic during the past several years continued in 1973. There was no serious threat to the United States, and Ellen was the only hurricane to acquire significant strength. Hebert and Frank (1974) discussed several factors that contributed to this inactivity. Upper tropospheric westerlies over the Caribbean remained stronger than normal in response to a well defined mid-Atlantic upper trough. Water temperatures over the Atlantic from Africa to the Antilles were slightly below normal. However, it is important to note that the magnitude of these anomalies was generally less than in 1972, which was the quietest season in over 40 years. The development of Ellen and Christine over the tropical eastern Atlantic gave evidence that the tropical Atlantic may be returning to normal.

Intuition suggests that the number of storms should be related to the number of "seedlings." Years with greater opportunities should produce an abundance of storms. However, our statistics over the past several years have not confirmed our intuition. On the contrary, we are finding remarkable stability in the number of seedlings that develop over the tropical Atlantic and Caribbean each year. The minor year-to-year variations in the total number of seedlings is largely related to developments over the subtropical latitudes, and storm formation depends primarily on environmental conditions. During the past three years the tropical Atlantic has been characterized by numerous seedlings, baroclinic environmental conditions, and few storms.

2. Census of 1973 tropical systems

The results of the 1973 hurricane season census are tabulated in Table 1 and several categories are summarized in Table 2 and Fig. 1. The philosophy of our counting procedure is described in previous articles, Simpson *et al.* (1968, 1969).

Table 1 describes the history of the 95 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 over the Atlantic north of latitude 20N. The Atlantic and eastern Pacific storms that were initiated by Atlantic seedlings are listed in the last two 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, the two depressions and two storms (Ellen and Christine) were spawned by tropical waves whose origin was in Africa. Once again we see that over 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 transversing 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 20N has been used as a dividing line. Of the 56 African systems, 51 were tracked to the Caribbean and 39 all the way to the Pacific Ocean. Over the tropical Atlantic, 13 disturbances formed with seven eventually passing through the Antilles. Another six were identified along the ITCZ and followed for at least 48 hours before dissipating. A total of 58 systems crossed the Antilles (51 from Africa plus 7 that formed in the Atlantic), of which 43 maintained their identity while transversing the Caribbean. The 11 disturbances that formed over the Caribbean added to the number

TABLE 1. Summary of the tropical systems in 1973.*

Dakar passage	Nature	Formed in Atlantic	Nature	Weakened in Atlantic	Barbados passage	Nature	Weakened in Caribbean	Formed Caribbean	San Andres passage	Nature	Formed in N. Atlantic	Atlantic Storm	Pacific Storm
											4/18	Dep.	
											4/24	Dep.	
April 30	Wave				May 5	Wave			May 8	Wave			
May 4	Wave				May 5	Wave			May 13	Wave			
		5/07	ITC	5/09							5/02	Dep.	
											5/11	Dep.	
May 10	Wave				May 16	Wave			May 19	Wave			
May 13	Wave				May 18	Wave			May 21	Wave			
May 16	Wave				May 24	Wave			May 27	Wave			
May 18	Wave				May 26	Wave	5/27						
May 22	Wave			5/25									
May 26	Wave				June 1	Wave			June 3	Wave			
May 28	Wave				June 5	Wave			June 8	Wave			
		5/31	ITC	6/02									
May 31	Wave				June 7	Wave			June 10	Wave			
June 02	Wave				June 9	Wave			June 12	Wave			
June 05	Wave				June 11	Wave			June 14	Wave			
June 08	Wave				June 13	Wave			June 15	Wave			
											6/08	Dep.	
								6/17	June 18	ITC			Bernice
June 12	Wave				June 17	Wave			June 20	Wave			
June 14	Wave				June 21	Wave			June 24	Wave			
June 17	Wave				June 24	Wave			June 27	Wave			
		6/20	ITC	6/22									
June 21	Wave				June 27	Wave	6/28						
June 23	Wave			6/25									
											6/24	Dep.	
								7/01	July 02	ITC			
June 27	Wave				July 04	Wave			July 07	Wave			
June 29	Wave			7/01									
July 02	Wave				July 08	Wave			July 11	Wave			Dep.
July 04	Wave				July 10	Wave	7/11						
											7/01	Alice	
July 07	Wave				July 13	Wave			July 16	Wave			
											7/09	Dep.	
July 09	Wave				July 15	Wave			July 18	Wave			Emily
								7/19	July 20	ITC			
		7/20	ITC	7/25									
								7/21	July 22	Dep.		Dep.	Florence
July 15	Wave				July 20	Wave			July 24	Wave			
July 17	Wave		Dep.		July 23	Wave			July 26	Wave			Glenda
								7/27	July 28	ITC			
July 21	Wave				July 27	Wave			July 31	Wave			
July 24	Wave			7/28									
											7/30	Alfa	
July 27	Wave				Aug. 01	Wave			Aug. 04	Wave			
		8/04			Aug. 04	Wave			Aug. 08	Wave			
July 31	Wave				Aug. 08	Wave			Aug. 12	Wave			Dep.
Aug. 06	Wave				Aug. 10	Wave			Aug. 14				
Aug. 08	Wave				Aug. 11	Wave	8/13						

TABLE 1 (*continued*).

Dakar passage	Nature	Formed in Atlantic	Nature	Weakened in Atlantic	Barbados passage	Nature	Weakened in Caribbean	Formed Caribbean	San Andres passage	Nature	Formed in N. Atlantic	Atlantic Storm	Pacific Storm
Aug. 09	Dep.				Aug. 14	Wave			Aug. 16	Wave		Brenda	Dep.
Aug. 10	Wave				Aug. 16	Wave	8/17						
Aug. 12	Wave				Aug. 19	Wave			Aug. 22	Wave			
		8/20			Aug. 21	Wave			Aug. 24	Wave			Dep.
Aug. 19	Wave				Aug. 24	Wave			Aug. 27	Wave			Heather
		8/27			Aug. 28	Wave	8/29						
								8/27	Aug. 29	Wave		Delia	
Aug. 23	Wave				Aug. 31	Wave			Sept. 09	Wave			
Aug. 26	Dep.				Sept. 03	Storm	9/06					Christine	
Aug. 31	Wave				Sept. 06	Wave	9/07						
		8/30	ITC	9/01									
Sept. 03	Wave			9/05									
								9/07	Sept. 08	ITC			
Sept. 04	Wave				Sept. 09	Wave			Sept. 11	Wave			
								9/12	Sept. 13	ITC			
		9/10			Sept. 12	Wave			Sept. 15	Wave			Jennifer
Sept. 08	Wave				Sept. 14	Wave			Sept. 17	Wave			Irah
Sept. 10	Wave				Sept. 16	Wave			Sept. 19	Wave			
Sept. 13	Wave				Sept. 20	Wave			Sept. 23	Wave		Ellen	Katherine
		9/20			Sept. 23	Wave			Sept. 26	Wave			
								9/26	Sept. 27	ITC			Dep.
								Dep.				Dep.	
											9/09	Dep.	
Sept. 18	Wave				Sept. 25	Wave			Sept. 29	Wave			Lillian
Sept. 21	Wave				Sept. 27	Wave			Oct. 01	Wave			
Sept. 23	Wave				Sept. 29	Wave			Oct. 03	Wave			Dep.
											9/24	Dep.	
Sept. 26	Wave				Oct. 02	Wave			Oct. 05	Wave			Dep.
		10/03			Oct. 05	Wave	10/06						Dep.
Sept. 30	Wave				Oct. 08	Wave			Oct. 11	Wave			
Oct. 03	Wave				Oct. 10	Wave			Oct. 14	Wave		Gilda	
											10/08	Bravo/Fran	
											10/10	Dep.	
Oct. 07	Wave				Oct. 16	Wave	10/18						
Oct. 12	Wave				Oct. 18	Wave	10/19						
Oct. 15	Wave				Oct. 21	Wave			Oct. 26	Wave			
Oct. 18	Wave				Oct. 28	Wave	10/29						
								10/27	Oct. 28	ITC			
Oct. 25	Wave				Nov. 04	Wave	11/05						
											10/26	Dep.	
Oct. 30	Wave				Nov. 06	Wave	11/07						
		11/08			Nov. 09	ITC	11/10						
		11/07	ITC	11/13									
								11/17	Nov. 17	Dep.			

* "Dep." indicates depression.

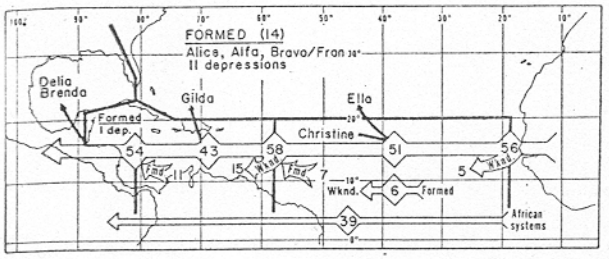

FIG. 1. Summary of the tropical systems that passed three key stations (Dakar, Barbados, and San Andres) in 1973 and those maintaining their identity while crossing the Atlantic and Caribbean.

TABLE 2. Summary of 1973 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	54	6	0	0	0	60
ITCZ	0	7	0	8	0	15
Depressions	2	(2)	14	3(2)	1	20(4)
Named storms	0	(2)	(2)	(2)	(1)	(7)
	56	13(4)	14(2)	11(4)	1(1)	95(11)

from the Antilles resulted in 54 seedlings entering Central America.

The depression tracks for the months April through November are shown in Fig. 2. The first four depressions of the year (two in April and two in May) were associated with the remains of old polar fronts and never acquired tropical characteristics. Three of the depressions warranted special consideration. During the past several years baroclinic depressions have been designated as subtropical storms and identified by letters of the phonetic alphabet if winds strengthen to gale force. In August, an upper tropospheric cold low penetrated downward to the surface between Hatteras and Bermuda and was designated Alfa when winds reached gale force off the mid-Atlantic coast. This system weakened before making landfall in Maine and produced no deaths or damages. A second sub-

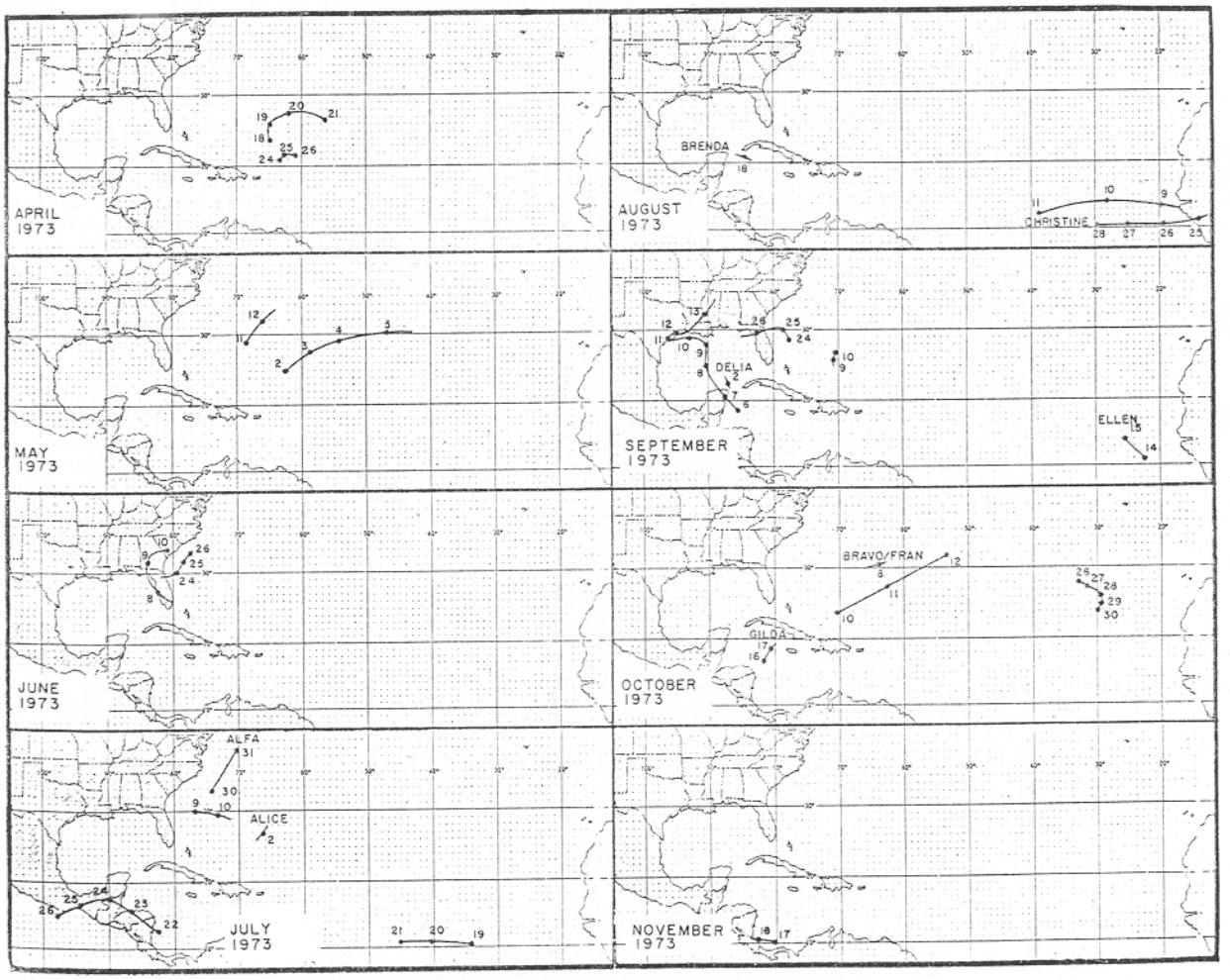

FIG. 2. Tracks of depressions in 1973.

tropical storm, Bravo, was spawned by a low level baroclinic zone southeast of Bermuda in October; Bravo later acquired a warm core and was redesignated Hurricane Fran. This type of transformation is fairly common and has been observed several times in the last four years.

A rare development sequence gave birth to a third subtropical storm in late October which was never phonetically designated in the interest of maintaining simplicity in our public warnings. Gilda formed over the northwest Caribbean, drifted northward across Cuba and lost tropical characteristics north of the Bahamas as winds decreased to less than gale force. The central pressure began falling again on 24 October as the remains of Gilda assumed the features of a large, severe subtropical cyclone.

Perhaps the most noteworthy depression of the year was one that developed near Swan Island in September as Delia lashed the northwest Gulf of Mexico. This depression moved towards the northwest and lingered on the Texas coast near Galveston for three days. This system produced 15 inches of rainfall over coastal regions of southeast Texas that had been saturated five days earlier by rains associated with Delia. The rainfall associated with this depression raised the crop losses associated with Delia to 15 million dollars.

Fig. 3 summarizes the source of eastern Pacific storms and hurricanes. Three-fourths of the storms were initiated by seedlings whose origin was on the Atlantic side of Central America, and half of the storms were triggered by African disturbances. Three of the storms formed along the Pacific ITCZ.

3. Comparison with other years

Table 3 compares the tropical systems in 1973 with averages determined over the previous five years within several categories. The total number of systems in 1973 was slightly less than the five years average. The year

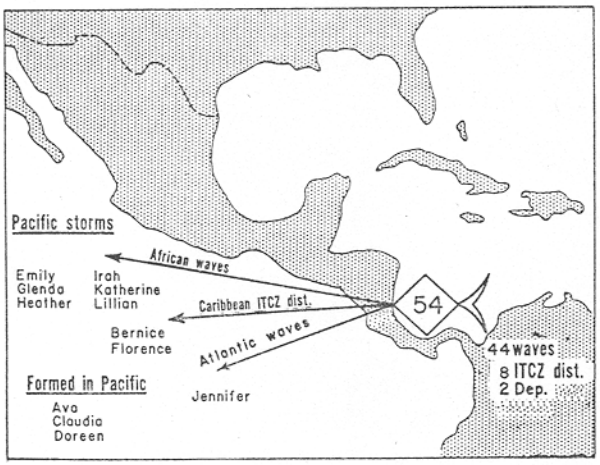

FIG. 3. Summary of the type of seedlings that initiated Pacific storms in 1973.

TABLE 3. Five-year summary of tropical systems within several categories compared with the results for 1972.

	1968	1969	1970	1971	1972	5-year average	1973
Total systems, all types	107	105	85	103	113	103	95
Dakar systems	57	58	54	56	57	56	56
Barbados systems	59	44	53	56	56	54	58
San Andres systems	40	43	45	58	49	47	54
Depressions	19	28	24	23	24	24	24
Named storms	7	13	7	12	4	9	7

to year variation seen in the first row of Table 3 is partly real and partly a consequence of our counting procedure. Years featuring strong systems may produce seasonal totals that will be less than years with weak disturbances because of the uncertainty in maintaining the continuity of weak systems. For example, when a weak disturbance emerges from Africa, it is generally associated with a poorly organized cloud pattern and the trans-Atlantic track is difficult to determine. In this case our rules would show the African system dissipating over the Atlantic. Later on if there is evidence of a system moving through the Antilles we would indicate a second development even though we realize this could be the African disturbance, and the counting scheme would register two systems. If the system had been strong it would have been counted as one and the systems in 1973 tended to be strong. A measure of this can be seen in the percentage of African systems tracked to the Caribbean and Pacific. Fig. 1 shows that 39 African systems were tracked to the Pacific. This is the highest number we have seen in our six years of experience.

One of the most remarkable results of our work is the consistency in the yearly number of African systems. This can be seen in Table 3 which shows annual variation over the last 6 years has been less than 5%. Apparently the environmental conditions that are so important for intensification to storm strength have very little control over the number of seedlings developing within the heart of the tropics. There is much greater variation in the number of seedlings forming over the subtropical latitudes, where the influence of the baroclinic westerlies is directly felt.

One parameter that we are finding very useful in evaluation of the character of a hurricane season is the nature of seedlings initiating the depressions and named storms. The results for the past seven years are shown in Table 4. The seedlings have been grouped under two main categories. African systems and disturbances that form primarily along the ITCZ have been listed under the tropical category. The second category of seedlings includes those forming over the subtropics from baroclinic sources either in the upper or lower troposphere. These are frequently referred to as subtropical cyclones.

The story of the 1973 hurricane season is well summarized in Table 4. Half of the depressions were initiated by the tropical type seedlings and half by baroclinic seedlings. If we disregard 1972, which was a very anomalous year, we see that during the prior five-year period approximately 75% of both the named storms and depressions were spawned by tropical type seedlings and 25% by baroclinic seedlings. If the statistics for the period from 1967 to 1971 are related to long-term values, then 1973 was also anomalous in that a greater percentage of the depressions formed over subtropical waters. The statistics shown in this table suggest that a very good indicator of the tropical character of a hurricane season is the simple ratio of the number of tropical depressions to the number of baroclinic depressions. A curve of this index is shown in Fig. 4. Low values of this ratio indicate a high number of baroclinic depressions and we have observed this is generally associated with anomalous baroclinic conditions over the tropics. The low values for the past three years with a minimum in 1972 are consistent with the lull observed in storm activity.

TABLE 4. Summary of the type of seedling that initiated Atlantic named storms and depressions during the years 1967 through 1972 compared with the results for 1973.

Year	Tropical		Baroclinic		Totals
	African systems	Disturbances	Upper troposphere	Lower troposphere	
			Named Storms		
1967	4	3	0	1	8
1968	2	3	1	1	7
1969	7	3	2	1	13
1970	4	2	1	0	7
1971	6	1	4	2	13
1972	1	0	1	2	4
6-year average	4	2	1.5	1	8.5
1973	3	3	0	1	7
			Depressions		
1967	15	5	4	5	29
1968	8	5	3	3	19
1969	11	8	3	6	28
1970	17	2	3	4	26
1971	11	1	7	4	23
1972	6	0	6	12	24
6-year average	11	3.5	5	5.5	25
1973	5	7	4	8	24

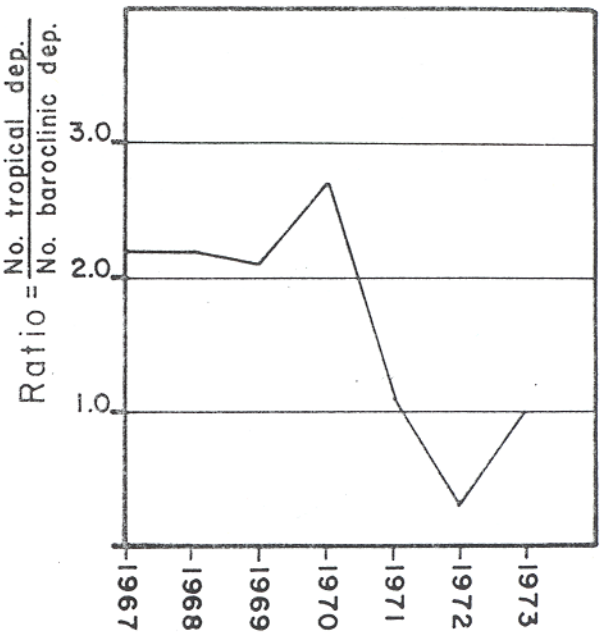

FIG. 4. Time graph of the ratio of the number of "tropical-type" depressions to the number of "baroclinic-type" depressions.

REFERENCES

Hebert, Paul J., and Neil L. Frank, 1974: Atlantic Hurricane Season of 1973. *Mon. Wea. Rev.*, **102**, 280–289.

Simpson, R. H., Neil L. Frank, David Shideler, and H. M. Johnson, 1968. Atlantic Tropical Disturbances, 1967. *Mon. Wea. Rev.*, **96**, 251–259.

——, ——, ——, ——, Atlantic Tropical Disturbances of 1968. *Mon. Wea. Rev.*, **97**, 240–255.