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Atlantic Hurricane Season of 1972

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ABSTRACT—A general overview of the 1972 hurricane season in the North Atlantic is presented together with detailed accounts of all named tropical cyclones.

1. GENERAL SUMMARY

The 1972 hurricane season was notable for at least three reasons. First, fewer tropical storms and hurricanes formed in the Atlantic than in any season since 1930, despite the fact that essentially the same number of hurricane seedlings were observed as in 1971 when above-normal storm activity occurred. Only two tropical cyclones occurred in 1930 and only three in 1929. Secondly, in 1972 as in 1971, most of the tropical cyclones developed in temperate latitudes, Agnes being the only one to form in the Tropics. There were no severe hurricanes, and only Betty had sustained winds of more than minimal hurricane force.

Finally, 1972 will be remembered as the year of record hurricane damage. Hurricane Agnes, following a 700-mi overland excursion after its landfall in northwest Florida, was responsible for the most damaging floods ever recorded when excessive rains fell in Pennsylvania, Maryland, and Virginia. Property damage in the United States attributed to Agnes is estimated to be near $3.1 billion. However, less than 120 lives were lost. Major damage occurred in western Cuba due to torrential rains, and seven lives were lost there.

In addition to the tropical cyclone activity, further experience was gained during 1972 with small, circular, hybrid cyclones, referred to in earlier articles as neutercanes (Simpson and Hope 1972, Simpson and Pelissier 1971). Aircraft reconnaissance provided details of circulation, and other sources of information shed new light on the structure and unstable energetics of these interesting, elusive, but potentially dangerous marine storms. Some of this information will be presented below.

Of more than casual interest are the circumstances that led to such an inactive hurricane season. In 1971, with about the same number of seedlings as in 1972 (Frank 1973), three times as many tropical storms formed (fig. 1). One reason for the lack of storm activity may have been the below-normal sea-surface temperatures in the region from the Lesser Antilles to Africa during much of the hurricane season. A typical example is given in figure 2. During this period the sea-surface temperatures in the extreme eastern Pacific were well above normal and tropical cyclones occurred there in greater numbers, larger sizes, and greater strength than normal. Figure 3 shows the temperature anomalies for the figure 2 temperatures. A second reason for inactivity was the persistently large vertical shear of the horizontal wind in the customary cyclogenetical areas of the Tropics during most of the season, as shown in figure 4. In contrast, however, the shear was appreciably smaller and sea-surface temperatures were more favorable for development in temperate latitudes of the Atlantic (Gray 1967). The unusual shear resulted mainly from strong west winds in the upper troposphere, which maintained a high percentage of steadiness.[1] Under these conditions, convective releases of latent heat in tropical disturbances do not remain sufficiently pooled in deep tropospheric columns to cause falling surface pressure and systematic development of mass circulation. Finally, the intertropical convergence zone and its attendant vorticities did not migrate northward with the equatorial trough in the eastern Atlantic or western Caribbean Sea as the season progressed. The reasons for this are not clearly apparent from information available, but some evidence suggests that this may have been a response to circulation anomalies in the Southern Hemisphere.

With the exception of Agnes, which developed from a disturbance that moved eastward from the Yucatan Peninsula on June 14, all of the 1972 tropical cyclones developed in temperate latitudes from disturbances located within or adjacent to a baroclinic circulation environment. While three of the four named storms reached hurricane intensity, they accounted for a total of only 8 hurricane days. Except for 1970, which had only 7 hurricane days, this year had the lowest total in the last three decades. The lowest pressure observed in any storm during the season was 976 mb. In storms other than Agnes, four lives were lost and damage to property was $1.78 million. Figure 5 shows the tropical cyclones of 1972, and table 1 summarizes the statistics of these four storms.

Bulletins were issued on three small, circular hybrid cyclones (neutercanes) and one larger subtropical cyclone. These were identified in 1972 by names from the phonetic alphabet for the first time. Figure 6 shows the tracks of these cyclones. Alfa, having its origin in a large-scale (Palmén type) cold Low, initially moved northeastward off the Florida coast to near Hatteras, N.C., where its progress was blocked by a developing high-pressure ridge. As this cold Low system was displaced southwestward by the ridge, an intense, small, low-pressure center developed rapidly, and, late on May 25, it attained winds of gale force. The extremely small center moved inland just

[1] During the annual NOAA hurricane review conference in November 1972, R. C. Gentry reported a steadiness of 200-mb winds over the Caribbean of 85–90 percent in August and September.

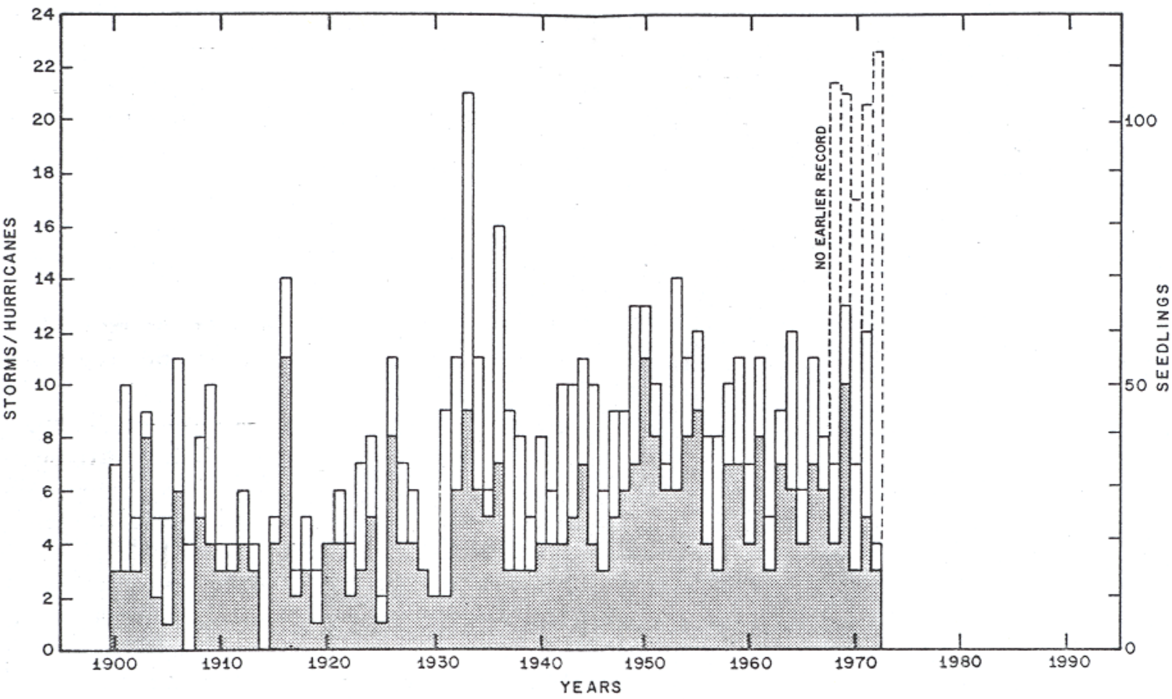

FIGURE 1.—Frequency of North Atlantic hurricanes (shaded) and tropical storms and hurricanes (unshaded) for the period 1900–72 and of seedlings for the period 1968–72 (Frank 1973).

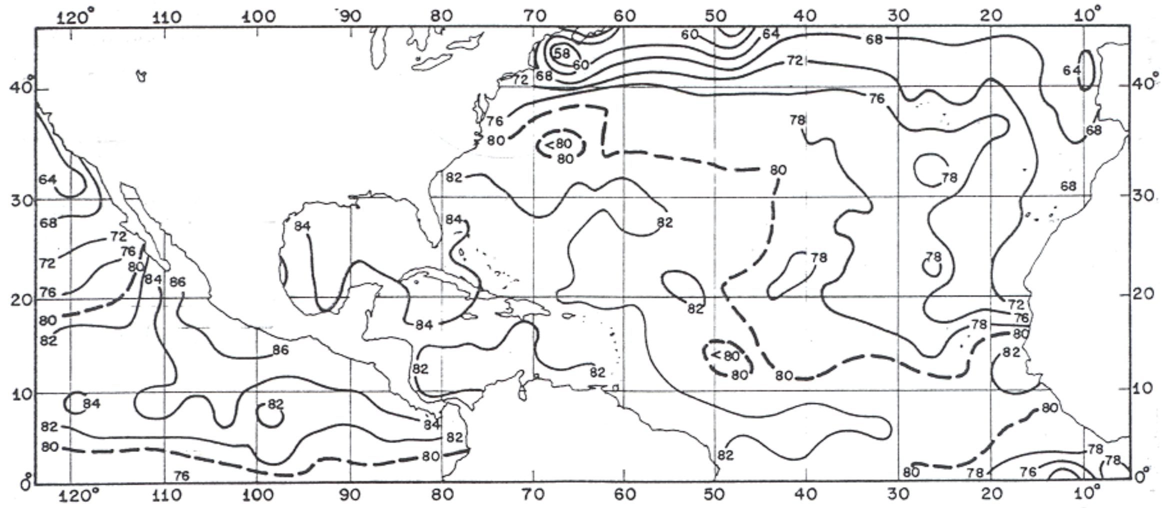

FIGURE 2.—Sea-surface temperature field (°F) for the North Atlantic and eastern North Pacific for the period Aug. 8–18, 1972. The 80°F isotherm indicates the Palmén threshold for hurricane development (Palmén 1948).

south of Brunswick, Ga., late on the 27th with sustained winds of 45 kt affecting a very small area. The microbarograph trace for Alfa from Fernandina Beach, Fla., characteristic of a tropical storm, is presented in figure 7.

Bravo developed on August 22 in a region of frontolysis as a very small cyclone, 30–40 mi in diameter. It moved slowly eastward, grew in size and strength, gradually acquired the structure of a tropical cyclone, and later became hurricane Betty. The reconnaissance of this system on August 25 showed some progress in acquiring a typical tropical structure. On this day, the ATS 3 satellite picture (fig. 8) showed not only the expanding well-organized circulation of Bravo, but also a secondary small neutercane to the west that after less than a day of existence failed to develop and disappeared.

Charlie, in contrast to the growth pattern of Bravo, formed on September 19 as a very small, circular cyclone moving initially northward, then rapidly evolved into a near-record extratropical cyclone with minimum pressure of 946 mb.

Delta developed in the mid-Atlantic from a cold Low, meandered southwestward and southward from the 35th to 30th parallel, then eastward, gradually losing its identity after 5 days.

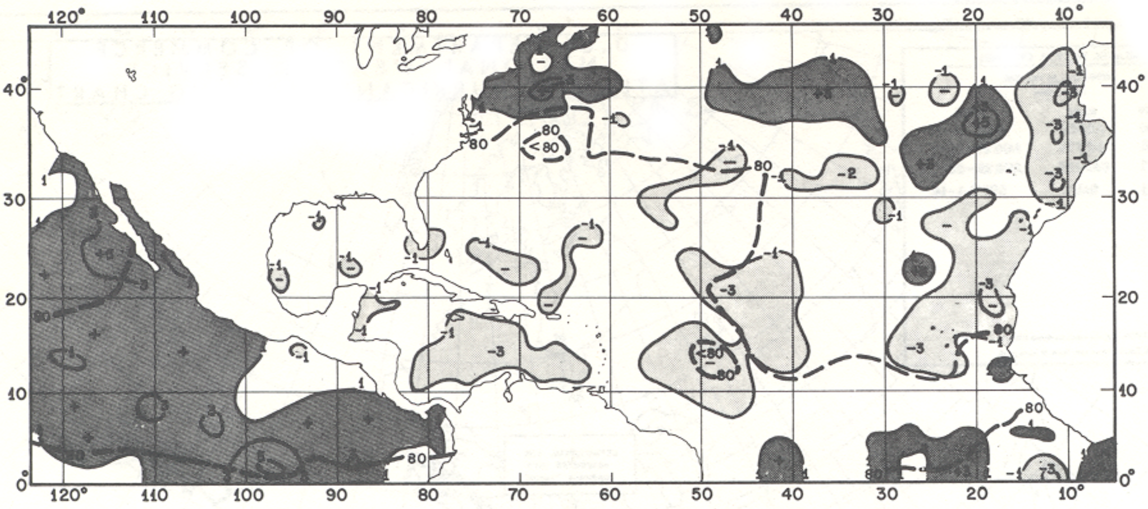

FIGURE 3.—Sea-surface temperature anomalies for figure 2, based on an objective analysis (Jarvinen 1973) and monthly normals (1941–71) from the Scripps Institution of Oceanography, La Jolla, Calif.

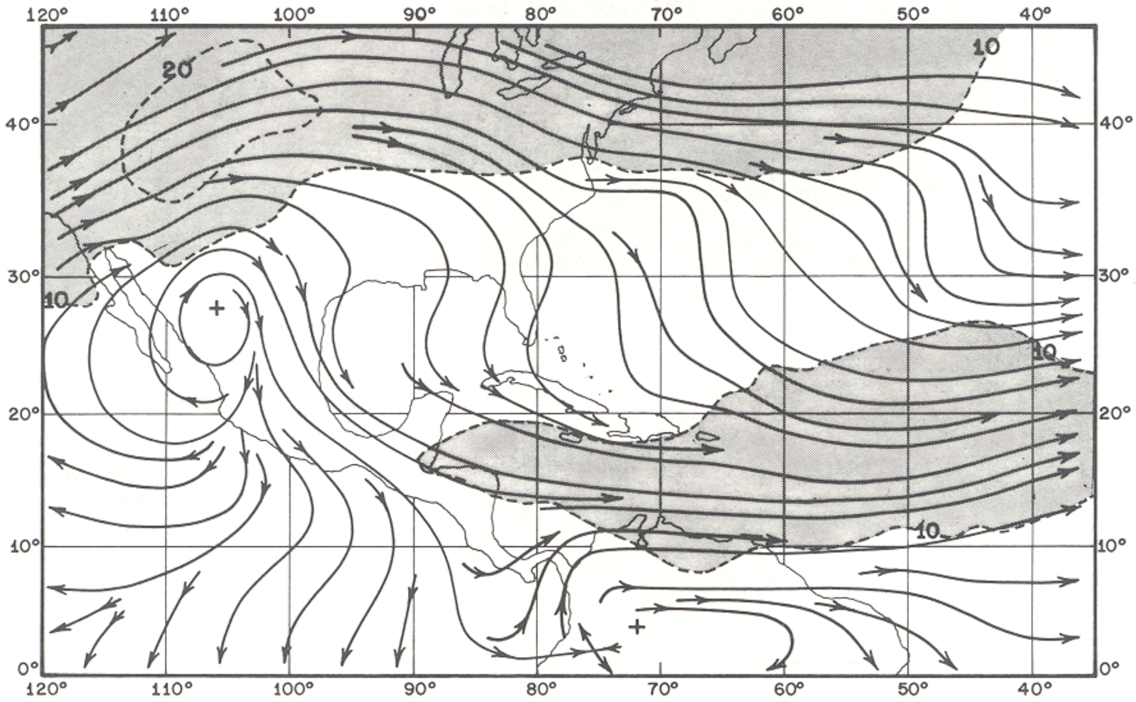

FIGURE 4.—NHC tropospheric mean wind shear field (600-to 200-mb upper mean minus the 1000-to 600-mb lower mean) for the period Aug. 15–Sept. 15, 1972.

All the midget cyclones were initially circular, and all formed between the 30th and 40th parallels with different metamorphosis of structure.

2. INDIVIDUAL STORMS

Hurricane Agnes, June 14–22

The life history of Agnes is most appropriately divided into two parts—one, a June hurricane that developed, strengthened, and moved to its landfall on the coast of the Florida panhandle in close accord with climatological expectancy, and the other, a dissipating tropical depression which, having moved inland, became rejuvenated under the stimulus of a vigorous baroclinic environment.

The *one* unusual feature of Agnes in the Gulf of Mexico—a circulation envelope 1,000 n.mi. in diameter, making it one of the largest June hurricanes of record—was maintained after the storm moved inland. The enormous moisture supply and near-saturated conditions in this large circulation were enhanced as the center proceeded northward, making the difference between what might have been a localized flooding condition and the record-breaking floods that did occur.

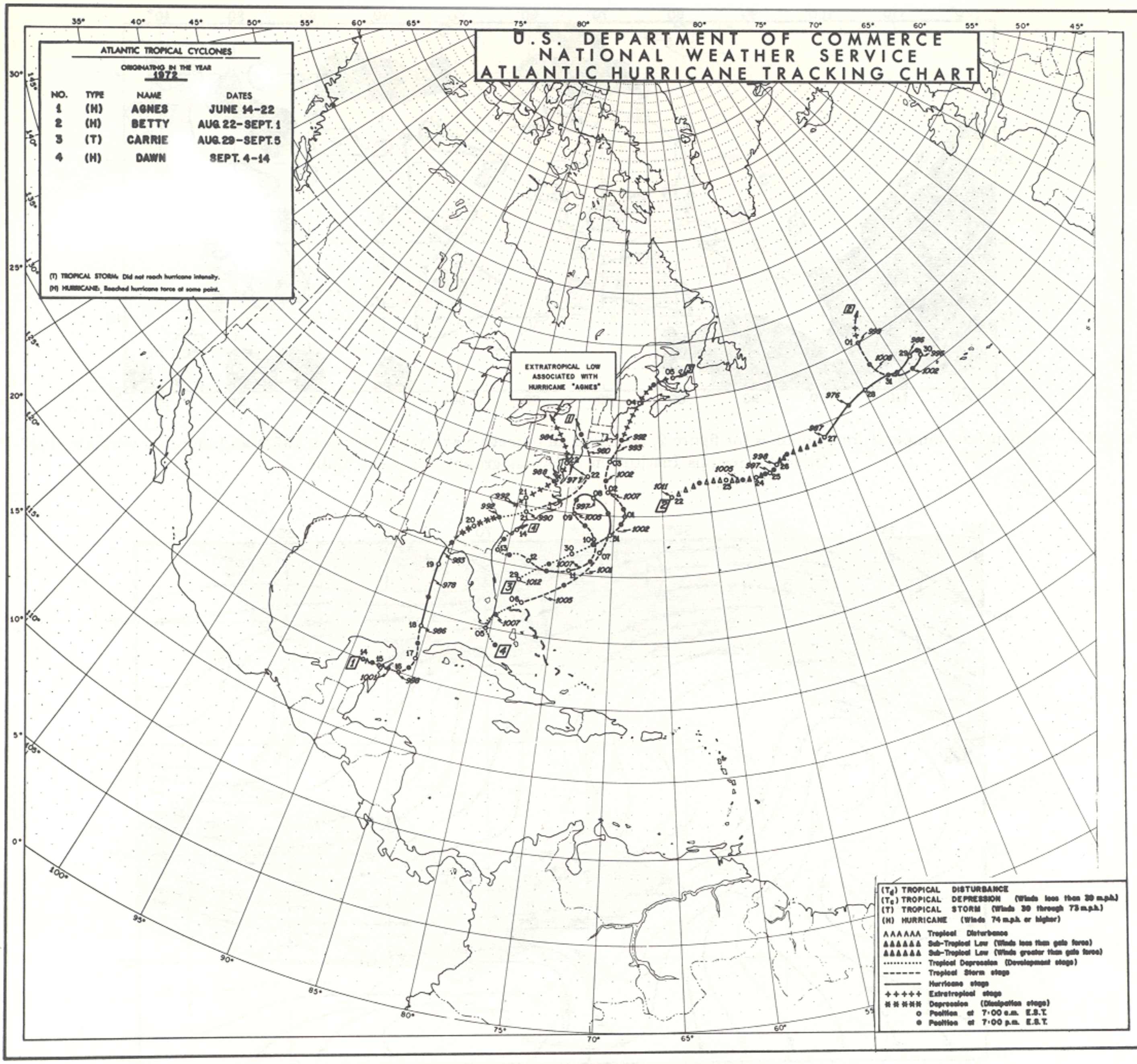

FIGURE 5.—Tracks of Atlantic tropical storms and hurricanes of 1972.

TABLE 1.—*Summary of North Atlantic tropical cyclone statistics, 1972*

Name	Date	Maximum sustained wind (kt)	Lowest pressure (mb)	U.S. damage ($ millions)	Deaths
1. Agnes (H)	June 14–22	75	977	3,097	U.S. 117 Cuba 7
2. Betty (H)	Aug. 22–Sept. 1	90	976		
3. Carrie (T)	Aug. 29–Sept. 5	60	992	1.78	U.S. 4
4. Dawn (H)	Sept. 4–14	70	997		

Hemispheric circulations and anomaly patterns during June prior to Agnes progressed in a manner favoring hurricane development in the western Caribbean Sea (Hebert and Miller 1969). On the synoptic scale, banded convection first appeared over the northwestern Caribbean Sea on June 11. A fairly strong baroclinic zone was established between the Yucatan and Florida peninsulas during the next 3 days as a weakening polar front and its associated upper trough moved to southern Florida and the western Bahamas. As the trough moved eastward, tropospheric wind shears over northern Yucatan and adjacent waters decreased, and the convective warming process led to localized pressure falls near Cozumel on the 14th. The strong depression that resulted moved eastward from the Yucatan peninsula on the 15th. Although military reconnaissance aircraft reported squalls of 40 kt and higher as early as the 14th, the ATS 3 film loops and reconnaissance reports on the 15th revealed only a poorly organized central area with no sustained winds of tropical storm strength. However, the depression reached tropical

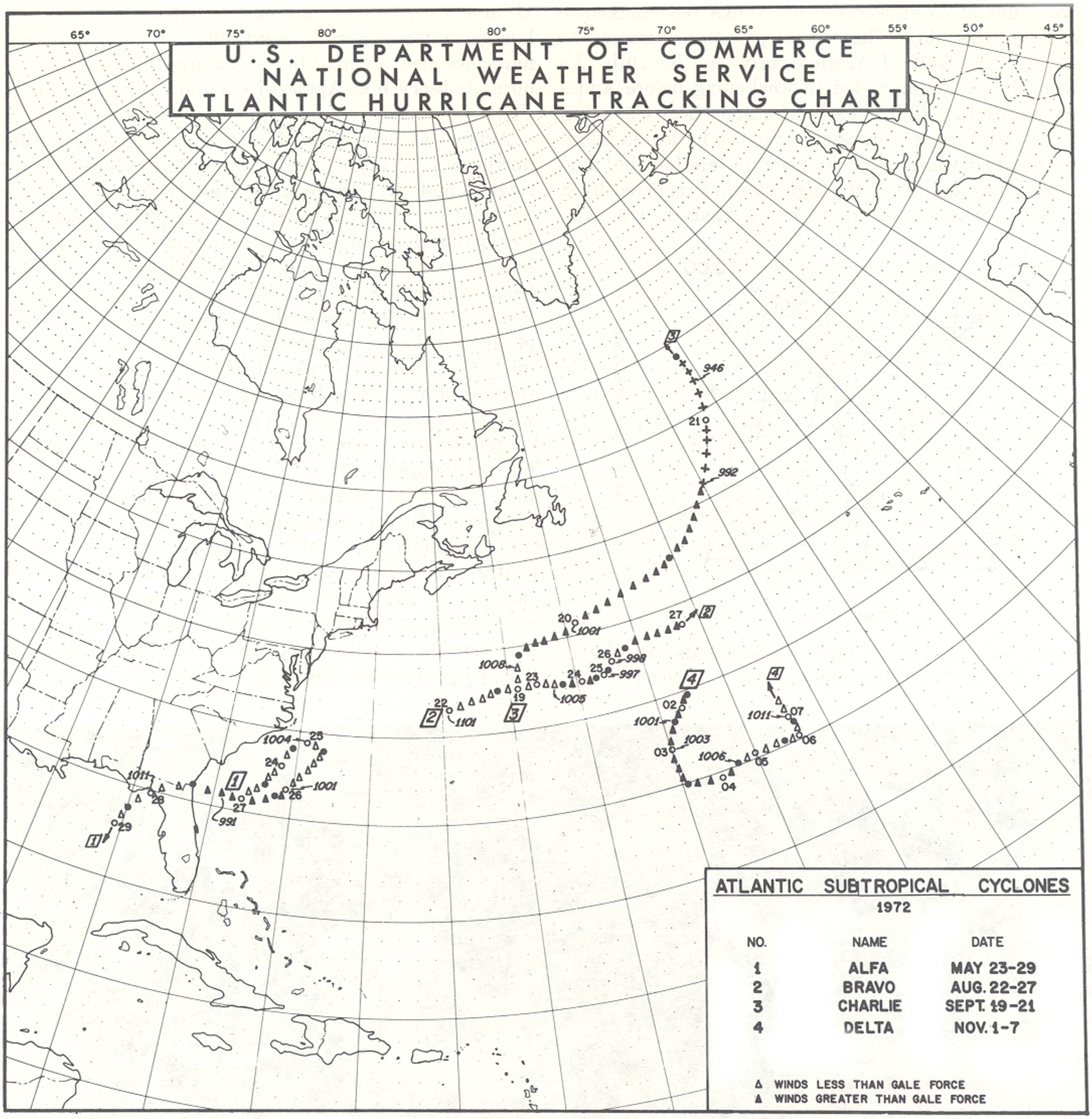

FIGURE 6.—Tracks of Atlantic subtropical cyclones of 1972.

storm strength while drifting eastward that night and was named early on the 16th.

Satellite pictures on the 16th revealed an extension of the disturbed weather area from the Agnes center eastward to Puerto Rico and northeastward more than 2,000 n.mi. into the Atlantic, associated with the lingering shear line and trough extending to the northeast of the storm center. With the growth of Agnes, a second organized convective system evolved within this extensive belt of disturbed weather, initially about 450 n.mi. south-southwest of Bermuda, and persisted as a strong depression throughout most of the life cycle of Agnes.

Figure 9 is an ATS 3 picture made on the 17th showing two well-defined circulation systems. The depression developed gale-force winds in squalls, posing a grave threat and causing considerable damage to some boats involved in the biennial Newport to Bermuda Yacht Race.

On a larger scale, this depression served to enhance the influx of moisture and saturated air into Agnes as the latter proceeded northward over land. As late as the 23d, this extensive, persistent band of disturbed weather east of Agnes spawned still another depression 1,000 n.mi. east of Bermuda.

Agnes became a hurricane on the 18th with sustained surface winds of 75 kt reported by NOAA reconnaissance aircraft late that day. The central pressure decreased to 978 mb in the Gulf of Mexico early on the 19th. An unfavorable environment led to weakening before Agnes made its initial landfall in early afternoon near Cape San Blas, Fla. Military reconnaissance reports indicated maximum sustained winds of 65 kt prior to landfall, but further weakening occurred; the highest wind reported by a land station was a gust to 48 kt at Apalachicola, Fla.

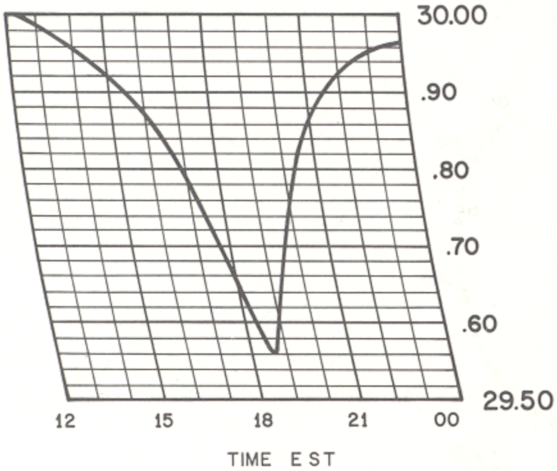

FIGURE 7.—Fernandina Beach, Fla., barogram on May 27, 1972, as subtropical cyclone Alfa moved inland just to the north.

Despite this, little doubt exists that sustained winds of hurricane force were present offshore (not only reconnaissance measurement but also storm tides of 6.4 ft above normal observed at Apalachicola and 7.0 ft at Cedar Key, Fla.).

Agnes was reduced to depression strength as it turned northeastward into Georgia on the 20th. However, as the ridge of high pressure over the western Atlantic continued to build, a major extratropical trough approached the weakening depression. Agnes' circulation experienced renewed acceleration as a result of a release of fresh energy from baroclinic sources, and the central pressure again fell. Early on the 21st, a secondary Low center developed west of the old Agnes depression center. The two Lows then moved in tandem. This complex system again reached tropical storm strength late on the 21st while the centers were still over land in North Carolina. The secondary Low center remained inland and ultimately became dominant, but not before the Agnes center moved offshore near Norfolk, Va., that evening to almost regain its previous strength. Military reconnaissance flights reported maximum sustained winds of 60 kt on the 22d, and the lowest central pressure recorded in Agnes (977 mb) was observed just off the New Jersey coast. The two centers turned northward and westward under the steering influence of a cold Low that had developed over the lower Ohio valley. The seaward center crossed the western tip of Long Island,

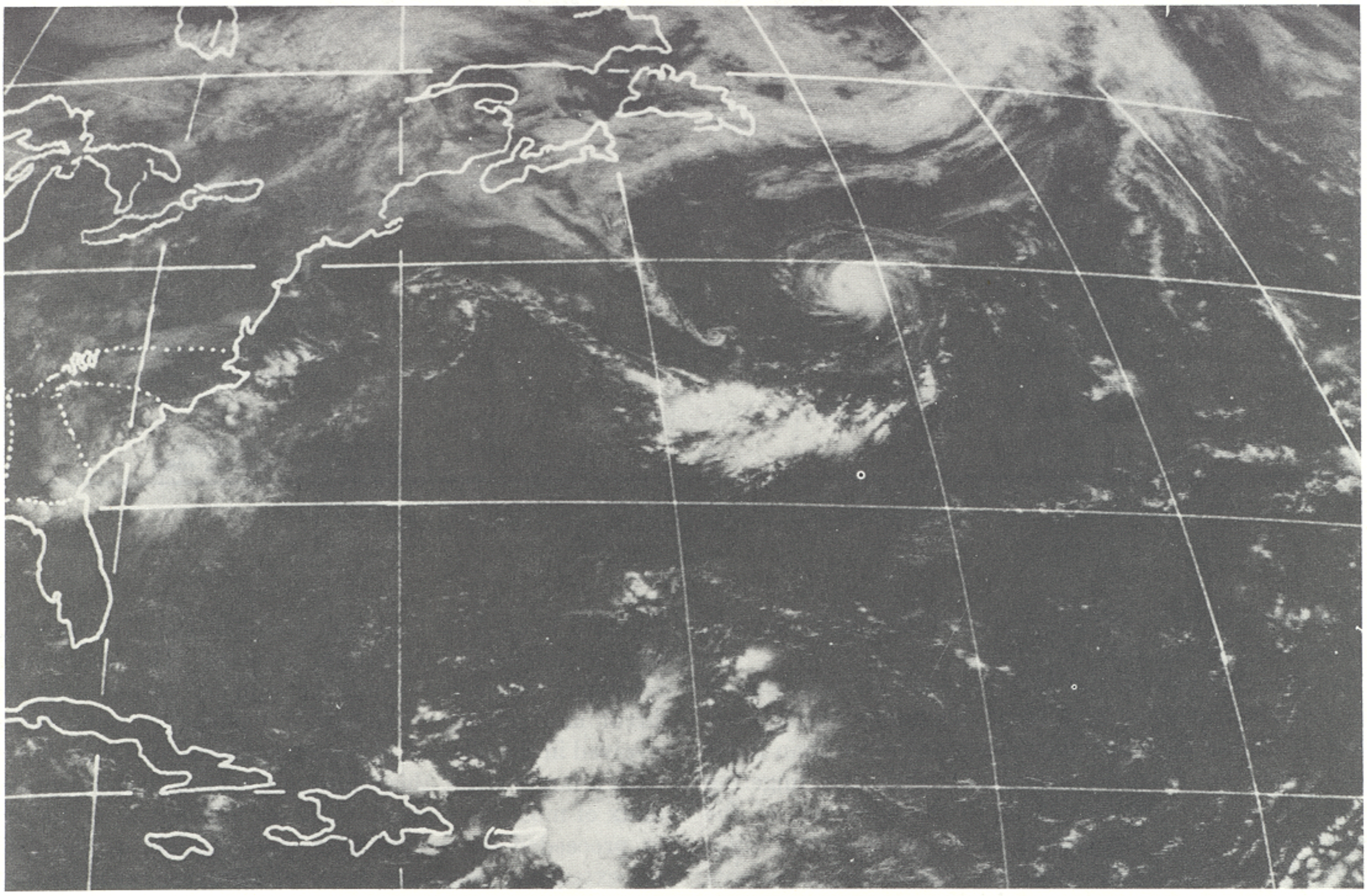

FIGURE 8.—Enlargement of ATS 3 satellite photograph for 1301 GMT, Aug. 25, 1972, showing subtropical cyclone Bravo and a secondary smaller system to the southwest.

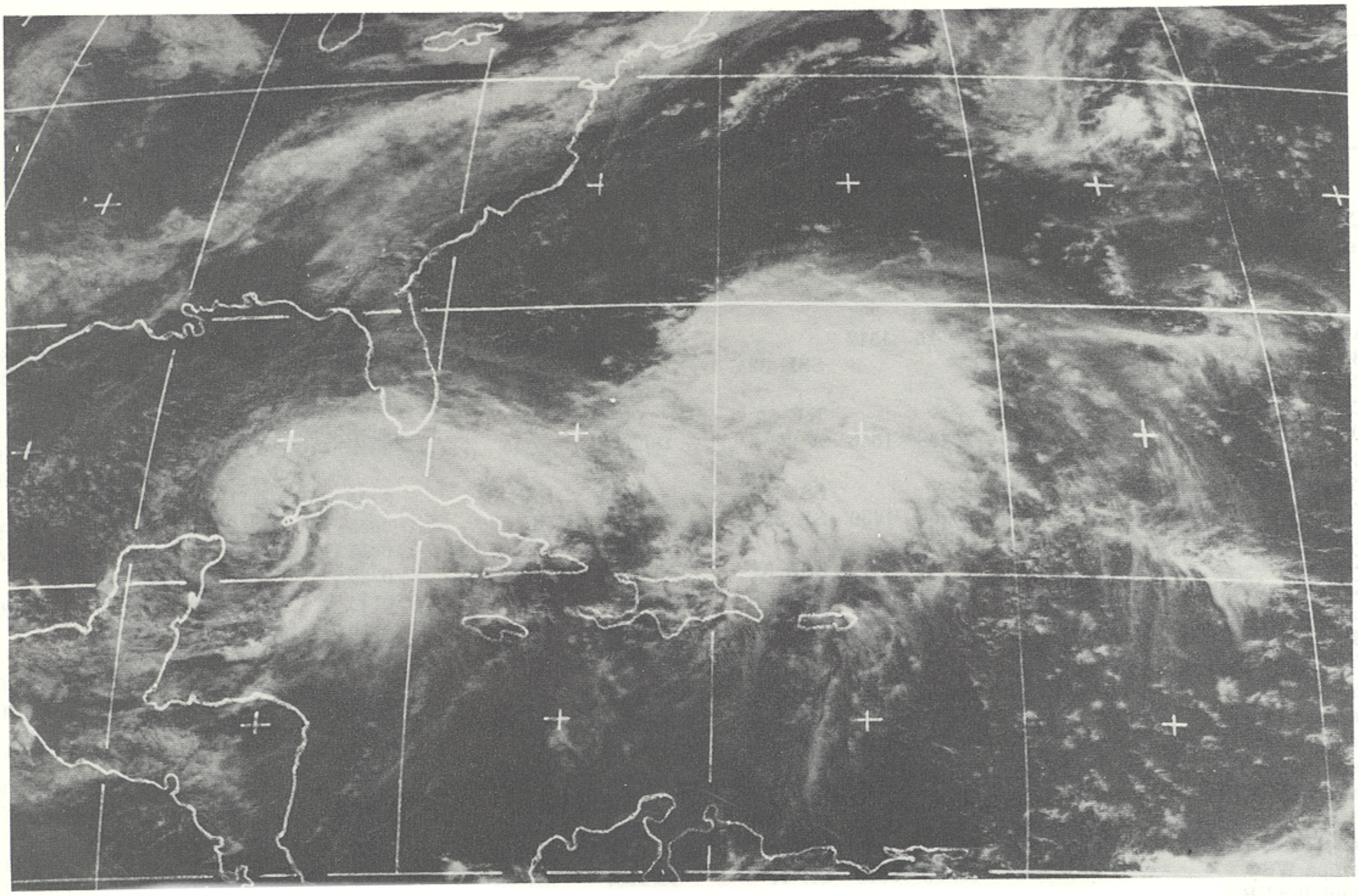

FIGURE 9.—Blowup of ATS 3 satellite photograph for 1331 GMT, June 17, 1972, showing hurricane Agnes and a large convective system to the east that spawned a tropical depression on the 18th.

N.Y., on the afternoon of the 22d and was absorbed that night over Connecticut into the circulation of the dominant secondary Low center, which had moved to northeastern Pennsylvania.

Satellite pictures gave evidence that the primary rain shield associated with Agnes as it crossed the Florida panhandle was transported into the Atlantic early on the 21st. The radar at Athens, Ga., observed a rapid decline of precipitation late on the 20th, and less than 4 in. of rain fell in Georgia during the passage of Agnes. With the formation of the secondary low center on the 21st, however, rainfall inland began to increase in response to baroclinic releases of energy. Six to 10 in. of rain fell over North Carolina and New York and 10–14 in. fell over broad areas of Virginia, Maryland, and Pennsylvania.

It is difficult, if not impossible, to determine how much of the rainfall might have occurred separately from the baroclinic system had Agnes not been located to the east. As in the case of hurricane Diane of 1955, the already saturated soil and the effect of the topography were also factors in producing the devastating floods. Regardless of the energy sources and circulation dynamics that caused the floods, however, this devastation could not have occurred without the extreme importations of moisture to the area by the depression that had been hurricane Agnes. Thus, the damage due to river floods, far exceeding the combined losses from Camille in 1969 and Betsy in 1965—previously the two most destructive storms of history—must be charged to Agnes, the greatest natural disaster of all times in terms of dollar losses.

The only deaths and significant damage not produced by river floods occurred in Florida as a result of tidal flooding, tornadoes, and windstorms. Tides of 3–5 ft above normal caused some damage from Fort Myers to the Tampa Bay area with more extensive damage around Apalachicola and Cedar Key with the 6- to 7-ft tides. Windstorms around Lake Okeechobee late on the 18th accounted for six of the nine deaths in Florida. A total of 15 tornadoes occurred in Florida on the 18th and 19th with two additional tornadoes in Georgia on the 19th.

Table 2 gives the meteorological data associated directly with Agnes although some rainfall amounts are included from South Carolina northward. Detailed information on the rainfall and river stages elsewhere can be found in climatic data publications of the National Climatic Center at Asheville, N.C.

Forecasts and warnings issued while Agnes was in the Gulf of Mexico were unusually accurate. The vector displacement error for 24-hr predictions averaged about 50 n.mi., less than half the long-term average. The 24-hr landfall error for the Florida coastline was less than 15 n.mi., and the time of landfall was within 2 hr. The hur-

TABLE 2.—*Hurricane Agnes, meteorological data, June 14–22, 1972*

Station	Date	Pressure (in.)		Wind (mi/hr)				Highest tide (ft above normal)	Time (EST)	Storm rainfall (in.)	Dates
		Low	Time (EST)	Fastest mile	Time (EST)	Gusts	Time (EST)				
Cuba											
Cape San Antonio										15. 32	13–18
Isle of Pines										16. 76	13–18
Florida											
Apalachicola WSO	19	29. 15	1512			E 55*	0612	6. 4	1512	3. 40	18–20
Big Pine Key	18			SSE 32	1140	SE 50	1200	1. 2		8. 43	17–20
Cedar Key	19					55†		7. 0		2. 31	
Crestview FAA	19			NE 39	0958						
Daytona Beach WSO	19	29. 68	1656	E 29	18/2237	E 45	0312	1. 7‡	0057	4. 37	18–19
Everglades										7. 30	17–20
Flamingo	18			SSE 42	0735	SSE 56	0700	2. 0		1. 89	
Fort Myers WSO	18	29. 65	1630	SE 25	0955	SE 53	0955	3. 0		5. 55	17–19
Jacksonville WSO	19			E 39	0637	SE 56	0637	2. 8		5. 36	18–20
Kennedy S/C	19			SSE 52	0330	SSE 69#	0330			6. 27	
Key West WSO	18	29. 59	0310	SE 43	0519	E 52	0144	1. 2	1430	6. 19	17–20
Lakeland WSO	18			SE 33	1828	SE 55	1816			4. 59	
Miami WSMO	18			ESE 25	2228	SE 36	1523			0. 92	
Naples										8. 97	17–20
Orlando WSO	18			ESE 30	2013	E 41	1928			5. 28	18–19
Panama City	19			NNE 35	0200	NNE 44	0200	3. 4		3. 10	
Panama City FAA	19	29. 16¶	1600	NE 40	0700						
Pensacola NAS	19	29. 44	1355	NNE 35	0737	NNE 49	0648			2. 58	18–19
Pensacola WSO	19	29. 45	1700	NNW 23	1556	N 43	1423	1. 7	0658	2. 34	18–20
St. Petersburg FAA	19	29. 58¶	0353	S 29	0850	S 48	1455	4. 1		2. 79	
Tallahassee WSO	19	29. 27	1709	S 31	1757	SSE 46	1817			7. 17	18–20
Tampa WSO	19	29. 59	0600	SE 27	18/2057	SE 43*	18/2048	5. 0	1115	3. 47	18–19
Tyndall AFB (Panama City)	19	29. 11	1458	NE 40	0655	NE 53	0655			5. 66	18–19
West Palm Beach WSO	18			E 32	1632	E 46	1632			1. 97	17–19
Alabama											
Dothan FAA	20	29. 26	2200	N 29	19/2157	N 43	19/2157			3. 93	19–21
Mobile WSO	19	29. 59	1745	N 22	1457	N 35	1452	1. 3	0330	1. 08	19
Georgia											
Albany FAA	20	29. 30	0555							4. 54	19–21
Augusta WSO	20	29. 32	1800	E 24	19/2010	E 35	19/1957			3. 70	19–21
Brunswick FAA	20	29. 47	1558			E 52	19/1056			8. 55	19–21
Macon WSO	20	29. 40	1010	E 33	19/1537	NE 35	19/1555			3. 18	19–20
Savannah WSO	20	29. 38	1800	E 37	19/1349	E 48	19/1340			3. 95	19–21
South Carolina											
Beaufort MCAS	21	29. 31	0200	SE 29	19/1941	ESE 46	19/1901			4. 11	19–21
Charleston WSO	21	29. 30	0400			E 40	19/2234	7. 0**		3. 10	19–21
Columbia WSO	21	29. 30	0300	E 24	19/2255	E 32	19/2254			4. 19	19–21
Florence FAA	21	29. 24	0400	WNW 23	1354	WNW 44	1354			3. 61	19–21
Greer WSO	21	29. 38	0200	E 21	20/0200	N 29	20/2156			5. 89	19–21
Myrtle Beach	21	29. 23	0700	WNW 29	1136	NW 46	1350			1. 57	19–21
North Carolina											
Cape Hatteras WSO	21	29. 13	1755	WNW 37	2158	WNW 62	2155			0. 43	20–21
Elizabeth City FAA	21	29. 11	1758	SSE 23	0600	SSW 35	1159				
Greensboro WSO	21	29. 30	0700	NW 26	0804	NNW 30	0747			5. 43	19–21
Raleigh WSFO	21	29. 25	0956	N 24	1256	WSW 31	22/1555			2. 92	19–21
Rocky Mount FAA	21	29. 18	1358	NNW 23	1555	NNW 35	1555			3. 11	20–21
Wilmington WSO	21	29. 20	1055	SE 26*	20/1038	SE 37	20/1004			2. 52	19–21
Virginia											
Chesapeake L/V	21	29. 12	2300								
Langley AFB	21	29. 11	1855	NNW 35	22/0055	NW 54	22/0058			0. 57	22–23
Norfolk WSO	21	29. 10	2000	NW 42	22/0037	NW 54	22/0032	1. 2	1730	0. 33	20–23
Richmond WSO	21	29. 14	1658	NW 31	1905	NW 32	1858			3. 28	20–23

See footnotes at end of table.

TABLE 2.—Concluded

Station	Date	Pressure (in.)		Wind (mi/hr)				Highest tide (ft above normal)	Time (EST)	Storm rainfall (in.)	Dates
		Low	Time (EST)	Fastest mile	Time (EST)	Gusts	Time (EST)				
District of Columbia											
Andrews AFB, Md.	21	29. 26	1855	NNW 29	2230	NNW 46	0209			5. 57	21–22
Dulles Int'l. AP, Va.	21	29. 29	1555	NNW 25	1855	N 50	1853			13. 65	20–23
Washington Nat'l. AP	21	29. 23	2215	NW 43	2317	NW 49	2203			8. 16	20–23
Maryland											
Assateague	22			SW 20	1100	SW 50	0800	4. 0		3. 14	21–23
Baltimore WSO	22	29. 24	0042	NW 37	0116	NW 39	0155			6. 41	20–23
Kentmorr Marina	22			NW 50	0224	NW 63	0212				
Ocean City CGS	22	29. 09	0400	W 52	0730			3. 0	1500		
Patuxent NAS	21	29. 12	2358	NNW 25	22/0158	NNW 43	22/0257			3. 53	21–23
Salisbury FAA	22	29. 07	0256	NNW 37	0700	NW 57	0708			3. 83	21–23
Delaware											
Dover AFB	22	29. 12	0355	NW 46	0928	NW 67	0918			3. 17	20–23
Indian River Inlet CGS	22	29. 12	0500	NW 46	1100	NW 50	1200	1. 5			
Wilmington WSO	22	29. 12	0807	NW 35	1055	WNW 51	1133			4. 94	21–23
New Jersey											
Atlantic City WSO	22	29. 01	0900	WNW 31	1255	W 49	1227	2–3		2. 12	22–23
Trenton WSO	22	29. 00	1300	SW 29	2018					2. 51	21–23
New York											
JFK Int'l. AP WSO	22	28. 98	1451	WSW 32	1651	WSW 47	1712			1. 25	21–23
LaGuardia Fld. WSO	22	28. 98	1454	NE 41	0848	WSW 44	1747	2. 9‡	1300	1. 22	21–23
New York City WSO	22	28. 99	1450	NE 36	0843	NE 55	0839	3.1††	1107	1. 86	21–23
Connecticut											
Hartford WSO	22	29. 00	1730	S 29	1931	S 46	1923			1. 62	22–23
New Haven FAA	22	29. 00	1712	SSW 29	2047	SW 40	1945				
Rhode Island											
Providence WSO	22	29. 11	1559	S 26	1928	S 38	1923	3. 2	1700	0. 26	22

*More than one occurrence
†Estimated
‡Above mean sea level
¶Altimeter setting
**Above mean low water
††Battery Park
#Upper limit of recorder

Note: Portions of the data in this table were furnished courtesy of Environmental Data Service, NOAA (DeAngelis and Hodge 1972).

ricane warning area issued at 1800 EDT on June 18 from St. Marks to the Panama City Beaches was one of the smallest of record. The forecast height and area of the maximum storm surge verified quite well. The weakening of the hurricane as it approached the coast did not verify hurricane force winds, but the recorded storm tides more than justified the hurricane warnings. Gale warnings with Agnes were issued elsewhere in Florida from Key West to Dry Tortugas and along most gulf coastal sections. As the center reintensified over North Carolina, gale warnings were issued on the 21st from Savannah, Ga., to Block Island, R.I.

Less well-forecast was the reintensification of the storm center while over land, the increased intensity of rainfall, and the attendant record-breaking floods. For such a disaster, the loss of life was low.

Hurricane Betty, August 22–September 1

The first evidence of the disturbance that was to develop into hurricance Betty appeared on the 21st in satellite pictures as a bright convective area within an old frontal zone about 250 n.mi. north-northwest of Bermuda. On the 22d, the SS *Visurgis* (OETK) reported southerly winds of 35 kt at 1200 GMT, backing to southeasterly 35 kt at 1500 GMT. The disturbance was designated subtropical cyclone Bravo on the 23d as ship reports suggested winds had reached gale force, and a closed circulation was more evident on ATS 3 pictures. The small size of some of these systems was revealed by the SS *Dordrecht* (PDRW), which reported 3-hourly isallobaric changes of 7–10 mb with a closed 1016 mb isobar of less than 125 n.mi. in diameter. During this development period, the northern portion of a middle tropospheric trough off the east coast moved eastward, leaving a cold Low east of the Georgia coast. Data from weather ship *Hotel* (38°N, 71°W) suggested a second residual cold pool embedded in a broad warm ridge over the area. This second cold pool appeared to be the initiating mechanism for the development.

Bravo continued eastward with little change in intensity during the next 24 hr. By the morning of the 25th, however, a deepening high-level trough to the northwest together with a building ridge to the south and east had enhanced the outflow mechanism and convective processes. Military reconnaissance reports indicated that a transformation to a warm core system was in progress. The central pressure had dropped to below 1000 mb with maximum sustained winds of 45 to 50 kt. The SS *Fort d'Orleans* (FNHW) passed near the center just before daybreak, reporting squalls to 55 kt and a minimum pressure of 997 mb with a 3-hourly fall of 12.3 mb at 0900 GMT. Unfavorable northwest winds over Bravo delayed further intensification until late on the 26th when acceleration and intensification took place in advance of another deepening trough. On the morning of the 27th, military reconnaissance aircraft found a central pressure of 987 mb and maximum sustained winds of 85 kt. The first satellite picture of the day clearly showed an eye, and reconnaissance reports indicated a classic eyewall. At this time, subtropical cyclone Bravo became hurricane Betty in the north central Atlantic about 800 n.mi. west of the Azores. Records indicate that this is the highest latitude at which a storm ever first became a hurricane. Steady deepening took place until the lowest central pressure of 976 mb and maximum sustained winds of 90 kt were reported late on the 27th.

After the short-wave trough in the westerlies passed by the hurricane, unfavorable northerly winds aloft restricted the outflow of warm air from Betty with subsequent weakening. As pressures built to the east of the center, deceleration took place. By the morning of the 30th, Betty turned back to the west, after coming within 150 n.mi. of the island of Corvo in the Azores. Later that day, winds dropped below hurricane force, and by late on the 31st they were barely of tropical storm strength. The storm accelerated northward ahead of another approaching trough and deepened to 998 mb, becoming extratropical about 500 n.mi. northwest of Corvo on the morning of September 1. Military reconnaissance reports indicated that maximum winds had increased to 70 kt.

No warnings other than marine were required and no deaths or damage associated with Betty have been reported.

Tropical Storm Carrie, August 29–September 5

The seedling disturbance from which Carrie originated is not easily traceable. A strong disturbance moved off the African coast on August 15, reached the Leeward Islands on the 25th as a weak system, and then, under the influence of an upper cold Low near Hispaniola, almost disappeared. By the 28th, the complex Low that remained had drifted northwestward just off the southeast Florida coast, and convection was increasing. From thermal winds on the National Hurricane Center (NHC) shear chart, it appeared to remain a cold-core system. The disturbance began moving northward on the 29th with the approach of a trough at higher latitudes. A closed circulation in lower layers first appeared early on the 29th, and, on the 31st, military reconnaissance aircraft reported sustained winds of 45–50 kt and a central pressure of 1002 mb as the center came abreast of Cape Hatteras.

Due to an unfavorable environment, no further development occurred as the vertical shear of the horizontal wind increased with time. On September 1, the central pressure rose to 1007 mb and the strongest sustained winds were only 40 kt. These winds reached a maximum more than 100 n.mi. north of the center and were probably more the result of the increasing pressure gradient in the anticyclone north of the storm than of the energetics of storm Carrie. On satellite pictures, the storm appeared to be "torn apart." However, on September 2 Carrie gained strength again with the approach of a new trough in the westerlies. Under the influence of baroclinic processes, it began losing its tropical characteristics, and, by late afternoon, a reconnaissance plane could find no evidence of tropical properties, although the central pressure had dropped to 992 mb. The center finally crossed the coast near Eastport, Maine, on the morning of the 4th and gradually weakened as it proceeded up the Gulf of St. Lawrence.

Gale warnings were issued from Cape May, N.J., to Eastport, Maine, as the storm moved northward. The strongest wind reported along the coast was 60 kt from the north on Cape Cod and the highest measured gust was 73 kt at Point Judith, R.I. Northerly gales of 45–55 kt were reported over most of Cape Cod, and four lives were lost in that area as numerous small boats, especially at Rockport, Mass., were capsized. Gales of 35–45 kt also occurred along the Maine coast. Heavy rains of 6–9 in. fell on Cape Cod with amounts of 2–4 in. recorded in the Boston, Mass., area on September 3. Most of the $1.78 million damage associated with Carrie was in Massachusetts, with lesser amounts elsewhere on the New England coast.

Hurricane Dawn, September 4–14

Dawn was similar to Carrie in its origin, growth cycle, and subsequent weakening under the influence of unfavorable baroclinic circulations. Carrie, however, survived these unfavorable conditions while Dawn did not.

A strong tropical wave moved off the African coast on August 28, gradually weakening as it crossed the Atlantic at a rapid pace. It reached the eastern Caribbean on September 1. Here, it interacted with the semipermanent upper tropospheric trough and its movement was retarded. On September 2, upper air data showed that the disturbance had a warm core. As a trough at higher latitudes moved into Alabama on September 4, the tropical disturbance became stationary near the southeast Florida coast and convection increased—a sequence of events similar to those that occurred during the development of Carrie. Although tropospheric temperatures rose over southeastern Florida, the wind shear in the vertical also increased, inhibiting storm development. The depression resumed its northward movement on September 5, intensification began, and Dawn became a named storm the following day when a military reconnaissance aircraft reported sustained winds of 50 kt near the center 200 n.mi. east of Cape Hatteras.

As Dawn moved northeastward on September 7, the circulation in the westerlies to the north generated a cold Low near Cape Hatteras. This Low profoundly influenced the future course and development of Dawn, which reached minimal hurricane strength on the 7th and was subsequently diverted from its northeastward course, first to the west and then to the south, due to interaction with the cold Low. Maximum flight-level winds observed were 70 kt late on the 7th, although the lowest central pressure of 997 mb occurred on the morning of the 8th.

In contrast to Carrie, which was steered rapidly into New England under the influence of an approaching trough in the westerlies, Dawn remained under the influence of the cold Low, which did not relinquish its grip until Dawn had been steered southward to the 32d parallel. Thereafter, it moved westward to the Georgia and South Carolina coasts, losing strength along the way.

Dawn was a trivial hurricane with trivial consequences. However, the influence of the rapidly developing cold Low on its movement, which was not anticipated by any of the prediction techniques, resulted in the largest 24-hr prediction errors in recent years, averaging 156 n.mi.

As Dawn turned toward the coast on September 8, storm warnings were issued from Chincoteague Inlet, Va., to Morgan's Inlet, N.C., and gale warnings elsewhere from Cape May, N.J., to Cape Lookout, N.C. Gales occurred along the outer banks of Cape Hatteras, but none were reported on the mainland. No significant damage or loss of life occurred with Dawn.

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