

Preliminary Report  
Hurricane Floyd  
7 - 17 September, 1999

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18 November, 1999

Updated 9 September 2014 for U.S. damage

Floyd was a large and intense Cape Verde hurricane that pounded the central and northern Bahama islands, seriously threatened Florida, struck the coast of North Carolina and moved up the United States east coast into New England. It neared the threshold of category five intensity on the Saffir/Simpson Hurricane Scale as it approached the Bahamas, and produced a flood disaster of immense proportions in the eastern United States, particularly in North Carolina.

a. Synoptic History

Floyd can be traced back to a tropical wave that emerged from western Africa on 2 September. This system was not particularly impressive-looking, in terms of the organization of the convection shown on satellite images, but there was evidence of curvature in the cloud lines. Overall the system was broad and disorganized, yet easily recognizable as a synoptic-scale entity.

The wave proceeded westward across the eastern tropical Atlantic at about the normal speed of propagation, 6 degrees of longitude per day, with little apparent change, for several days. A center of circulation was estimated late on 5 September near 15°N 32.5°W but the cloud pattern lacked sufficient deep convection for a Dvorak classification. On 6 September, there was enough of a curved band of deep convection present so that the system was classified as a T1.0 on the Dvorak scale around 1200 UTC. A favorable upper-level outflow pattern existed over the area, and the cloud pattern became more consolidated and better organized on the 7th. Tropical Depression Eight formed about 1000 miles east of the Lesser Antilles by 1800 UTC that day.

A deep-layer ridge prevailed to the north of the cyclone and the associated steering current moved the system west-northwestward at 12-15 knots for a couple of days. When it reached a position about 750 n mi east of the Leeward Islands, the cloud pattern became sufficiently well organized for the system to become Tropical Storm Floyd around 0600 UTC 8 September. Even though large-scale conditions appeared conducive for strengthening, there was a lack of a well-defined inner core. This was evidenced by visible, infrared, and microwave imagery that showed no tightly curved banding features or a concentration of deep convection close to the center, a condition that probably prevented rapid intensification during the early stages of the tropical cyclone. Floyd slowly strengthened and became a hurricane by 1200 UTC 10 September while centered about 200 n mi east-northeast of the northern Leeward Islands.

As Floyd was nearing hurricane status, a mid-tropospheric trough in the vicinity of 60°-65°W longitude caused a slowing of the forward speed, and then a turn toward the northwest. The northwestward motion continued until the 11th, keeping the hurricane well to the northeast of the islands of the northeastern Caribbean. On the 11th, Floyd neared the southwest portion of the mid-Atlantic upper-tropospheric trough which was situated to the north of Puerto Rico, i.e. close to its climatological position. Historically, hurricanes have had difficulty strengthening in this area. Floyd's upper-level outflow was disrupted over the southern semicircle by the trough and an anticyclone over the eastern Caribbean. Consequently, after strengthening nearly to category three status early on the 11th, the hurricane weakened to 85 knots around 0000 UTC on the 12th. Early on the 12th, rising mid- to upper-tropospheric heights to the north of Floyd forced a turn toward the west. The westward turn also marked the beginning of a major strengthening episode (this phenomenon has also been observed with many past hurricanes, e.g. Andrew of 1992). Maximum sustained winds increased from 95 knots to 135 knots, and the central pressure fell about 40 mb from early on the 12th to early on the 13th. From 0600 to 1800 on the 13th, Floyd was at the top end of category four intensity on the Saffir/Simpson Hurricane Scale.

One potential contributor to the significant strengthening of Floyd was the presence of enhanced upper oceanic heat content along its track. Analyses from the Physical Oceanography Division of NOAA/AOML showed relatively high values of heat content just to the east of the Bahamas a day or two before Floyd passed through the area.

Floyd was aimed at the central Bahamas until late on the 13th, when the heading became west-northwestward. The eye passed just 20 to 30 n mi northeast and north of San Salvador and Cat Islands on the night of the 13th. Floyd's eyewall passed over central and northern Eleuthera on the morning of the 14th, and after turning toward the northwest, Floyd struck Abaco island on the afternoon of the 14th. By the time the hurricane hit Abaco, it had weakened somewhat from its peak, but Floyd was still a borderline category three/four hurricane.

As a mid- to upper-tropospheric trough over the eastern United States eroded the subtropical ridge over the extreme western Atlantic, Floyd continued to turn gradually to the right. The center of the hurricane paralleled the central Florida coast, passing about 95 n mi east of Cape Canaveral around 0900 UTC 15 September. By the afternoon of the 15th, Floyd was abeam of the Florida/Georgia border and headed northward toward the Carolinas.

Although there was a fluctuation in intensity, related to an eyewall replacement event discussed in the next section, overall the intensity of Floyd diminished from the 13th to the 15th. Environmental causes for intensity change are not entirely understood, but two large-scale factors probably contributed to a gradual decline: the entrainment of drier air at low levels from the northwest, and increasing south-southwesterly vertical shear. As Floyd neared the North Carolina coast late on the 15th, its maximum winds decreased below category three status.

After turning toward the north-northeast with forward speed increasing to near 15 knots, Hurricane Floyd made landfall near Cape Fear, North Carolina at 0630 UTC 16 September as a category two hurricane with estimated maximum winds near 90 knots. Floyd was losing its eyewall structure as it made landfall. Continuing to accelerate north-northeastward, Floyd's center passed over extreme eastern North Carolina on the morning of the 16th and over the greater Norfolk, Virginia area around 1500 UTC that day. Floyd then weakened to a tropical storm and moved swiftly along the coasts of the Delmarva peninsula and New Jersey on the afternoon and early evening of the 16th, reaching Long Island by 0000 UTC 17 September. By that time, the storm's forward speed had increased to near 29 knots. The system decelerated as it moved into New England.

By late on the 16th and early on the 17th, Floyd was becoming more involved with a frontal zone that existed along the Atlantic seaboard. The system took the form of a frontal low and thus became extratropical by the time it reached the coast of Maine at 1200 UTC 17 September. The cyclone turned toward the northeast and then east-

northeast, moving over the coast of New Brunswick late on the 17th, Prince Edward Island early on the 18th and Newfoundland late on the 18th and early on the 19th. Floyd's extratropical remnant merged with a large extratropical low over the north Atlantic and was no longer a distinct entity by 1800 UTC 19 September.

## b. Meteorological Statistics

Table 1 lists the best track positions and intensities at six-hourly intervals. Figure 1 is a display of this track.

Figures 2(a,b) and 3 depict the best track curves of maximum one-minute average "surface" (10 meters above ground level) wind speed and minimum central sea-level pressure, respectively, as a function of time. Also plotted on Figs. 2a and 3 are aircraft reconnaissance and dropsonde data from the U.S. Air Force Reserves (the Hurricane Hunters) and NOAA, estimates from analyses of surface synoptic data, as well as Dvorak-technique estimates from the Tropical Analysis and Forecast Branch, TAFB, the Satellite Analysis Branch, SAB, and the U.S. Air Force Weather Agency (AFGWC in the figures) using satellite imagery. Figure 2b also shows the best track wind speed curve, but with only *in situ* data, i.e. flight level and dropsonde wind measurements. In both Figs. 2a and 2b the flight level winds are adjusted for elevation (90% of 700 mb wind speeds, 80% of 850 mb speeds, and 85% of 1500 ft speeds), and dropsonde wind measurements above the surface are adjusted to the 10 meter level using a mean hurricane eyewall profile determined by previous dropsonde measurements .

The peak intensity of Floyd, 135 knots, is based upon roughly 90% of the highest flight level (700 mb) winds of 149 knots at 0933 UTC 13 September. Minimum dropsonde-measured central pressure was 921 mb at 1121 UTC on that date.

Floyd is estimated to have been a 90-knot hurricane at landfall in North Carolina. There was a 10 meter anemometer measurement of sustained winds of 83 knots at 0710 UTC with gusts to 106 knots at 0716 UTC taken by University of Oklahoma meteorology professor Josh Wurman near Topsail Beach North Carolina. There were also unofficial reports of peak wind gusts to 120 knots (at 8 stories elevation) at Wrightsville Beach and 104 knots at the Wilmington Emergency Operations Center.

Table 2 lists ship reports of tropical storm force or greater wind speeds associated with Floyd. Table 3 lists a selection of surface observations from land stations and data buoys. Floyd's eye passed over NOAA data buoy 41010, located about 105 n mi east-northeast of Cape Canaveral, around 0900 UTC 15 September. That buoy

reported maximum 8-minute averaged winds of 72 knots at an anemometer height of 5 meters. At least three factors would imply a higher value for the 1-minute, 10 meter wind speed from the buoy observation: 1) going from an 8-minute to a 1-minute average; 2) going from 5 meters to 10 meters elevation; and 3) the presence of waves over 50 feet high. The best track intensity of Floyd when it passed over the buoy is near 100 knots, as indicated by dropsonde and aircraft flight level wind data. The center of the hurricane passed about 25 n mi west of the Frying Pan Shoals C-MAN station located about 30 n mi southeast of Cape Fear at 0500 UTC 16 September. This station reported winds sustained at 86 knots for a 20-minute period centered at that time, at an anemometer height of 44 meters.

On 13 September, just after Floyd reached maximum strength, there was evidence of a concentric eyewall. Figure 4 is a sequence of microwave images produced by the Naval Research Laboratory. Note that in the first image, during the deepening phase, there was a dominant inner eyewall with an eye diameter of 20 to 25 n mi. Later on, after peak intensity was reached, there was some indication of a concentric eyewall, particularly in the last image of this sequence. It is interesting to note that after this period, there was an apparent eyewall replacement, as suggested in the microwave image sequence shown in Fig. 5, and in radar imagery from NOAA/WP-3D aircraft research missions (not shown). It can be seen that the inner eyewall was dissipating while Floyd was centered near Eleuthera. This corresponded to a weakening of the hurricane to near 105 knots. The outer convective ring became the new eyewall by the time Floyd was centered over Abaco, corresponding to an eye diameter near 50 n mi. Afterwards, the new eye failed to contract significantly, while Floyd re-strengthened just slightly as it reached Abaco. After the disintegration of the inner eyewall the large-scale environment, as noted in the previous section, became less favorable. Consequently, after leaving the Bahamas, Floyd never regained its former intensity and, in fact, slowly weakened.

Heavy rainfall preceded Floyd over the mid-Atlantic states due to a pre-existing frontal zone and the associated overrunning. Hence, even though the tropical cyclone was moving fairly quickly, precipitation amounts were very large. Rainfall totals as high as 15 to 20 inches were recorded in portions of eastern North Carolina and Virginia. At Wilmington, North Carolina, the storm total of 19.06 inches included a 24-hour record of 15.06 inches. Totals of 12 to 14 inches were observed in Maryland, Delaware, and New Jersey. New records were set in Philadelphia for the most amount of rain in a calendar day, 6.63 inches. In southeastern New York, rainfall totals were generally in the 4 to 7 inch range but there was a report of 13.70 inches at Brewster. Totals of nearly 11 inches were measured in portions of New England.

Storm surge values as high as 9 to 10 feet were reported along the North Carolina coast.

A number of tornadoes were sighted in eastern North Carolina. There was a confirmed tornado in Bertie County and another in Perquimans County. The latter tornado destroyed two houses and damaged three or four others. At least ten tornadoes were reported by spotters in the Newport/Morehead City County Warning area, and these apparently caused some structural damage. Four tornadoes or funnel clouds were seen in the Wilmington area, but no damage was apparent.

#### c. Casualty and Damage Statistics

There were 57 deaths that were directly attributable to Floyd, 56 in the United States and 1 in Grand Bahama Island. The death toll by state is as follows: North Carolina 35, Pennsylvania 6, New Jersey 6, Virginia 3, Delaware 2, New York 2, Connecticut 1, and Vermont 1. Most of these deaths were due to drowning in freshwater flooding. Floyd was the deadliest hurricane in the United States since Agnes of 1972.

In the United States, the Property Claims Services Division of the Insurance Services Office reports that insured losses due to Floyd totaled 1.325 billion dollars. Ordinarily this figure would be doubled to estimate the total damage. However, in comparison to most hurricane landfalls, in the case of Floyd there was an inordinately large amount of freshwater flood damage, which probably alters the two to one damage ratio. Total damage estimates range from 3 to over 6 billion dollars. *Note - in 2011 the U.S. damage estimate was revised to \$6.9 billion.*

#### d. Forecast and Warning Critique

When averaged over the entire lifetime of the hurricane, the track forecasts for Floyd were excellent. Table 4 shows the average track errors for the official forecast and for a selection of objective guidance models. It can be seen that the average official forecast errors were substantially below the most recent ten-year averages. Also, on average, the official forecasts were better than all of the guidance except the UKMI model which had average track errors that were about equal to those of the official forecasts.

Although the *overall* average official forecast errors for Floyd were extremely low, the official forecasts were just ordinary if one considers only the period when hurricane warnings were in effect for the United States,. For example, the average

24-hour track forecast error for the latter period was roughly the same as the most recent ten-year average. Official track forecasts during the latter period also had a westward bias, and were somewhat slow. For example, the 36-hour official track forecasts during the period when hurricane warnings were in effect for the United States were an average of 104 n mi too far west and 70 n mi too far south. All of the track guidance models showed a similar westward and slow bias during this period.

Official intensity forecasts were fairly good (errors of 10 knots or less) for the first couple of days of Floyd's history. However, there were some large underforecasts of intensity, by as much as 30 to 40 knots, from 10-12 September. After Floyd reached its maximum intensity, the official forecasts did not show enough weakening. From 13 September onward, the wind speed was overpredicted in the advisories at practically every forecast time interval, by as much as 30 to 40 knots, and even 50 knots in one occasion. The Statistical Hurricane Intensity Prediction Scheme, SHIPS, performed similarly.

Table 5 is a chronology of the various watches and warnings that were issued for Floyd. A hurricane warning was issued for the northwest Bahamas more than 24 hours prior to the arrival of the eyewall at Eleuthera. For the United States, practically the entire east coast (the greater Miami area northward to Plymouth Massachusetts) was put under a hurricane warning for Floyd. To the authors' knowledge, the last time such an event occurred was during Hurricane Donna of 1960. Hurricane warnings for the southeast Florida coast proved unnecessary. However, given the forecast uncertainty and the required response times for evacuations and other preparations for such a large, severe hurricane, it was prudent to issue such warnings. The hurricane warning was issued for the coast of North Carolina at 0300 UTC 15 September. This is about 26-27 hours prior to the arrival of the eyewall in the Cape Fear area. Generally, for the coasts of South and North Carolina, hurricane warnings were issued at least 24 hours before the onset of tropical storm force winds.

According to preliminary information provided to the Federal Emergency Management agency, over 2 million people were evacuated for Floyd in the United States. This is probably the largest evacuation in U.S. history.

## Acknowledgements

Some of the data in this report was furnished by local National Weather Service Offices in Miami, Melbourne, Jacksonville, Charleston, Wilmington, Newport/Morehead City, Raleigh/Durham, Wakefield, Baltimore/Washington, Mount

Holly, New York, and Taunton. Stephen Baig produced the track chart, and James Franklin produced the wind and pressure plots.



Table 1. Best track, Hurricane Floyd, 7 - 17 September, 1999

| Date/Time<br>(UTC) | Position  |           | Pressure<br>(mb) | Wind<br>Speed<br>(kt) | Stage               |
|--------------------|-----------|-----------|------------------|-----------------------|---------------------|
|                    | Lat. (°N) | Lon. (°W) |                  |                       |                     |
| 7/1800             | 14.6      | 45.6      | 1008             | 25                    | tropical depression |
| 8/0000             | 15.0      | 46.9      | 1007             | 30                    | “                   |
| 0600               | 15.3      | 48.2      | 1005             | 35                    | tropical storm      |
| 1200               | 15.8      | 49.6      | 1003             | 40                    | “                   |
| 1800               | 16.3      | 51.1      | 1000             | 45                    | “                   |
| 9/0000             | 16.7      | 52.6      | 1000             | 45                    | “                   |
| 0600               | 17.1      | 53.9      | 1003             | 45                    | “                   |
| 1200               | 17.3      | 55.1      | 1003             | 50                    | “                   |
| 1800               | 17.9      | 56.3      | 996              | 60                    | “                   |
| 10/0000            | 18.3      | 57.2      | 995              | 60                    | “                   |
| 0600               | 18.6      | 58.2      | 990              | 60                    | “                   |
| 1200               | 19.3      | 58.8      | 989              | 70                    | hurricane           |
| 1800               | 20.2      | 59.6      | 975              | 70                    | “                   |
| 11/0000            | 20.8      | 60.4      | 971              | 80                    | “                   |
| 0600               | 21.4      | 61.1      | 963              | 95                    | “                   |
| 1200               | 21.9      | 62.0      | 962              | 95                    | “                   |
| 1800               | 22.5      | 63.0      | 966              | 90                    | “                   |
| 12/0000            | 22.7      | 64.1      | 967              | 85                    | “                   |
| 0600               | 22.8      | 65.2      | 960              | 95                    | “                   |
| 1200               | 23.0      | 66.2      | 955              | 105                   | “                   |
| 1800               | 23.2      | 67.4      | 940              | 115                   | “                   |
| 13/0000            | 23.4      | 68.7      | 931              | 125                   | “                   |
| 0600               | 23.6      | 70.0      | 922              | 135                   | “                   |
| 1200               | 23.9      | 71.4      | 921              | 135                   | “                   |
| 1800               | 24.1      | 72.9      | 923              | 125                   | “                   |
| 14/0000            | 24.5      | 74.0      | 924              | 115                   | “                   |
| 0600               | 24.9      | 75.3      | 927              | 105                   | “                   |
| 1200               | 25.4      | 76.3      | 930              | 105                   | “                   |
| 1800               | 26.1      | 77.0      | 930              | 110                   | “                   |
| 15/0000            | 27.1      | 77.7      | 933              | 115                   | “                   |
| 0600               | 28.2      | 78.5      | 935              | 110                   | “                   |
| 1200               | 29.3      | 78.9      | 943              | 100                   | “                   |
| 1800               | 30.6      | 79.1      | 947              | 95                    | “                   |
| 16/0000            | 32.1      | 78.7      | 950              | 90                    | “                   |
| 0600               | 33.7      | 78.0      | 956              | 90                    | “                   |
| 1200               | 35.7      | 76.8      | 967              | 70                    | “                   |
| 1800               | 38.0      | 75.3      | 974              | 60                    | tropical storm      |
| 17/0000            | 40.6      | 73.5      | 980              | 50                    | “                   |

Table 1 (continued). Best track, Hurricane Floyd, 7 - 17 September, 1999

|         |      |      |     |    |                 |
|---------|------|------|-----|----|-----------------|
| 17/0600 | 42.1 | 72.1 | 983 | 50 | tropical storm  |
| 1200    | 43.3 | 70.6 | 984 | 45 | extratropical   |
| 1800    | 44.2 | 68.9 | 985 | 45 | “               |
| 18/0000 | 44.8 | 67.3 | 987 | 40 | “               |
| 0600    | 45.4 | 65.5 | 990 | 35 | “               |
| 1200    | 46.6 | 63.0 | 992 | 35 | “               |
| 1800    | 47.7 | 59.3 | 992 | 35 | “               |
| 19/0000 | 48.0 | 56.3 | 992 | 35 | “               |
| 0600    | 48.5 | 52.5 | 994 | 35 | “               |
| 1200    | 49.5 | 48.0 | 992 | 40 | “               |
| 1800    |      |      |     |    | merged with low |

|         |      |      |     |     |  |
|---------|------|------|-----|-----|--|
| 13/1200 | 23.9 | 71.4 | 921 | 135 | minimum pressure                           |
| 14/1200 | 25.4 | 76.3 | 930 | 105 | landfall near Alice<br>Town, Eleuthera     |
| 14/1900 | 26.3 | 77.1 | 932 | 120 | landfall near Cherokee<br>Sound, Abaco     |
| 16/0630 | 33.8 | 78.0 | 956 | 90  | landfall near Cape<br>Fear, North Carolina |

Table 2. Ship reports of 34 knots or higher wind speed associated with Hurricane Floyd, September 1999.

| date/time<br>(UTC) | ship call sign | latitude<br>(°N) | longitude<br>(°W) | wind dir/<br>speed(knots) | pressure<br>(mb) |
|--------------------|----------------|------------------|-------------------|---------------------------|------------------|
| 08/1500            | <b>PDYI</b>    | 19.0             | 52.6              | 070/39                    | 1011.1           |
| 09/0900            | <b>DFSO</b>    | 17.2             | 53.7              | 180/37                    | 1004.2           |
| 09/1200            | <b>DFSO</b>    | 16.9             | 54.5              | 210/37                    | 1005.2           |
| 09/1500            | <b>DFSO</b>    | 16.6             | 55.4              | 180/45                    | 1005.5           |
| 12/1500            | <b>DGOO</b>    | 22.7             | 69.3              | 320/35                    | 1001.5           |
| 12/1800            | <b>DGOO</b>    | 23.5             | 69.5              | 340/37                    | 998.5            |
| 12/1800            | <b>ZCAH3</b>   | 24.9             | 63.1              | 130/58                    | 1009.3           |
| 12/2100            | <b>DGOO</b>    | 24.1             | 69.8              | 030/43                    | 994.8            |
| 13/0000            | <b>DGOO</b>    | 24.5             | 69.9              | 040/45                    | 994.8            |
| 13/0300            | <b>DGOO</b>    | 24.9             | 70.3              | /52                       | 997.0            |
| 13/0600            | <b>DGOO</b>    | 25.6             | 70.5              | 040/52                    | 998.5            |
| 13/0900            | <b>DGOO</b>    | 26.3             | 70.8              | 060/52                    | 999.5            |
| 13/1200            | <b>DILD</b>    | 24.9             | 53.1              | 170/37                    | 1013.9           |
| 13/1200            | <b>DGOO</b>    | 27.0             | 71.0              | 090/52                    | 1002.9           |
| 13/1800            | <b>KHRH</b>    | 19.5             | 74.7              | 360/50                    | 994.0            |
| 13/1800            | <b>WZJF</b>    | 21.3             | 66.9              | 135/35                    | 1009.5           |
| 14/0000            | <b>PPXI</b>    | 30.6             | 74.3              | 070/50                    | 1001.0           |
| 14/0900            | <b>WGJT</b>    | 22.0             | 73.5              | 180/35                    | 998.2            |
| 14/1200            | <b>PPXI</b>    | 30.4             | 71.0              | 110/45                    | 1001.0           |
| 14/1500            | <b>PEXU</b>    | 26.7             | 70.6              | 120/37                    | 1009.2           |
| 15/0300            | <b>SHIP</b>    | 30.3             | 74.3              | 100/45                    | 1006.5           |
| 15/0900            | <b>DGOS</b>    | 29.3             | 73.8              | 130/38                    | 1004.0           |
| 15/1200            | <b>DGOS</b>    | 28.9             | 73.8              | 130/47                    | 1003.5           |
| 15/1200            | <b>PFKV</b>    | 30.6             | 74.0              | 120/38                    | 1004.4           |
| 15/1800            | <b>PFKV</b>    | 30.3             | 74.0              | 130/36                    | 1003.6           |
| 16/0000            | <b>WRGQ</b>    | 31.5             | 75.4              | 160/46                    | (898.1)          |
| 16/0300            | <b>PEXU</b>    | 29.4             | 73.9              | 190/36                    | 1008.5           |
| 16/0600            | <b>WRGQ</b>    | 31.2             | 75.2              | 200/41                    | 1001.0           |
| 16/0600            | <b>SHIP</b>    | 36.8             | 73.0              | 140/36                    | 1006.8           |
| 16/1200            | <b>WZJE</b>    | 32.0             | 71.6              | 180/38                    | 1008.5           |
| 16/1200            | <b>3ELL6</b>   | 32.0             | 72.5              | 200/36                    | 1007.2           |

Table 2 (continued). Ship reports of 34 knots or higher wind speed associated with Hurricane Floyd, September 1999.

| date/time<br>(UTC) | ship call sign | latitude<br>(°N) | longitude<br>(°W) | wind dir/<br>speed(knots) | pressure<br>(mb) |
|--------------------|----------------|------------------|-------------------|---------------------------|------------------|
| 16/1800            | <b>BKJO</b>    | 34.7             | 72.2              | 190/60                    | 1005.0           |
| 16/1800            | <b>WZJE</b>    | 32.1             | 72.3              | 210/52                    | 1009.6           |
| 16/2100            | <b>DEDI</b>    | 40.4             | 70.9              | 130/42                    | 998.0            |
| 16/2100            | <b>SHIP</b>    | 36.6             | 69.5              | 180/47                    | 1007.0           |
| 17/0000            | <b>DEDI</b>    | 40.4             | 70.8              | 140/50                    | 993.3            |
| 17/0000            | <b>SHIP</b>    | 36.6             | 68.4              | 190/40                    | 1009.5           |
| 17/0000            | <b>WAUU</b>    | 36.0             | 68.5              | 190/46                    | 1009.7           |





Table 3 (continued). Hurricane Floyd, selected surface observations, September 1999.

| Location                   | Press.<br>(mb) | Date/<br>time<br>(UTC) | Sustained<br>wind<br>(kt) <sup>a</sup> | Peak<br>gust<br>(kt) | Date<br>/time<br>(UTC) <sup>b</sup> | Storm<br>surge<br>(ft) <sup>c</sup> | Storm<br>tide<br>(ft) <sup>d</sup> | total<br>rain<br>(in) |
|----------------------------|----------------|------------------------|--|----------------------|-------------------------------------|-------------------------------------|------------------------------------|-----------------------|
| <b>Maryland</b>            |                |                        |  |                      |                                     |                                     |                                    |                       |
| Annapolis                  |                |                        |  |                      |                                     |                                     |                                    | 11.60                 |
| Cambridge                  |                |                        |  |                      |                                     |                                     | 2.5                                |                       |
| Chestertown                |                |                        |  |                      |                                     |                                     |                                    | 14.00                 |
| Lewisetta                  |                |                        |  |                      |                                     |                                     | 3.5                                |                       |
| Martin State Airport       | 989.0          |                        |  |                      |                                     |                                     |                                    |                       |
| Mid-Bay Buoy               |                |                        |  | 60                   | 16/1710                             |                                     |                                    |                       |
| Ocean City                 | 976.8          | 16/1853                | 31                                     | 45                   | 16/1653                             |                                     |                                    | 1.71                  |
| Patuxent NAS               | 991.0          |                        | 30                                     | 36                   | 16/1555                             |                                     |                                    |                       |
| Salisbury                  | 980.4          | 16/1851                | 28                                     | 42                   | 16/2150                             |                                     |                                    | 5.08                  |
| Solomon's Island           |                |                        |  |                      |                                     |                                     | 3.0                                |                       |
| St. Inigoes                | 987.6          |                        |  |                      |                                     |                                     |                                    |                       |
| Tall Timbers               |                |                        |  | 62                   | 16/2040                             |                                     |                                    | 11.10                 |
| Thomas Point Light         |                |                        | 43                                     | 49                   | 16/1300                             |                                     |                                    |                       |
| <b>Delaware</b>            |                |                        |  |                      |                                     |                                     |                                    |                       |
| Cape Henlopen              |                |                        |  | 56                   | 16/PM                               |                                     |                                    |                       |
| Greenwood                  |                |                        |  |                      |                                     |                                     |                                    | 10.58                 |
| Lewes                      |                |                        |  |                      |                                     | 2.6                                 | 6.76                               |                       |
| Vernon                     |                |                        |  |                      |                                     |                                     |                                    | 12.36                 |
| Wilmington                 | 986.0          | 16/2106                | 32                                     | 40                   | 16/2214                             |                                     |                                    |                       |
| <b>New Jersey</b>          |                |                        |  |                      |                                     |                                     |                                    |                       |
| American Corners           |                |                        |  |                      |                                     |                                     |                                    | 10.20                 |
| Atlantic City              | 980.2          | 16/2054                | 23                                     | 34                   | 16/2345                             | 2.0                                 | 6.22                               |                       |
| Caldwell/Essex Co. Airport | 987.8          | 16/2353                |  | 38                   | 16/2353                             |                                     |                                    | 10.21                 |
| Cape May                   |                |                        |  |                      |                                     | 2.6                                 | 7.36                               |                       |
| Doylestown                 |                |                        |  |                      |                                     |                                     |                                    | 10.07                 |
| Federalburg                |                |                        |  |                      |                                     |                                     |                                    | 11.20                 |
| Neshanic                   |                |                        |  |                      |                                     |                                     |                                    | 10.07                 |
| Newark Int'l Airport       | 985.1          | 16/2351                | 38                                     | 46                   | 16/2351                             |                                     |                                    | 6.22                  |
| Pequanock                  |                |                        |  |                      |                                     |                                     |                                    | 11.04                 |
| Sandy Hook                 | 981.0          | 16/2306                | 34                                     | 45                   | 17/0024                             | 1.9                                 | 6.57                               |                       |
| Somerville                 |                |                        |  |                      |                                     |                                     |                                    | 13.34                 |
| Teterboro Airport          | 985.0          | 16/2351                | 24                                     | 38                   | 16/2351                             |                                     |                                    | 8.53                  |
| Wayne/Iflows               |                |                        |  |                      |                                     |                                     |                                    | 12.21                 |
| White House                |                |                        |  |                      |                                     |                                     |                                    | 12.98                 |
| <b>Pennsylvania</b>        |                |                        |  |                      |                                     |                                     |                                    |                       |
| Philadelphia               | 985.0          | 16/2136                | 32                                     | 42                   | 16/2136                             | 2.8                                 | 9.34                               |                       |
| <b>New York</b>            |                |                        |  |                      |                                     |                                     |                                    |                       |
| Central Park               | 983.8          | 16/2250                | 25                                     | 36                   | 16/1450                             |                                     |                                    | 5.02                  |
| Farmingdale Airport        | 981.6          | 16/2353                | 23                                     | 37                   | 16/2053                             |                                     |                                    | 3.13                  |
| HPN Airport                | 985.8          | 17/0050                | 25                                     | 42                   | 16/2350                             |                                     |                                    | 6.26                  |
| Islip/MacArthur Airport    | 983.4          | 17/0156                | 27                                     | 37                   | 16/2356                             |                                     |                                    |                       |
| JFK Int'l Airport          | 982.5          | 16/2351                | 30                                     | 41                   | 17/0051                             |                                     |                                    | 3.27                  |
| LaGuardia Airport          | 983.7          | 16/2351                | 30                                     | 41                   | 17/0051                             |                                     |                                    | 4.94                  |
| MGJ Airport                |                |                        | 29                                     | 44                   | 16/2039                             |                                     |                                    |                       |
| MTP Airport                | 986.9          | 17/0254                | 22                                     | 37                   | 17/0454                             |                                     |                                    |                       |
| Newburgh/Stewart Airport   | 992.6          | 17/0045                | 34                                     | 54                   | 16/2245                             |                                     |                                    |                       |
| NWS Upton                  |                |                        |  |                      |                                     |                                     |                                    | 3.50                  |
| Westhampton Airport        | 984.8          | 17/0153                | 28                                     | 43                   | 17/0153                             |                                     |                                    |                       |
| White Plains Airport       | 985.8          | 17/0050                | 25                                     | 42                   | 16/2350                             |                                     |                                    |                       |
| <b>Massachusetts</b>       |                |                        |  |                      |                                     |                                     |                                    |                       |
| Beverly                    |                |                        |  | 31                   |                                     |                                     |                                    |                       |

Table 3 (continued). Hurricane Floyd, selected surface observations, September 1999.

| Location   | Press.<br>(mb) | Date/<br>time<br>(UTC) | Sustained<br>wind<br>(kt) <sup>a</sup> | Peak<br>gust<br>(kt) | Date<br>/time<br>(UTC) <sup>b</sup> | Storm<br>surge<br>(ft) <sup>c</sup> | Storm<br>tide<br>(ft) <sup>d</sup> | total<br>rain<br>(in) |
|--|----------------|------------------------|--|----------------------|-------------------------------------|-------------------------------------|------------------------------------|-----------------------|
| Blue Hill Observatory-Milton                         |                |                        |  | 40                   |                                     |                                     |                                    |                       |
| Boston   |                |                        |  |                      |                                     |                                     | 10.7                               |                       |
| Boston/Logan Airport                                 |                |                        |  | 38                   |                                     |                                     |                                    |                       |
| Brewster   |                |                        |  | 63                   | 17/0545                             |                                     |                                    |                       |
| Buzzards Bay   |                |                        | 47                                     | 57                   | 17/0300                             |                                     |                                    |                       |
| Fox Point Hurricane Barrier                          |                |                        |  |                      |                                     | 4.2                                 |                                    |                       |
| Hadley   |                |                        |  |                      |                                     |                                     |                                    | 9.60                  |
| Hyannis  |                |                        |  | 62                   |                                     |                                     |                                    |                       |
| Lawrence   |                |                        |  | 32                   |                                     |                                     |                                    |                       |
| Martha's Vineyard                                    |                |                        |  | 34                   |                                     |                                     |                                    |                       |
| Nantucket  |                |                        |  | 32                   |                                     |                                     | 1.3                                |                       |
| New Bedford Hurr. Barrier                            |                |                        |  | 64                   | 17/0600                             | 2.5                                 |                                    |                       |
| Norwood  |                |                        |  | 27                   |                                     |                                     |                                    |                       |
| Orange   |                |                        |  | 29                   |                                     |                                     |                                    |                       |
| Plymouth   |                |                        |  | 33                   |                                     |                                     |                                    |                       |
| Southwick  |                |                        |  |                      |                                     |                                     |                                    | 9.16                  |
| Taunton  |                |                        |  | 38                   |                                     |                                     |                                    |                       |
| Westfield  |                |                        |  | 37                   |                                     |                                     |                                    |                       |
| Worcester  |                |                        |  | 30                   |                                     |                                     |                                    |                       |
| <b>Rhode Island</b>                                  |                |                        |  |                      |                                     |                                     |                                    |                       |
| Block Island   |                |                        |  | 39                   |                                     |                                     |                                    |                       |
| Newport  |                |                        |  | 35                   |                                     |                                     | 2.6                                |                       |
| Providence   |                |                        |  | 35                   |                                     |                                     | 5.9                                |                       |
| Westerly   |                |                        |  | 31                   |                                     |                                     |                                    |                       |
| <b>Connecticut</b>                                   |                |                        |  |                      |                                     |                                     |                                    |                       |
| Bridgeport Airport                                   | 981.8          | 17/0154                | 29                                     | 39                   | 16/2254                             |                                     |                                    |                       |
| Bristol  |                |                        |  |                      |                                     |                                     |                                    | 10.80                 |
| Burlington   |                |                        |  |                      |                                     |                                     |                                    | 9.45                  |
| Danbury Airport                                      | 987.1          | 17/0153                | 15                                     | 21                   | 17/0153                             |                                     |                                    |                       |
| Groton/New London Airport                            | 986.8          | 17/0145                | 30                                     | 43                   | 17/0045                             |                                     |                                    |                       |
| Hartford Airport                                     | 985.4          | 17/0253                |  |                      |                                     |                                     |                                    |                       |
| Meriden  | 984.5          | 17/0156                |  |                      |                                     |                                     |                                    |                       |
| MMK Airport  | 986.4          | 17/0155                | 20                                     | 34                   | 17/0155                             |                                     |                                    |                       |
| New Haven Airport                                    | 983.8          | 17/0145                | 33                                     |                      |                                     |                                     |                                    |                       |
| Southington  |                |                        |  |                      |                                     |                                     |                                    | 9.14                  |
| Willimantic  | 985.8          | 17/0352                |  | 31                   |                                     |                                     |                                    |                       |
| Windsor Locks  |                |                        |  | 37                   |                                     |                                     |                                    |                       |
| <b>New Hampshire</b>                                 |                |                        |  |                      |                                     |                                     |                                    |                       |
| Manchester   |                |                        |  | 28                   |                                     |                                     |                                    |                       |
| <b>NOAA National Data Buoy Center buoys</b>          |                |                        |  |                      |                                     |                                     |                                    |                       |
| 41004 (30.5°N 79.1°W)                                |                |                        | 54                                     | 72                   | 16/0200                             |                                     |                                    |                       |
| 41009 (28.5°N 80.2°W)                                | 980.9          | 15/0900                | 52                                     | 70                   | 15/1000                             |                                     |                                    |                       |
| 41008 (31.4°N 80.9°W)                                |                |                        | 24                                     | 31                   | 15/2100                             |                                     |                                    |                       |
| 41010 (28.9°N 78.5°W)                                | 939.6          | 15/0900                | 72                                     | 91                   | 15/0700                             |                                     |                                    |                       |
| 44009 (38.5°N 74.7°W)                                | 976.0          | 16/1900                | 39                                     | 52                   | 16/1800                             |                                     |                                    |                       |
| 44014 (36.8°N 74.8°W)                                | 981.4          | 16/1600                | 50                                     | 66                   | 16/1615                             |                                     |                                    |                       |
| 44025 (40.3°N 73.2°W)                                | 980.0          | 17/0000                | 33                                     | 43                   | 17/0600                             |                                     |                                    |                       |
| <b>NOAA National Data Buoy Center C-MAN stations</b> |                |                        |  |                      |                                     |                                     |                                    |                       |
| BUZM3(41.4°N 71.0°W)                                 |                |                        | 47                                     | 57                   | 17/0300                             |                                     |                                    |                       |
| CLKN7 (34.6°N 76.5°W)                                | 974.9          | 16/0500                | 63                                     | 79                   | 16/0450                             |                                     |                                    |                       |
| DSLN7 (31.2°N 75.3°W)                                | 985.8          | 16/0730                | 69                                     | 82                   | 16/0750                             |                                     |                                    |                       |



Table 3 (continued). Hurricane Floyd, selected surface observations, September 1999

| Location              | Press.<br>(mb) | Date/<br>time<br>(UTC) | Sustained<br>wind<br>(kt) <sup>a</sup> | Peak<br>gust<br>(kt) | Date<br>/time<br>(UTC) <sup>b</sup> | Storm<br>surge<br>(ft) <sup>c</sup> | Storm<br>tide<br>(ft) <sup>d</sup> | total<br>rain<br>(in) |
|-----------------------|----------------|------------------------|--|----------------------|-------------------------------------|-------------------------------------|------------------------------------|-----------------------|
| DUCN7 (36.2°N 75.8°W) | 977.0          | 16/0900                | 67                                     | 83                   | 16/0850                             |                                     |                                    |                       |
| FPSN7 (33.5°N 77.6°W) | 958.7          | 16/0600                | 86                                     | 97                   | 16/0512                             |                                     |                                    |                       |
| SAUF1 (29.9°N 81.3°W) | 992.9          | 15/1200                | 58                                     |                      | 15/1200                             |                                     |                                    |                       |

<sup>a</sup>ASOS and C-MAN are 2 min; buoys are 8 min.

<sup>b</sup>Date/time is for sustained wind when both sustained and gust are listed.

<sup>c</sup>Storm surge is water height above normal astronomical tide level.

<sup>d</sup>Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).

Table 4.

**Preliminary forecast evaluation of Hurricane Floyd  
Heterogeneous sample**

(Errors in nautical miles for tropical storm  
and hurricane stages with number  
of forecasts in parenthesis)

| Technique                                    | Period (hours) |              |               |               |               |
|--|----------------|--------------|---------------|---------------|---------------|
|  | 12             | 24           | 36            | 48            | 72            |
| CLIP   | 40 (35)        | 88 (33)      | 148 (31)      | 206 (29)      | 312 (25)      |
| GFDI   | 36 (34)        | 71 (32)      | 97 (30)       | 115 (28)      | 153 (25)      |
| GFDL*  | 31 (30)        | 66 (30)      | 96 (28)       | 109 (26)      | 155 (24)      |
| LBAR   | 30 (34)        | 59 (32)      | 92 (30)       | 112 (28)      | 120 (24)      |
| AVNI   | 38 (35)        | 77 (33)      | 119 (31)      | 141 (29)      | 187 (25)      |
| BAMD   | 37 (34)        | 70 (32)      | 106 (30)      | 147 (28)      | 239 (24)      |
| BAMM   | 50 (34)        | 96 (32)      | 137 (30)      | 175 (28)      | 243 (24)      |
| BAMS   | 63 (34)        | 123 (32)     | 173 (30)      | 207 (28)      | 263 (24)      |
| A98E   | 35 (33)        | 72 (31)      | 113 (29)      | 120 (27)      | 174 (24)      |
| NGPI   | 39 (29)        | 69 (27)      | 101 (25)      | 123 (23)      | 146 (19)      |
| UKMI   | 29 (32)        | 54 (30)      | 66 (26)       | 76 (24)       | 97 (21)       |
|  |                |              |               |               |               |
| NHC OFFICIAL                                 | 28 (35)        | 53 (33)      | 73 (31)       | 73 (29)       | 104 (25)      |
| NHC OFFICIAL<br>1989-1998 10-year<br>average | 48<br>(2005)   | 89<br>(1790) | 128<br>(1595) | 164<br>(1410) | 242<br>(1107) |

\* GFDL output not available until after forecast issuance.

Table 5. Watch and warning summary, Hurricane Floyd, September 1999

| Date/time<br>(UTC) | Action   | Location  |
|--------------------|--|---|
| 09/2100            | Tropical storm watch issued                          | Antigua, Barbuda, Anguilla,<br>and Dutch Saint Maarten  |
| 09/2200            | Tropical storm watch issued                          | French Saint Martin and Saint<br>Barthelemy   |
| 11/0300            | Tropical storm watch discontinued                    | Antigua, Barbuda, Anguilla<br>and Dutch Saint Maarten   |
| 11/0300            | Tropical storm watch discontinued                    | French Saint Martin and Saint<br>Barthelemy   |
| 12/0900            | Tropical Storm warning and hurricane watch<br>issued | Turks, Caicos, and Southeast<br>Bahamas   |
| 12/0900            | Hurricane watch issued                               | Central Bahamas   |
| 13/0000            | Hurricane warning issued                             | Central Bahamas   |
| 13/0000            | Hurricane watch issued                               | Northwest Bahamas   |
| 13/0900            | Hurricane watch upgraded to hurricane warning        | Northwest Bahamas   |
| 13/0900            | Hurricane watch issued                               | Florida: South of Flagler<br>Beach to Hallandale  |
| 13/1500            | Hurricane watch extended                             | South to include Miami-Dade<br>County and north of Flagler<br>Beach, Florida to Brunswick,<br>Georgia |
| 13/1800            | Hurricane watch extended                             | Including Lake Okeechobee   |
| 13/2100            | Hurricane watch upgraded to hurricane warning        | Florida City, Florida to south<br>of Brunswick, Georgia   |
| 13/2100            | Tropical storm warning issued                        | Florida Keys, north of Seven<br>Mile Bridge   |
| 13/2100            | Hurricane watch issued                               | Georgia: Brunswick to<br>Savannah   |
| 14/0300            | Hurricane watch extended                             | North of Savannah, Georgia to<br>Little River Inlet, South<br>Carolina                                |

Table 5. (continued) Watch and warning summary, Hurricane Floyd, September 1999

| Date/time<br>(UTC) | Action   | Location   |
|--------------------|--|--|
| 14/0900            | Tropical storm warning discontinued                    | Turks and Caicos Islands   |
| 14/1500            | Tropical storm warning discontinued                    | Southeast Bahamas  |
| 14/2100            | Tropical storm warning discontinued                    | Florida Keys, from the Seven Mile Bridge northward   |
| 14/2100            | Hurricane warning extended                             | Georgia and South Carolina coasts to Little River Inlet, South Carolina  |
| 14/2100            | Hurricane warning downgraded to tropical storm warning | Florida: Florida City to Boca Raton  |
| 14/2100            | Hurricane watch extended                               | North of Little River Inlet, South Carolina to Cape Charles Light, Virginia, south of New Point Comfort, including Pamlico and Albermarle sounds |
| 15/0300            | Hurricane warning extended                             | North of Little River Inlet, South Carolina to the North Carolina/Virginia border  |
| 15/0300            | Hurricane warning discontinued                         | Florida: Boca Raton to Ft. Pierce  |
| 15/0300            | Hurricane watch extended                               | North Carolina/Virginia border to Chincoteague, Virginia, including Chesapeake Bay, south of Smith Point   |
| 15/0300            | Hurricane warning discontinued                         | Central Bahamas  |
| 15/0300            | Tropical storm warning discontinued                    | Florida: Florida City to Ft. Pierce  |
| 15/0600            | Hurricane warning discontinued                         | Northwest Bahamas: New Providence, Bimini, Andros, and Berry Islands   |

Table 5. (continued) Watch and warning summary, Hurricane Floyd, September 1999

| Date/time<br>(UTC) | Action  | Location   |
|--------------------|---|--|
| 15/0900            | Tropical storm watch issued                             | Chincoteague, Virginia to Cape Henlopen, Delaware, including Chesapeake Bay north of Smith Point and the Potomac from Cobb Island to Smith Point |
| 15/1200            | Hurricane warning discontinued                          | Florida: South of Sebastian Inlet to Ft. Pierce<br>Northwest Bahamas: Grand Bahama and Abaco Islands   |
| 15/1500            | Hurricane warning discontinued                          | Florida: Sebastian Inlet to Titusville   |
| 15/1500            | Tropical storm watch extended                           | North of Chincoteague, Virginia to Sandy Hook, New Jersey, including Delaware Bay  |
| 15/1700            | Tropical storm watch extended                           | North of Sandy Hook, New Jersey to Montauk Point on Long Island, New York, including Delaware Bay  |
| 15/1900            | Hurricane warning discontinued                          | Florida: Titusville to Fernandina Beach  |
| 15/2100            | Hurricane warning extended                              | North of North Carolina/Virginia border to Chincoteague, Virginia, including Chesapeake Bay, south of Smith Point                                |
| 15/2100            | Tropical storm watch upgraded to tropical storm warning | North of Chincoteague, Virginia to Sandy Hook, New Jersey, including northern Chesapeake Bay, the Potomac Basin, and Delaware Bay                |

Table 5. (continued) Watch and warning summary, Hurricane Floyd, September 1999

| Date/time<br>(UTC) | Action                          | Location   |
|--------------------|---------------------------------|--|
| 15/2100            | Tropical storm watch extended   | North of Sandy Hook, New Jersey to the Merrimack River, Massachusetts, including Long Island Sound                           |
| 16/0300            | Hurricane warning discontinued  | North of Fernandina Beach, Florida to Edisto Beach, South Carolina   |
| 16/0300            | Hurricane warning extended      | North of Chincoteague, Virginia to Cape Henlopen, Delaware   |
| 16/0300            | Tropical storm warning extended | North of Sandy Hook, New Jersey to Plymouth, Massachusetts   |
| 16/0900            | Hurricane warning extended      | North of Cape Henlopen, Delaware to Manasquan Inlet, New Jersey and from Moriches Inlet, New York to Plymouth, Massachusetts |
| 16/0900            | Tropical storm warning extended | North of Plymouth, Massachusetts to Merrimack River, Massachusetts   |
| 16/1100            | Hurricane warning discontinued  | From South Santee River, South Carolina, southward   |
| 16/1300            | Hurricane warning discontinued  | South Santee River, South Carolina to Surf City, North Carolina  |
| 16/1500            | Hurricane warning discontinued  | North Carolina: North of Surf City to Cape Hatteras  |
| 16/1800            | Hurricane warning discontinued  | Cape Hatteras, North Carolina to Cape Charles Light, Virginia, including southern Chesapeake Bay                             |

Table 5. (continued) Watch and warning summary, Hurricane Floyd, September 1999

| Date/time<br>(UTC) | Action   | Location   |
|--------------------|--|--|
| 16/2100            | Hurricane warning downgraded to tropical storm warning | Cape Charles Light, Virginia to the Merrimack River, Massachusetts, including Chesapeake Bay, the Potomac Basin, Delaware Bay, and Long Island Sound |
| 17/0300            | Tropical storm warning discontinued                    | Cape Charles Light, Virginia to Sandy Hook, New Jersey, including Chesapeake Bay, the Potomac Basin, and Delaware Bay                                |
| 17/0900            | Tropical storm warning discontinued                    | Sandy Hook, New Jersey to the Merrimack River, Massachusetts, including Long Island Sound  |

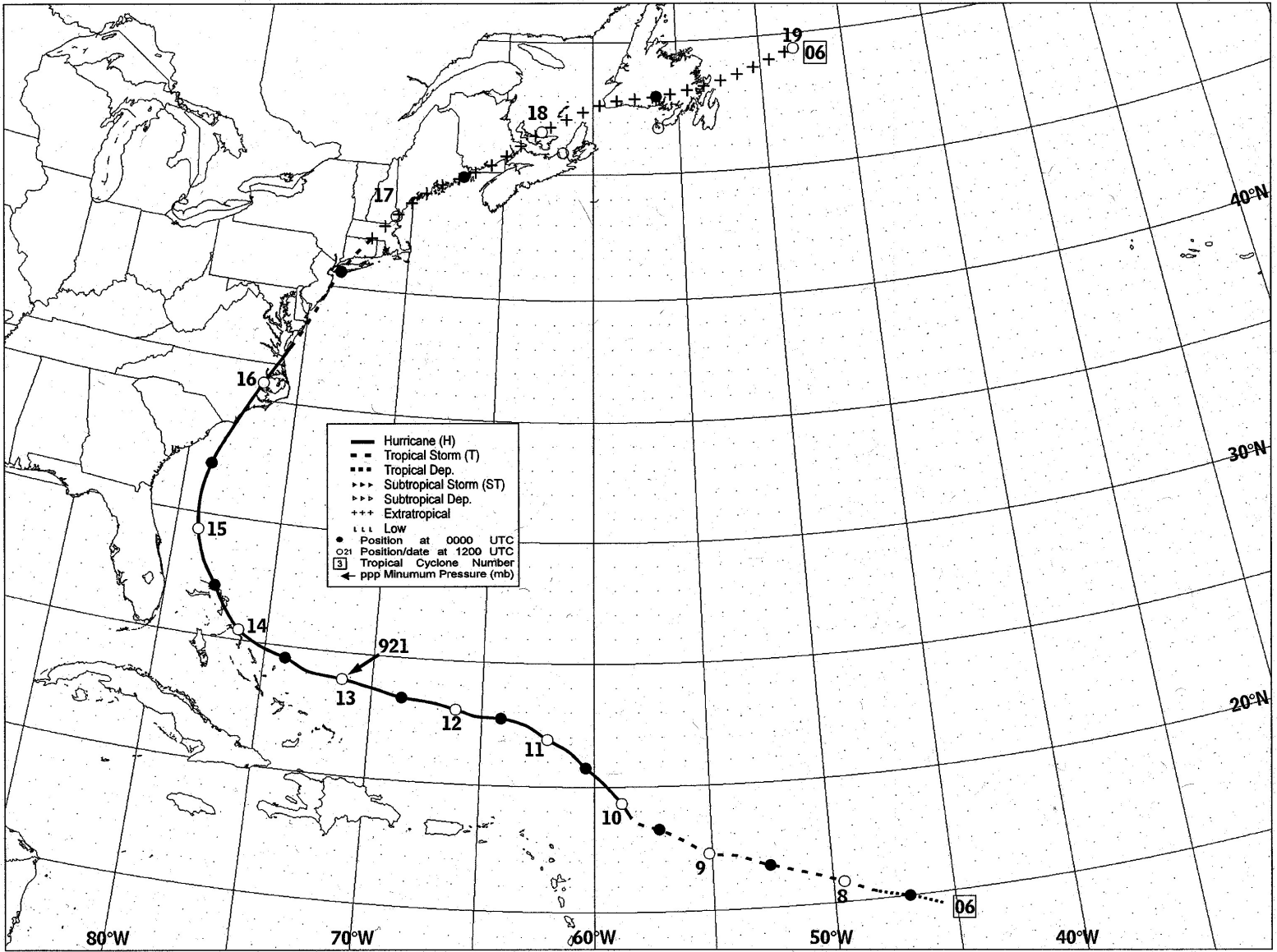


Figure 1. Best track positions for Hurricane Floyd, 07-17 September 1999.



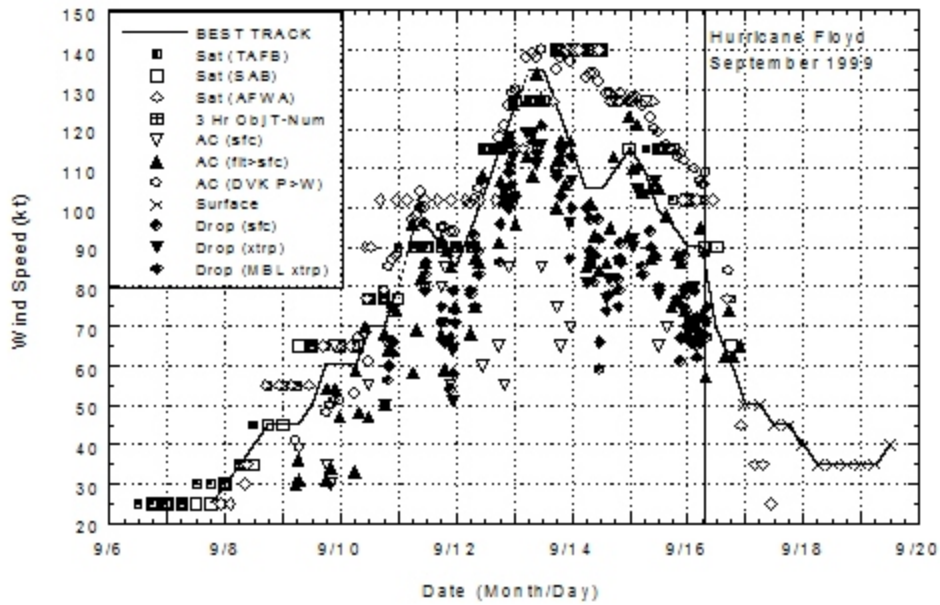


Fig. 2a. Best track maximum sustained wind speed curve for Hurricane Floyd, showing all available intensity estimates and wind observations. Aircraft wind measurements have been adjusted for elevation (90% of 700 mb wind speeds, 80% of 850 mb speeds, and 85% of 1500 ft speeds), and dropsonde wind measurements above the surface are adjusted to the 10 meter level using a mean hurricane eyewall profile determined by previous dropsonde measurements. Vertical line denotes landfall.

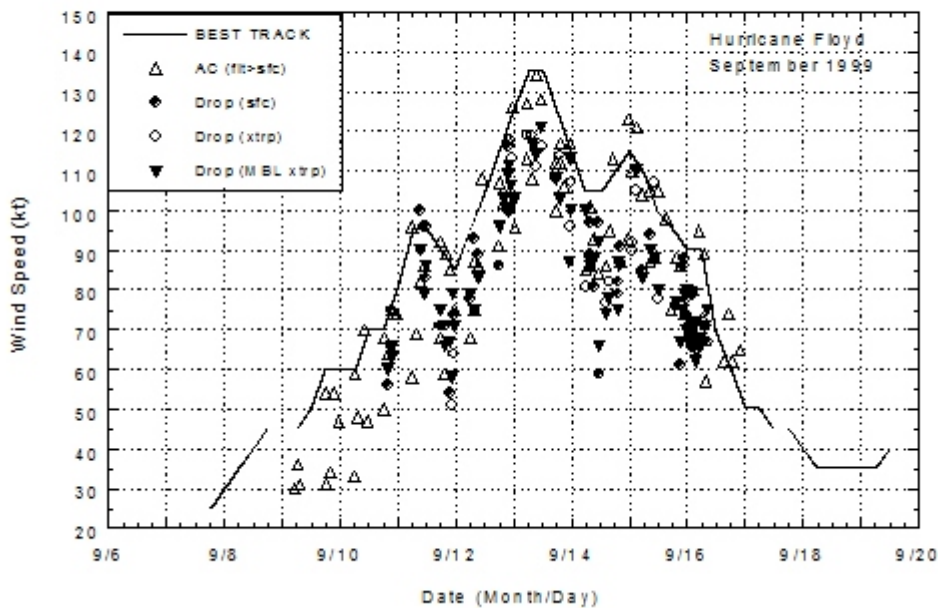


Fig. 2b. Best track maximum sustained wind speed curve for Hurricane Floyd, showing only *in situ* wind observations adjusted for elevation as indicated in Fig. 2a.

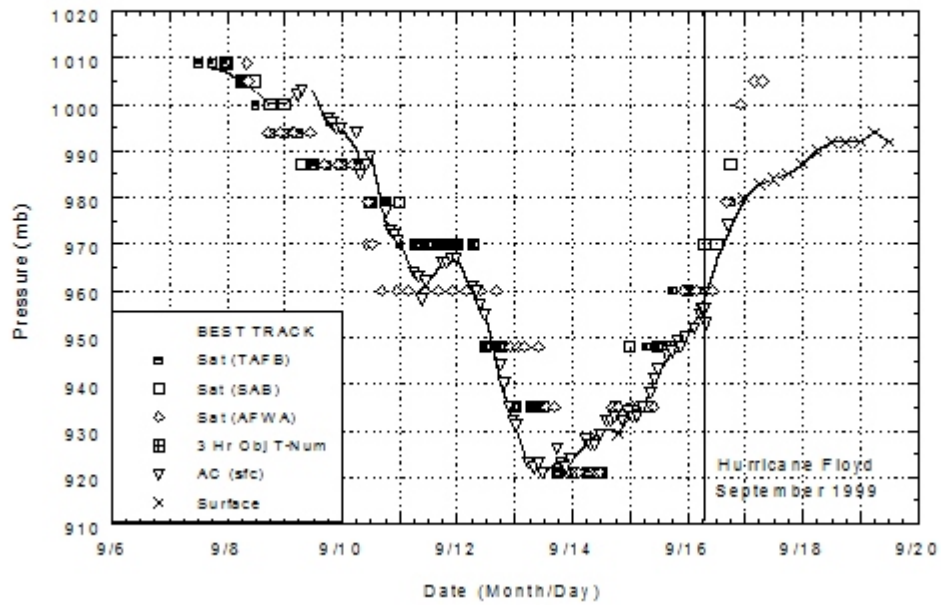


Fig. 3. Best track minimum central pressure curve and central pressure observations or estimates for Hurricane Floyd. Vertical line denotes landfall.

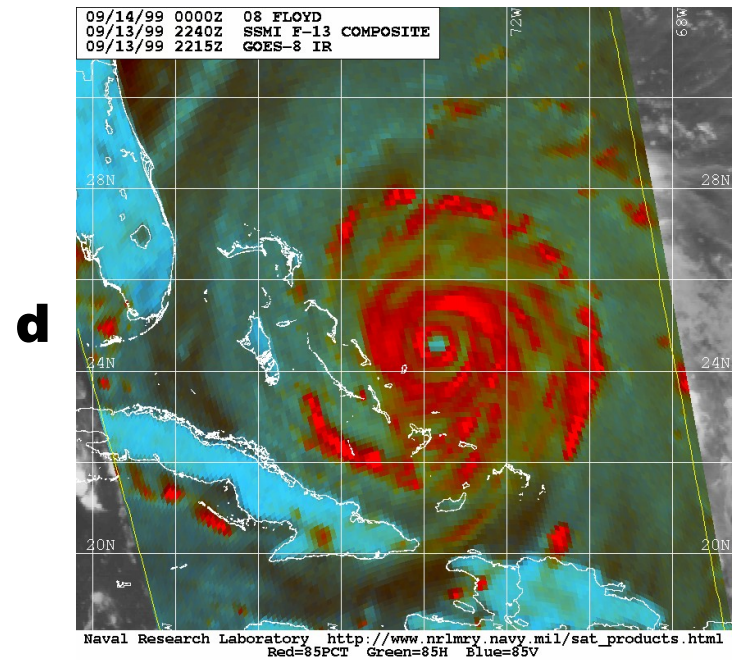
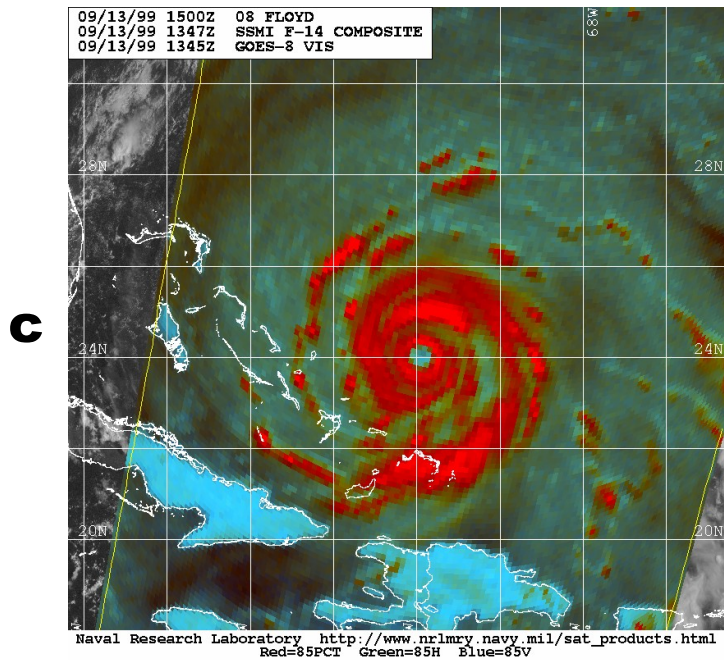
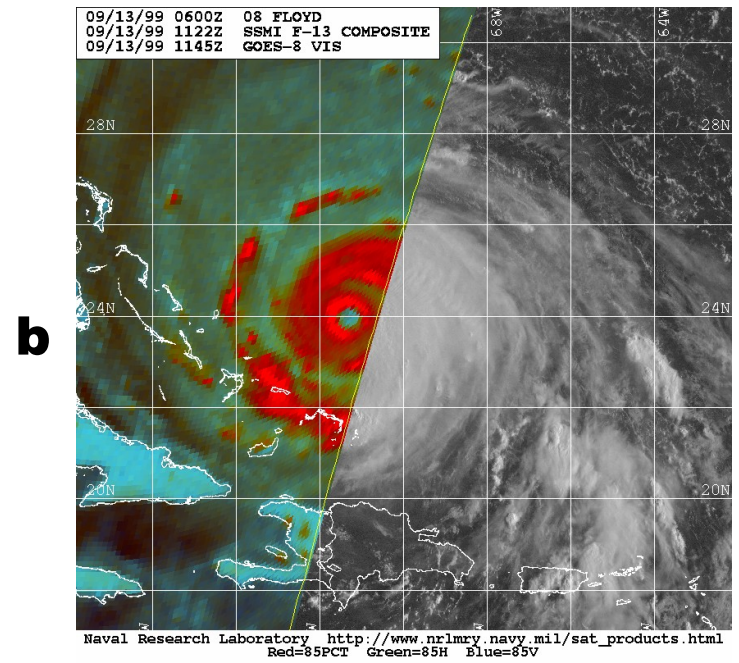
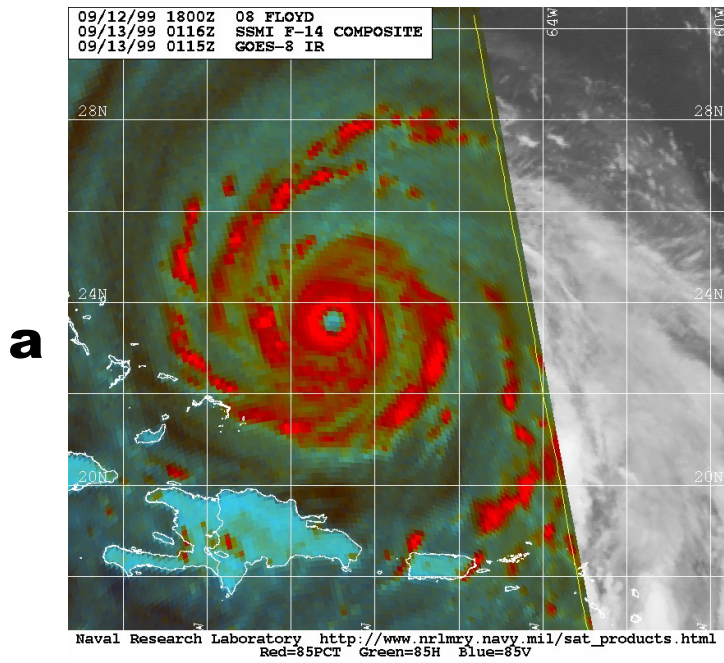


Fig. 4. Sequence of microwave images of Hurricane Floyd at: (a) 0116 UTC, (b) 1122 UTC, (c) 1347 UTC, and (d) 2240 UTC 13 September, 1999.

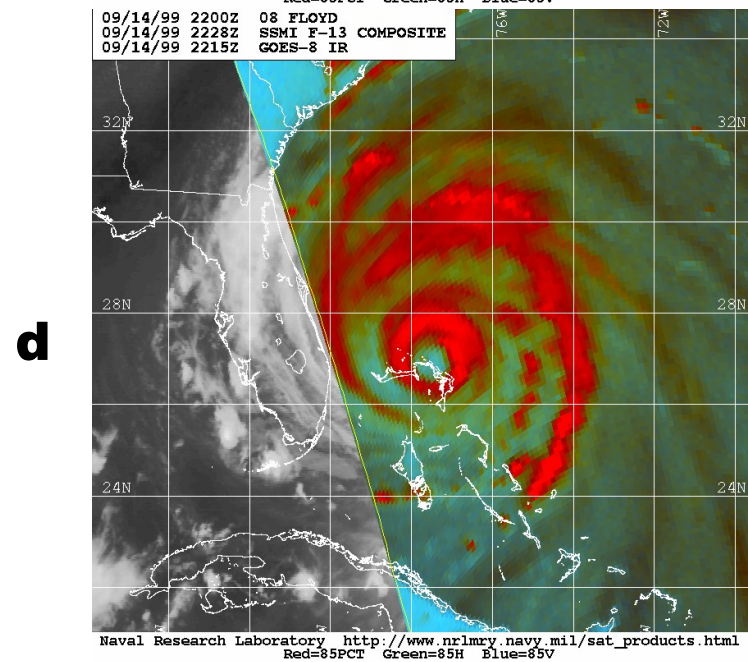
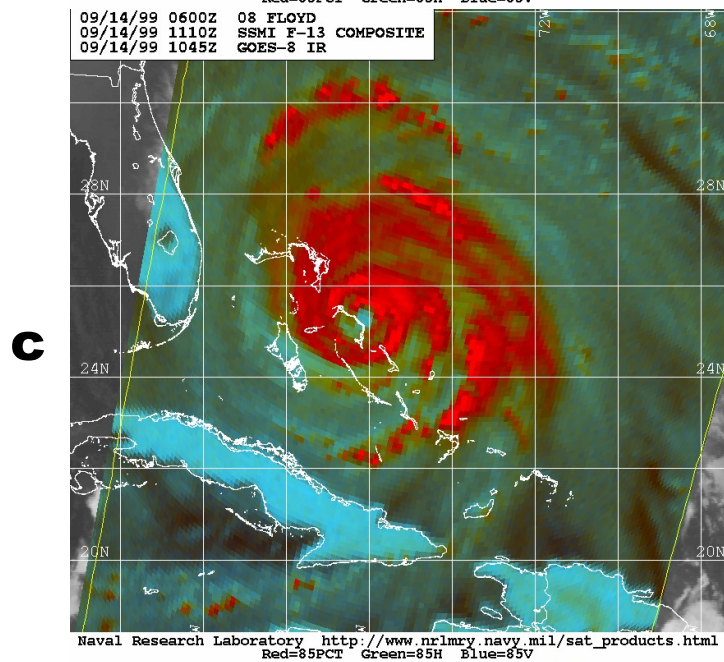
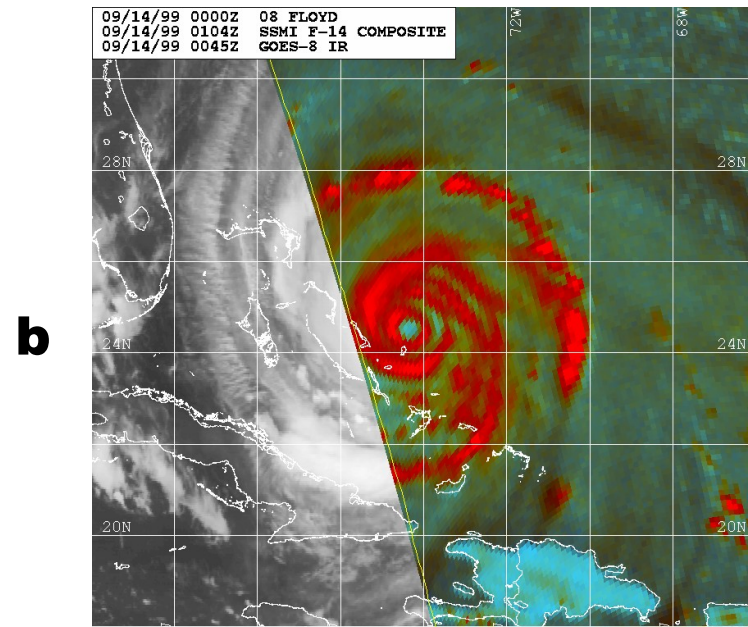
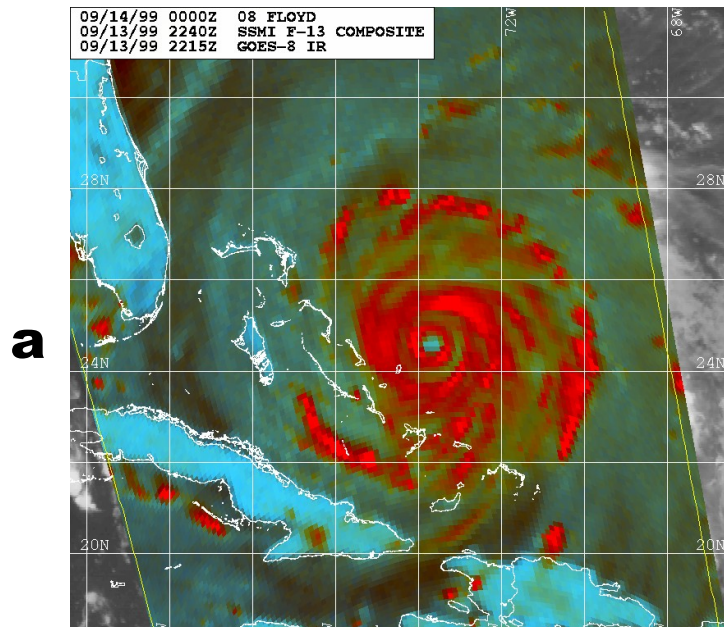


Fig. 5. Sequence of microwave images of Hurricane Floyd at: (a) 2240 UTC 13 September, (b) 0104 UTC, (c) 1110 UTC, and (d) 2228 UTC 14 September, 1999.