

Tropical Cyclone Report  
Tropical Storm Chris  
(AL042006)  
1-4 August 2006

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Chris was a tropical storm whose center remained north of the Lesser Antilles before the cyclone weakened and moved across the Turks and Caicos and the southeastern Bahamas as a tropical depression. Chris had little impact on these areas.

a. Synoptic History

The tropical wave that eventually spawned Chris moved off the west coast of Africa early on 26 July, and maintained vigorous convection for the next couple of days as it moved westward at 15-20 kt. By late on 28 July, the convection weakened considerably and also became less organized as the system moved into a region of large-scale subsidence and drier air in the middle- and upper-levels of the troposphere. Although convective activity became disorganized, the wave's wind field remained well-defined. The wave continued to propagate westward at a slightly slower forward speed, and a small burst of deep convection developed on the northern end of the sharp wave axis early on 30 July about 550 n mi east of the southern Leeward Islands. Convection continued to increase in vertical depth and organization, and Dvorak satellite classifications were initiated by the Tropical Analysis and Forecast Branch at 1745 UTC. Late on 31 July, the system turned west-northwestward and convective organization rapidly increased. As the wave passed just north of French buoy 41100, the winds at the buoy switched direction from northeasterly to westerly, indicating a small surface low pressure area existed along the wave axis, which confirmed a similar signature in QuikSCAT wind data around 2100 UTC. It is estimated that a tropical depression formed at 0000 UTC 1 August about 205 n mi east-southeast of Barbuda. The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1.

The depression continued on a west-northwestward track at a slower forward speed of about 10 kt and, despite moderate upper-level westerly wind shear, strengthened into a tropical storm 6 h later. Aircraft reconnaissance flights into Tropical Storm Chris ensued around midday, and flight-level wind data indicated Chris had strengthened and become better organized. The cyclone reached its peak intensity of 55 kt early on 2 August about 55 n mi east-northeast of Anguilla in the northern Leeward Islands. Around midday on 3 August, a strong subtropical high pressure system to the north forced Chris westward, and the cyclone began to weaken as both westerly upper-level shear and dry air entrainment increased (Fig. 4). Chris passed about 100 n

mi north of Puerto Rico and Hispaniola and weakened to a tropical depression at 1800 UTC when the cyclone was centered about 195 n mi east-southeast of Grand Turk Island.

As the depression moved westward toward Great Inagua Island in the southeastern Bahamas, increasing wind shear caused associated thunderstorm activity to dissipate and Chris degenerated into a non-convective remnant low pressure system by 0600 UTC 4 August about 80 n mi east-southeast of Grand Turk Island. The remnant circulation accelerated slightly as it skirted the northern coast of Cuba for the next 60 h before it dissipated at 1200 UTC 6 August near Havana, Cuba.

#### b. Meteorological Statistics

Observations in Tropical Storm Chris (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB) and the U. S. Air Force Weather Agency (AFWA), as well as flight-level and dropwindsonde observations from flights of the 53<sup>rd</sup> Weather Reconnaissance Squadron (WRS) of the U. S. Air Force Reserve Command. Microwave satellite imagery from NOAA polar-orbiting satellites, the NASA Tropical Rainfall Measuring Mission (TRMM), the NASA QuikSCAT, and Defense Meteorological Satellite Program (DMSP) satellites were also useful in tracking Chris.

There were a total of 31 aircraft center penetrations made by the 53<sup>rd</sup> WRS. In addition, there was one synoptic surveillance mission flown on 2-3 August by the NOAA Aircraft Operations Center Gulfstream-IV jet aircraft around the periphery of Chris. The estimated peak intensity for Chris of 55 kt on 2 August is based on an 850 mb flight-level wind of 67 kt, corresponding to about 54 kt at the surface. The minimum central pressure of 1001 mb is based on a dropsonde pressure of 1002 mb that was accompanied by a 15-kt surface wind, which indicates that the dropsonde probably did not sample the center of the cyclone and its lowest pressure.

There were no ship reports of winds of tropical storm force associated with Chris. Selected surface observations from land stations are given in Table 3.

#### c. Casualty and Damage Statistics

Direct effects from Chris were mainly confined to brief periods of heavy rainfall and some localized floods. News reports indicate rainfall from the storm caused the Fajardo River in Puerto Rico to overflow its banks, and the flood waters temporarily closed a highway in the northeastern portion of the island. Rainfall reached up to 2 in across portions of Hispaniola, the Turks and Caicos, the Bahamas, and eastern Cuba. In some of the mountainous areas of Hispaniola, there were unofficial reports of near 4 in of rain. Although the center of Chris passed about 100 n mi to the north of Dominican Republic, the cyclone still caused heavy rainfall and significant floods in Santo Domingo. The floods left several people temporarily homeless due to water entering their homes, and many roads were impassable near the capital city due to the

combined effects of high water and mud slides. Flood waters also covered rice fields in the northeastern portion of the country. Overall, damage was minor and there were no casualties reported in association with Chris.

News reports indicate that there were indirect economic effects associated with the Chris official forecasts. Beginning on 2 August, NHC official forecasts projected Chris to move across the southeastern and central Gulf of Mexico as a category 1 hurricane. In response to these forecasts, these price for crude oil rose on the New York Mercantile Exchange at branch offices in London. Natural gas prices also rose considerably in New York Mercantile Exchange electronic trading that same day. Anticipation of a threat to supply by a potential Hurricane Chris coupled with high demand during an ongoing heat wave were cited as factors in the price move.

#### d. Forecast and Warning Critique

The genesis of Chris was forecast quite well. Atlantic Tropical Weather Outlooks (TWOAT) from the National Hurricane Center began describing the area of disturbed weather from which Chris originated more than 4 days prior to when tropical cyclogenesis occurred. Possible formation of a tropical depression was explicitly mentioned at 0221 UTC 28 July, resulting in a lead time of more than 79 h.

A verification of official and guidance model track forecasts is given in Table 4. Average official track (OFCL) errors for Chris were 27, 48, 63, 88, and 164 n mi for the 12, 24, 36, 48, and 72 h forecasts, respectively. The number of forecasts ranged from eleven at 12 h to only one at 72 h. These errors are lower than the average long-term official track errors (Table 4) at all times. The track forecasts showed little cross-track bias and correctly anticipated Chris' future path remaining north of the Caribbean island chain. The only models that significantly outperformed OFCL was the interpolated Navy NOGAPS (NGPI) and the 4-member GUNA consensus model.

Average official intensity errors (Table 5) for Chris were 8, 18, 19, 20, and 5 kt for the 12, 24, 36, 48, and 72 h forecasts, respectively. For comparison, the average long-term official intensity errors are 6.3, 9.8, 12.1, 14.8, 18.4, and 19.8 kt (Table 5). The negative effects of vertical wind shear were anticipated from the outset and intensity forecasts were held lower than most of the available statistical and climatological models. However, the longer duration of the wind shear conditions and the effects of mid-level dry entrainment were not expected. This resulted in actual intensities being much lower than forecast, including prognoses of hurricane strength at forecast time periods when in actuality Chris no longer existed as a tropical cyclone. Overall, the OFCL intensity forecasts showed no skill and were beaten by nearly every model, including the 'zero-skill' SHIFOR model.

Watches and warnings issued for Chris are listed in Table 2.

Acknowledgements:

Some of the data for this report was supplied by the NOAA National Weather Service Forecast Office (WFO) in San Juan, Puerto Rico. News reports were obtained from Bloomberg.com, FinancialNews.com, Univision Television--Puerto Rico, and ZeeNews.com.

Table 1. Best track for Tropical Storm Chris, 1-4 August 2006.

| Date/Time (UTC) | Latitude (°N) | Longitude (°W) | Pressure (mb) | Wind Speed (kt) | Stage               |
|-----------------|---------------|----------------|---------------|-----------------|---------------------|
| 01 / 0000       | 16.3          | 58.1           | 1011          | 30              | tropical depression |
| 01 / 0600       | 16.8          | 58.9           | 1009          | 35              | tropical storm      |
| 01 / 1200       | 17.2          | 59.8           | 1006          | 40              | "                   |
| 01 / 1800       | 17.7          | 60.6           | 1004          | 50              | "                   |
| 02 / 0000       | 18.1          | 61.4           | 1003          | 50              | "                   |
| 02 / 0600       | 18.5          | 62.2           | 1001          | 55              | "                   |
| 02 / 1200       | 19.0          | 63.0           | 1001          | 55              | "                   |
| 02 / 1800       | 19.6          | 63.9           | 1004          | 50              | "                   |
| 03 / 0000       | 19.9          | 64.8           | 1007          | 50              | "                   |
| 03 / 0600       | 20.2          | 65.8           | 1010          | 40              | "                   |
| 03 / 1200       | 20.4          | 66.8           | 1011          | 35              | "                   |
| 03 / 1800       | 20.6          | 67.7           | 1011          | 30              | tropical depression |
| 04 / 0000       | 20.7          | 68.7           | 1011          | 30              | "                   |
| 04 / 0600       | 20.8          | 70.2           | 1011          | 25              | low                 |
| 04 / 1200       | 21.2          | 71.1           | 1011          | 25              | "                   |
| 04 / 1800       | 21.3          | 72.2           | 1012          | 25              | "                   |
| 05 / 0000       | 21.5          | 73.4           | 1012          | 25              | "                   |
| 05 / 0600       | 21.6          | 75.0           | 1012          | 20              | "                   |
| 05 / 1200       | 21.8          | 76.3           | 1012          | 20              | "                   |
| 05 / 1800       | 22.1          | 77.6           | 1012          | 20              | "                   |
| 06 / 0000       | 22.4          | 78.9           | 1012          | 20              | "                   |
| 06 / 0600       | 22.8          | 80.2           | 1013          | 20              | "                   |
| 06 / 1200       | 23.2          | 81.7           | 1013          | 15              | "                   |
| 06 / 1800       |               |                |               |                 | dissipated          |
| 02 / 0600       | 18.5          | 62.2           | 1001          | 55              | minimum pressure    |

Table 2. Watch and warning summary for Tropical Storm Chris, 1-4 August 2006.

| Date/Time (UTC) | Action   | Location   |
|-----------------|--|--|
| 1 / 0300        | Tropical Storm Watch issued                            | Saba, St. Barthelemy, St. Eustatius, St. Maarten, St. Martin   |
| 1 / 0900        | Tropical Storm Watch issued                            | Puerto Rico, U.S. Virgin Islands, British Virgin Islands   |
| 1 / 0900        | Tropical Storm Watch Changed to Tropical Storm Warning | Saba, St. Barthelemy, St. Eustatius, St. Maarten, St. Martin   |
| 1 / 0900        | Tropical Storm Warning Issued                          | Anguilla, Antigua, Barbuda, Nevis, St. Kitts   |
| 1 / 2100        | Tropical Storm Watch changed to Tropical Storm Warning | Puerto Rico, U.S. Virgin Islands, British Virgin Islands   |
| 2 / 0600        | Tropical Storm Warning discontinued                    | Saba, St. Eustatius  |
| 2 / 0900        | Tropical Storm Warning discontinued                    | Antigua, Barbuda, Nevis, St. Kitts   |
| 2 / 1500        | Tropical Storm Warning discontinued                    | Barthelemy, St. Maarten, St. Martin  |
| 2 / 1500        | Hurricane Watch issued                                 | Turks and Caicos Islands, and Southeastern Bahamas...including Acklins, Crooked Island, Inaguas, Mayaguana, and Ragged Islands |
| 2 / 1800        | Tropical Storm Warning discontinued                    | Anguilla   |
| 3 / 0300        | Tropical Storm Watch issued                            | Haiti/DR Border east to Cabo Engano of Hispaniola  |
| 3 / 0900        | Hurricane Watch downgraded to Tropical Storm Watch     | Turks and Caicos Islands, and Southeastern Bahamas...including Acklins, Crooked Island, Inaguas, Mayaguana, and Ragged Islands |
| 3 / 0900        | Tropical Storm Warning discontinued                    | Puerto Rico, U.S. Virgin Islands, British Virgin Islands   |
| 3 / 1500        | Tropical Storm Watch discontinued                      | Cabo Francis Viejo west to Haiti/DR Border of Hispaniola   |
| 3 / 1500        | Tropical Storm Watch in effect                         | Cabo Francis Viejo to Cabo Engano of Hispaniola  |

|          |   |  |
|----------|---|--|
| 4 / 0000 | Tropical Storm Watch discontinued                       | Cabo Francis Viejo west to Haiti/DR Border, Cabo Samana east to Cabo Engano of Hispaniola                                      |
| 4 / 0000 | Tropical Storm Watch modified                           | Haiti/DR Border east to Samana of Hispaniola   |
| 4 / 0300 | Tropical Storm Watch upgraded to Tropical Storm Warning | Turks and Caicos Islands, and Southeastern Bahamas...including Acklins, Crooked Island, Inaguas, Mayaguana, and Ragged Islands |
| 4 / 0300 | Tropical Storm Watch issued                             | La Mole St. Nicolas east to Haiti/DR border of Hispaniola  |
| 4 / 0300 | Tropical Storm Watch issued                             | Long Island and Exumas in Central Bahamas  |
| 4 / 1200 | Tropical Storm Watch discontinued                       | La Mole St. Nicolas, Haiti eastward to Cabo Samana, DR of Hispaniola   |
| 4 / 2100 | Tropical Storm Warning discontinued                     | Turks and Caicos Islands, and all of Southeastern Bahamas  |
| 5 / 0300 | Tropical Storm Watch discontinued                       | Central Bahamas  |

Table 3. Selected surface observations for Tropical Storm Chris, 1-4 August 2006.

| Location                   | Minimum Sea Level Pressure |             | Maximum Surface Wind Speed   |                             |           | Storm surge (ft) <sup>c</sup> | Storm tide (ft) <sup>d</sup> | Total rain (in) |
|----------------------------|----------------------------|-------------|------------------------------|-----------------------------|-----------|-------------------------------|------------------------------|-----------------|
|                            | Date/time (UTC)            | Press. (mb) | Date/time (UTC) <sup>a</sup> | Sustained (kt) <sup>b</sup> | Gust (kt) |                               |                              |                 |
| <b>Bahamas</b>             |                            |             |                              |                             |           |                               |                              |                 |
| Grand Turk                 | 04/1000                    | 1012.5      | 04/1500                      | 30                          |           |                               |                              |                 |
| <b>Puerto Rico</b>         |                            |             |                              |                             |           |                               |                              |                 |
| Cayey Lago Caritte USGS    |                            |             |                              |                             |           |                               |                              | 2.39            |
| Ceiba (TJNR) ASOS          | 03/0854                    | 1015.2      |                              |                             |           |                               |                              | 1.05            |
| Fajardo USGS               |                            |             |                              |                             |           |                               |                              | 3.09            |
| Jayuya USGS                |                            |             |                              |                             |           |                               |                              | 1.37            |
| Las Piedras USGS           |                            |             |                              |                             |           |                               |                              | 3.08            |
| San Juan (TJSJ) ASOS       | 03/0659                    | 1014.6      |                              |                             |           |                               |                              | 0.53            |
| San Juan Isla Grande USGS  |                            |             |                              |                             |           |                               |                              | 2.93            |
| <b>U.S. Virgin Islands</b> |                            |             |                              |                             |           |                               |                              |                 |
| St. Croix (TISX) ASOS      | 02/2100                    | 1015.9      |                              |                             |           |                               |                              | 0.16            |
| St. John –Bethany (USGS)   |                            |             |                              |                             |           |                               |                              | 0.00            |
| St. Thomas (TIST) ASOS     | 03/0854                    | 1014.6      | 02/2218                      | 24                          | 29        |                               |                              | 2.26            |

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

<sup>b</sup> Except as noted, sustained wind averaging periods for C-MAN and land-based ASOS reports are 2 min; buoy averaging periods are 8 min.

<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 (heterogeneous sample) for Tropical Storm Chris, 1-4 August 2006. Forecast errors (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in bold-face type. Verification includes the depression stage.

| Forecast Technique                  | Forecast Period (h) |               |               |               |                |              |              |
|-------------------------------------|---------------------|---------------|---------------|---------------|----------------|--------------|--------------|
|                                     | 12                  | 24            | 36            | 48            | 72             | 96           | 120          |
| CLP5                                | <b>26</b> (11)      | <b>47</b> (9) | 72 (7)        | 90 (5)        | 204 (1)        |              |              |
| GFNI                                | <b>24</b> (7)       | <b>32</b> (5) | <b>38</b> (3) | <b>42</b> (1) |                |              |              |
| GFDI                                | 35 (10)             | 66 (8)        | 87 (6)        | 98 (4)        |                |              |              |
| GFSI                                | 35 (11)             | 57 (9)        | 70 (7)        | <b>74</b> (5) | 228 (1)        |              |              |
| AEMI                                | 32 (11)             | 58 (9)        | 66 (7)        | <b>68</b> (5) |                |              |              |
| NGPI                                | <b>24</b> (8)       | <b>44</b> (6) | <b>57</b> (4) | <b>61</b> (2) |                |              |              |
| UKMI                                | 30 (4)              | 75 (2)        |               |               |                |              |              |
| A98E                                | <b>26</b> (11)      | <b>41</b> (9) | <b>61</b> (7) | 100 (5)       | 258 (1)        |              |              |
| A9UK                                | 31 (6)              | 53 (5)        | 76 (4)        | 103 (3)       | 245 (1)        |              |              |
| BAMD                                | 50 (11)             | 93 (9)        | 133 (7)       | 174 (5)       | 298 (1)        |              |              |
| BAMM                                | 33 (11)             | 56 (9)        | 75 (7)        | <b>79</b> (5) | <b>119</b> (1) |              |              |
| BAMS                                | <b>26</b> (11)      | 48 (9)        | 64 (7)        | <b>72</b> (5) | <b>120</b> (1) |              |              |
| CONU                                | 27 (11)             | <b>43</b> (9) | <b>60</b> (7) | <b>64</b> (5) |                |              |              |
| GUNA                                | <b>15</b> (4)       | <b>33</b> (2) |               |               |                |              |              |
| OFCL                                | 27 (11)             | 48 (9)        | 63 (7)        | 88 (5)        | 164 (1)        |              |              |
| NHC Official<br>(2001-2005<br>mean) | 37<br>(1930)        | 65<br>(1743)  | 91<br>(1569)  | 118<br>(1410) | 171<br>(1138)  | 231<br>(913) | 303<br>(742) |



Table 5. Preliminary intensity forecast evaluation (heterogeneous sample) for Tropical Storm Chris, 1-4 August 2006. Forecast errors (kt) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in bold-face type. Verification includes the depression stage.

| Forecast Technique               | Forecast Period (h) |                 |                 |                 |                |               |               |
|----------------------------------|---------------------|-----------------|-----------------|-----------------|----------------|---------------|---------------|
|                                  | 12                  | 24              | 36              | 48              | 72             | 96            | 120           |
| SHF5                             | 8.5 (11)            | <b>15.4</b> (9) | <b>16.6</b> (7) | <b>19.8</b> (5) | 25.0 (1)       |               |               |
| GFDI                             | 11.1 (10)           | <b>15.0</b> (8) | <b>17.3</b> (6) | <b>10.5</b> (4) |                |               |               |
| SHIP                             | 8.5 (11)            | <b>16.2</b> (9) | <b>16.6</b> (7) | <b>17.6</b> (5) | 14.0 (1)       |               |               |
| DSHP                             | 8.5 (11)            | <b>16.2</b> (9) | <b>16.6</b> (7) | <b>18.2</b> (5) | <b>4.0</b> (1) |               |               |
| FSSE                             | 9.9 (10)            | <b>16.8</b> (8) | <b>18.8</b> (6) | <b>18.5</b> (4) |                |               |               |
| ICON                             | 9.5 (10)            | <b>15.6</b> (8) | <b>16.8</b> (6) | <b>13.5</b> (4) |                |               |               |
| OFCL                             | 8.2 (11)            | 17.8 (9)        | 19.3 (7)        | 20.0 (5)        | 5.0 (1)        |               |               |
| NHC Official<br>(2001-2005 mean) | 6.3<br>(1930)       | 9.8<br>(1743)   | 12.1<br>(1569)  | 14.3<br>(1410)  | 18.4<br>(1138) | 19.8<br>(913) | 21.8<br>(742) |

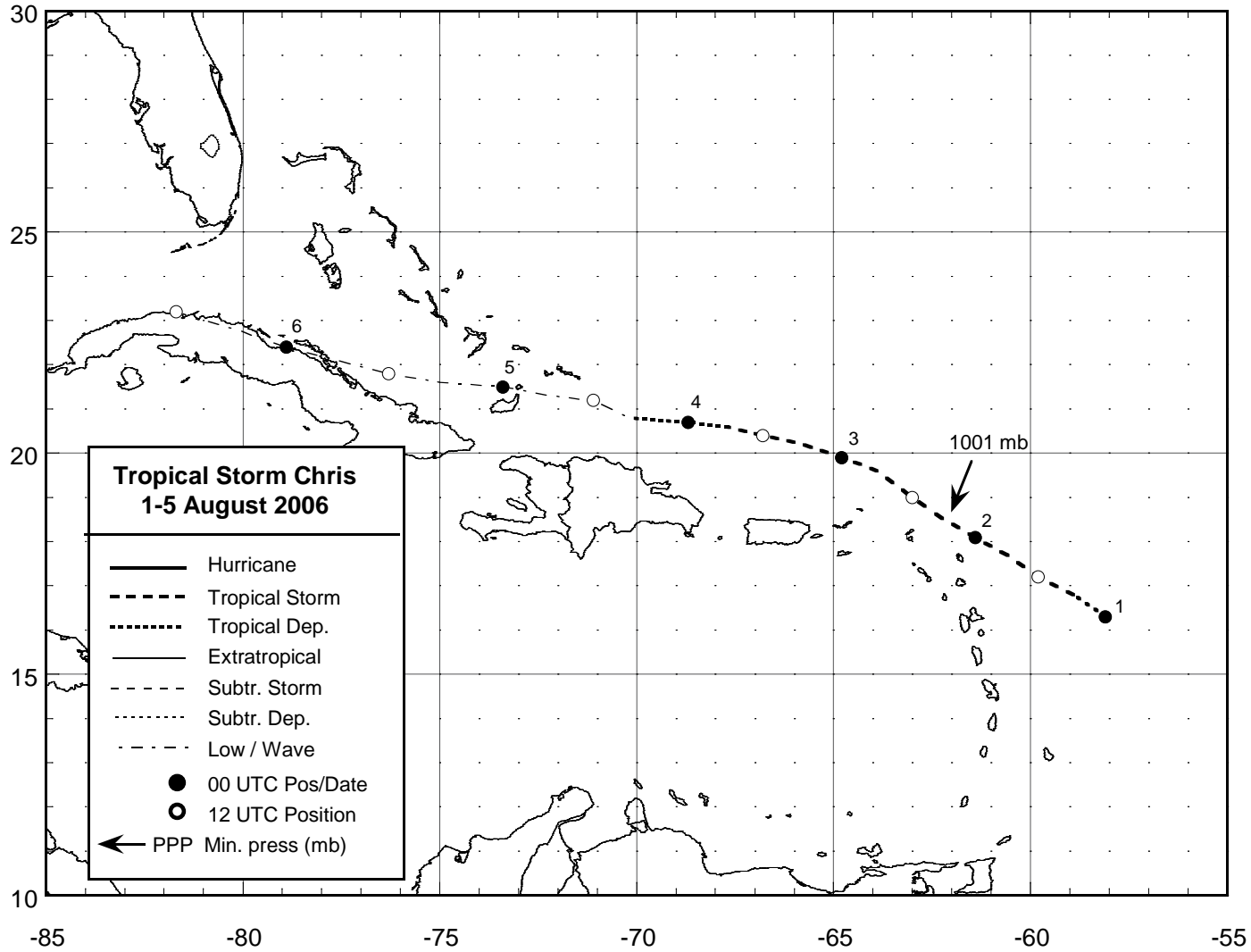


Figure 1. Best track positions for Tropical Storm Chris, 1-4 August 2006.

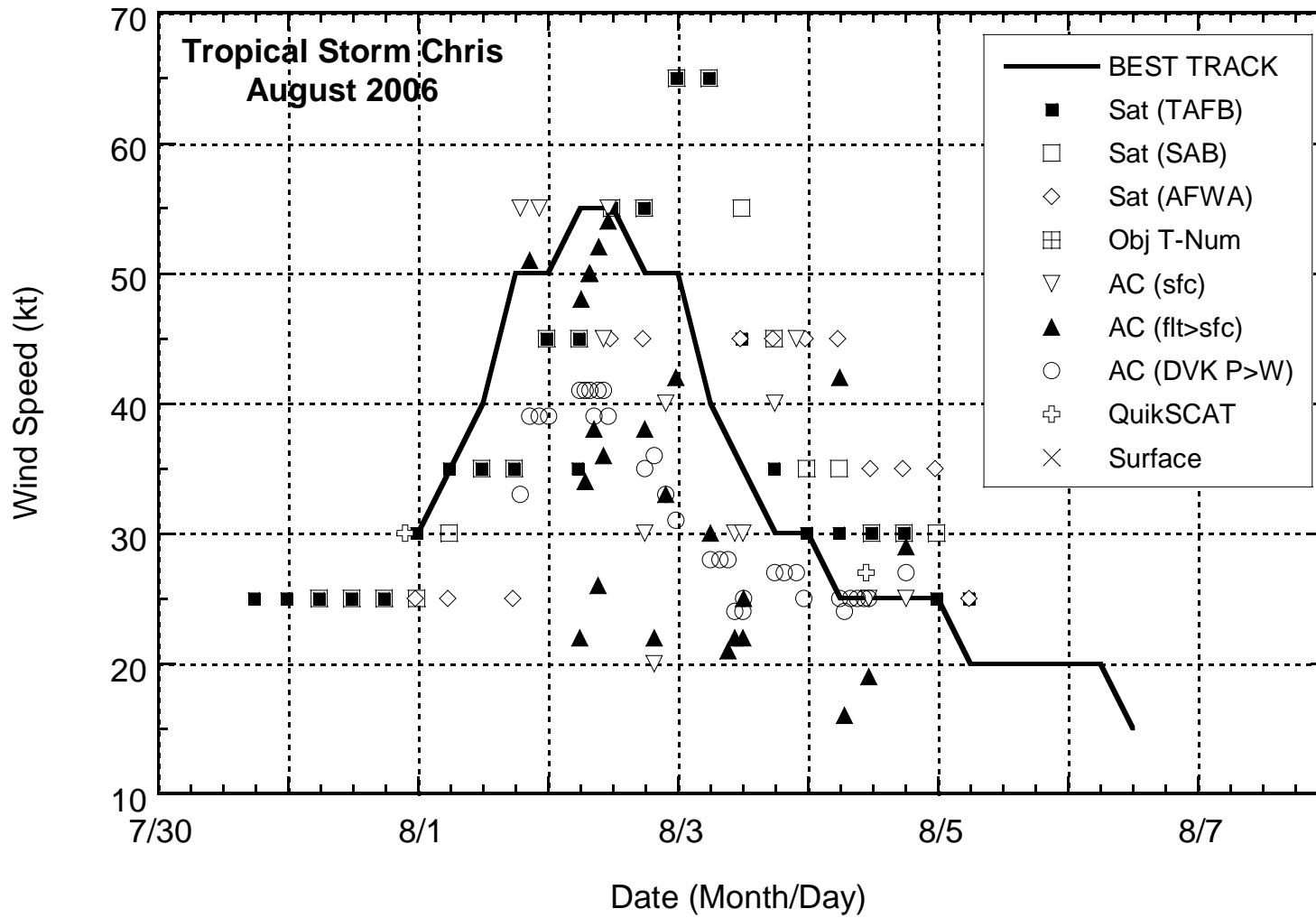


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Chris, 1-4 August 2006.

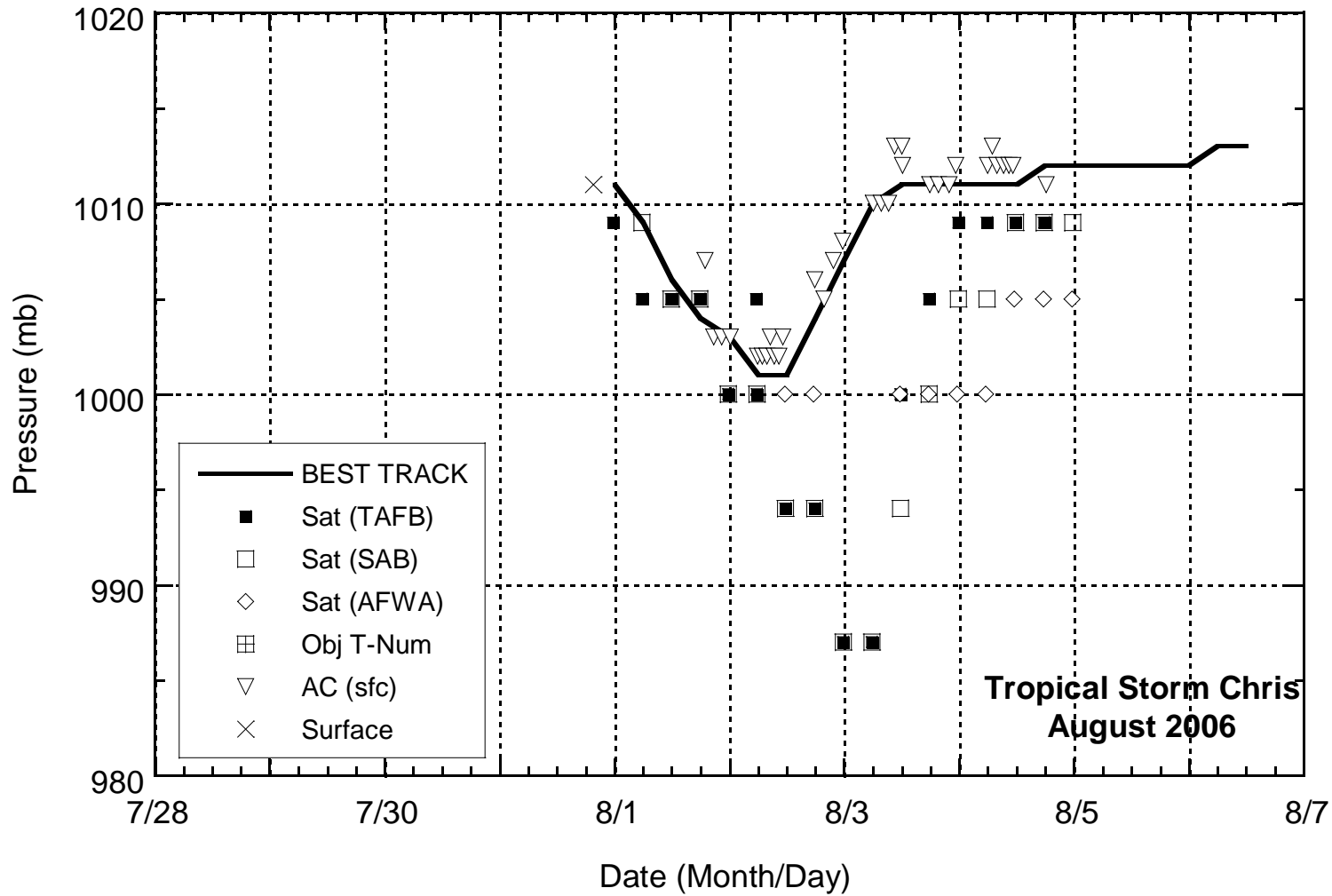


Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Chris, 1-4 August 2006.

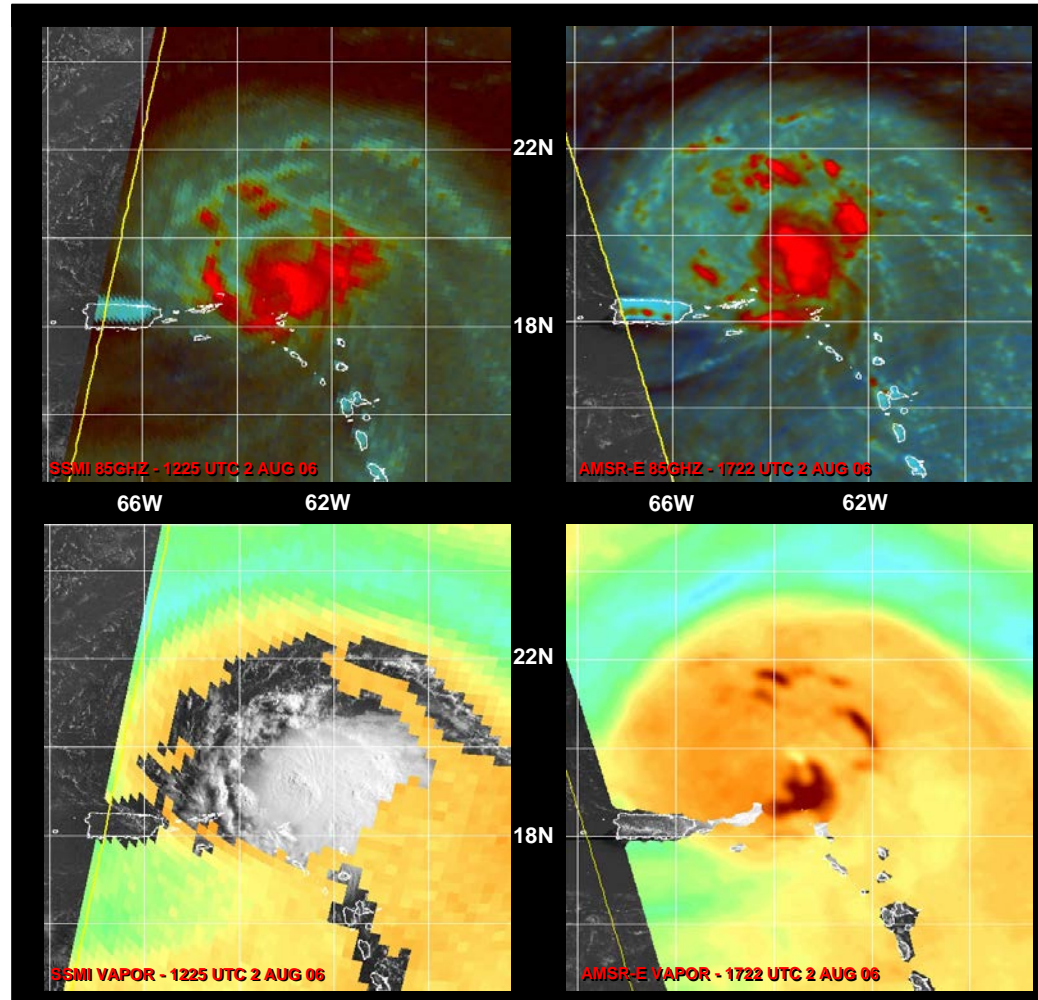


Figure 4. Microwave imagery from 1225 UTC 2 Aug 2006 SSMI (left) and 1722 UTC 2 AUG 2006 AMSR-E (right) overpasses showing the structure of Chris in 85GHZ data (top panels). The left panels show Chris near its peak intensity of 55 kt with a weak mid-level eye feature forming. The lower panels show mid-level dry air (blue and green shades) wrapping around the northern semicircle and intruding into the southwestern quadrant toward the center. (images from the U.S. Navy Research Laboratory, Monterey, CA).