NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

HURRICANE CRISTOBAL

(AL042014)

23 – 29 August 2014

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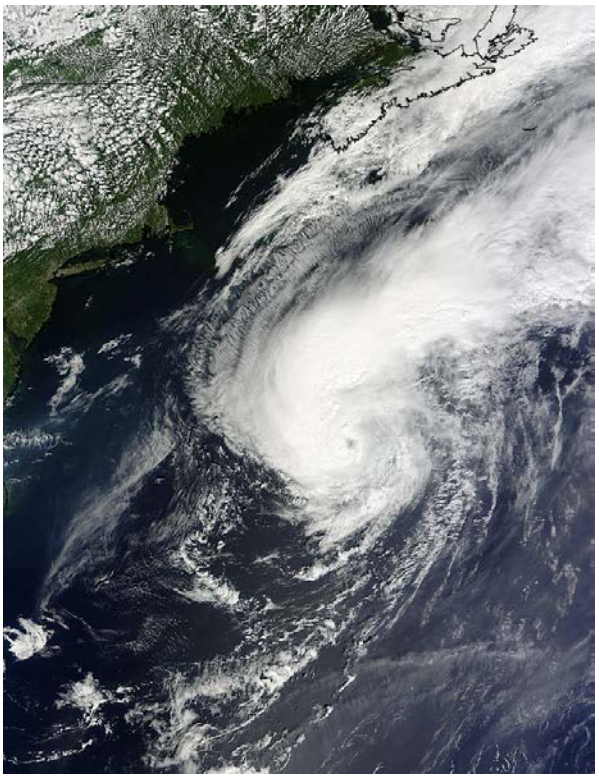

MODIS VISIBLE IMAGE OF HURRICANE CRISTOBAL AT 1530 UTC 28 AUGUST 2014, JUST BEFORE ITS PEAK INTENSITY. IMAGE COURTESY OF NASA.

Cristobal was a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that remained at sea over most of its lifetime, reaching its peak intensity at a rather high latitude. It produced very heavy rains over the Turks and Caicos Islands and the southeastern Bahamas.

Hurricane Cristobal

23 – 29 AUGUST 2014

SYNOPTIC HISTORY

Cristobal can be traced back to a tropical wave that moved off the west coast of Africa late on 14 August. This system, along with another wave to the west, produced a broad area of disturbed weather that moved westward across the tropical Atlantic and approached the Leeward Islands by 21 August. That day, the disturbance's cloud pattern began to show signs of organization, with curved low-cloud lines that were suggestive of a developing circulation. However, observations from an Air Force Reserve Hurricane Hunter aircraft that afternoon indicated that the system did not have a well-defined circulation. Over the next couple of days, the disturbance moved west-northwestward across the northern Leeward Islands, Puerto Rico and Hispaniola, and then approached the Turks and Caicos Islands. A Hurricane Hunter aircraft investigated the system again on 22 August when it was near Hispaniola, but still did not find a well-defined center of circulation. It was not until the afternoon of 23 August that aircraft data indicated a definite circulation center, signifying the formation of a tropical depression at 1800 UTC that day just to the south of the Caicos Islands. 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[1].

During the early stages of Cristobal's existence, the cyclone moved slowly north-northwestward to northward toward a break in the mid-level subtropical ridge. Moderate northwesterly to northerly shear was affecting the system, and it strengthened quite slowly. Cristobal became a tropical storm by 0600 UTC 24 August while centered just north of Mayaguana in the southeastern Bahamas. The next day, the storm turned to the north-northeast and northeast at a slower forward speed, under the influence of a mid-level trough to the north of the tropical cyclone. Despite persistent north-northwesterly shear and a rather disorganized overall cloud pattern, and with the low-level center partially exposed, Cristobal strengthened into a hurricane around 0000 UTC 26 August. Over the following day or so the system moved on a generally northward heading, at a faster forward speed, along the western periphery of a subtropical ridge. Significant strengthening was likely inhibited during this time by dry air intrusions into the inner core of the hurricane, and Cristobal's intensity fluctuated between 65 and 70 kt. By 28 August, the cyclone accelerated toward the northeast and east-northeast in the flow ahead of a mid-latitude shortwave trough. On that day, Cristobal's cloud pattern became significantly more symmetrical and the hurricane strengthened to its peak intensity of 75 kt by 1800 UTC, at an unusually high latitude of 37.5°N over the open Atlantic. Soon after reaching its maximum intensity, the cyclone's cloud pattern began to lose symmetry and the central convection decreased in coverage and intensity. By 1200 UTC 29 August, a frontal boundary wrapped

[1] A digital record of the complete best track, including wind radii, can be found on line at ftp://ftp.nhc.noaa.gov/atcf. Data for the current year's storms are located in the *btk* directory, while previous years' data are located in the *archive* directory.

around the southern portion of the circulation, and the system became extratropical. Post-tropical cyclone Cristobal maintained hurricane-force winds into 30 August, however, while speeding northeastward to east-northeastward. The extratropical cyclone turned toward the north-northeast and back toward the northeast while weakening very slowly, passing over Iceland on 1 September. It merged with another extratropical low over the far north Atlantic shortly thereafter.

METEOROLOGICAL STATISTICS

Observations in Cristobal (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), and objective Advanced Dvorak Technique (ADT) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA Tropical Rainfall Measuring Mission (TRMM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Cristobal. The estimated 75-kt maximum intensity of Cristobal is based on a blend of subjective and objective Dvorak classifications. There was also an ASCAT surface wind measurement of 70 kt just after the time of maximum intensity. SFMR-estimated surface winds of 57 kt and 71 kt at around 1200 UTC 24 August and 0000 UTC 26 August, respectively, are considered to be rain-contaminated and have been discounted.

Ship and buoy reports of winds of tropical storm force associated with Cristobal are given in Table 2.

The slow-moving tropical cyclone dumped torrential rains over the Turks and Caicos Islands and the southeastern Bahamas. A rainfall total of 10.9 inches was observed at Providenciales International Airport in the Caicos Islands on 22-23 August, and there was severe flooding at that airport. Portions of the Caicos Islands were reportedly inundated by floodwaters up to a depth of 5 feet. Heavy rains also occurred over portions of Hispaniola.

CASUALTY AND DAMAGE STATISTICS

Cristobal caused seven direct deaths[2], all due to drowning. Rip currents claimed the lives of two young men at Sandy Hook, New Jersey, and Ocean City, Maryland. One person drowned

[2] Deaths occurring as a direct result of the forces of the tropical cyclone are referred to as "direct" deaths. These would include those persons who drowned in storm surge, rough seas, rip currents, and freshwater floods. Direct deaths also include casualties resulting from lightning and wind-related events (e.g., collapsing structures). Deaths occurring from such factors as heart attacks, house fires, electrocutions from downed power lines, vehicle accidents on wet roads, etc., are considered indirect" deaths.

in rain-induced floodwaters at Providenciales in the Caicos Islands, two people drowned in Haiti and two people drowned in the Dominican Republic. In Haiti, there was flood damage and at least 3,600 people were displaced. Over 600 homes were damaged or destroyed by flooding in the Dominican Republic. Flood damage also likely occurred in the Turks and Caicos Islands, although no monetary estimates are available from there or from Hispaniola.

FORECAST AND WARNING CRITIQUE

The genesis of Cristobal was well anticipated at the longer time ranges (Table 3). The system from which the tropical cyclone formed was introduced into the Tropical Weather Outlook 162 h prior to formation with a low chance of development within both two and five days. The genesis probabilities were raised to the medium category 96 and 144 h prior to formation for two and five days, respectively. However, 120 h prior to formation, the system became less well organized and both the two- and five-day genesis probabilities were reduced back to the low category. Three days before development, the two-day genesis probability was increased to medium and the five-day probability was increased to high. The two-day genesis probability was again set to high 42 h before Cristobal formed.

A verification of NHC official track forecasts for Cristobal is given in Table 4a. Official forecast track errors were larger than the mean official errors for the previous 5-yr period at all forecast intervals, especially beyond 36 h. The mean climatology and persistence forecast errors were much higher than the long-term averages, likely because of the abrupt northeastward to east-northeastward acceleration of the cyclone following a period of very slow motion. This suggests that Cristobal's track was more difficult than normal to forecast. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. EMXI had lower errors than the official forecasts at every forecast interval and was the best performing model. The consensus models TVCA and FSSE were also good performers, and were comparable to or better than the official forecasts at most lead times. In general, the large errors of the NHC track predictions were due to large westward and slow biases in the official forecasts, particularly during the early stages of the tropical cyclone's lifetime.

A verification of NHC official intensity forecasts for Cristobal is given in Table 5a. In contrast to the track forecasts, the official intensity forecast errors were lower than the mean official errors for the previous 5-yr period. The mean climatology and persistence errors were lower than the 5-yr means at all lead times suggesting that, again in contrast to track, Cristobal's intensity was easier than normal to forecast. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. HWFI, IVCN, and FSSE were comparable to or better than the official forecasts through 36 h. Beyond that, the mean official intensity forecasts were better than any of the available guidance, save for OCD5 at 48 h.

Watches and warnings associated with Cristobal are given in Table 6.

Table 1. Best track for Hurricane Cristobal, 23-29 August 2014.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
23 / 1800	21.5	72.2	1005	30	tropical depression
24 / 0000	22.0	72.5	1004	30	"
24 / 0600	22.6	72.9	1002	35	tropical storm
24 / 1200	23.3	73.0	1001	40	"
24 / 1800	24.0	73.0	1001	45	"
25 / 0000	24.2	73.0	998	45	"
25 / 0600	24.4	72.9	996	45	"
25 / 1200	24.7	72.7	993	50	"
25 / 1800	24.9	72.4	992	50	"
26 / 0000	25.1	72.1	989	65	hurricane
26 / 0600	25.6	72.0	989	65	"
26 / 1200	26.7	71.8	988	65	"
26 / 1800	28.1	71.4	987	65	"
27 / 0000	29.5	71.5	983	70	"
27 / 0600	30.6	72.0	983	70	"
27 / 1200	31.6	72.2	983	70	"
27 / 1800	32.3	71.8	984	65	"
28 / 0000	33.5	70.7	984	65	"
28 / 0600	34.8	69.0	982	65	"
28 / 1200	36.3	67.1	979	70	"
28 / 1800	37.5	63.6	971	75	"
29 / 0000	39.1	58.8	965	75	"
29 / 0600	41.2	53.9	967	70	"
29 / 1200	44.2	49.0	970	65	extratropical
29 / 1800	46.7	45.9	972	65	"
30 / 0000	48.6	42.8	974	65	"

30 / 0600	49.9	39.5	974	65	"
30 / 1200	51.3	36.2	971	60	"
30 / 1800	54.0	32.0	971	60	"
31 / 0000	58.0	28.9	971	60	"
31 / 0600	61.0	27.0	963	60	"
31 / 1200	62.0	26.0	964	60	"
31 / 1800	63.0	24.5	968	55	"
01 / 0000	64.0	22.0	974	50	"
01 / 0600	65.0	19.5	978	50	"
01 / 1200	66.0	17.0	980	45	"
01 / 1800	67.0	15.4	982	45	"
02 / 0000	68.0	15.0	984	40	"
02 / 0600	69.0	15.0	985	35	"
02 / 1200					merged with another extratropical cyclone
29 / 0000	39.1	58.8	965	75	minimum pressure and maximum winds

Table 2. Selected ship and buoy reports with winds of at least 34 kt for Hurricane Cristobal, 23-29 August 2014.

Date/Time (UTC)	Ship/Buoy ID	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
24 / 1200	WGJT	23.0	71.3	170 / 36	1005.5
24 / 2300	WGJT	20.7	68.5	180 / 35	1008.7
25 / 0800	KIRH	25.6	68.0	170 / 35	1005.0
26 / 1250	41047	27.5	71.5	090 / 35	995.7
26 / 1650	41047	27.5	71.5	290 / 35	990.5
27 / 1950	41048	32.0	69.5	180 / 37	1004.7
27 / 2050	41048	32.0	69.5	180 / 35	1004.6
27 / 2150	41048	32.0	69.5	190 / 37	1004.3
27 / 2250	41048	32.0	69.5	200 / 39	1004.4
27 / 2350	41048	32.0	69.5	200 / 37	1004.6
28 / 0050	41048	32.0	69.5	200 / 35	1005.3
28 / 0150	41048	32.0	69.5	220 / 35	1006.1
28 / 0250	41048	32.0	69.5	220 / 35	1006.9
29 / 1000	CGUM	46.8	54.6	040 / 37	999.3
29 / 1100	CGUM	46.9	54.8	040 / 38	1000.4

Table 3. Number of hours in advance of formation associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the “Low” category do not include forecasts of a 0% chance of genesis.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<30%)	162	162
Medium (30%-50%)	96	144
High (>50%)	42	72

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Cristobal, 23-29 August 2014. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	33.7	53.7	73.3	103.2	150.7	277.2	825.9
OCD5	69.4	149.1	205.7	225.0	340.7	387.8	739.3
Forecasts	21	19	17	15	11	7	3
OFCL (2009-13)	28.8	45.5	61.2	77.8	114.5	158.4	208.2
OCD5 (2009-13)	48.2	100.1	160.2	220.8	326.6	410.7	479.4

Table 4b. Homogeneous comparison of selected track forecast guidance model errors (n mi) for Hurricane Cristobal, 23-29 August 2014. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	32.9	52.0	69.0	96.1	99.3	143.3	
OCD5	71.5	161.0	218.1	229.4	440.4	614.1	
GFSI	**31.8**	52.1	74.8	109.4	160.5	212.0	
GHMI	41.7	85.4	131.9	181.8	221.2	183.2	
HWFI	36.7	57.5	73.3	**93.2**	105.2	168.0	
EMXI	**32.6**	**44.2**	**54.9**	**80.2**	**93.2**	**49.5**	
CMCI	49.2	82.9	114.0	121.0	161.1	212.8	
NVGI	39.4	84.5	99.6	**95.4**	153.2	245.9	
GFNI	36.4	82.5	101.3	109.0	137.6	349.7	
AEMI	**32.4**	57.4	86.9	117.8	106.4	151.9	
EGRI	**32.2**	53.3	75.2	107.6	126.9	**136.5**	
FSSE	**31.1**	**44.5**	**65.3**	**84.9**	114.4	**69.4**	
TVCA	**31.6**	**49.9**	72.3	**89.6**	113.8	**67.2**	
LBAR	50.5	105.6	146.7	189.0	305.2	198.8	
BAMD	42.8	94.2	161.7	214.2	401.3	1222.7	
BAMM	39.1	79.9	132.7	168.1	258.5	710.6	
BAMS	56.2	102.8	133.3	152.2	207.9	495.9	
Forecasts	17	16	14	12	7	3	

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Cristobal, 23-29 August 2014. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**3.6**	**5.5**	**6.8**	**7.0**	**3.6**	**2.1**	**3.3**
OCD5	6.3	7.6	5.9	8.1	9.5	13.7	12.0
Forecasts	21	19	17	15	11	7	3
OFCL (2009-13)	6.3	9.7	11.9	13.7	15.3	15.4	15.7
OCD5 (2009-13)	7.4	11.1	13.8	15.7	18.3	18.2	18.1

Table 5b. Homogeneous comparison of selected intensity forecast guidance model errors (kt) for Hurricane Cristobal, 23-29 August 2014. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	3.6	5.9	7.9	6.3	2.1	5.0	
OCD5	6.1	7.3	**5.4**	**6.2**	6.0	17.7	
GHMI	4.5	7.1	12.1	13.8	20.3	24.7	
HWFI	4.0	**5.4**	**7.6**	10.5	10.3	5.7	
GFNI	4.9	**5.1**	11.2	13.9	9.1	9.3	
IVCN	4.1	**4.8**	**6.7**	8.2	7.1	9.0	
DSHP	4.8	6.1	**6.6**	7.8	8.1	5.0	
LGEM	5.6	7.1	**7.4**	7.8	5.1	10.3	
EMXI	5.6	6.9	9.3	11.9	10.9	12.7	
FSSE	4.1	**4.4**	**7.6**	7.9	10.6	15.3	
Forecasts	18	16	14	12	7	3	

Table 6. Watch and warning summary for Hurricane Cristobal, 23-29 August 2014.

Date/Time (UTC)	Action	Location
23 / 2100	Tropical Storm Warning issued	Central Bahamas, Southeastern Bahamas, and the Turks and Caicos
24 / 2100	Tropical Storm Warning discontinued	Southeastern Bahamas, and the Turks and Caicos
25 / 1500	Tropical Storm Warning discontinued	All
25 / 2100	Tropical Storm Watch issued	Bermuda
28 / 1500	Tropical Storm Watch discontinued	All

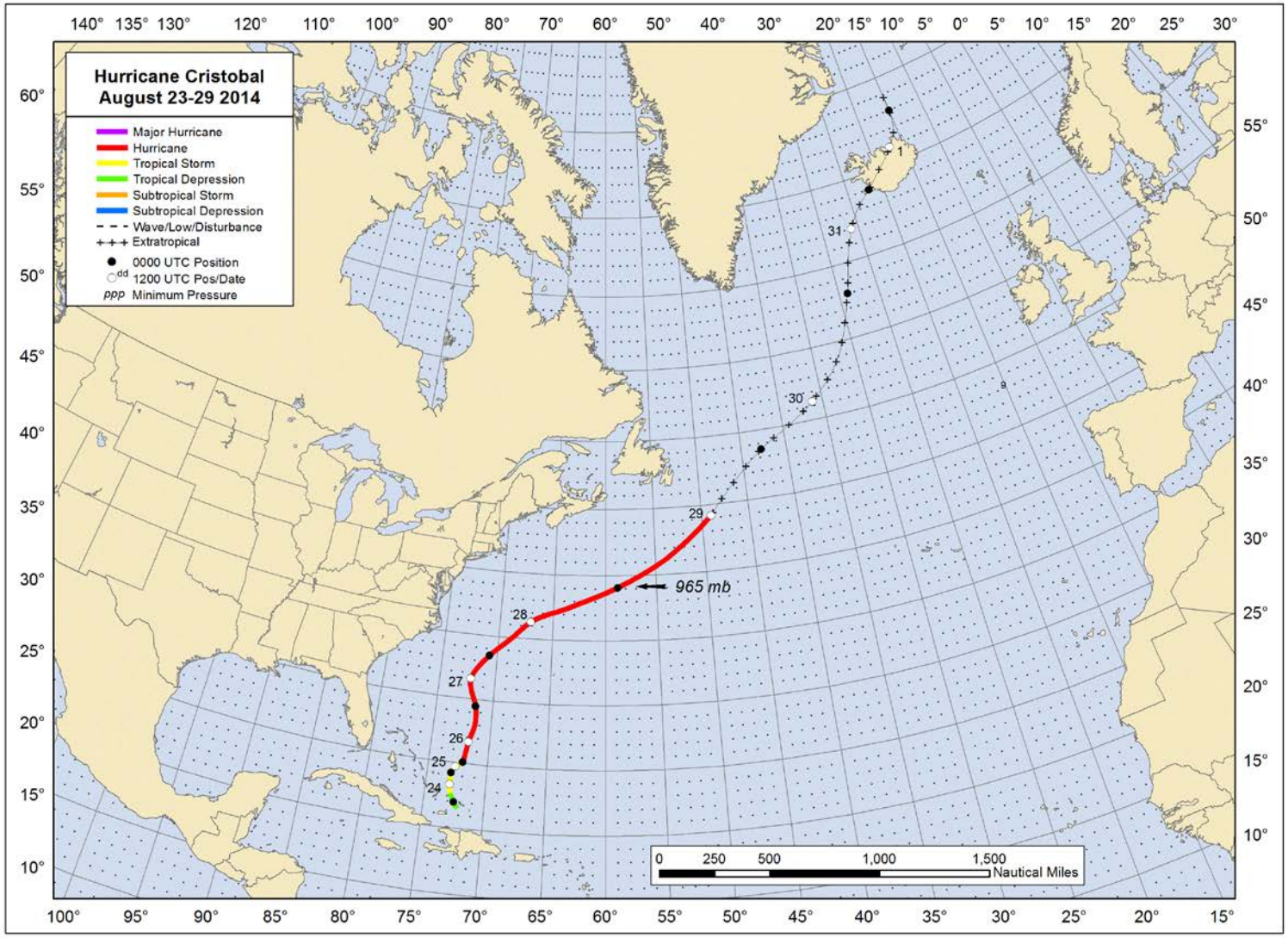

Figure 1. Best track positions for Hurricane Cristobal, 23-29 August 2014. Track during the extratropical stage is partially based on analyses from the NOAA Ocean Prediction Center.

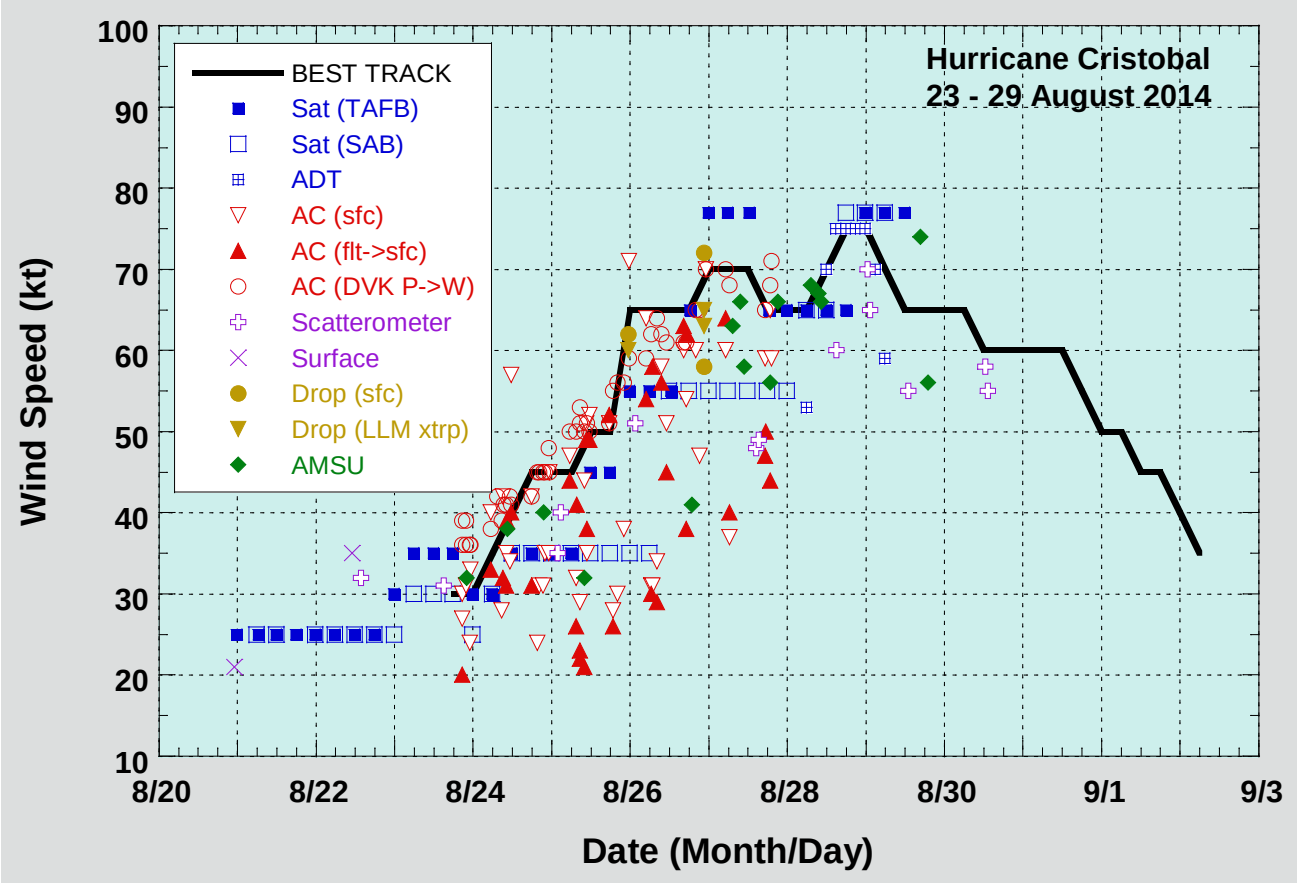

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Cristobal, 23-29 August 2014. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

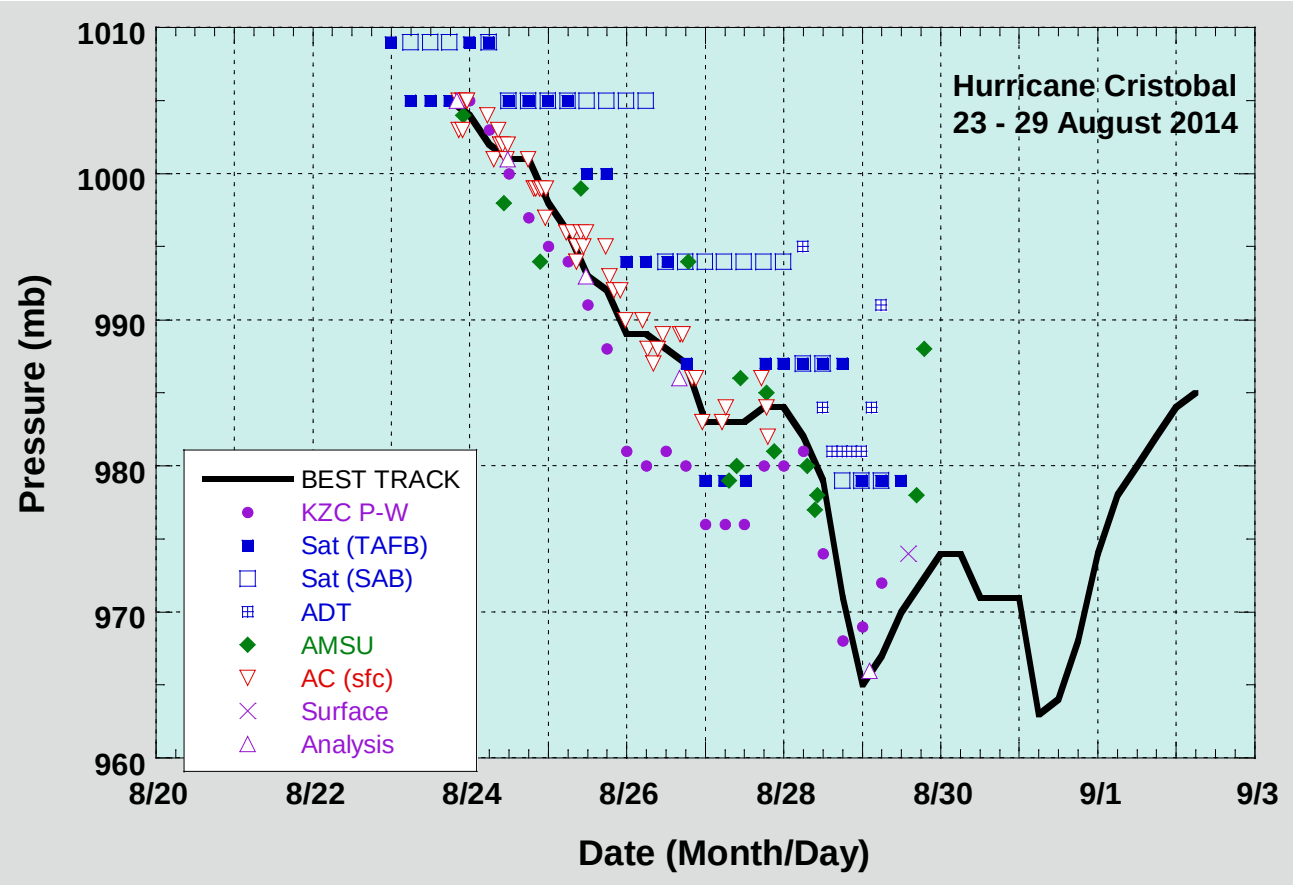

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Cristobal, 23-29 August 2014. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC.