

Tropical Cyclone Report
Hurricane Chris
(AL032012)
18-22 June 2012

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Chris was a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) of non-tropical origins. No June tropical cyclone became a hurricane farther north than Chris.

a. Synoptic History

Chris developed from a baroclinic low that formed along a cold front near Bermuda. The frontal system, accompanied by a weak low pressure area, moved off the coast of the southeastern/mid-Atlantic states early on 13 June. The system moved steadily southeastward over the next couple of days, and became stationary about 250 n mi southwest of Bermuda by 1200 UTC 15 June. To the west, a strong mid- to upper-level trough moved quickly southeastward over the eastern United States and emerged off the southeastern U.S. coast early on 16 June. The trough continued to amplify and dig sharply southeastward, and became negatively tilted southwest of Bermuda by late that same day. Early on 17 June, the trough had closed off into an upper-low about 250 n mi southwest of Bermuda; the upper-low moved north-northeastward and became juxtaposed with the stationary surface low later that day. Associated strong mid- to upper-level cold air advection (Fig. 1) began to de-stabilize the atmosphere, which enhanced the development of modest convection near the center of the surface low pressure system. The vertically coupled extratropical system strengthened and passed over Bermuda around 1800 UTC with an area of gales.

After the gale center and cold front passed over Bermuda, there was only a slight temperature decrease of about 2°C; surface observations from Bermuda and nearby ships indicated temperatures had quickly recovered to their pre-frontal values less than 6 h later. Convection persisted and gradually became better organized around the gale center, and scatterometer wind data from 1352 UTC 17 June to 1330 UTC 18 June revealed during that 24-h period (Fig. 2) that the surface winds associated with the system strengthened and expanded. Synoptic-scale analyses indicate that the frontal system previously associated with the low had mixed out and redeveloped well north of the low-level center, where both air and sea-surface temperature gradients were most pronounced and more conducive for frontogenesis to occur. Some modest inner-core convection formed near the center during the remainder of 18 June, and is estimated that the system made the transition to a subtropical storm by 1800 UTC that day when the cyclone was located about 380 n mi north-northeast of Bermuda. At this time, the system's radius of maximum winds was approximately 100-120 n mi and the upper-low was still collocated with or very near the low-level circulation center, which supports the subtropical cyclone designation. The "best track" chart of Chris' path is given in Fig. 3, with the wind and

pressure histories shown in Figs. 4 and 5, respectively. The best track positions and intensities are listed in Table 1¹.

The subtropical storm moved northeastward and slowed down over the next 36 h. The cyclone's convective organization fluctuated during this time, with an eye-like feature occasionally appearing. Thunderstorm activity gradually became more concentrated around the circulation center with a large curved band of deeper convection becoming established in the southern semicircle. The cold upper low separated from the rest of the circulation by 1200 UTC 19 June, and is estimated that Chris made the transition to a tropical storm at that time when the cyclone was centered about 500 n mi south-southwest of Cape Race, Newfoundland.

Shortly after Chris acquired tropical cyclone status, it moved into the mid-latitude westerlies and accelerated to the east at an average forward speed of about 20 kt, which brought the cyclone over cooler waters. Despite this, the cyclone developed a well-defined, 15 n mi diameter eye embedded within a central dense overcast of cold-topped thunderstorms by 2000 UTC 20 June. Soon thereafter, Chris turned northeastward around the eastern periphery of a second mid- to upper-level trough, during which time the eye persisted. Satellite classifications indicate Chris became a hurricane at an unusually high latitude early on 21 June, and reached its peak intensity at around 1200 UTC 21 June, when the system was located about 550 n mi southeast of Cape Race.

After achieving peak intensity, Chris turned northward around the upper low and maintained hurricane status for another 6 h. By 0000 UTC 22 June, the combination of sea-surface temperatures less than 18°C and increasing mid-level shear caused the hurricane to weaken to a tropical storm. A turn to the northwest brought the cyclone over even colder waters, and Chris quickly made the transition to an extratropical low pressure system around 1200 UTC that same day about 335 n mi east-southeast of Cape Race. The small extratropical gale area made a cyclonic loop over the next 24 h around the periphery of a new upper low that had cut off in the high-latitude westerlies, after which it turned northeastward and steadily weakened over the far North Atlantic. By 1800 UTC 24 June, the post-tropical cyclone was absorbed by a much larger baroclinic low pressure system when it was about 400 n mi northwest of the island of Flores in the westernmost Azores.

b. Meteorological Statistics

Observations in Chris (Figs. 4 and 5) 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 (UW-CIMSS). 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

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 *bt* directory, while previous years' data are located in the *archive* directory.

Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Chris.

Ship reports of tropical-storm-force winds associated with Chris are given in Table 2. A sustained wind of 40 kt with a gust of 56 kt was reported on Bermuda at 1940 UTC 17 June when a small convectively induced vortex and squall line passed over the island during the early non-tropical phase of Chris.

The estimated peak intensity of 75 kt at 1200 UTC 21 June is based on a blend of subjective and ADT² satellite intensity estimates ranging from 65 kt to 80 kt when Chris possessed a distinct eye in multi-spectral satellite imagery (Fig. 6).

A time-series plot of the center or eye temperature and the mean-cloud-top surrounding ring temperature, as part of the UW-CIMSS ADT post-storm re-analysis (Fig. 7), was used in conjunction with vertical cross-sections of the GFS (Fig. 8) and ECMWF (not shown) models to help determine when extratropical, subtropical, and subtropical status changes occurred. GFS model cross-sections of potential vorticity and winds along a southwest-to-northeast axis through the center of the storm clearly show a tilted vortex column remained attached to the cold upper-level low through at least 0000 UTC 19 June, suggesting that a subtropical status was preferable to a tropical one. By 1200 UTC later that day, however, the low- and mid-level circulations finally separated from the cold upper-low circulation, which had sheared out well to the northeast, resulting in Chris making the transition to a tropical storm (albeit it one with a relatively shallow warm core).

Chris became a hurricane at 39.4°N latitude, making it the farthest-north hurricane to develop during the month of June. The only other hurricanes to develop north of 35°N latitude so early in the season were unnamed hurricanes in June 1959 (at 38.4°N 65.3°W) and June 1893 (at 38.3°N 72.9°W).

c. Casualty and Damage Statistics

There were no reports of damage or casualties associated with Chris.

d. Forecast and Warning Critique

The genesis of Chris was somewhat well anticipated. The disturbance from which Chris formed was first mentioned in the Tropical Weather Outlook at 1200 UTC 17 June 30 h before genesis occurred. The disturbance was initially assigned a low chance (<30%) of subtropical or tropical cyclone formation. The chance of development was raised to the medium category (30%-50%) only 6 h before the time of formation in the post-storm analysis.

² The ADT values shown in Figures 3 and 4 were obtained from UW-CIMSS (Tim Olander, personal communication) as part of a re-analysis of the original ADT values by using an eye as the “scene type” instead of the original curved band and shear patterns that the algorithm used operationally; the latter two scene types yielded much lower current intensity (CI) values.

A verification of NHC official track forecasts for Chris is given in Table 3a. Since Chris was a short-lived tropical cyclone, only 9, 7, 5, and 3 official forecasts verified at 12, 24, 36, and 48 h, respectively. Official forecast track (OFCL) errors were lower than the mean official errors at all available times for the previous 5-yr period. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. Although the number of forecast models verified is small, it is noteworthy that OFCL forecasts were better than all of the models at 36 h.

A verification of NHC official intensity forecasts for Chris is given in Table 4a. Official forecast intensity errors were greater than the mean official errors for the previous 5-yr period at 12, 24, and 36 h, respectively. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The primary reason for the larger than average intensity errors was the unanticipated strengthening of Chris to hurricane status over the cool waters of the far northern Atlantic Ocean, where sea-surface temperatures were less than 20°C.

There were no coastal tropical cyclone watches or warnings associated with Chris.

Acknowledgements

Special thanks are offered to John Cangialosi and Dr. Michael Brennan from the National Hurricane Center for their preparation of the Hurricane Leslie track map and the GFS model cross-sections, respectively.

Table 1. Best track for Hurricane Chris, 18-22 June 2012.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
17 / 0000	28.8	68.8	1009	20	low
17 / 0600	29.3	66.9	1008	25	"
17 / 1200	30.4	65.4	1007	30	"
17 / 1800	31.8	64.2	1004	35	"
18 / 0000	33.4	63.5	1004	35	"
18 / 0600	35.1	62.8	1004	35	"
18 / 1200	36.7	62.0	1004	35	"
18 / 1800	38.0	61.3	1004	40	subtropical storm
19 / 0000	38.6	60.4	1003	40	"
19 / 0600	39.1	59.6	1003	40	"
19 / 1200	39.4	58.7	1003	40	tropical storm
19 / 1800	39.5	58.0	1003	40	"
20 / 0000	38.9	56.7	1003	40	"
20 / 0600	38.3	54.7	1002	40	"
20 / 1200	38.1	52.5	1001	45	"
20 / 1800	38.2	50.2	999	50	"
21 / 0000	38.6	47.5	991	60	"
21 / 0600	39.5	45.5	982	70	hurricane
21 / 1200	40.5	43.9	974	75	"
21 / 1800	41.9	42.9	975	70	"
22 / 0000	43.3	42.8	978	60	tropical storm
22 / 0600	44.5	43.9	982	50	"
22 / 1200	44.8	45.8	985	45	extratropical
22 / 1800	44.2	47.8	988	40	"
23 / 0000	42.6	48.4	989	35	"
23 / 0600	40.9	47.4	989	35	"
23 / 1200	40.0	45.0	990	35	"
23 / 1800	40.5	42.5	991	30	"
24 / 0000	41.4	40.2	991	30	"
24 / 0600	42.9	38.5	993	25	"
24 / 1200	43.7	38.2	995	20	"
24 / 1800					absorbed by larger extratropical low
21 / 1200	40.5	43.9	974	75	minimum pressure and maximum intensity

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Chris, 18-22 June 2012.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
19 / 1200	LAVY4	38.6	57.9	280 / 35	1009.0
20 / 1500	DHAF	37.1	51.7	230 / 35	1007.0
20 / 1800	DHAF	36.8	50.4	210 / 38	1006.1
20 / 2100	ZCDJ3	37.1	47.9	200 / 35	1007.0
22 / 0900	YJUF7	46.7	48.0	030 / 35	1004.4
22 / 1200	YJUF7	46.7	48.0	030 / 36	1003.7
22 / 1500	YJUF7	46.7	48.0	030 / 45	1002.1
22 / 1800	VCXF	46.4	48.4	040 / 35	1002.0
22 / 1800	YJQN7	46.4	48.4	030 / 35	1002.5
22 / 1800	YJUF7	46.7	48.0	040 / 38	1003.5
23 / 0600	WAHK	41.0	52.3	330 / 37	1005.0

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Chris. Mean errors for the 5-year period 2007-11 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 (Chris)	25.6	41.7	51.8	62.5			
OCD5 (Chris)	109.4	230.6	337.5	351.4			
Forecasts	9	7	5	3			
OFCL (2007-11)	30.4	48.4	65.9	83.1	124.4	166.5	213.4
OCD5 (2007-11)	46.9	95.2	151.7	211.6	316.8	404.3	485.2

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Chris. 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 3a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	25.1	48.9	54.0	74.5			
OCD5	101.0	229.7	325.2	326.6			
GFSI	29.7	62.0	84.6	142.9			
AEMI	30.8	59.9	68.8	98.5			
EMXI	20.9	41.3	114.0	58.7			
HWFI	23.4	47.6	76.3	47.9			
GHMI	29.7	42.0	59.1	113.5			
TVCA	24.2	41.4	76.5	53.7			
CMCI	33.9	49.5	54.0	67.6			
FSSE	22.4	49.9	65.4	49.0			
NAMI	31.4	70.5	110.1	76.8			
LBAR	66.1	136.7	172.2	200.0			
BAMS	57.6	88.0	92.0	98.1			
BAMM	36.5	63.4	103.9	64.3			
BAMD	46.1	116.2	195.1	245.5			
Forecasts	7	5	4	2			

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Chris. Mean errors for the 5-yr period 2007-11 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 (Chris)	10.0	17.1	21.0	15.0			
OCD5 (Chris)	12.3	20.3	23.4	18.0			
Forecasts	9	7	5	3			
OFCL (2007-11)	7.1	10.8	13.0	15.0	16.9	17.1	18.1
OCD5 (2007-11)	8.4	12.4	15.4	17.7	20.5	21.5	21.2

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Chris. 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	10.0	17.1	21.0	15.0			
OCD5	12.3	20.3	23.4	18.0			
DSHP	10.6	11.3	13.4	10.0			
LGEM	11.0	14.3	17.0	11.3			
HWFI	12.9	21.1	25.6	22.0			
GHMI	13.1	23.6	28.4	25.7			
FSSE	11.2	17.3	21.0	17.0			
Forecasts	9	7	5	3			

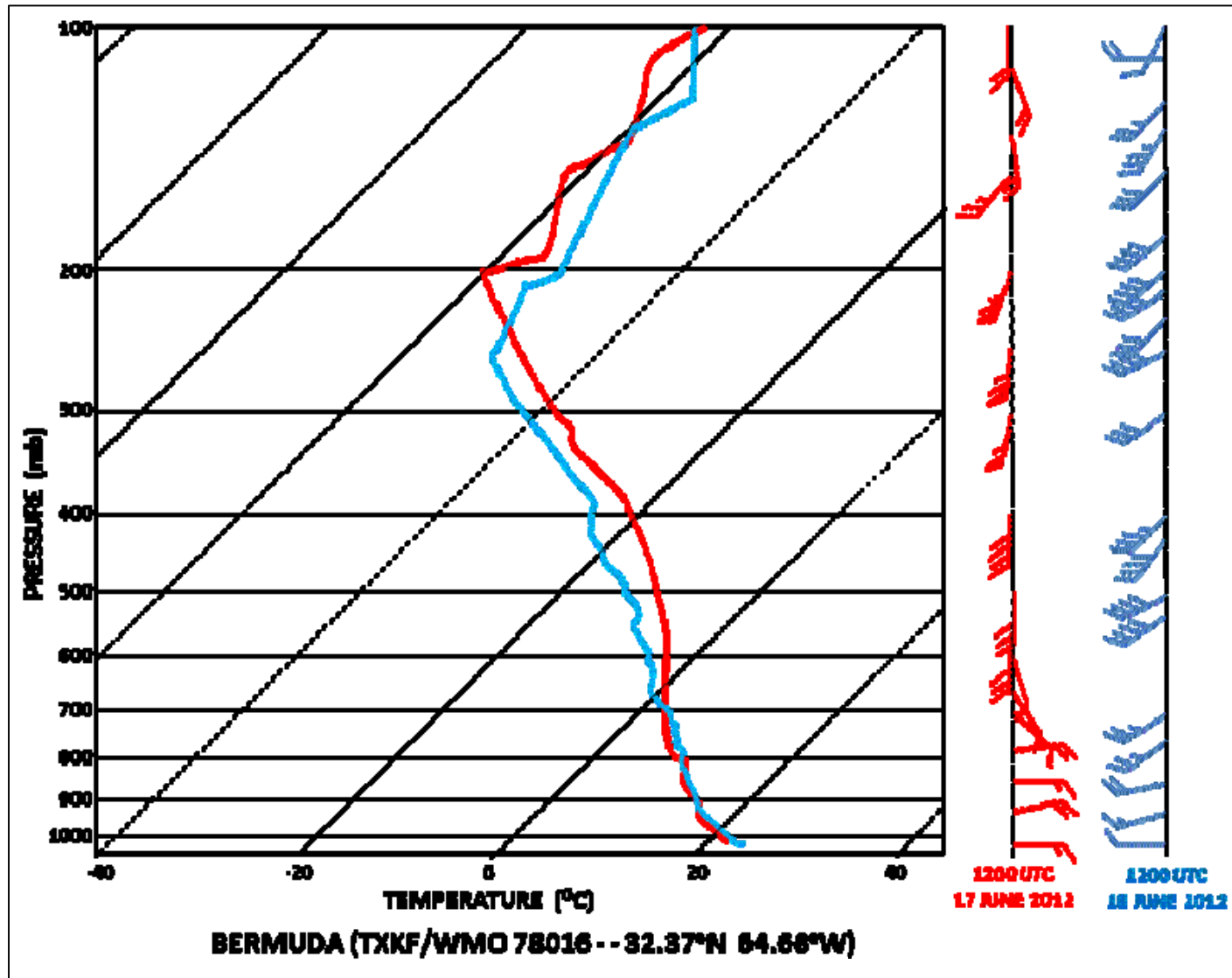


Figure 1. Bermuda (TXKF) vertical temperature and wind profiles for 1200 UTC 17 June 2012 (red) and 1200 UTC 18 June 2012 (blue). During the 24-h period between the soundings, little change in temperature occurred below the 700 mb level, whereas significant cooling occurred between 700 mb and 250 mb in association with the traversal of a mid- to upper-level low across Bermuda.

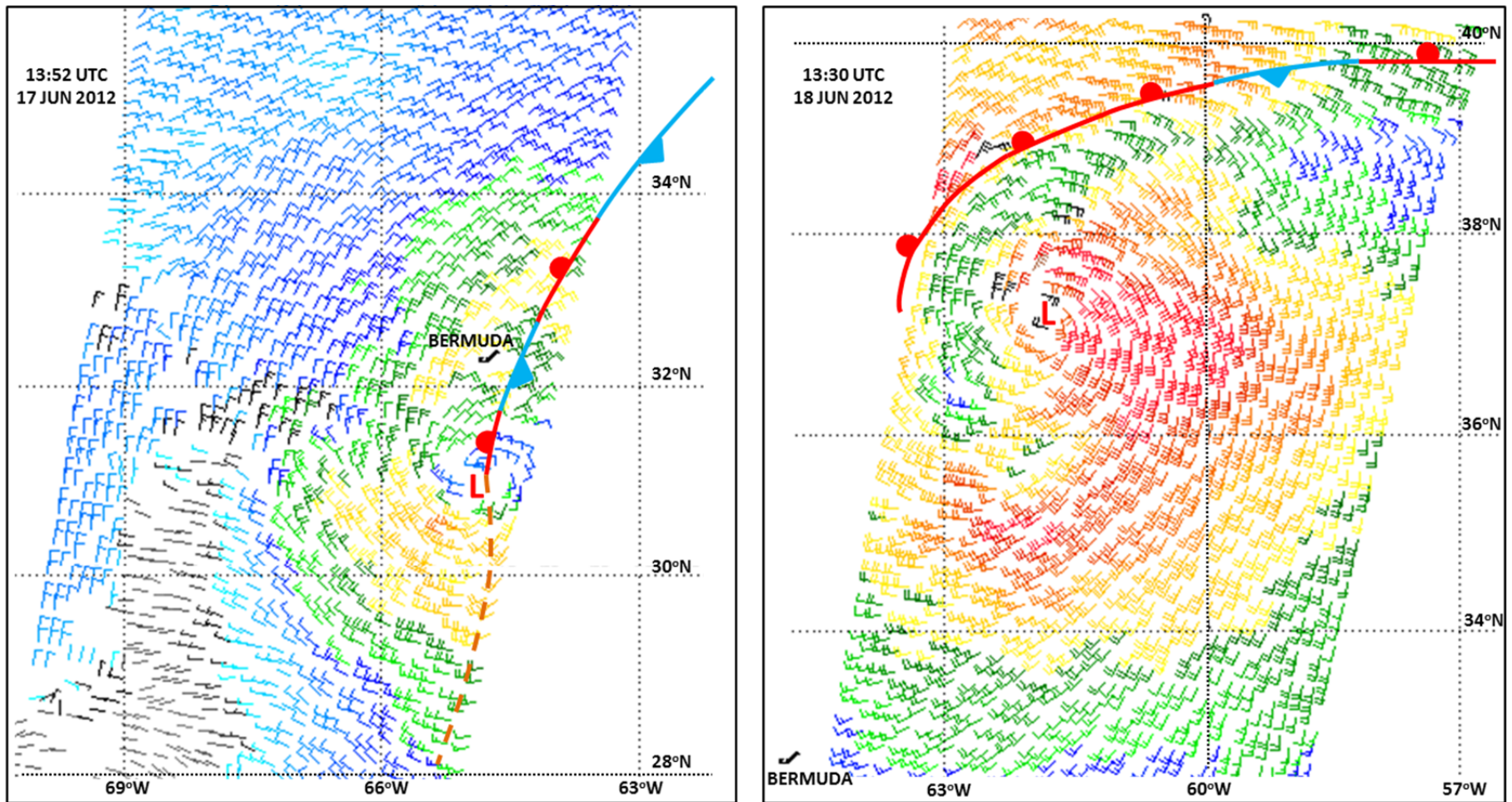


Figure 2. ASCAT satellite scatterometer surface wind data showing the evolution of Chris' precursor low pressure system between 1352 UTC 17 June 2012 (left panel) and 1330 UTC 18 June 2012 (right panel), respectively. Synoptic-scale frontal systems superimposed onto the scatterometer imagery are based on the author's analyses of observational data from Bermuda and nearby ships. (Scatterometer wind data courtesy of the European Space Agency; wind plot graphics courtesy of NOAA-NESDIS Center for Satellite Applications and Research).

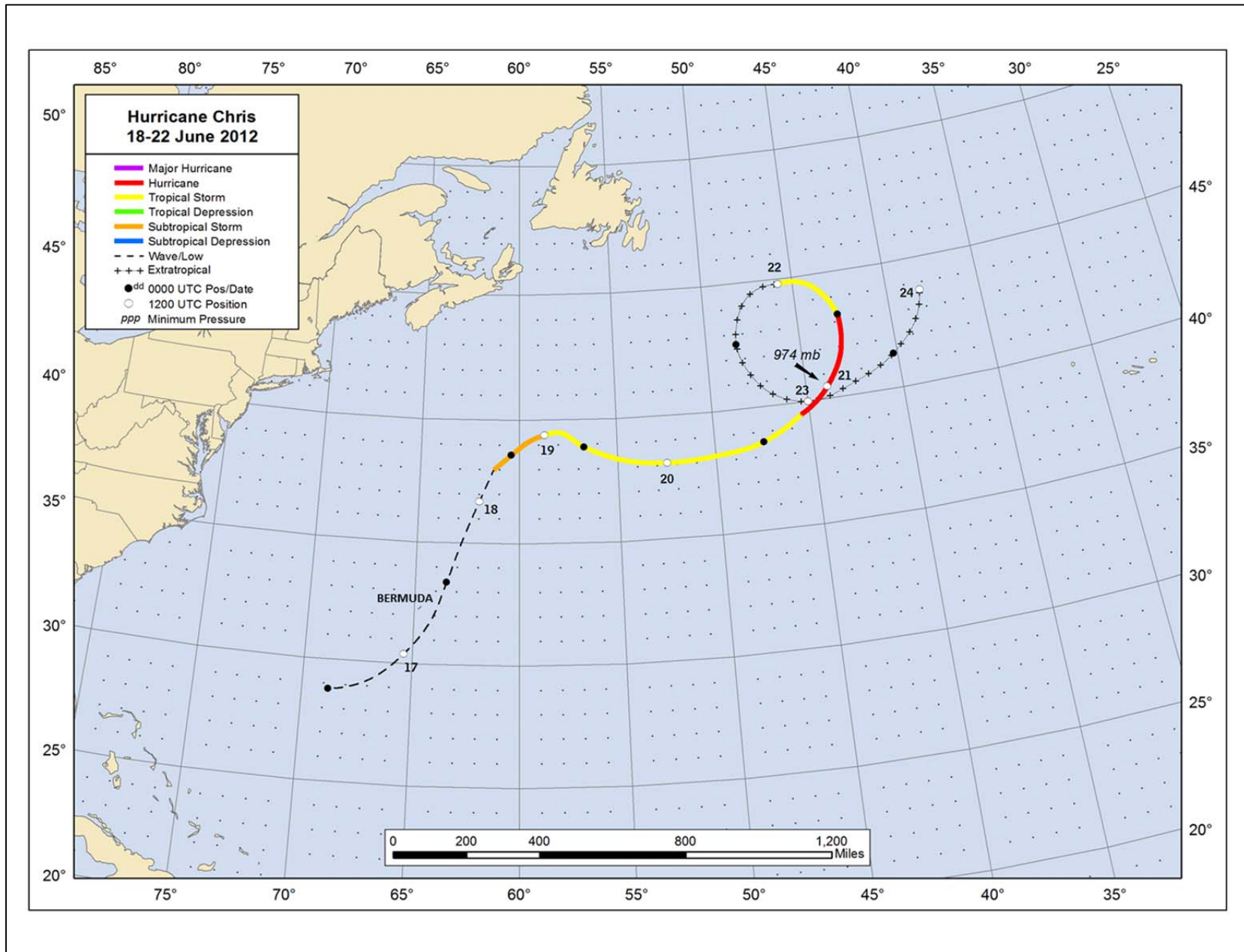


Figure 3. Best track positions for Hurricane Chris, 18-22 June 2012. Track during the extratropical stage is based partly on NOAA Ocean Prediction Center analyses.

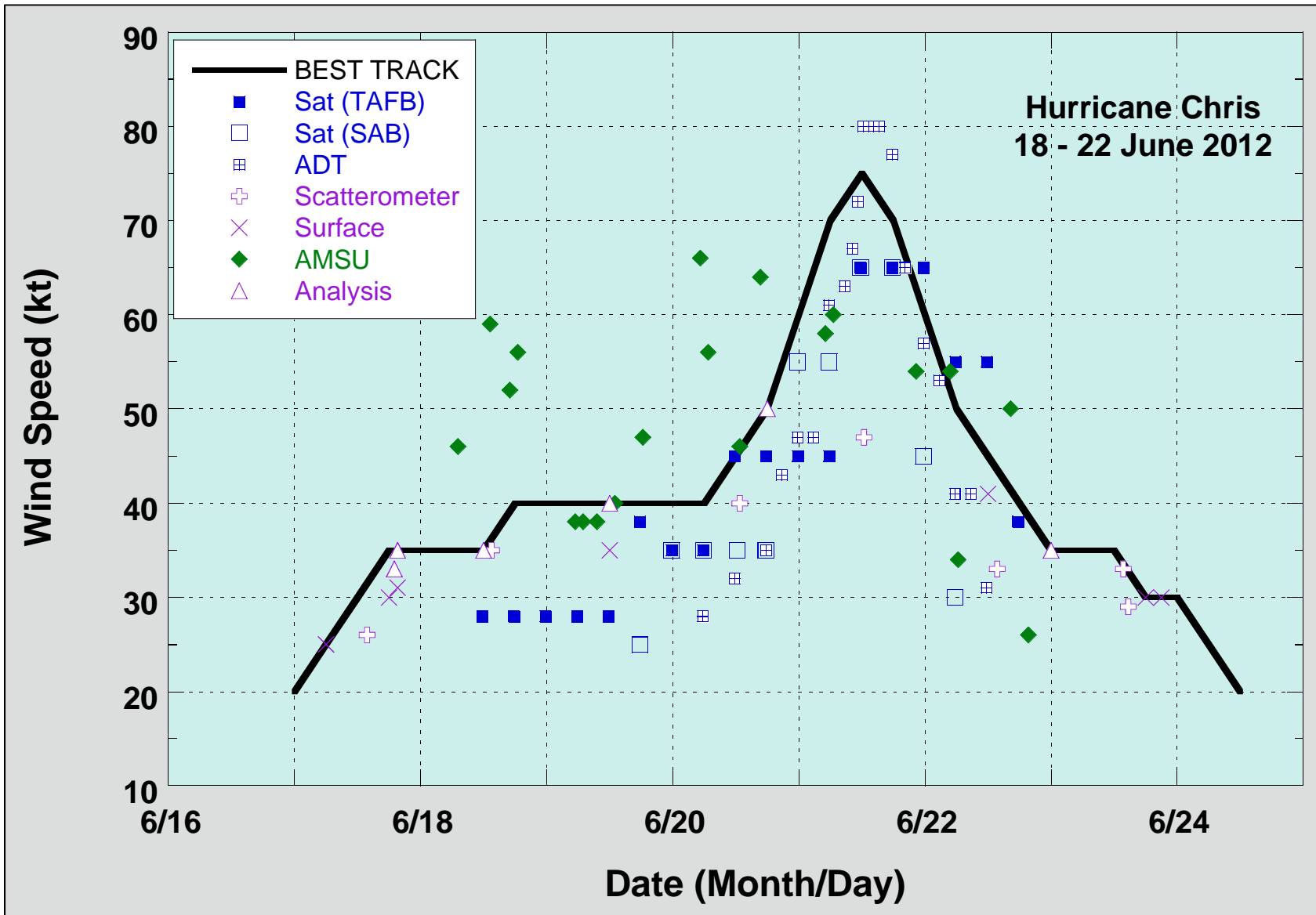


Figure 4. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Chris, 18-22 June 2012. Advanced Dvorak Technique estimates represent CI numbers. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Estimates during the extratropical stage are based partly on analyses from the NOAA Ocean Prediction Center. Dashed vertical lines correspond to 0000 UTC.

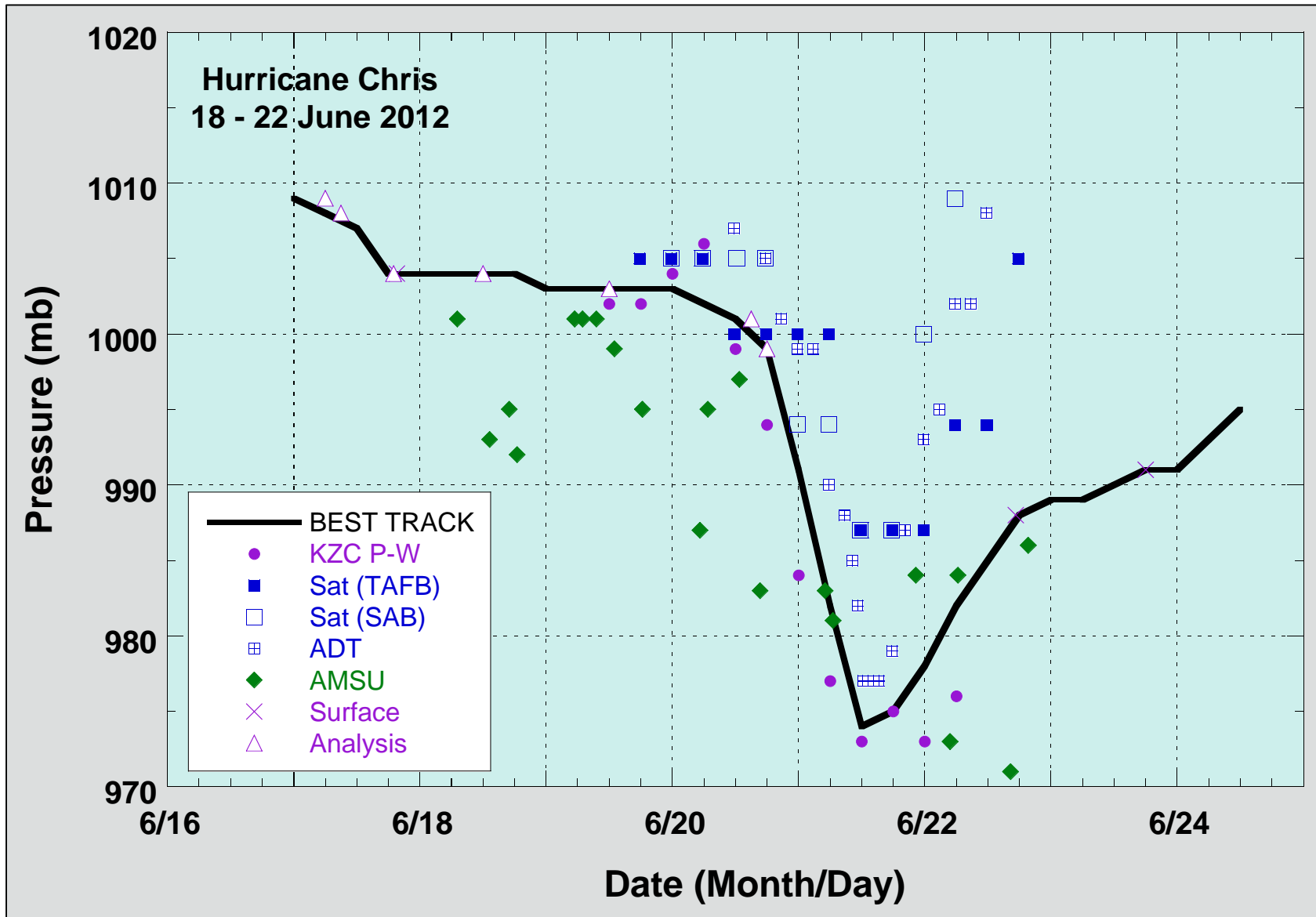


Figure 5. Selected pressure observations and best track minimum central pressure curve for Hurricane Chris, 18-22 June 2012. Advanced Dvorak Technique estimates represent CI numbers. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. The KZC P-W values are obtained by applying the Knaff-Zehr-Courtney pressure-wind relationship to the best track wind data. Estimates during the extratropical stage are based partly on analyses from the NOAA Ocean Prediction Center. Dashed vertical lines correspond to 0000 UTC.

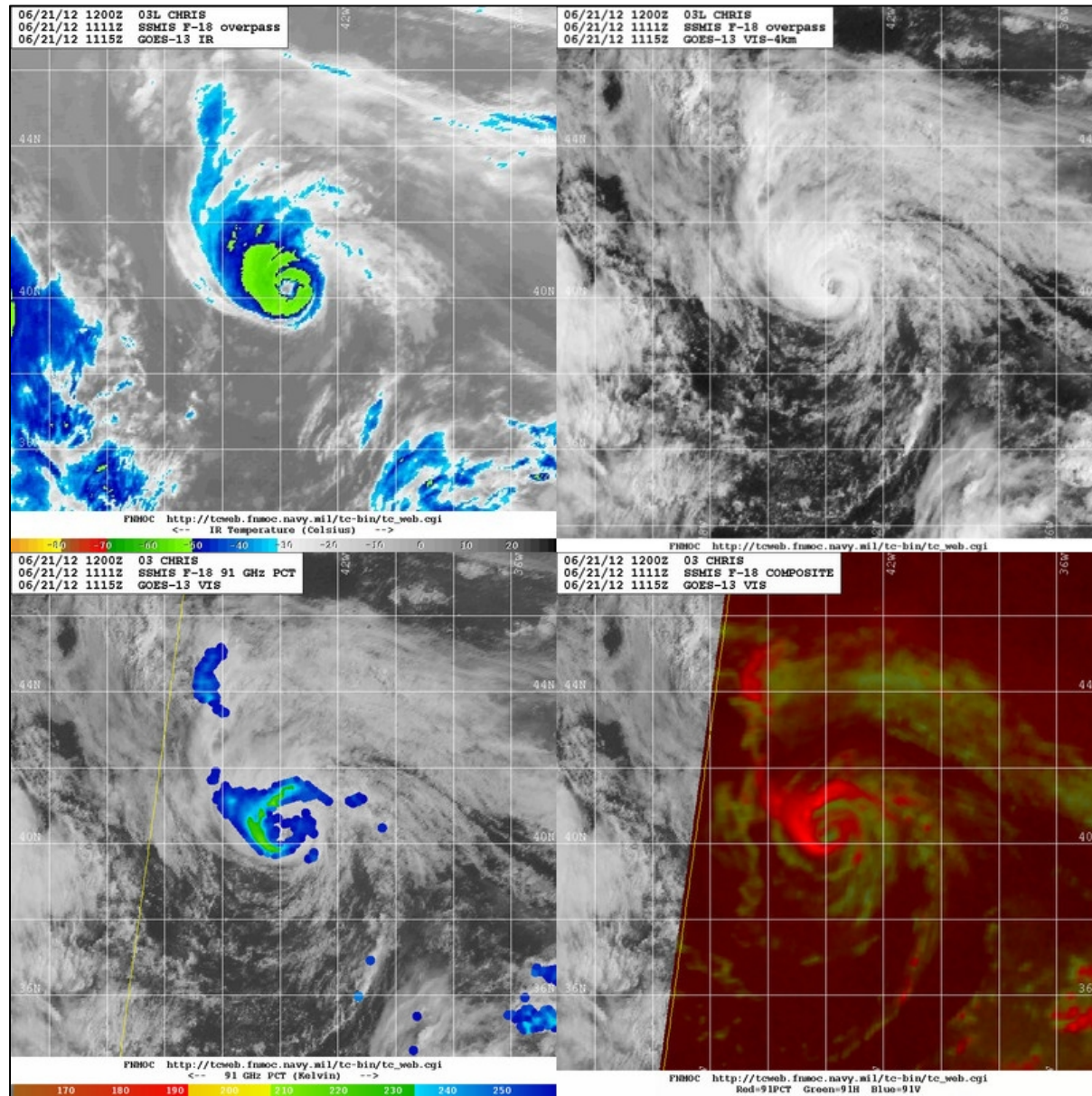


Figure 6. Multi-spectral satellite imagery indicating a well-defined eye feature at 1111 UTC 21 June 2012 when Chris was near its peak intensity of 75 kt (imagery courtesy of U.S. Navy Fleet Numerical and Oceanography Center, Monterey, CA).

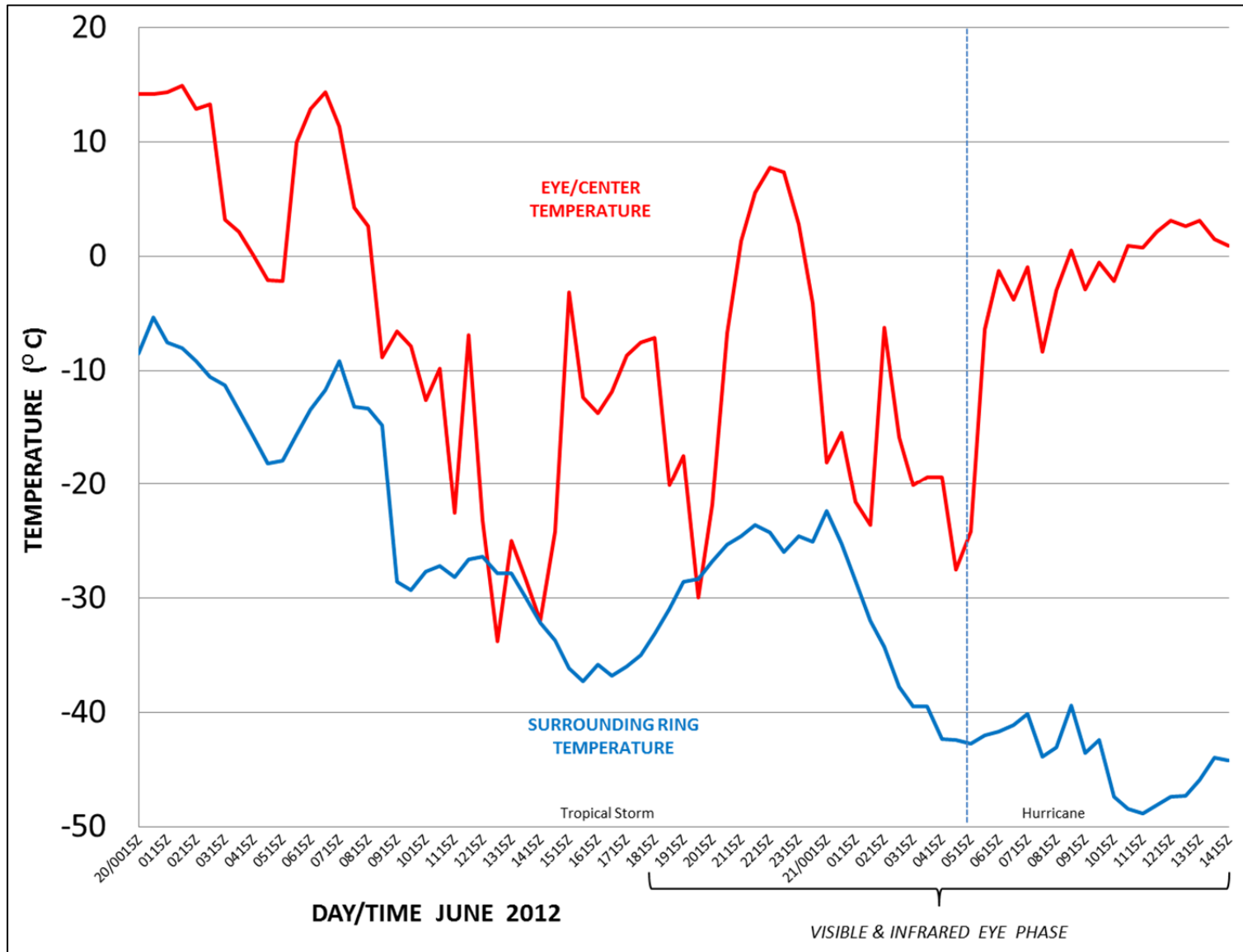


Figure 7. Center and surrounding ring temperature for Hurricane Chris during the period 0015 UTC 20 June to 1415 UTC 21 June 2012 when an eye feature was present in visible and infrared satellite imagery. Temperature data were provided by the University of Wisconsin CIMSS (UW-CIMSS) Advanced Dvorak Technique (ADT). The surrounding ring temperature is the mean cloud top temperature averaged within an 80-km annulus beginning at least 24km from the determined center position of the tropical cyclone. Dashed vertical line indicates approximate time of tropical storm-to-hurricane status change.

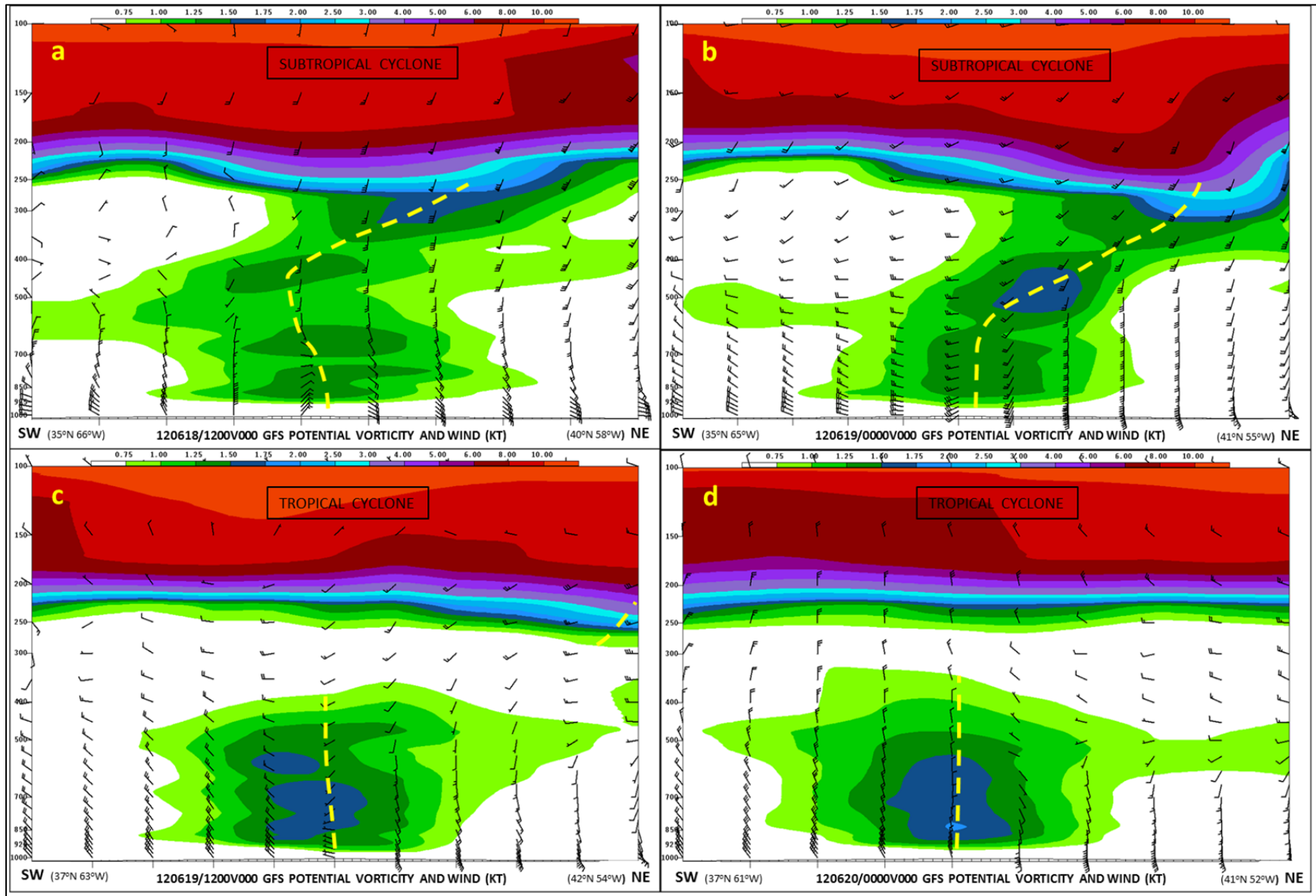


Figure 8. NOAA GFS model vertical cross-sections of potential vorticity (PVU) and winds (kt) along southwest-to-northeast axes through the center of Chris at (a) 1200 UTC 18 June, (b) 0000 UTC 19 June, (c) 1200 UTC 19 June, and (d) 0000 UTC 20 June. Dashed yellow line indicates approximate center of vortex column associated with Chris. The transition from subtropical to tropical cyclone status occurred by 1200 UTC 19 June when the upper cold low sheared away to the northeast of the main vortex column.