NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE SANDRA

(EP222015)

23 – 28 November 2015

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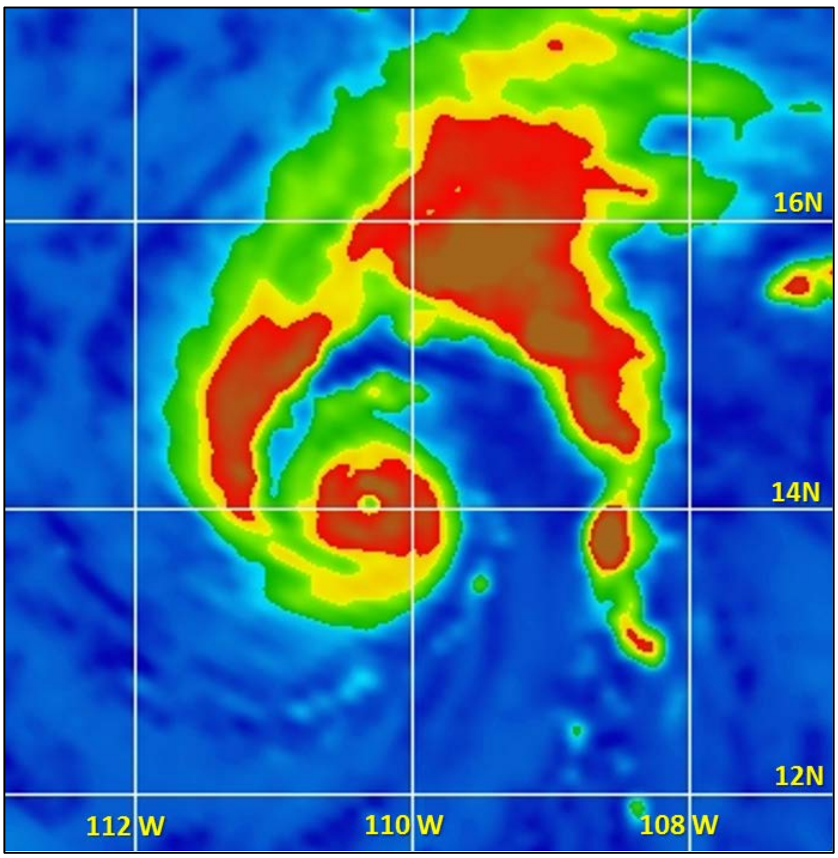

0706 UTC 26 NOV 2015 89GHZ GPM SATELLITE IMAGE OF SANDRA REVEALING A TINY EYE NEAR THE TIME OF PEAK INTENSITY. IMAGE COURTESY NAVAL RESEARCH LABORATORY, MONTEREY, CA.

Sandra was a late-season category 4 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that remained over the open eastern North Pacific Ocean during its lifetime. Sandra weakened to a remnant low pressure system and dissipated just offshore of the northwestern coast of Mexico. Sandra is the latest-forming major hurricane in the eastern North Pacific basin during the satellite era, surpassing Hurricane Kenneth in 2011.

Hurricane Sandra

23 – 28 NOVEMBER 2015

SYNOPTIC HISTORY

The precursor disturbance from which Sandra formed was a tropical wave that moved off of the west coast of Africa on 6 November. The wave moved westward across the tropical Atlantic producing only sporadic convection over the next several days. When the disturbance moved into the southwestern Caribbean Sea on 17-18 November, however, the system encountered low-level westerly winds associated with the eastern North Pacific intertropical convergence zone (ITCZ), resulting in the development of considerable thunderstorm activity and the formation of a broad 1004-mb surface low pressure area. Although the deep-layer vertical wind shear across that area was strong enough to inhibit the development of a tropical cyclone, the low was still able to develop vertically up to at least the 400-mb level, which set the stage for significant development afterwards when the low moved into the eastern North Pacific basin.

The surface low and associated convection weakened while the system moved across Central America. However, deep convection redeveloped near the center of the low after it emerged over the Pacific Ocean off of the coast of Nicaragua early on 21 November. The system moved westward at 10-15 kt for the next couple days and convection continued to increase, while in the Gulf of Tehuantepec a gap wind event developed to the north of the broad low. Horizontal wind shear and strong low-level cyclonic vorticity associated with the gale-force winds appear to have contributed to a spin up of a tight surface low by 1200 UTC 23 November, within the west side of the broader cyclonic gyre. Six hours later, convection became sufficiently organized for the low to be considered a tropical depression when it was located about 380 n mi south-southwest of Acapulco, Mexico. 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 depression moved west-northwestward along the southern periphery of a deep-layer subtropical ridge located across central Mexico. Moving over a region of sea-surface temperatures near 30° C, and embedded within an environment of light vertical wind shear and mid-level moisture, the small cyclone strengthened, becoming a tropical storm by 0000 UTC 24 November when it was located about 500 n mi south of Manzanillo, Mexico. During this time, the radius of maximum winds (RMW) gradually decreased. When Sandra reached an intensity of 50 kt around 1800 UTC 24 November, a primitive eye feature with a diameter of 20-25 n mi had developed, and a period of rapid intensification began. During the next 36 h, the cyclone strengthened by 80 kt, becoming a hurricane by 0600 UTC 25 November about 475 n mi southwest of Manzanillo, and then a major hurricane by 0000 UTC 26 November about 560 n mi south of the southern tip of the Baja California peninsula. By the time Sandra had reached its peak intensity of 130 kt at 0600 UTC 26 November, the RMW had contracted to the point where a pinhole eye, with a diameter of less than 5 n mi, was evident in passive microwave satellite imagery (cover page). Sandra is the latest-forming major hurricane in the eastern North Pacific basin during the satellite era, surpassing Kenneth’s major hurricane status in 2011 by almost four days (Stewart 2011).

Now moving northward through a break in the subtropical ridge, Sandra began to encounter increasing southwesterly vertical wind shear, and the hurricane began to weaken. The shear was modest at first, causing Sandra to only weaken by 20 kt over the next 18 h. However, after 0000 UTC 27 November, the 850-200 mb vertical wind shear increased to more than 20 kt (Fig. 4), inducing a more rapid weakening. Sandra dropped below major hurricane status by 0600 UTC 27 November while the system turned toward the north-northeast, being steered between the subtropical ridge to the east of the cyclone and an approaching deep-layer trough to its west. Rapid weakening continued, and Sandra became a tropical storm by 0000 UTC 28 November when the cyclone was located about 205 n mi southwest of Mazatlán, Mexico.

For the next 16 h, Sandra was devoid of significant deep convection and quickly spun down to a remnant low. Due to becoming more vertically shallow, the cyclone stopped moving northeastward and made a sharp jog toward the northwest under the influence of a narrow low-level ridge. However, a brief burst of vigorous convection redeveloped in the northeastern quadrant by 1800 UTC 28 November, and the low turned back toward the northeast in response to the deep-layer southwesterly steering flow. By 1800 UTC 29 November, the shallow and elongated cyclone succumbed to vertical wind shear in excess of 40 kt, and degenerated into a trough of low pressure about 50 n mi southwest of Culiacán, Mexico.

METEOROLOGICAL STATISTICS

Observations in Sandra (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. 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 Sandra.

There were no ship or land-based reports of sustained winds of tropical storm force associated with Sandra. However, 35-kt wind gusts were reported on Socorro Island at 0000 UTC and 0015 UTC 27 November when Sandra was passing about 100 n mi southeast of the island.

During Sandra's entire intensification phase, time of peak intensity, and weakening phase through 0000 UTC 28 November, the cyclone was over sea-surface temperatures > 29^{O} C. The hurricane was also embedded within a moist mid-level (700-500 mb) environment with relative humidity values >70% through 1200 UTC 26 November and >60% through 1800 UTC 27 November (based on the GFS analyses used in the SHIPS intensity model guidance). Given that both of these parameters are typically favorable for strengthening to occur, it appears that the 850-200 mb vertical wind shear was the primary modulating factor (Fig. 4) of Sandra's intensity. Hurricane Sandra began strengthening when it first developed a closed surface circulation around 1200 UTC 23 November. The intensification process continued until 0600 UTC 26 November. During this time, vertical wind shear values were <10 kt, and reached a minimum value of 3 kt only 6 h before Sandra achieved its peak intensity of 130 kt. Shortly after reaching its peak intensity, the hurricane slowly weakened over the next 18 h when the vertical shear increased to more than 10 kt. During this time, there was no evidence in passive microwave satellite imagery (Fig. 5) that an eyewall replacement cycle had occurred. During this period, however, the pinhole eye did increase to a diameter of 5-10 n mi.

Winds and Pressure

Sandra's estimated peak intensity of 130 kt at 0600 UTC 26 November is based on an average of a Dvorak satellite intensity estimate of T6.5/127 kt from TAFB and an ADT intensity estimate of T6.8/135 kt from CIMSS-UW. The estimated minimum central pressure of 934 mb is based on the Knaff-Zehr-Courtney (KZC) pressure-wind relationship.

Sandra is the latest-forming major hurricane in the eastern North Pacific basin during the satellite era, and it is the only the second major hurricane to have occurred in the month of November. The previous latest-occurring major hurricane was Kenneth, which reached a peak intensity of 125 kt on 22 November 1985. Prior to Kenneth, the previous latest-occurring major hurricane was Xina, which briefly reached a peak intensity of 100 kt on 29 October 1985. Sandra is also only one of seven hurricanes to have occurred during the month of November since official record keeping began in 1949.

Rainfall and Flooding

Sandra weakened to a non-convective remnant low pressure system and dissipated just offshore of the northwestern coast of Mexico, and no heavy rainfall or flooding reports were received from either mainland Mexico or Baja California Sur. However, beneficial rainfall amounts over southwestern Mexico ahead of the approaching cyclone and its remnants were generally in the range of 1 to 3 inches.

CASUALTY AND DAMAGE STATISTICS

There were no reports of damage or casualties received in association with Sandra.

FORECAST AND WARNING CRITIQUE

The genesis of Sandra was very well forecast (Table 2). The disturbance that became Sandra was first introduced into the Tropical Weather Outlook (TWO) with a 20% (low) chance of formation in five days at 1200 UTC 19 September, and was first mentioned in the 48-h forecast period at 1200 UTC 21 September with a 10% (low) chance of development 54 h before genesis occurred. The 5-day and 48-h formation probabilities were increased to the medium chance category (40% - 60%) 84 h and 42 h, respectively, before Sandra developed. The 5-day genesis probability reached the high (> 60%) chance category 72 h before genesis occurred, and the 48-h probability reached the high chance category 30 h before Sandra formed into a tropical cyclone. The global models, especially the GFS, indicated tropical cyclogenesis was likely to occur several days in advance.

A verification of NHC official track forecasts for Sandra is given in Table 3a. Official forecast track errors were greater than the mean official errors for the previous 5-yr period at 12 h through 96 h. At the 12- and 24-h periods, OFCL errors were about 50% worse than the 5-yr average, whereas the climatology (OCD5) errors were only about 30% worse than average, indicating that NHC track forecasts were not particularly skillful at those times. The reasons for the larger-than-average forecast track errors was due to Sandra moving slower than forecast and also not making as wide of a turn as expected before recurvature into the higher latitudes occurred (Fig. 6). A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. Despite the aforementioned less skillful track forecasts, OFCL forecasts were still comparable to or even outperformed most of the track model guidance at nearly every forecast time, except for the GFSI model at all times, the consensus models

TVCE and TCON at 24 h-72 h. The ECMWF model (EMXI) had track errors that were more than 30%-50% greater than the NHC official track errors (OFCL) at all times. Those large errors may have been caused by the ECMWF's poor model initialization of both the location, strength, and vertical structure of Sandra during the cyclone's tropical depression and tropical storm stages prior to Sandra becoming a major hurricane. In contrast, the GFS model (GFSI) showed a stronger and more robust tropical cyclone in the model fields, and it also initialized Sandra much closer to the NHC official best track positions during all stages of the cyclone's lifetime.

A verification of NHC official intensity forecasts for Sandra is given in Table 4a. OFCL intensity errors compared to the mean official errors for the previous 5-yr period were higher than average at 12h through 48 h. Only at 72 h were the NHC intensity errors lower than average. The higher-than-average intensity errors were due primarily to not capturing the rapid intensification period that Sandra underwent shortly after the cyclone formed, despite nearly every OFCL forecast being above the available intensity guidance just prior to the time of Sandra's peak intensity. In contrast, Sandra's rapid weakening phase was extremely well forecast (Fig. 7). Despite the larger-than-average errors, a homogeneous comparison of the official intensity errors with selected guidance models (Table 4b) shows that NHC official intensity forecasts outperformed all of the available intensity guidance at all forecast periods.

Watches and warnings associated with Sandra are given in Table 5.

REFERENCES

Stewart, S.R., 2012: *Hurricane Kenneth (EP132011) Tropical Cyclone Report*, NOAA National Hurricane Center, Miami, FL. pp. 14. (http://www.nhc.noaa.gov/data/tcr/EP132011_Kenneth.pdf)

Table 1. Best track for Hurricane Sandra, 23 - 28 November 2015.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage*
23 / 1200	10.9	100.5	1006	25	low
23 / 1800	10.8	102.0	1005	30	tropical depression
24 / 0000	10.8	103.3	1004	35	tropical storm
24 / 0600	10.9	104.4	1002	40	"
24 / 1200	11.2	105.5	1000	45	"
24 / 1800	11.5	106.6	999	50	"
25 / 0000	11.8	107.6	996	60	"
25 / 0600	12.1	108.5	989	70	hurricane
25 / 1200	12.3	109.3	976	85	"
25 / 1800	12.7	109.7	967	95	"
26 / 0000	13.3	110.2	957	110	"
26 / 0600	14.1	110.2	934	130	"
26 / 1200	15.2	110.2	943	120	"
26 / 1800	16.3	110.2	947	115	"
27 / 0000	17.4	109.8	951	110	"
27 / 0600	18.5	109.3	963	95	"
27 / 1200	19.3	108.8	970	85	"
27 / 1800	20.0	108.2	978	75	"
28 / 0000	20.7	108.8	987	60	tropical storm
28 / 0600	21.2	109.1	994	40	low
28 / 1200	21.7	109.0	1002	35	"
28 / 1800	22.4	108.7	1007	30	"
29 / 0000	23.1	108.3	1008	30	"
29 / 0600	23.5	107.9	1009	25	"
29 / 1200	24.2	107.7	1010	20	"
29 / 1800					dissipated
26 / 0600	14.1	110.2	934	130	minimum pressure and maximum intensity

Table 2. Number of hours in advance of formation of Hurricane Sandra 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 (<40%)	54	102
Medium (40%-60%)	42	84
High (>60%)	30	72

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Sandra, 23 - 28 November 2015. 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	34.7	54.9	70.1	81.1	104.2	124.6	
OCD5	44.6	96.2	168.0	245.9	434.0	571.5	
Forecasts	16	14	12	10	6	2	
OFCL (2010-14)	23.4	36.4	47.2	59.4	89.0	123.6	159.5
OCD5 (2010-14)	36.6	74.2	116.5	159.7	245.6	331.1	427.4

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Sandra, 23 - 28 November 2015. 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	29.2	54.6	71.5	84.3	103.9		
OCD5	42.7	97.3	176.2	268.2	452.3		
GFSI	**28.9**	**51.6**	**62.9**	**76.5**	**97.2**		
EMXI	38.7	74.4	108.8	131.3	137.9		
EGRI	44.1	73.8	84.2	112.0	199.5		
CMCI	61.4	116.9	177.7	227.9	384.1		
NVGI	37.4	79.3	114.8	111.9	155.4		
AEMI	35.2	61.2	76.1	**82.1**	**91.8**		
HWFI	**28.6**	**49.4**	77.0	84.8	119.8		
GHMI	36.8	59.0	79.2	**79.5**	167.8		
GFNI	40.4	83.1	106.1	123.4	304.5		
FSSE	32.5	55.3	73.2	92.1	129.5		
TVCE	31.2	**54.0**	**67.1**	**80.4**	**94.6**		
TCON	31.1	**51.4**	**62.9**	**69.2**	**91.1**		
BAMD	44.8	98.3	143.3	173.3	**101.9**		
BAMM	39.1	82.3	136.1	198.8	214.8		
BAMS	74.6	145.4	222.6	312.2	449.8		
LBAR	35.0	87.3	140.7	193.8	270.8		
Forecasts	13	12	10	8	4		

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Sandra, 23 - 28 November 2015. 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	6.3	11.8	16.7	21.5	17.5	**5.0**	
OCD5	9.9	18.9	28.3	32.4	28.3	8.0	
Forecasts	16	14	12	10	6	2	
OFCL (2010-14)	5.9	9.8	12.5	14.0	15.5	16.3	14.9
OCD5 (2010-14)	7.7	12.8	16.4	18.8	21.1	20.9	19.7

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Sandra, 23 - 28 November 2015. 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	6.8	12.9	16.5	20.0	11.3		
OCD5	10.8	20.8	29.7	31.0	17.5		
GFSI	12.3	22.9	30.7	32.6	16.8		
EMXI	17.5	32.8	42.9	43.0	27.0		
NVGI	13.4	24.4	30.1	29.0	15.5		
HWFI	10.4	18.4	23.7	24.6	18.3		
GHMI	13.6	23.2	32.7	28.6	17.3		
GFNI	15.8	29.1	35.2	30.6	17.3		
FSSE	8.5	13.9	16.8	21.3	12.3		
DSHP	9.4	16.4	21.1	25.1	17.8		
LGEM	8.5	15.4	19.7	23.6	21.3		
ICON	10.2	17.8	22.8	24.8	17.3		
IVCN	10.2	17.8	22.8	24.8	17.3		
Forecasts	14	12	10	8	4		

Table 5. Watch and warning summary for Hurricane Sandra, 23 - 28 November 2015.

Date/Time (UTC)	Action	Location
26 / 2100	Tropical Storm Watch issued	Baja California peninsula from Todos Santos to Los Barriles.
27 / 1500	Tropical Storm Watch discontinued	All
27 / 1500	Tropical Storm Warning issued	Coast of mainland Mexico from Altata to San Blas and for Las Islas Marías.
28 / 0900	Tropical Storm Warning discontinued	All

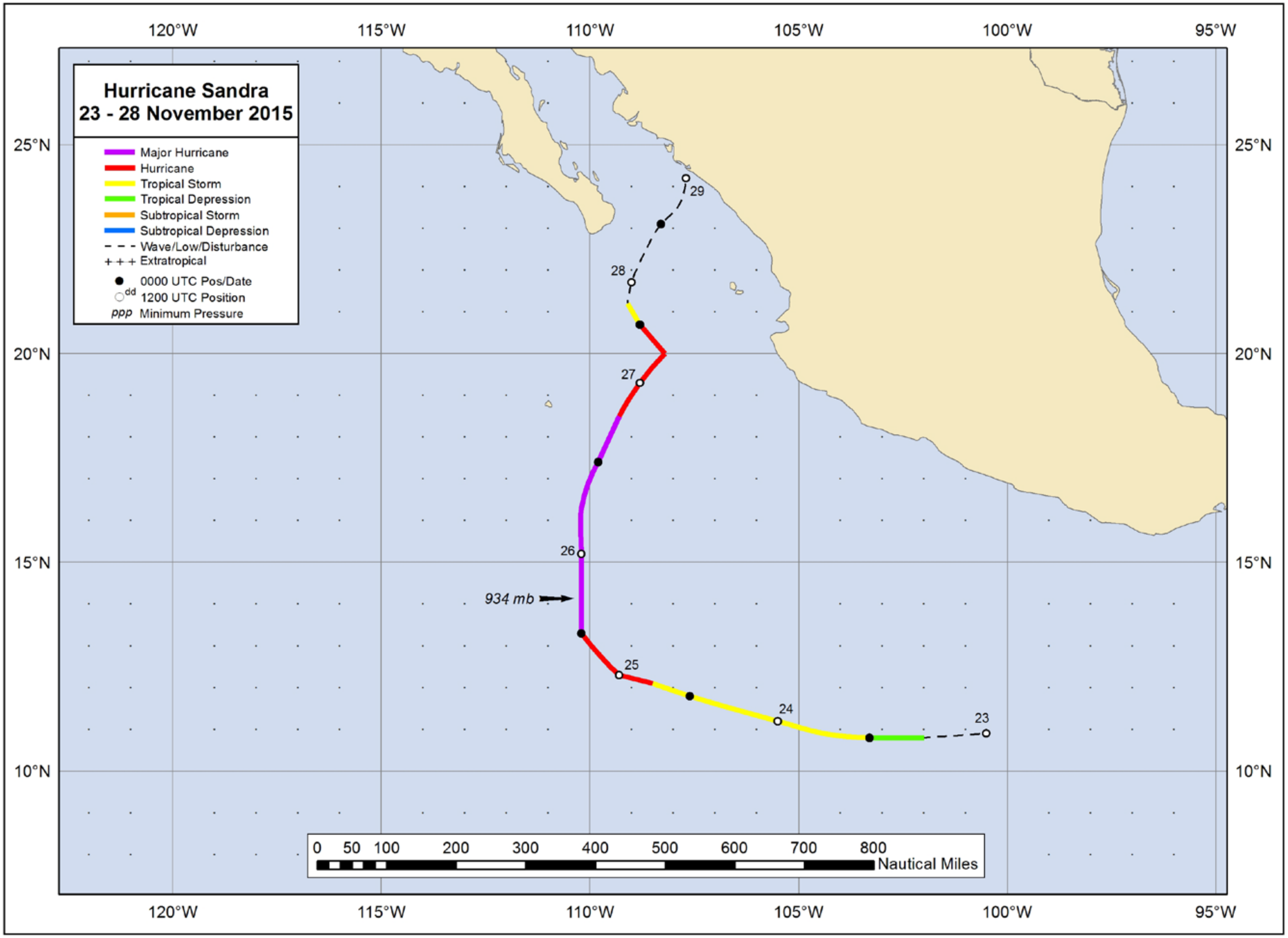

Figure 1. Best track positions for Hurricane Sandra, 23-28 November 2015.

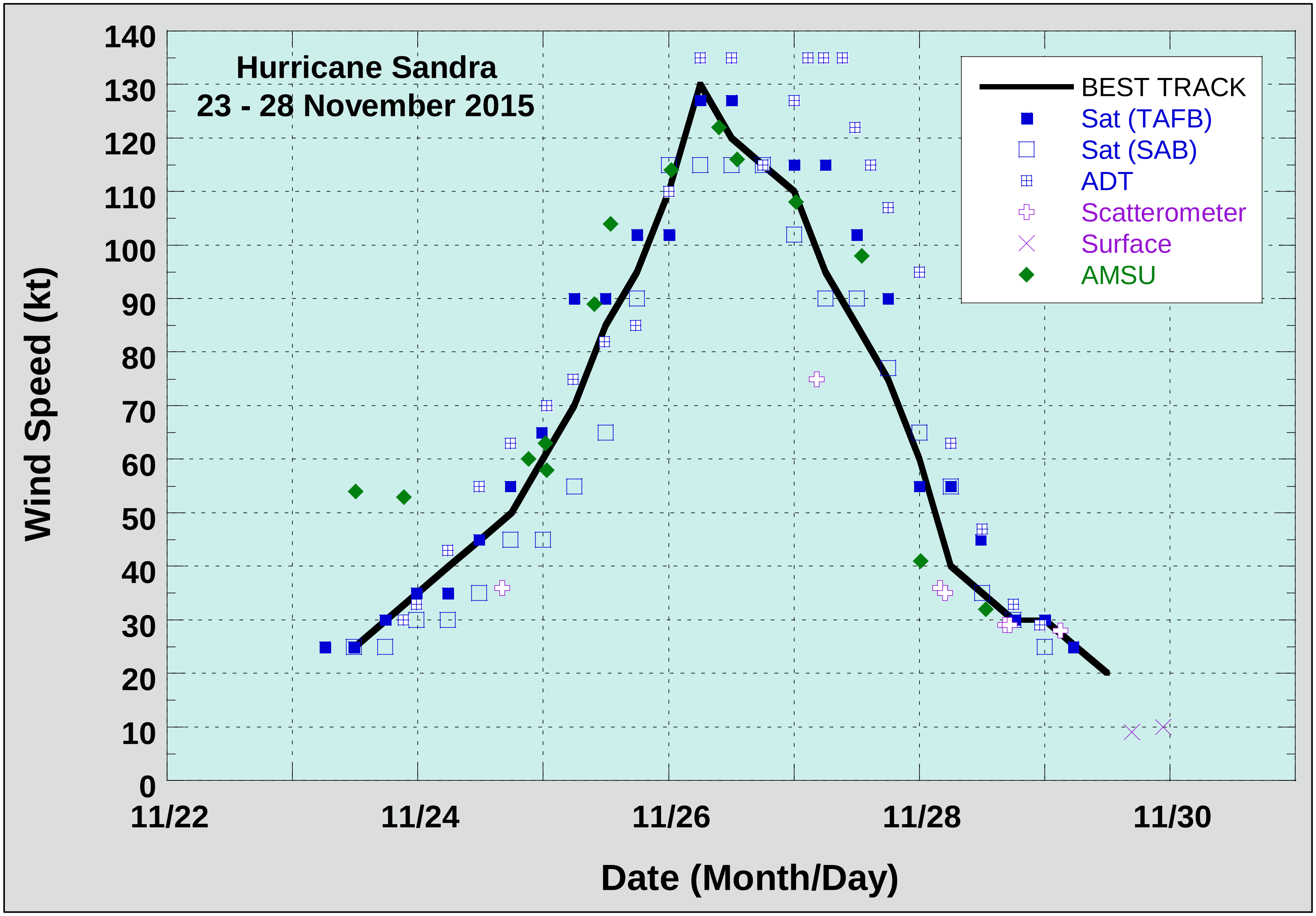

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Sandra, 23-28 November 2015. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC.

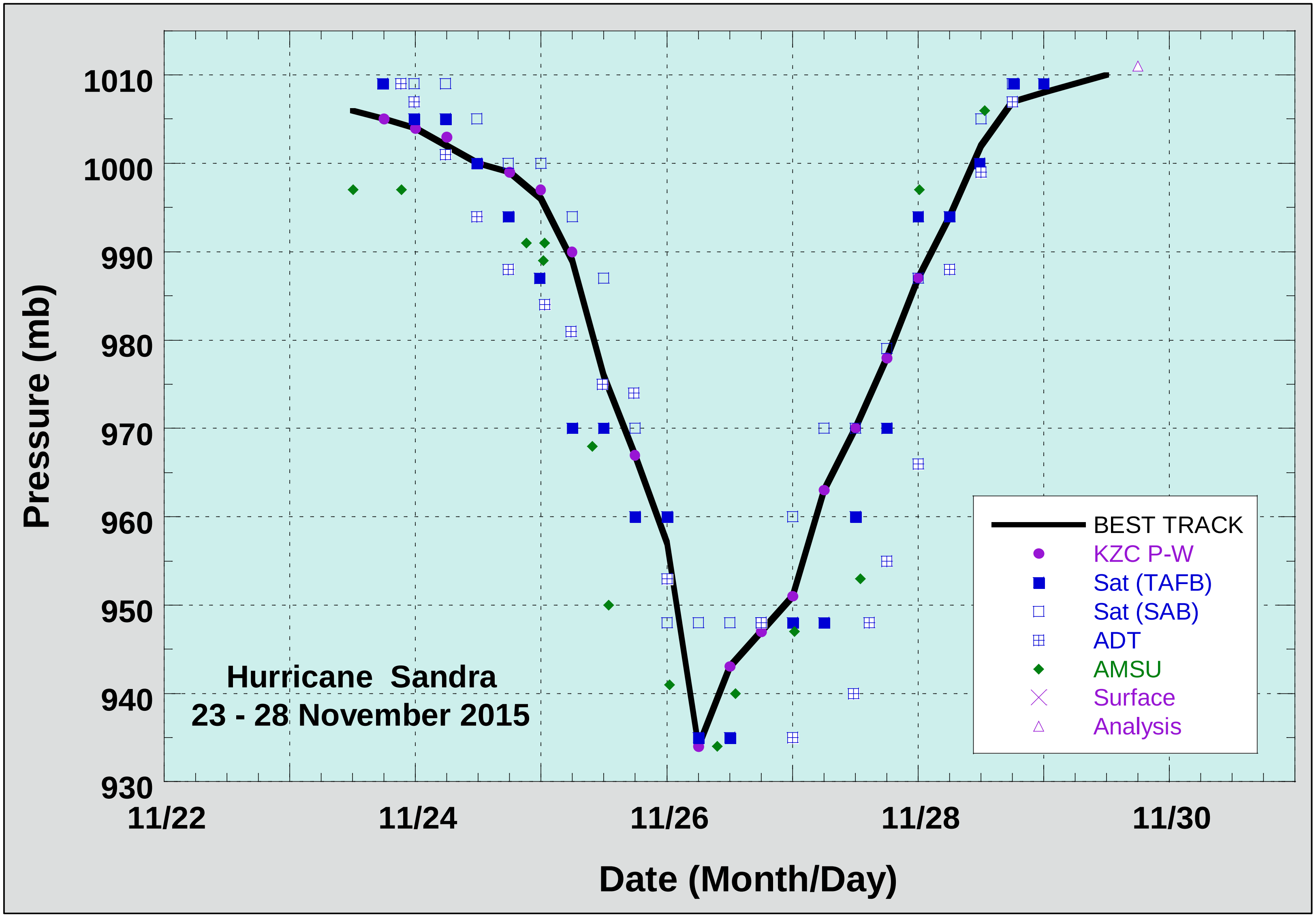

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Sandra, 23-28 November 2015. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological 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.

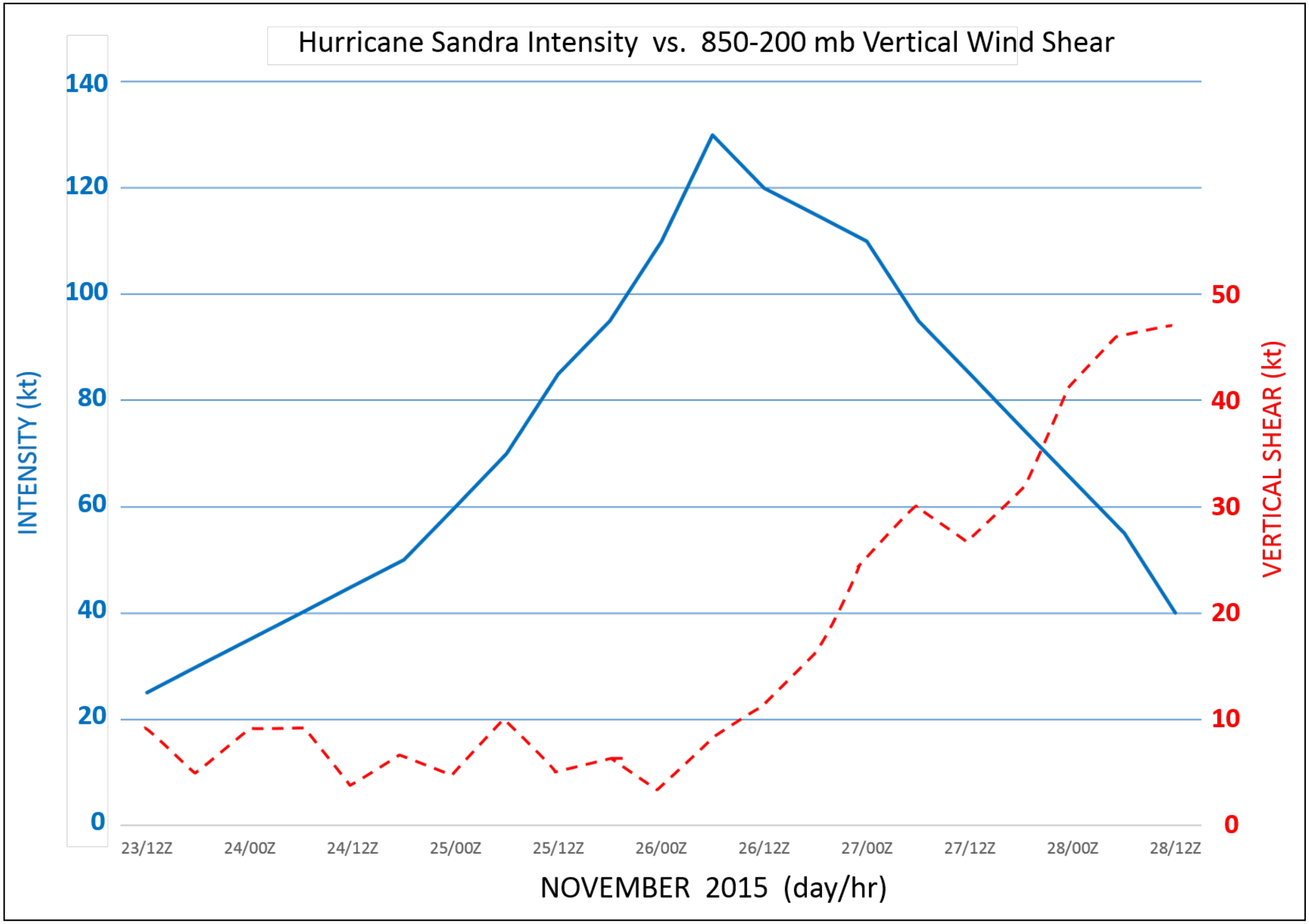

Figure 4. Plot of Hurricane Sandra's intensity (kt) versus GFS-based SHIPS model 850-200-mb analyzed environmental vertical wind shear (kt) for the period 1200 UTC 23 November to 1200 UTC 28 November 2015. Plot includes the pre-genesis low stage.

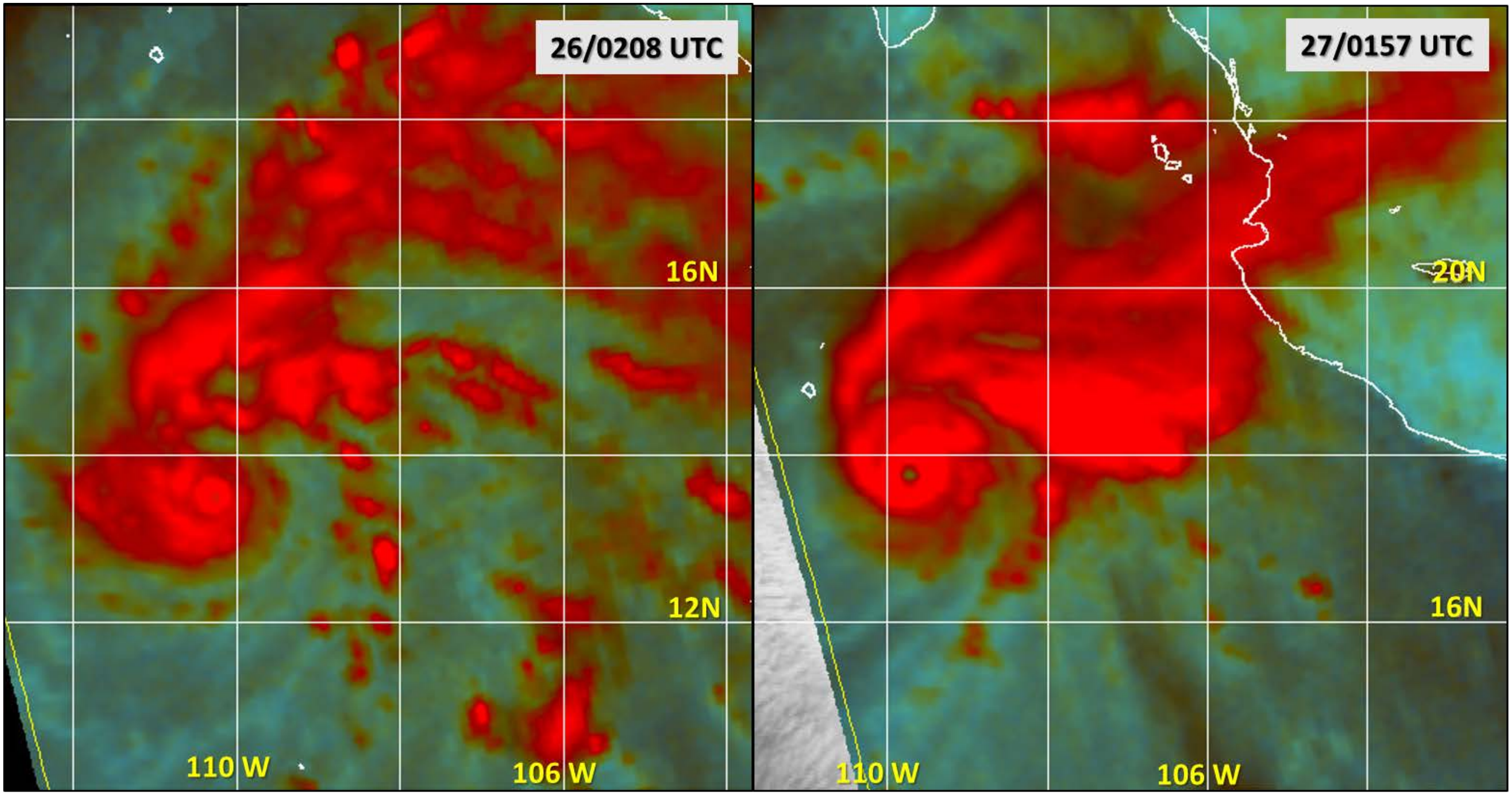

Figure 5. Special Sensor Microwave Imager/Sounder (SSMI/S) 91 GHz Composite images showing Hurricane Sandra's inner-core region at 0208 UTC 26 November (left) and 0157 UTC 27 November (right). A pinhole eye is barely evident in the 0208 UTC 26 November image; by 0157 UTC 27 November, the eye diameter had expanded to 5-10 n mi. During the 24-h period between these two images, there was no evidence of an eyewall replacement cycle.

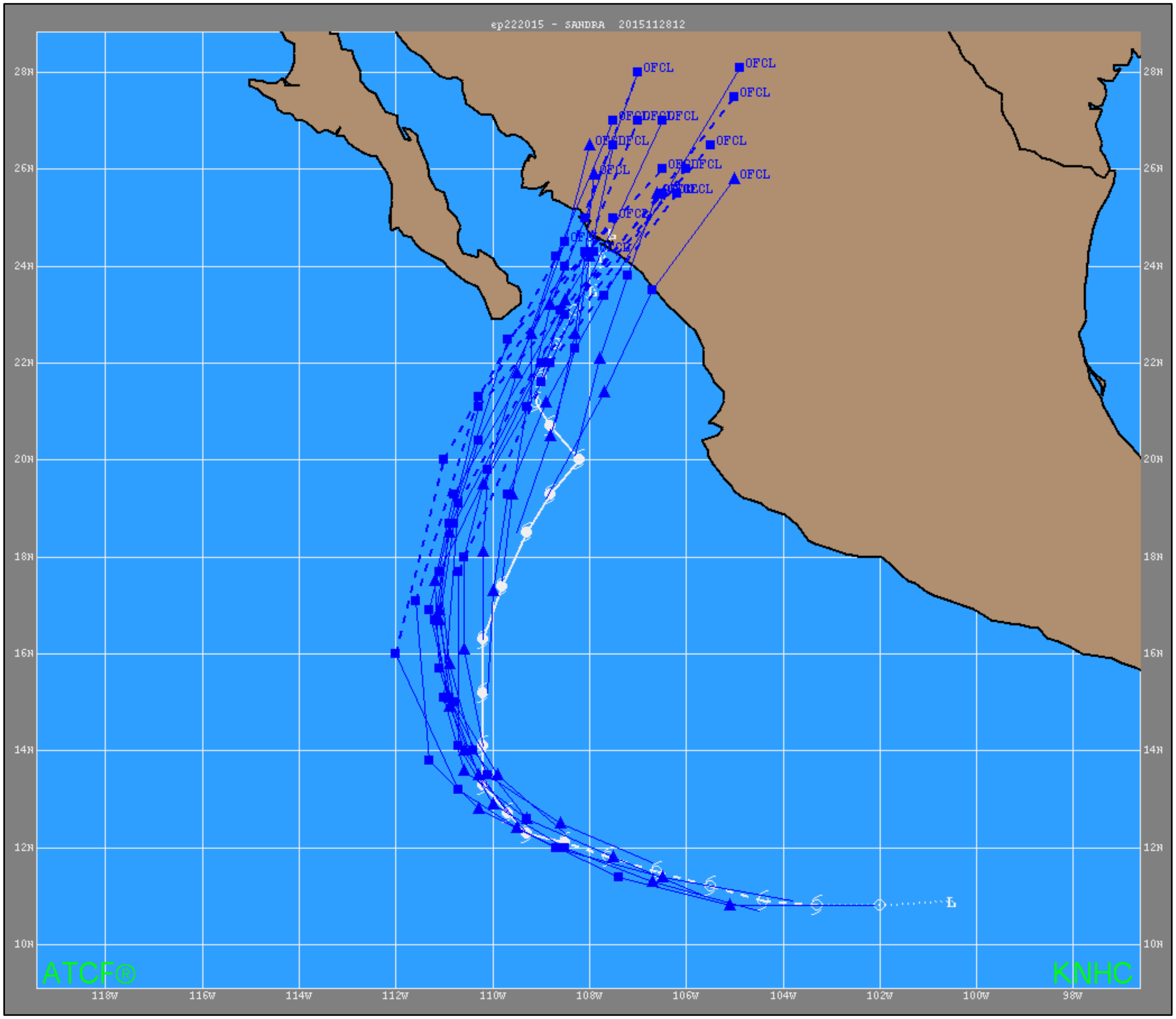

Figure 6. NHC official track forecasts (solid dark blue lines) plotted against official intensity 'best track' (solid white line with tropical cyclone symbols given at 6 h interval) for Hurricane Sandra.

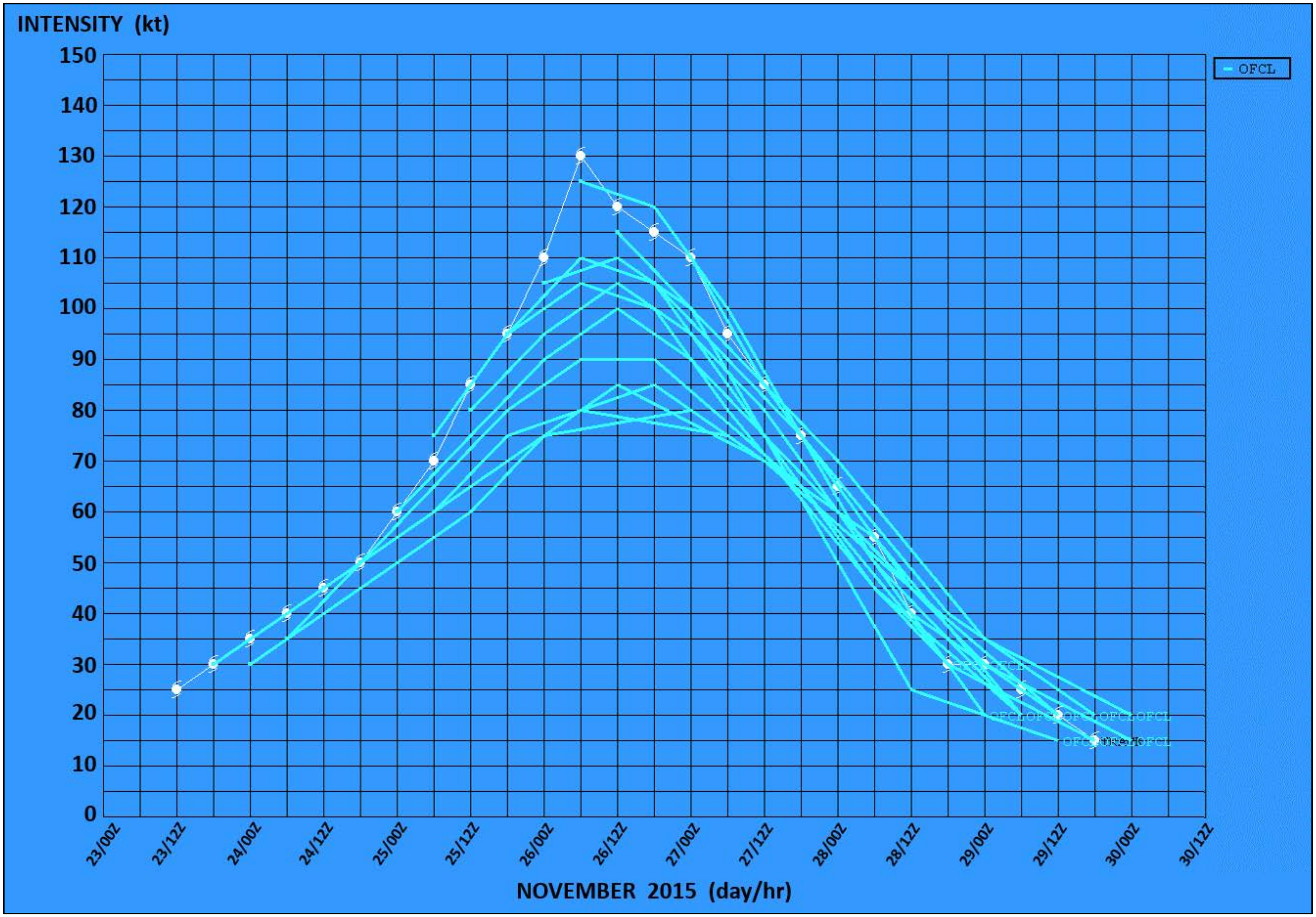

Figure 7. NHC official intensity forecasts (solid light blue lines) plotted against official intensity 'best track' (solid white line with tropical cyclone symbols given at 6 h interval) for Hurricane Sandra.