Tropical Cyclone Report
Hurricane Kenneth
(EP132011)
19-25 November 2011

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Kenneth was a compact but unusually strong late-season category 4 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that remained over the open ocean during its entire lifetime. Kenneth is the latest-forming major hurricane in the eastern North Pacific basin during the satellite era.

a. Synoptic History

The tropical wave that helped spawn Kenneth moved across the coast of western Africa on 2 November. The wave moved quickly and uneventfully westward across the tropical Atlantic Ocean accompanied by very limited convection. The wave reached northern South America on 9 November and moved into the southwestern Caribbean Sea on 13 and 14 November, where a brief flare-up of deep convection occurred. Scatterometer data and surrounding surface observations indicated that a broad low pressure system formed along the wave axis prior to the system's moving across Central America on 15 November. By the time the low pressure system emerged over the eastern North Pacific the next day, showers and thunderstorms had increased, mainly in small bands well removed from the ill-defined center. As the large disturbance moved westward over the next few days into a monsoon-like low-level wind environment, it developed a well-defined circulation center and Dvorak satellite analyses were initiated early on 18 November. The convective pattern slowly improved over the next 36 h, and it is estimated that a tropical depression formed around 1800 UTC 19 November about 400 n mi south 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 best track positions and intensities are listed in Table 1[1].

After reaching depression status, convective organization changed little during the ensuing 24-h period as the system turned west-northwestward. However, by 1800 UTC 20 November, a small burst of deep convection developed near the center of the cyclone, and it is estimated that the system became a tropical storm at that time while located about 450 n mi southwest of Acapulco. Over the course of the next 42 h, the combination of warm sea-surface temperatures (SST) exceeding 28°C and weak deep-layer vertical wind shear (< 10 kt) allowed Kenneth to rapidly intensify into a category 4 hurricane. The cyclone reached hurricane status around 1200 UTC 21 November when a low- to mid-level eye became apparent in microwave satellite imagery, and Kenneth reached its peak intensity of 125 kt just 24 h later when it was

[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.

located about 380 n mi south-southwest of Socorro Island, Mexico. At that time, microwave and infrared satellite imagery indicated the compact major hurricane possessed a cloud-free eye with a diameter of only 10-12 n mi (Fig. 4).

Other than a few small wobbles in the track, Kenneth was a well-behaved hurricane that maintained a basic westward motion for most of the remainder of its lifetime. The hurricane's peak intensity lasted for only a little more than 6 h, after which rapid weakening occurred despite the otherwise favorable SSTs and environmental shear conditions. Microwave satellite imagery indicated that Kenneth did not experience an eyewall replacement cycle, which is a fairly common cause of weakening in intense hurricanes. Instead, water vapor products and SHIPS model moisture analyses suggest that mid-level dry air intrusions (e.g., see Fig. 4), in combination with cold, upwelled water beneath the cyclone, caused the eyewall convection to erode. This was especially apparent on the west side of the eye. Cold upwelling conditions created by the intense inner-core winds seems highly probable since upper-ocean heat content values were near zero, which indicates that the favorable warm ocean temperatures did not extend much below the sea surface. In addition, SST anomalies cooled by more than 2^{o}C in a narrow region directly along the path of Kenneth during the time the cyclone was a major hurricane. (Fig. 5). Although oceanic cooling also occurred elsewhere along the track prior to Kenneth reaching major hurricane status, the magnitude of cooling during the hurricane's most intense phase was more than twice as large as it was during the cyclone's earlier weaker phase.

Hurricane Kenneth's rapid weakening ceased around 1800 UTC 23 November, when the cyclone became a tropical storm again about 375 n mi south-southwest of Clarion Island, Mexico. A slower weakening trend ensued and Kenneth became a depression around 0600 UTC 25 November when it was located about 615 n mi west-southwest of Clarion Island. The cyclone degenerated into a non-convective remnant low pressure system 6 h later when it was situated over sub-26^{o} C sea-surface temperatures. The remnant low continued on a faster westward track over cooler waters, and scatterometer wind data indicate the system lost its closed surface circulation by 0600 UTC 26 November about 900 n mi west-southwest of Clarion Island.

b. Meteorological Statistics

Observations in Kenneth (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. In addition, intensity estimates and microwave imagery from NOAA polar-orbiting satellites, including UW-CIMSS Advanced Microwave Sounding Unit (AMSU) were utilized. Data and imagery from NOAA polar-orbiting satellites, 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 Kenneth.

Ship reports of tropical-storm-force winds associated with Kenneth are given in Table 2.

The estimated maximum intensity of 125 kt at 1200 UTC and 1800 UTC 22 November is based on a blend of subjective Dvorak satellite intensity estimates of T6.5/127 kt from TAFB and SAB, and a 3-h average ADT value obtained from UW-CIMSS intensity estimate data. The estimated minimum central pressure of 940 mb at 1200 UTC 22 November is based on a blend of the aforementioned satellite intensity estimates and Knaff-Zehr-Courtney (KZC) pressure-wind relationship values.

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

c. Casualty and Damage Statistics

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

d. Forecast and Warning Critique

The genesis of Kenneth was forecast exceptionally well, especially given the late-season time period during which it formed. The incipient disturbance that went on to become Kenneth was first introduced in the eastern North Pacific Tropical Weather Outlook (TWOEP) with a "low" (<30%) probability of development at 1200 UTC 16 November, which was 78 h before genesis occurred. The genesis probability was increased to the "medium" (30%-50%) category at 1800 UTC 17 November, and reached the "high" (>50%) category of formation at 1200 UTC 18 November, which was 30 h prior to development. Genesis probabilities gradually increased and reached a maximum of 80% 6 h before Kenneth formed.

A verification of NHC official track (OFCL) forecasts for Kenneth is given in Table 3a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period at all forecast times, especially at days 3-5. In comparison, the OCD5 persistence-climatology baseline forecast errors were near their 5-yr average errors through 48 h, and were much larger than the average errors at 72-120 h. This implies that track forecasts for Kenneth were potentially more difficult than usual to predict. The unusually large OCD5 errors beyond 48 h were due primarily to the model predicting that Kenneth would recurve northeastward into the mid-latitude westerlies, which is a typical track scenario for late-season hurricanes. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. OFCL track forecast errors were better than every forecast model at every forecast time period with the exception of the ECMWF (EMXI) model at 24-72 h and the Medium-depth Beta and Advection Model (BAMM) at 12-24 h. Some forecast models such as the FSSE, GFNI, NGPI, and EGRI that make up the NHC forecast model suite did not meet the homogeneity requirements due to various reasons and, therefore, were not available for comparison.

A verification of OFCL intensity forecasts for Kenneth is given in Table 4a. The official forecast intensity errors were higher than the mean official errors for the previous 5-yr period at all forecast times except at 96 h where the official forecast errors were only slightly lower. However, OCD5 climatology forecast errors displayed a similar characteristic and were likewise higher than the mean errors for the previous 5-yr period at all forecast times except at 96 h. This indicates that Kenneth's intensity was more difficult than normal to forecast. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The main cause for the larger-than-average intensity errors, especially at 48 h, was the rapid intensification and rapid weakening that occurred over a 72-h period from 20-23 November. None of the model guidance captured the overall intensity trend during that time, which was reflected in the 40-50% larger OFCL intensity forecast errors at 24-72 h. Even after Kenneth had started its rapid intensification phase during the 12-h period between 1800 UTC 20 November and 0600 UTC 21 November, none of the intensity models had any forecasts close to Kenneth's estimated peak intensity, nor did they predict continued rapid intensification (Fig. 6). Even the GFS-based SHIPS and LGEM statistical-dynamical intensity models did not capture the rapid intensification right up until the time that Kenneth reached its peak intensity 42 h after the sharp deepening process began. The official intensity forecasts were bested by only a few models at some of the forecast times. Overall, however, the OFCL forecasts outperformed the majority of the available intensity guidance through 72 h, including the HWRF regional model (HWFI) at all forecast times.

There were no tropical cyclone watches or warnings associated with Kenneth.

Table 1. Best track for Hurricane Kenneth, 19-25 November 2011.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
18 / 1200	9.2	96.5	1007	25	low
18 / 1800	9.2	97.0	1007	25	"
19 / 0000	9.4	97.7	1006	25	"
19 / 0600	9.7	98.5	1006	25	"
19 / 1200	9.9	99.5	1006	25	"
19 / 1800	10.1	100.7	1006	30	tropical depression
20 / 0000	10.2	101.9	1006	30	"
20 / 0600	10.4	103.1	1005	30	"
20 / 1200	10.8	104.2	1005	30	"
20 / 1800	11.5	105.3	1004	35	tropical storm
21 / 0000	12.0	106.5	1001	45	"
21 / 0600	12.2	107.8	995	55	"
21 / 1200	12.6	109.0	987	65	hurricane
21 / 1800	13.0	110.1	979	80	"
22 / 0000	13.0	111.2	970	95	"
22 / 0600	13.0	112.3	955	110	"
22 / 1200	12.9	113.4	940	125	"
22 / 1800	12.6	114.3	942	125	"
23 / 0000	12.5	115.3	951	115	"
23 / 0600	12.5	116.3	965	95	"
23 / 1200	12.7	117.3	978	75	"
23 / 1800	13.0	118.2	986	60	tropical storm
24 / 0000	13.3	119.1	995	55	"
24 / 0600	13.4	120.1	999	50	"
24 / 1200	13.4	121.1	1001	45	"
24 / 1800	13.4	122.0	1003	40	"
25 / 0000	13.4	122.9	1005	35	"
25 / 0600	13.3	124.1	1006	30	tropical depression
25 / 1200	13.2	125.5	1007	25	low
25 / 1800	13.1	127.1	1008	20	"
26 / 0000	13.1	129.1	1009	20	"
26 / 0600					dissipated
22 / 1200	12.9	113.4	940	125	minimum pressure and maximum intensity

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Kenneth, 19-25 November 2011.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
20 / 1800	LAXS2	13.3	104.6	090 / 37	1012.5
21 / 0000	LAXS2	13.8	105.8	060 / 36	1010.0
21 / 0600	S6SR	8.4	108.8	350 / 37	1014.0
23 / 0500	LAXS2	17.4	115.2	020 / 40	1015.0
23 / 0600	LAXS2	17.4	115.4	020 / 40	1015.0

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Kenneth, 19-25 November 2011. Mean errors for the 5-yr period 2006-10 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 (Kenneth)	**26.6**	**44.2**	**57.5**	**68.2**	**72.7**	**65.8**	**23.2**
OCD5 (Kenneth)	37.8	72.1	103.8	158.1	282.9	483.6	594.5
Forecasts	21	19	17	15	11	7	3
OFCL (2006-10)	29.7	49.9	69.0	86.6	119.0	155.8	197.7
OCD5 (2006-10)	38.4	74.8	115.3	155.9	226.3	273.7	310.4

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Kenneth, 19-25 November 2011. 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	25.3	42.2	57.5	68.2	72.7	65.8	23.2
OCD5	36.2	69.8	103.8	158.1	282.9	483.6	594.5
EMXI	27.0	**41.4**	**51.3**	**53.6**	**59.4**	97.3	136.1
GFSI	30.0	47.5	65.4	87.5	133.3	173.6	101.6
AEMI	30.4	53.8	84.2	111.9	153.8	161.8	152.4
CMCI	40.8	73.8	117.1	158.1	162.3	187.5	261.4
GHMI	32.4	51.2	74.8	91.5	91.3	107.3	80.0
HWFI	35.9	72.3	113.3	150.2	233.2	276.5	245.2
TVCA	26.0	45.7	65.6	81.4	103.9	114.0	70.6
TVCC	28.5	43.0	64.9	81.2	97.4	108.1	102.2
TVCE	25.7	45.3	63.0	77.2	97.5	111.8	63.1
LBAR	36.8	68.4	116.7	160.5	259.5	201.8	126.7
BAMS	45.4	81.0	120.6	156.7	225.4	263.1	170.6
BAMM	**24.3**	**41.6**	58.7	80.5	122.6	170.5	154.4
BAMD	31.3	53.8	73.7	97.1	164.5	280.9	226.0
Forecasts	20	18	17	15	11	7	3

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Kenneth, 19-25 November 2011. Mean errors for the 5-yr period 2006-10 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 (Kenneth)	11.0	20.3	27.4	32.7	27.3	**17.1**	20.0
OCD5 (Kenneth)	15.9	25.2	33.6	40.3	32.5	12.3	24.0
Forecasts	21	19	17	15	11	7	3
OFCL (2006-10)	7.2	11.0	13.2	15.1	17.2	17.9	18.7
OCD5 (2006-10)	8.5	12.3	15.4	17.8	20.2	21.9	21.7

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Kenneth, 19-25 November 2011. 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	11.5	21.1	27.4	32.7	27.3	17.1	20.0
OCD5	16.5	26.1	33.6	40.3	32.5	**12.3**	24.0
DSHP	14.3	21.3	**25.7**	**29.3**	**26.5**	23.1	23.3
LGEM	13.7	22.4	28.8	34.0	28.7	**16.7**	**18.3**
HWFI	17.1	26.1	34.0	42.9	35.5	29.0	32.7
GHMI	12.6	**18.7**	**21.0**	**24.3**	27.5	31.4	34.3
IVCN	13.9	**20.7**	**24.6**	**30.9**	28.5	25.0	27.3
Forecasts	20	18	17	15	11	7	3

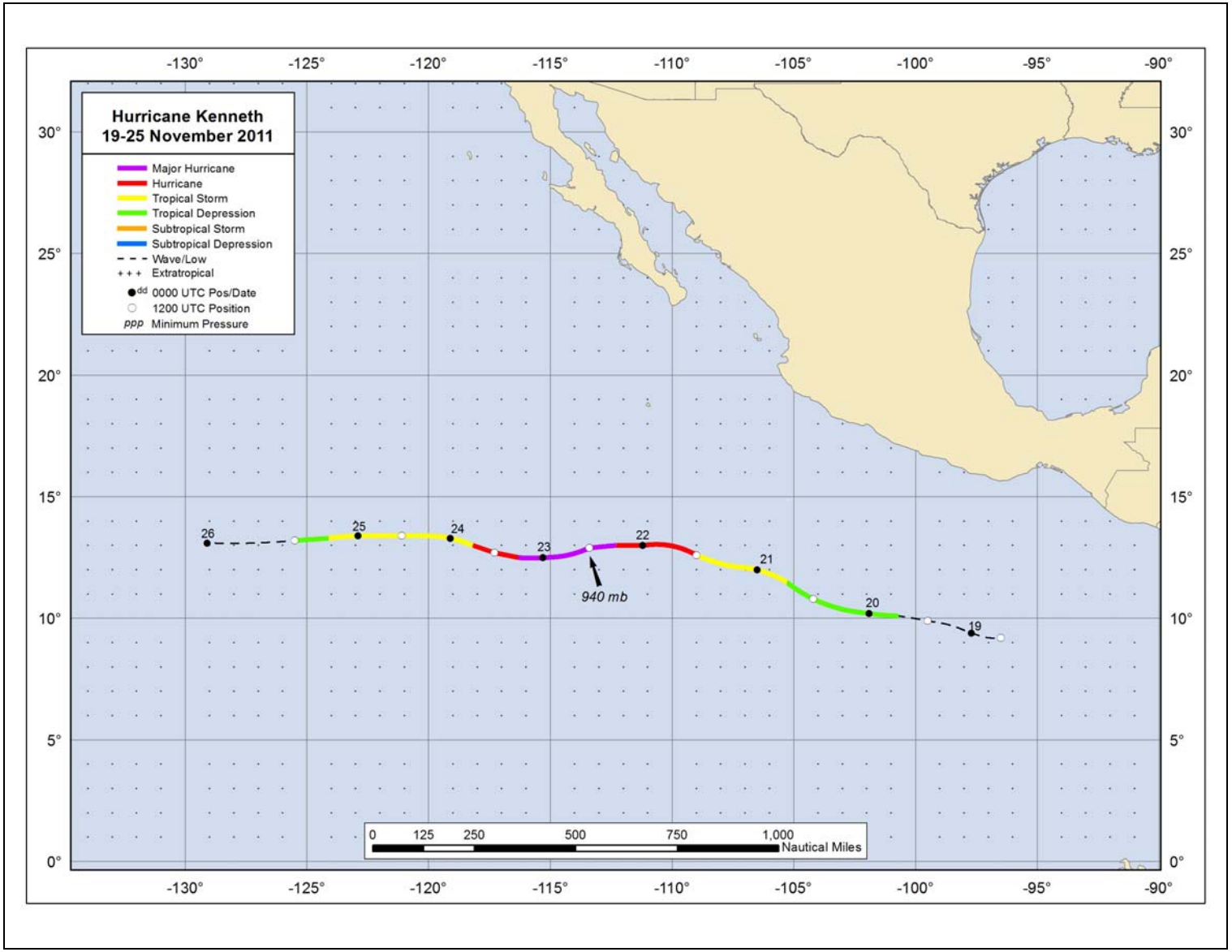

Figure 1. Best track positions for Kenneth, 19-25 November 2011.

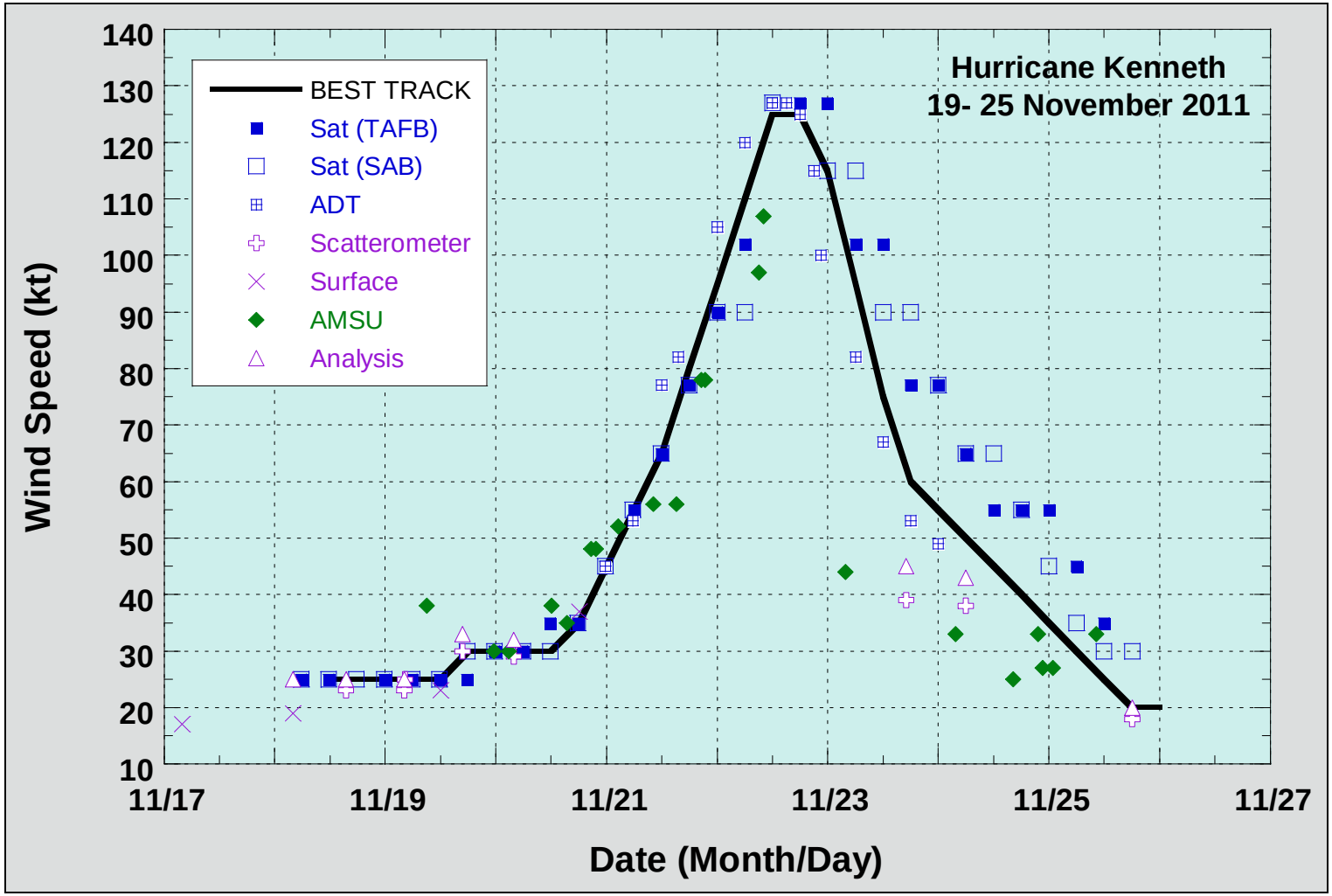

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Kenneth, 19-25 November 2011. Advanced Dvorak Technique estimates (ADT) represent linear averages over a three-hour period centered on the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC.

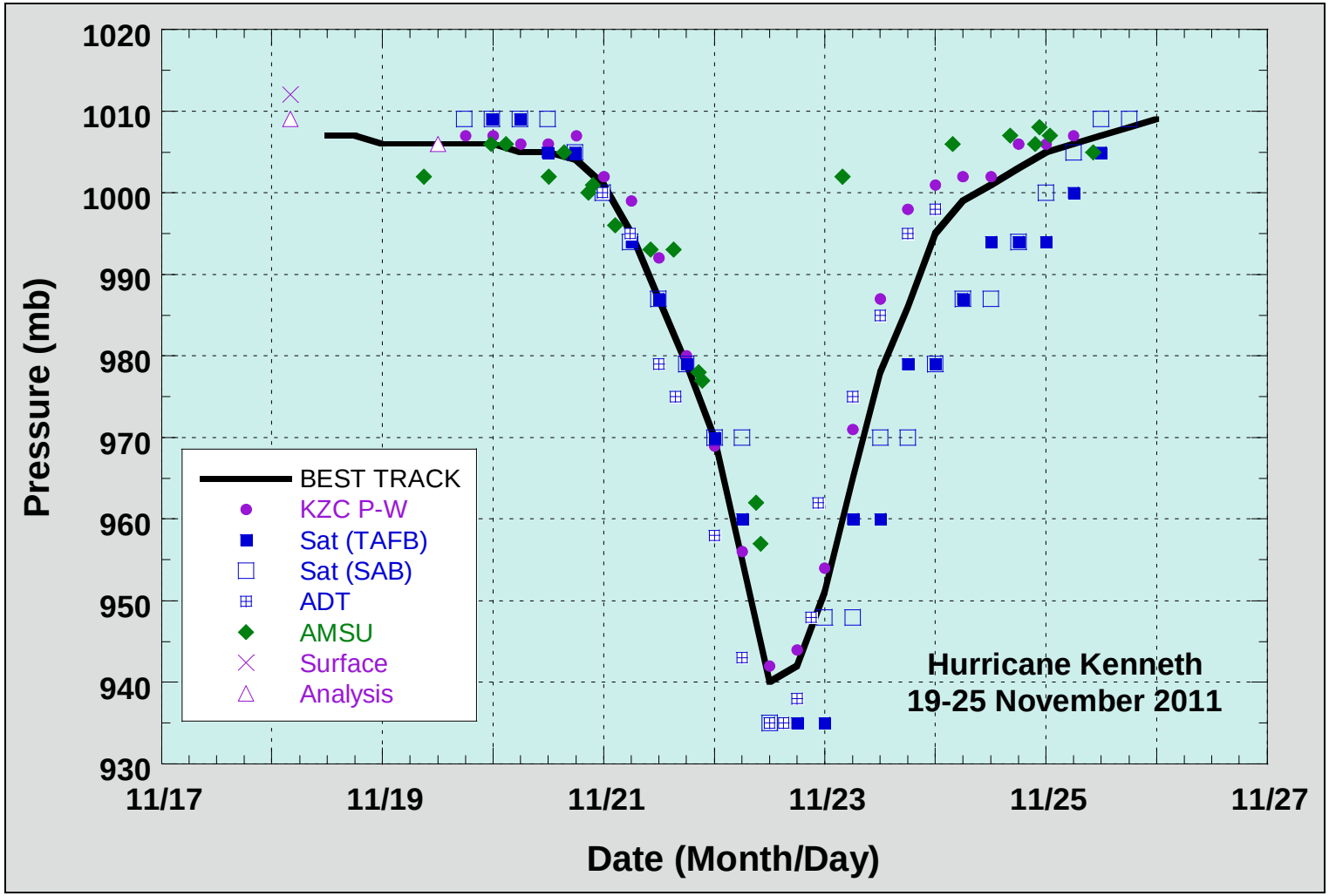

Figure 3. Selected pressure observations and best track minimum central pressure curve for Kenneth, 19-25 November 2011. Advanced Dvorak Technique estimates (ADT) represent linear averages over a three-hour period centered on the nominal observation time. AMSU intensity estimates are from the Cooperative 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. Dashed vertical lines correspond to 0000 UTC.

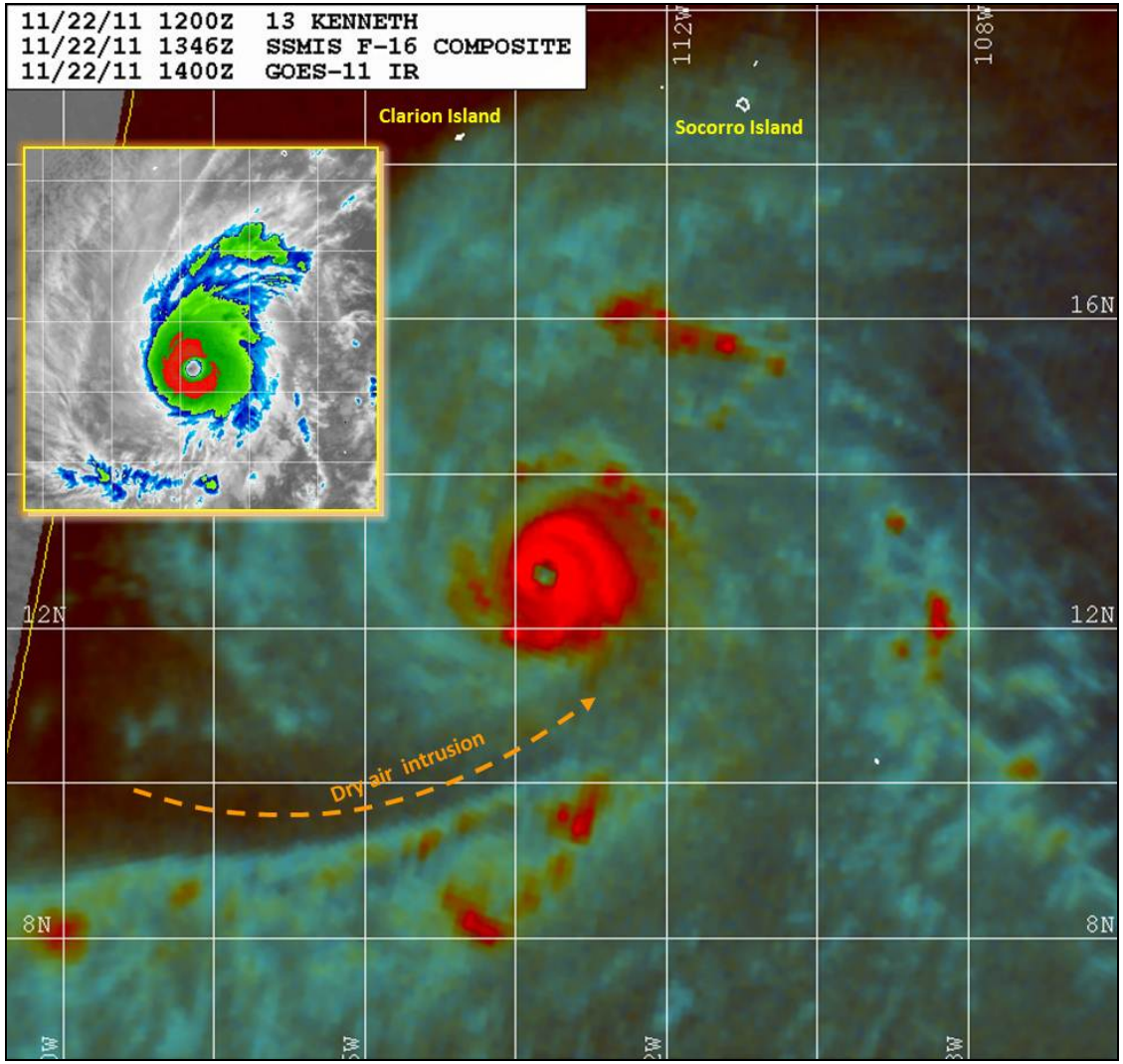

Figure 4. A 1346 UTC 22 November 2011 SSMI/S 91 GHz microwave image showing a small, well-defined eye when Kenneth was at its peak intensity of 125 kt. Inset picture is a 1400 UTC 22 November GOES-11 infrared image, which indicates a well-defined, cloud-free eye. A pronounced mid-level dry air intrusion (dark-colored region) was already underway in the southwestern quadrant of the compact hurricane. Images courtesy of the U.S. Navy Fleet Numerical Meteorology and Oceanography Center, Monterey, CA.

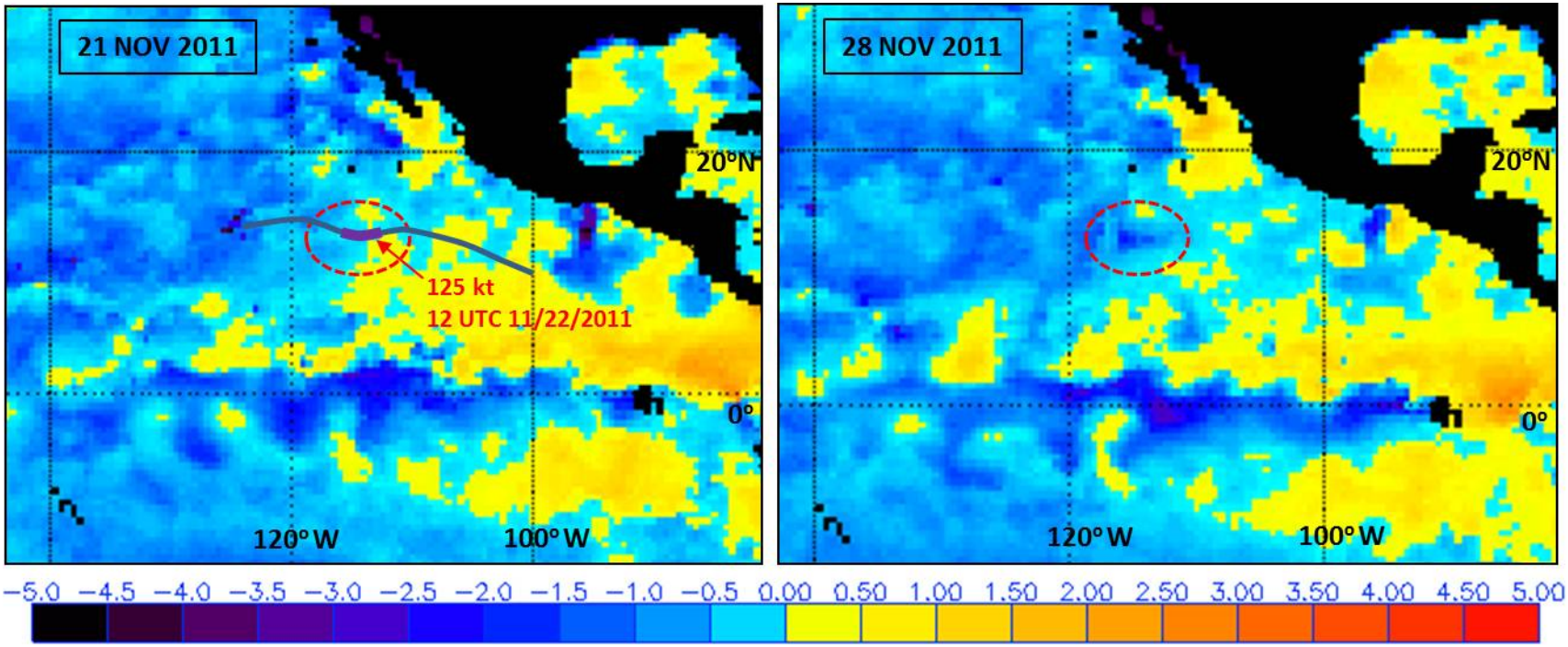

Figure 5. Eastern North Pacific SST anomalies (^{o}C) for 21 November 2011 (left) and 28 November 2011 (right). Kenneth's track (solid gray line) is superimposed on the left panel along with the portion of the track where the small cyclone had obtained major hurricane status (purple line). Prior to the rapid intensification and major hurricane phase, SST anomalies were slightly positive (warm) around 0.0 to 0.5^{o}C. However, by 28 November, which was six days after Kenneth had traversed the region indicated by the red-dashed oval, SST anomalies had decreased (cooled) to less than -2^{o}C, which indicates that cold upwelling likely had occurred. Raw data images courtesy of NOAA National Environmental Satellite, Data, and Information Service (NESDIS).

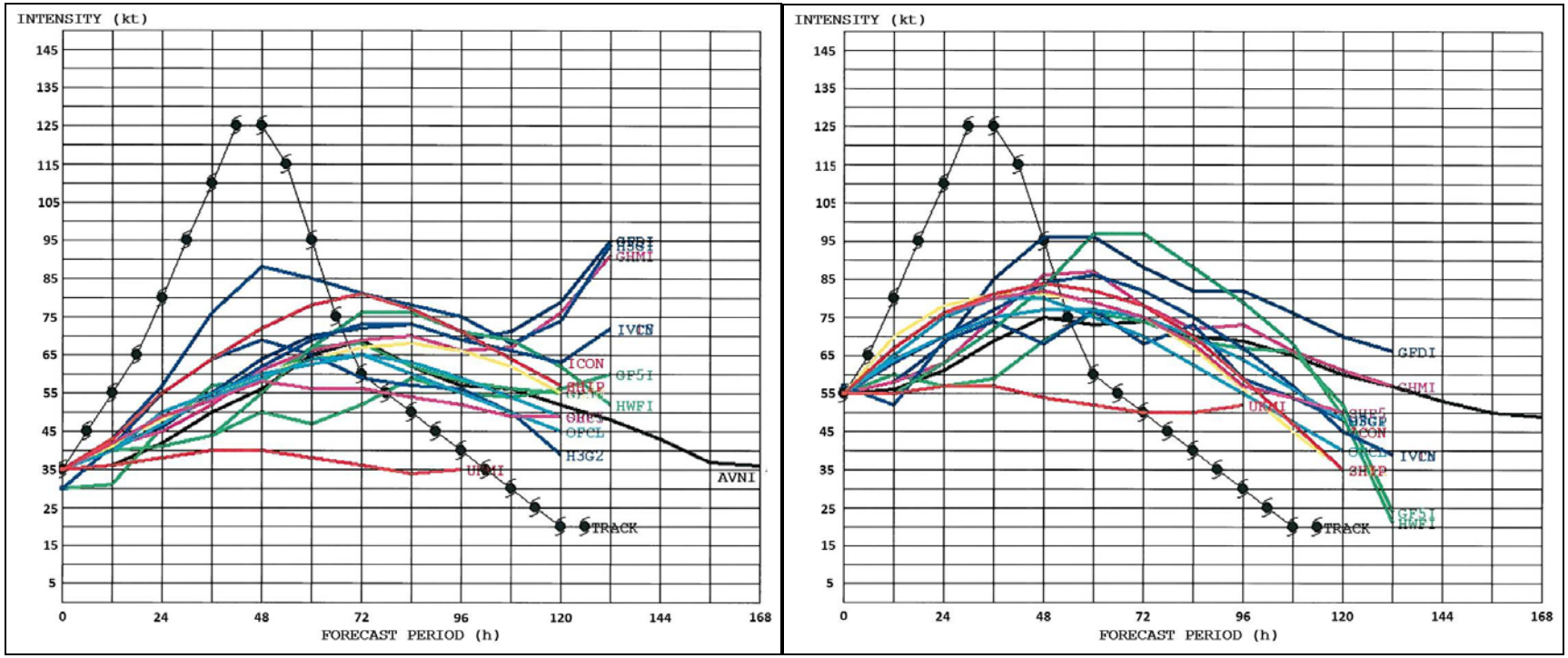

Figure 6. NHC intensity guidance for Kenneth at 1800 UTC 20 November 2011 (left) and 0600 UTC 21 November 2011 (right). Official 'best track' intensity values (kt) in 6-h increments are indicated by the black line connecting the hurricane symbols. Note the models' inability to predict not only rapid intensification and Kenneth's peak intensity of 125 kt, but also rapid weakening. Furthermore, the models all forecast Kenneth to reach its peak intensity about 36 h later than when it actually occurred, which was also during the period of rapid weakening.