Tropical Cyclone Report
Hurricane Kenna
22-26 October 2002

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26 December 2002

After reaching a peak intensity of 145 kt, Hurricane Kenna made landfall near the fishing village of San Blas, Mexico, as a category 4 hurricane (on the Saffir-Simpson Hurricane Scale) with 120 kt winds. Only an unnamed hurricane in 1959 and Madeline in 1976 are known to have been stronger at the time of landfall than Kenna. Kenna was responsible for four deaths.

a. Synoptic History

Kenna developed from a disturbance that moved westward across Central America and entered the eastern North Pacific basin on 19 October. Using satellite Hovmoeller diagrams, it is possible to track the disturbance back to about 70° west longitude on 16 October, and the disturbance may have been associated with a tropical wave that passed Barbados late on 14 October. After crossing Central America, the disturbance gradually became better organized, and Dvorak classifications began late on 20 October. The system continued to develop, and became a tropical depression at 0000 UTC 22 October about 325 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. The depression moved westward and quickly reached tropical storm strength at 0600 UTC 22 October. Kenna, moving around the periphery of mid-level high pressure over Mexico, turned to the west-northwest with little change in strength for the next 18 hours. During this time, much of Kenna's deep convection was associated with rainbands well removed from the circulation center, but on 23 October, Kenna strengthened when these bands began to dissipate and convection became concentrated closer to the center. Kenna became a hurricane about 400 n mi south of Cabo Corrientes, Mexico, between 1200 and 1800 UTC 23 October. Kenna continued to strengthen on 24 October, while its heading turned to the northwest and then north late in the day as its forward speed slowed to about 9 kt. At 1800 UTC 24 October, roughly 24 hours after reaching hurricane strength, reports from a reconnaissance aircraft indicated that Kenna's winds had reached 140 kt and its minimum pressure had fallen to 917 mb.

The flow ahead of a large mid- to upper-level trough west of Baja California turned Kenna to the northeast beginning late on 24 October. As Kenna began to accelerate toward the coast of Mexico, satellite imagery suggests that Kenna intensified slightly and reached its peak intensity of 145 kt with a minimum pressure of 913 mb near 0000 UTC 25 October. At this time Kenna was about 125 n mi west-southwest of Cabo Corrientes. Kenna continued to accelerate, and although the hurricane was still over warm waters, it began to weaken under increasing shear associated with the upper trough. By 1200 UTC that day, a second reconnaissance aircraft reported that the

minimum pressure had risen to near 940 mb. Despite the sharp increase in pressure, Kenna's convective activity increased in the hours just prior to landfall, and cloud top temperatures dropped to near -90 °C. The reconnaissance aircraft reported extremely severe turbulence that was among the most intense ever experienced by the flight crew. Data from the aircraft indicated that the hurricane's maximum winds were only slowly decreasing, and Kenna made landfall near San Blas, Mexico, at 1630 UTC, with winds estimated to be near 120 kt. Kenna continued moving northeastward and weakened very rapidly inland over the mountains of Mexico; by 0000 UTC 26 October it was a minimal tropical storm, and the circulation dissipated by 0600 UTC. The remnants of Kenna moved into the northwestern Gulf of Mexico later that day, and enhanced rainfall in the southeastern United States.

b. Meteorological Statistics

Observations in Kenna (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 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command.

On several occasions, the reconnaissance aircraft reported 700 mb flight-level winds of about 145 kt, corresponding to a surface wind of about 130 kt. A dropsonde at 1857 UTC 24 October reported average winds of 180 kt over the layer from 75-225 m (the lowest 150 m of wind data available). Adjustment of this observation to the surface using the mean eyewall wind profile yields a surface estimate of 140 kt, and this was the basis for the assigned best track maximum wind near the time of the reconnaissance mission. The peak intensity of 145 kt is based on an increase in both subjective and objective Dvorak T-numbers in the hours after the aircraft mission concluded. While the Dvorak classifications were highest at 0600 UTC 25 October, a sequence of microwave passes shows that the eyewall began to decay after 0111 UTC. As a result, the peak intensity of Kenna has been assigned to 0000 UTC on the 25th.

The lowest observed pressure in Kenna was 918 mb at 1859 UTC 24 October. However, the dropsondes released in the eye of Kenna tended to miss the pressure center, as the surface winds on these drops were near 30 kt. Therefore, minimum pressures in the best track are slightly lower than the raw values reported in aircraft vortex messages and plotted in Fig. 3. Kenna's minimum pressure is estimated to be 913 mb, based again on an increase in Dvorak classification numbers after the time of the aircraft mission.

The reconnaissance mission on 25 October provided some interesting observations. The highest satellite-based intensity estimates occurred at 0600 UTC, when the minimum pressure is estimated to have been 915 mb. After 0600 UTC, the eye rapidly disappeared. At 1335 UTC, the aircraft reported a minimum pressure of 945 mb, 27 mb higher than what had been observed 17 hours previously, yet the peak 700 mb flight-level winds (147 kt) were virtually unchanged. As noted earlier, there was a burst of very deep convection in the early morning hours just prior to landfall, with cloud top temperatures near -89 °C. The conflicting signals from the pressure and wind data make it difficult to assign a landfall intensity. The best track landfall intensity of 120 kt

is a compromise of the various observations, including a rapid deterioration in the overall satellite presentation despite the deep cold convection, and reflects a concern that the aircraft wind report may not have been completely representative of surface conditions. One could easily argue for a landfall intensity either 10 kt higher or lower than the value given here.

Surface observations from land stations are given in Table 2. There were very few observations from the landfall of Kenna. At Tepic, Nayarit (located about 15 n mi inland) the peak measured wind (10 min mean) was 76 kt, with a storm total rainfall of 3.35 in (85 mm). At Islas Marias, about 40 n mi to the left of the track of Kenna, 1.38 in (35 mm) of rain was recorded. The maximum rain totals reported from the states of Colima and Nayarit were 9.84 in (250 mm) and 4.72 in (120 mm), respectively.

The Meteorological Service of Mexico estimates that the storm surge in San Blas was as high as 16 ft (5 m). Storm surge also affected Puerto Vallarta, but no measurements are available. There were reports of 10 ft waves rushing inland from the bay.

There were no ship reports of winds of tropical storm force associated with Kenna.

c. Casualty and Damage Statistics

Mexican authorities report four deaths from Kenna. In San Blas, an elderly woman died when the wall of her house collapsed. One person in Santiago Escuintla was killed by flying debris. There were two deaths due to drowning. An elderly man drowned in Santiago Escuintla, and another elderly man fell into the river Florido. Both of these are believed to have occurred during the storm as the victims fled their homes. All but roughly 200 or so of the 9000 residents of San Blas evacuated the village, likely accounting for the relatively low number of casualties. There are media reports of over100 injuries in San Blas and Puerto Vallarta from flying glass and other debris.

In Puerto Vallarta, storm surge was primarily responsible for the estimated $5 million (U.S. currency) of damage, largely to hotels. There are no estimates of damage in San Blas, however, media reports indicate that 80 to 90% of the homes were damaged or destroyed. Large commercial shrimp boats were dragged up to 300 yards from their docks.

d. Forecast and Warning Critique

Average official track errors (with the number of cases in parentheses) for Kenna were 27 (14), 41 (12), 70 (10), 93 (8), and 175 (4) n mi for the 12, 24, 36, 48, and 72 h forecasts, respectively (OFCL, Table 3). These errors are significantly lower than the average official track errors for the 10-yr period 1992-2001 (36, 67, 97, 125, and 182 n mi, respectively). The landfall location, in particular, was extremely well forecast (Fig. 4). The official forecast errors were also smaller than nearly all of the objective track model errors including, most notably, those from the Global Forecast System (AVNI). The Global Forecast System consistently forecast Kenna's landfall too far to the north, and often seemed to initialize the vortex poorly. Outperforming OFCL was the deep layer BAM (BAMD), and at 72 h, the GFDI, UKMI, and the consensus models GUNS and GUNA. That

the BAMD was a good performing model and the AVNI was not is interesting, as it indicates that the Global Forecast System did well in forecasting the environmental steering flow inputs to the BAMD, but did not handle the hurricane itself very well.

Although the OFCL track errors were relatively low, they did contain a significant slow bias. For example, the 48 h bias vector was 198°/71 n mi, or 76% of the mean absolute error. The first forecasts to indicate a landfall within the 72 h forecast period were slow by about 10-14 hours. This bias decreased to about 7 hours one day prior to landfall.

Kenna intensified from 40 to 140 kt in 42 hours. The strengthening of such tropical cyclones is rarely anticipated, and Kenna was no exception (Fig. 5). Average official intensity errors were 15, 27, 41, 52, and 49 kt for the 12, 24, 36, 48, and 72 h forecasts, respectively. These are much larger than the average official intensity errors over the 10-yr period 1992-2001 (7, 12, 16, 18, and 21 kt, respectively). There was a 75 kt under-forecast at 48 h, four under-forecasts of at least 50 kt at 36 h, and even a 30 kt under-forecast at 12 h. The official forecast errors were comparable to those from the SHIPS and GFDI models, which also had large under-forecast biases.

Table 4 lists the watches and warnings associated with Kenna. The hurricane warning was issued roughly 25 hours prior to landfall.

Table 1. Best track for Hurricane Kenna, 22-26 October 2002.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
22 / 0000	11.4	99.4	1006	30	tropical depression
22 / 0600	11.5	100.4	1004	35	tropical storm
22 / 1200	11.7	101.4	1003	35	"
22 / 1800	12.1	102.5	1003	35	"
23 / 0000	12.6	103.6	1002	40	"
23 / 0600	13.1	104.6	997	50	"
23 / 1200	13.6	105.7	990	60	"
23 / 1800	14.2	106.9	980	75	hurricane
24 / 0000	14.9	108.0	970	90	"
24 / 0600	15.5	108.5	955	105	"
24 / 1200	16.4	108.8	935	125	"
24 / 1800	17.3	108.8	917	140	"
25 / 0000	18.3	108.3	913	145	"
25 / 0600	19.3	107.5	915	145	"
25 / 1200	20.4	106.5	939	130	"
25 / 1800	22.1	105.1	960	100	"
26 / 0000	23.7	103.5	1000	35	tropical storm
26 / 0600					dissipated
25 / 0000	18.3	108.3	913	145	minimum pressure
25 / 1630	21.7	105.4	950	120	landfall near San Blas, Mexico

Table 2. Selected surface observations for Hurricane Kenna, 22-26 October 2002.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Mexico								
Tepic			?	76				3.35
Puerto Vallarta	25/1350	997.6	25/1415	30	40			
San Blas						16		
Islas Marias		1007	?	81[d]				1.38
Colima, site unknown								9.84
Nayarit, site unknown								4.72

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Except as noted, sustained wind averaging periods are 10 min.
[c] Storm surge estimated, reference height unknown.
[d] Estimated.

Table 3. Preliminary forecast evaluation (heterogeneous sample) for Hurricane Kenna, 22-26 October 2002. Forecast errors for tropical storm and hurricane stages (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in bold-face type. Asterisks indicate models not available at forecast time.

Forecast Technique	Forecast Period (h)				
	12	24	36	48	72
CLP5	56 (14)	149 (12)	253 (10)	348 (8)	488 (4)
GFDI	40 (13)	68 (11)	121 (9)	136 (7)	**156 (4)**
GFDL*	36 (13)	48 (11)	78 (9)	125 (7)	**131 (4)**
LBAR	27 (14)	50 (12)	88 (10)	125 (8)	291 (4)
AVNI	37 (12)	75 (12)	107 (10)	139 (8)	210 (4)
AVNO*	53 (14)	76 (12)	112 (10)	144 (8)	226 (4)
AEMI	35 (9)	89 (9)	122 (7)	157 (6)	241 (3)
BAMD	28 (14)	49 (12)	**61 (10)**	**66 (8)**	**133 (4)**
BAMM	34 (14)	58 (12)	83 (10)	112 (8)	249 (4)
BAMS	44 (14)	84 (12)	140 (10)	194 (8)	362 (4)
NGPI	40 (14)	103 (12)	157 (10)	181 (8)	227 (4)
NGPS	46 (14)	72 (12)	128 (10)	182 (8)	225 (4)
UKMI	50 (13)	83 (11)	92 (9)	108 (7)	**160 (4)**
UKM*	47 (7)	76 (6)	94 (5)	114 (4)	205 (2)
GUNS	27 (13)	56 (11)	89 (9)	115 (7)	**135 (4)**
GUNA	**19 (11)**	47 (11)	79 (9)	101 (7)	**133 (4)**
OFCL	27 (14)	41 (12)	70 (10)	93 (8)	175 (4)
NHC Official (1992-2001 mean)	36 (2203)	67 (1947)	97 (1700)	125 (1472)	182 (1091)

Table 4. Watch and warning summary for Hurricane Kenna, 22-26 October 2002.

Date/Time (UTC)	Action	Location
24 / 0900	Hurricane Watch issued	Mazatlan to Cabo Corrientes
24 / 0900	Tropical Storm Watch issued	South of Cabo Corrientes to Manzanillo
24 / 1500	Watches upgraded to Hurricane Warning	Mazatlan to La Fortuna
24 / 1500	Watch upgraded to T.S. Warning	South of La Fortuna to Manzanillo
25 / 2100	All Warnings discontinued	-

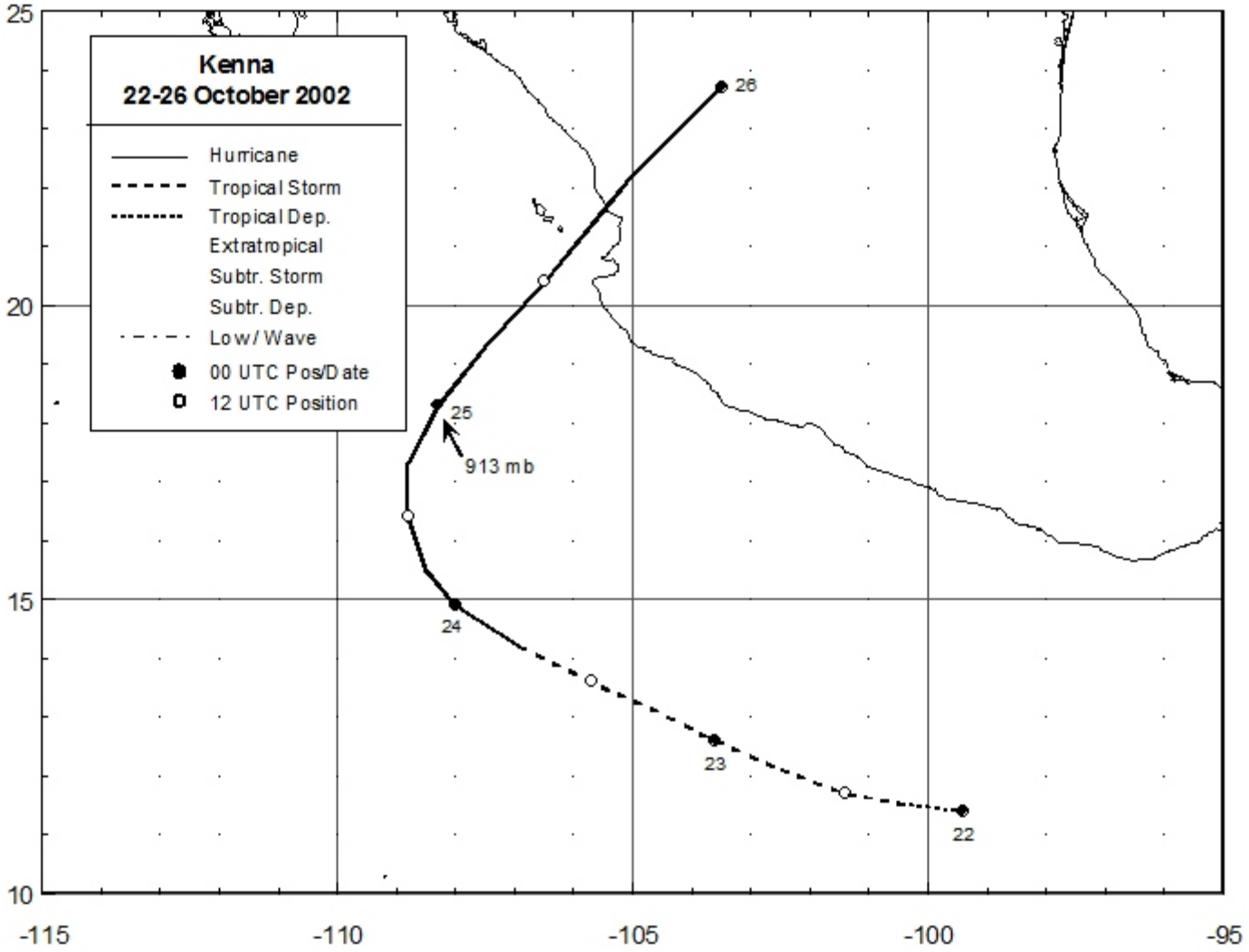

Figure 1. Best track positions for Hurricane Kenna, 22-26 October 2002.

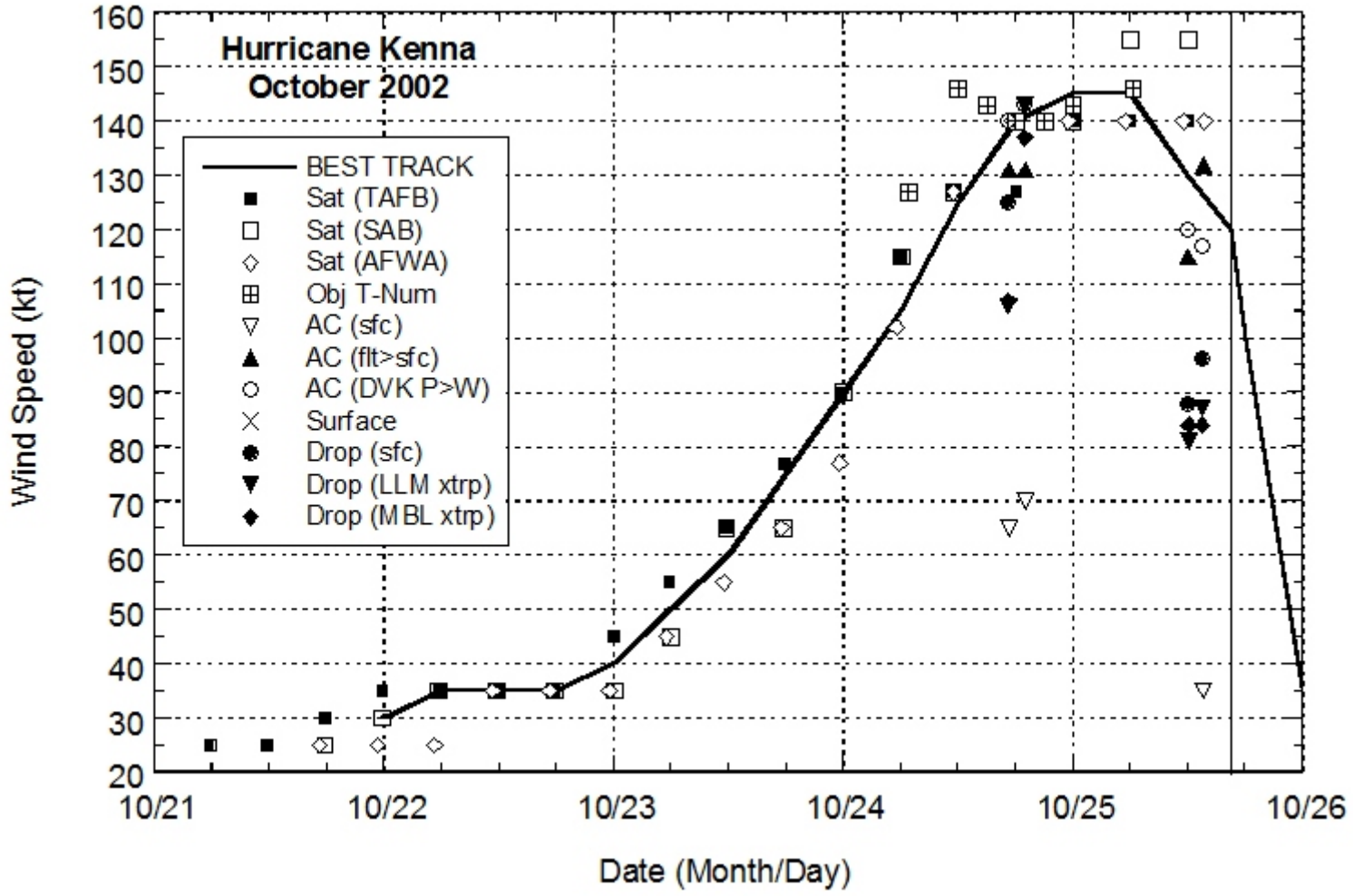

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Kenna, 22-26 October 2002. Aircraft observations have been adjusted for elevation using a 90% reduction factor for observations from 700 mb. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM), and from the sounding boundary layer mean (MBL). Objective Dvorak estimates are 3-h linear averages. Landfall is indicated by the solid vertical line.

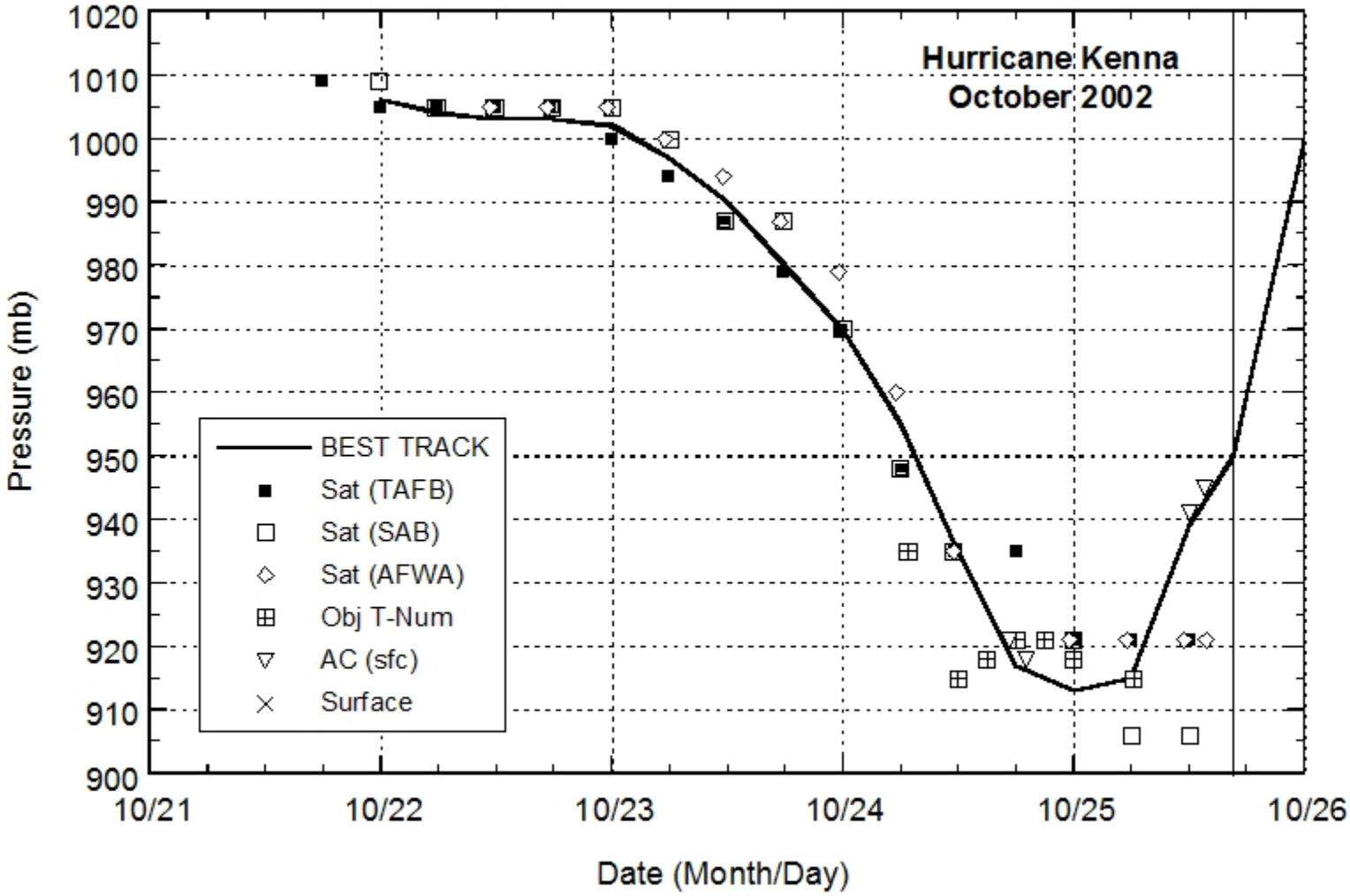

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Kenna, 22-26 October 2002. Objective Dvorak estimates are 3-h linear averages. Landfall is indicated by the solid vertical line.

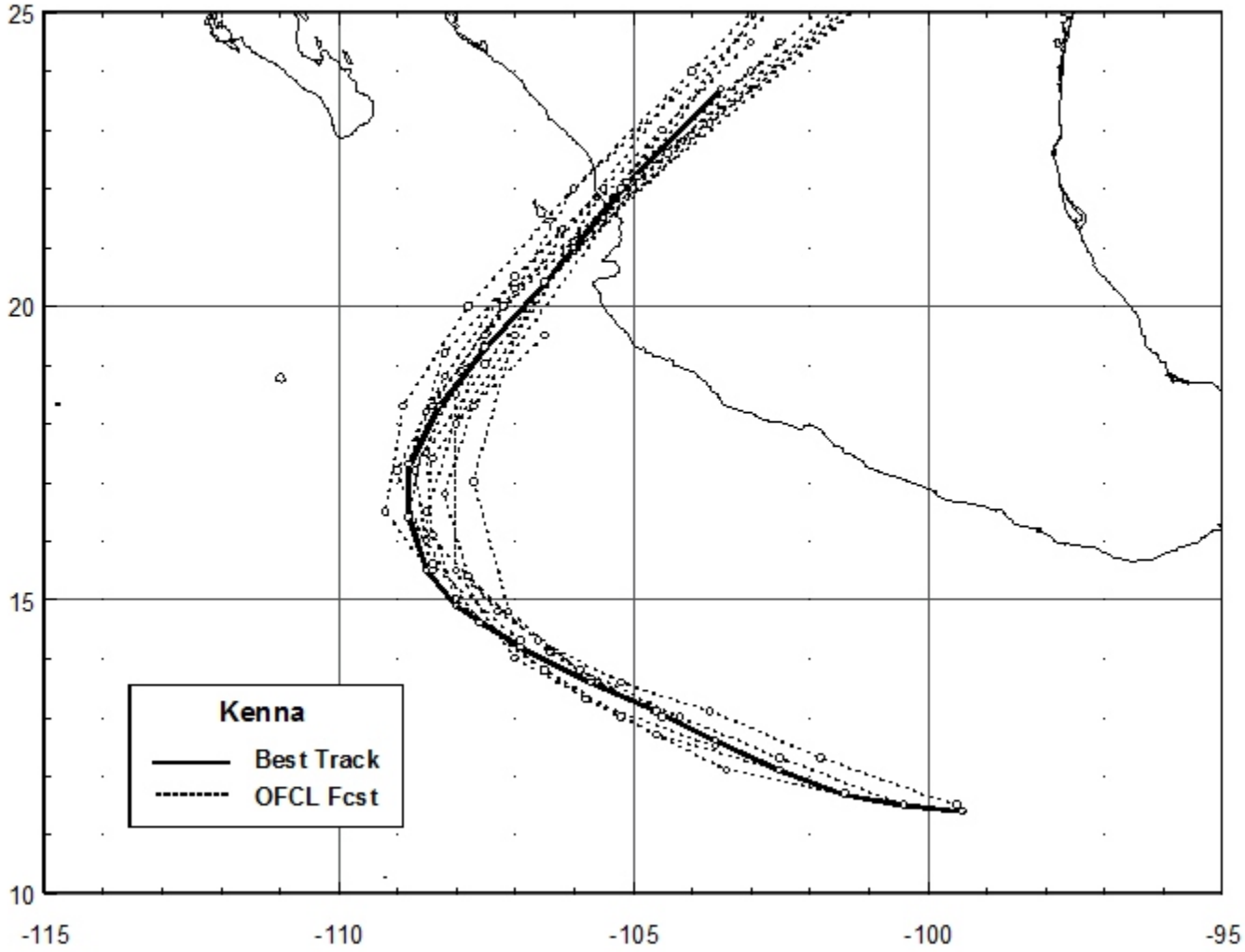

Figure 4. Official track forecasts (dashed lines, with 0, 12, 24, 36 ,48, and 72 h positions indicated) for Hurricane Kenna, 22-26 October 2002. The best track is given by the thick solid line with positions given at 6 h intervals.

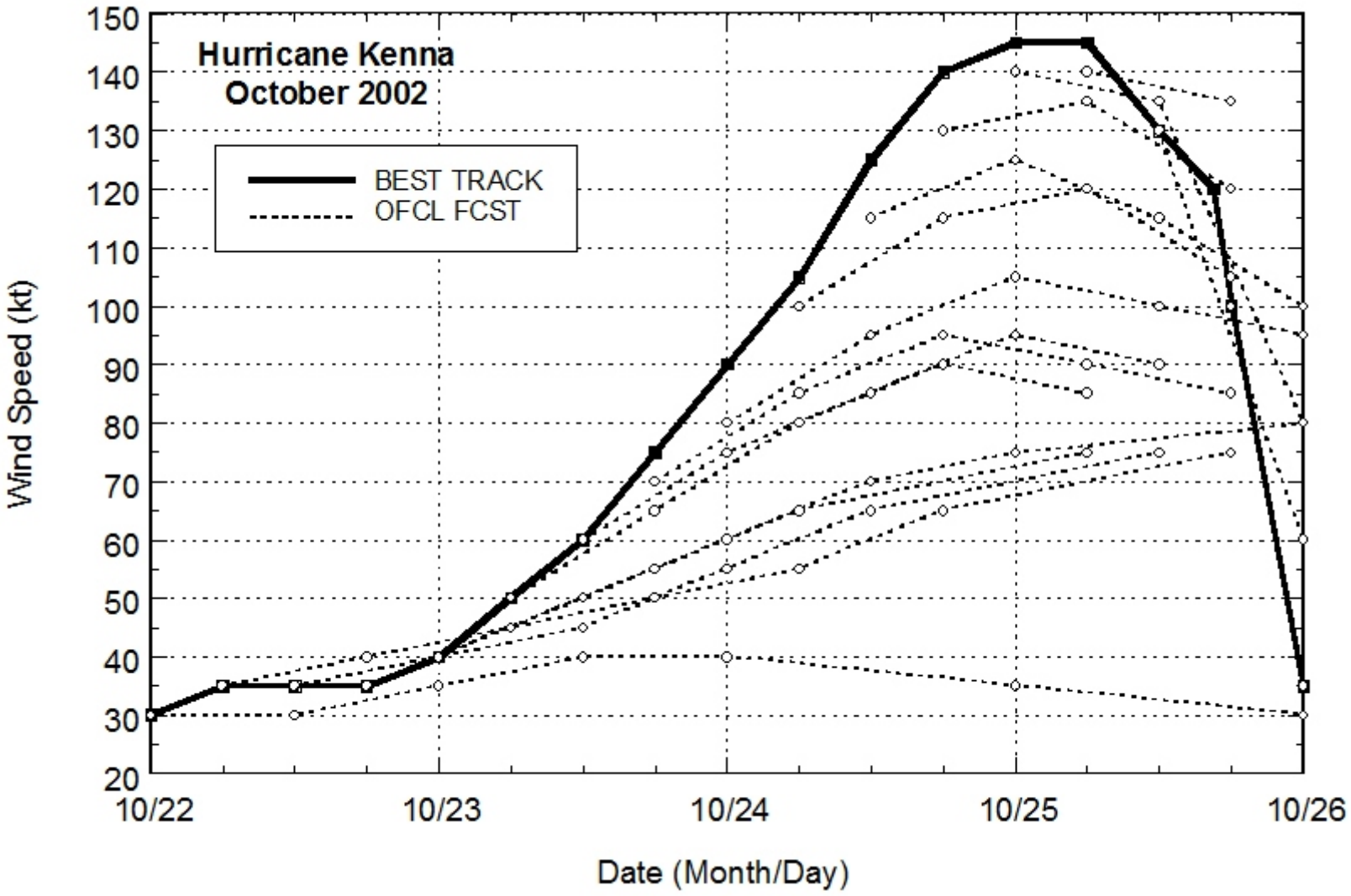

Figure 5. Official intensity forecasts (dashed lines) for Hurricane Kenna, 22-26 October 2002. The best track intensity is given by the thick solid line.