

Tropical Cyclone Report
Hurricane Paul
(EP172006)
21-26 October 2006

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Paul was a category two hurricane on the Saffir-Simpson scale over the open waters of the eastern North Pacific. Paul eventually weakened to a tropical storm as it passed south of Baja California, then made landfall along the coast of mainland Mexico near the southern end of Isla Altamura and later dissipated inland over mainland Mexico. Paul caused significant rainfall and floods in the Mexican state of Sinaloa and was responsible for four deaths in Mexico.

a. Synoptic History

Paul formed from a tropical wave that emerged from the west coast of Africa on 4 October. The wave moved westward across the Atlantic Ocean and Caribbean Sea during the next two weeks and produced little deep convection. The wave crossed Central America on 18 October and moved into a pre-existing area of disturbed weather over the eastern North Pacific on 19 October, which resulted in the formation of a larger area of convection that extended northward to the southern coast of Mexico. An area of low pressure later developed on 20 October, and a tropical depression is estimated to have formed around 0600 UTC 21 October about 230 n mi south-southwest of Manzanillo, Mexico. The “best track” chart 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 quickly became more organized and strengthened to a tropical storm only six hours after genesis. Under the influence of increasing easterly shear associated with a middle to upper-tropospheric ridge over Mexico, however, only modest additional development occurred during the next 24 h. As Paul reached the western periphery of the ridge late on 22 October, vertical shear decreased, and the cyclone rapidly intensified between 1800 UTC 22 October and 1200 UTC 23 October. During this 18 h period, maximum sustained winds increased from 45 kt to 90 kt. In addition, Paul’s forward speed decreased as it began to turn toward the north. The hurricane then began to interact with a large middle to upper-level trough off the west coast of the United States, resulting in increasing westerly shear and subsequent weakening starting late on 23 October.

After its center passed just west of Socorro Island early on 24 October, Paul became embedded within an area of deep southwesterly flow ahead of the upper-level trough and it accelerated northeastward. Weakening was temporarily arrested early on 25 October due to a burst of deep convection as the cyclone approached the southern tip of Baja California. However, strong vertical shear began to displace the convection to the northeast while the center was passing about 40 n mi south of Cabo San Lucas Mexico early on 25 October. The low-level

circulation became completely exposed a few hours later, and Paul weakened to a depression by 0000 UTC 26 October as it approached the coast of mainland Mexico. The increasingly shallow cyclone turned toward the north with a decrease in forward speed and made landfall along the coast of mainland Mexico near the southern end of Isla Altamura around 0400 UTC 26 October. Paul dissipated a few hours later approximately 50 n mi northwest of Culiacán near La Bahía de Santa María, Mexico.

b. Meteorological Statistics

Observations in Paul (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). Microwave satellite imagery from NOAA polar-orbiting satellites, the NASA Tropical Rainfall Measuring Mission (TRMM), the NASA AQUA, the NASA QuikSCAT, and Defense Meteorological Satellite Program (DMSP) satellites were also useful in tracking Paul. Observations from aircraft include flight-level and dropwindsonde data from two missions flown by the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command. A total of four center fixes was obtained during these missions.

The estimated peak intensity of 90 kt at 1200 UTC 23 October is based on unanimous subjective Dvorak intensity estimates from TAFB, SAB, and AFWA. While subsequent subjective satellite intensity estimates indicated that Paul maintained this intensity for another 12-18 h, the best track intensity during this period is set beneath those estimates based on the aircraft data. A flight-level wind of 88 kt at 1745 UTC 23 October was measured in the northeastern quadrant. This observation corresponds to a surface wind speed estimate of about 79 kt using the standard 90% adjustment factor from 700 mb. There was a single ship report of winds of tropical storm force in the vicinity of Paul, although this observation was judged to be incorrect.

c. Casualty and Damage Statistics

Since Paul weakened considerably before passing south of the Baja California peninsula as a tropical storm, it spared land areas from significant damage. However, the cyclone produced large waves and high surf over southern portions of Baja California that resulted in two deaths there. One death involved an American tourist who was swept out to sea, while the second death occurred when a fisherman was swept off rocks in high surf.

Paul weakened to a tropical depression as it approached mainland Mexico but still produced very heavy rainfall resulting in floods in the state of Sinaloa. According to media reports, five thousand homes were damaged in Sinaloa causing 20,000 people to be displaced. The worst flooding occurred in Villa Juárez where a canal overflowed and flooded streets with approximately three feet of water. Two deaths occurred in the municipality of Navolato where a truck was swept away by a swollen river, bringing the total death toll directly attributable to Paul to four.

d. Forecast and Warning Critique

The disturbance which eventually became Paul was first mentioned in the National Hurricane Center (NHC) eastern North Pacific Tropical Weather Outlook (TWO) beginning at 1600 UTC 19 October. The possibility that a tropical depression could form was first indicated in the TWO 24 h later at 1600 UTC 20 October, approximately 14 hours prior to genesis.

A verification of official and guidance model track forecasts is given in Table 2. Average official track errors for Paul were 38, 71, 96, 144, 201, and 231 n mi for the 12, 24, 36, 48, 72, and 96 h forecasts, respectively. The official track errors for Paul are larger than the average long-term track errors at all forecast times, largely owing to a slower than expected northward turn. In addition, Paul's sudden decoupling and weakening on 25 October resulted in an abrupt, unanticipated deceleration. The official track forecasts were bested by the GUNA and CONU consensus models for the 12, 24, 36, and 48 h forecasts but were better than the consensus models for the 72 h forecasts. Among the individual dynamical models, only the NOGAPS model consistently performed better than the official forecast with smaller track errors for the 24, 36, 48, and 72 h forecasts.

Average official intensity errors were 11, 17, 21, 16, 14 and 11 kt for the 12, 24, 36, 48, 72, and 96 h forecasts, respectively. These errors are higher than the average long-term official intensity errors of 6, 11, and 14 kt for the 12, 24, and 36 h forecasts, respectively. Conversely, the official forecast intensity errors were lower than the long-term average intensity errors of 17, 19, and 18 kt for the 48, 72, and 96 h forecasts, respectively. The higher than normal forecast errors for the shorter-term forecasts were due to the rapid intensification that took place from 22-23 October, which once again highlights the difficulty in forecasting rapid intensity changes. The official intensity forecasts were better than the simple model consensus (ICON) for the 36, 48, and 96 h forecasts. Of the individual intensity models, none consistently beat the official forecasts.

Watches and warnings that were issued by the government of Mexico for Paul are listed in Table 5. Both a hurricane watch and a tropical storm warning were issued for southern portions of Baja California. A tropical storm watch was issued along the coast of mainland Mexico from Mazatlan to Altata approximately 43 hours prior to landfall near the southern end of Isla Altamura. A tropical storm warning was issued for the same area approximately 13 hours prior to landfall.

Table 1. Best track for Hurricane Paul, 21-26 October 2006.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
21 / 0600	15.7	105.6	1004	30	tropical depression
21 / 1200	15.8	106.5	1002	35	tropical storm
21 / 1800	15.8	107.4	1000	45	"
22 / 0000	15.8	108.1	1000	45	"
22 / 0600	15.8	108.8	1000	45	"
22 / 1200	15.8	109.5	1000	45	"
22 / 1800	15.8	110.2	994	55	"
23 / 0000	15.9	110.8	980	75	hurricane
23 / 0600	16.1	111.3	973	85	"
23 / 1200	16.3	111.4	970	90	"
23 / 1800	16.7	111.6	978	80	"
24 / 0000	17.3	111.8	979	75	"
24 / 0600	18.0	111.9	987	65	"
24 / 1200	18.8	111.9	992	55	tropical storm
24 / 1800	19.8	111.5	998	45	"
25 / 0000	20.8	111.0	1000	40	"
25 / 0600	21.7	110.3	1000	40	"
25 / 1200	22.6	109.3	1001	40	"
25 / 1800	23.7	108.1	1003	35	"
26 / 0000	24.5	108.1	1005	25	tropical depression
26 / 0600	25.0	108.1	1008	25	remnant low
26 / 1200					dissipated
23 / 1200	16.3	111.4	970	90	minimum pressure
26/0400	24.8	108.1	1007	25	landfall near the southern end of Isla Altamura

Table 2. Preliminary track forecast evaluation (heterogeneous sample) for Hurricane Paul, 21-26 October 2006. Forecast errors (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in bold-face type. Verification includes the depression stage. * Output from these models is unavailable at forecast time

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
CLP5	35 (18)	75 (16)	140 (14)	201 (12)	349 (8)	490 (4)	
GFNI	42 (15)	82 (13)	125 (11)	164 (9)	387 (5)	475 (2)	
GFDI	46 (18)	85 (16)	142 (14)	269 (12)	522 (7)	480 (3)	
GFDL*	35 (18)	72 (16)	109 (14)	196 (12)	524 (7)	561 (2)	
GFDN*	36 (17)	69 (14)	111 (12)	149 (10)	314 (6)	414 (2)	
GFSI	60 (18)	90 (14)	120 (13)	174 (11)	242 (5)	254 (1)	
GFSO*	51 (17)	97 (14)	104 (11)	166 (9)	157 (2)	162 (1)	
AEMI	52 (18)	96 (16)	134 (14)	160 (12)	147 (7)	170 (2)	
NGPI	39 (16)	61 (13)	84 (12)	124 (10)	169 (6)	432 (1)	
NGPS*	31 (17)	57 (15)	67 (13)	93 (11)	162 (7)		
UKMI	49 (16)	93 (14)	136 (12)	167 (10)	92 (6)	586 (2)	
UKM*	46 (9)	71 (8)	118 (7)	169 (6)	170 (4)	125 (2)	
BAMD	62 (18)	130 (16)	215 (14)	328 (12)	639 (8)	946 (4)	
BAMM	40 (18)	69 (16)	107 (14)	169 (12)	339 (8)	549 (4)	
BAMS	55 (18)	104 (16)	156 (14)	206 (12)	272 (8)	277 (4)	
CONU	36 (18)	66 (16)	89 (14)	129 (12)	226 (8)	340 (3)	
GUNA	37 (16)	62 (11)	94 (11)	142 (9)	296 (2)		
FSSE	39 (17)	64 (15)	93 (13)	167 (11)	279 (7)	301 (3)	
OFCL	38 (18)	71 (16)	96 (14)	144 (12)	201 (8)	231 (4)	
NHC Official (2001-2005 mean)	35 (1300)	60 (1152)	83 (1009)	103 (877)	145 (652)	192 (465)	231 (313)

Table 3. Preliminary intensity forecast evaluation (heterogeneous sample) for Hurricane Paul, 21-26 October 2006. Forecast errors (kt) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in bold-face type. Verification includes the depression stage. * Output from this model is unavailable at forecast time.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
SHF5	11.9 (18)	17.4 (16)	24.9 (14)	27.8 (12)	15.4 (8)	12.3 (4)	
GFDI	11.5 (18)	19.0 (16)	19.3 (14)	19.1 (12)	17.3 (6)	14.0 (3)	
GFDL*	11.3 (18)	14.8 (16)	20.6 (14)	17.0 (12)	14.6 (7)	8.0 (2)	
SHIP	11.0 (18)	16.0 (16)	22.1 (14)	22.5 (12)	20.3 (8)	22.8 (4)	
DSHP	11.0 (18)	16.0 (16)	22.0 (14)	20.0 (12)	12.9 (8)	14.3 (4)	
FSSE	11.4 (17)	16.4 (15)	20.2 (13)	17.1 (11)	15.3 (7)	6.3 (3)	
ICON	11.2 (17)	17.3 (15)	19.9 (13)	15.4 (11)	14.0 (5)	5.0 (2)	
OFCL	10.8 (18)	16.9 (16)	21.1 (14)	15.8 (12)	13.8 (8)	11.3 (4)	
NHC Official (2001-2005 mean)	6.2 (1300)	10.8 (1152)	14.3 (1009)	16.5 (876)	18.7 (652)	18.3 (465)	19.3 (313)

Table 4. Watch and warning summary for Hurricane Paul, 21-26 October 2006.

Date/Time (UTC)	Action	Location
23/0300	Hurricane Watch issued	Agua Blanca to La Paz
24/0900	Hurricane Watch replaced with Tropical Storm Warning	Agua Blanca to La Paz
24/0900	Tropical Storm Watch issued	Mazatlan to Altata
25/0300	Tropical Storm Watch discontinued	Mazatlan to Altata
25/1500	Tropical Storm Warning issued	Mazatlan to Altata
25/1500	Tropical Storm Warning discontinued	Agua Blanca to La Paz
25/2300	Tropical Storm Warning discontinued	Mazatlan to Altata

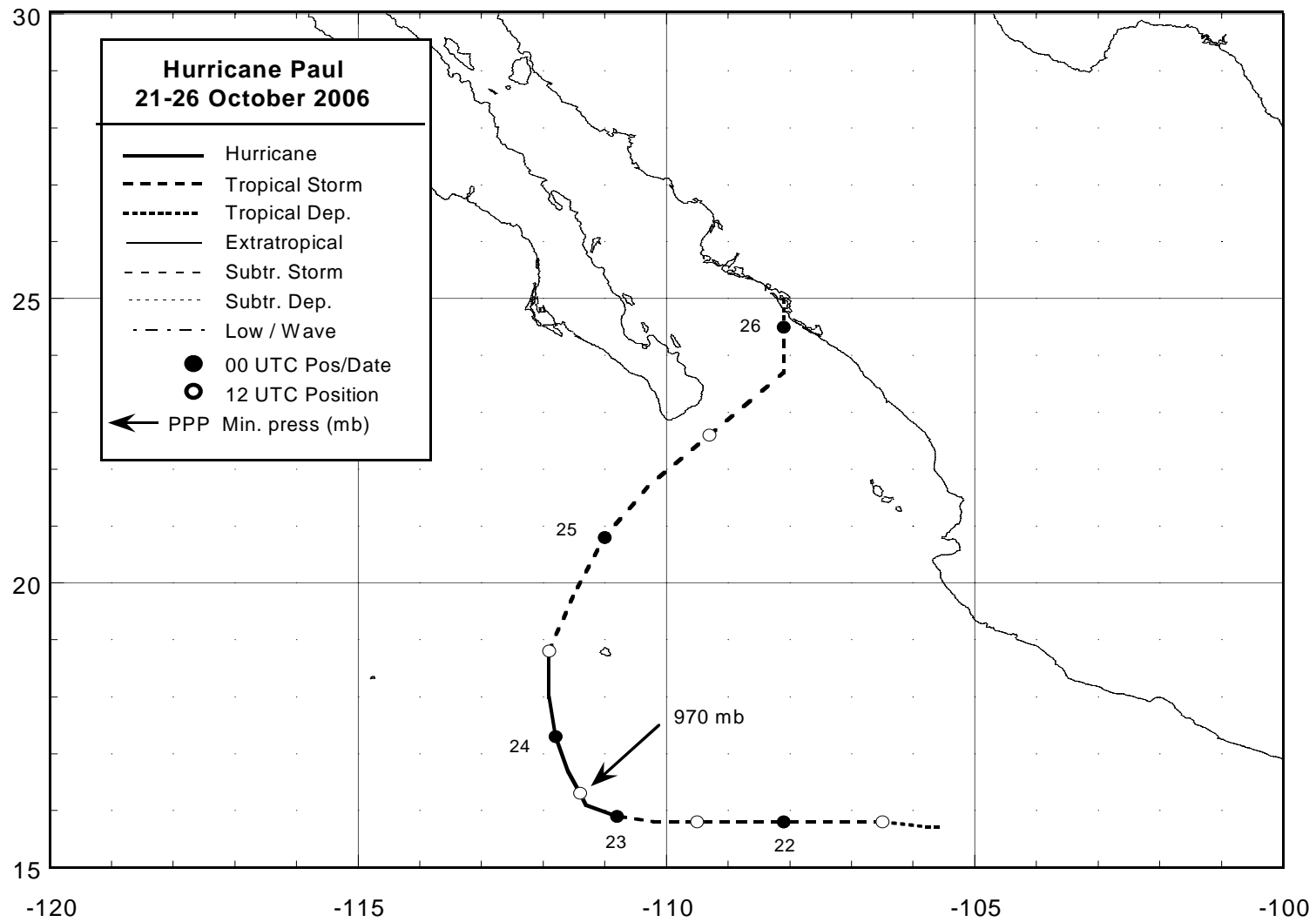


Figure 1. Best track positions for Hurricane Paul, 21-26 October 2006.

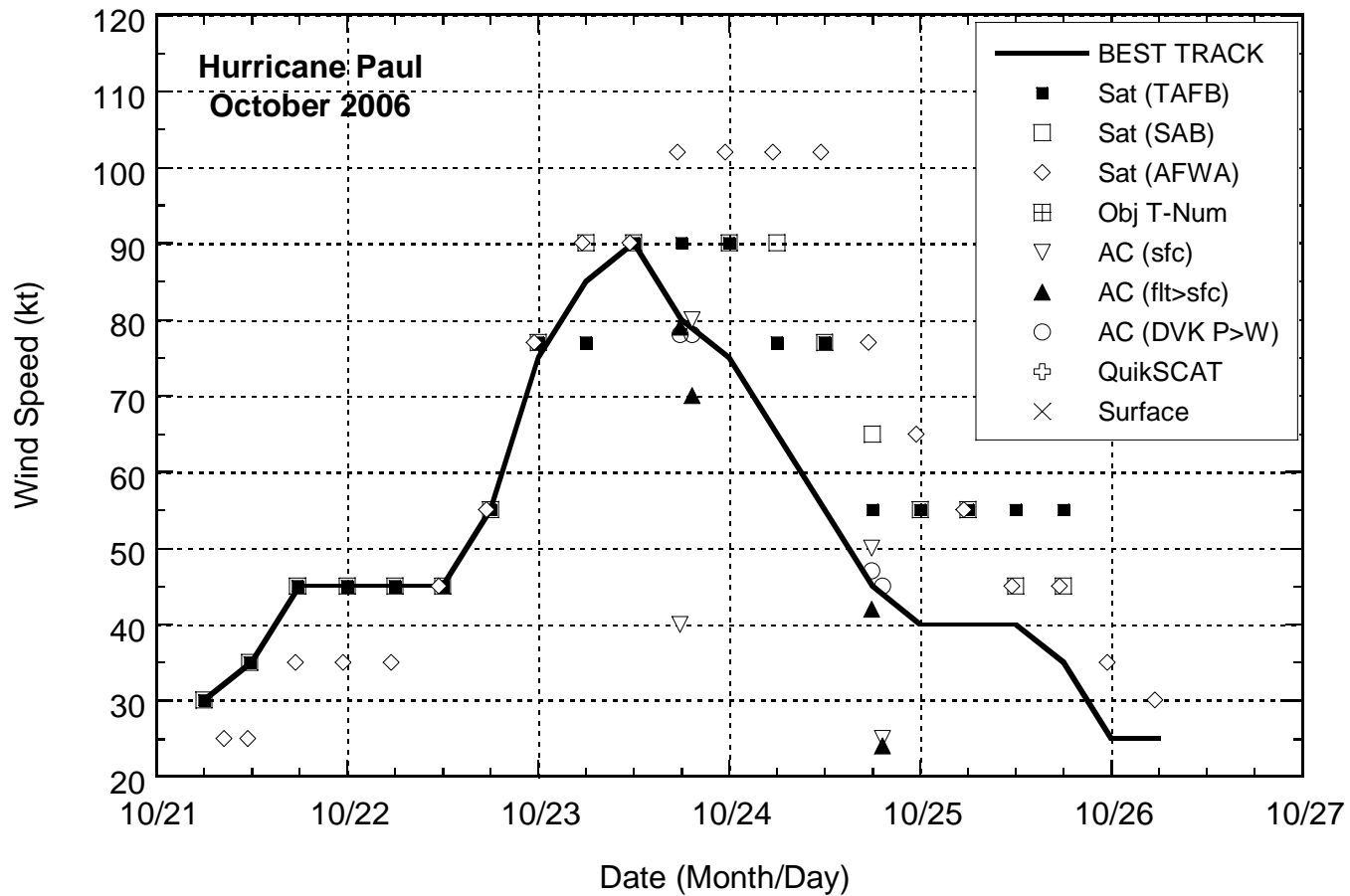


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Paul, 21-26 October 2006. Aircraft observations have been adjusted for elevation using 90% and 80% reduction factors for observations from 700 mb and 850 mb respectively.

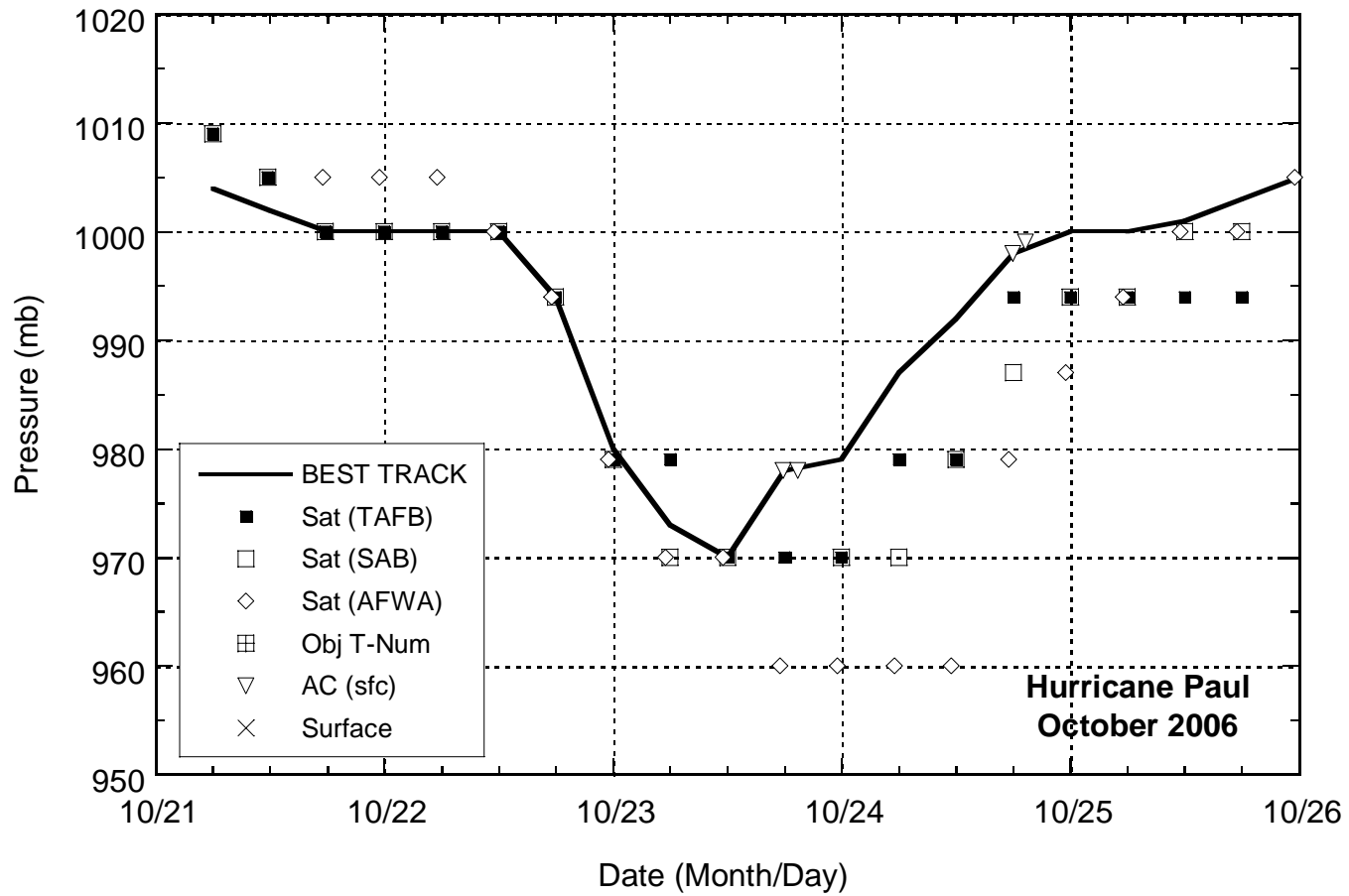


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Paul, 21-26 October 2006.