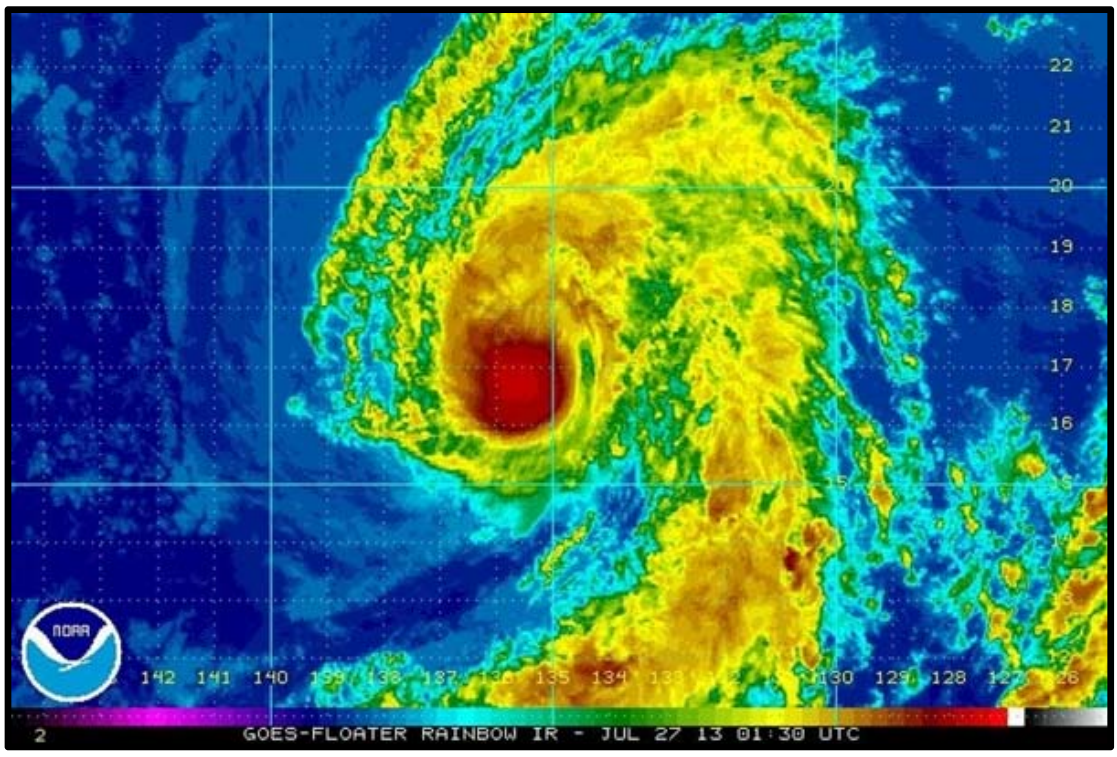
NATIONAL HURRICANE CENTER
CENTRAL PACIFIC HURRICANE CENTER
TROPICAL CYCLONE REPORT

TROPICAL STORM FLOSSIE

(EP062013)

25 – 30 July 2013

John P. Cangialosi
National Hurricane Center
Derek Wroe
Central Pacific Hurricane Center
4 November 2013



NOAA GOES-15 SATELLITE IMAGE OF TROPICAL STORM FLOSSIE AT 0130 UTC 27 JULY 2013.

Flossie was a tropical storm that formed in the eastern North Pacific, and then moved into the central Pacific basin where it produced gusty winds and heavy rains over the Hawaiian Islands.

Tropical Storm Flossie

25 – 30 JULY 2013

SYNOPTIC HISTORY

The genesis of Flossie appears to be partly associated with a tropical wave that moved off the west coast of Africa on 9 July. The wave traveled westward across the Atlantic basin at 15 to 20 kt, and moved over Central America on 18 July. Thunderstorm activity gradually increased near the wave axis during the next several days while it moved south of Mexico. On 24 July, when the disturbance was located well to the south-southwest of the Baja California peninsula, the thunderstorm activity consolidated and gained organization; however, data from the European Space Agency's Advanced Scatterometer (ASCAT) indicated that the system did not have a well-defined center of circulation at that time. Visible satellite imagery and microwave data indicated that the circulation became better defined late on 24 July, and it is estimated that a tropical depression formed by 0000 UTC 25 July, when it was located about 850 n mi west-southwest of the southern tip of the Baja California peninsula. The depression strengthened to a tropical storm 6 h later. The "best track" chart of Flossie'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].

Flossie gradually strengthened over the next couple of days while it moved westward over relatively warm water and within a low wind shear environment. The tropical storm reached its peak intensity of 60 kt by 1200 UTC 27 July when it was located just east of 140°W longitude. At that time, an eye became apparent in microwave images (Fig. 4), with a corresponding warm spot in geostationary infrared imagery. The tropical storm moved into the area of responsibility of the Central Pacific Hurricane Center (CPHC) a few hours later. Shortly after crossing 140°W, Flossie briefly weakened to an intensity of 50 kt when a narrow upper-level trough developed to its west and imparted southwesterly vertical wind shear over the cyclone. As the trough weakened, deep convection increased around the center of Flossie, leading to a short period of re-intensification between 0600 and 1200 UTC 28 July.

A gradual weakening trend resumed late on 28 July and accelerated on 29 July. As Flossie moved westward, it encountered northwesterly vertical wind shear produced by an anticyclone aloft over the Hawaiian Islands. The shear began to significantly disrupt the upper-level outflow of Flossie and displaced the associated deep convection to the south of the center (Fig. 5). Under persistent northwesterly vertical wind shear, Flossie weakened to a tropical depression at 0000 UTC 30 July when the system was centered about 20 n mi northeast of the Island of Maui, and it degenerated to a post-tropical remnant low at 1200 UTC 30 July near the northern coast of the Island of Kauai.

[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.

METEOROLOGICAL STATISTICS

Observations in Flossie (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB), CPHC, Joint Typhoon Warning Center (JTWC) 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), ASCAT, NASA/NOAA Joint Polar Satellite System Suomi National Polar-orbiting Partnership, and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Flossie. The estimated peak intensity of 60 kt is based on Dvorak satellite estimates from TAFB and SAB.

No ship or land reports of winds of tropical storm force associated with Flossie were received. The highest sustained wind measured on land at an official observing site was 31 kt at Keahole Airport in Kailua-Kona, Hawaii, and the highest official wind gust was 43 kt at Kahului Airport in Kahului, Hawaii. Selected surface observations are given in Table 2.

Flossie produced rainfall totals of generally 1.5 to 4 inches over the Hawaiian Islands. The highest report was on Mount Waialeale on the Island of Kauai, where a storm total of 9.27 inches was recorded. Selected rainfall totals are given in Table 2.

High surf in excess of 15 feet affected east-facing shores of the Main Hawaiian Islands with minor coastal inundation reported.

CASUALTY AND DAMAGE STATISTICS

Flossie caused minor damage on the Hawaiian Islands, mainly across Maui and Hawaii Counties on 29 and 30 July. On the Island of Maui, one man suffered injuries when lightning struck and damaged his home. Power outages affected more than 10,000 homes on the Islands of Maui and Hawaii due to lightning strikes and gusty winds downing trees.

FORECAST AND WARNING CRITIQUE

The development of Flossie was generally well predicted. The disturbance from which Flossie formed was introduced in the National Hurricane Center's Tropical Weather Outlook at 1200 UTC 21 July, about 84 h before genesis occurred. Initially, the disturbance was assessed to have a low chance (<30%) of development during the next 48 h. The chance of development was raised to the medium category (30 to 50%) at 0000 UTC 23 July, 48 h before genesis, and to the high category (>50%) 6 h before formation occurred.

A verification of NHC official track forecasts for Flossie is given in Table 3a. Official forecast track errors were greater than the mean official errors for the previous 5-yr period at all forecast times. A homogeneous comparison of the NHC official track errors with selected guidance models is given in Table 3b. The Global Forecast System (GFSI) and its ensemble mean (AEMI) were among the best performing models for Flossie. The simpler Beta and Advection Model shallow layer (BAMS) also performed well.

A homogeneous comparison of CPHC official track errors with selected guidance models for Flossie is given in Table 3c. The United Kingdom Meteorological Office model (EGRI) had smaller average errors than the CPHC official forecasts beyond 12 h, while the TVCE consensus outperformed the official forecasts in the 12 to 48 h range. Otherwise, CPHC official track errors were better than or comparable to nearly all of the guidance.

A verification of NHC official intensity forecasts for Flossie is given in Table 4a. NHC forecast intensity errors were much lower than the mean official errors for the previous 5-yr period. A homogeneous comparison of the NHC official intensity errors with selected guidance models is given in Table 4b. The statistical-dynamical models and consensus aids outperformed the dynamical models at most of the forecast times.

A homogeneous comparison of CPHC official intensity errors with selected guidance models for Flossie is given in Table 4c. The HWRF model (HWFI) had smaller average errors than the CPHC forecasts beyond 12 h. Otherwise, CPHC official intensity errors were better than or comparable to nearly all of the guidance.

Coastal watches and warnings associated with Flossie are given in Table 5. This event marked the first occasion for which tropical storm watches had been issued for the Main Hawaiian Islands since Tropical Storm Felicia in 2009, and the first time tropical storm warnings had been issued since Tropical Storm Flossie in 2007. The initial tropical storm watch was issued at 0300 UTC 28 July for the Islands of Hawaii, Maui, Molokai, Lanai, and Kahoolawe, with tropical storm watches expanding westward that day to Oahu at 0900 UTC and to the Islands of Kauai and Niihau at 2100 UTC. Tropical storm warnings were first posted for the Islands of Hawaii, Maui, Molokai, Lanai, and Kahoolawe at 0900 UTC 28 July, with tropical storm warnings expanding westward to Oahu at 2100 UTC that day and to the Islands of Kauai and Niihau at 1500 UTC 29 July. Since Flossie weakened when it approached the Hawaiian Islands, tropical storm conditions did not occur in the warning area, and all tropical storm warnings were discontinued by 0300 UTC 30 July.

Table 1. Best track for Tropical Storm Flossie, 25-30 July 2013.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
25 / 0000	14.9	121.8	1005	30	tropical depression
25 / 0600	14.9	123.5	1004	35	tropical storm
25 / 1200	14.9	125.2	1003	35	"
25 / 1800	15.0	126.8	1002	40	"
26 / 0000	15.2	128.4	1001	40	"
26 / 0600	15.5	130.0	1000	45	"
26 / 1200	15.9	131.6	999	45	"
26 / 1800	16.3	133.3	998	50	"
27 / 0000	16.7	135.0	997	50	"
27 / 0600	17.1	136.6	996	55	"
27 / 1200	17.7	138.4	994	60	"
27 / 1800	18.4	140.2	996	55	"
28 / 0000	18.9	142.3	999	50	"
28 / 0600	19.3	144.3	999	50	"
28 / 1200	19.7	146.0	998	55	"
28 / 1800	19.8	147.7	1000	50	"
29 / 0000	19.7	149.4	1001	50	"
29 / 0600	19.9	151.1	1002	45	"
29 / 1200	20.2	152.7	1004	40	"
29 / 1800	20.5	154.2	1006	35	"
30 / 0000	21.0	155.7	1007	30	tropical depression
30 / 0600	21.8	157.4	1009	30	"
30 / 1200	22.3	159.4	1011	25	low
30 / 1800					dissipated
27 / 1200	17.7	138.4	994	60	maximum winds and minimum pressure

Table 2. Selected surface observations in the Hawaiian Islands associated with Tropical Storm Flossie.

Location (State of Hawaii)	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
International Civil Aviation Organization (ICAO) Sites						
Hilo (PHTO)	29/1653	1009.8	29/2153	23	33	
Kailua-Kona (PHKO)	29/2353	1010.5	30/0118	31	37	
Lanai City (PHNY)	30/0156	1008.5	29/2106	28	35	
Kahului (PHOG)	30/0154	1008.7	30/0454	28	43	
Kalaeloa (PHJH)	30/0253	1010.8	30/0953	25	29	
Honolulu (PHNL)	31/0053	1017.0	31/0053	22	28	
Non-METAR Observations						
Kula 1 (KLFH1)			30/0448	21	38	
Kaneloa (KAOH1)			29/1953	27	41	
Honokanaia (HKAH1)			30/0353	20	46	
Hakioawa (HKIH1)			30/0452	29	46	
PTA East (PTAH1)			28/1959	24	32	
PTA Range 17 (PTRH1)			30/1749	20	35	
Kaupo Gap (KPGH1)			30/0435	17	33	5.27
Kula 1 (KLFH1)			30/0448	21	38	2.26
Lanai 1 (LNIH1)			29/1637	29	43	
Marine Observations						
Hilo (ILOH1) 19.73°N 155.06°W	29/2130	1009.9	29/2154	25	36	
Kahului Bay (KLIH1) 20.90°N 156.47°W	30/0224	1007.8	30/0448	26	37	
Kawaihae (KWHH1) 20.03°N 155.83°W	30/0118	1009.1	30/0118	21	26	
Other						
Mount Waialeale (WLLH1)						9.27
Kilohana RG (KLOH1)						4.75

Puu Kukui (PKKH1)						4.68
Kepuni USGS (KPNH1)						4.07
Puu Alii (PAFH1)						4.05
Ulupalakua Ranch (ULUH1)						3.63
Oahu Forest NWR (OFRH1)						3.32
Kawainui Stream (KWSH1)						3.21
Wailua Ditch (WLDH1)						3.15
Molokai 1 (MLKH1)						3.11
Waialae Ridge (WLGH1)						2.94
Mohihi Crossing (MCRH1)						2.89
Poamoho RG 1 (PMHH1)						2.53
Kamuela Upper (KUUH1)						2.52
Wainiha River (WNHH1)						2.12
Waiakoali (WKRH1)						2.05
Punaluu Stream (PNSH1)						2.02
Manoa Lyon Arboretum (MNLH1)						2.01

[a] Date/time is for sustained wind when both sustained and gust are listed.

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Flossie for forecasts made between 0000 UTC 25 July and 1200 UTC 27 July 2013. 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	30.9	48.4	71.9	98.5	153.9	273.9	413.2
OCD5	49.8	95.5	151.4	213.0	348.8	517.1	817.4
Forecasts	11	11	11	11	10	6	2
OFCL (2008-12)	27.0	43.1	57.8	71.9	101.7	137.2	165.9
OCD5 (2008-12)	37.4	73.0	114.9	158.3	238.4	313.5	389.1

Table 3b. Homogeneous comparison of NHC official forecasts with selected track forecast guidance models (in n mi) for Tropical Storm Flossie for forecasts made between 0000 UTC 25 July and 1200 UTC 27 July 2013. 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	28.7	45.9	70.9	95.2	138.8		
OCD5	46.7	88.8	144.9	207.6	312.7		
GFSI	**26.4**	**39.9**	**60.2**	**82.3**	**124.8**		
GHMI	**27.2**	47.3	**61.3**	**72.7**	**128.0**		
HWFI	29.6	**43.0**	**61.4**	**81.2**	158.7		
EGRI	30.4	**38.7**	**52.4**	**74.4**	**121.0**		
EMXI	**27.1**	46.5	72.0	100.5	160.4		
CMCI	34.0	53.1	75.6	**90.2**	143.0		
AEMI	**24.1**	**37.4**	**59.3**	**82.0**	**137.5**		
FSSE	**28.6**	**42.0**	**60.7**	**79.2**	**136.0**		
TVCE	**24.3**	**32.3**	**44.4**	**57.2**	**106.5**		
LBAR	35.6	49.3	78.0	109.5	152.5		
BAMS	34.5	**38.1**	**48.8**	**64.3**	**57.0**		
BAMM	32.0	52.7	71.3	**93.6**	**117.7**		
BAMD	40.1	69.1	106.4	149.5	223.3		
NAMI	48.2	73.6	87.9	111.3	176.6		
Forecasts	9	9	9	8	6		

Table 3c. Homogeneous comparison of CPHC official forecasts with selected track forecast guidance models (in n mi) for Tropical Storm Flossie for forecasts made after 1200 UTC 27 July 2013. Errors smaller than the CPHC official forecast are shown in boldface type.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	27.6	38.6	47.7	72.2			
GFSI	32.2	46.9	64.4	112.2			
GHMI	30.5	49.1	76.6	123.5			
HWFI	28.7	42.3	62.0	124.4			
EGRI	32.6	**33.2**	**36.8**	**53.5**			
EMXI	28.4	42.0	**26.6**	**38.0**			
CMCI	33.4	52.4	60.6	**65.3**			
AEMI	31.5	40.9	54.4	94.6			
TVCE	**24.9**	**34.1**	**40.6**	79.7			
LBAR	45.2	71.8	65.6	81.6			
BAMS	37.9	69.3	92.7	87.6			
BAMM	42.7	60.2	78.3	117.9			
BAMD	53.9	88.9	107.2	141.3			
Forecasts	9	7	5	3			

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Flossie for forecasts made between 0000 UTC 25 July and 1200 UTC 27 July 2013. 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	**5.0**	**5.9**	**5.9**	**8.2**	**8.5**	**6.7**	**0.0**
OCD5	5.0	6.1	7.5	8.4	6.4	13.0	7.0
Forecasts	11	11	11	11	10	6	2
OFCL (2008-12)	6.3	10.5	13.4	14.5	15.3	17.0	17.3
OCD5 (2008-12)	7.6	12.5	16.5	18.8	20.4	20.3	20.6

Table 4b. Homogeneous comparison of NHC official forecasts with selected intensity forecast guidance models (in kt) for Tropical Storm Flossie for forecasts made between 0000 UTC 25 July and 1200 UTC 27 July 2013. 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	5.0	6.0	6.0	8.5	8.9	5.0	
OCD5	5.5	6.4	7.0	**7.4**	**6.0**	12.5	
GHMI	**4.5**	7.6	13.1	13.2	**7.1**	11.3	
HWFI	5.3	**4.0**	**5.7**	9.4	11.8	6.3	
DSHP	5.2	**5.3**	**4.6**	**5.0**	**4.8**	6.5	
LGEM	5.2	**4.1**	7.6	8.6	10.4	9.5	
FSSE	5.6	**4.6**	6.4	**6.4**	**8.2**	5.3	
ICON	**4.6**	**3.3**	6.9	**7.8**	**8.8**	9.0	
Forecasts	10	10	10	10	9	4	

Table 4c. Homogeneous comparison of CPHC official forecasts with selected intensity forecast guidance models (in kt) for Tropical Storm Flossie for forecasts made after 1200 UTC 27 July 2013. Errors smaller than the CPHC official forecast are shown in boldface type.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	4.4	7.9	7.0	3.3			
GHMI	6.3	8.1	**6.2**	4.0			
HWFI	5.8	**6.4**	**4.8**	**1.0**			
DSHP	5.2	9.4	10.6	6.0			
LGEM	6.7	11.7	12.8	8.7			
ICON	5.4	8.1	7.2	**3.0**			
Forecasts	9	7	5	3			

Table 5. Watch and warning summary for Tropical Storm Flossie, 25-30 July 2013.

Date/Time (UTC)	Action	Location
28 / 0300	Tropical Storm Watch issued	Islands of Hawaii, Maui, Molokai, Lanai, and Kahoolawe
28 / 0900	Tropical Storm Watch issued	Island of Oahu
28 / 0900	Tropical Storm Watch changed to Tropical Storm Warning	Islands of Hawaii, Maui, Molokai, Lanai, and Kahoolawe
28 / 2100	Tropical Storm Watch issued	Islands of Kauai and Niihau
28 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Island of Oahu
29 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Island of Kauai
30 / 0300	Tropical Storm Warning discontinued	All islands

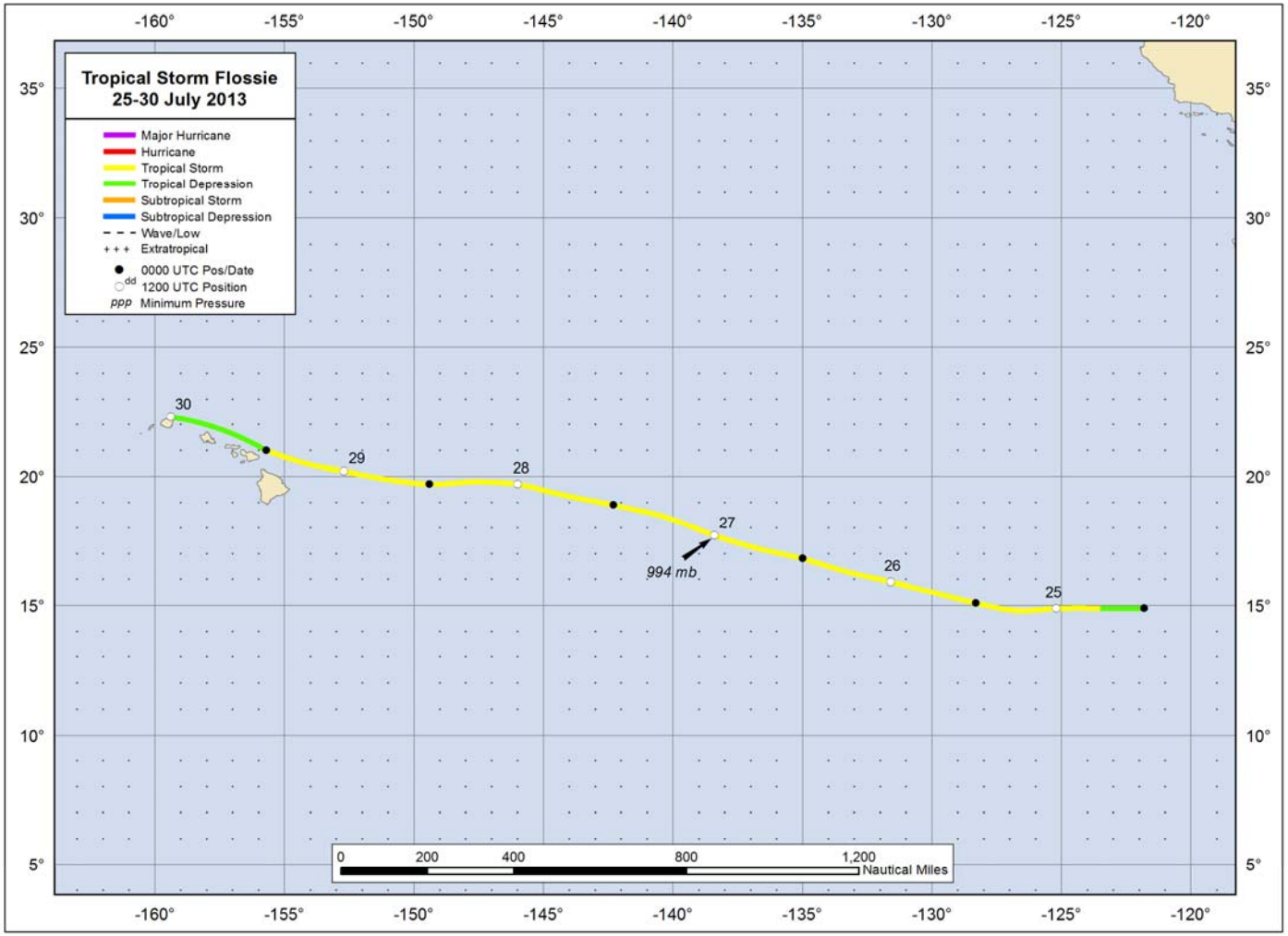


Figure 1. Best track positions for Tropical Storm Flossie, 25-30 July 2013. Track west of 140°W longitude was produced by the Central Pacific Hurricane Center.

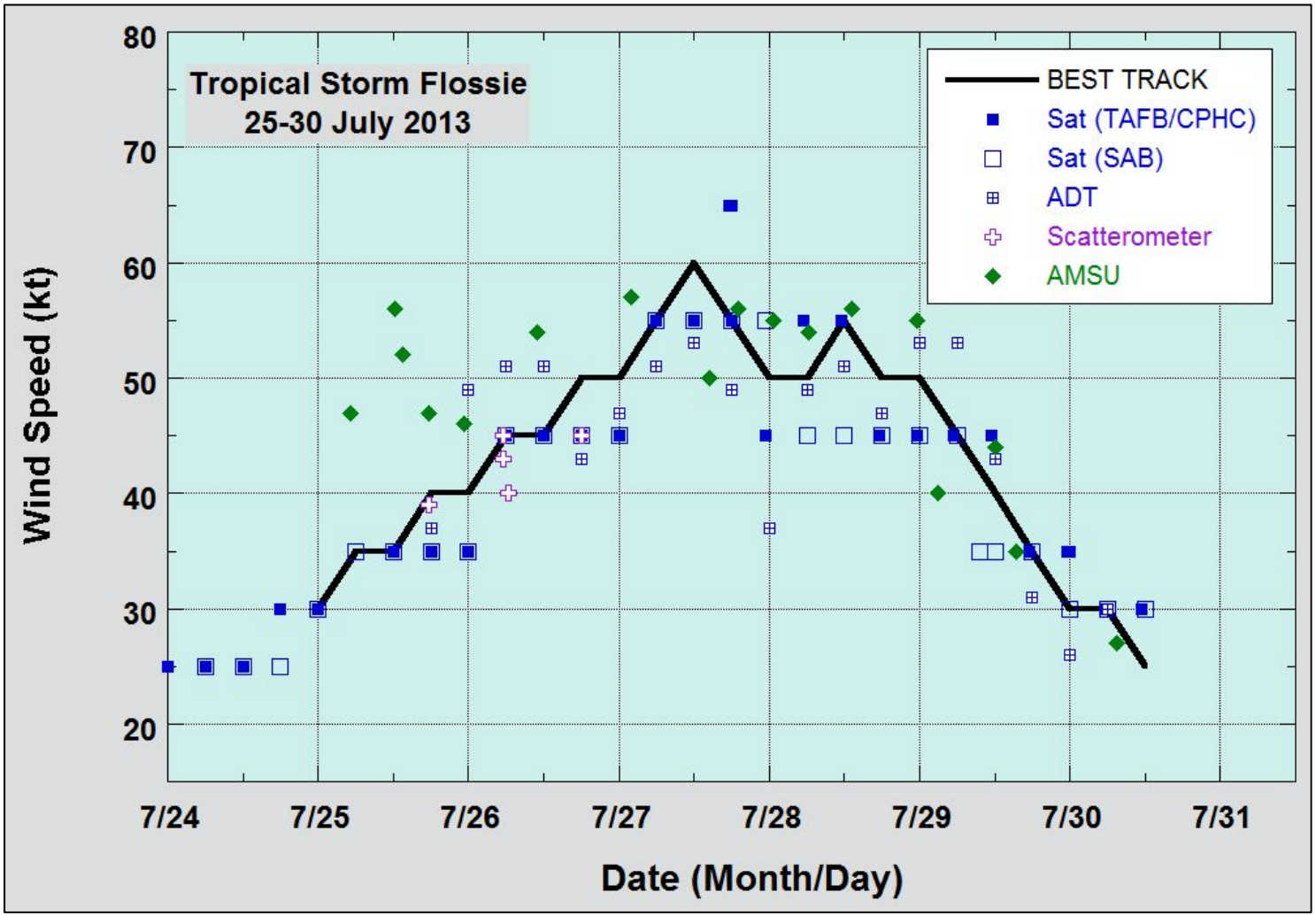


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Flossie, 25-30 July 2013. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC. Best track data after 1200 UTC 27 July were produced by the Central Pacific Hurricane Center.

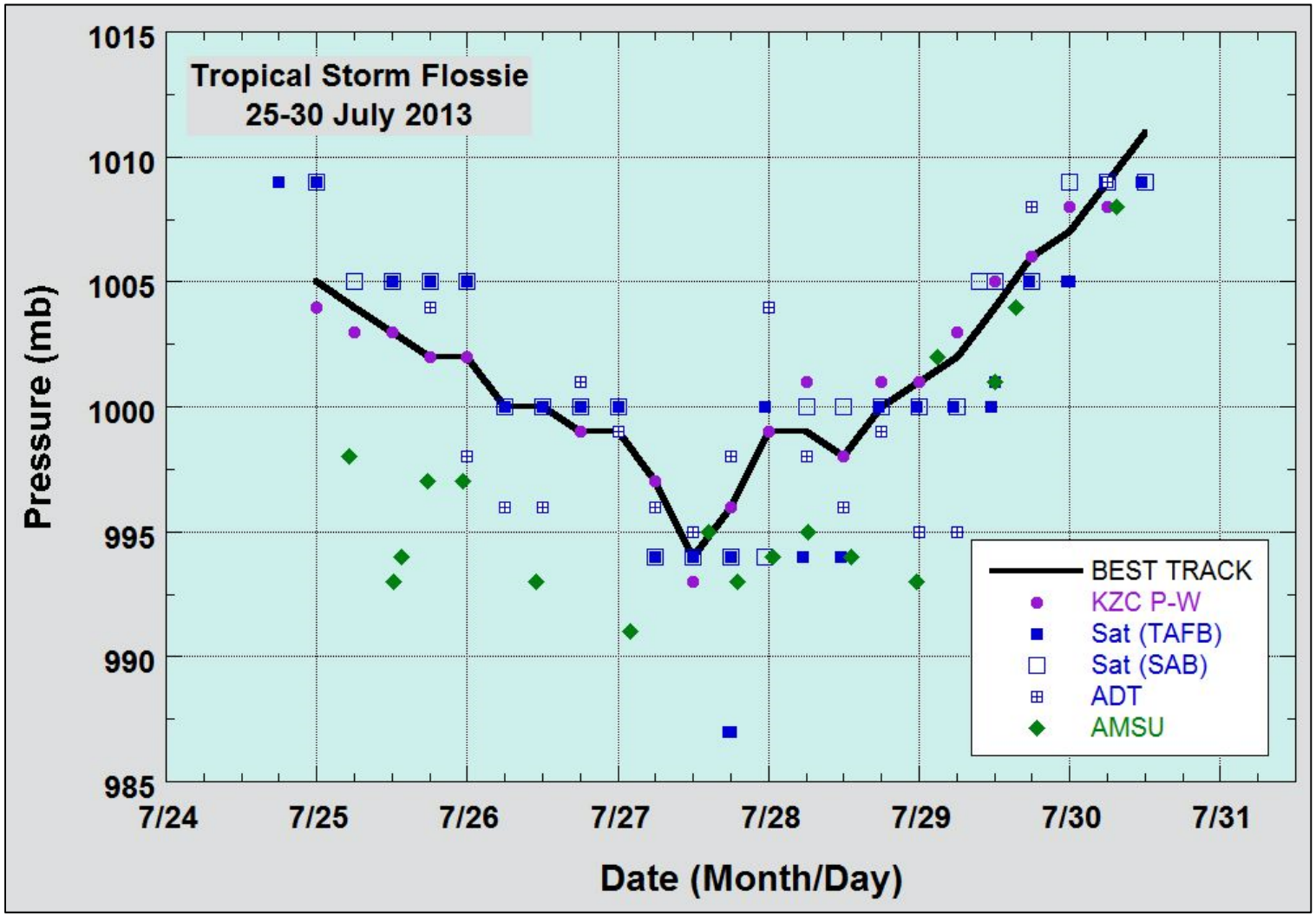


Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Flossie, 25-30 July 2013. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological 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. Best track data after 1200 UTC 27 July were produced by the Central Pacific Hurricane Center.

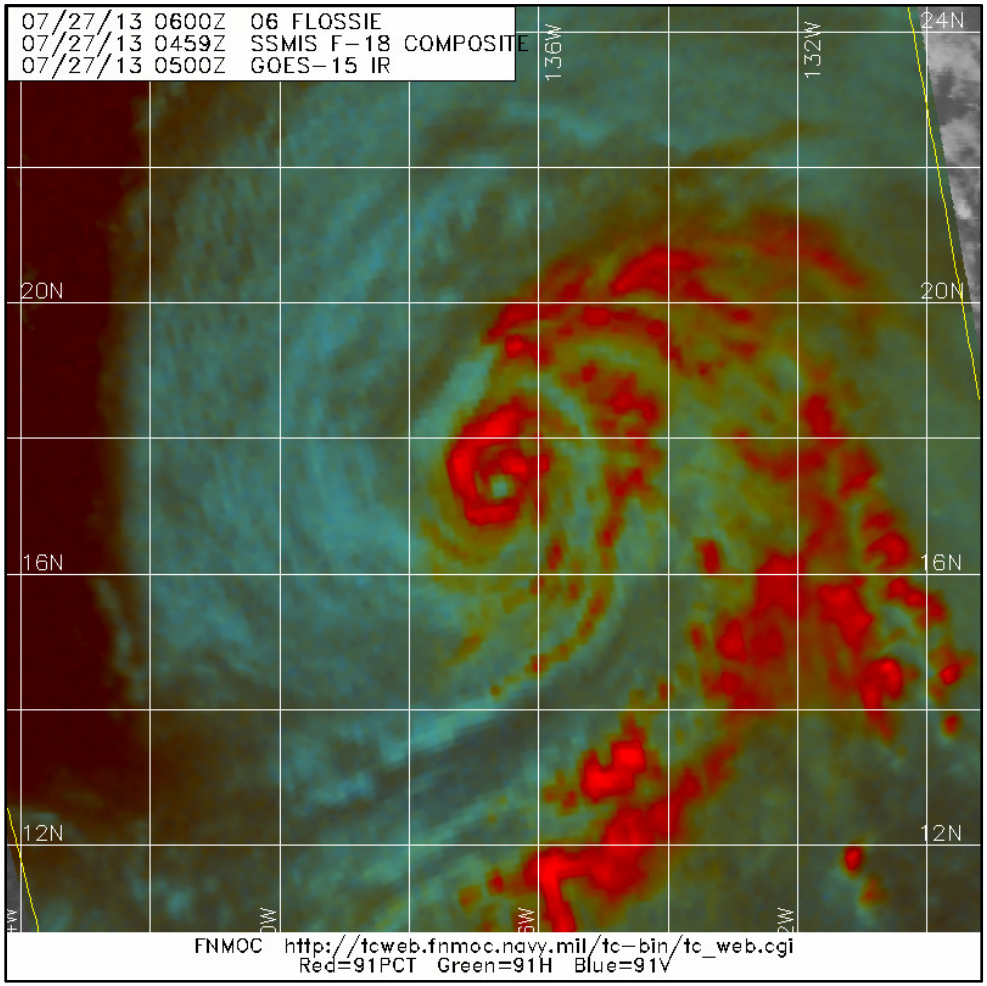


Figure 4. SSMI/S microwave (85-GHz) color composite image at 0459 UTC 27 July, around the time of peak intensity. Image courtesy of Fleet Numerical Meteorology and Oceanography Center.

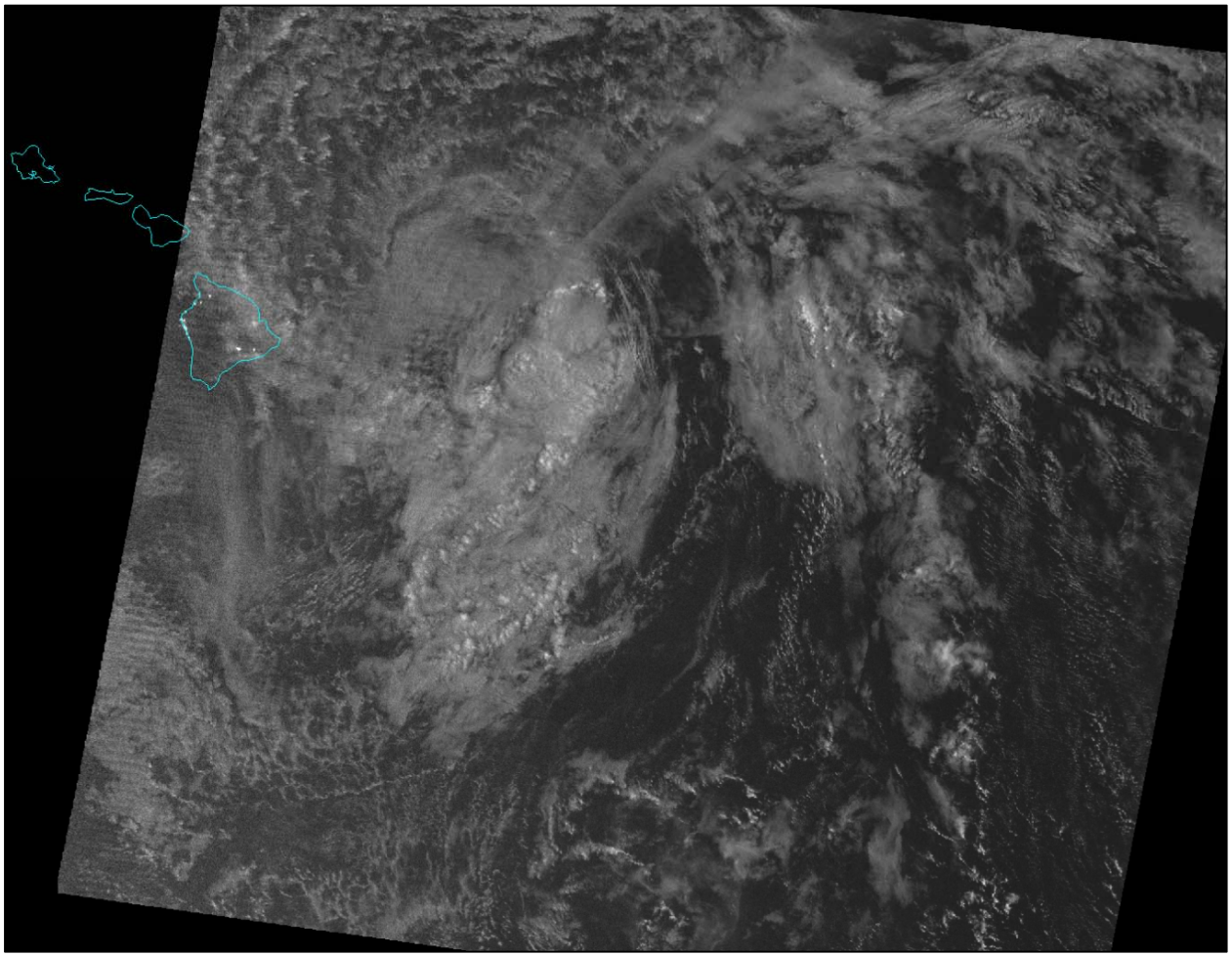


Figure 5. VIIRS Day/Night Band image at 1100 UTC 29 July used to find system center at night. Image courtesy of the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison.