

Tropical Cyclone Report  
Hurricane Felicia  
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Felicia strengthened into a major hurricane over the western portion of the eastern North Pacific basin. The hurricane gradually weakened over the central Pacific, and dissipated just east of the Hawaiian Islands.

a. Synoptic History

Felicia's genesis can be traced to a tropical wave that was first detected in satellite imagery over the tropical Atlantic on 23 July. The wave was barely identifiable for several days but became better defined as it approached the Lesser Antilles on 26 July. Little change in the wave was noted as it passed through the Caribbean Sea and moved across Central America during the last few days of July. Scattered deep convection began to develop in association with the wave after it moved into the eastern North Pacific on 29 July, but it was not until the wave passed 110°W on 1 August that deep convection increased further and showed signs of organization. Satellite images indicated several curved bands on 3 August around a developing circulation center, and the disturbance is estimated to have become a tropical depression by 1800 UTC 3 August. Additional organization occurred and the depression became a tropical storm around 0000 UTC 4 August, centered about 990 n mi southwest of the southern tip of Baja California. 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<sup>1</sup>.

Within an environment of low vertical wind shear and 28°-29°C sea surface temperatures, Felicia began a period of rapid intensification from the time it formed. A NASA Tropical Rainfall Measuring Mission (TRMM) 85-GHz microwave pass at 1327 UTC 4 August captured Felicia in the middle of this intensification phase, revealing a well-defined mid-level eye-like feature within a central dense overcast (Fig. 4). Microwave imagery and Dvorak satellite estimates suggest that Felicia continued to rapidly intensify and reached hurricane strength around 1800 UTC 4 August.

Felicia initially moved west-northwestward between 12 and 14 kt to the south of a well-defined deep-layer ridge covering the central portion of the eastern North Pacific. However,

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<sup>1</sup> 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 *brk* directory, while previous year's data are located in the *archive* directory.

Felicia slowed to a forward speed of 9 to 10 kt and started moving on a more northwestward heading by 5 August, when it reached the western extent of a ridge to its north and encountered a trough digging along 130°W. The cyclone may have also been involved in a weak binary interaction with Tropical Storm Enrique to its northeast during its developing stage, with the separation distance between the two as little as 425 n mi around 1200 UTC 6 August. Despite their proximity, the tracks of the two cyclones indicate that whatever interaction occurred was minimal.

On a northwestward course, Felicia continued to rapidly intensify and reached its estimated peak intensity of 125 kt at 0600 UTC 6 August, while located about 1465 n mi east-southeast of Hilo, Hawaii. Although the environmental shear remained fairly light, gradual weakening began during the next 24 hours, followed by a faster weakening after Felicia began moving over 26° to 27°C sea surface temperatures. Around this time, mid-level ridging building to the north and west of the hurricane replaced the mid- to upper-tropospheric trough that was along 130°W. The change in steering features resulted in a more west-northwesterly course just prior to Felicia's entrance into the central North Pacific basin a hurricane with 80 kt winds around 1200 UTC 8 August.

Early on 9 August, aircraft reconnaissance data and microwave imagery indicated that the flight-level center was no longer collocated with the surface center. This marked the beginning of a weakening trend, as Felicia encountered increasing westerly vertical wind shear produced by a broad upper-level trough over and north of the Hawaiian islands. Felicia weakened to a tropical storm by 1200 UTC that day while centered about 550 n mi east of Hilo. By 0000 UTC 10 August, the shear had exacted a substantial toll on Felicia, as the low-level circulation center had become exposed from deep convection displaced to the northeast, and maximum winds had diminished to 45 kt, down from 75 kt just 24 hours earlier. As the tropical storm weakened, the dominant steering flow was a low- to mid-level subtropical ridge to the north, causing Felicia to assume a westward motion for the remainder of its existence.

Gradual weakening continued through 10 August in an environment of continued strong westerly shear. The upper-level trough responsible for the shear also created diffluence aloft, however, which helped to maintain an area of deep convection displaced to the north-northeast of the exposed low-level center. While this convection continued, aircraft reconnaissance and QuikSCAT data continued to indicate winds of tropical storm force to the north of the circulation center through early on 11 August. Later that day, the diffluent pattern aloft broke down, while vertical wind shear remained strong over the cyclone, and deep convection diminished. Felicia weakened to a tropical depression by 1200 UTC 11 August while centered 120 n mi northeast of Hilo, and became a remnant low around 1800 UTC. Shortly thereafter, the low-level circulation center became ill-defined as it interacted with the high terrain of the Big Island of Hawaii, and the circulation dissipated. Remnant moisture then continued westward over the rest of the Hawaiian Islands for the next couple of days.

#### b. Meteorological Statistics

Observations in Felicia (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis

Branch (SAB), the Central Pacific Hurricane Center (CPHC), and the Joint Typhoon Warning Center (JTWC). Data and imagery from NOAA polar-orbiting satellites, including the Advanced Microwave Sounding Unit (AMSU) intensity estimates using the CIMSS technique, the NASA Tropical Rainfall Measuring Mission (TRMM), the NASA QuikSCAT, the NASA Aqua, the Department of Defense Windsat, and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in tracking Felicia and later constructing its best track. Flight-level, dropsonde, and Stepped-Frequency Microwave Radiometer (SFMR) data were also obtained during five C-130J aircraft missions flown by the 53<sup>rd</sup> Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command. The NOAA G-IV jet also flew three synoptic surveillance missions around Felicia during 7-9 August.

The estimated peak intensity of Felicia of 125 kt is based on several subjective Dvorak intensity estimates of 127 kt and a 3-hour Automated Dvorak Technique (ADT) mean of 6.5 (127 kt) at 0000 UTC 6 August. Several QuikSCAT passes were also helpful in estimating the tropical-storm-force wind radii of Felicia and its intensity as the cyclone approached Hawaii as a tropical storm.

No ship reports of tropical-storm-force winds or greater were received in association with Felicia.

While approaching the Hawaiian Islands from the east, Felicia generated large swells, resulting in surf heights of 6 to 10 ft that affected east-facing shores of the state during 10-12 August.

Although Felicia dissipated as a tropical cyclone before reaching the Hawaiian Islands, widespread heavy rainfall and some freshwater flooding occurred as the remnants of the system passed over the state during 11-13 August. A portion of Kamehameha Highway near Waikane on the island of Oahu was closed for several hours on 13 August, as Waikane Stream overflowed its banks and sent floodwaters over the road. The greatest rainfall totals associated with the remnants of Felicia were 14.63 in at Oahu Forecast National Wildlife Refuge on the island of Oahu, 13.46 in at Mount Waialeale on the island of Kauai, and 6.28 in at West Wailuaki on the island of Maui.

c. Casualty and Damage Statistics

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

d. Forecast and Warning Critique

The genesis of Felicia was not well anticipated. The area of disturbed weather from which Felicia developed was introduced to the Tropical Weather Outlook about 30 h prior to the tropical cyclone's formation. The first several outlooks indicated slow development of the system but did not explicitly mention the possibility that a tropical depression could form until 18 hours before genesis occurred. The potential for genesis never reached the "high" category (> 50% in 48 h).

A verification of NHC official track forecasts is provided in Table 2b. Average official track errors for Felicia (with the number of cases in parentheses) were 22 (18), 38 (18), 51 (18), 63 (18), 75 (18), 91 (15), and 150 (11) n mi for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. These errors are much lower than the long-term NHC average track errors, especially at 48 h and beyond. Interestingly, NHC forecasts exhibited skill above or rivaling the often difficult-to-beat variable consensus (TVCN) model through 72 h in Table 2b. Additionally, BAMD produced the lowest overall track errors for Felicia at all time ranges except 72 h. It is worth noting that OCD5 errors were also smaller than average, suggesting that the track of Felicia was easier to forecast than average. This may also help explain the small OFCL errors.

A verification of NHC official intensity forecasts are shown in Table 3b. The average official intensity errors were 8 (18), 14 (18), 18 (18), 19 (18), 12 (18), 9 (15) and 10 (11) kt for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. For comparison, the average long-term official intensity errors are 6, 10, 13, 15, 18, 19, and 19 kt, respectively. NHC forecast intensity errors were higher than the long-term average intensity errors through 48 h, revealing the inability of early forecasts to capture Felicia's period of rapid intensification starting at the time of genesis. It should be noted that none of the intensity guidance models for Felicia performed well through the 48 h time range. The large OCD5 errors at these time ranges indicate increased difficulty associated with these forecasts. Interestingly, NHC forecast intensity errors were substantially lower than the long-term average at 72 h and beyond, likely because they did not involve forecasting the initial rapid intensification phase.

Table 4 summarizes the tropical storm watches issued by the CPHC in association with Felicia.

Table 1. Best track for Hurricane Felicia, 3-11 August 2009.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
03 / 1800	11.0	121.1	1007	25	tropical depression
04 / 0000	11.5	122.4	1004	35	tropical storm
04 / 0600	11.8	123.7	1000	45	"
04 / 1200	12.0	124.9	994	55	"
04 / 1800	12.2	126.1	987	65	hurricane
05 / 0000	12.6	126.9	980	75	"
05 / 0600	13.2	127.6	972	85	"
05 / 1200	13.7	128.5	960	100	"
05 / 1800	14.2	129.3	948	115	"
06 / 0000	14.7	130.1	935	125	"
06 / 0600	15.1	130.8	935	125	"
06 / 1200	15.7	131.5	940	120	"
06 / 1800	16.2	132.3	944	115	"
07 / 0000	16.7	133.2	948	115	"
07 / 0600	17.3	134.0	955	105	"
07 / 1200	17.7	135.2	960	100	"
07 / 1800	18.1	136.3	965	95	"
08 / 0000	18.6	137.4	970	90	"
08 / 0600	18.9	138.7	973	85	"
08 / 1200	19.2	140.1	976	80	"
08 / 1800	19.6	141.4	981	75	"
09 / 0000	19.9	142.7	982	75	"
09 / 0600	20.2	144.0	984	70	"
09 / 1200	20.5	145.3	994	60	tropical storm
09 / 1800	20.9	146.5	1001	50	"
10 / 0000	21.0	147.7	1002	45	"
10 / 0600	21.0	148.7	1003	45	"
10 / 1200	20.9	149.6	1005	40	"
10 / 1800	20.9	150.6	1007	40	"
11 / 0000	20.9	151.6	1008	35	"
11 / 0600	20.9	152.5	1009	35	"
11 / 1200	20.8	153.3	1010	30	tropical depression
11 / 1800	20.7	154.2	1010	30	low
12 / 0000					dissipated
06 / 0000	14.7	130.1	935	125	minimum pressure/maximum wind

Table 2a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Felicia. Mean errors for the five-year period 2004-8 are shown for comparison. Official errors that are smaller than the five-year means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL (Felicia)	<b>21.6</b>	<b>38.2</b>	<b>51.2</b>	<b>63.1</b>	<b>75.0</b>	<b>90.5</b>	<b>150.4</b>
OCD5 (Felicia)	26.2	47.0	75.1	106.6	170.4	213.9	207.7
Forecasts	18	18	18	18	18	15	11
OFCL (2004-8)	31.0	51.7	71.7	90.2	123.6	161.3	201.8
OCD5 (2004-8)	38.4	73.6	111.9	149.1	214.2	261.1	311.5

Table 2b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Felicia east of 140°W. 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 2a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	18.9	36.3	49.1	60.9	71.8	89.8	149.5
OCD5	24.6	48.4	76.8	111.2	173.3	214.4	213.9
GFSI	25.8	41.9	51.8	61.0	72.2	120.6	178.8
GHMI	19.5	39.4	57.5	73.1	106.2	129.4	197.2
HWFI	26.1	48.9	62.9	78.8	113.5	150.0	200.8
NGPI	38.7	73.9	96.3	107.5	104.5	132.5	181.5
EMXI	22.3	44.4	62.2	79.4	97.2	93.3	<b>122.4</b>
TVCN	20.9	39.8	54.7	64.2	76.4	<b>85.4</b>	<b>127.4</b>
TVCC	21.1	44.3	57.3	77.3	92.3	122.7	174.5
BAMS	25.0	53.2	79.2	105.4	129.4	163.7	178.4
BAMM	20.9	38.3	56.7	83.9	140.7	165.0	<b>147.0</b>
BAMD	<b>16.2</b>	<b>29.5</b>	<b>45.2</b>	<b>59.4</b>	82.2	<b>85.6</b>	<b>90.5</b>
LBAR	24.2	39.1	<b>47.4</b>	<b>53.2</b>	78.7	107.4	<b>147.3</b>
Forecasts	14	14	14	14	14	12	9

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Felicia east of 140°W. Mean errors for the five-year period 2004-8 are shown for comparison. Official errors that are smaller than the five-year means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL (Felicia)	8.3	13.9	18.1	18.9	<b>11.7</b>	<b>9.3</b>	<b>10.0</b>
OCD5 (Felicia)	10.4	15.1	19.6	18.7	9.1	10.5	13.5
Forecasts	18	18	18	18	18	15	11
OFCL (2004-8)	6.2	10.2	13.3	15.1	17.7	19.0	18.8
OCD5 (2004-8)	7.1	11.5	14.7	16.8	18.9	20.3	20.2

Table 3b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Felicia. 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	8.3	13.9	18.1	18.9	11.7	9.6	11.7
OCD5	10.4	15.1	19.6	<b>18.7</b>	<b>9.1</b>	10.7	12.6
HWFI	12.2	17.1	20.3	20.4	14.0	10.9	15.3
GHMI	13.4	24.9	33.9	30.4	19.7	14.0	14.8
DSHP	10.1	14.3	18.2	<b>17.5</b>	13.2	11.9	<b>11.3</b>
LGEM	10.7	18.3	23.7	24.6	18.4	13.9	<b>10.1</b>
ICON	11.0	18.1	23.4	22.7	15.8	11.1	<b>9.8</b>
IVCN	11.3	18.2	23.2	22.2	14.4	9.6	<b>10.4</b>
Forecasts	18	18	18	18	18	14	9



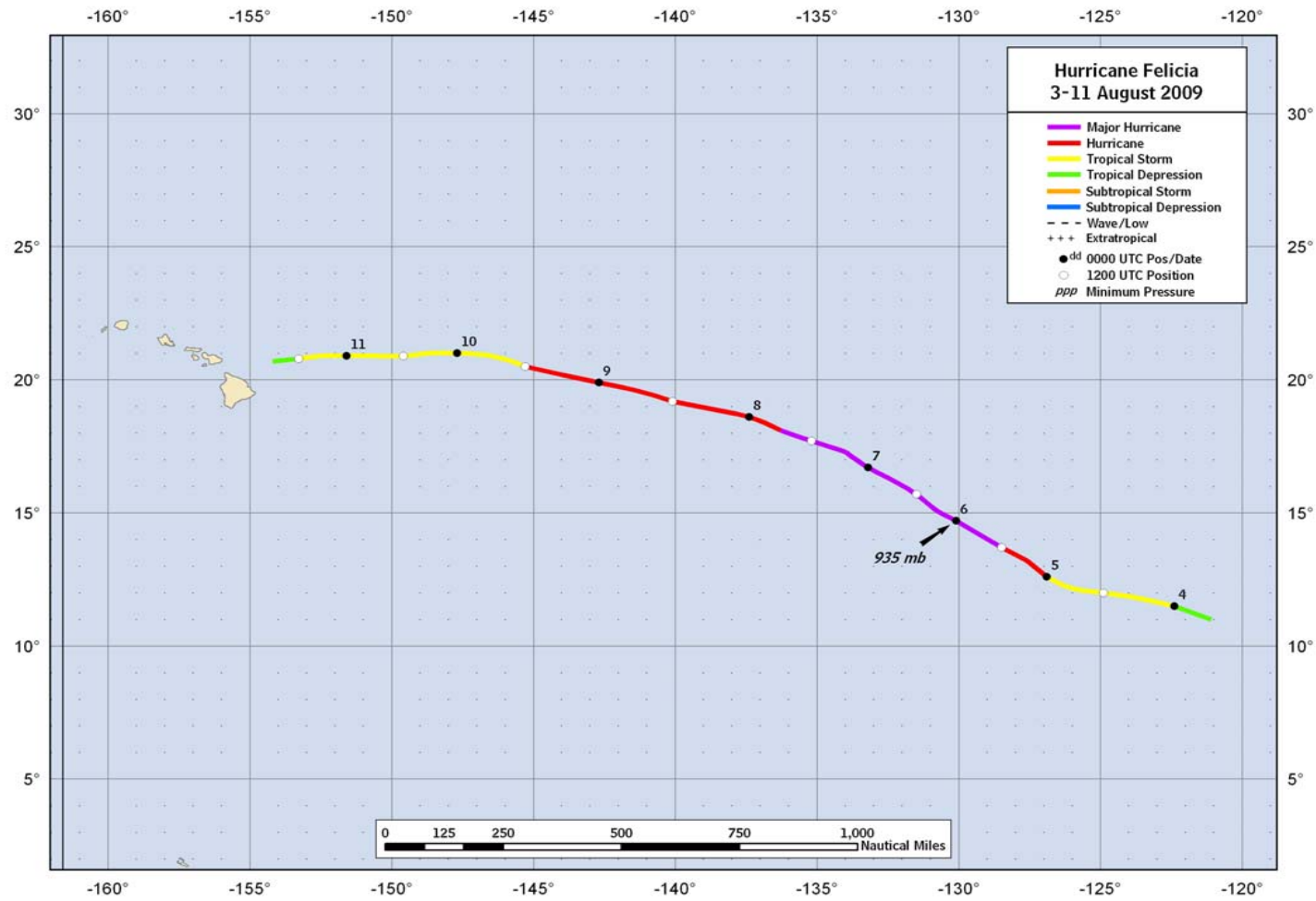


Figure 1. Best track positions for Hurricane Felicia, 3-11 August 2009.

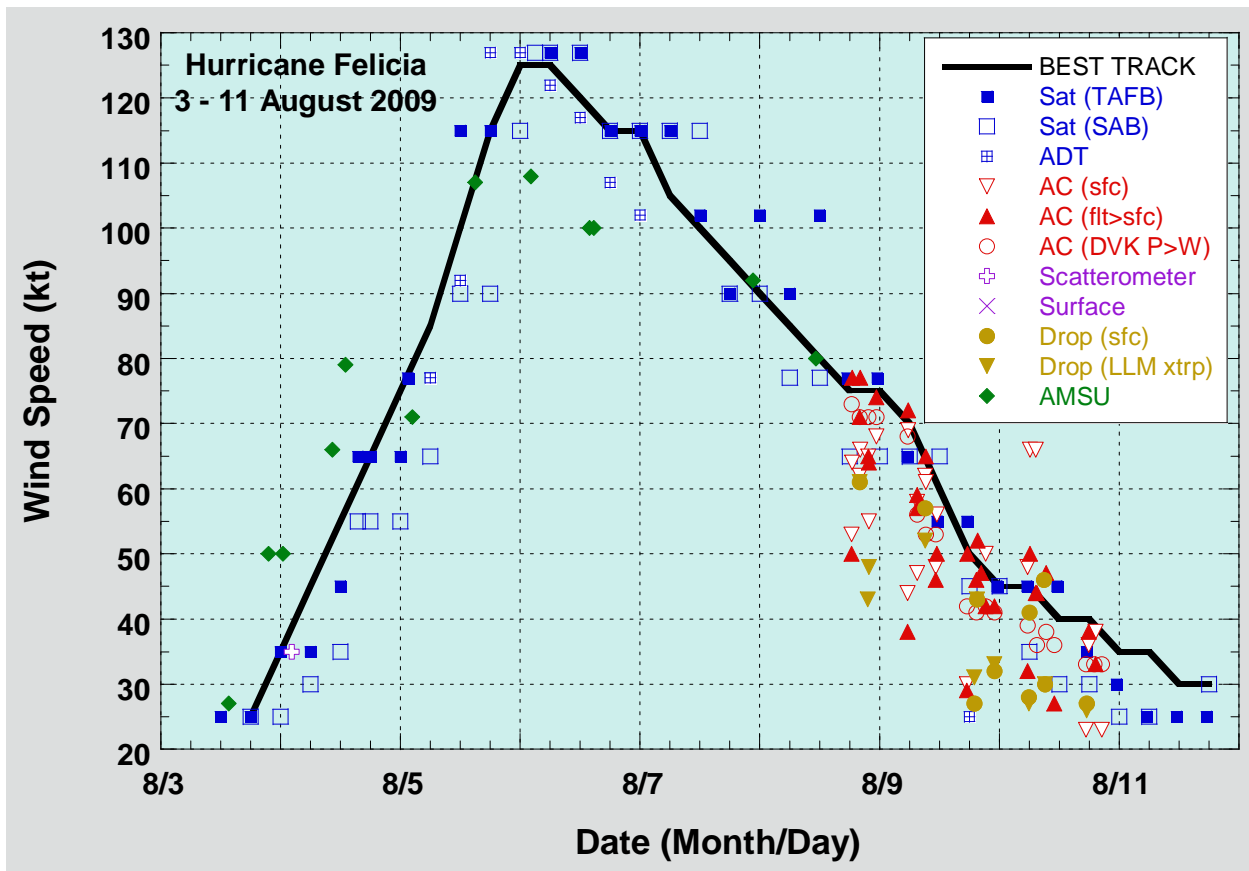


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Felicia, 3 – 11 August 2009. Dashed vertical lines correspond to 0000 UTC.

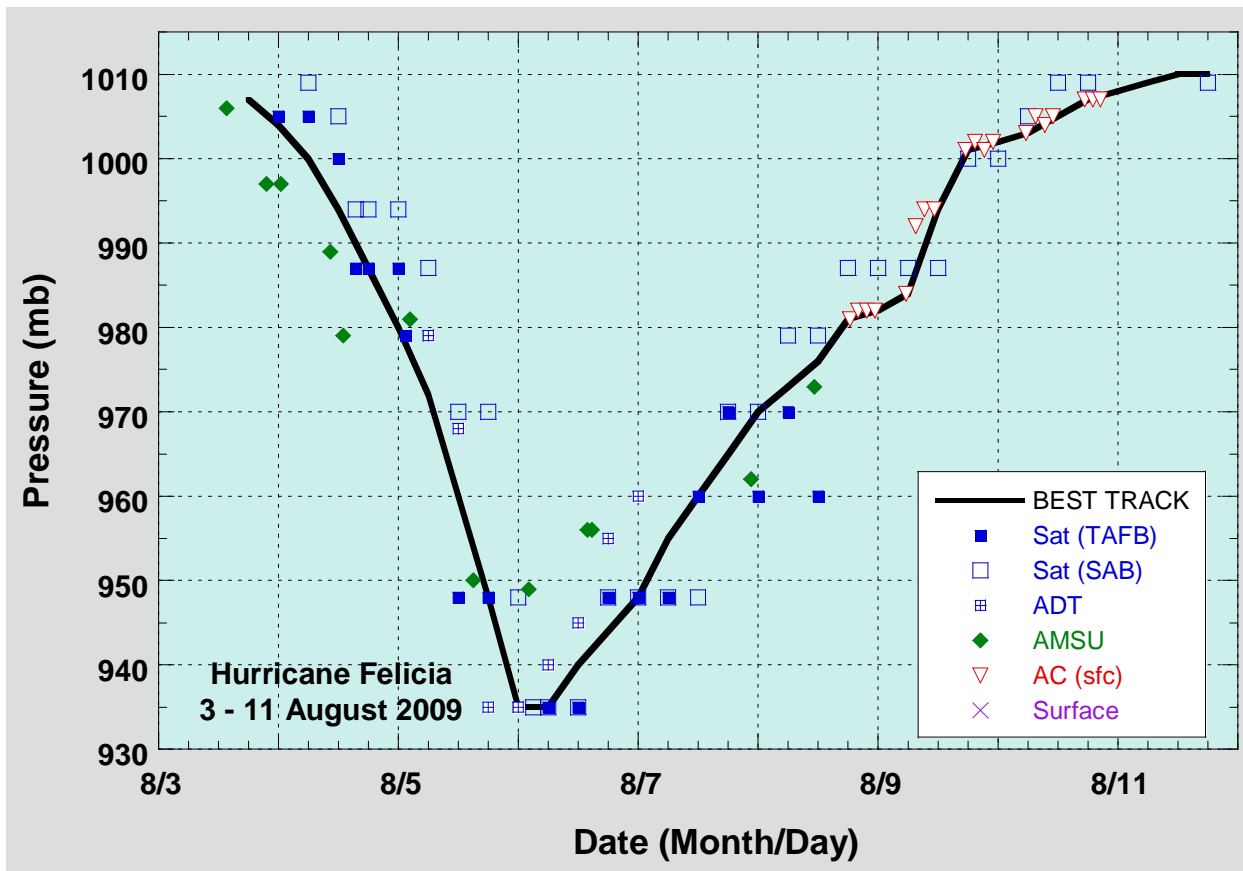


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Felicia, 3 – 11 August 2009. Dashed vertical lines correspond to 0000 UTC.

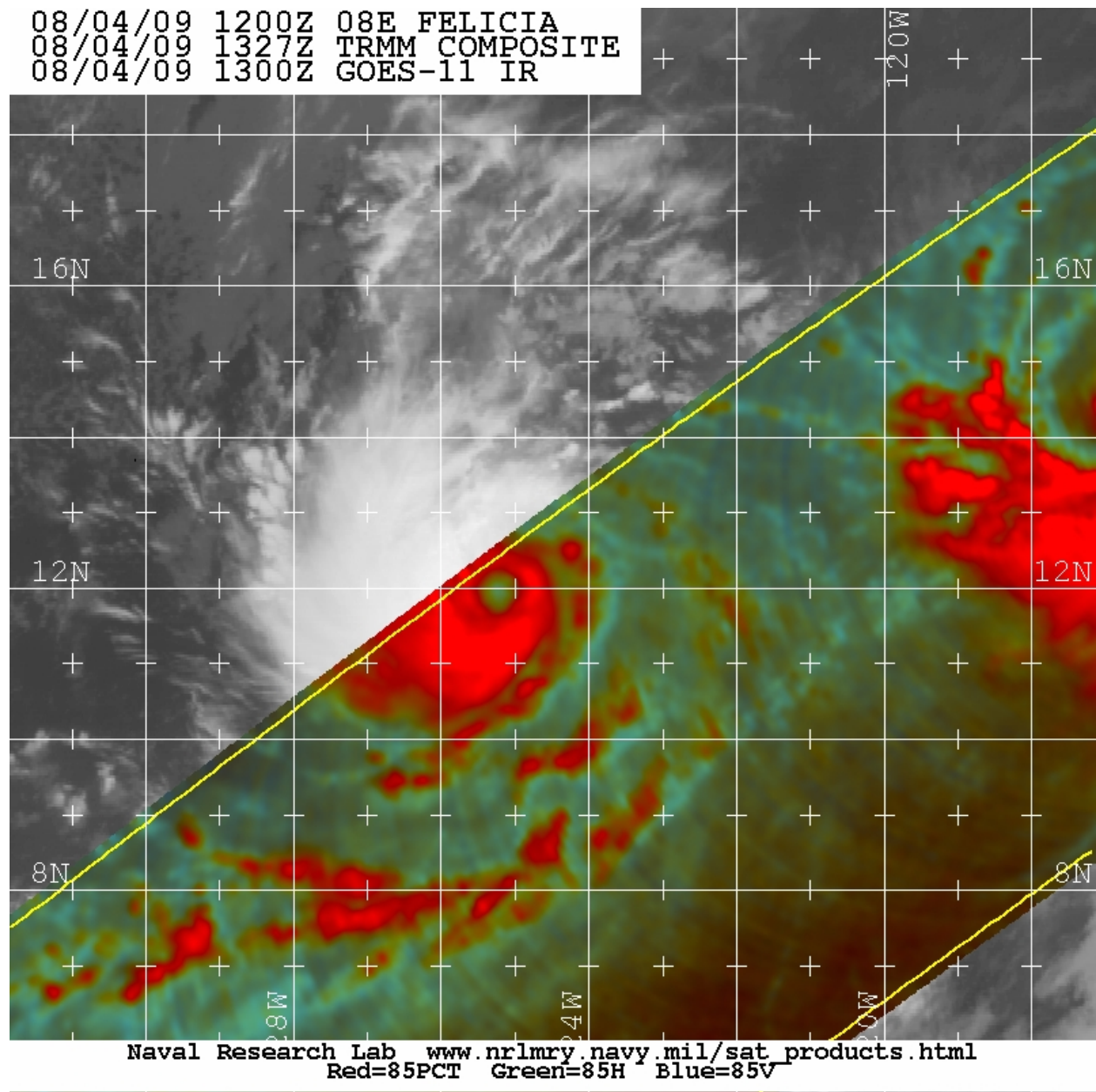


Figure 4. An 85 GHz channel pass over Felicia from a NASA Tropical Rainfall Measuring Mission (TRMM) microwave pass at 1327 UTC 4 August. Image provided by the Naval Research Laboratory's Marine Meteorology Division in Monterey, CA.