NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM IVO

(EP102019)

21–25 August 2019

Daniel P. Brown
National Hurricane Center
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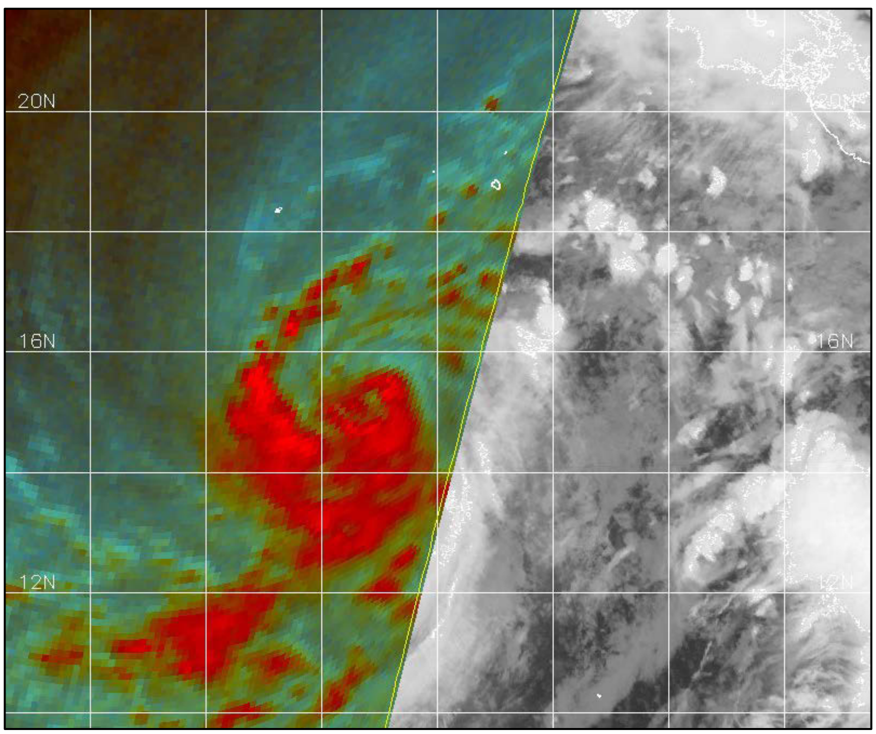

85-GHZ COLOR COMPOSITE IMAGE OF TROPICAL STORM IVO AT 1116 UTC 22 AUGUST 2019 FROM THE SPECIAL SENSOR MICROWAVE/IMAGER (SSM/I) NEAR THE TIME OF IVO'S PEAK ITENSITY. IMAGE COURTESY OF THE FLEET NUMERICAL METEOROLOGICAL AND OCEANOGRAPHY CENTER (FNMOC).

Ivo was a strong tropical storm that passed near Clarion Island before weakening and dissipating over cool waters well west of the Baja California peninsula.

Tropical Storm Ivo

21–25 AUGUST 2019

SYNOPTIC HISTORY

The development of Ivo can be traced back to a couple of tropical waves that moved across the far eastern Pacific Ocean beginning on 14 August. The initial tropical wave appears to have departed the west coast of Africa on 4 August while the following wave moved over the eastern tropical Atlantic a few days later. When the leading tropical wave entered the far eastern Pacific, it spawned a broad area of low pressure south of the coast of Guatemala early on 16 August. The wave continued westward while the broad low moved westward to west-northwestward at a slower rate. Showers and thunderstorms increased markedly in association with the system during the next couple of days, but this did not result in an increase in organization of the circulation. The broad low passed a couple of hundred n mi south of the southeastern coast of Mexico early on 19 August. Around this time, the second tropical wave moved through the area. This resulted in a further increase in the thunderstorm activity, but the system still lacked a well-defined circulation. The broad low continued westward during the next 24 to 36 h while the convective activity showed signs of organization. Early on 21 August, satellite wind data indicated that the circulation became better defined, which resulted in the formation of a tropical depression by 0600 UTC 21 August about 250 n mi south of Manzanillo, Mexico. The depression strengthened and became Tropical Storm Ivo 6 h later. The "best track" chart of Ivo'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 formation, Ivo moved quickly westward to the south of a mid-level ridge that extended from northwestern Mexico westward over the eastern Pacific Ocean. The cyclone was situated within favorable atmospheric and oceanic conditions and steady strengthening occurred during the next 24 h. By 1200 UTC 22 August, microwave satellite data (cover photo) indicated that deep convection associated with the system had become significantly better organized with a mid-level banding eye feature evident, and Ivo reached its estimated peak intensity of 60 kt. Around that time, the western portion of the ridge weakened, and Ivo's forward motion slowed to around 10 kt. Northeasterly vertical wind shear also increased over Ivo, ending the cyclone's strengthening phase and causing the deep convection to become confined to the southern portion of the circulation. The tropical storm turned sharply northwestward and then north-northwestward by early 23 August around the western portion of the mid-level ridge. Ivo maintained an intensity of 55 kt when its center passed very close to Clarion Island just before 1200 UTC 23 August. Thereafter, strong northeasterly shear, gradually decreasing sea surface temperatures and a less favorable thermodynamic environment along the cyclone's path caused Ivo to gradually weaken while it continued north-

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[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.

northwestward. Deep convection associated with the system waned shortly after 0000 UTC 25 August, and the system degenerated into a remnant low 6 h later, when it was located about 385 n mi west of the southern tip of the Baja California peninsula. The remnant low continued to move north-northwestward to northwestward, but its forward speed slowed considerably later that day. Early on 26 August, the low became nearly stationary, and then turned southeastward within the low-level steering flow to the west of the Baja California peninsula. The low degenerated into a trough of low pressure shortly after 0000 UTC 27 August, when it was located several hundred n mi west of the west coast of the Baja California peninsula.

METEOROLOGICAL STATISTICS

Observations in Ivo (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 and Satellite Consensus (SATCON) 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 Global Precipitation Mission (GPM), 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 Ivo.

Observations in Ivo also include flight-level and stepped frequency microwave radiometer (SFMR) data from a NOAA WD-P3 aircraft that conducted a NESDIS ocean winds research mission into the storm on 24 August when Ivo was weakening west of the Baja California peninsula. The NOAA WD-P3 aircraft also flew daily research missions originating in Costa Rica from 17–20 August when Ivo's incipient disturbance was located over the far eastern portion of the eastern Pacific basin. These missions were conducted in conjunction with the National Center for Atmospheric Research (NCAR) / National Science Foundation (NSF) G-V aircraft as part of the NCAR/NSF Organization of Tropical East Pacific Convection (OTREC) Experiment. Data from these flights included flight-level winds, SFMR, and dropwindsonde observations, which helped to assess the structure of the disturbance at that time.

Ivo's estimated peak intensity of 60 kt is based on SATCON estimates of 60–62 kt from UW/CIMSS between 1200 and 1800 UTC 22 August. Subjective Dvorak classifications from TAFB and SAB were T3.5 (55 kt) at that time, but microwave imagery from around 1200 UTC 22 August (cover photo) indicated that the system exhibited a mid-level eye feature and excellent banding. Given the well-organized appearance of the inner core, the slightly higher SATCON estimates are the basis for the peak intensity of Ivo. About 24 h after the tropical storm reached its peak intensity it passed very close to Clarion Island, and an automated observing station on that island reported peak sustained winds of 53 kt with a gust to 66 kt at 1430 UTC 23 August.

There were no ship reports of winds of tropical storm force or greater in association with Ivo.

CASUALTY AND DAMAGE STATISTICS

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

FORECAST AND WARNING CRITIQUE

The genesis of Ivo was extremely well forecast. The disturbance from which Ivo developed was introduced into the Tropical Weather Outlook more than a week before formation occurred (Table 2). The system was assigned a low (<40%) chance of formation during the next 5 days beginning at 0600 UTC 13 August, about 8 days before genesis. The 5-day formation potential was raised to the medium (40–60%) category exactly 5 days before genesis, and the high (>60%) category 4.5 days before formation. The short-range (2-day) genesis potential was introduced in the Outlook a little less than 5 days before formation, raised to the medium category a little more than 4 days before development, and it reached the high category about 36 h before formation occurred.

A verification of NHC official track forecasts for Ivo is given in Table 3a. Official forecast track errors were greater than the mean official errors for the previous 5-yr period. The OCD5 errors were also much larger than their 5-yr means, indicating the forecasts for Ivo were more difficult than normal. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. Several of the consensus models outperformed the official forecast at various time periods, but GFEX was the only aid to best the NHC forecast at each verifying period through 72 h, albeit for only one verifying forecast at day 3. The GFSI had lower mean errors than the official forecast at 12 and 24 h, while the EMXI had small mean errors at 36, 48, and 72 h. The official forecast and most of the dynamical models did not capture Ivo's atypically fast motion toward the west after formation, and did not anticipate the sharpness of the poleward turn made by the tropical cyclone on 23 August. These factors led to the higher-than-average mean NHC track errors.

A verification of NHC official intensity forecasts for Ivo is given in Table 4a. Official forecast intensity errors were lower than the long-term means through 24 h, and were generally comparable to the mean errors from 36 to 72 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The official forecast was superior to all of the intensity models at 12 h, but was bested by both EMXI and LGEM from 24 through 72 h. Several of the consensus aids also exhibited lower mean errors than the official forecast from 24 to 48 h. The early NHC intensity forecasts called for Ivo to reach hurricane strength within a couple of days. Although Ivo did strengthen during the first 24 h of its existence as a tropical cyclone, the vertical wind shear was not anticipated to become as prohibitive as it did. This resulted in a high bias in the NHC intensity forecasts and caused the slightly larger than average mean error at 72 h.

There were no coastal watches or warnings issued in association with Ivo.

Table 1. Best track for Tropical Storm Ivo, 21–25 August 2019.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
21 / 0600	15.0	105.1	1007	30	tropical depression
21 / 1200	15.3	106.9	1006	35	tropical storm
21 / 1800	15.6	108.7	1004	40	"
22 / 0000	15.6	110.6	999	45	"
22 / 0600	15.5	112.1	996	50	"
22 / 1200	15.5	113.1	990	60	"
22 / 1800	15.8	113.8	990	60	"
23 / 0000	16.5	114.0	992	55	"
23 / 0600	17.5	114.4	992	55	"
23 / 1200	18.4	114.8	992	55	"
23 / 1800	19.3	115.1	994	50	"
24 / 0000	20.1	115.4	996	45	"
24 / 0600	20.8	115.7	996	45	"
24 / 1200	21.5	116.0	998	40	"
24 / 1800	22.2	116.2	999	40	"
25 / 0000	23.0	116.4	1001	35	"
25 / 0600	23.9	116.8	1004	30	low
25 / 1200	24.8	117.3	1007	25	"
25 / 1800	25.6	117.8	1007	25	"
26 / 0000	26.1	118.1	1008	20	"
26 / 0600	26.3	118.1	1009	15	"
26 / 1200	26.4	118.0	1009	15	"
26 / 1800	26.3	117.9	1009	15	"
27 / 0000	25.9	117.5	1009	15	"
27 / 0600					dissipated
22 / 1200	15.5	113.1	990	60	maximum wind and minimum pressure

Table 2. Number of hours in advance of formation associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the "Low" category do not include forecasts of a 0% chance of genesis.

	Hours Before Genesis	
	48-Hour Outlook	120-Hour Outlook
Low (<40%)	114	192
Medium (40%-60%)	102	120
High (>60%)	36	108

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Ivo. Mean errors for the previous 5-yr period are shown for comparison.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	34.2	55.7	52.3	74.3	93.7		
OCD5	51.1	108.7	196.5	333.3	469.3		
Forecasts	13	11	9	7	3		
OFCL (2014-18)	21.1	32.2	41.8	51.8	75.7	101.1	133.7
OCD5 (2014-18)	34.0	69.7	109.0	148.4	223.5	285.5	356.7

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Ivo. 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	31.3	50.7	60.6	83.0	116.5		
OCD5	56.4	113.4	199.0	360.2	596.8		
GFSI	**27.3**	**43.6**	65.0	92.0	117.7		
HMNI	37.0	67.3	101.3	134.4	185.4		
HWFI	**30.2**	53.9	83.7	106.9	139.1		
EMXI	35.8	55.4	**50.0**	**40.8**	**70.7**		
CMCI	**24.8**	**32.5**	**42.1**	**68.4**	166.7		
NVGI	41.1	81.3	129.8	170.1	126.0		
CTCI	36.5	55.8	67.3	97.9	172.5		
AEMI	**26.1**	**45.7**	67.7	99.4	140.6		
HCCA	**27.5**	**43.3**	**51.0**	**71.3**	117.2		
FSSE	**29.2**	**41.8**	**46.3**	**73.2**	127.7		
TVCX	32.4	51.0	**56.1**	**74.8**	**106.4**		
GFEX	**29.7**	**46.5**	**51.8**	**66.1**	**83.0**		
TVCE	32.5	51.6	63.2	89.1	128.2		
TVDG	32.6	**47.6**	**57.1**	**78.8**	**107.5**		
TABD	43.8	81.8	123.4	169.6	291.4		
TABM	31.9	**50.0**	73.5	101.2	151.7		
TABS	46.4	107.8	153.6	201.0	153.2		
Forecasts	8	7	6	4	1		

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Ivo. 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	**2.3**	**4.5**	**10.0**	**12.1**	16.7		
OCD5	4.4	8.3	12.0	19.0	25.0		
Forecasts	13	11	9	7	3		
OFCL (2014-18)	6.1	10.0	12.2	13.7	15.5	15.4	15.7
OCD5 (2014-18)	7.9	13.1	16.7	19.2	21.8	22.9	22.1

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Ivo. 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	2.5	5.0	9.2	11.2	15.0		
OCD5	4.0	9.3	14.7	25.8	30.0		
GFSI	5.6	7.1	9.7	12.8	**14.0**		
HMNI	5.0	8.1	**7.3**	**6.8**	**11.0**		
HWFI	4.5	**3.4**	**3.8**	12.0	23.0		
EMXI	4.6	**4.3**	**3.3**	**2.0**	**8.0**		
HCCA	4.8	8.3	**8.8**	**10.5**	18.0		
FSSE	4.1	7.9	**8.7**	14.0	22.0		
LGEM	3.5	**4.3**	**5.0**	**6.2**	**8.0**		
DSHP	4.0	**3.6**	**5.3**	**11.0**	21.0		
ICON	4.0	**4.7**	**4.8**	**9.0**	16.0		
IVCN	3.6	**4.6**	**4.8**	**8.2**	15.0		
IVDR	4.1	5.1	**5.2**	**8.5**	15.0		
Forecasts	8	7	6	4	1		

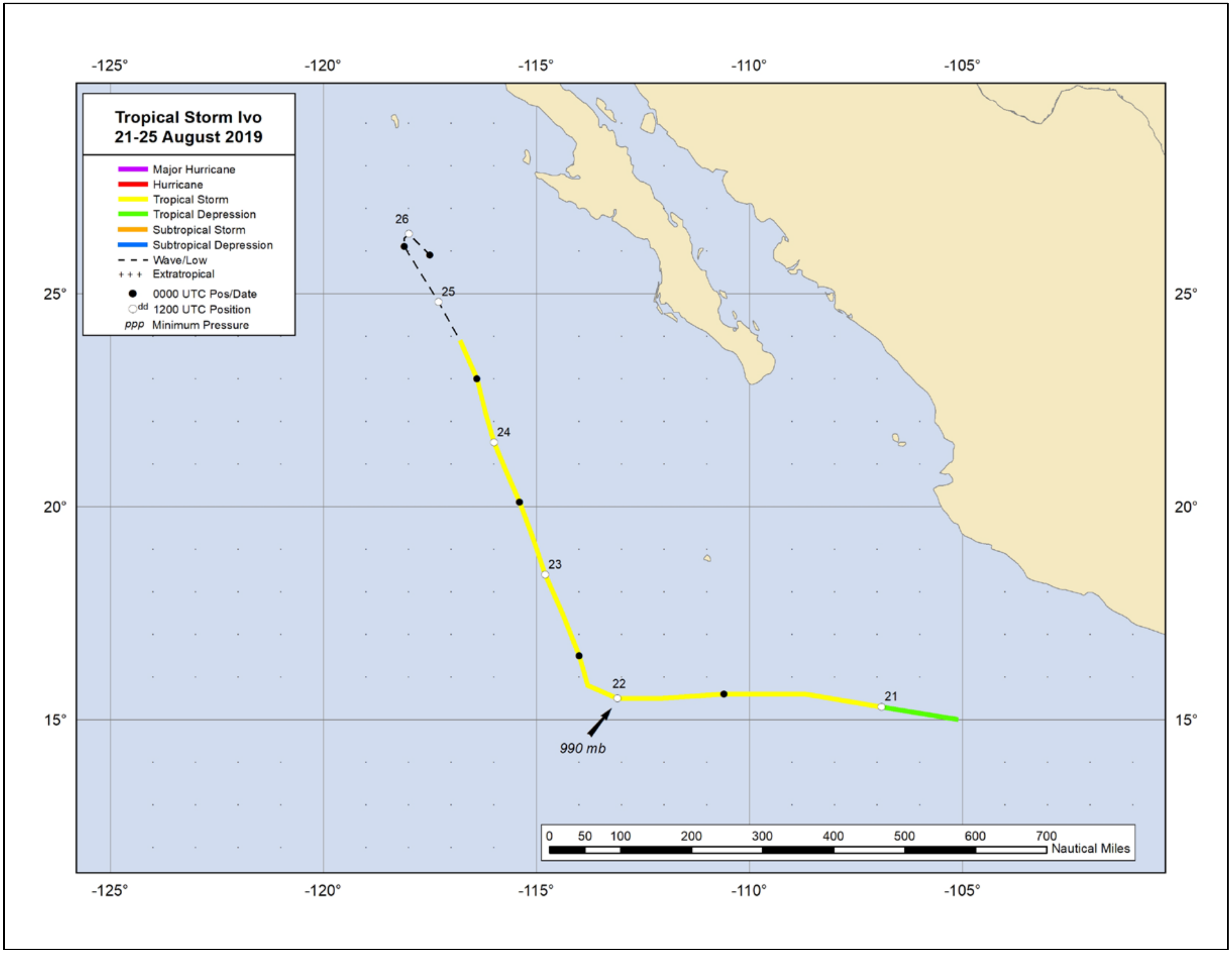

Figure 1. Best track positions for Tropical Storm Ivo, 21–25 August 2019.

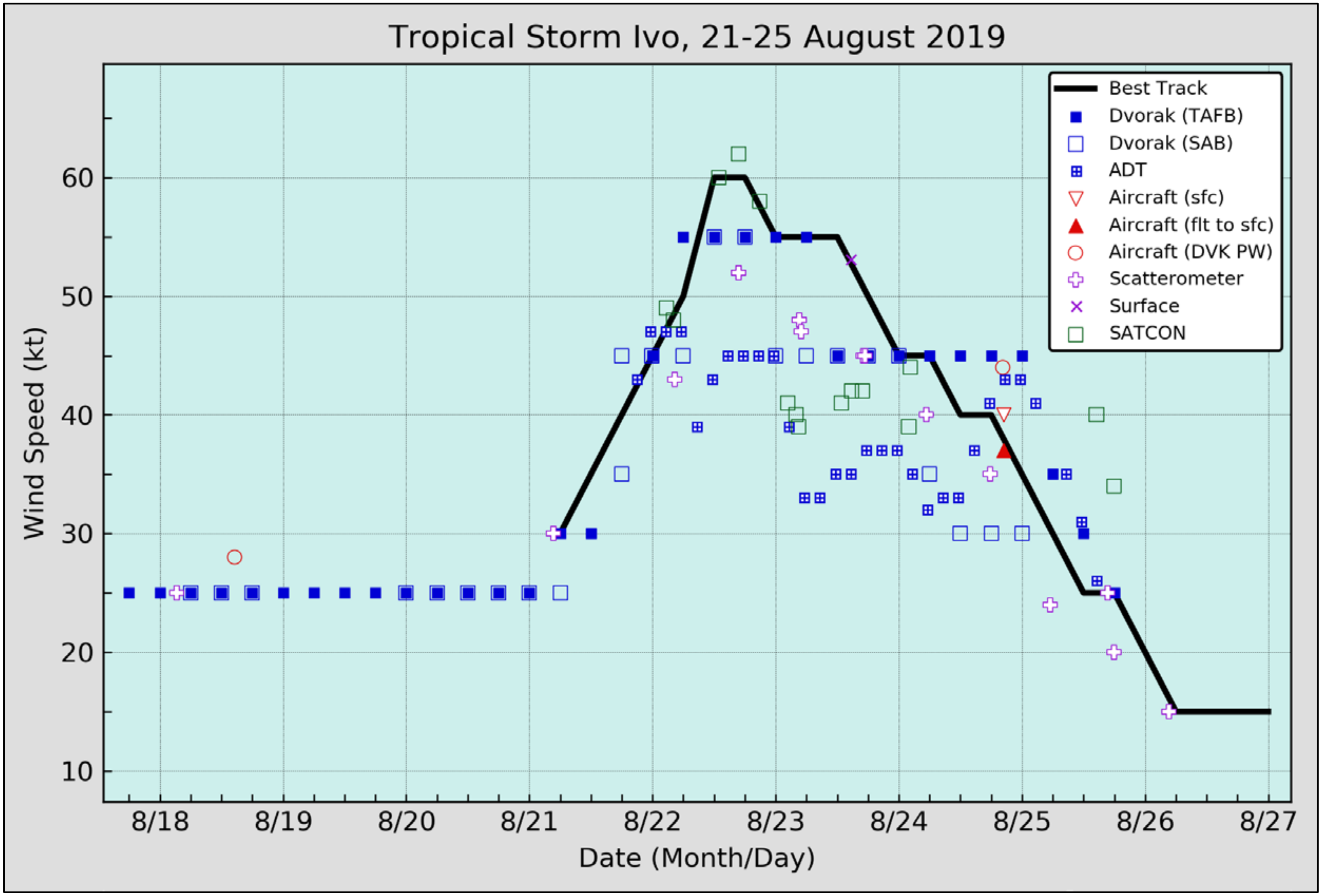

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Ivo, 21–25 August 2019. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.

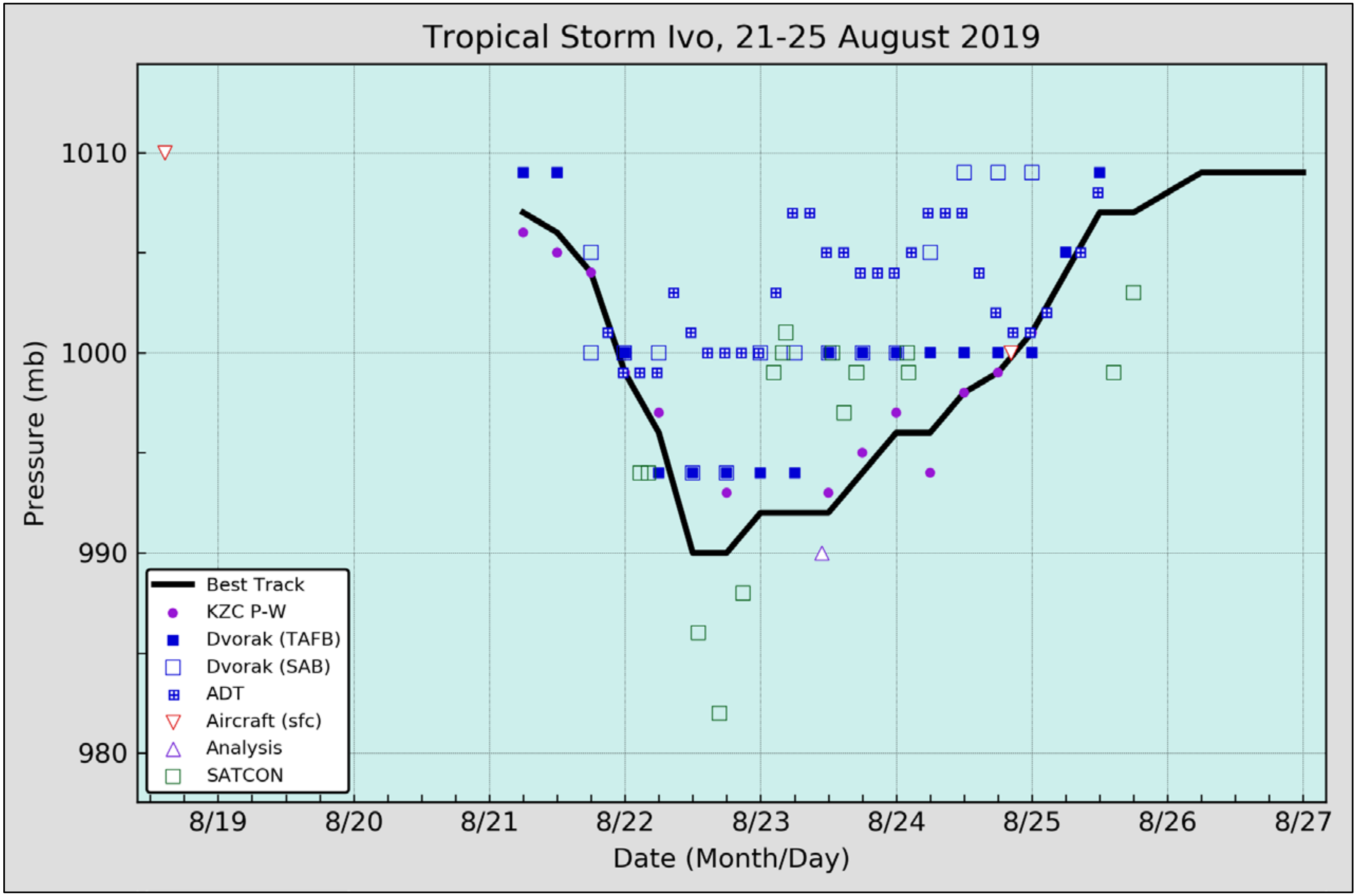

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Ivo, 21–25 August 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC.