NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

HURRICANE NORMA

(EP172017)

14–19 September 2017

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National Hurricane Center
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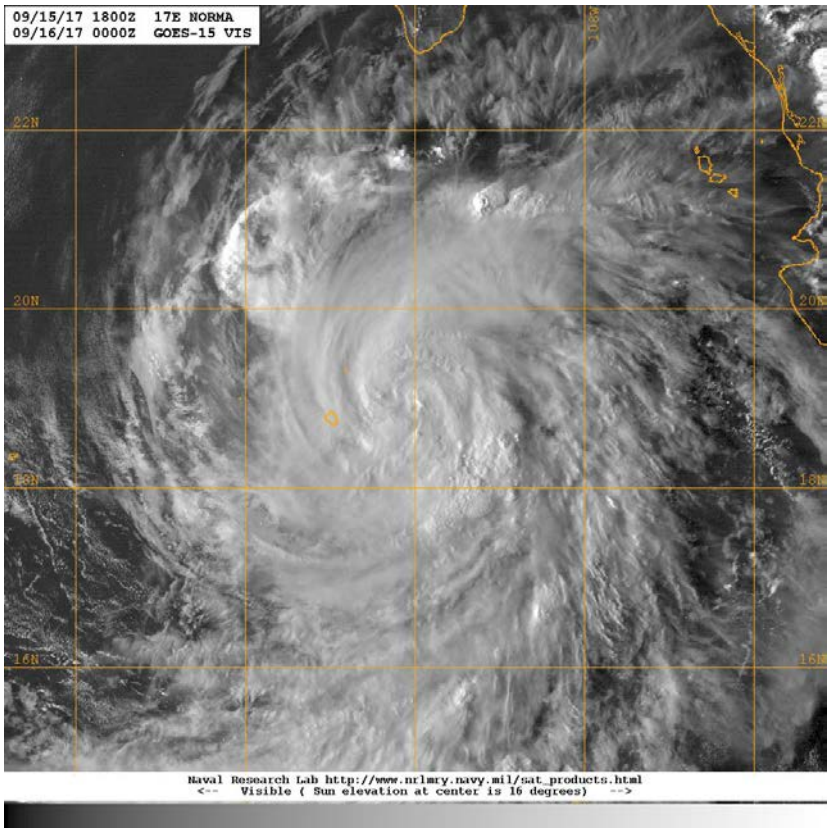


GOES-15 VISIBLE IMAGE FOR HURRICANE NORMA AT MAXIMUM INTENSITY ON 0000 UTC 16 SEPTEMBER 2017 (COURTESY OF NAVAL RESEARCH LABORATORY).

Norma – a Category 1 hurricane on the Saffir-Simpson Hurricane Wind Scale – briefly threatened Baja California before weakening and turning back to sea.

Hurricane Norma

14–19 SEPTEMBER 2017

SYNOPTIC HISTORY

A vigorous African easterly wave emerged off of the west coast of North Africa on 27 August. This system developed over the next couple days as it moved westward across the tropical North Atlantic and spawned Hurricane Irma on 30 August. After this, the southern portion of the wave continued westward at low latitudes with minimal convection and reached the eastern North Pacific on 7 September. Little change in organization occurred for the next four days as the wave continued westward. From 12 September through early 14 September, deep convection steadily became more organized in a favorable environment enhanced by a convectively-coupled Kelvin wave, and a tropical depression formed by 0600 UTC 14 September about 390 n mi south of the southern tip of the Baja California peninsula. The tropical cyclone continued to develop and reached tropical storm status 6 h later. The "best track" chart of Norma'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].

While genesis occurred, Norma and its precursor disturbance turned northward with a forward speed of about 5 kt, due to the steering induced by a mid-level ridge southeast of the tropical storm. Steadily intensifying within a conducive environment of moderate to low tropospheric wind shear, very warm ocean waters, and moderate mid-level moisture, the cyclone reached hurricane intensity around 0000 UTC 16 September about 235 n mi south of the southern tip of the Baja California peninsula. At about the same time, steering currents collapsed as a blocking ridge formed north of Norma over northwestern Mexico, and as a result, Norma meandered on 16 September. The cyclone's convective structure degraded late that day, likely due to advection of drier air into the system and cooler water being upwelled underneath the very slow moving tropical cyclone. As a result, Norma weakened back to a tropical storm around 1200 UTC on that date while located about 225 n mi south of the southern tip of the Baja California peninsula. The next day, the mid-level ridge shifted southeastward and strengthened, allowing Norma to again move toward the north. This was followed by a west-northwestward motion at about 5 kt over the next few days. While this motion allowed Norma to traverse warm waters again and remain in low vertical shear conditions on 17–18 September, marginal mid-level moisture and weak upper-level divergence likely prevented intensification. Beginning late on 18 September, Norma moved over cool waters and weakened, with the system becoming a tropical depression at 0600 UTC 19 September about 230 n mi west-southwest of the southern tip of the Baja California peninsula. The associated deep convection dissipated by 0000 UTC 20 September, and Norma became a remnant low at that time. The low subsequently meandered in

[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.

the weak low-level flow for a couple of days until dissipation occurred shortly after 0600 UTC 22 September.

METEOROLOGICAL STATISTICS

Observations in Norma (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 from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from one flight of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command. 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 Norma.

Norma's estimated peak intensity of 65 kt on 16 September is based upon a blend of ADT, AMSU, TAFB, and SAB maximum sustained wind estimates. However, the spread in these intensity estimates is considerable, and the confidence in Norma's peak intensity is low.

There were no reports of damage or casualties associated with Norma, and there were no ship or land-based stations that observed tropical-storm-force or greater winds from Norma.

FORECAST AND WARNING CRITIQUE

The genesis of Norma was very well forecast. The disturbance from which Norma developed was introduced with a low chance of formation in the 5-day Tropical Weather Outlook (TWO) 114 h prior to genesis (Table 2), with the 5-day genesis probability reaching a high chance 42 h in advance of formation. Likewise, the 48-h TWO successfully anticipated Norma's formation. The system was introduced with a low chance of formation into the 48-h TWO 60 h prior to genesis and subsequently reached the high category 12 h before genesis.

A verification of NHC official (OFCL) track forecasts for Norma is given in Table 3a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period at 12 to 36 h, but were larger at 48 h and much larger at 72, 96, and 120 h. In contrast, the climatology-persistence model (CLIPER/OCD5) errors were substantially smaller than typically observed at 96 and 120 h, albeit with a small number of forecasts. A homogeneous comparison of the OFCL track errors with selected guidance models is given in Table 3b, and the forecast tracks of the usually-top-performing models are shown in Figure 4. The European Center for Medium Range Weather Forecasts model (EMXI) was by far the best performing track guidance. The OFCL

forecasts and most of the remaining guidance – including several of the consensus techniques – had a substantial northeastward bias, erroneously taking Norma inland across Baja California Sur and even mainland Mexico in some cases. It is possible that this bias was due to many models incorrectly maintaining too strong and deep of a vortex. It is notable that the Hurricane Weather Research Forecast model (HWFI) outperformed its parent model (the Global Forecast System, GFSI) in having much less of a northeastward bias in its track forecasts.

A verification of NHC OFCL intensity forecasts for Norma is given in Table 4a. Official forecast intensity errors were smaller than the mean official errors for the previous 5-yr period for 12 and 24 h, but larger at 36 h and beyond. The larger than typical OFCL intensity errors are again surprising given that CLIPER/OCD5 had smaller than usual errors for all time periods, again suggesting that Norma should have been easier to forecast than usual. Most of the OFCL intensity errors had a high bias due to overforecasting both the peak intensity and the maximum winds after the peak. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. HWFI was by far the best guidance for intensity forecasting for Norma. As suggested above, the highly skillful intensity forecasts by HWFI may have also contributed toward it outperforming the GFSI for track prediction.

Watches and warnings for Mexico associated with Norma are listed in Table 5. However, because of the poorly forecast westward turn and weakening, no significant impacts from wind, surge, or rainfall occurred in Mexico.

Table 1. Best track for Hurricane Norma, 14–19 September 2017.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
14 / 0600	16.4	109.5	1006	30	tropical depression
14 / 1200	16.9	109.4	1004	35	tropical storm
14 / 1800	17.4	109.3	1003	40	"
15 / 0000	17.9	109.4	1001	45	"
15 / 0600	18.3	109.5	998	50	"
15 / 1200	18.6	109.7	994	55	"
15 / 1800	18.8	110.0	989	60	"
16 / 0000	18.9	110.1	985	65	hurricane
16 / 0600	19.0	110.2	985	65	"
16 / 1200	19.2	110.2	988	60	tropical storm
16 / 1800	19.5	110.2	989	55	"
17 / 0000	19.8	110.2	997	50	"
17 / 0600	20.2	110.3	999	45	"
17 / 1200	20.6	110.5	1001	45	"
17 / 1800	21.0	110.8	1001	45	"
18 / 0000	21.1	111.2	999	45	"
18 / 0600	21.2	111.6	999	45	"
18 / 1200	21.3	112.0	999	45	"
18 / 1800	21.4	112.5	1002	40	"
19 / 0000	21.4	113.1	1004	35	"
19 / 0600	21.4	113.6	1004	30	tropical depression
19 / 1200	21.5	114.2	1005	30	"
19 / 1800	21.7	114.8	1005	30	"
20 / 0000	21.9	115.4	1006	30	remnant low
20 / 0600	22.0	116.0	1007	25	"
20 / 1200	22.1	116.6	1007	25	"
20 / 1800	22.1	117.2	1007	25	"
21 / 0000	22.1	117.5	1007	25	"
21 / 0600	22.4	117.5	1007	25	"
21 / 1200	22.5	117.3	1008	20	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
21 / 1800	22.6	117.0	1008	20	"
22 / 0000	22.5	116.5	1010	20	"
22 / 0600	22.3	116.0	1010	20	"
22 / 1200					dissipated
16 / 0000	118.9	110.1	985	65	maximum winds 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%)	60	114
Medium (40%-60%)	36	108
High (>60%)	12	42

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Norma, 14–19 September 2017. 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	**14.4**	**25.0**	**42.7**	59.1	113.6	215.8	372.5
OCD5	24.0	55.0	87.8	104.1	92.8	128.0	131.1
Forecasts	20	18	16	14	10	6	2
OFCL (2012-16)	22.2	33.9	43.8	54.8	80.0	108.9	145.1
OCD5 (2012-16)	36.7	72.0	112.2	150.2	217.0	271.0	340.2

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Norma, 14–19 September 2017. 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	14.5	23.0	42.4	64.7	134.3	243.2	
OCD5	24.7	55.4	89.3	108.0	**91.7**	**124.5**	
GFSI	17.2	31.2	55.0	84.2	191.2	431.4	
HWFI	19.3	29.5	47.5	68.3	**131.0**	266.0	
HMNI	20.0	28.3	**36.8**	**55.0**	136.4	251.8	
EGRI	20.0	35.2	50.8	**62.7**	**104.3**	**154.4**	
EMXI	**13.8**	**22.3**	**36.8**	**55.7**	**87.2**	**95.2**	
CMCI	23.9	35.9	**40.7**	**45.1**	**69.0**	**177.7**	
CTCI	**14.4**	27.5	48.3	82.8	176.3	342.5	
TCON	16.4	25.9	45.3	**64.4**	137.0	268.1	
TVCE	**13.7**	23.5	**41.4**	**63.5**	**132.0**	245.4	
TVCX	**13.5**	**22.7**	**39.6**	**58.3**	**124.8**	**218.0**	
FSSE	15.2	26.0	45.9	66.9	148.5	274.6	
HCCA	**11.9**	**21.1**	**40.3**	**63.4**	135.7	**241.6**	
AEMI	17.1	32.1	50.3	72.7	158.0	305.0	
TABS	27.2	53.6	58.1	88.7	165.3	298.4	
TABM	23.7	35.0	**42.2**	67.5	170.9	368.5	
TABD	17.0	29.4	48.4	80.7	196.9	454.3	
Forecasts	16	15	13	11	7	3	

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Norma, 14–19 September 2017. 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**	**8.6**	11.9	16.1	23.0	19.2	20.0
OCD5	5.9	10.1	11.2	8.4	13.0	10.8	12.5
Forecasts	20	18	16	14	10	6	2
OFCL (2012-16)	5.8	9.4	11.8	13.2	15.0	15.7	14.9
OCD5 (2012-16)	7.6	12.2	15.7	18.1	20.6	21.8	20.0

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Norma, 14–19 September 2017. 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	5.3	9.1	11.8	14.6	21.9	18.8	
OCD5	5.7	9.8	**11.4**	**9.3**	**15.3**	**11.8**	
HWFI	5.6	**5.6**	**7.4**	**7.3**	**7.6**	**9.8**	
HMNI	6.5	11.0	**11.3**	**12.1**	**18.1**	19.3	
CTCI	5.9	9.6	**9.1**	**11.1**	**12.8**	**11.8**	
DSHP	6.6	12.2	15.1	19.2	27.0	**17.3**	
LGEM	6.3	11.4	13.1	**14.2**	**20.5**	**16.0**	
GFSI	8.7	14.4	18.9	24.5	27.8	21.3	
EMXI	8.5	13.3	18.2	19.4	26.4	23.3	
ICON	5.4	9.3	**11.4**	**12.6**	**18.0**	**13.8**	
IVCN	**5.2**	**8.8**	**10.4**	**12.1**	**16.8**	**12.5**	
IVCX	**5.2**	**9.0**	**10.2**	**12.2**	**17.0**	**14.0**	
HCCA	5.4	10.7	13.6	**14.0**	**17.1**	**14.8**	
FSSE	5.3	10.1	13.4	16.1	**21.0**	**18.5**	
Forecasts	17	16	14	12	8	4	

Table 5. Wind watch and warning summary for Norma, 14–19 September 2017.

Date/Time (UTC)	Action	Location
16 / 0900	Tropical Storm Watch issued	Coast of Mexico from Todos Santos to Sante Fe
16 / 0900	Tropical Storm Warning issued	Coast of Mexico from Los Barriles to Todos Santos
16 / 1500	Tropical Storm Watch issued	Coast of Mexico from Sante Fe to Cabo San Lazaro
17 / 1500	Tropical Storm Warning changed to Watch	Coast of Mexico from Los Barriles to Todos Santos
17 / 1500	Tropical Storm Watch discontinued	Coast of Mexico from Todos Santos to Cabo Lazaro
18 / 0300	Tropical Storm Watch discontinued	Coast of Mexico from Los Barriles to Todos Santos

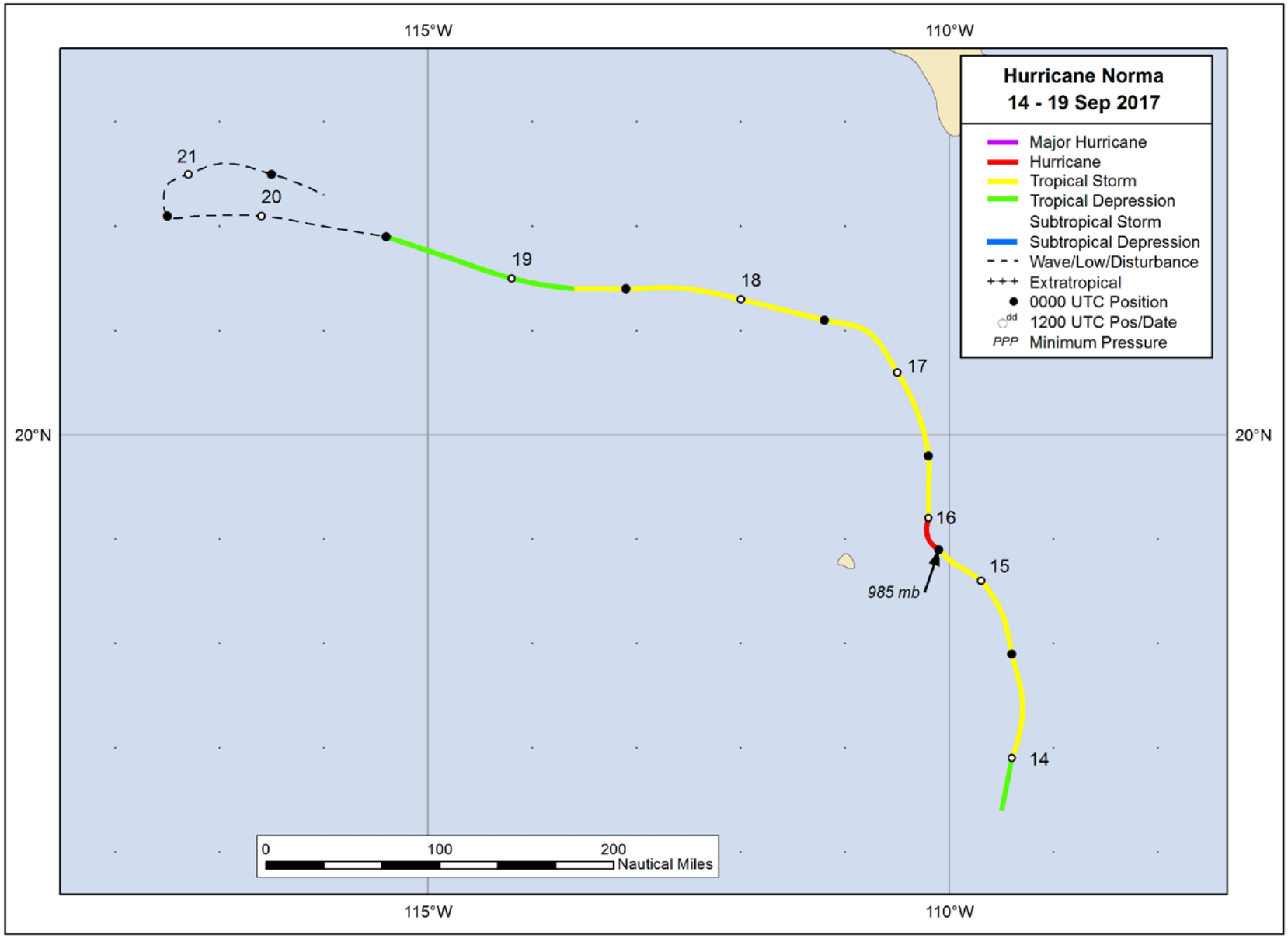


Figure 1. Best track positions for Hurricane Norma, 14–19 September 2017.

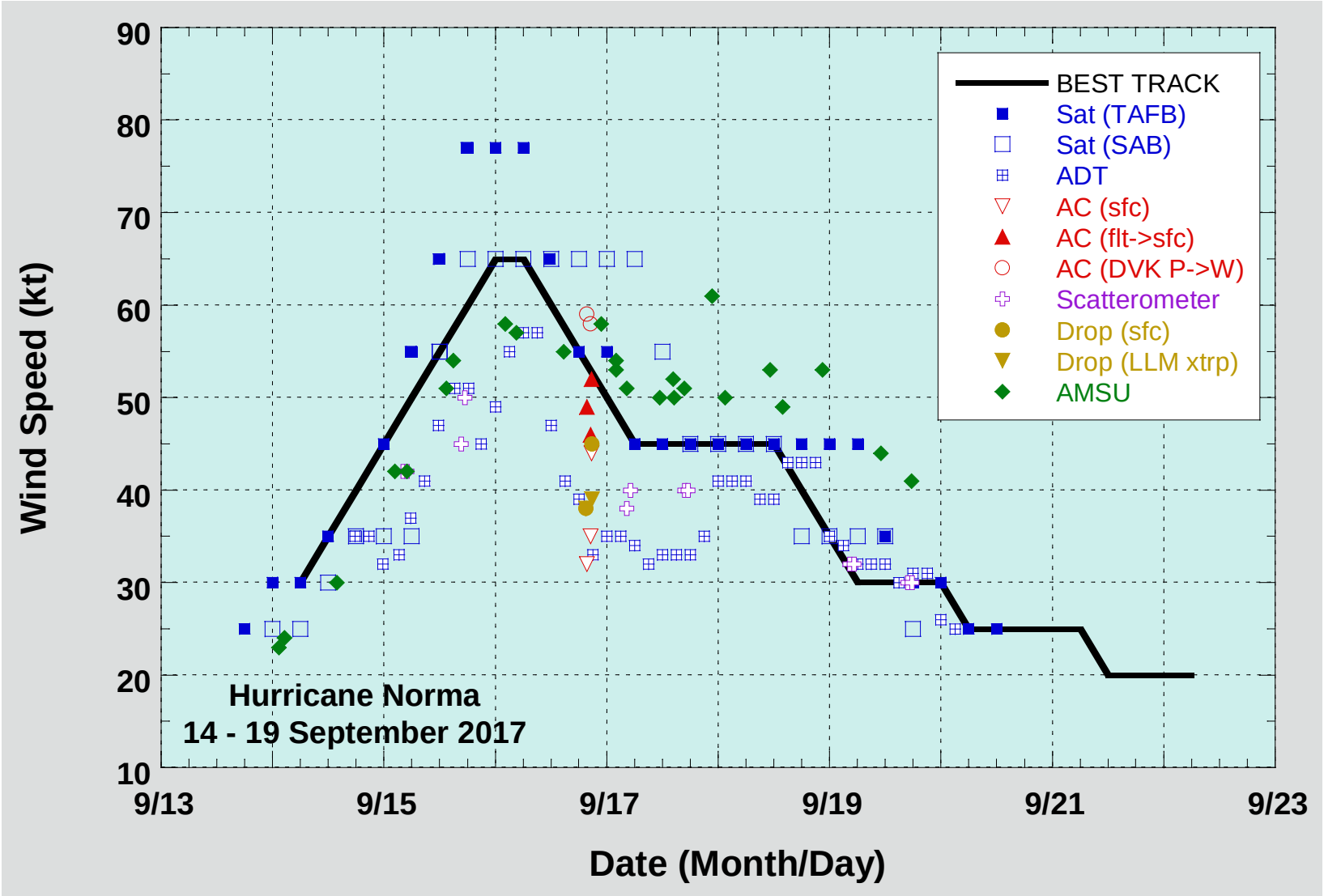


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Norma, 14–19 September 2017. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Vertical lines correspond to 0000 UTC.

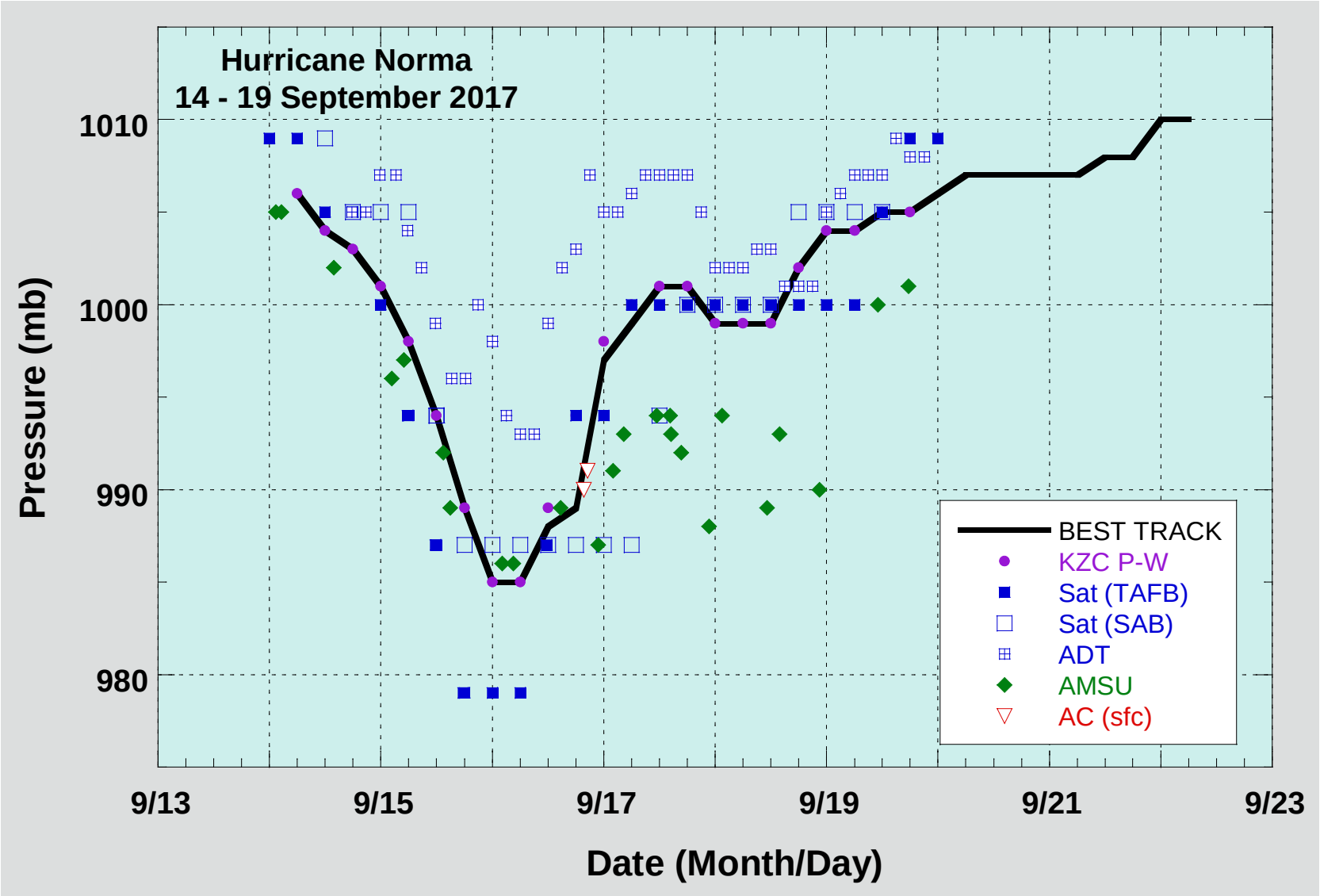
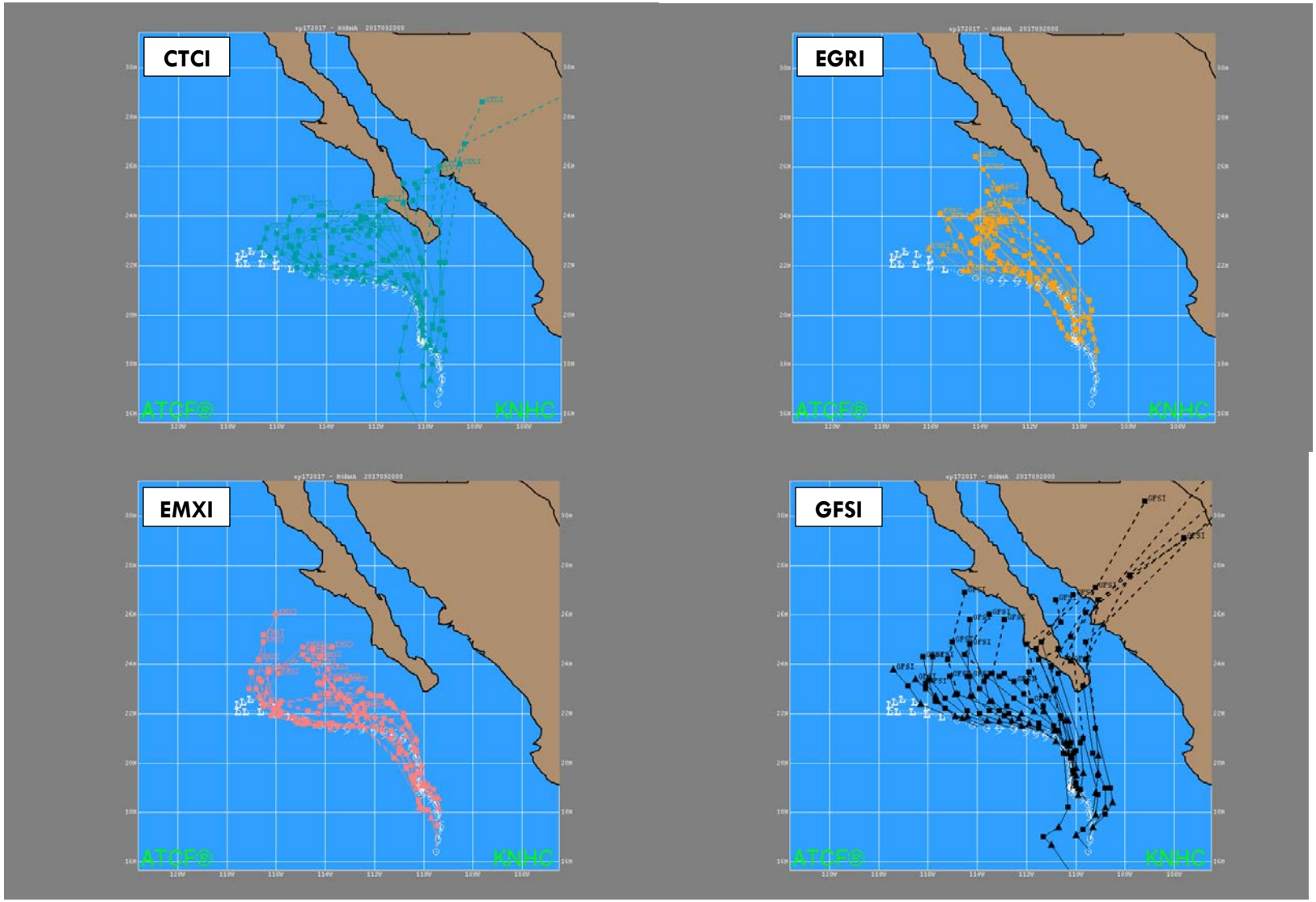


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Norma, 14–19 September, 2017. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Vertical lines correspond to 0000 UTC.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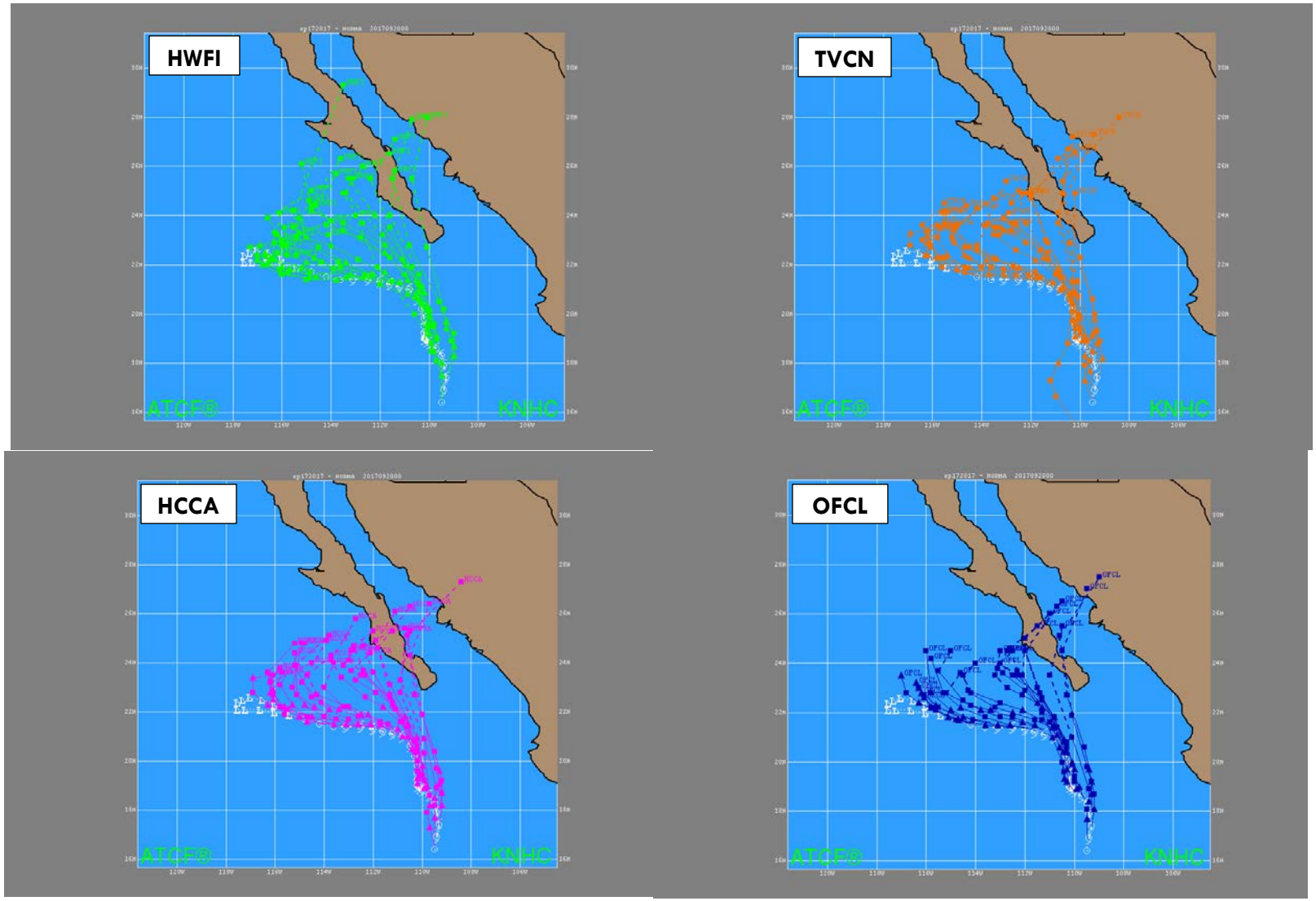

Figure 4. Track forecasts for Norma from the Coupled Ocean/Atmosphere Mesoscale Prediction System-Tropical Cyclones model (CTCI – left top row), United Kingdom Meterological Office global model (EGRI – right top row), European Center for Medium Range Weather Forecasts model (EMXI – left second row), Global Forecast System (GFSI – right second row), Hurricane Weather Research Forecast model (HWFI – left third row), track variable consensus technique (TVCN – right third row), the HFIP Corrected Consensus Approach (HCCA – left bottom row), and NHC official (OFCL – right bottom row).