

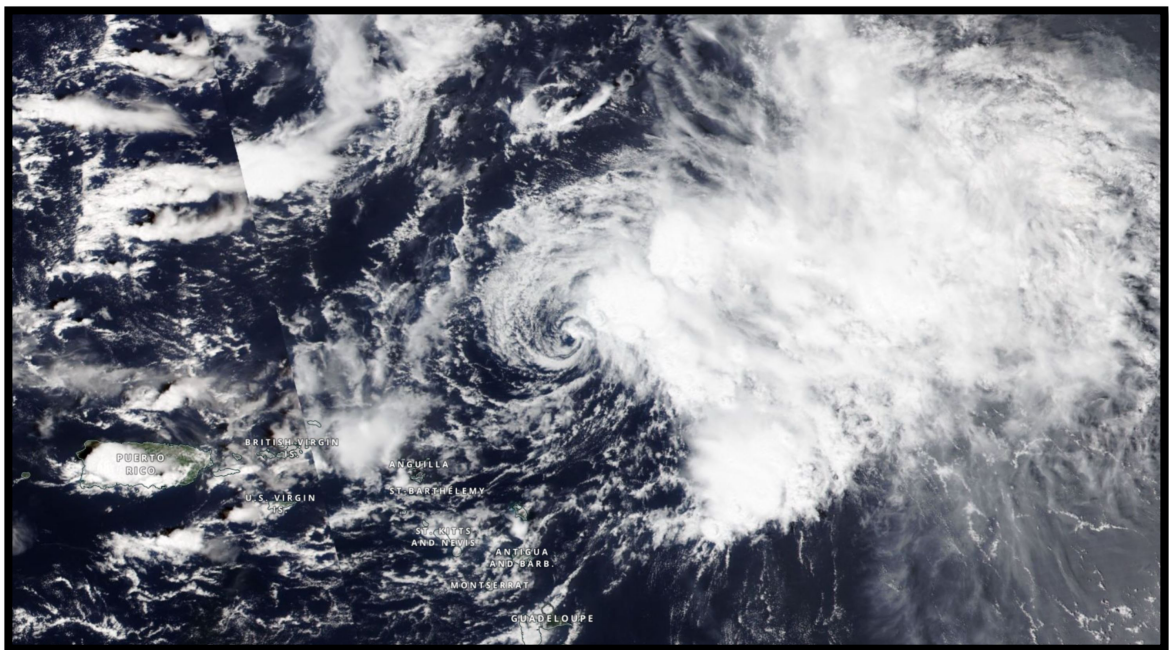


NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM PETER (AL162021)

19 – 22 September 2021

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National Hurricane Center
14 December 2021



NOAA-20 VISIBLE INFRARED IMAGING RADIOMETER SUITE (VIIRS) TRUE COLOR VISIBLE SATELLITE IMAGE OF TROPICAL STORM PETER AT 1640 UTC 20 SEPTEMBER 2021, DURING THE TIME OF ITS PEAK INTENSITY (IMAGE COURTESY OF NASA WORLDVIEW)

Peter was a short-lived and poorly organized tropical storm whose center passed about a hundred nautical miles north of the northern Leeward Islands. Peter produced locally heavy rainfall over portions of Puerto Rico, but impacts were limited.

Tropical Storm Peter

19 – 22 SEPTEMBER 2021

SYNOPTIC HISTORY

Peter originated from a tropical wave that moved off the west coast of Africa on 13 and 14 September while producing a large burst of deep convection near the coasts of Senegal and Guinea-Bissau. The shower and thunderstorm activity showed some subsequent mid-level cyclonic turning over the eastern tropical Atlantic Ocean on 14 and 15 September but did not increase in organization, and the system lacked a closed surface wind circulation. After moving steadily westward at 15 to 20 kt across the eastern and central tropical Atlantic for a few days, showers and thunderstorms became more concentrated near the system on 17 and 18 September, but scatterometer data on the morning of 18 September indicated that the disturbance still did not have a well-defined surface circulation. Later that day, a counterclockwise wind shift at NOAA buoy 41040 east of the Lesser Antilles, as well as satellite images, indicated that a closed surface wind circulation had developed, and it is estimated that a tropical depression formed by 0000 UTC 19 September while located about 525 n mi east of the northern Leeward Islands. The depression strengthened into a tropical storm 6 h later. 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 1¹.

At its formation, Peter was embedded in an environment of relatively low deep-layer (200–850-mb) shear (about 10 kt) and over sea surface temperatures of about 28 degrees Celsius. These conditions allowed the cyclone to strengthen for a short period, reaching a peak intensity of 45 kt by 1800 UTC 19 September while located about 280 n mi east of the northern Leeward Islands. A low- to mid-level ridge stretching across the central and western Atlantic steered Peter toward the west-northwest—closer to an upper-level low located north of Puerto Rico—which resulted in a steady increase in southwesterly shear to nearly 30 kt by early on 20 September. Consequently, Peter’s intensification ceased, with the low-level center becoming displaced to the west of the associated deep convection (cover image). Peter weakened on 21 September due to continued strong southwesterly shear, becoming a tropical depression by 1800 UTC that day about 115 n mi north of St. Thomas. The depression continued to lose organization as the shear turned out of the west and increased further on 22 September, and Peter degenerated into a surface trough by 0000 UTC 23 September while located about 200 n mi north of Puerto Rico. Peter’s remnants turned northward and then northeastward over the western Atlantic for the next few days, and a new well-defined low formed about 300 n mi east of Bermuda early on 28 September. However, the low’s shower activity never became sufficiently organized for the system to be reclassified as a tropical cyclone, and the low dissipated about 500 n mi south of Cape Race, Newfoundland, on 29 September.

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 *bt* directory, while previous years’ data are located in the *archive* directory.

METEOROLOGICAL STATISTICS

Observations in Peter (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and 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. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from five flights 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 Peter.

Winds and Pressure

Peter's estimated peak intensity of 45 kt from 1800 UTC 19 September through 0000 UTC 21 September is based on aircraft and scatterometer wind data. An Air Force Reserve Hurricane Hunter aircraft measured a peak 925-mb flight-level wind of 58 kt at 0124 UTC 20 September, which adjusts to a surface intensity of just under 45 kt. SFMR winds slightly below 50 kt were measured on the same flight, and the estimated peak intensity is therefore a blend of the adjusted flight-level and SFMR data. An ASCAT-A scatterometer pass also showed that Peter was producing 40- to 45-kt winds at 2330 UTC 20 September.

Peter's estimated minimum central pressure of 1005 mb is based primarily on an extrapolated pressure from the reconnaissance flight early on 20 September.

Rainfall and Flooding

Although Peter passed to the north of Puerto Rico, peripheral moisture produced locally heavy rains on the island, particularly on 21 September. Table 2 provides selected rainfall totals from Puerto Rico for the period from 21 through 24 September, and Figure 4 provides an analysis of gauge- and radar-derived rainfall totals during the peak of the event. The highest rainfall total measured by gauges was 3.76 inches at Lares and Morovis. However, the combined gauge- and radar-derived analysis in Figure 4 suggests that higher totals occurred in other isolated locations, particularly in Lares Municipality in the western part of the island where 5 to 6 inches of rain may have occurred.

CASUALTY AND DAMAGE STATISTICS

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

FORECAST AND WARNING CRITIQUE

Peter's genesis was forecast to occur much sooner than what actually happened, especially for the 2-day predictions. Table 3 provides the number of hours in advance of formation with the first NHC Tropical Weather Outlook (TWO) forecast in each likelihood category. A low (<40%) chance of genesis during the next 5 days was first indicated in the TWO 186 h (7.75 days) before Peter formed, and the 5-day chances were raised to the medium (40–60%) and high (>60%) categories 168 h (7 days) and 138 h (5.75 days) before formation, respectively. For the 2-day forecast period, the precursor disturbance was given a low, medium, and high chance of genesis 156, 120, and 108 h (6.5, 5, and 4.5 days) before formation, respectively. Conditions initially appeared conducive for Peter's precursor disturbance to develop after it moved off the coast of Africa, and indeed the system showed some signs of organization over the eastern Atlantic on 14 and 15 September, leading to an increase in both the 2- and 5-day genesis probabilities to the high category. As shown in Figure 5, NHC depicted a high chance of genesis farther east over the tropical Atlantic for quite a few forecasts (red areas in Fig. 5d). However, the system never acquired a closed surface wind circulation during that period, possibly due to its fast forward motion, and Peter's formation location only fell within 54% of NHC's high category 5-day forecast genesis areas. After the failed genesis over the eastern Atlantic, the 2-day probabilities were lowered to the medium category 48 h before Peter formed and then raised back to the high category 30 h before formation.

After Peter had dissipated north of Puerto Rico, the remnants were re-introduced into the TWO over two days later on 25 September, with both the 2- and 5-day genesis probabilities reaching the medium category on 27 September. Although a well-defined surface low formed east of Bermuda on 28 September, the system never had sufficiently organized deep convection to regenerate into a tropical cyclone.

A verification of NHC official track forecasts for Peter is given in Table 4a. Official forecast track errors were higher than the mean official errors for the previous 5-year period at all verifying time periods. OCD5 errors were lower than their respective 5-year means at nearly all forecast times, suggesting that Peter's track should have been easier to forecast than usual. The bulk of the forecast errors appear to be due to Peter moving farther west than expected while passing north of the northern Leeward Islands and Puerto Rico, a result of the decoupling of the low- and mid-level circulations caused by strong shear. Therefore, NHC official track forecasts valid after 1800 UTC 20 September ended up being a little bit too far to the north and east.

A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b and Fig. 6. Due to the homogeneity requirement, the UKMET (EGRI) and COAMPS-TC (CTCI) were not included in the verification. The official track forecasts were competitive with the best-performing models through 36 h, but were then bested by many of the deterministic models and consensus aids from 48 to 72 h. The European (EMXI), HMON (HMNI), and NAVGEM (NVGI) models were the poorest-performing models, having larger errors than the NHC official forecasts.

A verification of NHC official intensity forecasts for Peter is given in Table 5a. Unlike the official forecast track errors, the official forecast intensity errors were lower than the mean errors for the previous 5-year period at all verifying forecast times. OCD5 errors were higher than their



respective 5-year means at nearly all forecast times, suggesting that Peter's intensity should have been more difficult to forecast than usual. NHC correctly anticipated that environmental conditions would not support significant strengthening.

A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b and Fig. 7. The NHC intensity forecasts performed better than most of the models through 36 h, but many of the models had slightly better performance from 48 to 72 h. Although the HWRF (HWFI) model's intensity errors were not large in an absolute sense (5–10 kt), these errors were notably higher than those of the other models and the official forecasts at nearly all forecast times (Fig. 6). These errors appear to be the result of the HWRF having a low bias during Peter's strengthening phase and a high bias during its weakening phase.

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



Table 1. Best track for Tropical Storm Peter, 19–22 September 2021.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
19 / 0000	16.4	52.7	1007	30	tropical depression
19 / 0600	16.8	54.4	1006	35	tropical storm
19 / 1200	17.3	55.8	1006	40	"
19 / 1800	17.9	57.0	1005	45	"
20 / 0000	18.4	58.0	1005	45	"
20 / 0600	18.8	59.0	1005	45	"
20 / 1200	19.2	60.1	1006	45	"
20 / 1800	19.5	61.2	1007	45	"
21 / 0000	19.6	62.3	1007	45	"
21 / 0600	19.6	63.2	1007	40	"
21 / 1200	19.8	64.0	1008	35	"
21 / 1800	20.2	64.6	1008	30	tropical depression
22 / 0000	20.6	65.2	1008	30	"
22 / 0600	21.0	65.8	1008	30	"
22 / 1200	21.4	66.4	1008	30	"
22 / 1800	21.7	66.9	1008	30	"
23 / 0000					dissipated
19 / 1800	17.9	57.0	1005	45	maximum winds and minimum pressure



Table 2. Selected rainfall totals (inches) in Puerto Rico between 21–24 September 2021 for Tropical Storm Peter.

Location	Total Rain (inches)
Hydrometeorological Automated Data System (HADS) Sites	
Lares (LARP4) (18.30N 66.87W)	3.76
Corozal 1 NW (COPR4) (18.35N 66.33W)	3.63
Bayamon (BAYP4) (18.34N 66.14W)	3.38
Arecibo (ACIP4) (18.34N 66.67W)	3.06
Toa Baja 2 S (TOAP4) (18.41N 66.26W)	2.84
Utua 6 WNW (UTHP4) (18.29N 66.78W)	2.83
San Lorenzo 6 S (SLMP4) (18.11N 65.94W)	2.51
Ciales 1 SE (CIAP4) (18.32N 66.46W)	2.48
Patillas 2 NW (PATP4) (18.03N 66.03W)	2.32
Caguas 4 NW (BZBP4) (18.27N 66.10W)	2.08
Juncos 6 ESE (GUV4) (18.20N 65.83W)	2.08
NWS Cooperative Observer (COOP) Sites	
Morovis 1 N (18.33N 66.41W)	3.76
Dos Bocas (18.34N 66.67W)	3.06
Maricao 2 SSW (MRCP4) (18.15N 66.99W)	2.77
Maricao Fish Hatchery (18.17N 66.99W)	2.69
Toa Baja Levittown (18.44N 66.17W)	2.53
Toro Negro Forest (18.17N 66.49W)	2.12
Arecibo Observatory (ARBP4) (18.35N 66.75W)	1.94
Roosevelt Roads (18.26N 65.64W)	1.94
Palmarejo Vega Baja (18.38N 66.43W)	1.88
NWS San Juan (18.43N 65.99W)	1.57
Aguirre (17.96N 66.22W)	1.54

Table 3. 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. Number in the parentheses () indicates the number of hours in advance of formation that the system was re-introduced into the corresponding genesis category after being lowered.

	Hours Before Genesis	
	48-Hour Outlook	120-Hour Outlook
Low (<40%)	156	186
Medium (40%-60%)	120	168
High (>60%)	108 (30)	138

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Peter, 19–22 September 2021. 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	60	72	96	120
OFCL	40.1	52.4	72.5	104.1	123.2	152.6		
OCD5	48.8	76.5	112.2	154.6	200.5	250.7		
Forecasts	14	12	10	8	6	4		
OFCL (2016-20)	23.9	36.3	49.1	63.9	79.0	94.1	128.1	169.7
OCD5 (2016-20)	45.1	97.2	157.2	216.7	271.1	325.4	414.4	490.0



Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Peter, 19–22 September 2021. 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	60	72	96	120
OFCL	38.3	53.9	80.1	112.2	129.8	169.0		
OCD5	44.7	73.2	108.4	151.6	194.0	246.3		
GFSI	38.8	57.1	72.6	90.1	106.3	113.5		
EMXI	45.5	77.7	113.2	146.1	168.7	183.6		
CMCI	30.5	46.8	63.3	82.6	94.5	109.5		
NVGI	54.8	84.6	121.0	158.2	206.1	256.9		
HWFI	39.4	52.2	69.6	93.4	113.5	93.7		
HMNI	36.5	65.7	102.9	162.5	184.4	233.8		
HCCA	38.6	57.6	84.5	118.2	139.3	137.1		
FSSE	46.9	63.4	82.1	103.4	122.6	125.9		
AEMI	36.1	56.1	82.9	116.4	142.6	149.0		
GFEX	39.1	59.7	84.9	112.3	127.3	135.4		
TVCA	37.8	52.1	74.0	101.8	118.9	118.2		
TVCX	38.2	54.6	76.0	103.5	119.1	118.6		
TVDG	36.8	53.5	72.8	99.6	113.4	116.2		
TABS	51.1	90.0	133.9	181.2	224.1	267.2		
TABM	36.6	58.6	89.2	113.3	131.2	140.5		
TABD	62.8	138.7	226.0	304.7	374.3	439.4		
Forecasts	9	9	8	7	5	3		



Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Peter, 19–22 September 2021. 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	60	72	96	120
OFCL	3.9	6.2	5.5	5.0	2.5	3.8		
OCD5	5.3	11.2	19.2	24.1	29.8	32.8		
Forecasts	14	12	10	8	6	4		
OFCL (2016-20)	5.4	8.0	9.6	10.9	11.5	12.1	13.3	14.5
OCD5 (2016-20)	7.0	11.0	14.3	16.8	18.3	19.7	21.7	23.0



Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Peter, 19–22 September 2021. 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 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	4.4	6.1	5.6	4.3	3.0	3.3		
OCD5	4.7	11.4	20.5	27.4	33.0	36.7		
HWFI	7.4	8.8	9.6	5.7	5.8	4.7		
HMNI	6.4	7.3	7.0	3.1	2.6	1.7		
DSHP	4.1	5.7	6.2	2.9	2.2	2.3		
LGEM	3.8	6.1	5.9	2.6	2.8	3.3		
ICON	5.0	6.4	6.9	3.4	2.4	1.3		
IVCN	5.2	7.0	7.2	3.6	2.6	1.0		
IVDR	5.7	7.6	7.4	3.9	2.4	1.0		
HCCA	5.0	6.4	6.4	3.3	3.6	2.0		
FSSE	5.3	7.0	6.1	2.3	3.0	3.7		
GFSI	6.7	8.7	8.4	3.6	3.4	5.0		
EMXI	5.6	6.7	6.0	2.9	1.2	2.7		
Forecasts	9	9	8	7	5	3		

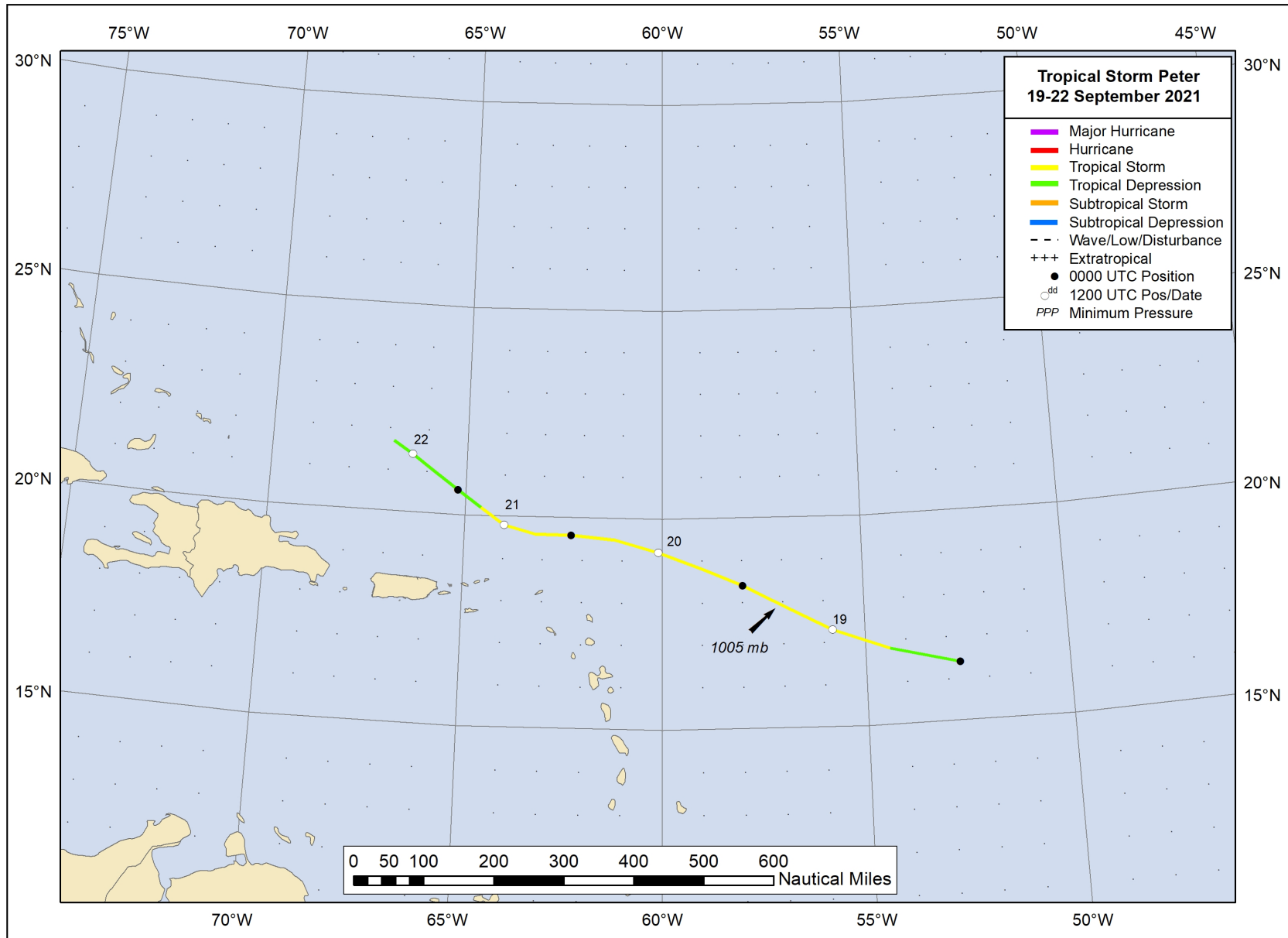


Figure 1. Best track positions for Tropical Storm Peter, 19–22 September 2021.

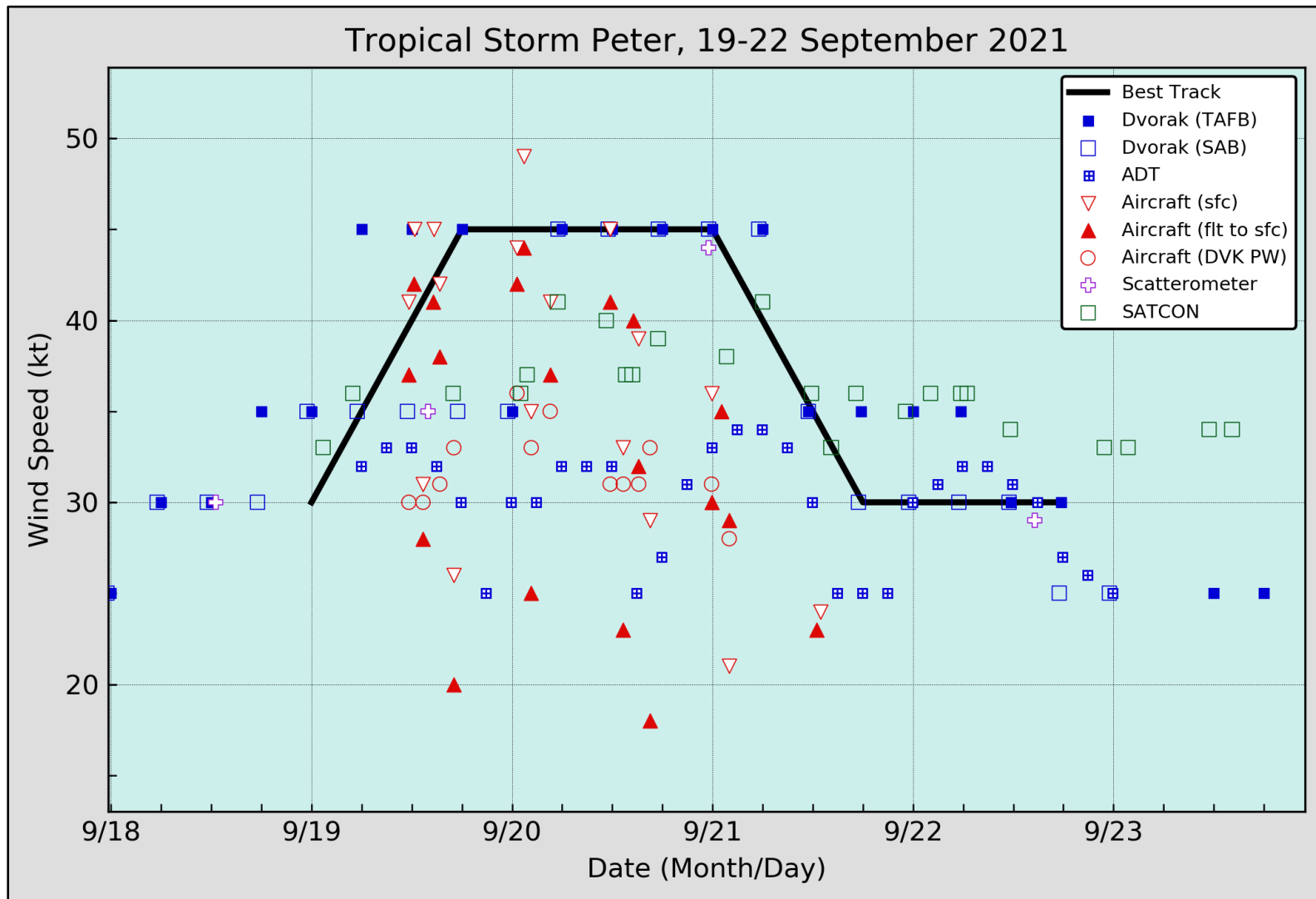


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Peter, 19–22 September 2021. Aircraft observations have been adjusted for elevation using 75% adjustment factors for observations from 1500 ft. Advanced Dvorak Technique estimates represent 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.

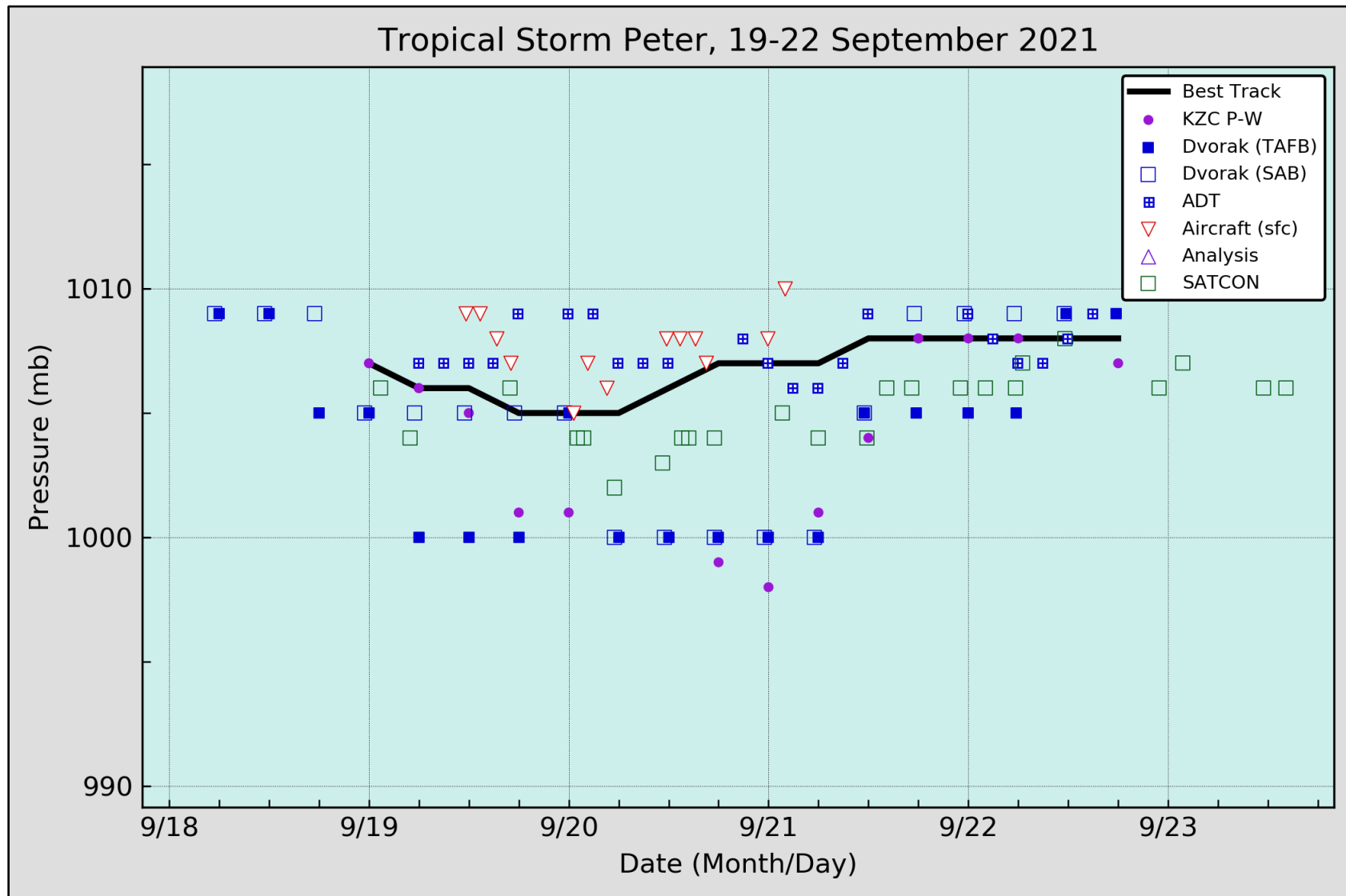
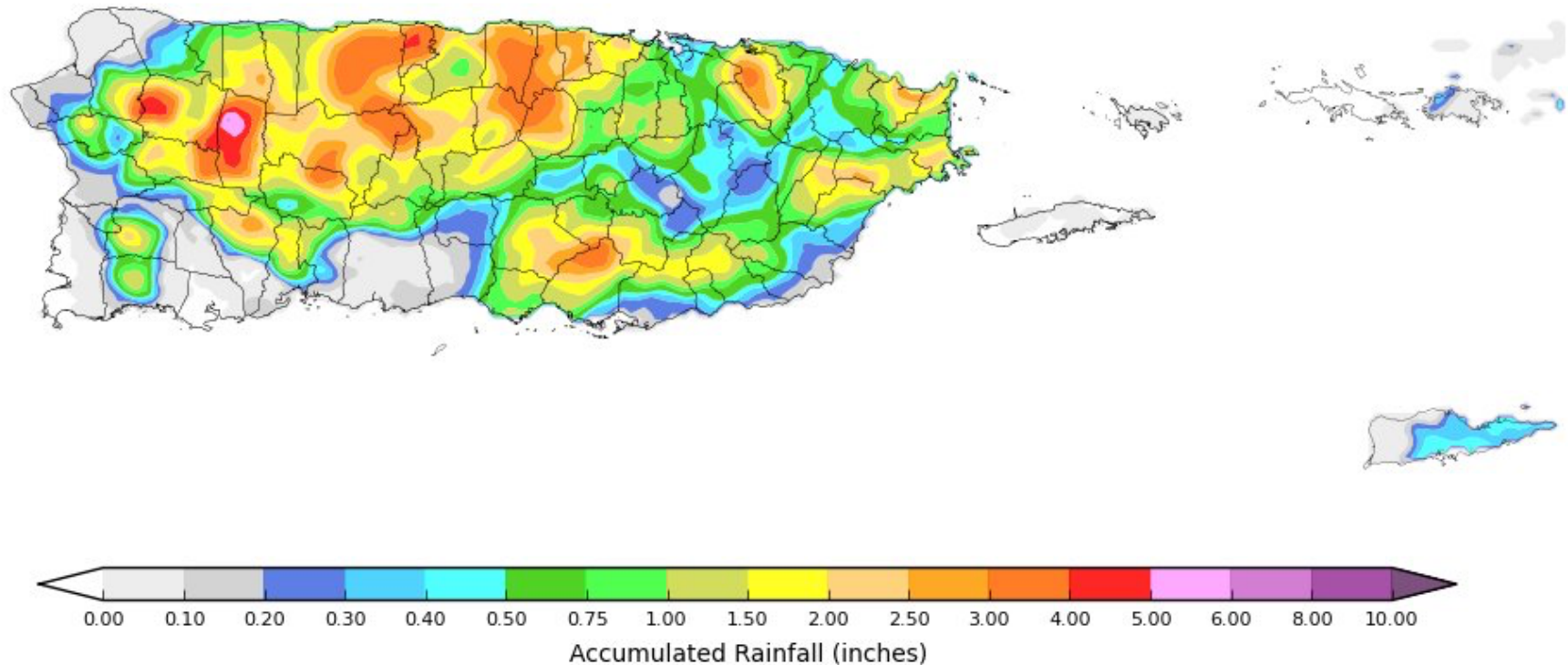


Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Peter, 19–22 September 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for 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.

Preliminary Rainfall Totals for Puerto Rico and the U.S. Virgin Islands

Data Source: MPE (Radar Estimates & Rain Gages)

Valid from 09/21/2021 12Z to 09/22/2021 06Z



National Weather Service

San Juan, PR

09/22/2021 05:04 GMT

Figure 4. Multi-Sensor Precipitation Estimator (MPE) rainfall totals (inches) from Puerto Rico and the U.S. Virgin Islands from 1200 UTC 21 September through 0600 UTC 22 September associated with Tropical Storm Peter. Image courtesy of the National Weather Service in San Juan, Puerto Rico.

Peter Tropical Weather Outlook Areas - From 11 Sep 2021 To 19 Sep 2021

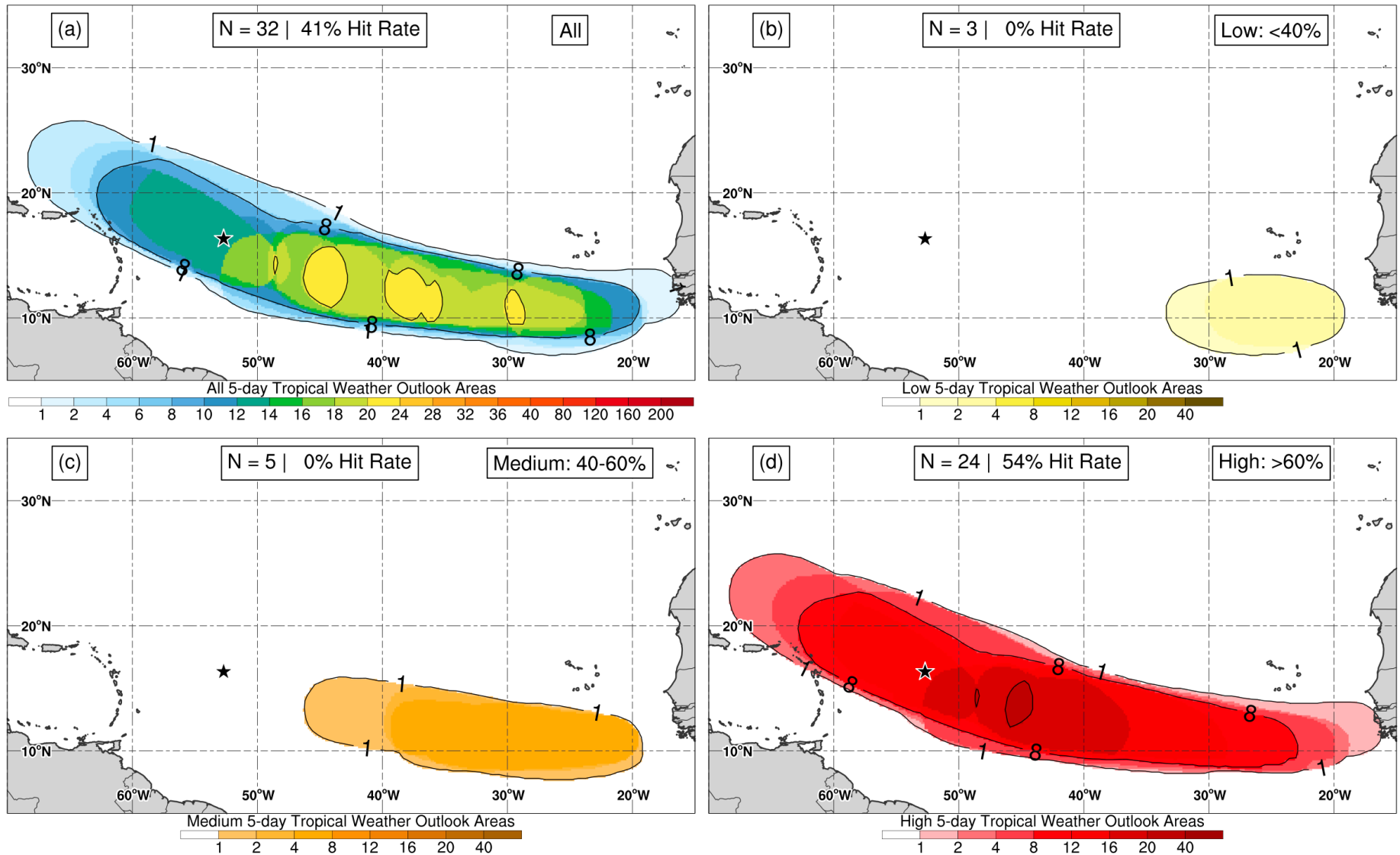


Figure 5. Composites of 5-day tropical cyclone genesis areas depicted in NHC's Tropical Weather Outlooks prior to the formation of Tropical Storm Peter for (a) all probabilistic genesis categories, (b) the low (<40%) category, (c) medium (40–60%) category, and (d) high (>60%) category. Peter's location of genesis is indicated by the black star.

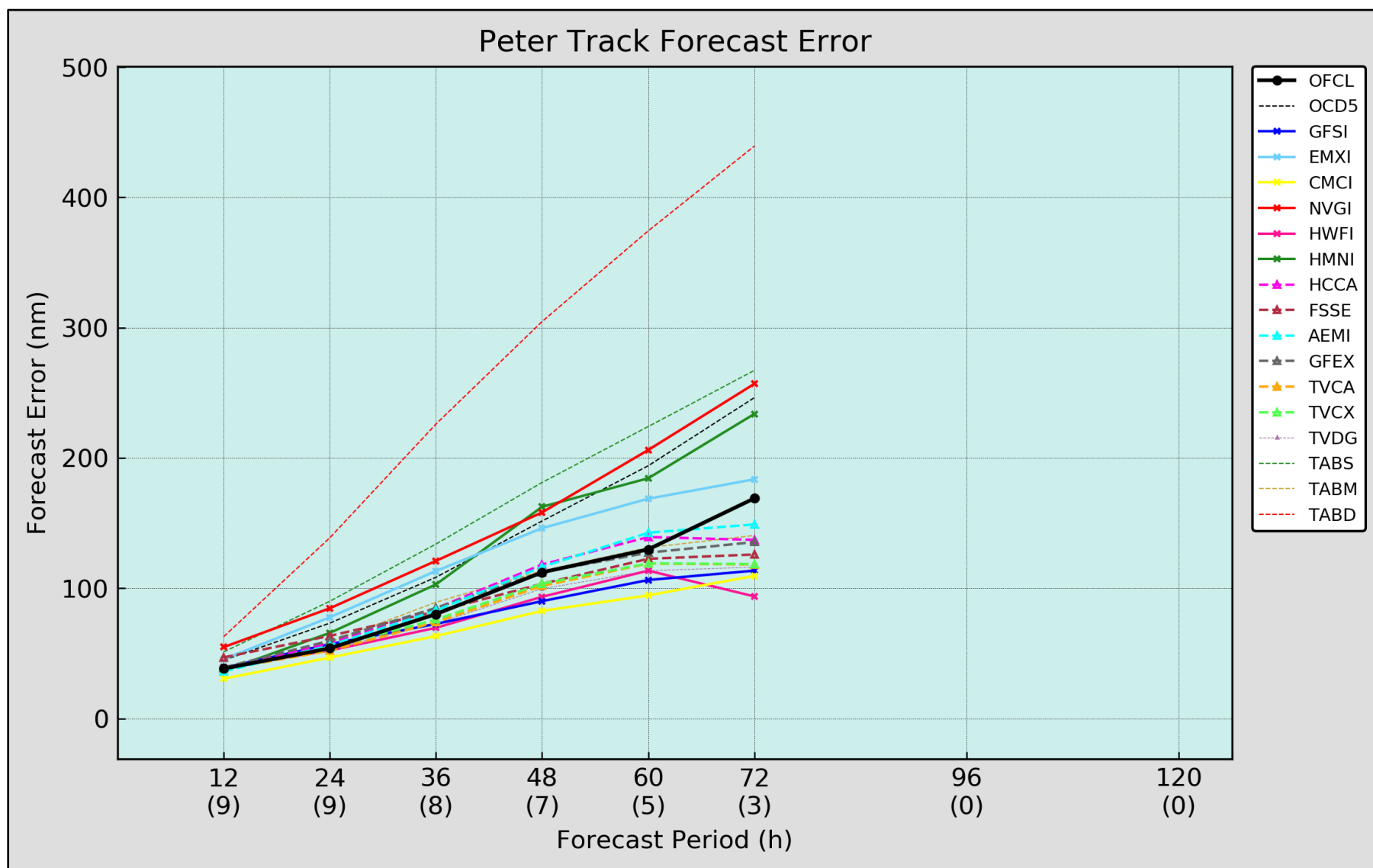


Figure 6. Homogeneous comparison of selected track forecast guidance model errors (in n mi) for Tropical Storm Peter, 19–22 September 2021. Official NHC track errors are denoted by the thick black line.

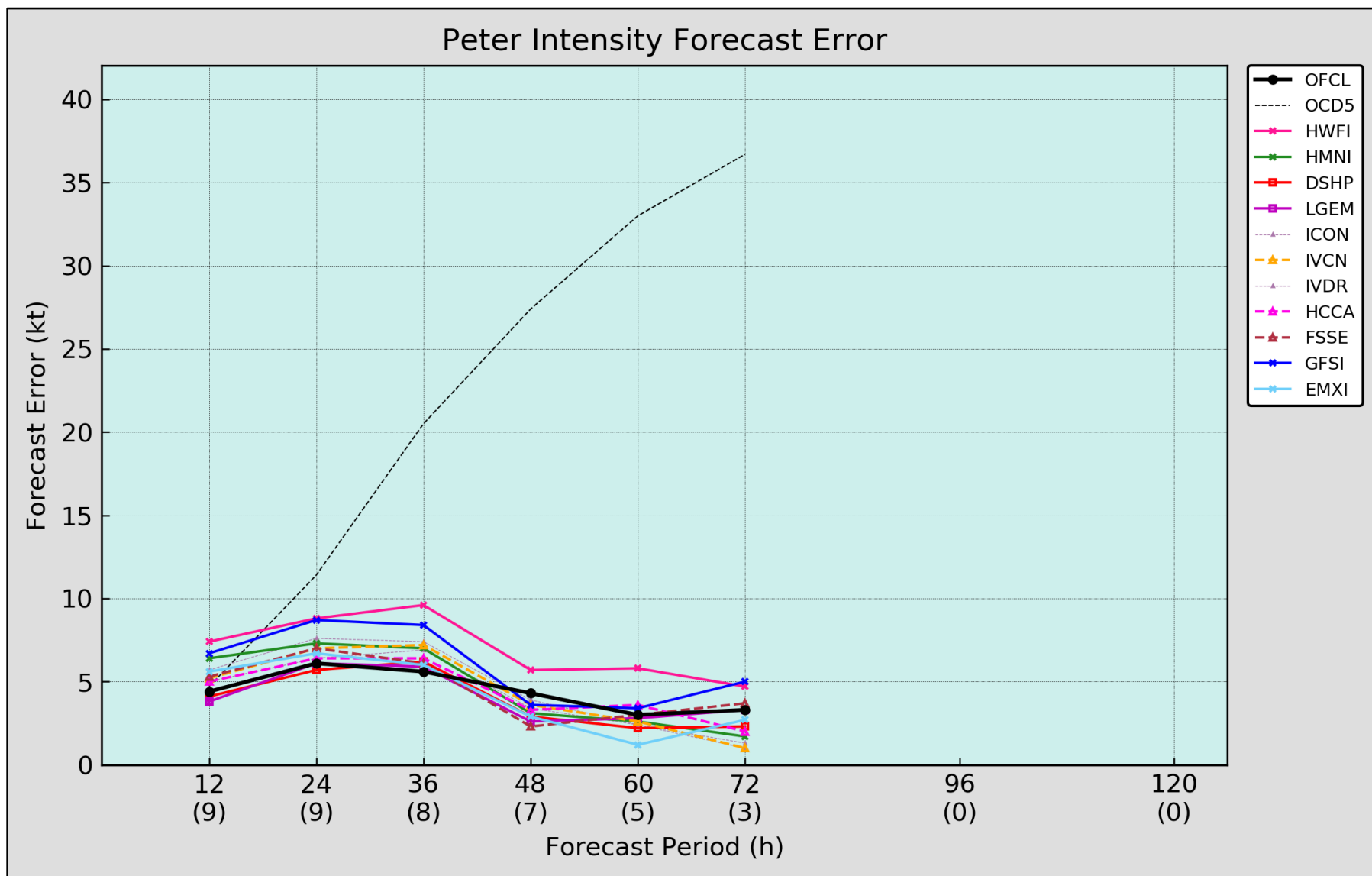


Figure 7. Homogeneous comparison of selected intensity forecast guidance model errors (in kt) for Tropical Storm Peter, 19–22 September. Official NHC intensity errors are denoted by the thick black line.