NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE LORENZO

(AL132019)

23 September–2 October 2019

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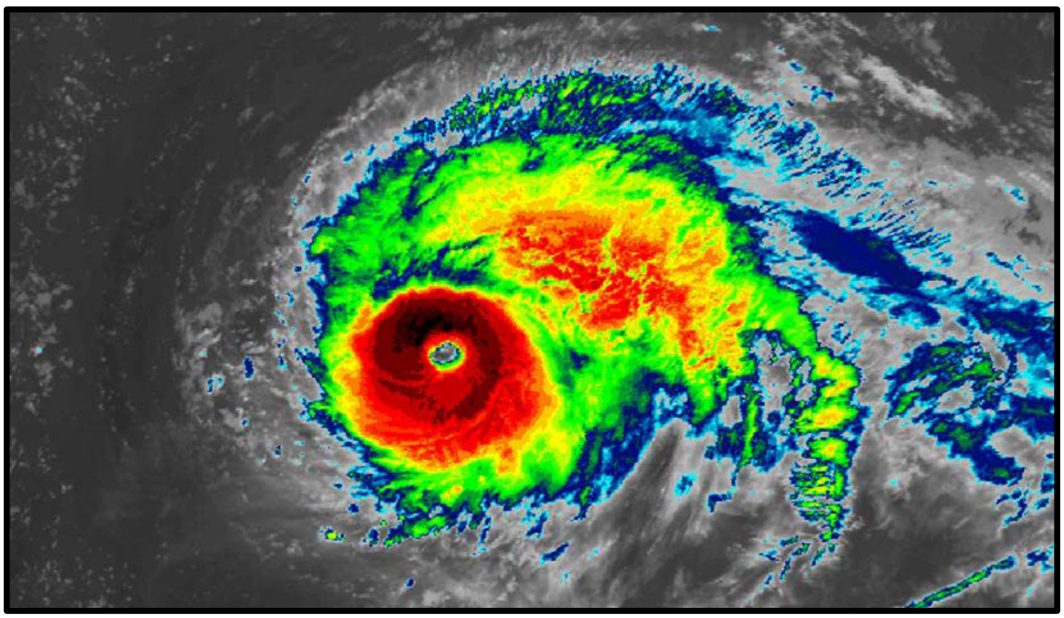
16 December 2019



GOES-E CH-13 INFRARED IMAGE OF LORENZO AT 0200 UTC 29 SEPTEMBER NEAR THE TIME OF ITS PEAK INTENSITY.

Lorenzo was one of the strongest hurricanes on record in the eastern or central Atlantic. It briefly became a category 5 hurricane (on the Saffir-Simpson Hurricane Wind Scale) and later brought hurricane-force winds and large damaging waves to portions of the Azores when it passed just west of those islands as a category 1 storm. As a post-tropical/extratropical cyclone, Lorenzo produced tropical-storm-force winds across portions of Ireland. Lorenzo was the second deadliest hurricane of the 2019 hurricane season and caused 19 deaths, including 11 crewmembers of the *Bourbon Rhode,* which sank near the eyewall of the hurricane on 26 September. Eight people also died along the U.S. east coast due to dangerous surf conditions generated by the hurricane.

Hurricane Lorenzo

23 SEPTEMBER–2 OCTOBER 2019

SYNOPTIC HISTORY

Lorenzo formed from a tropical wave that moved off the west coast of Africa on 22 September. The wave's convection was likely enhanced by the favorable phase of the Madden-Julian Oscillation and showed signs of organization before it even reached the Atlantic Ocean. A broad low developed around the time the wave moved off the coast, and the low became well-defined by 1800 UTC 22 September. The associated convection became sufficiently organized to classify the system as a tropical depression just 6 h later when it was located about 280 n mi southwest of Dakar, Senegal. The cyclone quickly strengthened and became a tropical storm by 0600 UTC 23 September. The "best track" chart of Lorenzo'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].

Lorenzo initially moved westward to west-northwestward, steered by a subtropical ridge to its north. The cyclone steadily strengthened while its large circulation consolidated during the next 24 h. The strengthening trend was briefly interrupted by an increase of wind shear on 24 September, but the shear decreased by 0000 UTC 25 September. Lorenzo then rapidly strengthened 70 kt over the next 48 h and reached an initial peak intensity of 125 kt around 0000 UTC 27 September. Around that same time, the hurricane slowed and turned northwestward in response to a break that developed within the subtropical ridge. The combination of an eyewall replacement cycle and an intrusion of dry air into the inner core of the hurricane caused Lorenzo to weaken during the next 24 h, though it remained a major hurricane through that time. Shortly after 0600 UTC 28 September, Lorenzo turned northward as it rounded the western periphery of the subtropical ridge. It redeveloped a single closed eyewall around that same time. A second period of rapid intensification ensued during which Lorenzo's intensity increased by 40 kt in only 21 h. Lorenzo became a category 5 hurricane when it reached its peak intensity of 140 kt around 0300 UTC 29 September, while centered about 1400 n mi southwest of the Azores (cover image).

Lorenzo then weakened even faster than it had strengthened. Shear associated with an upper-level trough over the north-central Atlantic and an influx of drier mid-latitude air caused Lorenzo's eyewall to collapse. Ocean cooling from extensive upwelling associated with the hurricane's large size likely also contributed to the decay of Lorenzo's convective structure. The hurricane consequently weakened to a category 2 storm by 1800 UTC 29 September, just 15 h after its peak. Lorenzo was a large system from its initial formation, and its wind field grew further on 29–30 September, even as its strongest winds quickly decreased. The large size of the hurricane made it a prolific generator of large waves and swell that affected most of the North

[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.

Atlantic basin from late September through early October (Fig. 4). These swells first reached the east coast of the United States on 30 September and caused hazardous surf and rip currents along U.S. beaches for several days.

Meanwhile, the hurricane accelerated northeastward in the flow between a large mid-latitude trough over the far north-central Atlantic and the subtropical ridge. Lorenzo began to lose its tropical characteristics as it neared the Azores on 1 October, but it still brought hurricane-force winds to the western portions of the islands when it passed just to the west of Flores and Corvo Islands early on 2 October. Large damaging waves generated by the hurricane also affected many islands in the Azores. By 1200 UTC that day, Lorenzo became a frontal post-tropical cyclone about 240 n mi north of Graciosa Island.

The still-powerful extratropical cyclone continued to move quickly northeastward for about 36 h before it abruptly turned east-southeastward on 4 October. The cyclone gradually weakened during this period, but maintained an expansive wind field. The center of Lorenzo moved over northwest Ireland around 0600 UTC 4 October and became poorly defined shortly thereafter. Since the cyclone was still quite large, a substantial portion of the Republic of Ireland experienced gale-force winds on 4 October as Lorenzo and its remnants moved across the country.

METEOROLOGICAL STATISTICS

Observations in Lorenzo (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 Lorenzo.

Two NOAA P-3 Hurricane Hunter aircraft and the NOAA G-IV jet flew a total of 6 research missions in and around Lorenzo. Observations from those missions include flight-level winds, stepped frequency microwave radiometer (SFMR), and dropwindsondes. The NOAA P-3s each flew an additional mission in support of search and rescue operations after the vessel *Bourbon Rhode* sank on 26 September.

The 140-kt peak intensity of Lorenzo at 0300 UTC 29 September is based primarily on a Dvorak data-T pattern of T-7.0/140 kt that lasted from 0100 UTC to 0300 UTC with corresponding ADT values of 143 kt. In real time, special 0130 UTC Dvorak classifications of T7.0/7.0 were provided by both TAFB and SAB, while a SATCON fix showed a similarly high value of 135 kt. No reconnaissance data was available at the time of Lorenzo's estimated peak intensity.

It is worth noting that the best track typically has an uncertainty of about 10%. The rapid intensification and subsequent rapid weakening of Lorenzo on 28 and 29 September complicates the intensity analysis since the hurricane's peak appears to have occurred on a shorter timescale than the 6-hourly best track can typically represent. Most satellite-based intensity estimate techniques are developed using 6-hourly data, and it is unknown how well they represent large short-term fluctuations in storm strength. The Final-T and Current Intensity numbers associated with the 0130 UTC TAFB fix were later corrected to T-6.5/6.5 (127 kt) due to Dvorak constraints, although the data-T remained 7.0. The highest SATCON value was also amended to 127 kt based on later microwave data that was valid shortly after Lorenzo's apparent peak. Accounting for those adjustments, the final intensity estimates near 0300 UTC 29 September range from 127 kt to 143 kt, underscoring the uncertainty in Lorenzo's peak intensity. Out of respect for the impressive infrared satellite appearance and given the uncertainty associated with the modified fixes in this case, the operational assessment of 140 kt has been maintained in the final best track.

Regardless of Lorenzo's precise peak intensity, it was among the strongest hurricanes on record in the eastern or central Atlantic. Its 140-kt peak intensity is the highest for any hurricane east of 50°W in the Atlantic hurricane database back to 1851. In the reliable satellite era (since 1966), only one other hurricane, Igor in 2010, even reached 130 kt in that portion of the Atlantic. Records for the eastern and central Atlantic are less reliable prior to the satellite era, but it is noteworthy that there are no hurricanes on record comparable to Lorenzo.

Lorenzo brought hurricane conditions to portions of the Azores when it passed near the westernmost islands. Sustained hurricane-force winds were measured on Corvo Island, and a number of other sites in the Azores reported hurricane-force gusts. The system later brought gale-force winds to Ireland as a post-tropical/extratropical cyclone. Ship reports of winds of tropical-storm-force or gale-force winds associated with Lorenzo are given in Table 3. Selected surface observations from land stations and data buoys are given in Table 4, including observations in Ireland after Lorenzo became extratropical.

CASUALTY AND DAMAGE STATISTICS

Lorenzo was responsible for 19 direct deaths[2], all due to hazardous surf and marine conditions. Eleven crewmembers of the oceanic tugboat *Bourbon Rhode* perished when it sank on 26 September near the center of the then-rapidly intensifying hurricane. Search and rescue operations during the following days led to the successful rescue of three members of the crew. Four bodies were recovered, and the remainder of the crew is presumed lost at sea.

Rip currents and hazardous surf associated with swells generated by Lorenzo were responsible for eight additional deaths along the east coast of the United States. A fisherman in Middletown, RI, drowned after falling into rough surf along the shore, while two teenagers died at Rockaway Beach, NY, after they were swept away by a rip current. Another man drowned while swimming in hazardous conditions at Vero Beach, FL. Four deaths associated with Lorenzo occurred along the beaches of North Carolina. Surf conditions and a rip current in the area were

[2] Deaths occurring as a direct result of the forces of the tropical cyclone are referred to as "direct" deaths. These would include those persons who drowned in storm surge, rough seas, rip currents, and freshwater floods. Direct deaths also include casualties resulting from lightning and wind-related events (e.g., collapsing structures). Deaths occurring from such factors as heart attacks, house fires, electrocutions from downed power lines, vehicle accidents on wet roads, etc., are considered indirect" deaths.

likely factors in the drowning death of a man at Duck, and another man was found dead in the water at Nags Head. Two men, one of whom was fishing in shallow water, drowned after getting caught in rip currents at Kure Beach just a few hours apart.

Lorenzo caused moderate damage in the Azores, primarily on Flores and Corvo Islands. Local media reported that the commercial port of Lajes on Flores Island was totally destroyed (Fig. 5), while downed trees and power lines caused power outages across both islands. As many as 100 people were evacuated from homes in the Azores, including in the city of Horta where waves reached a street and affected several homes. A total damage estimate in the Azores was not available. Despite the strong winds and powerful waves that occurred there, no deaths or serious injuries were reported in the Azores.

Lorenzo had only minor impacts in the Republic of Ireland as a post-tropical/extratropical cyclone. About 20,000 customers lost power across the country due to downed trees and power lines. No deaths associated with Lorenzo were reported in Ireland, however, the Irish Coast Guard responded to several incidents, including a kitesurfer that broke his leg and had to be airlifted by helicopter to a hospital.

FORECAST AND WARNING CRITIQUE

Genesis

The genesis of Lorenzo was fairly well forecast, considering how far east it developed. The wave from which Lorenzo developed was first introduced into the 5-day Tropical Weather Outlook with a low (< 40%) chance of development at 1200 UTC 19 September, 84 h prior to formation and about 72 h before it moved off the coast of Africa (Table 2). The probability was increased to the medium (40–60%) and high (> 60%) categories 78 h and 60 h before genesis occurred, respectively. The wave was first shown to have a low chance of development in the 48-h forecast 60 h before genesis occurred, and the probability reached the high category 18 h before Lorenzo formed. In general, the global deterministic models and their associated ensembles forecast the development of Lorenzo quite well, as there were indications that a tropical cyclone would form near the west coast of Africa as early as 7 days before genesis.

Track

A verification of NHC official track forecasts for Lorenzo is given in Table 5a. Official forecast track errors were consistently lower than the mean errors for the previous 5-yr period. A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b. All of the track consensus aids had generally low errors. Both the Florida State Superensemble (FSSE) and an average of the GFS and ECMWF (GFEX) were better than the official forecast at most forecast hours. The ECMWF was the best-performing individual model at 12–72 h, and it had lower errors than the NHC forecast through 48 h. However, it was only an average performer at longer ranges. No other single model consistently outperformed the consensus aids or the NHC track forecast.

Intensity

A verification of NHC official intensity forecasts for Lorenzo is given in Table 6a. Official forecast intensity errors were higher than the mean official errors for the previous 5-yr period at 12 h and 24 h, but were lower at 36 h and beyond. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b. The FSSE was the best intensity consensus aid, and it had lower errors than the official forecast at all verifying times except 120 h. The regional hurricane models generally outperformed the statistical-dynamical guidance, but no individual model was consistently better than the NHC intensity forecast.

The relatively high errors in the short-term forecasts were primarily associated with Lorenzo's rapid intensification and weakening that occurred on 28 and 29 September. No intensity models properly captured the large swings in Lorenzo's intensity that occurred during that period (Fig. 6). Notably, no members of the intensity consensus at 0600 or 1200 UTC 28 September (less than 24 h prior to Lorenzo's peak) predicted that Lorenzo would strengthen more than 5 kt. This trend continued with each subsequent model cycle as Lorenzo strengthened. The collapse of Lorenzo's inner core and subsequent rapid weakening were also problematic since the dynamical models were unable to accurately predict the hurricane's structural evolution during that period.

Watches and Warnings and International Coordination

A summary of international watches and warnings associated with Lorenzo are given in Table 7. The NHC began providing information to forecasters in the Azores as early as 25 September. Beginning 28 September, daily coordination calls were conducted with Met Éireann in Ireland and the United Kingdom Meteorological Office to coordinate forecasts and hazard messaging for Lorenzo's potential impacts in that region as a post-tropical cyclone. NHC/TAFB also provided 35 spot forecasts in support of the U.S. Coast Guard District 7's search and rescue missions for the crew of the *Bourbon Rhode*.

ACKNOWLEDGMENTS

Observations and other information about Lorenzo's impacts in the Azores were provided by the Portuguese Institute for the Sea and the Atmosphere (IPMA). Images of Lorenzo's impact in the Azores were provided by Fred Fournier. Fran Achorn provided archived Ocean Prediction Center sea state analyses, and Andrew Penny provided archived ECMWF wave model analyses.

Table 1. Best track for Hurricane Lorenzo, 23 September–2 October 2019.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
22 / 1800	10.9	18.8	1008	25	low
23 / 0000	11.0	20.4	1007	30	tropical depression
23 / 0600	11.0	21.9	1007	35	tropical storm
23 / 1200	11.1	23.3	1006	40	"
23 / 1800	11.2	24.6	1004	45	"
24 / 0000	11.4	25.9	1002	50	"
24 / 0600	11.8	27.2	999	55	"
24 / 1200	12.2	28.7	997	55	"
24 / 1800	12.6	30.2	997	55	"
25 / 0000	13.0	31.6	993	60	"
25 / 0600	13.4	33.0	988	70	hurricane
25 / 1200	13.9	34.5	983	75	"
25 / 1800	14.4	36.0	979	80	"
26 / 0000	14.5	37.5	975	85	"
26 / 0600	14.7	38.8	967	95	"
26 / 1200	15.2	39.8	955	105	"
26 / 1800	16.0	40.6	947	115	"
27 / 0000	17.1	41.2	937	125	"
27 / 0600	18.1	41.9	937	125	"
27 / 1200	18.9	42.7	943	120	"
27 / 1800	19.6	43.5	948	110	"
28 / 0000	20.3	44.2	952	105	"
28 / 0600	21.1	44.6	957	100	"
28 / 1200	22.0	44.9	957	105	"
28 / 1800	22.9	45.0	951	115	"
29 / 0000	23.8	45.0	936	130	"
29 / 0300	24.3	45.0	925	140	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
29 / 0600	24.7	45.0	933	130	"
29 / 1200	25.6	44.8	945	110	"
29 / 1800	26.4	44.4	950	90	"
30 / 0000	27.2	44.0	954	90	"
30 / 0600	28.2	43.6	955	90	"
30 / 1200	29.2	43.2	955	90	"
30 / 1800	30.2	42.7	955	90	"
01 / 0000	31.2	41.9	956	90	"
01 / 0600	32.6	40.7	957	85	"
01 / 1200	34.3	39.0	957	85	"
01 / 1800	35.9	36.8	958	85	"
02 / 0000	37.8	34.4	959	85	"
02 / 0600	40.2	31.4	959	80	"
02 / 1200	43.0	28.0	959	70	extratropical
02 / 1800	45.9	24.4	960	65	"
03 / 0000	49.2	21.5	961	60	"
03 / 0600	52.0	18.7	962	60	"
03 / 1200	54.5	15.7	963	60	"
03 / 1800	55.8	13.3	966	60	"
04 / 0000	55.4	10.5	977	55	"
04 / 0600	54.5	8.2	985	50	"
04 / 1200					dissipated
29 / 0300	24.3	45.0	925	140	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	84
Medium (40%-60%)	36	78
High (>60%)	18	60

Table 3. Selected ship reports with winds of at least 34 kt for Lorenzo. All ship reports of 34 kt winds were associated with the post-tropical/extratropical stage of the cyclone.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
03/0600	SHJC	49.5	8.6	190/43	1009.6
04/0200	EUCFR0	49.8	4.1	250/35	1008.2
04/0300	EUCFR0	50.0	4.1	250/38	1007.8
04/1100	EUCFR1	49.7	3.7	250/41	1009.3
04/1200	ZDNC2	49.7	3.7	250/36	1009.3
04/1200	EUCFR1	49.7	2.0	240/40	1006.5

Table 4. Selected surface observations for Hurricane Lorenzo, 23 September–2 October 2019. Observations in Ireland and buoys maintained by the United Kingdom Meteorological Office are from Post-Tropical/Extratropical Cyclone Lorenzo 2–4 October 2019.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)	Storm tide (ft)	Estimated Inundation (ft)	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Buoy Observations									
13008 – Reggae (PIRATA) (15.00 38.01W)	26/0200	988.4	26/0100	51 (4 m)	64				
62105 (UK Met Office) (55.42N 12.57W)	03/1900	969.0	03/1100	41 (3 m)	54				
64045 (UK Met Office) (59.07N 11.42W)	03/1900	999	03/1600	33 (3 m)	46				
62029 (UK Met Office) (48.72N 12.43W)	03/0400	1003	03/0400	31 (3 m)	42				
4401556 (Drifting buoy) (23.97N 45.15W)	29/0100	953							
Azores									
International Civil Aviation Organization (ICAO) Sites									
Flores Island (LPFL) (39.45N 31.13W)			02/0430	52 (10-min)	77				
São Miguel (LPPD) (37.74N 25.71W)			02/0800	26 (10-min)	38				
Other Automated Sites									
Angra Do Heroismo (CU3AC) (38.67N 27.22W)			02/0701	22	39				
Corvo (39.67N 31.12W)			02/0830	64	88				
Horta (CU7BC) (38.52N 28.66W)			02/0535	50	60				
Horta/Faial Island (38.52N 28.72W)			02/0800	48	78				
Republic of Ireland									
International Civil Aviation Organization (ICAO) Sites									
Cork (EICK) (51.85N 8.50W)	03/1400	1001.0	04/1030	24 (10-min)	38				
Ireland West Airport (Knock) (EIKN) (53.91N 8.82W)	04/0500	992.0	04/0630	32 (10-min)	49				0.21
Shannon (EINN) (52.70N 8.92W)	04/0000	1000.1	04/0700	30 (10-min)	48				0.02
Met Éirean Observing Sites									
Athenry (53.29N 8.79W)	04/0100	996.7	04/0000	21 (10-min)	44				0.18
Belmullet (54.22N 10.03W)	04/0100	988.6	04/0100	39 (10-min)	54				0.05
Claremorris (54.71N 8.99W)	04/0600	993.2	04/0600	26 (10-min)	46				0.13
Finner Camp (54.50N 8.23W)	04/0600	985.8	04/0300	22 (10-min)	38				1.30
Gurteen (53.05N 8.01W)	04/0700	997.7	04/0800	24 (10-min)	39				0.13

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)	Storm tide (ft)	Estimated Inundation (ft)	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Mace Head (53.32N 9.90W)	04/0000	994.2	04/0600	46 (10-min)	58				0.04
Malin Head (55.37N 7.34W)	04/0300	992.4	04/0800	30 (10-min)	40				0.05
Markree (54.18N 8.46W)	04/0600	988.7							0.28
Newport (Furness) (53.92N 9.57W)	04/0100	992.2	04/0600	34 (10-min)	57				0.41
Roaches Point (51.79N 8.24W)	03/1500	1001.2	04/1200	31 (10-min)	45				
Sherkin Island (51.48N 9.43W)	03/1300	1001.6	04/0400	31 (10-min)	45				0.03
Valentia (51.94N 10.24W)	03/1100	998.5	04/0400	23 (10-min)	36				0.04
Private Weather Stations									
Ardoone (54.25N 10.03W)	04/0030	988	04/0000	50	59				0.05
Oranmore (53.27N 8.93W)			04/0442	20	41				0.01
Westport (53.78N 9.56W)	04/0033	991	04/0301	32	43				0.01

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Wind averaging periods and non-standard observing heights for land stations are noted, when known. Sustained wind averaging periods for buoys averaging periods are 8 min.

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Lorenzo, 23 September–2 October 2019. 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	**19.0**	**25.2**	**34.0**	**45.2**	**68.2**	**90.5**	**102.0**
OCD5	32.9	67.2	111.9	150.9	244.5	364.4	521.6
Forecasts	36	34	32	30	26	22	18
OFCL (2014-18)	23.6	35.5	47.0	61.8	96.0	136.0	179.6
OCD5 (2014-18)	44.8	97.6	157.4	220.1	340.7	446.6	536.6

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Lorenzo, 23 September–2 October 2019. 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	72	96	120
OFCL	20.0	26.3	35.2	47.8	69.2	89.1	97.8
OCD5	33.9	76.0	122.1	155.6	261.6	406.1	594.0
HCCA	**19.7**	28.0	39.9	51.2	**67.3**	89.5	111.6
FSSE	**19.2**	**25.2**	**35.1**	**42.4**	**66.7**	94.2	131.9
TVCA	**19.2**	28.3	40.6	55.7	78.1	99.7	101.3
TVCX	**17.9**	**25.9**	38.2	52.7	74.0	95.8	**97.7**
TVDG	**19.5**	29.0	42.2	59.3	84.2	105.6	105.5
GFEX	**15.8**	**20.7**	**29.8**	**44.3**	**66.7**	93.9	**95.1**
AEMI	21.1	35.4	49.6	69.4	93.2	115.8	107.0
GFSI	20.1	33.3	48.3	69.9	106.1	144.8	175.7
EMXI	**14.6**	**17.9**	**26.2**	**39.4**	78.4	109.6	173.9
EGRI	27.7	51.2	80.5	108.9	154.9	170.9	185.1
NVGI	24.4	44.3	65.1	87.5	123.3	140.4	133.4
HWFI	24.8	38.1	50.8	65.8	85.0	126.8	136.3
HMNI	22.9	33.0	42.1	51.6	71.6	96.2	106.5
TABD	29.1	57.8	96.0	140.2	200.2	257.9	401.9
TABM	24.4	39.0	58.4	83.7	122.6	176.2	212.0
TABS	36.4	81.2	121.5	150.2	164.3	176.1	168.4
Forecasts	28	27	25	23	21	18	14

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Lorenzo, 23 September–2 October 2019. 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	7.6	10.7	**8.6**	**8.7**	**12.7**	**11.6**	**11.4**
OCD5	11.1	15.4	15.4	16.3	21.9	23.8	23.6
Forecasts	36	34	32	30	26	22	18
OFCL (2014-18)	5.3	7.9	9.9	11.2	13.3	14.4	14.2
OCD5 (2014-18)	6.9	10.9	14.3	17.4	20.9	22.0	22.8

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Lorenzo, 23 September–2 October 2019. 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 6a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	8.8	11.4	9.8	9.0	13.4	9.7	11.7
OCD5	11.4	15.6	15.6	15.3	20.3	18.8	21.1
HCCA	**8.5**	**10.8**	11.0	10.9	14.4	12.6	14.3
FSSE	**8.2**	**9.9**	**9.6**	**8.8**	**12.6**	**9.2**	12.3
ICON	8.9	**11.3**	12.2	14.0	16.0	11.1	12.1
IVCN	**8.6**	**10.8**	11.9	13.0	14.7	**9.6**	**10.9**
IVDR	**8.4**	**11.0**	12.5	13.5	15.5	10.7	**11.4**
HWFI	9.5	**11.0**	12.7	15.1	18.7	12.9	12.9
HMNI	8.9	11.9	12.8	12.8	16.2	12.7	12.4
DSHP	9.4	12.6	14.3	17.0	20.8	19.4	20.3
LGEM	10.3	14.2	15.6	17.7	19.6	17.4	18.7
GFSI	9.0	13.9	17.1	20.4	23.8	16.5	16.1
EMXI	10.9	15.3	17.0	20.7	22.7	15.6	20.7
Forecasts	29	28	26	24	22	19	15

Table 7. Watch and warning summary for Hurricane Lorenzo.

Date/Time (UTC)	Action	Location
30/0300	Tropical Storm Watch issued	Eastern Azores
30/0300	Hurricane Watch issued	Central Azores to Western Azores
30/1500	Tropical Storm Watch changed to Tropical Storm Warning	Eastern Azores
30/1500	Hurricane Watch changed to Hurricane Warning	Central Azores to Western Azores
2/1500	Tropical Storm Warning Discontinued	Eastern Azores
2/1500	Hurricane Warning Discontinued	Central Azores to Western Azores

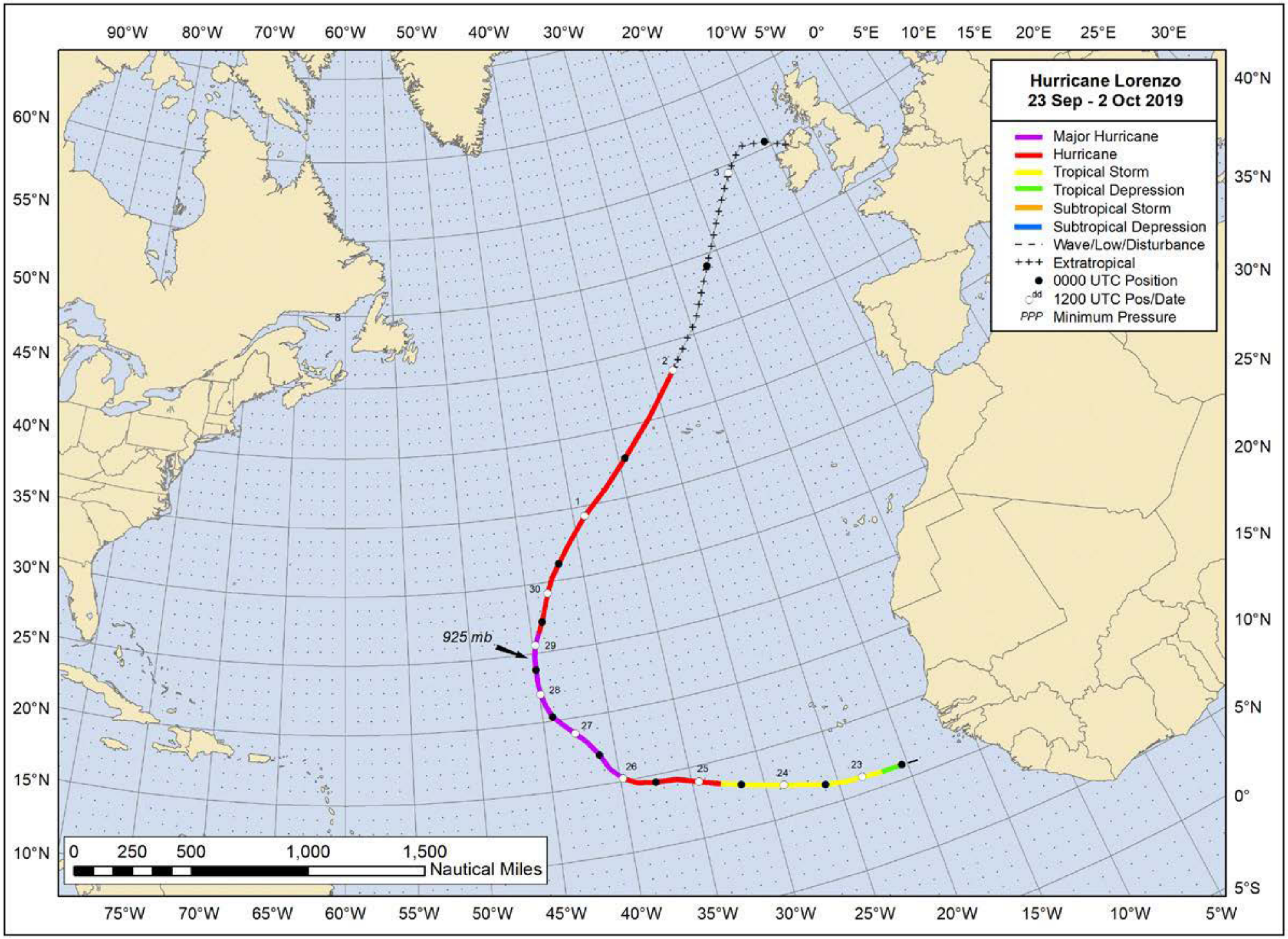


Figure 1. Best track positions for Hurricane Lorenzo 23 September–2 October 2019.

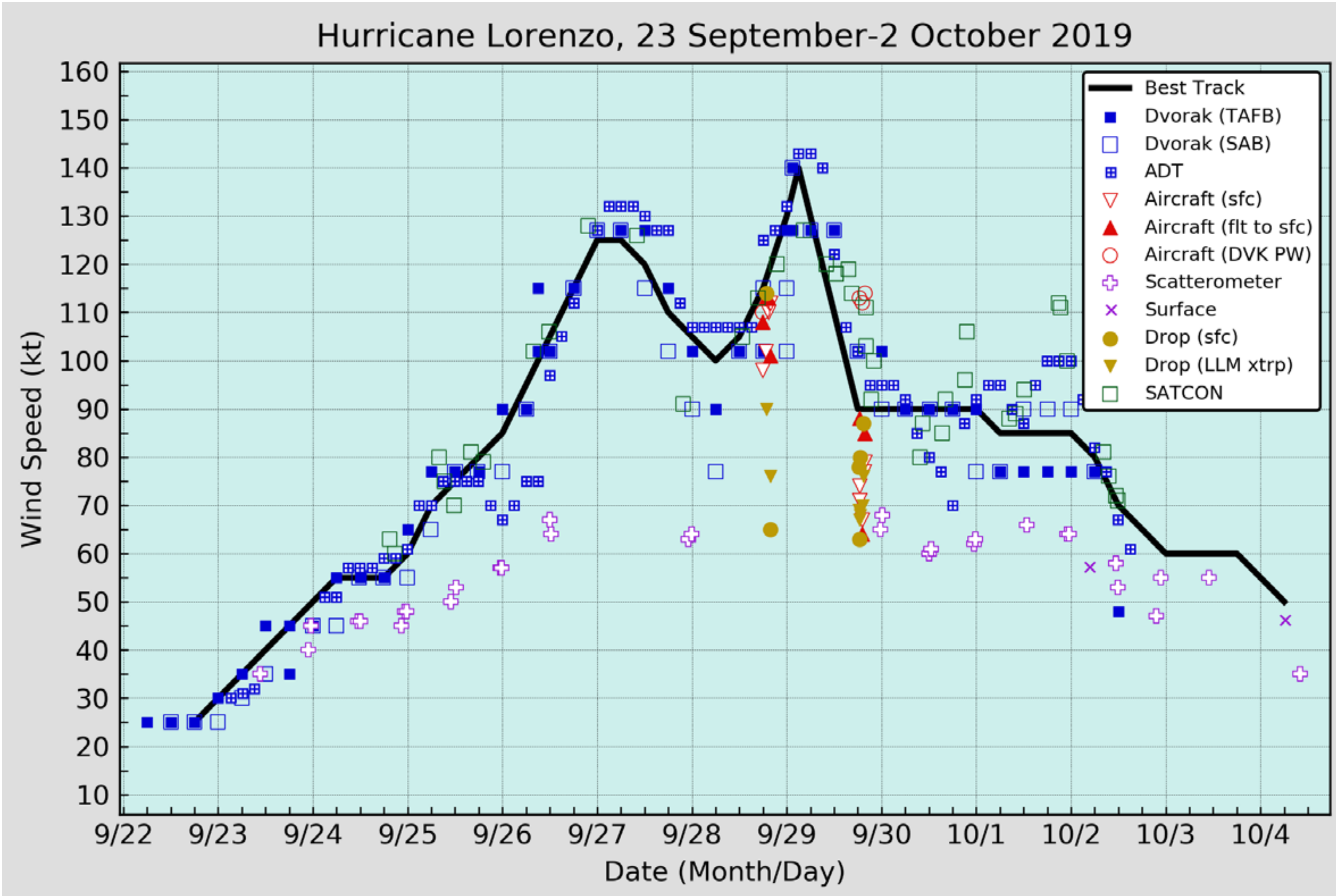


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Lorenzo. Aircraft observations have been adjusted for elevation using a 90% adjustment factor for observations from 700 mb. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM xtrp). 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.

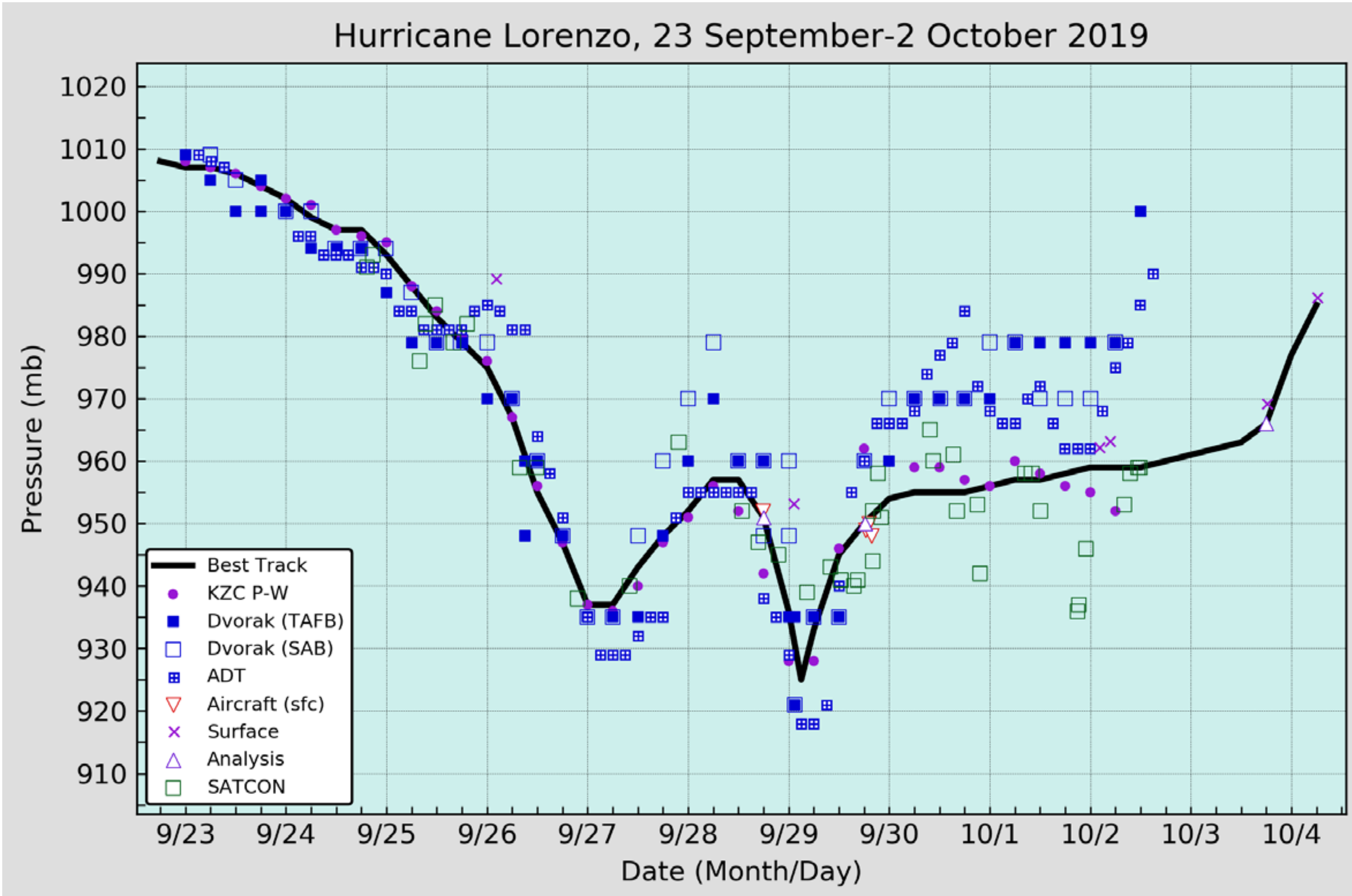


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Lorenzo. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite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

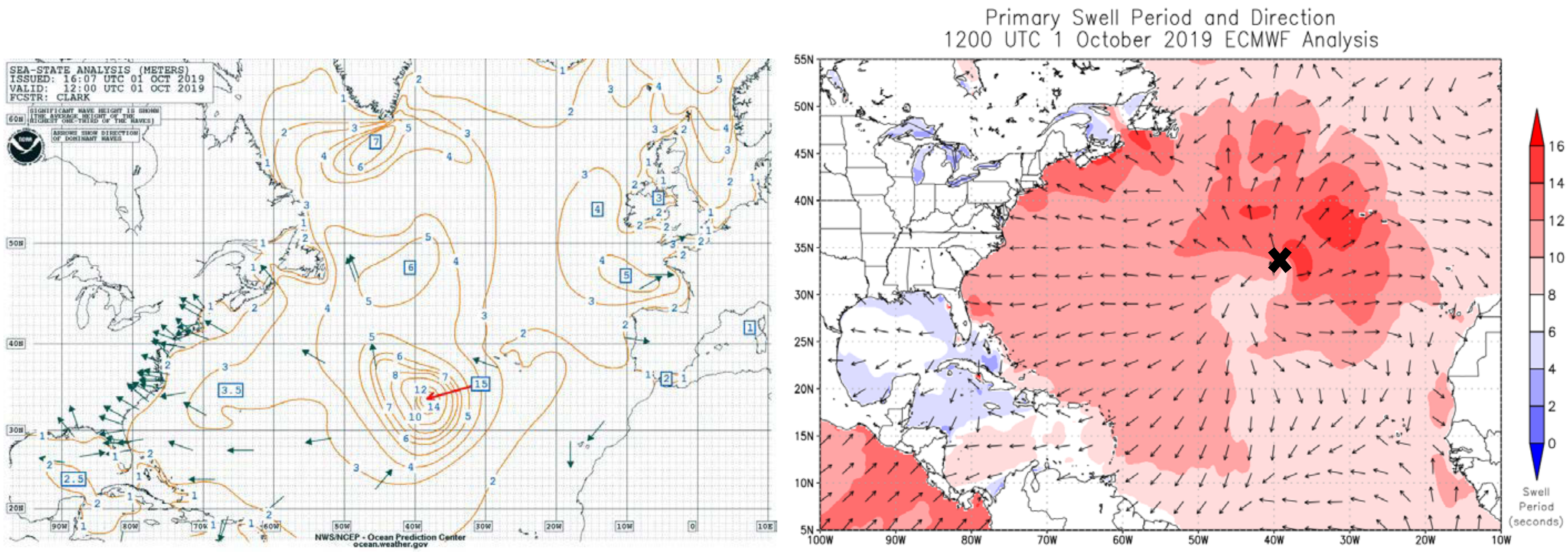


Figure 4. Waves and swell associated with Hurricane Lorenzo, valid at 1200 UTC 1 October 2019. The image on the left is the North Atlantic sea state analysis from the Ocean Prediction Center. The orange contours show significant wave height (average height of the highest one-third of the waves) in meters and the arrows show the direction of the dominant waves. The image on the right shows the mean total swell period (seconds) and direction in the ECMWF wave model analysis at the same time. The black X shows the approximate location of Lorenzo at the time of the model analysis. Large waves and long-period swells from Lorenzo affected most of the North Atlantic basin in late September and early October. Rip currents and rough surf caused 8 deaths along the east coast of the United States between 30 September and 3 October.

Figure 6. Extensive damage to the commercial port on Flores due to damaging wind and waves associated with the passage of Lorenzo. The bottom two images show a before and after aerial view of the port. Images courtesy of Fred Fournier/AeroGrafica.pt

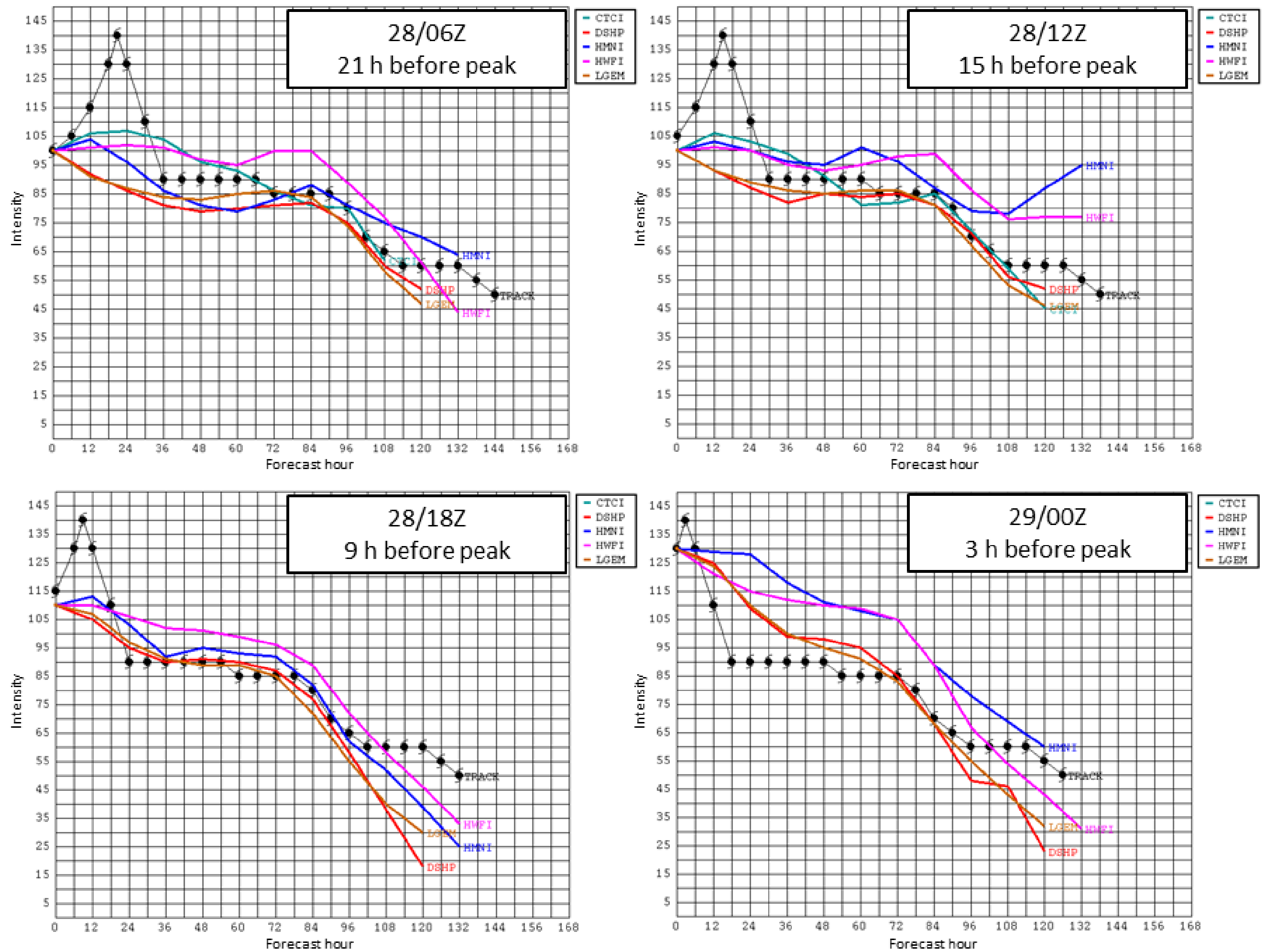


Figure 7. Intensity guidance available during the 4 advisory cycles prior to Lorenzo's peak intensity. The 5 members of the intensity variable consensus (IVCN) are pictured with colored lines (HWFI, HMNI, CTCI, DSHP, LGEM) and the best track is in black. The CTCI model was not available for the 28/18Z and 29/00Z forecasts. None of these models properly forecast the rapid strengthening or weakening of Lorenzo on 28–29 September. Differences between the initial model intensities and the best track at 28/12Z and 28/18Z are due to adjustments made to the best track in post-analysis.