NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

TROPICAL STORM MELISSA

(AL142019)

11–14 October 2019

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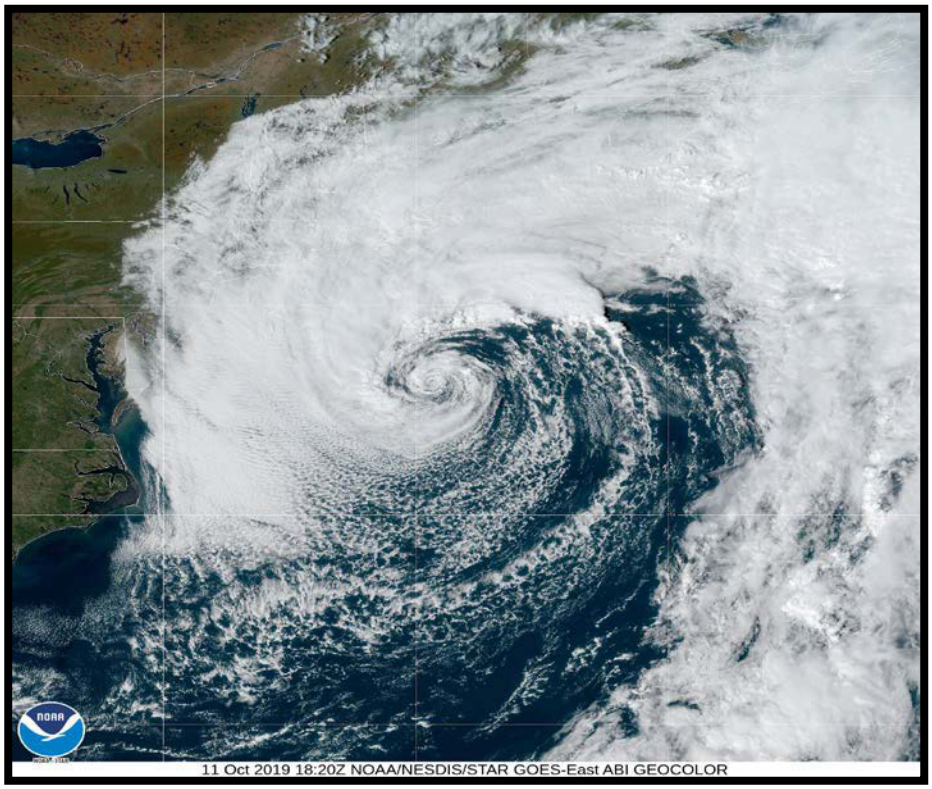

GOES-EAST GEOCOLOR VISIBLE IMAGE OF MELISSA AS A SUBTROPICAL STORM OFF THE NORTHEAST U.S. COAST AT 1820 UTC 11 OCTOBER 2019. IMAGE COURTESY OF NOAA/NESDIS/STAR.

Melissa evolved from an extratropical low to a subtropical storm and then to a tropical storm while it meandered off the coast of New England over the course of a few days. Minor to moderate coastal flooding and beach erosion occurred along portions of the mid-Atlantic and New England coasts.

Tropical Storm Melissa

11–14 OCTOBER 2019

SYNOPTIC HISTORY

On 6 October, a cold front stalled over the southwestern Atlantic Ocean. Over the next two days, the tail end of the front lifted northwestward ahead of an approaching mid-latitude trough moving across the eastern United States, and a frontal low producing gale-force winds formed by 1800 UTC 8 October about 70 n mi east of Cape Hatteras, North Carolina. The low moved quickly northeastward and strengthened off the mid-Atlantic coast of the United States on 9 October, but it then occluded early on 10 October and began meandering southeast of the New England coast as a strong nor'easter with maximum sustained winds of 55 kt. The associated occluded front became detached from the low itself the next day, and at the same time, deep convection developed just to the north of the low's center. Because the surface low had a large radius of maximum winds (more than 100 n mi) and was collocated with an upper-level low, the cyclone's structural changes marked its transition to a subtropical storm by 0600 UTC 11 October while it was located about 180 n mi south-southeast of Nantucket, Massachusetts. Melissa was at its peak intensity at the time of genesis, still with maximum winds of 55 kt. The "best track" chart of Melissa'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].

Melissa continued to meander off the coast of New England as a subtropical storm for another day and a half, and its maximum winds gradually decreased. On 12 October, deep convection developed over Melissa's center, and the cyclone's gale-force wind field, as well as its radius of maximum winds, contracted considerably. Melissa became a tropical storm by 1200 UTC that day while centered about 230 n mi south-southeast of Nantucket, and it began to move faster toward the east-northeast as the upper-level pattern became more progressive. Moderate-to-strong westerly shear affected Melissa during its tropical phase, which led to most of the deep convection being displaced to the east of the center—as well as an additional decrease in intensity—while the cyclone moved farther out over the Atlantic. Even stronger shear and cold waters caused all deep convection to dissipate early on 14 October, and as Melissa merged with a nearby front, it became a gale-force extratropical low by 1200 UTC while located about 350 n mi south of Cape Race, Newfoundland. The circulation of the extratropical low opened up later that day, and the cyclone dissipated soon after 1800 UTC.

[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.

METEOROLOGICAL STATISTICS

Observations in Melissa (Figs. 2 and 3) include subjective satellite-based Dvorak technique and Hebert-Poteat subtropical cyclone technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) 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 Melissa.

Melissa's estimated peak intensity of 55 kt at the time of genesis into a subtropical storm at 0600 UTC 11 October is based on ASCAT data from a few hours earlier which showed winds around 50 kt. In addition, the cruise ship *Caribbean Princess* (call sign ZCDG8) reported winds of 50 kt at 0200 UTC 11 October when it passed through the northeastern portion of Melissa's circulation. Given the typical undersampling of the ASCAT instrument, and that the ship may not have measured the strongest winds, Melissa's peak intensity is estimated to be 55 kt. The estimated minimum central pressure of 994 mb is based on several ship observations, particularly from the cruise ship *Grandeur of the Seas* (call sign C6SE3), which measured a quality-controlled pressure of 999 mb with 45-kt winds.

Ship reports of winds 34 kt or greater associated with Melissa are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3. Sustained tropical-storm-force winds occurred over portions of extreme southeastern New England during Melissa's transition from an extratropical cyclone to a subtropical and tropical storm (Fig. 4). The highest sustained winds measured on land were 43 kt at Wellfleet and 37 kt at Provincetown and Siasconset, Massachusetts. A gust to 57 kt was reported at Wellfleet, and a gust to 52 kt was measured at Provincetown. A site just offshore in Buzzards Bay measured a sustained wind of 41 kt and a gust to 50 kt, and NOAA buoy 44008 southeast of Nantucket reported a sustained wind of 49 kt and a gust to 56 kt.

Even though Melissa remained offshore, minor to moderate coastal flooding occurred along portions of the New England and mid-Atlantic coasts from Massachusetts to North Carolina, including within Chesapeake Bay, due to storm surge, high surf, and a spring tide. The highest measured storm surge[2] was 3.90 ft above normal tide levels at a National Ocean Service (NOS) gauge at Lewes, Delaware. The combined effect of the surge and tide produced inundation levels of 1 to 3 ft above ground level, with the highest reported water levels being 2.9 ft above Mean

[2] Several terms are used to describe water levels due to a storm. **Storm surge** is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum. **Storm tide** is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88) or Mean Lower Low Water (MLLW). **Inundation** is the total water level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height above ground level. At the coast, normally dry land is roughly defined as areas higher than the normal high tide line, or Mean Higher High Water (MHHW).

Higher High Water (MHHW) at Atlantic City, New Jersey, and Lewisetta, Virginia (Fig. 5). Elsewhere along the mid-Atlantic coast, water levels of 2.8 ft MHHW were measured at Bishops Head and Solomons Island, Maryland, and 2.7 ft MHHW was observed at Lewes, Delaware, and Duck, North Carolina.

A few inches of rain fell across portions of extreme southeastern New England from Melissa's outer rain bands. A maximum of 3.43 inches of rain was measured on Nantucket, and other sites in Massachusetts and Rhode Island recorded less than three inches.

CASUALTY AND DAMAGE STATISTICS

There were no reported deaths associated with Melissa, and damage was minor. Storm surge, high tides, and rough surf caused minor to moderate coastal flooding and beach erosion along portions of the mid-Atlantic coast while Melissa meandered offshore. The flooding caused the closure of several roads near the coasts of New Jersey, Delaware, Maryland, and Virginia, and overwash of coastal dunes occurred as far south as the North Carolina Outer Banks. Gusty winds brought down some trees and power lines across southeastern Massachusetts.

FORECAST AND WARNING CRITIQUE

NHC forecasters recognized the possibility of Melissa's transition to a subtropical cyclone well in advance, but they never had much confidence the transition would actually occur. Table 4 provides the number of hours in advance of formation associated with the first NHC Tropical Weather Outlook (TWO) forecast in each likelihood category. The formation of a non-tropical low pressure system was first mentioned in the TWO and given a low (<40%) 5-day chance of becoming a tropical or subtropical cyclone 132 h (5.5 days) before Melissa became a subtropical storm. The precursor extratropical low was given a low 48-h chance of becoming a subtropical cyclone 78 h (3.25 days) before Melissa's genesis. However, neither of these probabilistic forecasts ever reached the medium or high categories before formation occurred since it was believed the low would remain extratropical.

A verification of NHC official track forecasts for Melissa is given in Table 5a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period at all time periods for which official forecasts verified (12–48 h), even though climatology and persistence (OCD5) errors were much larger than normal at 36 and 48 h. A homogeneous comparison of official track errors with selected guidance models is given in Table 5b. Some models, including the ECMWF model (EMXI) and the UKMET model (EGRI), were not available for enough forecast cycles to meet the homogeneity requirement for the verification sample. The NHC official track forecasts were accurate overall and had lower errors than most of the model guidance. The only models that had lower errors than the official forecasts at more than one verifying time were the Florida State Superensemble (FSSE) and the GFS ensemble mean (AEMI).

A verification of NHC official intensity forecasts for Melissa is given in Table 6a. Official forecast intensity errors were lower than the mean official errors for the previous 5-yr period at all forecast times for which the official forecasts verified (12–48 h). A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b. Despite the generally low NHC official intensity forecast errors, most intensity models had even lower errors. NHC's forecasts had a slight low bias, anticipating that Melissa would weaken faster than it did.

Coastal tropical cyclone wind and storm surge watches or warnings were not issued in association with Melissa. The National Weather Service already had high wind and coastal flood warnings in effect when Melissa made the transition from a nor'easter to a subtropical storm, and these warnings were maintained in lieu of issuing tropical cyclone warnings to avoid message confusion in the midst of the event.

Table 1. Best track for Tropical Storm Melissa, 11–14 October 2019.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
08 / 1800	35.0	74.1	1009	40	extratropical
09 / 0000	36.1	72.4	1009	40	"
09 / 0600	37.0	70.4	1008	45	"
09 / 1200	37.7	68.8	1007	45	"
09 / 1800	38.4	68.1	1006	50	"
10 / 0000	38.9	68.2	1004	55	"
10 / 0600	38.9	68.7	1002	55	"
10 / 1200	38.6	69.2	1000	55	"
10 / 1800	38.0	69.2	998	55	"
11 / 0000	37.9	68.4	996	55	"
11 / 0600	38.4	68.7	994	55	subtropical storm
11 / 1200	38.6	69.4	995	50	"
11 / 1800	38.2	69.7	996	50	"
12 / 0000	37.8	69.1	997	50	"
12 / 0600	37.9	68.4	998	45	"
12 / 1200	38.0	67.5	998	45	tropical storm
12 / 1800	38.2	66.3	998	45	"
13 / 0000	38.6	64.9	998	45	"
13 / 0600	39.1	63.5	999	40	"
13 / 1200	39.5	61.7	1000	40	"
13 / 1800	39.7	59.8	1001	35	"
14 / 0000	40.0	57.9	1002	35	"
14 / 0600	40.5	55.5	1003	35	"
14 / 1200	40.8	52.9	1004	35	extratropical
14 / 1800	40.9	49.8	1004	35	"
15 / 0000					dissipated
11 / 0600	38.4	68.7	994	55	maximum winds and minimum pressure

Table 2. Selected ship reports with winds of at least 34 kt for Tropical Storm Melissa and the predecessor extratropical low. Note that many wind observations are taken from anemometers located well above the standard 10-m observation height.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
08 / 2300	C6BR3	33.8	65.8	150 / 35	1027.0
09 / 0000	WLMQ	33.7	67.3	170 / 45	1014.4
09 / 0400	WARL	40.6	70.9	060 / 35	1020.2
09 / 0500	WARL	40.7	70.9	060 / 38	1020.1
09 / 0600	WARL	40.8	70.9	060 / 38	1020.2
09 / 0800	V7NQ9	38.8	72.0	050 / 35	1015.0
09 / 0800	WARL	41.0	70.9	060 / 37	1020.4
09 / 0900	C6BI7	34.6	68.7	310 / 39	1012.8
09 / 1000	WARL	41.3	70.9	050 / 35	1021.8
09 / 1400	C6PT7	37.9	65.1	130 / 44	1013.3
09 / 2000	V7NQ9	37.5	70.7	050 / 35	1015.0
09 / 2300	V7NQ9	37.0	70.8	360 / 35	1011.0
10 / 0200	C6SE3	43.3	63.3	090 / 35	1031.8
10 / 0400	C6SE3	42.9	63.3	080 / 35	1029.7
10 / 0500	C6SE3	42.6	63.3	070 / 44	1027.5
10 / 0600	WCE506	41.5	71.4	020 / 35	1021.2
10 / 0600	C6SE3	42.2	63.3	080 / 47	1026.4
10 / 0600	ZCEK6	43.2	65.9	060 / 42	1023.1
10 / 0700	9HJC9	43.3	66.8	050 / 38	1024.0
10 / 0800	9HJC9	43.3	66.5	050 / 35	1024.0
10 / 0900	C6SE3	41.3	63.3	080 / 48	1022.1
10 / 0900	WCE506	41.5	71.4	010 / 36	1020.9
10 / 0900	C6SE3	41.7	63.3	080 / 43	1023.9
10 / 1000	C6SE3	41.0	63.3	080 / 50	1021.1
10 / 1000	WCE506	41.5	71.4	010 / 35	1020.9
10 / 1600	C6SE3	39.6	62.9	090 / 40	1017.7
10 / 1700	C6SE3	39.5	63.1	100 / 45	1014.7
10 / 1700	WCE506	41.5	71.4	010 / 35	1021.4
10 / 1800	C6SE3	39.7	63.7	090 / 40	1012.7
10 / 2000	9V9922	37.6	74.7	010 / 35	1020.0

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
10 / 2000	WCE506	41.5	71.4	010 / 38	1020.3
10 / 2200	WMCU	39.0	73.9	360 / 39	1017.1
10 / 2300	WCE506	41.5	71.4	020 / 36	1020.7
11 / 0000	WMCU	39.4	73.8	350 / 39	1017.7
11 / 0000	WCE506	41.5	71.4	020 / 35	1020.4
11 / 0000	C6FV8	43.6	64.5	080 / 40	1018.0
11 / 0100	C6SE3	38.7	65.9	150 / 35	1008.7
11 / 0200	ZCDG8	43.2	65.5	070 / 50	1023.9
11 / 0300	WMCU	39.9	73.7	010 / 37	1018.9
11 / 0400	9V9922	37.0	75.4	030 / 35	1020.0
11 / 0400	C6SE3	38.4	66.9	140 / 42	1003.7
11 / 0500	C6SE3	38.3	67.3	170 / 45	1002.6
11 / 0600	WCE506	41.5	71.4	010 / 35	1019.0
11 / 0600	PDAN	43.5	66.5	060 / 36	1023.5
11 / 0800	WCE506	41.5	71.4	010 / 37	1017.8
11 / 0800	PDAN	43.7	66.9	050 / 42	1023.6
11 / 0800	PDAN	43.9	67.2	060 / 40	1024.3
11 / 0900	C6FN5	43.7	67.2	050 / 35	1024.4
11 / 0900	PDAN	44.0	67.6	050 / 43	1026.0
11 / 1000	WCE506	41.5	71.4	010 / 36	1017.4
11 / 1000	C6FN5	43.5	67.3	050 / 35	1023.1
11 / 1100	WCE506	41.5	71.4	020 / 37	1017.5
11 / 1100	C6FN5	43.4	67.4	050 / 35	1022.5
11 / 1200	C6FN5	43.3	67.5	060 / 38	1022.5
11 / 1300	C6FN5	43.2	67.6	060 / 40	1021.9
11 / 1400	C6FN5	43.0	67.7	050 / 40	1021.2
11 / 1500	C6FN5	42.9	67.8	050 / 40	1020.1
11 / 1600	9V3143	34.5	74.7	340 / 35	1016.0
11 / 1600	V7YW2	41.9	62.6	090 / 36	1016.0
11 / 1600	C6FN5	42.8	67.8	050 / 50	1019.3
11 / 1700	KRIJ	36.3	72.7	310 / 35	1011.9
11 / 1800	KRIJ	36.2	72.4	350 / 35	1010.8
11 / 1800	C6SE3	37.1	71.2	320 / 48	1006.6

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
11 / 1800	A8AX8	40.3	72.8	020 / 40	1015.8
11 / 1800	WCE506	41.5	71.4	010 / 37	1017.3
11 / 1800	IOSN3	43.0	70.6	040 / 35	1020.6
11 / 1900	C6SE3	37.1	71.8	340 / 49	1006.7
11 / 1900	C6FN5	42.4	67.9	050 / 45	1016.3
11 / 2000	C6SE3	37.1	71.9	350 / 43	1007.7
11 / 2100	KRIJ	36.0	71.4	320 / 35	1008.6
11 / 2100	C6FN5	42.1	68.2	030 / 50	1014.9
11 / 2200	C6SE3	37.0	72.5	350 / 51	1012.7
11 / 2200	ZCEK6	40.5	70.1	050 / 40	1007.9
11 / 2200	C6FN5	41.9	68.3	030 / 50	1013.9
11 / 2300	C6SE3	37.0	72.9	360 / 48	1013.7
11 / 2300	PDAN	44.1	68.1	060 / 35	1021.9
11 / 2300	IOSN3	43.0	70.6	040 / 36	1019.5
12 / 0000	KABL	36.8	73.8	360 / 38	1015.7
12 / 0000	C6SE3	37.0	73.3	350 / 46	1015.7
12 / 0000	C6FN5	41.6	68.5	090 / 45	1011.4
12 / 0100	C6SE3	36.9	73.7	360 / 40	1015.7
12 / 0100	WCE506	41.5	71.4	010 / 35	1016.2
12 / 0100	C6FN5	41.5	68.6	090 / 45	1011.1
12 / 0100	PDAN	43.8	68.3	050 / 35	1020.5
12 / 0200	C6FN5	41.3	68.6	050 / 45	1010.5
12 / 0300	C6FN5	41.1	68.7	360 / 45	1009.5
12 / 0300	ZCDG8	43.7	68.3	030 / 50	1018.7
12 / 0300	IOSN3	43.0	70.6	040 / 35	1017.3
12 / 0400	C6FN5	40.9	68.8	060 / 45	1008.5
12 / 0600	C6BR3	35.0	67.3	110 / 46	1009.0
12 / 0600	V7DQ4	37.7	66.2	180 / 35	1002.0
12 / 0600	C6FN5	40.5	68.9	050 / 40	1006.6
12 / 0700	PDAN	42.6	69.6	040 / 35	1014.6
12 / 0800	C6BI7	41.5	69.5	040 / 42	1008.2
12 / 0900	C6BR3	35.7	68.0	270 / 48	1007.0
12 / 1100	C6FN5	40.5	69.9	020 / 43	1007.9

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
12 / 1100	C6BI7	41.9	69.7	040 / 40	1012.4
12 / 1400	C6FN5	40.5	70.5	060 / 40	1009.9
12 / 1400	C6FN5	40.5	70.4	050 / 40	1009.7
12 / 1600	V7DQ4	37.9	68.0	020 / 40	998.0
12 / 1600	C6FN5	40.5	70.9	020 / 40	1011.2
12 / 1800	C6FN5	40.5	71.3	020 / 35	1011.6
13 / 0700	WMKN	40.3	62.8	020 / **	1004.4
14 / 1200	WDC692	39.7	53.1	300 / 39	1011.6

Table 3. Selected surface observations for Tropical Storm Melissa (including during the extratropical phase before Melissa became a subtropical cyclone).

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Massachusetts									
International Civil Aviation Organization (ICAO) Sites									
Nantucket (KACK) (41.25N 70.06W)			10/1520	35	47				3.43
Martha's Vineyard (KMVY) (41.39N 70.61W)			10/1058		45				1.01
Falmouth – Cape Cod Coast Guard Air Station (KFMH) (41.66N 70.52W)			11/0845		40				
Hyannis (KHYA) (41.67N 70.28W)			11/2225		39				1.04
Plymouth (KPYM) (41.91N 70.73W)			10/1848		39				1.07
Provincetown (KPVC) (42.07N 70.22W)			11/1205		38				
Lawrence (KLWM) (42.72N 71.12W)			11/1751		37				0.03
Chatham (KCQX) (41.69N 69.99W)			11/2147		36				2.01
Boston (KBOS) (42.36N 71.01W)			11/0835		36				0.09
Beverly (KBVY) (42.58N 70.92W)			11/1437		34				0.05
Coastal-Marine Automated Network (C-MAN) Sites									
Buzzards Bay (BUZM3) (41.40N 71.03W)	12/1000	1011.2	11/1120	41 (25 m, 10 min)	50				
National Ocean Service (NOS) Sites									
Woods Hole (BZBM3) (41.52N 70.67W)	12/1100	1011.3				1.97	2.48	1.6	
Nantucket Island (NTKM3) (41.29N 70.10W)	12/0842	1010.1	10/0148	28 (9 m)	42	2.57		1.5	
Boston (BHBM3) (42.35N 71.05W)						2.46	6.00	1.2	
Fall River (FRVM3) (41.70N 71.16W)	12/0954	1012.7				2.05	3.50	1.2	
Borden Flats Light at Fall River (BLTM3) (41.71N 71.17W)			10/1942	29 (13 m)	39				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Weatherflow Sites									
Vineyard Haven (41.46N 70.59W)			10/1217	35 (10 m)	47				
Wellfleet (41.93N 69.98W)			11/0409	34 (6 m)	47				
Dog Bar Breakwater (42.58N 70.67W)			11/1151	34 (14 m)	47				
Sagamore Beach (41.79N 70.52W)			11/1848	34 (10 m)	42				
Duxbury (42.06N 70.65W)			11/1848	34 (12 m)	41				
Nantucket Harbor DB (41.32N 70.04W)			10/1540		47				
Kalmus (41.93N 69.98W)			11/1819		46 (10 m)				
West Island (41.58N 70.82W)			11/1000		43 (10 m)				
Hull (42.31N 70.89W)			10/2344		43 (12 m)				
Hatch Beach (41.63N 70.28W)			11/1211		42 (10 m)				
Chatham (41.66N 69.98W)			11/1354		42 (9 m)				
Chapin (41.73N 70.23W)			10/0103		42 (9 m)				
Woods Hole Passage Light (41.52N 70.68W)			10/0642		41 (12 m)				
Children's Island (42.51N 70.82W)			11/1433		41 (9 m)				
Scituate (42.20N 70.72W)			11/1435		40 (10 m)				
Pleasure Bay (42.33N 71.02W)			11/0752		40 (9 m)				
Duxbury Bay (42.04N 70.67W)			10/1944		39 (15 m)				
Deer Island (42.34N 70.95W)			11/1526		39 (17 m)				
Plum Island (42.81N 70.82W)			12/0023		39 (15 m)				
West Dennis (41.65N 70.17W)			11/1343		38 (13 m)				
Nantucket Harbor (41.31N 70.06W)			10/1655		37 (7 m)				
West Falmouth (41.60N 70.65W)			10/0845		36 (10 m)				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Dread Ledge (42.46N 70.89W)			11/1209		36 (11 m)				
Squantum (42.28N 71.01W)			11/0602		34 (16 m)				
Mesonet Sites									
Cisco			10/0730	36	47				
Citizen Weather Observer Program (CWOP) Sites									
Wellfleet (FW3885) (41.94N 69.98W)			11/1251	43	57				
Provincetown (FW5824) (42.07N 70.19W)			11/1235	37	52				
Siasconset (DW0935) (41.26N 69.96W)			10/1516	37	48				
Rockport			11/1955		48				
Nantucket Harbor			10/1540		47				
Truro			9/1347		44				
West Chatham			11/2210		38				
Gloucester			11/1010		36				
Milton			11/1637		36				
Orleans			10/1445		35				
Wareham			10/1038		35				
Bourne			11/0714		34				
Winchester									2.89
Ham Radio									
Nantucket			10/1615		52				
Aquinnah			10/1227		50				
Edgartown			10/1147		48				
Marstons Mills			11/1144		44				
Fairhaven			11/0809		39				
Fall River			11/1000		37				
Plymouth			11/0835		36				
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
3 ENE Harwich									2.48
West Harwich									2.20

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Rhode Island									
ICAO Sites									
Block Island (KBID) (41.17N 71.58W)			11/1116		41				0.44
North Kingstown - Quonset (KBID) (41.60N 71.41W)			11/1850		40				
Newport (KUUU) (41.53N 71.28W)			11/0910		39				0.49
Westerly (KWST) (41.35N 71.80W)			10/1404		37				0.97
Providence (KPVD) (41.72N 71.43W)			11/1928		34				0.93
Pawtucket (KSFZ) (41.92N 71.49W)			11/1752		34				0.36
NOS Sites									
Newport (NWPR1) (41.51N 71.33W)	12/0936	1012.2	10/2042	24 (8 m)	36	2.17	3.30	1.5	
Quonset Point (QPTR1) (41.59N 71.41W)			11/1330	30 (7 m)	38	2.03		1.3	
Conimicut Light (CPTR1) (41.72N 71.34W)			11/1048	28 (21 m)	37	1.96		1.1	
Providence (FOXR1) (41.81N 71.40W)			11/0730	24 (18 m)	36	1.89	3.42	1.1	
Potter Cove, Prudence Island (PTCR1) (41.64N 71.34W)			11/1212	26 (9 m)	34				
Weatherflow Sites									
Block Island Jetty (41.20N 71.59W)			11/1151	38 (11 m)	46				
University of Rhode Island (41.49N 71.42W)			10/0944	35 (10 m)	43				
Sakonnet Vineyards (41.53N 71.19W)			11/1033		42 (10 m)				
Ninigret Pond (41.34N 71.69W)			10/1340		40 (11 m)				
Point Judith (41.36N 71.50W)			10/0954		43 (16 m)				
Beavertail (41.45N 71.40W)			10/1033		37 (12 m)				
CWOP Sites									
Middletown			11/1243		36				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Hydrometeorological Automated Data System (HADS) Sites									
Providence 1.4 SE			11/0906		36				
South Kingston 3.9 SW			11/1225		36				
Ham Radio									
Bristol			11/1308		37				
Warwick			11/0854		36				
Watch Hill			11/1411		35				
Connecticut									
ICAO Sites									
New Haven (KHVN) (41.26 72.89W)			10/1253		36				
Groton/New London (KGON) (41.33 72.05W)			11/1815		35				
NOS Sites									
Bridgeport (BRHC3) (41.18 73.18W)	14/2000	1011.6				2.77	5.30	1.8	
New Haven (NWHC3) (41.28 72.91W)	14/1936	1011.8				2.49		1.7	
New London (NLNC3) (41.36 72.09W)	14/1936	1012.3				2.16	2.90	1.7	
Weatherflow Sites									
Stonington Outer Breakwater 4 (41.32N 71.91W)			11/1244		43 (11 m)				
USCG Academy (41.37N 72.09W)			11/1557		40 (17 m)				
University of Connecticut, Department of Marine Sciences									
New London Ledge Light, New London Harbor (LDLC3) (41.31N 72.08W)			11/1815		43 (20 m)				
New York									
ICAO Sites									
Downtown Manhattan / Wall Street Heliport (KJRB) (40.70N 74.00W)			11/1156		38				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Montauk Airport (KMTP) (41.08N 71.92W)			11/1754		35				
Islip – MacArthur Airport (KISP) (40.80N 73.10W)			10/1310		34				
Westhampton Beach – Gabreski Airport (KFOK) (40.84N 72.63W)			9/1855		34				
NOS Sites									
The Battery (BATN6) (40.70N 74.01W)	14/2036	1012.4				3.13	4.72	2.4	
Bergen Point West Reach (BGNN6) (40.64N 74.15W)	14/2030	1012.4				3.17		2.3	
Turkey Point Hudson River NERRS (TKPN6) (42.01N 73.94W)	14/1930	1011.2				2.96		2.1	
Kings Point (KPTN6) (40.81N 73.77W)	14/2030	1012.8				3.23	5.63	2.0	
Montauk (MTKN6) (41.05 71.96W)	12/1018	1012.4				2.50	2.97	2.0	
Weatherflow Sites									
Great Gull Island (41.20N 72.12W)			10/0924	34 (16 m)	41				
Napeague (41.01N 72.06W)			10/1436		42 (10 m)				
Shinnecock Light (40.84N 72.48W)			11/2103		39 (12 m)				
Mecox Bay (40.91N 72.32W)			10/1625		36 (10 m)				
CWOP Sites									
Stony Brook (EW5678) (40.91N 73.12W)			11/0649	36 (48 m)	50				
Baiting Hollow (EW4141) (40.97N 72.71W)			11/0000		42 (24 m)				
Hampton Bays (EW9356) (40.85N 72.49W)			11/2104		39 (9 m)				
Shirley (EW5679) (40.74N 72.87W)			11/2159		38 (12 m)				
Orient (FW2389) (41.16N 72.24W)			10/0415		36 (2 m)				
Eastport (FW1522) (40.85N 72.73W)			11/1658		35 (21 m)				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Cutchogue (DW5360) (41.00N 72.44W)			11/2123		34 (2 m)				
Beechhurst (FW1633) (40.80N 73.80W)			11/1542		34				
New Jersey									
NOS Sites									
Atlantic City (ACYN4) (39.36N 74.42W)	14/2036	1014.1				3.52	4.84	2.9	
Cape May (CMAN4) (38.97N 74.96W)	14/0730	1013.7				3.82	5.04	2.6	
Sandy Hook (SDHN4) (40.47N 74.01W)	14/2048	1013.0				3.48	4.87	2.5	
Ship John Shoal (SJSN4) (39.31N 75.38W)	14/2012	1014.8				3.47		2.3	
Burlington – Delaware River (BDRN4) (40.08N 74.87W)	14/2012	1012.9				2.72		2.1	
Robbins Reef (ROBN4) (40.66N 74.07W)	14/2042	1012.2	11/0136	29 (16 m)	34				
Pennsylvania									
NOS Sites									
Marcus Hook (MRCP1) (39.81N 75.41W)	14/2006	1013.1				3.07		2.4	
Philadelphia (PHBP1) (39.93N 75.14W)	14/2012	1012.8				2.91	5.96	2.4	
Bridesburg (BDSP1) (39.98N 75.08W)	14/2006	1013.5				2.85		2.3	
Newbold (NBLP1) (40.14N 74.75W)	14/2006	1013.5				2.76		2.0	
Delaware									
NOS Sites									
Lewes (LWSD1) (38.78N 75.12W)	14/0730	1014.1				3.90	4.69	2.7	
Brandywine Shoal Light (BRND1) (38.99N 75.11W)	12/1924	1014.5				3.56		2.5	
Delaware City (DELD1) (39.58N 75.59W)	14/2000	1013.7				3.01		2.4	
Reedy Point (RDYD1) (39.56N 75.57W)	14/1954	1013.3				3.12	5.16	2.3	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Maryland									
NOS Sites									
Bishops Head (BISM2) (38.22N 76.04W)	14/0724	1014.6				2.81	3.56	2.8	
Solomons Island (SLIM2) (38.32N 76.45W)	12/1900	1013.8				2.73	3.40	2.8	
Annapolis (APAM2) (38.98N 76.48W)	12/1836	1013.7				2.94	3.38	2.7	
Cambridge (CAMM2) (38.57N 76.07W)	12/1906	1014.0				2.81	3.58	2.6	
Tolchester Beach (TCBM2) (39.21N 76.25W)	14/2024	1014.4				2.62		2.6	
Baltimore, Fort McHenry (BLTM2) (39.27N 76.58W)	14/2000	1013.7				2.88	3.33	2.5	
Ocean City Inlet (OCIM2) (38.33N 75.09W)	14/0736	1014.7				3.12	3.25	2.4	
Chesapeake City (CHCM2) (39.53N 75.81W)	14/2024	1014.1				2.77		2.4	
District of Columbia									
NOS Sites									
Washington (WASD2) (38.87N 77.02W)	12/1748	1014.3				2.98	4.26	2.5	
Virginia									
NOS Sites									
Lewisetta (LWTV2) (38.30N 76.46W)	12/1942	1014.0				2.81	3.55	2.9	
Wachapreague (WAHV2) (37.61N 75.69W)	14/0754	1013.8				3.33	4.65	2.8	
Dahlgren (NCDV2) (38.32N 77.04W)	12/1900	1013.3				2.84	3.63	2.8	
Chesapeake Channel (CHBV2) (37.03N 76.08W)	14/0824	1012.8				3.19		2.7	
Yorktown USCG Training Center (YKTV2) (37.23N 76.48W)	14/0724	1013.5				2.82	3.75	2.7	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Windmill Point (WNDV2) (37.62N 76.29W)						2.60	2.94	2.7	
Money Point (MNPV2) (36.78N 76.30W)	14/0818	1013.2				3.08		2.6	
Sewells Point (SWPV2) (36.95N 76.33W)	14/0830	1013.7				2.99	3.77	2.6	
Kiptopeke (KPTV2) (37.17N 75.99W)						2.79	3.56	2.5	
North Carolina									
NOS Sites									
Duck (DUKN7) (36.18N 75.75W)	14/0748	1013.7	9/0006		36 (9 m)	3.04	4.16	2.7	
Wrightsville Beach (JMPN7) (34.21N 77.79W)	12/2006	1015.1				2.11	3.82	2.1	
Oregon Inlet Marina (ORIN7) (35.80N 75.55W)	9/0006	1014.6				2.14	2.45	2.0	
USCG Station Hatteras (HCGN7) (35.21N 75.70W)	9/0000	1013.9				2.11	2.18	2.0	
Beaufort (BFTN7) (34.72N 76.67W)	9/0000	1014.4				1.98	3.38	1.9	
Wilmington (WLON7) (34.23N 77.95W)	12/1948	1015.4				2.05	3.54	1.5	
Marine Observations									
NOAA Buoys									
Nantucket (44008) (40.50N 69.25W)	12/0700	1006.1	10/0645	49 (4 m, 1 min)	56				
Georges Bank (44011) (41.07N 66.59W)	12/1740	1006.2	10/1142	45 (4 m, 1 min)	49				
Texas Tower #4, East of Long Beach, NJ (44066) (39.62N 72.64W)	12/0650	1011.7	10/2122	43 (4 m, 1 min)	49				
Long Island (44025) (40.25N 73.16W)	12/0850	1013.1	11/0130	35 (5 m, 1 min)	39				
Cape Cod (44018) (42.21N 70.14W)	12/1750	1011.9	11/1251	35 (5 m, 1 min)	41				
Nantucket Sound (44020)[l] (41.49N 70.28W)	12/1200	1010.6	10/0417	33 (4 m, 1 min)	41				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
New York Harbor Entrance (44065) (40.37N 73.70W)	12/2040	1013.5	09/1201	33 (4 m, 1 min)	37				
Boston (44013) (42.35N 70.65W)	12/1750	1012.2	11/1400	31 (5 m, 10 min)	39				
Northeastern Regional Association of Coastal Ocean Observing Systems Buoys									
Massachusetts Bay (44029) (42.52N 70.57W)			10/0645		36 (4 m)				

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Except as noted, sustained wind averaging periods for C-MAN and land-based reports are 2 min; buoy averaging periods are 8 min.
[c] Storm surge is water height above normal astronomical tide level.
[d] For most locations, storm tide is water height above the North American Vertical Datum of 1988 (NAVD88).
[e] Estimated inundation is the maximum height of water above ground. For NOS tide gauges, the height of the water above Mean Higher High Water (MHHW) is used as a proxy for inundation.
[l] Incomplete data
[E] Estimated

Table 4. 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%)	78	132
Medium (40%-60%)	-	-
High (>60%)	-	-

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Melissa, 11–14 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	**19.1**	**21.8**	**30.3**	**50.3**			
OCD5	43.2	100.7	199.7	307.0			
Forecasts	10	8	6	4			
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 Tropical Storm Melissa, 11–14 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	18.4	21.3	31.2	53.6			
OCD5	39.5	95.9	201.7	323.8			
GFSI	19.3	30.0	57.0	90.8			
HWFI	21.4	50.2	56.0	59.7			
HMNI	27.4	60.3	76.5	71.1			
CTCI	27.3	42.4	75.2	114.0			
TVCA	**18.0**	24.4	40.4	69.9			
TVCX	18.5	25.3	39.9	71.7			
TVDG	**18.1**	23.3	39.4	73.0			
GFEX	**17.6**	22.7	39.9	68.9			
HCCA	19.0	**19.8**	31.8	58.5			
FSSE	**17.0**	24.9	31.7	**52.3**			
AEMI	23.5	27.7	**29.4**	**42.9**			
TABS	40.7	67.5	120.2	209.5			
TABM	27.8	50.3	95.1	143.5			
TABD	42.5	110.5	218.6	358.5			
Forecasts	9	7	5	3			

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Melissa, 11–14 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	**3.0**	**7.5**	**8.3**	**8.8**			
OCD5	4.3	8.8	15.3	20.8			
Forecasts	10	8	6	4			
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 Tropical Storm Melissa, 11–14 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	2.8	7.1	7.0	8.3			
OCD5	3.8	7.7	14.2	18.3			
DSHP	**2.7**	**4.9**	**4.8**	**1.7**			
LGEM	2.9	**4.0**	**4.8**	**4.0**			
HWFI	3.1	**4.7**	**4.2**	**5.0**			
HMNI	4.7	7.3	7.0	**4.0**			
CTCI	2.9	**3.7**	**3.2**	**4.7**			
ICON	**2.7**	**4.6**	**4.4**	**2.3**			
IVCN	**2.7**	**3.9**	**4.0**	**1.3**			
HCCA	3.1	**4.7**	**4.4**	**1.7**			
FSSE	**2.3**	**4.6**	**4.2**	**2.0**			
GFSI	3.6	**5.1**	**4.4**	**6.0**			
Forecasts	9	7	5	3			

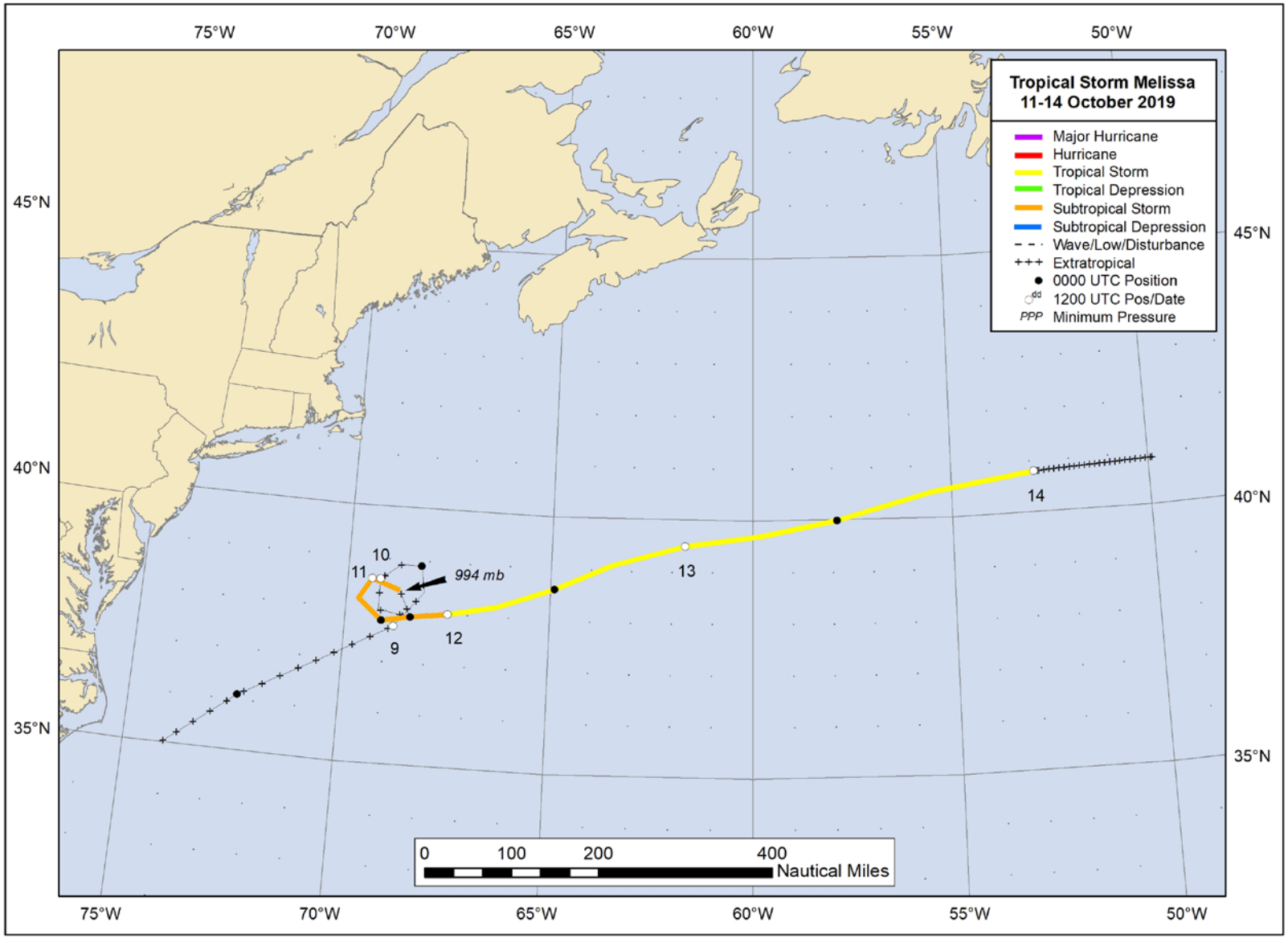

Figure 1. Best track positions for Tropical Storm Melissa, 11–14 October 2019.

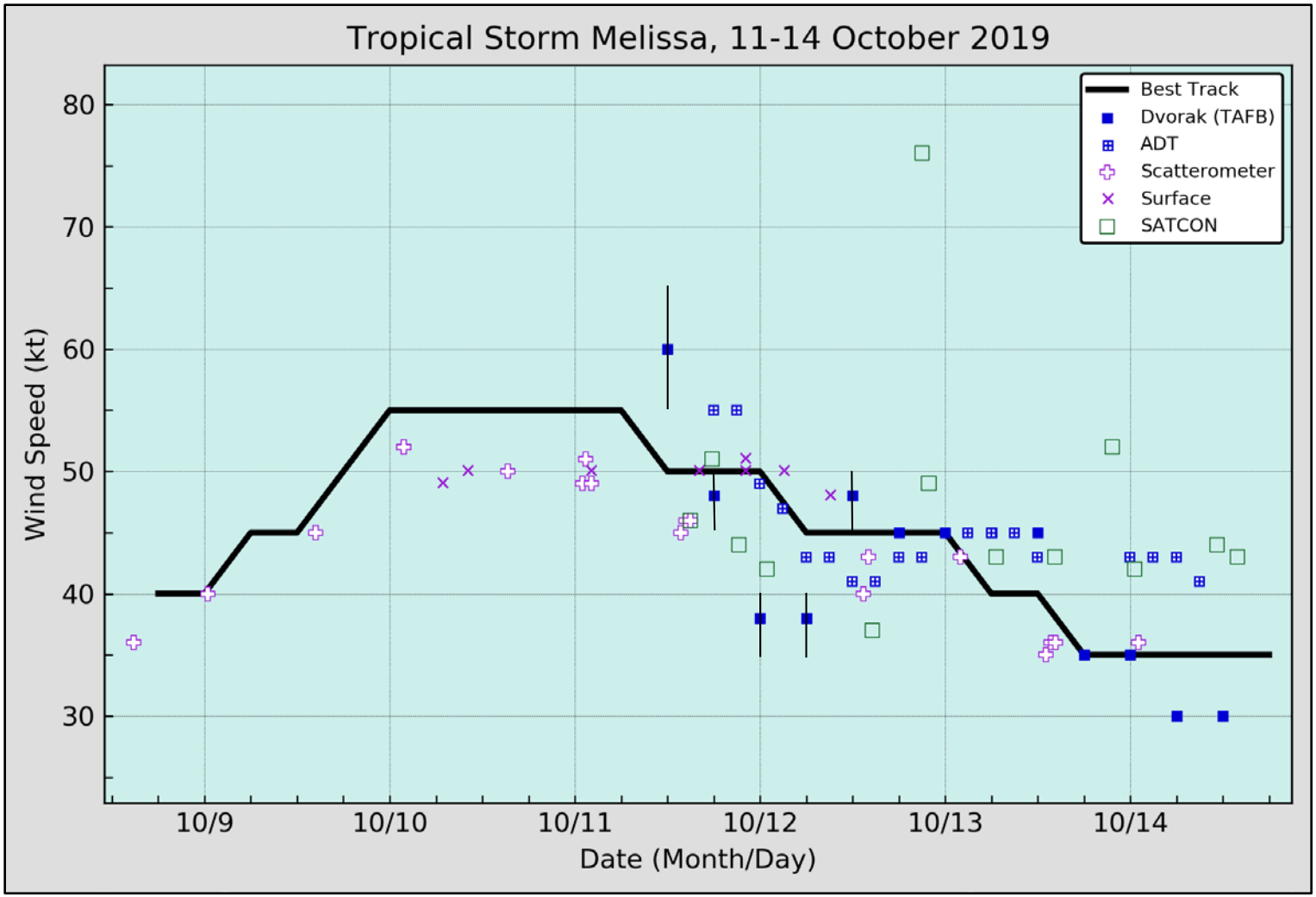

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Melissa, 11–14 October 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC. Short solid lines depict intensity ranges associated with Hebert-Poteat subtropical satellite classifications.

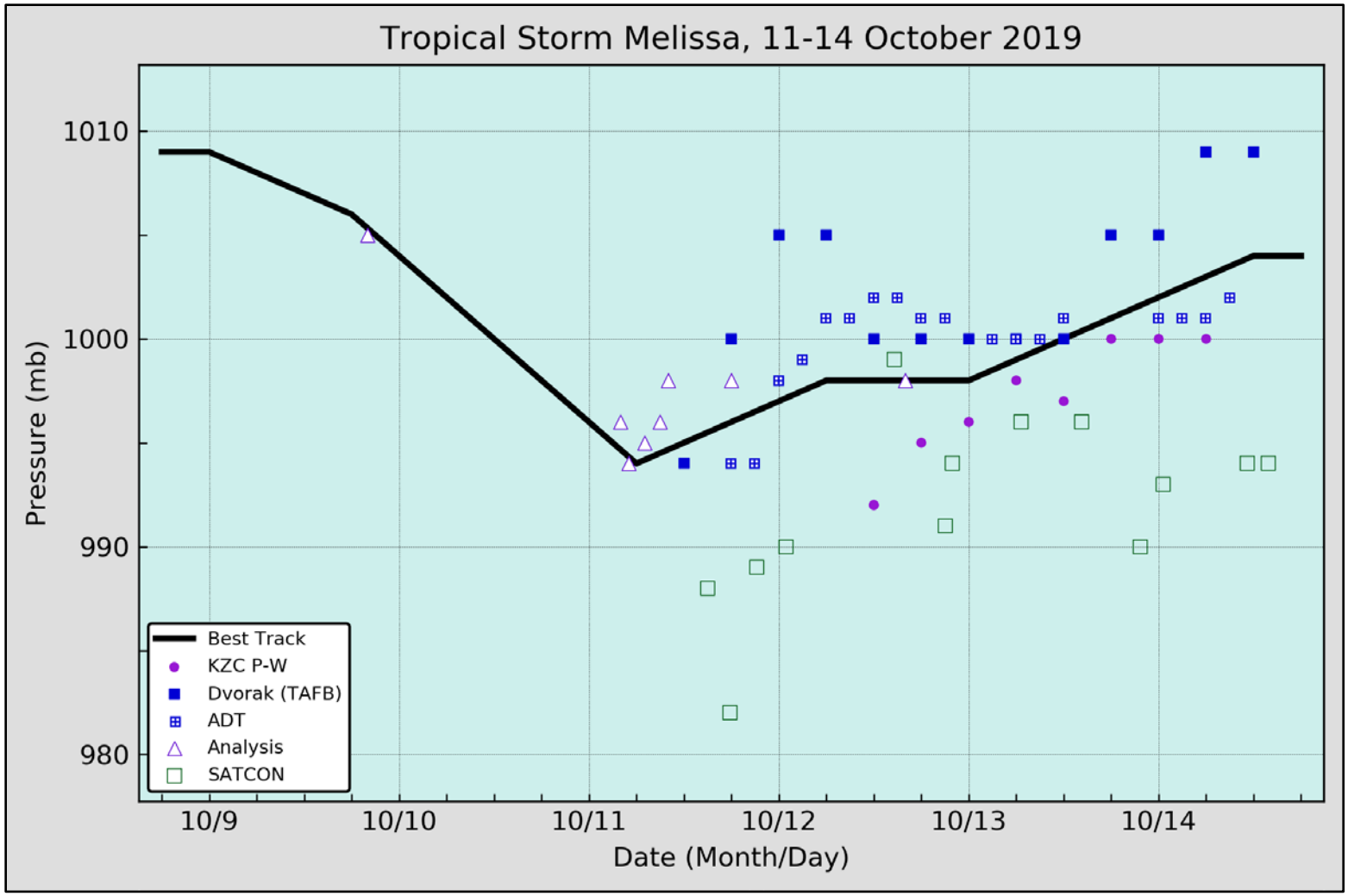

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Melissa, 11–14 October 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for 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.

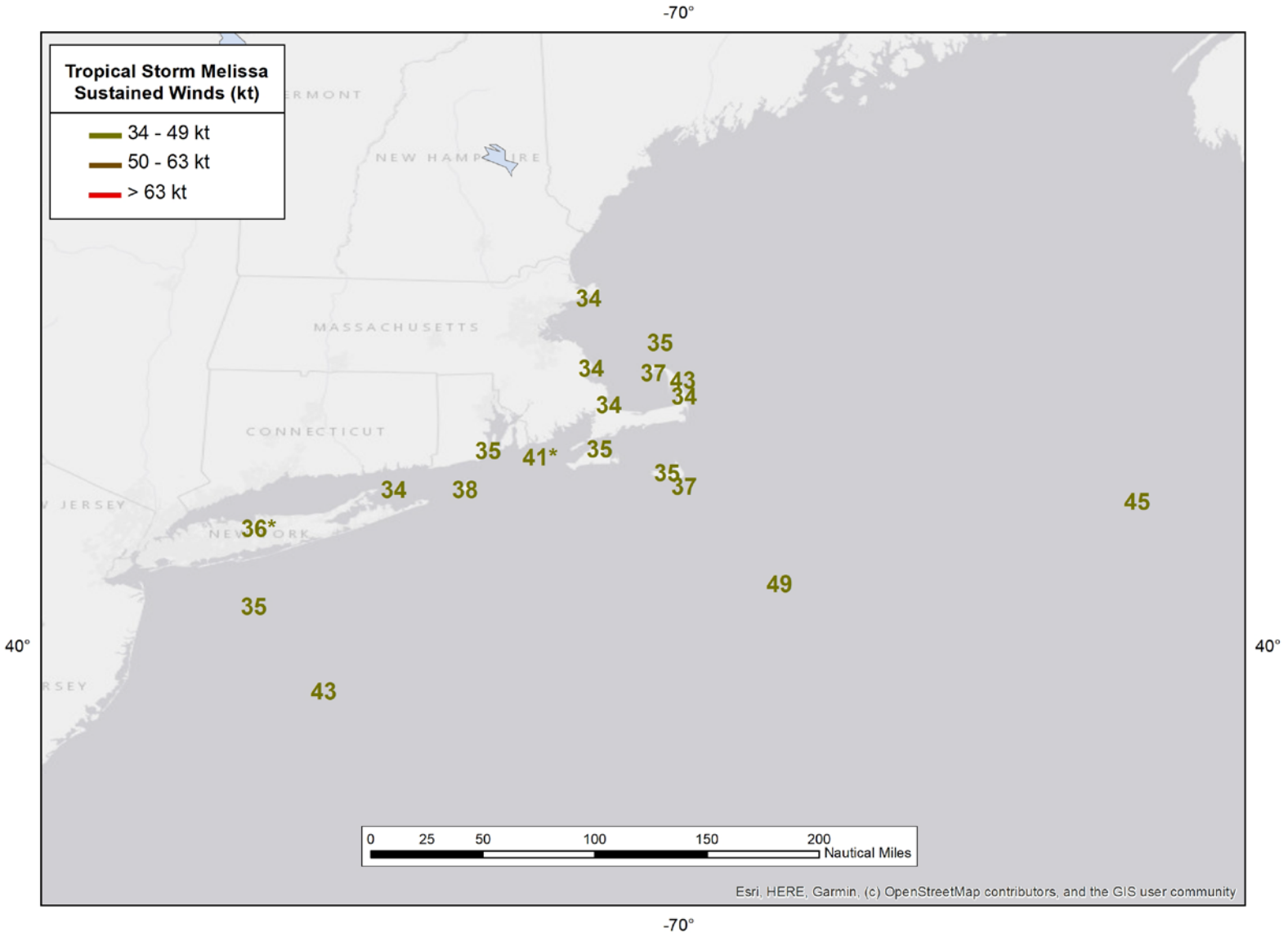

Figure 4. Select sustained winds (kt) reported during the extratropical, subtropical, and tropical phases of Melissa, 9–14 October 2019. An asterisk denotes observations taken at 20 m or higher elevation.

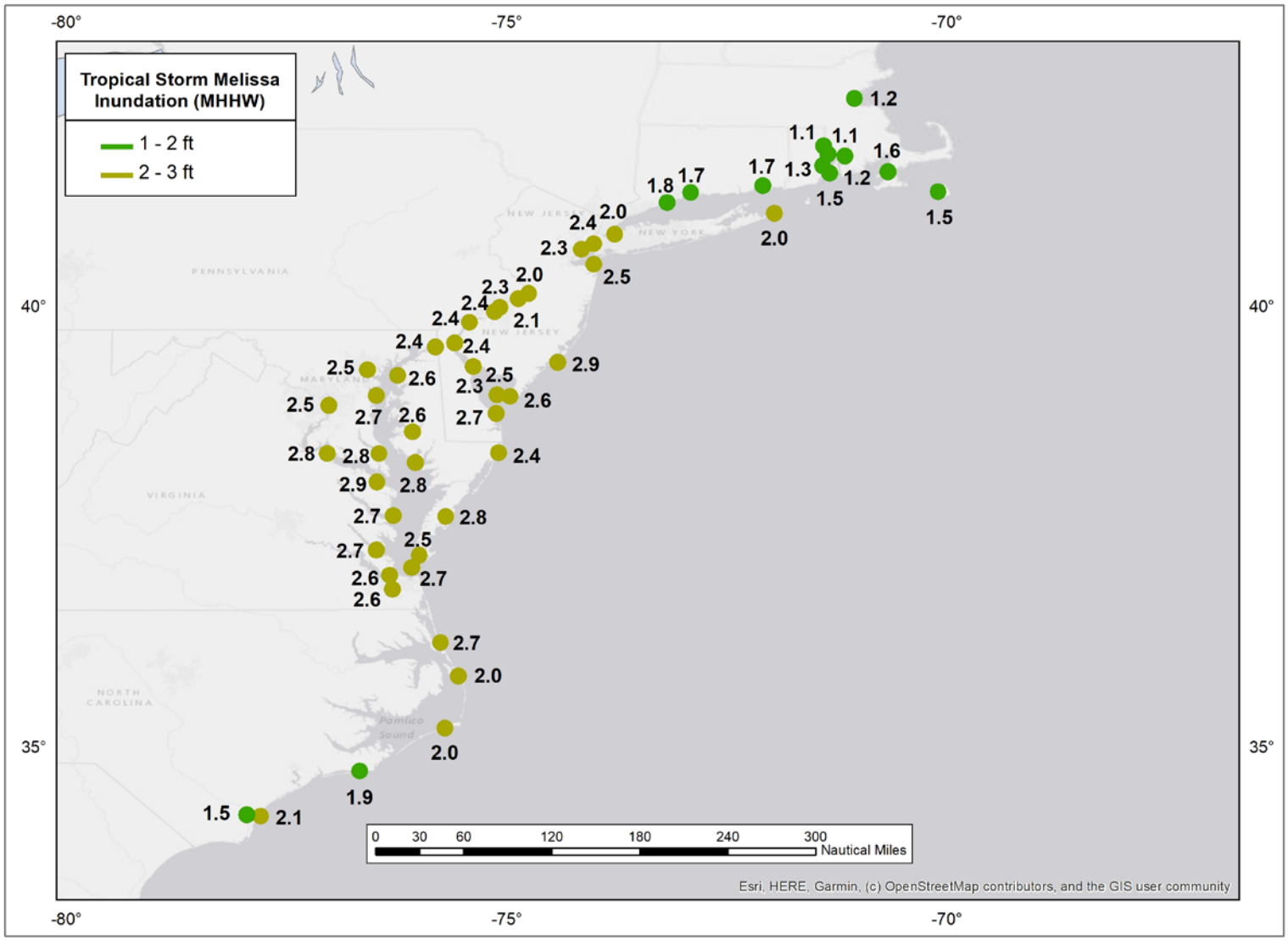

Figure 5. Storm tide measurements in feet above Mean Higher High Water (MHHW) from NOS gauges during the extratropical, subtropical, and tropical phases of Melissa, 9–14 October 2019. MHHW is used as a proxy for inundation, or storm surge over normally dry ground.