NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM OPHELIA

(AL162023)

22–23 September 2023

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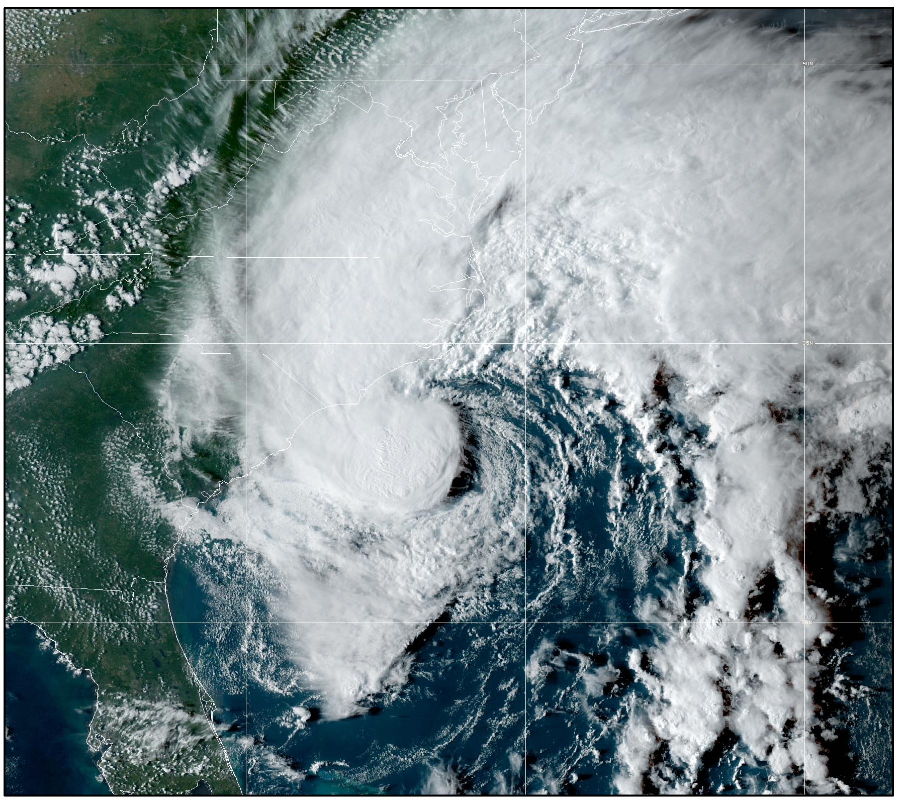

GOES-16 GEOCOLOR IMAGE OF TROPICAL STORM OPHELIA AT 2130 UTC 22 SEPTEMBER 2023 NEAR THE TIME OF PEAK INTENSITY. IMAGE COURTESY OF NOAA/NESDIS/STAR.

Ophelia was a tropical storm that made landfall near Emerald Isle, North Carolina. The storm brought significant wind, rainfall, and storm surge impacts to a large portion of the southeast and mid-Atlantic coasts of the United States, however there were no reports of fatalities or injuries associated with Ophelia.

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SYNOPTIC HISTORY

Ophelia formed from non-tropical origins. A cold front that initially moved off the southeastern coast of the United States on 18 September became stationary over the western Atlantic the following day. Showers and thunderstorms gradually increased along this boundary over the northern Bahamas and adjacent Atlantic waters east of Florida by 20 September. The next day, a mid- to upper-level trough that moved southeastward over the southeastern United States aided in the development of a non-tropical low-pressure area along the front about 240 n mi east of Cape Canaveral, Florida, by 1200 UTC 21 September. As the mid-level trough cut off over the western Atlantic, the surface low began to deepen while it moved north-northeastward. By 0000 UTC 22 September, the low was producing a large area of gale-force winds north of the center. After 0600 UTC that day, the low turned north-northwestward at a faster forward speed around the northeastern portion of the mid- to upper-level low. The low began to deepen at a faster rate that morning while thunderstorm activity increased over the northern portion of the circulation. By 1200 UTC that day, winds associated with the low reached storm force. During the next 6 h, the low shed its frontal structure and deep convection began to rotate around the northwestern portion of the circulation as it became better organized in a band just west of the center. This evolution marked the low's transition to a tropical storm with estimated maximum sustained winds of 60 kt at 1800 UTC 22 September (Fig. 1). The "best track" chart of Ophelia's path is given in Fig. 2, with the wind and pressure histories shown in Figs. 3 and 4, respectively. The best track positions and intensities are listed in Table 1[1].

After the system became a tropical storm, a burst of deep convection developed over the low-level center, and a ragged low- to mid-level eye feature was briefly noted in radar imagery from Morehead City, North Carolina. At 0000 UTC 23 September, Ophelia was centered about 75 n mi south of Cape Lookout, North Carolina, and the storm turned northward shortly thereafter, while approaching the coast of eastern North Carolina. Although deep convection near the center waned over the next few hours, it redeveloped prior to 0600 UTC, and reconnaissance aircraft data indicated that Ophelia maintained its intensity as it neared the coast. The storm made landfall around 1015 UTC with an estimated intensity of 60 kt near the western end of Emerald Isle, North Carolina. After landfall, the center of Ophelia moved north-northwestward to northward inland over the eastern part of the state. The storm's intensity began decreasing soon after landfall, and Ophelia weakened to a 40-kt tropical storm by 1800 UTC when it was centered just southeast of Roanoke Rapids, North Carolina. By this time, the system's peak winds were

[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.

occurring well east and northeast of the center over water. Shortly thereafter, Ophelia's forward speed slowed, and the storm continued to weaken. By 0000 UTC 24 September, Ophelia became an extratropical cyclone with peak winds of 30 kt when it was located over southern Virginia. The post-tropical cyclone continued to weaken on 24 September while it moved slowly northward to north-northeastward across Virginia and into southern Maryland by 1800 UTC. Shortly thereafter, the circulation became ill-defined, and the low dissipated. The remnants of the system moved across New Jersey and off the U.S. Mid-Atlantic coast the next day where they then meandered over the western Atlantic for a couple of days.

METEOROLOGICAL STATISTICS

Observations in Ophelia (Figs. 3 and 4) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), 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 two flights of the 53rd Weather Reconnaissance Squadron (WRS) of the U.S. Air Force Reserve Command (Fig. 5). 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 Ophelia.

Ship reports of winds of tropical storm force associated with Ophelia are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3.

Winds and Pressure

Ophelia's peak and landfall intensity of 60 kt is based on flight-level, SFMR, and dropsonde data from the 53rd WRS. The first of two reconnaissance missions by the 53rd WRS found peak 850-mb flight-level winds of 75 kt, and an SFMR surface wind of 60 kt around 1900 UTC 22 September. A little less than two hours later, the same aircraft measured a peak SFMR wind of 70 kt in association with a short-lived, ragged mid-level eye-like feature that was seen in land-based radar imagery. The peak 850-mb flight-level winds that occurred earlier on the same leg were also 70 kt but a standard wind reduction from that level (0.80) only supports surface winds of 56 kt. In addition, three dropwindsondes measured mean boundary-layer winds in the lowest 150 m of the sonde that support surface winds of 56 to 61 kt. Ultra-High Resolution (UHR) ASCAT data (Fig. 6) from early on 23 September provided by NOAA NESDIS during the post-analysis suggests Ophelia's winds were in the 65–70 kt range. UHR ASCAT data is still being evaluated for its utility in estimating the peak winds of a tropical cyclone. The 12.5 km resolution ASCAT data from those same passes revealed peak winds of 50–55 kt (Fig. 3). It should be noted that the typical intensity analysis uncertainty of NHC best tracks is about ±10%. Given that analysis uncertainty, it is possible that Ophelia briefly produced hurricane-force winds, however these winds were likely associated with transient mesoscale features.

Scatterometer data from around 1500 UTC 22 September and reconnaissance aircraft observations beginning around 1800 UTC that day were the basis for marking Ophelia's transition from an extratropical low to a tropical storm. These data indicated that Ophelia's radius of maximum winds (RMW) had decreased from more than 150 n mi at 1800 UTC 21 September to about 60 n mi 24 h later. The smaller RMW, the development of convection near and just west of the storm's center that afternoon (cover photo), and the dissipation of the frontal structure near the core of the cyclone were the basis for designating Ophelia as a tropical cyclone.

Ophelia's landfall intensity of 60 kt at 1015 UTC 23 September is based on flight-level wind data from 53rd WRS aircraft, and a surface wind report from a Coastal Marine-Automated Network (C-MAN) station at Cape Lookout, North Carolina. Unfortunately, no SFMR surface wind estimates were available from the 53rd WRS mission that occurred just before landfall. The C-MAN site at Cape Lookout measured a peak 10-minute wind of 54 kt at 0940 UTC 23 September. Using World Meteorological Organization (WMO) guidelines[2] for converting winds between various averaging periods, the 10-minute wind at Cape Lookout corresponds to a peak one-minute wind of about 60 kt (Fig. 3). This observation was located within Ophelia's estimated RMW of 30 n mi, and it appears that this station likely captured Ophelia's strongest winds.

Ophelia's estimated minimum pressure of 981 mb at 0600 UTC 23 September is based on dropwindsonde data from the Air Force Reserve Hurricane Hunter aircraft. Just after 0600 UTC 23 September, a center dropwindsonde measured a minimum pressure of 982 mb with 15 kt surface winds, which supports the minimum pressure of 981 mb. The landfall pressure in North Carolina is estimated to have been 981 mb. This is supported by a few land-based observations. A Citizen Weather Observing Program (CWOP) site at Cape Carteret, North Carolina, reported a minimum pressure of 982.4 mb at 1030 UTC 23 September (Table 3). There are no wind data associated with the observation, so it is not known if it occurred during the calm of the center passage. This was the lowest pressure measured on land. At Cherry Point, North Carolina, a minimum pressure of 984.3 mb that was associated with winds of 33 kt was reported. That observation supports a pressure of around 981 mb. About 90 minutes after landfall at 1154 UTC, a minimum pressure of 982.8 mb with 22-kt winds was observed at Coastal County Regional Airport (KEWN) in New Bern.

Sustained tropical-storm-force winds occurred across the North Carolina Outer Banks and widespread tropical-storm-force wind gusts occurred across much of eastern North Carolina. A sustained wind of 49 kt with a gust to 65 kt was reported at a CWOP site in Southport, North Carolina (Table 3). At Jennette's Pier, a sustained wind of 47 kt with a gust to 58 kt was observed. A wind gust of 58 kt was reported in Cherry Point, and wind gusts to 54 and 52 kt were reported at Beaufort and Jacksonville, respectively. Ophelia's large wind field also brought sustained tropical-storm-force winds along with wind gusts of 45 to 55 kt across southeastern Virginia and portions of eastern Maryland. Gusty winds also occurred farther north along the coast of

[2] Harper, B. A., J. D. Kepert, and J. D. Ginger, 2010: Guidelines for converting between various wind averaging periods in tropical cyclone conditions. World Meteorological Organization Rep., 54 pp.

Delaware and portions of New Jersey. A WeatherFlow observing site at Chesapeake Light in Virginia measured a sustained wind of 48 kt with a gust to 55 kt. A wind gust of 49 kt was reported at Virginia Beach, and a wind gust of 48 kt was observed at Norfolk. The strongest wind gusts in Maryland occurred at a WeatherFlow site near Ocean City which measured sustained winds of 38 kt with a gust to 51 kt.

Storm Surge[3]

Tropical Storm Ophelia produced minor to moderate storm surge inundation along coastal North Carolina, including the rivers and sounds, as well as in the Chesapeake Bay and Delmarva Peninsula (Fig. 7). Maximum storm surge inundation of 3 to 5 ft above ground level (AGL) occurred along the banks of the Pamlico and Neuse Rivers, as well as the banks of the Pamlico Sound. Figure 8 shows maximum water levels from various sensor networks including NOS tide gauges, USGS stream gages, and North Carolina Department of Public Safety water level gauges. The peak water level measured during this event was from the USGS stream gage (Pamlico River) at Washington, North Carolina, which recorded 4.94 ft above Mean Higher High Water (MHHW). Additional North Carolina Department of Public Safety gauges located along the riverbanks measured water levels greater than 3 ft above MHHW at New Bern (Trent River), Hobucken (Jones Bay), and Belhaven (Pungo River). NWS crews surveyed moderate storm surge inundation in these areas, with highest inundation levels near Washington, North Carolina.

Storm surge inundation of 1 to 3 ft AGL occurred near the landfall location between Cape Fear and Cape Lookout in North Carolina (Fig. 7), where the NOS tide gauge at Beaufort recorded a maximum water level of 1.75 ft above MHHW (Fig. 8). Additionally, 1 to 3 ft of inundation occurred along the Outer Banks of North Carolina (Fig. 7), where NOS tide gauges at Oregon Inlet and Duck recorded maximum water levels of 2.52 and 1.67 ft above MHHW, respectively (Fig. 8).

Storm surge inundation of 2 to 4 ft AGL occurred in the lower Chesapeake Bay (Fig. 7), where the NOS tide gauge at Sewells Point, Virginia, recorded a maximum water level of 2.98 ft MHHW (Fig. 8). This peak occurred ahead of the landfall in North Carolina due to the extensive wind field. Many other NOS tide gauges recorded water levels greater than 2 ft MHHW in this area; notable measurements include: 2.85 ft at Money Point, Virginia; 2.76 ft MHHW at Chesapeake Channel; 2.69 ft at Yorktown, Virginia; and 2.62 ft at Dahlgren, Virginia, along the Potomac River (Fig. 8). Storm surge inundation of 1 to 3 ft AGL occurred in the northern Chesapeake Bay (Fig. 7), where the NOS tide gauge at Baltimore, Maryland, and Annapolis, Maryland, reached 2.29 and 2.31 ft above MHHW, respectively (Fig. 8).

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[3] 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).

Storm surge inundation of 1 to 3 ft AGL occurred on the lower Delmarva Peninsula (Fig. 7), where the NOS tide gauge at Wachapreague, Virginia, measured a maximum of 2.31 ft above MHHW (Fig. 8). Water levels were elevated through the Delaware Bay.

Rainfall and Flooding

Ophelia produced a widespread area of 3 to 5 inches of rain across eastern North Carolina, and southeastern and central Virginia (Fig. 9). Closer to the track of Ophelia's center, a swath of 5 to 7 inches of rain fell over portions of eastern North Carolina with storm total maximum amounts of 8 to 9.5 inches that were recorded along and just west of the track of the storm over southeastern North Carolina (Fig. 9). The maximum rainfall (9.51 inches) was reported near Greenville, North Carolina. Near Jacksonville, North Carolina, 8.82 inches was recorded at an NWS Cooperative Observer Program (COOP) site, and a storm total rainfall amount of 8.11 inches was measured at a CoCoRaHS site near Cape Carteret. These rains caused flash flooding, especially in the Greenville, North Carolina area. Isolated flash flooding also occurred in southeastern and central Virginia where some road closures were reported. The maximum rainfall amount reported in Virginia was 6.63 inches near Stafford.

Some portions of coastal Maryland, Delaware, and New Jersey also recorded rainfall amounts of 3 to 5 inches. The maximum amount in this area was 6.77 inches near Tom's River, New Jersey.

Tornadoes

There was one tornado reported in association with Ophelia near Peach in Perquimans County, North Carolina. The short-lived EF-0 tornado touched down in a field causing no damage.

CASUALTY AND DAMAGE STATISTICS

There were no reports of fatalities or injuries in association with Ophelia. There was at least one water rescue required near Greenville, North Carolina, when a driver attempted to drive through a flooded roadway. The storm's widespread gusty winds, storm surge, and heavy rainfall caused mostly minor damage from eastern North Carolina through New Jersey. Wind damage was generally limited to portions of eastern North Carolina and consisted of downed trees and some powerlines. Minor roof damage was reported in Carteret County, North Carolina, and a gas station canopy was blown down in New Hanover County. Gusty winds also caused a few downed trees in portions of coastal Virginia and Maryland. Storm surge flooding occurred along rivers and creeks in eastern North Carolina with sound side flooding also reported on some of the barrier islands. In New Bern, North Carolina, significant storm surge flooding occurred along Waterfront Park. Water covered Front Street in New Bern and entered a few homes in that area. In Dare County, North Carolina, storm surge is reported to have covered some roadways.

Heavy rainfall from Ophelia also caused flash flooding in portions of eastern North Carolina. In Pitt County, several road closures were reported around Greenville. In Virginia, heavy rainfall caused some flooding of roadways. At the height of the storm, 70,000 homes across eastern North Carolina and Virginia lost electricity. The NOAA National Centers for Environmental Information (NCEI) estimates Ophelia caused about $450 million in damage in the United States.

Just offshore of North Carolina, five people, including three children, were rescued from an anchored sailing vessel near Cape Lookout Bight.

FORECAST AND WARNING CRITIQUE

Genesis

The genesis of Ophelia was challenging to forecast (Table 4). The potential for tropical or subtropical cyclone development was first mentioned in the Tropical Weather Outlook (TWO) at 0000 UTC 18 September, about 114 h before Ophelia became a tropical cyclone. The chance of genesis for the system remained in the low category (<40%) for the next few days because it was not clear if the system would shed its frontal structure and fully transition into a tropical or subtropical cyclone. While its future structure was uncertain, the potential for gusty winds, heavy rainfall, and high surf along portions of the coastal Carolinas and Mid-Atlantic states was increased. These hazards were highlighted in the TWO as early as 0600 UTC 19 September, more than three days before Ophelia became a tropical cyclone. The 7-day probabilities of development were raised to the medium category (40–60%) 48 h before genesis, and the high category (>60%) 12 h before Ophelia became a tropical cyclone. Uncertainty regarding the ultimate structure of the system also resulted in a lag in NHC introducing and raising the short-term (48 h) probabilities of genesis. A low 48-h probability of development was assigned to the system exactly 48 h before tropical cyclone formation, and those probabilities were raised to the medium and high categories 24 and 12 h before formation, respectively. Despite the less-than-desirable lead time of the medium and high chances of formation, NHC initiated Potential Tropical Cyclone Advisories on the non-tropical low at 1500 UTC 21 September (when the probabilities were still in the medium category) to issue tropical storm and storm surge warnings for portions of North Carolina and the U.S. Mid-Atlantic coast. The location of genesis was well anticipated as all of the TWOs issued prior to formation encapsulated Ophelia's genesis location (Fig. 10).

Track

A verification of NHC official track forecasts for Ophelia is given in Table 5a. Since NHC's verification requires the system to be classified as a tropical cyclone at both the forecast's initial time and the projection's valid time, only three 12-h and one 24-h official forecast satisfied those criteria. The NHC track forecast errors were greater than the 5-yr mean at 12 h, but lower than the long-term mean at 24 h, albeit for the small sample size. A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b, however due to the small sample size no meaningful conclusions can be drawn. Despite the large and sprawling structure of the precursor low when advisories where initiated, the NHC forecasts accurately predicted the landfall location and timing in eastern North Carolina from the very first advisory (Fig. 11).

Intensity

A verification of NHC official intensity forecasts for Ophelia is given in Table 6a. Official intensity forecast errors were lower than the 5-year means at both 12 and 24 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b, however the small sample size precludes any meaningful comparisons. The NHC intensity forecast accurately anticipated strengthening of the non-tropical low and transition of the system into a tropical cyclone. Ophelia intensified more than the initial NHC forecasts, and its 60-kt estimated landfall intensity was about 10 kt higher than the peak shown in the first few official forecasts.

Wind Watches and Warnings

Watches and warnings associated with Ophelia and its precursor disturbance are given in Table 7. Potential tropical cyclone advisories were initiated on the precursor low to issue tropical storm warnings for a portion of the U.S. Mid-Atlantic coast. A Hurricane Watch was issued at 2100 UTC 22 September for a portion of the North Carolina coast after Ophelia strengthened into a 60-kt tropical storm. This watch helped to highlight the potential for stronger winds near the center of the system as it made landfall in North Carolina early on 23 September. The initial Tropical Storm Warnings provided about 24 h of lead time in North Carolina ahead of the initial arrival of tropical-storm-force winds associated with the system. This marked the first time that NHC issued Potential Tropical Cyclone advisories on a system that was not in the high category (>60%) of development. Since confidence of the system's transition into a tropical or subtropical cyclone was not high, the lead time for the initial tropical storm warning was less than the typical 36 hours.

Storm Surge Forecasts and Warnings

Storm surge watches and warnings associated with Ophelia and its precursor disturbance are given in Table 8. Figure 12 shows the timeline of the Storm Surge Watch and Warning overlaid on the hydrograph at select water level sensors: Sewells Point, Virginia; Oregon Inlet, North Carolina; and Washington, North Carolina (geographically labeled in Figs. 7 and 8). A Storm Surge Watch was first issued at 1500 UTC 21 September, when the system was designated as a Potential Tropical Cyclone. The watch was issued from Surf City, North Carolina, to Chincoteague, Virginia, and for the Chesapeake Bay south of Smith Point, including the Albemarle and Pamlico Sounds. The watch area included all the locations in Figure 12. The initial peak storm surge forecast was 2 to 4 ft AGL for all areas. Six hours later (2100 UTC 21 September), the Storm Surge Watch was extended to the Tidal Potomac south of Colonial Beach, and a portion of the Storm Surge Watch was upgraded to a Storm Surge Warning including Washington, North Carolina, and Sewells Point, Virginia (Fig. 12). In the warning areas along the Pamlico, Pungo, Neuse and Bay Rivers, the peak storm surge forecast was increased to 3 to 5 ft AGL. At 1500 UTC 22 September, the Storm Surge Watch on the Outer Banks, as well as portions of the Albemarle Sound, was upgraded to a warning (see Oregon Inlet, Fig. 12). Finally, a Storm Surge Warning was issued 6 hours later (2100 UTC 22 September) from Bogue Inlet to Beaufort Inlet, south of Cape Lookout, and the peak surge forecast for the Pamlico, Pungo, Neuse, and

Bay Rivers was increased to 4 to 6 ft. The aerial extent of the Storm Surge Watch and Warning from this advisory is shown in Fig. 8.

Ultimately, several water level sensors along the Pamlico, Pungo, Neuse, and Bay Rivers measured more than 3 ft MHHW, including Washington, North Carolina (Fig. 12). These observations supported the issuance of the Storm Surge Warning (3 ft MHHW/AGL is used as a first-cut threshold for verification). The peak storm surge forecast range (4 to 6 ft AGL) overlaps the final NHC analysis (3 to 5 ft AGL).

In the lower Chesapeake Bay, the final NHC storm surge analysis of 2 to 4 ft AGL and the Sewells Point observation (2.98 ft above MHHW) support the issuance of the Storm Surge Warning. The peak storm surge forecast range is consistent with the final NHC analysis.

Water levels in the storm surge warning areas along the Albemarle Sound, Outer Banks, and Delmarva Peninsula did not exceed 3 ft AGL. Given the complexity of Ophelia's large wind field and its transformation from a non-tropical low to a tropical cyclone, the NWS decided to message the storm threat using tropical cyclone storm surge watches and warnings in lieu of Coastal Flood Warnings.

Impact-Based Decision Support Services (IDSS) and Public Communication

The NHC began communication with emergency managers on 21 September as Ophelia's precursor disturbance developed in the southwestern Atlantic Ocean. Five decision support briefings were provided to emergency managers and coordinated through the FEMA Hurricane Liaison Team embedded at the NHC. The briefings were federal video-teleconferences with FEMA HQ, FEMA Region 3, FEMA Region 4, North Carolina, and Virginia. These briefings continued through 23 September as Ophelia moved inland over North Carolina and Virginia.

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Table 1. Best track for Tropical Storm Ophelia, 22–23 September 2023.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
21 / 1200	28.5	76.0	1012	30	extratropical
21 / 1800	29.0	75.6	1012	30	"
22 / 0000	29.5	75.3	1008	35	"
22 / 0600	30.3	75.1	1002	40	"
22 / 1200	31.6	75.5	996	50	"
22 / 1800	32.7	76.1	989	60	tropical storm
23 / 0000	33.3	76.6	983	60	"
23 / 0600	33.8	77.1	981	60	"
23 / 1015	34.7	77.1	981	60	"
23 / 1200	35.1	77.1	982	50	"
23 / 1800	36.3	77.5	997	40	"
24 / 0000	36.8	77.6	1002	30	extratropical
24 / 0600	37.2	77.6	1006	25	"
24 / 1200	37.9	77.4	1009	20	"
24 / 1800	38.9	76.9	1010	20	"
25 / 0000					dissipated
23 / 0600	33.8	77.1	981	60	Maximum wind and minimum pressure
23 / 1015	34.7	77.1	981	60	Landfall near Emerald Isle, North Carolina

Table 2. Selected ship reports with winds of at least 34 kt for Tropical Storm Ophelia, 22–23 September 2023.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/ speed (kt)	Pressure (mb)
22 / 1700	VRUX7	35.2	75.0	050 / 42	1011.8
22 / 1800	VRUX7	35.5	74.9	070 / 40	1011.8
22 / 1900	VRUX7	35.8	74.9	070 / 40	1011.8
22 / 2000	VRUX7	36.1	75.0	090 / 40	1011.8
22 / 2100	VRUX7	36.3	75.1	050 / 41	1012.8
22 / 2200	LAVN4	33.6	69.7	120 / 40	1019.0
22 / 2200	WTEA	33.8	78.3	350 / 35	1006.4
22 / 2200	WTEA	33.9	78.3	340 / 35	1006.1
22 / 2200	VRUX7	36.6	75.2	050 / 41	1012.8
22 / 2300	WTEA	33.8	78.3	360 / 39	1005.6
22 / 2300	WTEA	33.9	78.3	340 / 38	1005.4
23 / 0000	WTEA	33.8	78.3	340 / 42	1004.7
23 / 0100	WTEA	33.8	78.3	340 / 36	1003.4
23 / 0200	WTEA	33.8	78.3	360 / 35	1002.8
23 / 0200	VRUX7	36.7	75.4	090 / 35	1013.8
23 / 0300	WTEA	33.8	78.3	170 / 46	1001.6
23 / 0300	VRUX7	36.8	75.3	090 / 35	1010.8
23 / 0400	VRUX7	36.8	75.1	090 / 35	1010.8
23 / 0500	WTEA	33.8	78.3	340 / 39	1001.2
23 / 0500	VRUX7	36.7	75.3	090 / 40	1013.2
23 / 0600	VRUX7	36.7	75.4	090 / 38	1009.8
23 / 0800	WTEA	33.9	78.3	360 / 38	1000.2
23 / 0900	WTDF	39.0	75.2	040 / 38	1014.0
23 / 1000	WTDF	39.0	75.2	040 / 40	1012.9

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/ speed (kt)	Pressure (mb)
23 / 1100	WTDF	39.0	75.2	040 / 41	1012.8
23 / 1200	WTDF	39.0	75.2	050 / 38	1012.8
23 / 1300	WTDF	39.0	75.2	050 / 37	1012.2
23 / 1500	WTDF	39.0	75.2	050 / 35	1012.3
23 / 1600	OYRO2	39.0	69.9	090 / 35	1017.0
23 / 1800	VRTX6	38.9	76.4	050 / 35	1010.0
23 / 1800	WTDF	39.0	75.2	040 / 35	1010.6
23 / 2000	WTDF	39.0	75.2	050 / 35	1009.6
23 / 2100	WTDF	39.0	75.2	040 / 35	1009.6

Table 3. Selected surface observations for Tropical Storm Ophelia, 22–23 September 2023.

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)				
North Carolina									
International Civil Aviation Organization (ICAO) Sites									
Beaufort (KMRH) (34.72N 76.65W)	23/0958	989.1	23/0858	32 (10 m, 2 min)	54				
Bogue Field (KNJM) (34.69N 77.03W)	23/1028	983.4	23/0939	30 (10 m, 2 min)	48				
Coastal Carolina Airport New Bern (KEWN) (35.07N 77.04W)	23/1154	982.8	23/1140	31 (10 m, 2 min)	48				
Cape Hatteras (KHSE) (35.22N 75.62W)	23/0940	1000.5	23/1215	33 (10 m, 2 min)	45				
Cherry Point (KNKT) (34.88N 76.91W)	23/1056	984.3	23/1056	33 (10 m, 2 min)	58				
Jacksonville (KNCA) (34.71N 77.44W)	23/0953	992.4	23/0953	31 (10 m, 2 min)	52				
Piney Island (KNBT) (35.02N 76.46W)	23/0635	999.7[l]	22/2310	37[l] (10 m, 2 min)	52[l]				
Wilmington (KILM) (34.27N 77.90W)	23/0853	997.3	23/0700	30 (10 m, 2 min)	49				
Hydrometeorological Automated Data System (HADS) Sites (NWS)									
Cedar Island Ferry (CTIN7) (35.02N 76.31W)	23/1112	994.2	22/1930	38					
Coastal-Marine Automated Network (C-MAN) Sites									
Cape Lookout (CLKN7) (34.62N 76.52W)	23/1000	990.5	23/0940	54 (10 m, 10 min)	66				
National Ocean Service (NOS) Sites									
Beaufort (BFTN7) (34.72N 76.67W)	23/1012	987.9	23/0930	40 (7 m)	52	3.26	3.21	1.75	
Duck (DUKN7) (36.18N 75.75W)	23/1542	1001.7	23/0254	44	48	2.91	3.17	1.67	
Oregon Inlet (ORIN7) (35.77N 75.53W)	23/1130	1001.9	23/0118	37 (7 m)	47	2.77	2.99	2.52	
Wrightsville Beach (JMPN7) (34.21N 77.79W)	23/0754	995.2	23/0336	33	47				
WxFlow Sites									
Federal Point (XFED) (33.96N 77.94W)	23/0630	997.0	23/0355	42 (15 m)	52				

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)				
Coastal Ocean Research and Monitoring Program (CORMP) Sites									
Sunset Beach Nearshore (41024) (33.84N 78.48W)	23/0708	1000.6	23/0108	31 (3 m)	45				
Wrightsville Beach Nearshore (41038) (34.14N 77.72W)	23/0808	994.5	23/0308	38 (3 m)	53				
Wrightsville Beach Offshore (41037) (33.99N 77.36W)	23/0708	986.6	23/0608	47 (3 m)	71				
WeatherStem Sites									
Carova Beach (1329W) (36.52N 75.87W)	23/1850	1002.4	23/0240	35	46				
ECU (1573W) (35.87N 75.66W)	23/1250	1001.4	22/1550	31	47				
Citizen Weather Observer Program (CWOP) Sites									
Beaufort (AV211) (34.76N 76.41W)	23/1014	992.9	23/1004	44	57				
Cape Carteret 0.6 E (EW9396) (34.69N 77.05W)	23/1030	982.4							6.20
Emerald Isle (EW7222) (34.65N 77.08W)	23/1005	985.1							6.16
Harkers Island (GW3382) (34.69N 76.53W)	23/0958	990.9	23/0918	43	46				
Havelock (DW9307) (34.90N 76.78W)	23/1103	988.5	23/1017	33	51				
Jacksonville 7 W (EW2293) (34.74N 77.55W)	23/1041	993.2							8.64
Nags Head (FW5918) (35.87N 75.58W)	23/1254	1002.7	23/0153	37	47				
Rodanthe (EW7670) (35.60N 75.47W)	23/1200	1000.3	22/2301	33	48				
Southport (FW6543) (33.76N 77.95W)			22/1745	49[l]	65[l]				
Winterville (GW3801) (35.52N 77.42W)	23/1445	993.6							7.60
Public/Other									
Avon (AVNS) (35.37N 75.51W)	23/1140	1000	22/2305	38 (5 m, 2 min)	49				
Avon-Ocean (AVNO) (35.35N 75.50W)	23/1123	1001	22/2153	39 (12 m)	49				
Buxton (BXTN) (35.26N 75.52W)	23/1117	1000	22/2312	39 (10 m, 2 min)	53				
Frisco (FSCOWDS) (35.25N 75.63W)	23/1102	1000	22/2147	37 (10 m, 2 min)	47				
Jennettes Pier (JNTP) (35.91N 75.59W)	23/1505	1000	23/0200	47 (18 m)	58				

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)				
Kites (KITE) (35.58N 75.47W)	23/1148	1000	23/1918	35 (16 m, 2 min)	47				
Morehead City (FTMACON) (34.70N 76.69W)	23/0955	986.9	23/0915	40 (10 m, 2 min)	57				
Oregon Inlet (OI) (35.80N 75.55W)	23/1129	1001	23/0134	36 (10 m, 2 min)	49				
Oregon Inlet CG (OICG) (35.77N 75.53W)	23/1101	1000	23/0136	40 (10 m, 2 min)	59				
Pamlico Sound (PMSD) (35.43N 75.83W)	23/0348	1002	22/2318	44 (13 m)	53				
Real Slick (RLSK) (35.57N 75.49W)			22/2110	36 (6 m)	46				
Waves (WAVES) (35.57N 75.47W)	23/0944	1001	22/2259	32 (11 m, 2 min)	45				
United States Geological Survey (USGS)									
Pamlico River (02084472) (35.54N 77.06W)							5.06	4.94	
North Carolina Department of Public Safety									
Jones Bay at Hobucken (HBKN7) (35.24N 76.59W)							3.09	3.33	
Pungo River at Belhaven (BLHN7) (35.53N 76.62W)							3.58	3.42	
Trent River at New Bern (30015) (35.10N 77.03W)							4.19	4.46	
NWS Cooperative Observer Program (COOP) Sites									
Jacksonville (JEON7) (34.80N 77.40W)									8.82
Perrytown (PYTN7) (35.06N 77.09W									6.37
Remote Automated Weather Stations (RAWS)									
Buxton (TT700) (35.25N75.53W)			22/2230	18	45				
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Cape Carteret 0.8 NE (NC-CR-109) (34.70N 77.05W)									6.80

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)				
Cape Carteret 1 NNW (NC-CR-158) (34.71N 77.07W)									6.99
Cape Carteret 1.5 NE (NC-CR-146) (34.71N 77.04W)									8.11
Cape Carteret 4 NW (NC-CR-157) (34.74N 77.11W)									6.31
Greenville 2.8 ESE (NC-PT-35) (35.59N 77.33W)									9.51
Greenville 2.8 WSW (NC-PT-62) (35.58N 77.42W)									6.42
Greenville 4.4 SE (NC-PT-19) (35.54N 77.35W)									6.78
Greenville 5 SE (NC-PT-88) (35.55N 77.31W)									6.05
Greenville 7.1 SSE (NC-PT-18) (35.51N 77.32W)									6.28
Greenville 7.3 SSE (NC-PT-93) (35.50N 77.34W)									7.52
New Bern 1.4 WSW (NC-CN-22) (35.11N 77.10W)									6.61
New Bern 2.6 SW (NC-CN-74) (35.09N 77.10W)									6.85
New Bern 3.8 S (NC-CN-94) (35.07N 77.08W)									6.00
New Bern 5.3 SW (NC-CN-44) (35.07N 77.15W)									6.14
New Bern 8.8 W (NC-CN-31) (35.14N 77.23W)									6.65
Swansboro 2.7 NE (NC-CR-162) (34.71N 77.09W)									7.42
Trent Woods 1 NNE (NC-CN-67) (35.09N 77.09W)									6.20
Trent Woods 1 WNW (NC-CN-96) (35.08N 77.11W)									7.19
Trent Woods 1.2 ENE (NC-CN-89) (35.09N 77.08W)									6.10
Trent Woods 1.3 SSE (NC-CN-15) (35.06N 77.09W)									6.37
Winterville 2.5 NNW (NC-PT-23) (35.56N 77.42W)									6.13
Winterville 2.8 WNW (NC-PT-63) (35.55N 77.44W)									6.06
Virginia									
ICAO Sites									
Norfolk (KORF) (36.90N 76.19W)	23/1751	1001.9	23/0245	37 (10 m, 2 min)	48				
Norfolk NAS (KNGU) (36.92N 76.27W)	23/1759	1002.5	23/0316	28 (10 m, 2 min)	45				
Virginia Beach (KNTU) (36.82N 76.02W)	23/1756	1002.5	23/0056	31 (10 m, 2 min)	49				
Wallops Island (KWAL) (37.93N 75.47W)	23/2054	1006.6	23/0527	33 (10 m, 2 min)	49				

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)				
HADS Sites (NWS)									
Chincoteague Bay Inlet (CHIV2) (37.90N 75.41W)			23/0354	37					
NOS Sites									
Cape Henry (CHYV2) (36.93N 76.01W)	23/1830	1003.0	23/0024	43 (28 m, 2 min)	52				
Cape Henry 8 NW (CHBV2) (37.03N 76.08W)	23/1854	1001.4	23/0236	40 (5 m)	47			2.76	
Rappahannock Lt (RPLV2) (37.54N 76.02W)	23/1854	1005.4	23/0142	42 (17 m, 2 min)	48				
South Craney Island (CRYV2) (36.89N 76.34W)	23/1754	1001.6	23/0306	33 (9 m)	45				
Wachapreague (WAHV2) (37.61N 75.69W)	23/2042	1004.8	23/0436	36 (7 m)	48				
Willoughby DS (WDSV2) (36.98N 76.32W)	23/1848	1001.8	23/0100	39 (12 m, 2 min	46				
Dahlgren (NCDV2) (38.31N 77.92W)						2.63	3.49	2.62	
Yorktown USCG Training Center (YKTV2) (37.22N 76.47W)						3.24	3.73	2.69	
Sewells Point (SWPV2) (36.94N 76.32W)						3.61	4.13	2.98	
Money Point (MNPV2) (36.77N 76.30W)								2.85	
Chesapeake Bay Interpretive Buoy System (CBIBS) Sites									
Cape Henry 6 NW (44064) (37.00N 76.09W)			23/0212	39 (3 m)	54				
Stingray Point (44058) (37.57N 76.26W)			23/0900	36 (3 m)	47				
York Spit (44072) (37.20N 76.27W)			23/0218	36 (3 m)	53				
WxFlow Sites									
Bavon (XNPC) (37.33N 76.27W)	23/1951	1003	23/0246	38 (13 m)	48				
Cape Henry (XHEN) (36.93N 76.01W)	23/1815	1002	23/0230	44 (23 m)	53				
Chesapeake Lt (XCLT) (36.90N 75.71W)	23/1820	1003	22/2350	48 (41 m)	55				
Hampton (XTHM) (37.05N 76.26W)	23/1940	1003	23/0245	36 (6 m)	46				
Newport News (XMGL) (36.95N 76.39W)	23/1822	1002	23/0512	43 (20 m)	48				
Poquoson (XPQR) (37.16N 76.38W)	23/2006	1002	23/0256	38 (7 m)	47				
Third Island (XBBT) (37.04N 76.08W)	23/1912	1001	23/0047	44 (16 m)	54				
Virginia Beach (XLHI) (36.92N 76.09W)	23/1806	1003	23/0236	38 (7 m)	48				

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)				
Virginia Beach (XRUD) (36.83N 75.97W)	23/1844	1003	23/0044	39 (9 m)	47				
Public/Other									
HRBT - South Island (VA080) (36.98N 76.30W)			23/0445	32	47				
Stafford (38.4N 77.46W)									6.63
Maryland									
C-MAN Sites									
Thomas Point (TPLM2) (38.90N 76.44W)	23/2000	1008.9	23/1120	35 (18m, 10 min)	41				
CBIBS Sites									
Gooses Reef (44062) (38.56N 76.42W)			23/1506	35 (3 m, 6 min)	49				
Lower Potomac (44042) (38.03N 76.34W)			23/0830	33 (3 m, 6 min)	45				
Patapsco (44043) (39.15N 76.39W)			23/1248	35 (3 m, 6 min)	47				
WxFlow Sites									
Ocean City (XOCN) (38.33N 75.08W)	23/2113	1008	23/0713	38 (10 m)	51				
NOS Sites									
Baltimore (BLTM2) (39.27N 76.57W)						2.75	3.12	2.29	
Annapolis (APAM2) (38.98N 76.48W)						2.69	2.98	2.31	
New Jersey									
Tom's River TWP 3.6 WSW (US1NJOCOO92) (39.97N 74.23W)									6.77

[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. Values with an asterisk (*) indicate that the station is non-tidal, and the value is referenced to Mean Sea Level (MSL).

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	**168-Hour Outlook**
Low (<40%)	48	114
Medium (40%-60%)	24	48
High (>60%)	12	12

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Ophelia, 22–23 September 2023. 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	32.8	**18.8**						
OCD5	46.6	122.9						
Forecasts	3	1						
OFCL (2018-22)	23.8	35.7	47.8	61.4	76.1	90.5	125.7	172.1
OCD5 (2018-22)	46.4	99.2	157.4	215.0	254.9	321.2	405.1	486.6

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Ophelia, 22–23 September 2023. Errors smaller than the NHC official forecast are shown in boldface type.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	32.8	18.8						
OCD5	46.6	122.9						
GFSI	35.9	24.0						
HMNI	40.6	24.5						
HWFI	41.1	**15.4**						
HFAI	35.1	18.8						
HFBI	36.2	**7.7**						
UKMI	**24.5**	46.3						
EGRI	**27.8**	40.9						
EMXI	**25.6**	**18.0**						
CMCI	37.4	35.9						
NVGI	35.5	**12.9**						
CTCI	51.6	**12.9**						
AEMI	**32.1**	24.0						
HCCA	**32.4**	**12.0**						
FSSE	33.6	25.9						
TVCX	34.2	**6.0**						
GFEX	**31.5**	24.0						
TVCA	34.2	**7.7**						
TVDG	34.2	**12.9**						
TABD	55.3	129.2						
TABM	39.9	44.4						
TABS	48.9	57.4						
Forecasts	3	1						

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Ophelia, 22–23 September 2023. 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	**1.7**	**5.0**						
OCD5	4.7	31.0						
Forecasts	3	1						
OFCL (2018-22)	5.1	7.6	8.9	10.1	10.7	11.5	13.3	15.5
OCD5 (2018-22)	6.8	10.7	13.9	16.5	18.3	20.2	22.9	23.4

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Ophelia, 22–23 September 2023. Errors smaller than the NHC official forecast are shown in boldface type.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	1.7	5.0						
OCD5	4.7	31.0						
HWFI	9.0	7.0						
HMNI	5.0	**1.0**						
HFAI	4.3	**2.0**						
HFBI	5.7	**4.0**						
CTCI	4.0	**4.0**						
DSHP	**1.3**	**1.0**						
LGEM	2.3	**1.0**						
ICON	3.7	**1.0**						
IVCN	4.0	**2.0**						
IVDR	5.0	**2.0**						
HCCA	4.3	**4.0**						
FSSE	4.0	**0.0**						
GFSI	6.0	**1.0**						
EMXI	6.3	**1.0**						
Forecasts	3	1						

Table 7. Coastal wind watch and warning summary for Tropical Storm Ophelia, 22–23 September 2023.

Date/Time (UTC)	Action	Location
21 / 1500	Tropical Storm Warning issued	Cape Fear, NC to Fenwick Island, DE
21 / 1500	Tropical Storm Warning issued	Albemarle and Pamlico Sounds and Chesapeake Bay south of Smith Point
21 / 2100	Tropical Storm Warning issued	Chesapeake Bay from Smith Point to North Beach and into the Tidal Potomac to Cobb Island
22 / 2100	Hurricane Watch issued	Surf City, NC to Ocracoke Inlet, NC
23 / 1200	Hurricane Watch discontinued	All
23 / 1500	Tropical Storm Warning discontinued	Cape Lookout, NC to Cape Fear, NC
23 / 2100	Tropical Storm Warning discontinued	Cape Lookout, NC to Ocracoke Inlet, NC
24 / 0000	Tropical Storm Warning discontinued	All

Table 8. Storm surge watch and warning summary for Tropical Storm Ophelia, 22–23 September 2023.

Date/Time (UTC)	Action	Location
21 / 1500	Storm Surge Watch issued	Surf City, NC to Chincoteague, VA
21 / 1500	Storm Surge Watch issued	Albemarle and Pamlico Sounds and Chesapeake Bay south of Smith Point
21 / 2100	Storm Surge Warning issued	Duck, NC to Chincoteague, VA
21 / 2100	Storm Surge Warning issued	Albemarle and Pamlico Sounds, Neuse River, Pamlico River, and Chesapeake Bay south of Windmill Point
21 / 2100	Storm Surge Watch issued	Tidal Potomac south of Colonial Beach
22 / 1500	Storm Surge Warning issued	Ocracoke Inlet, NC to Duck, NC
22 / 1500	Storm Surge Warning issued	Tidal Potomac south of Colonial Beach, and portions of the western Albemarle Sound
22 / 2100	Storm Surge Warning issued	Bogue Inlet, NC to Beaufort Inlet, NC
23 / 1500	Storm Surge Warning discontinued	Bogue Inlet, NC to Ocracoke Inlet, NC
23 / 1500	Storm Surge Watch discontinued	Surf City, NC to Bogue Inlet, NC
23 / 1800	Storm Surge Warning discontinued	Neuse River
23 / 2100	Storm Surge Warning discontinued	Duck, NC to Suffolk, VA including portions of the Albemarle Sound
23 / 2100	Storm Surge Warning discontinued	Ocracoke Inlet, NC to Hatteras Inlet, NC, including the Pamlico River and Pamlico Sound
23 / 2100	Storm Surge Watch discontinued	Portions of the Pamlico and Albemarle Sounds
24 / 0000	Storm Surge Warning discontinued	All
24 / 0000	Storm Surge Watch discontinued	All

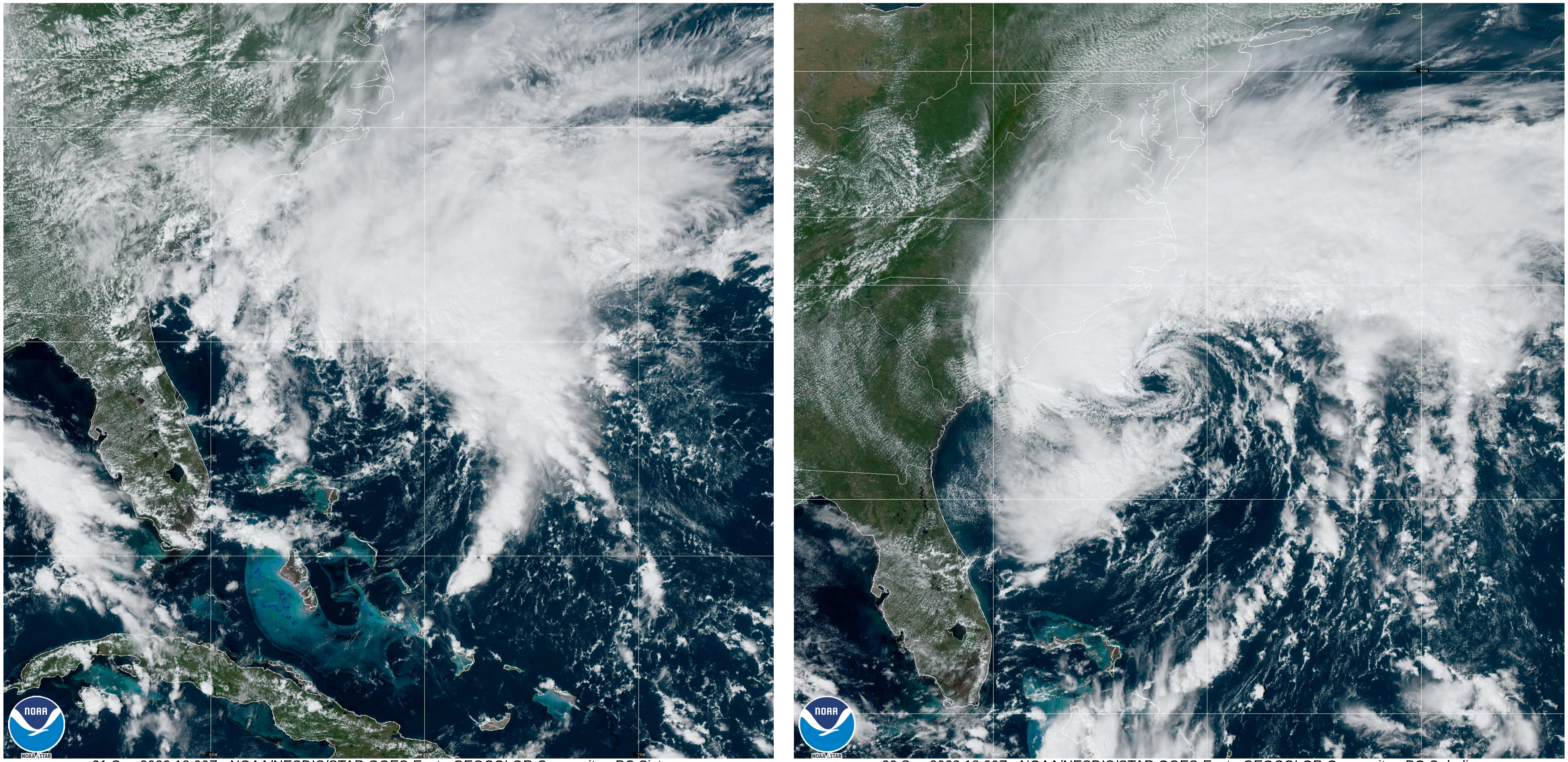


Figure 1. GOES-16 Geocolor image of Ophelia's precursor non-tropical low-pressure area at 1800 UTC 21 September (left), and 24 h later when the low is estimated to have become a tropical storm at 1800 UTC 22 September (right). Note the increase in convective activity near the center and the increase in organization during that 24-h period.

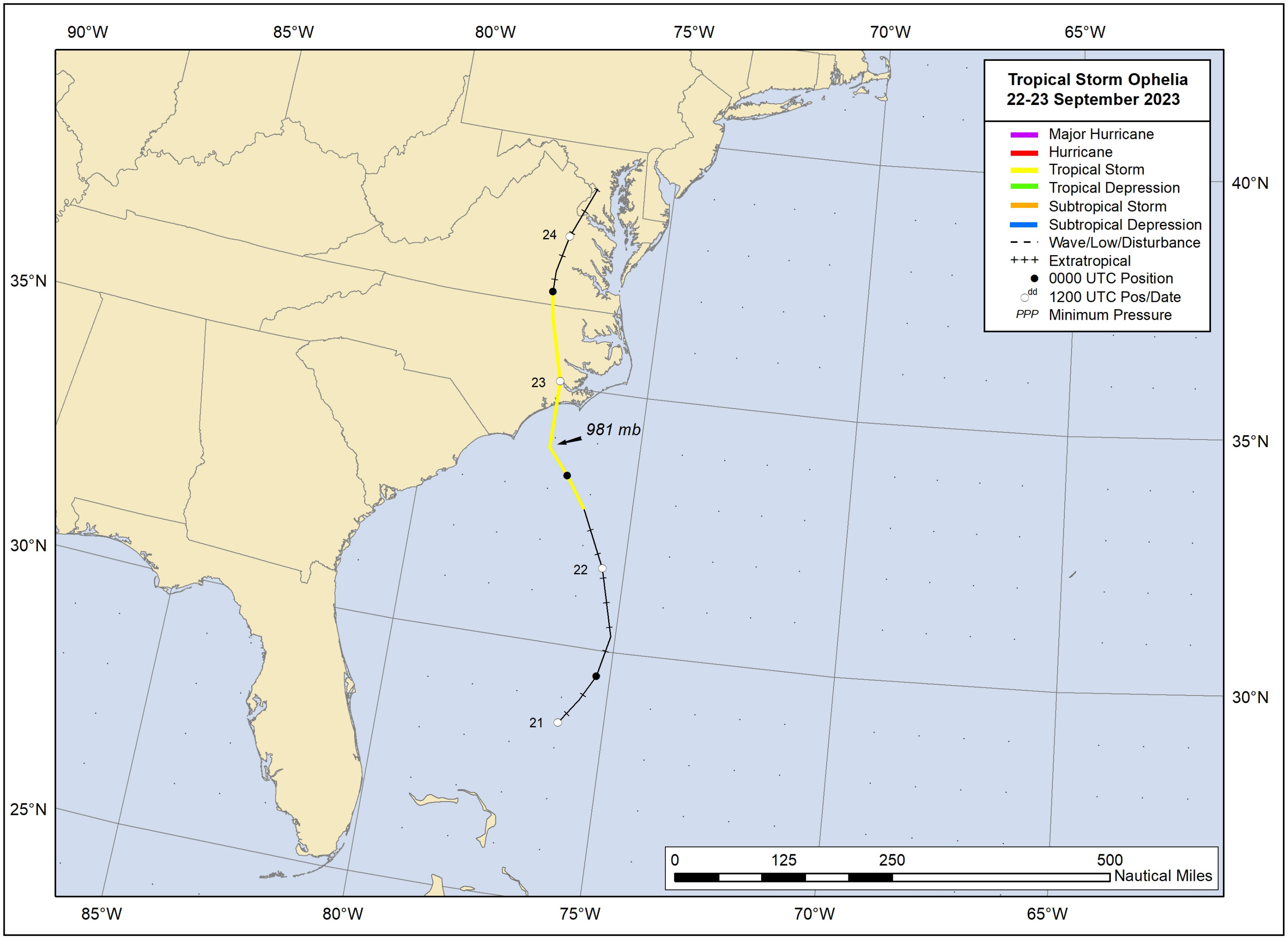


Figure 2. Best track positions for Tropical Storm Ophelia, 22–23 September 2023. Track over the United States during the extratropical stage is partially based on analyses from the NOAA Weather Prediction Center.

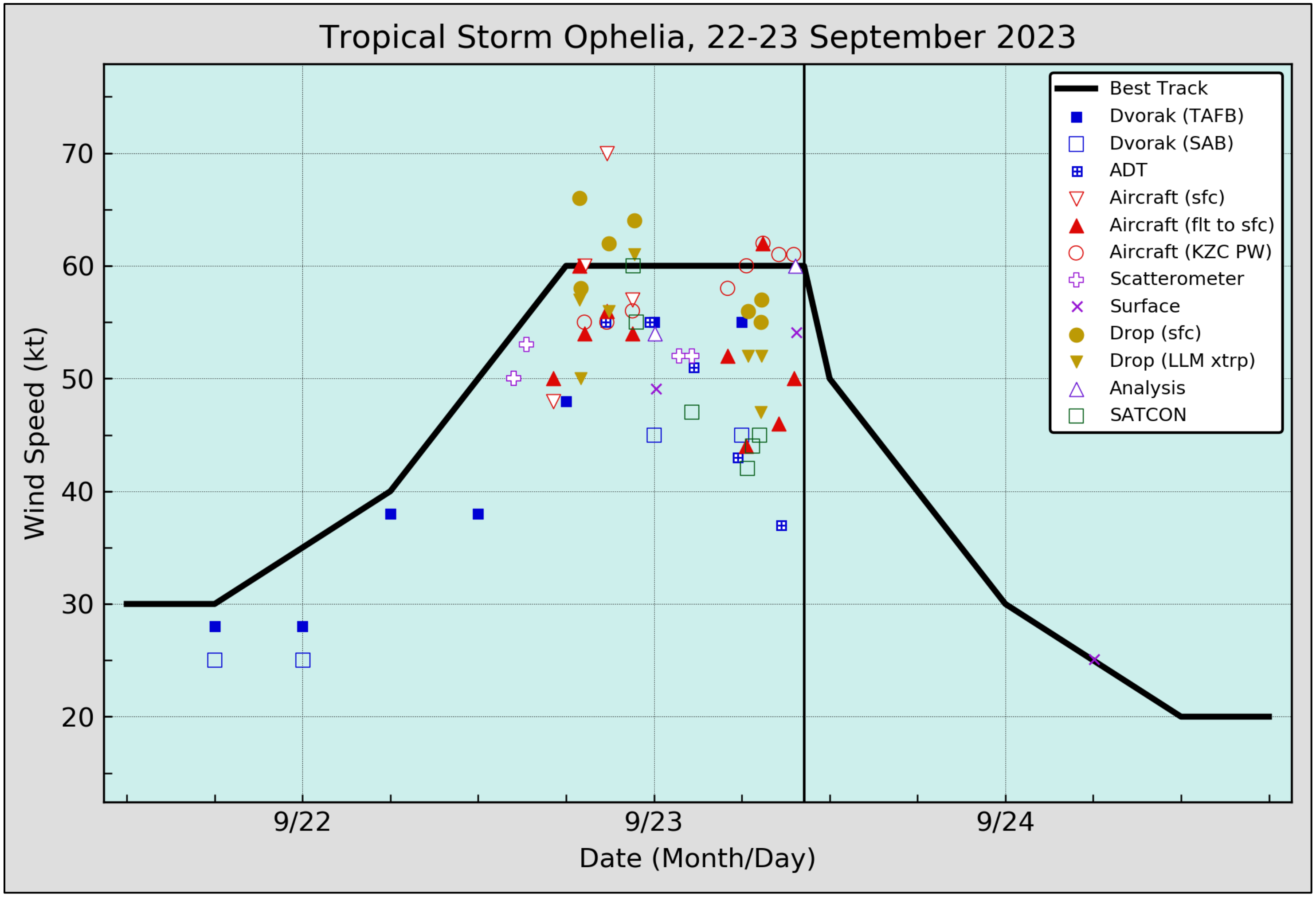


Figure 3. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Ophelia, 22–23 September 2023. Aircraft observations have been adjusted for elevation using 90%, 80%, and 75% adjustment factors for observations from 700 mb, 850 mb, and 925 mb, respectively. 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). 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, and solid vertical lines correspond to landfalls.

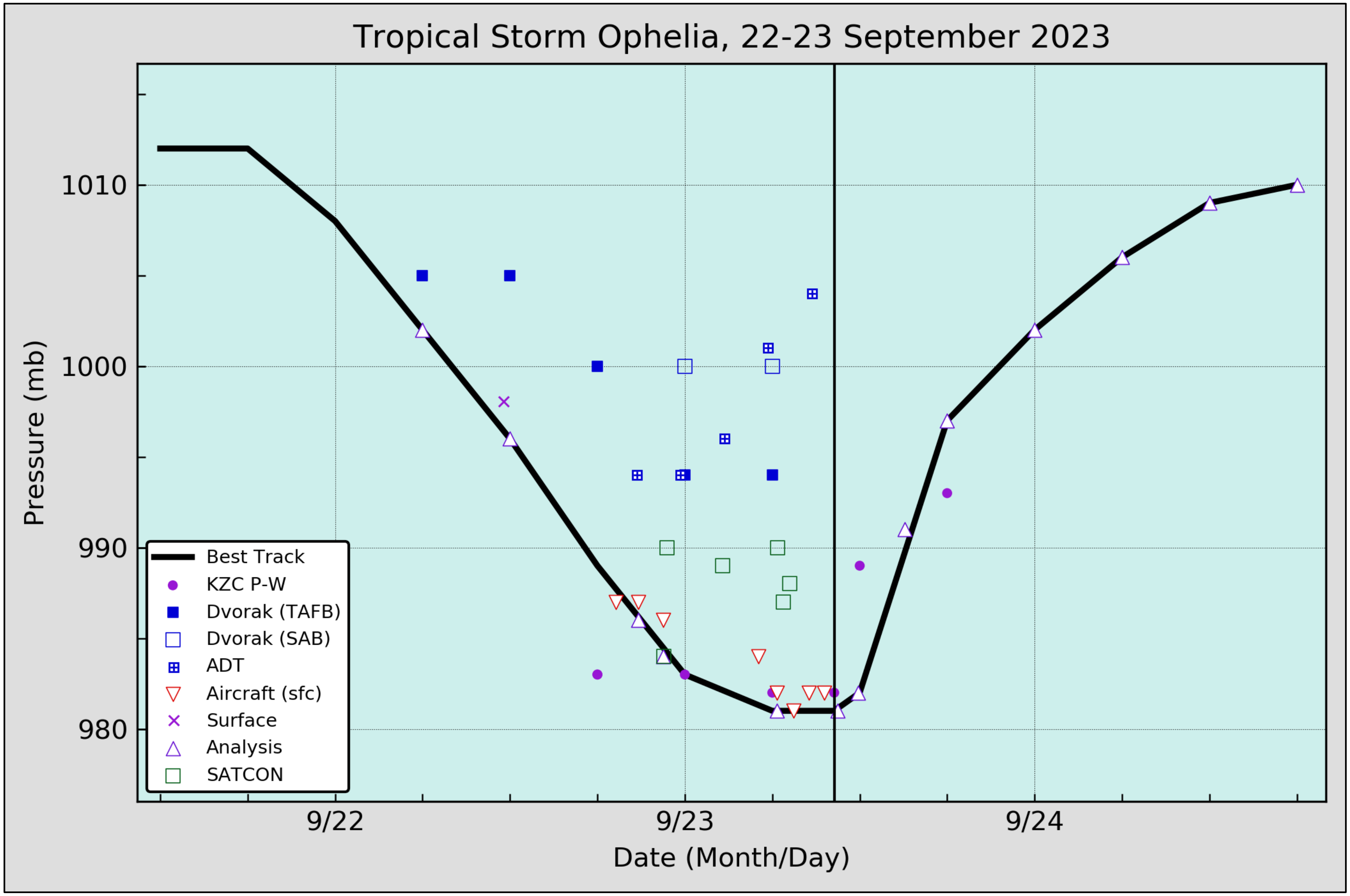


Figure 4. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Ophelia, 22–23 September 2023. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for 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, and solid vertical lines correspond to landfalls.

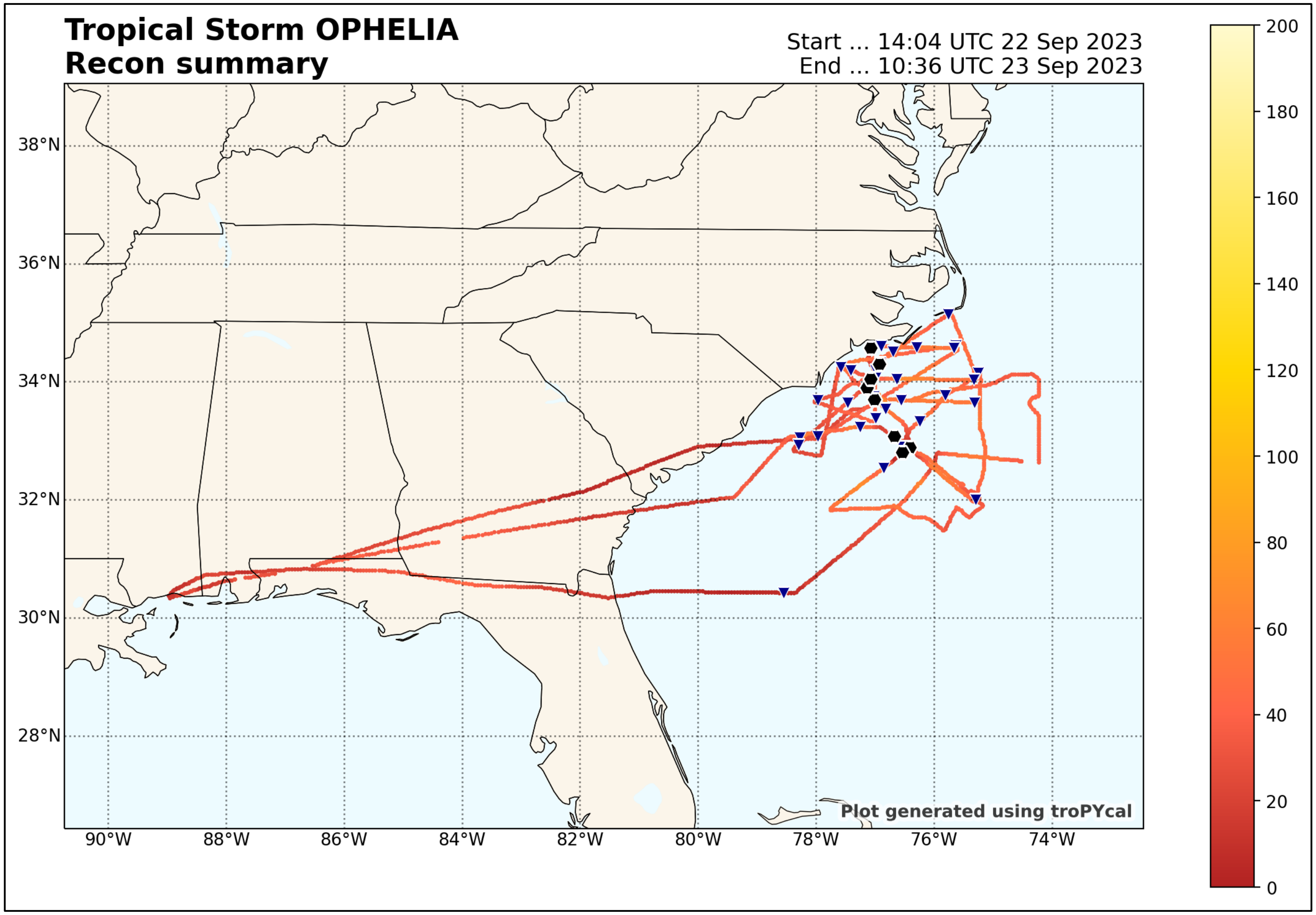
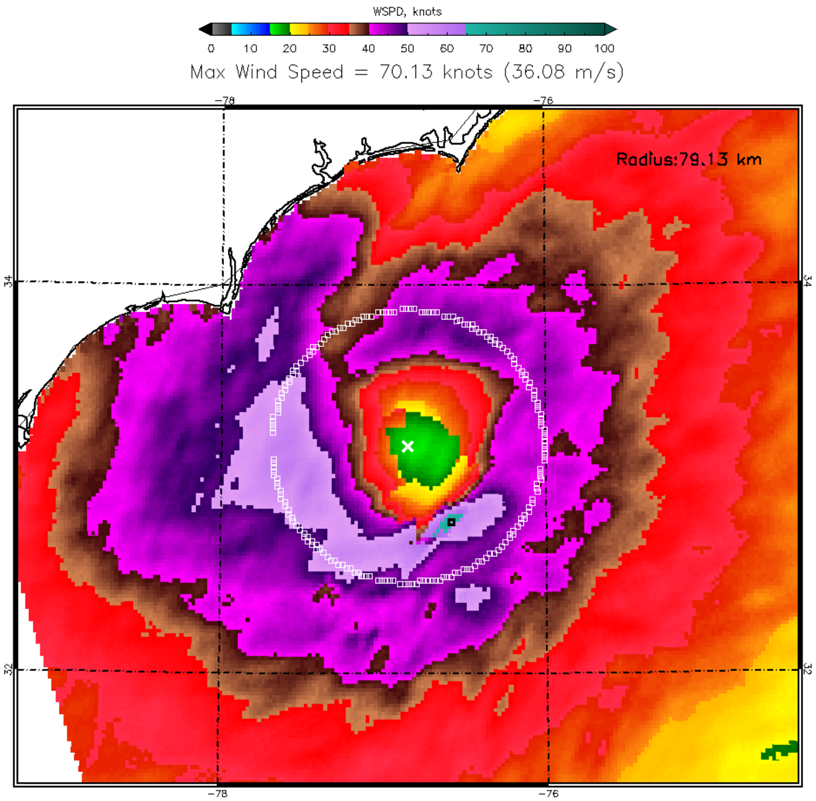


Figure 5. Air Force Reserve Hurricane Hunter aircraft flight tracks (red) from reconnaissance missions into Ophelia on 22–23 September 2023. The black markers denote center fixes, and the blue triangles indicate dropsonde locations. The color coding of the flight tracks is based on the observed flight-level wind speed with the color legend to the right of the map representing the color associated with the various wind speeds in knots.



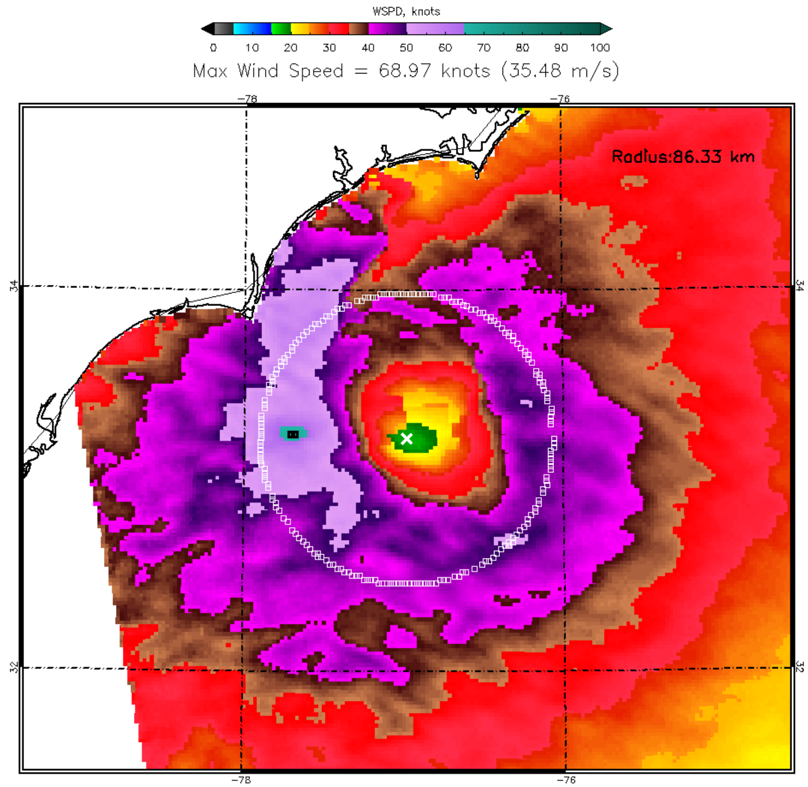


Figure 6. Ultra-High Resolution (UHR) ASCAT-B (left) and ASCAT-C (right) surface (10 m) wind data at 0143 and 0235 UTC 23 September, respectively. Data courtesy of Zorana Jelenak (UCAR).

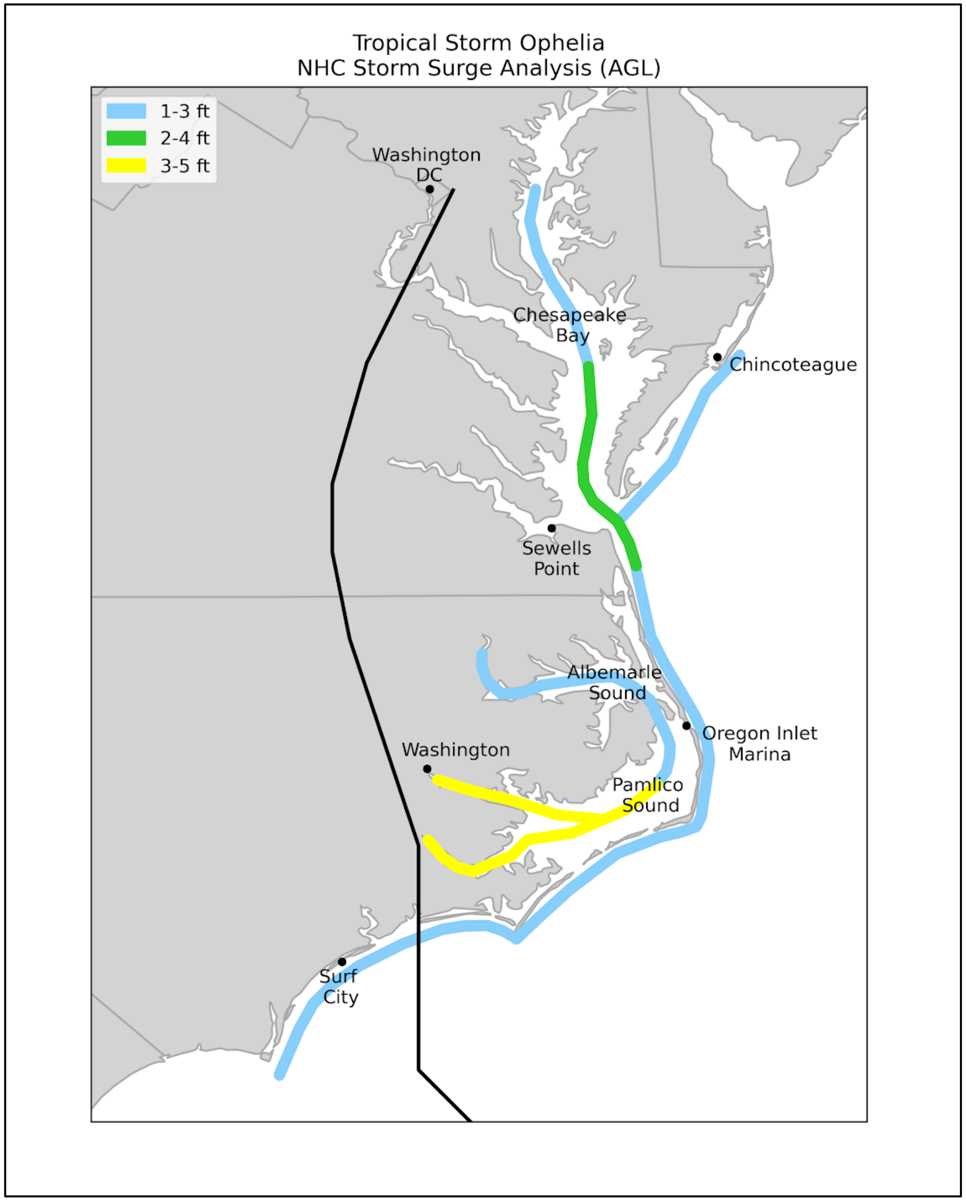


Figure 7. Analyzed storm surge inundation (feet above ground level, AGL) along the coast of North Carolina, Virginia, and Maryland from Ophelia.

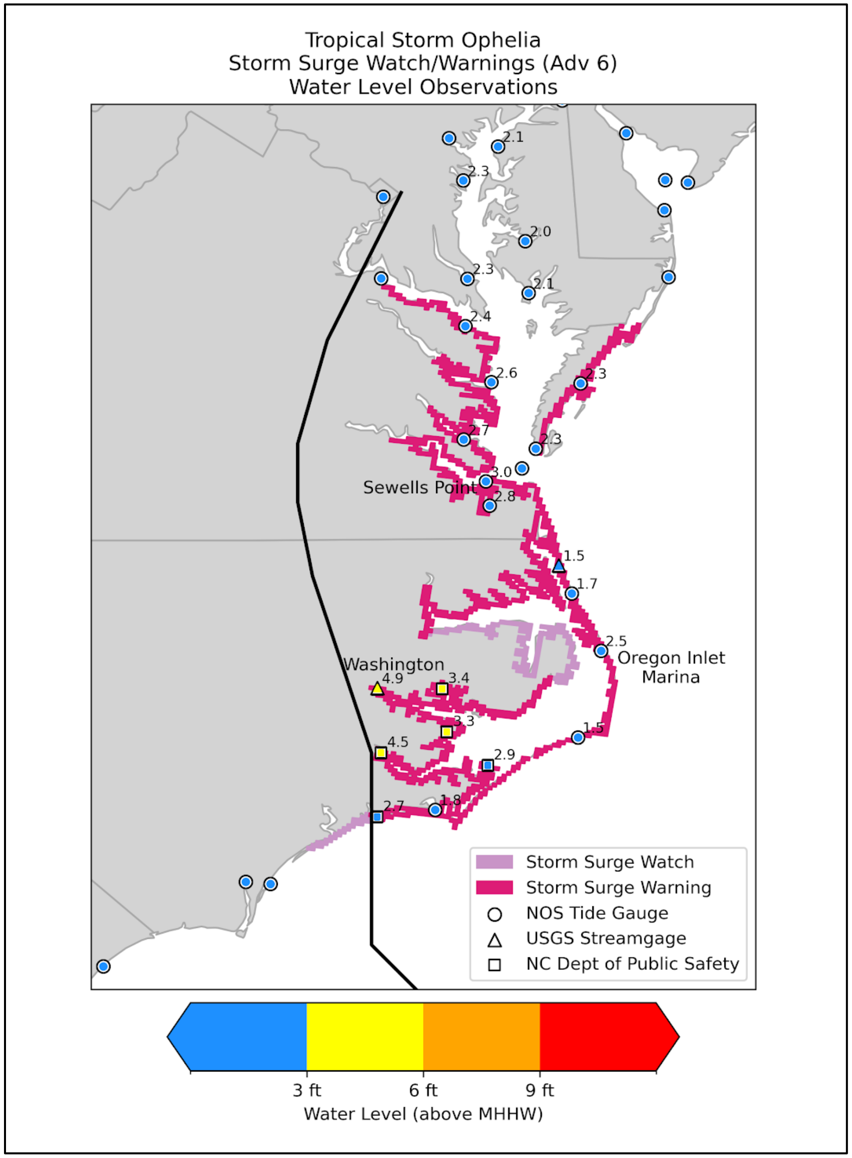


Figure 8. Maximum water levels (ft above MHHW) during Tropical Storm Ophelia measured by NOS, USGS, and North Carolina Department of Public Safety observing networks, as well as the extent of the storm surge watches (lavender) and warnings (magenta) from 2100 UTC 22 September (Adv 6). Ophelia's track is overlaid (black line).

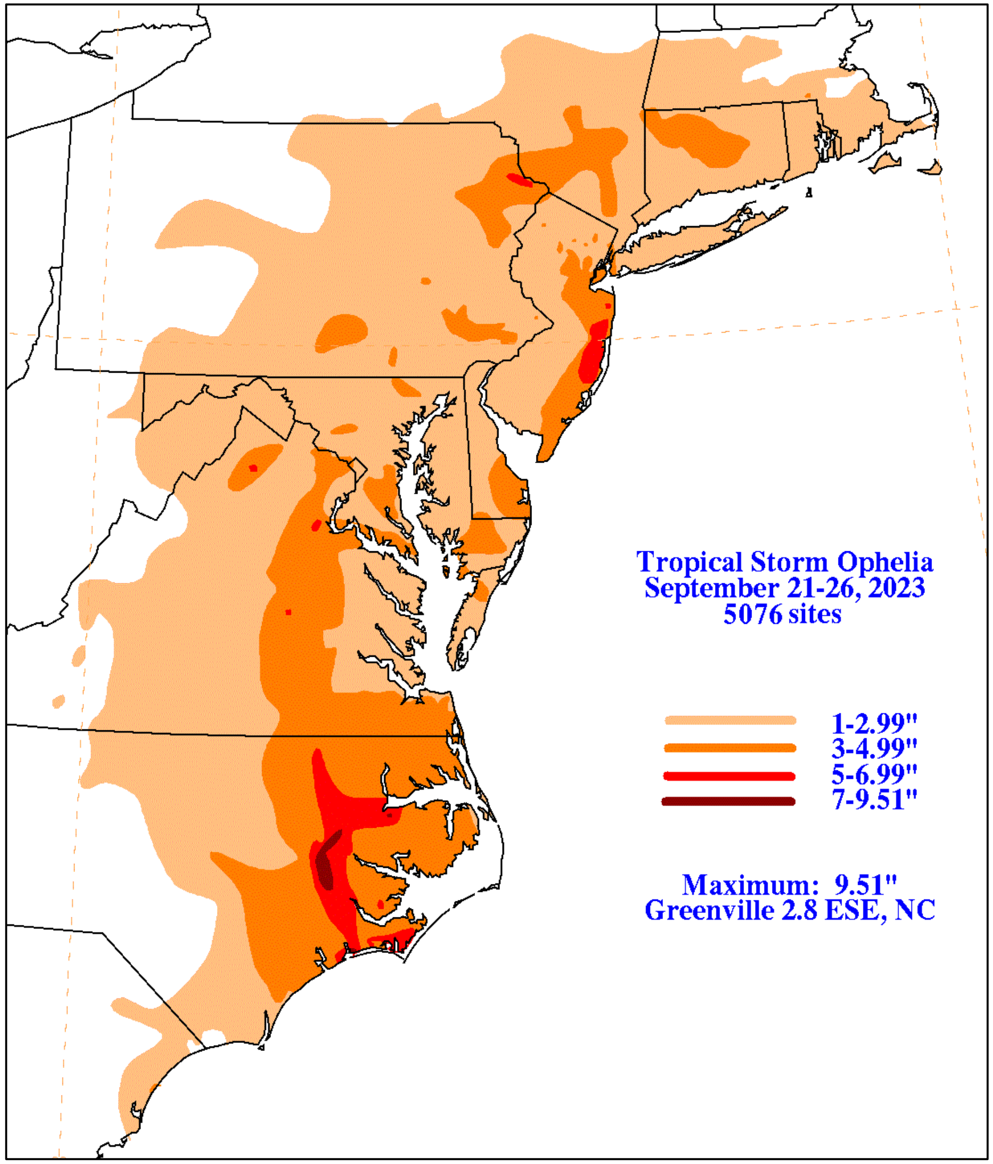


Figure 9. Observed rainfall (inches) from Tropical Storm Ophelia over the eastern United States. Image courtesy of David Roth from NOAA's Weather Prediction Center.

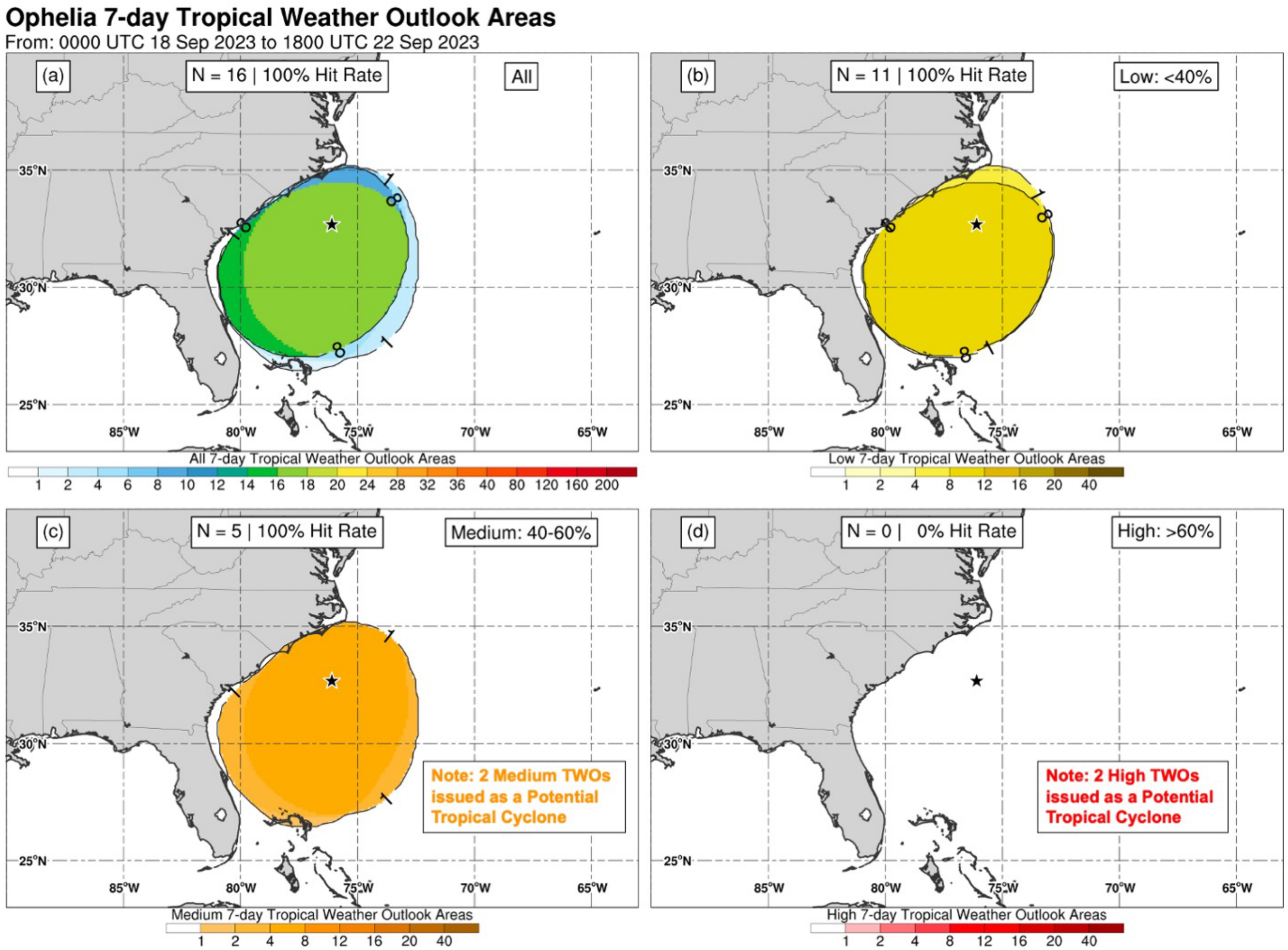


Figure 10. Composites of 7-day tropical cyclone genesis areas depicted in NHC's Tropical Weather Outlooks prior to the formation of Ophelia for (a) all probabilistic genesis categories, (b) the low (<40%) category, (c) medium (40–60%) category, and (d) high (>60%) category. The location of genesis is indicated by the black star.

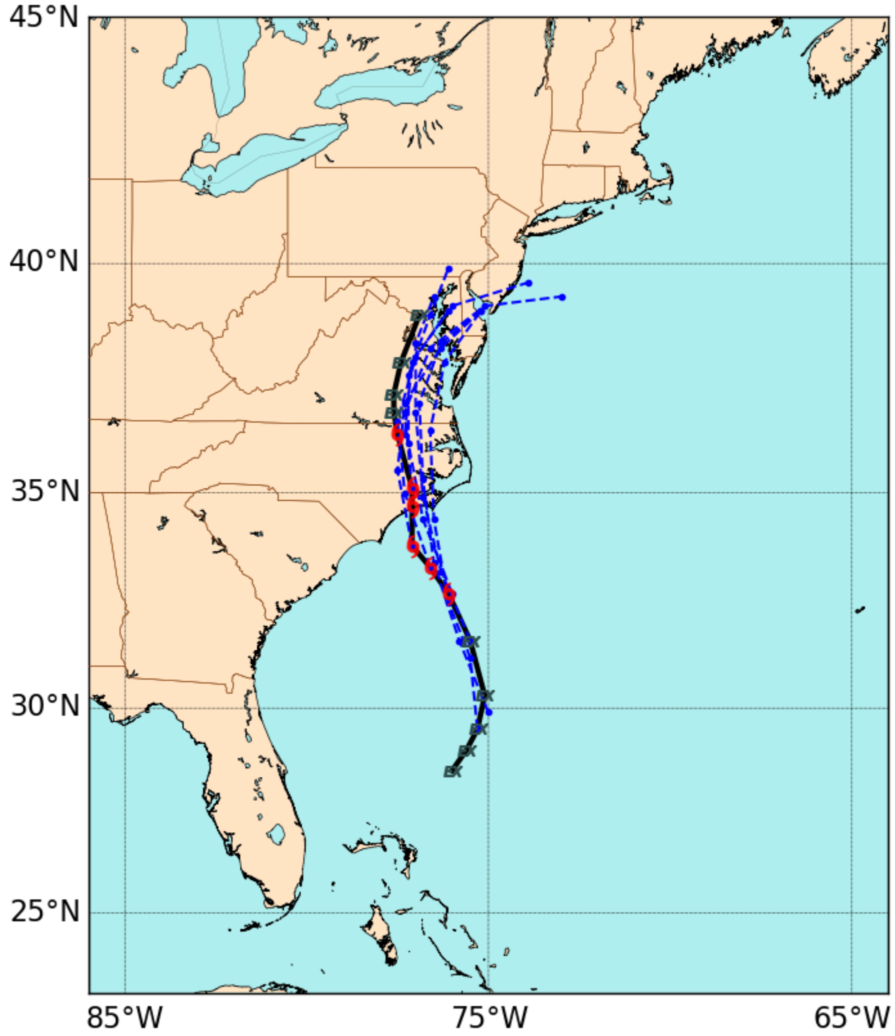


Figure 11. Selected official track forecasts (blue lines) for Tropical Storm Ophelia, 22–23 September 2023. The best track is given by the thick solid line with the positions given at 6-h intervals.

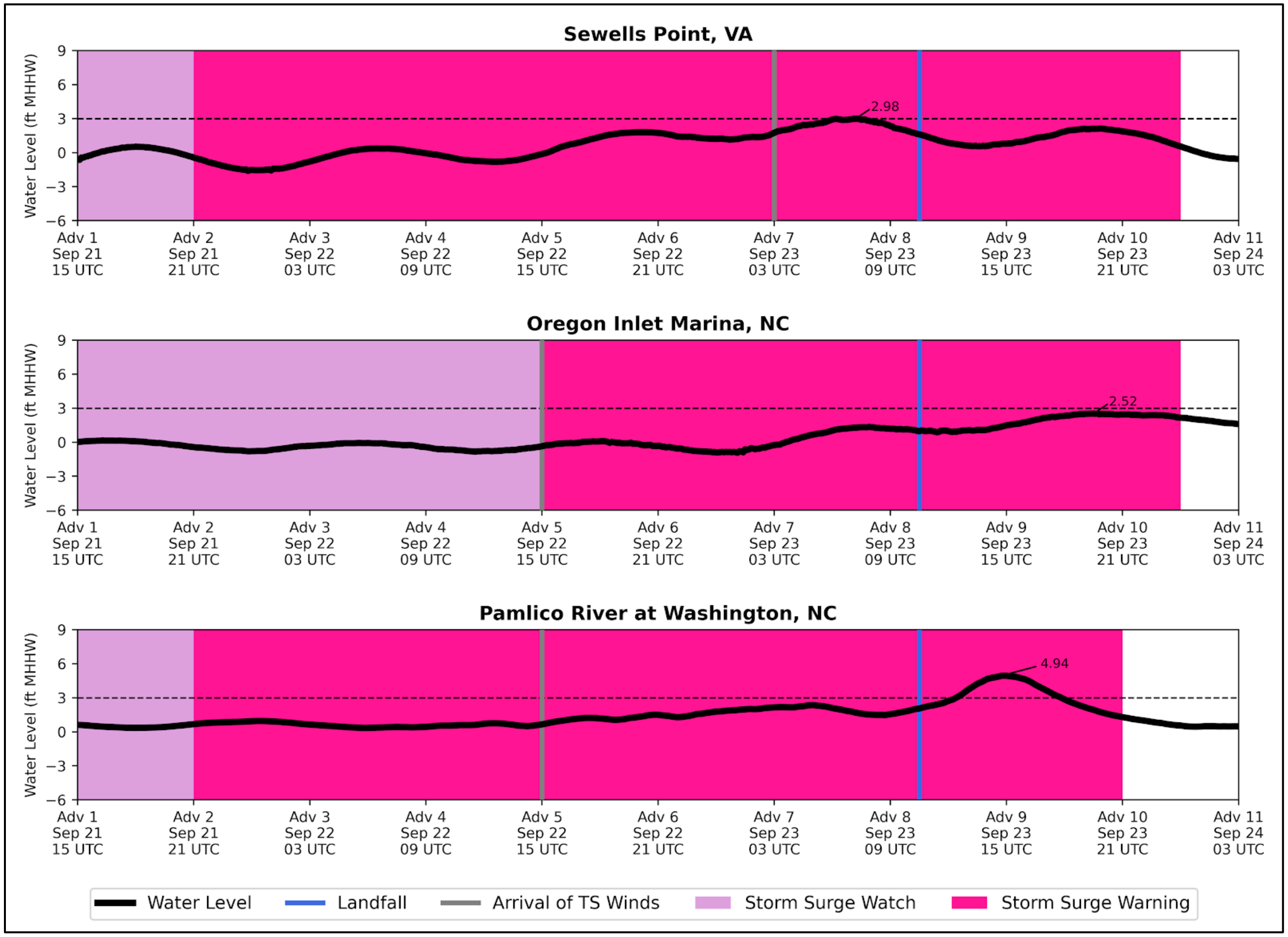


Figure 12. Timeline of NHC storm surge watches and warnings for Ophelia compared with verifying onset time of tropical-storm-force winds (gray), landfall (blue), and the water level measurements (black line) at NOS/USGS water level sensors in the warning area. See Figures 7 and 8 for location references.