NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE IAN

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23–30 September 2022

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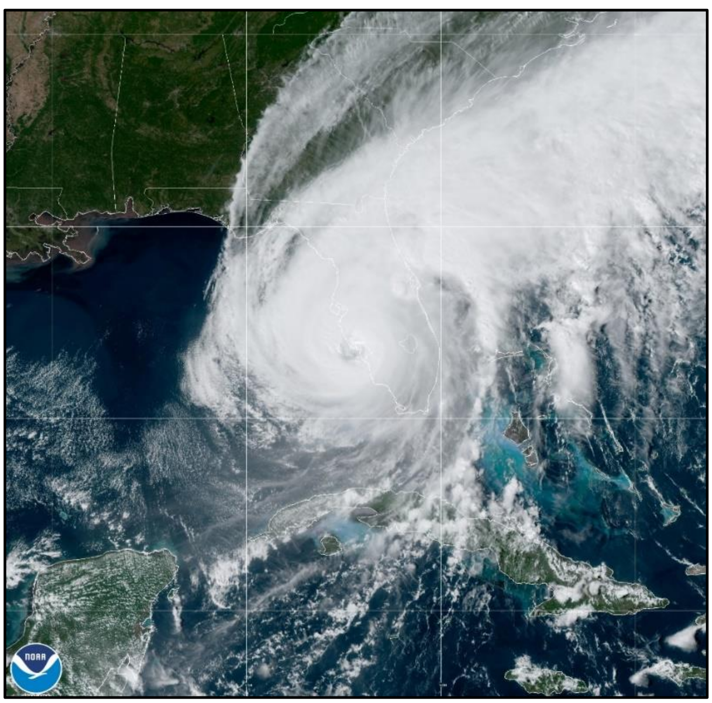

GOES-16 GEOCOLOR IMAGE FROM 28 SEPTEMBER 2022 AT 1910 UTC NEAR THE TIME OF IAN'S LANDFALL IN SOUTHWESTERN FLORIDA. CREDIT: NOAA/NESDIS/STAR

Ian made landfall in southwestern Florida at category 4 intensity (on the Saffir-Simpson Hurricane Wind Scale), producing catastrophic storm surge, damaging winds, and historic freshwater flooding across much of central and northern Florida. Ian was responsible for over 150 direct and indirect deaths and over $112 billion in damage, making it the costliest hurricane in Florida's history and the third-costliest in United States history. Ian also made landfall as a category 3 hurricane in western Cuba bringing widespread damage and loss of power to the entire island. Ian made its final landfall as a category 1 hurricane in South Carolina.

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Hurricane Ian

23–30 September 2022

SYNOPTIC HISTORY

The origins of Ian can be traced back to a robust tropical wave that moved off the west coast of Africa from 14–15 September. The wave remained embedded in the monsoon trough and Inter-tropical Convergence Zone (ITCZ) as it moved slowly across the Atlantic for the next six days, with occasional bursts of disorganized convection. The wave reached the Windward Islands on 21 September, and convective activity increased while the wave was over the southeastern Caribbean. However, an equatorward outflow channel from Hurricane Fiona, located to the north of the disturbance, generated moderate-to-strong vertical wind shear which slowed organization. Despite the continued shear, around 0600 UTC 23 September, infrared satellite imagery indicated that the system had enough organization of its associated deep convection and a sufficiently well-defined low-level circulation to designate the formation of a tropical depression when it was located about 130 n mi east-northeast of Aruba. The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1].

A mid-level ridge building to the north of the depression caused the system to move on a general west-northwestward track away from the Aruba, Bonaire, and Curaçao island chain. The cyclone became a tropical storm 18 h after genesis, at 0000 UTC 24 September, when it was located 335 n mi southeast of Jamaica, which coincided with the subtropical ridge turning Ian toward the west. Moderate-to-strong vertical wind shear initially limited intensification of Ian, preventing alignment of the low- and mid-level centers while the storm moved over the Caribbean Sea south of Jamaica. Early on 25 September, the storm turned northwestward, and later that day convection near Ian's core started to coalesce. Ian began its first period of rapid intensification at 1800 UTC 25 September when it moved around the southwestern periphery of the aforementioned ridge. By 0600 UTC 26 September, Ian became a hurricane as it passed about 100 n mi south-southwest of Grand Cayman Island. The storm continued to rapidly intensify over warm waters (30°C and higher) and in a low vertical wind shear environment as it turned northward towards Cuba. Ian's rapid intensification continued while it approached the southwestern coast of Cuba, and it became a major hurricane by 0600 UTC 27 September. The storm made landfall a few hours later near La Coloma in the Pinar del Rio Province at 0830 UTC 27 September as a 110-kt category 3 hurricane.

Ian weakened only slightly while it passed over Cuba, and the center of the hurricane emerged over the southeastern Gulf of Mexico around 1400 UTC 27 September. Atmospheric and oceanic conditions remained very conducive for additional strengthening as the storm moved

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[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.

toward the north-northeast between the western side of a subtropical ridge and a broad trough over the eastern United States. Shortly after entering the Gulf, an eyewall replacement cycle began. This structural change resulted in a larger radius of maximum winds (RMW), an expanded overall wind field, and surprisingly, a slight increase in intensity once the eyewall replacement cycle completed. At 0200 UTC 28 September, the eye of the 110-kt hurricane passed directly over the Dry Tortugas. Ian intensified further later than morning and reached its peak intensity of 140 kt (a category 5 hurricane) at 1200 UTC 28 September.

Environmental conditions became less favorable soon thereafter, and Ian weakened slightly during the next several hours before it made landfall on the barrier island of Cayo Costa, Florida, at 1905 UTC 28 September with an intensity of 130 kt. An hour and a half later, at 2035 UTC, the center of Ian's large eye made another landfall near Punta Gorda, Florida, with an estimated intensity of 125 kt. The cyclone steadily weakened as it moved northeastward across the Florida peninsula late that day and overnight, and it became a tropical storm with maximum sustained winds of 60 kt by 1200 UTC 29 September, just as the center was emerging over the Atlantic waters near Cape Canaveral, Florida.

Once over the western Atlantic Ian re-strengthened to a 65-kt hurricane by 1800 UTC 29 September with much of its convection displaced to the north of the center while the hurricane interacted with a trough over the eastern United States. Ian turned northward early on 30 September and began to accelerate toward the coast of South Carolina. The hurricane made its final landfall near Georgetown, South Carolina, with an intensity of 70 kt at 1805 UTC 30 September.

Shortly after landfall, Ian merged with a front over North Carolina, marking its transition to an extratropical cyclone by 0000 UTC 1 October as it moved inland. By 1200 UTC that day, surface, radar, and satellite imagery indicated that Ian had dissipated, and a separate mid-latitude low had formed to the northeast.

METEOROLOGICAL STATISTICS

Observations in Ian (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), objective Advanced Dvorak Technique (ADT) and AI-Enhanced Advanced Dvorak Technique (AiDT)[2] 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 a combined 28 flights of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command and the NOAA Aircraft Operations Center. The Air Force Reserve Hurricane Hunters made 14 flights into Ian and reported 37 center fixes. The NOAA Hurricane Hunters flew 8 missions into the storm with 16 center fixes, and there were 6 synoptic surveillance missions flown by the NOAA G-IV jet. Data

[2] Olander, T., A. Wimmers, C. Velden, and J. P. Kossin, 2021: Investigation of Machine Learning Using Satellite-Based Advanced Dvorak Technique Analysis Parameters to Estimate Tropical Cyclone Intensity. *Wea. Forecasting*, **36**, 2161–2186, https://doi.org/10.1175/WAF-D-20-0234.1.

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 Ian. Data from the weather radars in the United States provided important information on Ian.

Ship reports of winds of tropical storm force associated with Ian are given in Table 2, and selected significant storm surge observations given in Table 3. A supplemental file containing a larger selection of surface and buoy observations is available for download on the NHC website at https://www.nhc.noaa.gov/data/tcr/supplemental/ian.xlsx. This file also contains rainfall reports from National Weather Service Cooperative (COOP) stations and the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) sites.

Winds and Pressure

Ian's estimated peak intensity of 140 kt and minimum central pressure of 937 mb at 1200 UTC 28 September are based on data from Air Force Reserve Unit and NOAA reconnaissance aircraft. During the missions, the maximum 10-second averaged flight-level winds reported in the hurricane's core were 160 kt from a NOAA aircraft at 750 mb (an altitude of about 6800 ft) at 1013 UTC 28 September. These flight-level winds support a surface intensity estimate of 136 kt. There were also multiple peak SFMR surface wind estimates from both Air Force and NOAA aircraft of 137-138 kt at 1030 UTC and 1013 UTC, respectively. The SFMR data from the Air Force instrument was flagged as unreliable in the real-time products, but reprocessing in the post-storm analysis using an updated algorithm no longer flagged the peak values. Due to extreme turbulence in the region where the maximum sustained winds were located in the western quadrant, the aircraft was only able to sample that part of Ian's core once. A profile of the winds from the NOAA P-3 Tail Doppler Radar showed a shallow maximum of winds largely below the aircraft altitude with speeds exceeding 160 kt 500-1000 ft (150-300 m) above the surface (Fig. 4). The combination of these data, and the consideration of potential undersampling from the SFMR[3], support a peak intensity of 140 kt. It should be noted that the NHC best track intensities typically have an uncertainty of around ±10%, and that there is very little practical difference between a 140-kt category 5 and a 135-kt category 4 hurricane.

A dropsonde from an Air Force Reserve aircraft reported a pressure of 937 mb with a surface wind of 2 kt around 1200 UTC 28 September, and these data are the basis for the minimum pressure of 937 mb.

Cuba and Elsewhere in the Caribbean

An Air Force Reserve reconnaissance aircraft was in the storm until about 0400 UTC 27 September, over 4 hours before landfall in Cuba. The aircraft measured a peak 700-mb flight level wind speed of 101 kt (reducing to 91 kt) and SFMR retrievals of 97 kt. Infrared satellite and Cuban radar imagery showed Ian's eye became more distinct just before landfall, and objective satellite intensity estimates (ADT and AiDT) increased to 110-113 kt. The more organized satellite

[3] Klotz, B. W., and D. S. Nolan, 2019: SFMR Surface Wind Undersampling over the Tropical Cyclone Life Cycle. *Mon. Wea. Rev.*, **147**, 247–268, https://doi.org/10.1175/MWR-D-18-0296.1.

and radar presentation and increasing satellite intensity estimates were the justification for the 110 kt intensity at landfall in Cuba. Ian's estimated landfall pressure of 947 mb is based on an extrapolated pressure of 947 mb measured by a NOAA Hurricane Hunter aircraft at 1024 UTC.

Ian brought hurricane conditions to portions of western Cuba. The Instituto de Meteorología de Cuba reported a peak 10-minute sustained wind of 90 kt with a gust of 118 kt in San Juan y Martinez at 0755 UTC 27 September. A conversion of the 10-minute wind yields an equivalent 1-minute sustained wind of 100–110 kt[4]. In Pinar del Rio, an observing station measured a 10-minute sustained wind of 89 kt with a 105-kt gust at 1112 UTC 27 September. The same station measured a minimum pressure of 956.7 mb at 0850 UTC 27 September.

Based on the data available at the time this report was written, no sustained tropical-storm-force were reported in the Cayman Islands, Jamaica, or the Bahamas. However, these islands did report wind gusts of tropical storm strength.

Florida and Georgia

The estimated intensity at the Dry Tortugas landfall is based on data from an Air Force Reserve aircraft that completed two passes through the center of Ian between 0205 and 0323 UTC 28 September. The peak 700-mb flight-level winds were 118 kt which reduces to 106 kt at the surface. The peak SFMR measurement was 99 kt. Based on the flight-level wind reduction and accounting for undersampling of the SFMR, the intensity is estimated to be 110 kt. The central pressure of 952 mb is based on a dropsonde released from the same aircraft that measured a pressure of 952 mb with a surface wind of 5 kt.

The estimated intensity at the Cayo Costa landfall is based on data from an Air Force Reserve aircraft. At 1723 UTC 28 September a peak flight-level wind of 136 kt was reported (reducing to 122 kt) paired with an SFMR measurement of 121 kt. When accounting for undersampling and the large radius of maximum wind (greater than 30 n mi), a correction factor can be applied to the SFMR observations that equates to 128 kt. Therefore, Ian's estimated intensity at the Cayo Costa landfall is 130 kt.

The Air Force Reserve aircraft released a dropsonde in the center of Ian that measured a surface pressure of 939 mb (at 1807 UTC 28 September) with 6 kt of wind just above the surface about an hour before the Cayo Costa landfall. At 1903 UTC, the same aircraft reported an extrapolated minimum central pressure of 942 mb (though this method tends to have higher uncertainty). A blend of these data was the basis for the estimated central pressure of 941 mb at the Cayo Costa landfall.

Ian's landfall intensity in mainland southwestern Florida is estimated to be 125 kt. Because of instrument failure, no reliable surface observations exist from the coastal areas where the eyewall came on shore. In addition, aircraft reconnaissance was no longer in the storm environment. The highest reported sustained wind observation near the landfall location with a complete dataset was 94 kt at 2020 UTC 28 September with a peak gust of 122 kt from a WeatherSTEM station (anemometer elevation unknown) in Iona, Florida. Farther inland, the

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[4] Harper, B. A., J. D. Kepert, and J. D. Ginger. Guidelines for converting between various wind averaging periods in tropical cyclone conditions. World Meteorological Organization. August 2010. https://library.wmo.int/doc_num.php?explnum_id=290

Florida Coastal Monitoring Program placed a mobile meteorological tower near the Punta Gorda airport that measured peak sustained winds of 78 kt with a gust of 96 kt at 1959 UTC 28 September.

Elsewhere, in northern Cape Coral, Florida, a WeatherSTEM station (anemometer elevation unknown) measured sustained winds of 80 kt with a peak gust of 96 kt at 1840 UTC 28 September. In Punta Gorda, Florida, an Automated Surface Observing Station (ASOS) reported sustained winds of 76 kt with a peak gust of 117 kt at approximately 2025 UTC 28 September. However, both of these stations stopped reporting wind observations shortly after their peak values were observed, and the datasets are incomplete.

The lowest pressure reported in the third Florida landfall area was 951.2 mb at 2023 UTC 28 September by Josh Morgerman (iCyclone) located in Punta Gorda. On the same day, a Citizen Weather Observer Program (CWOP) station, also located in Punta Gorda, reported a minimum pressure of 951.6 mb at 2030 UTC. These observations were on the northern side of the large eye and indicate the minimum central pressure of Ian was rising as it moved inland. The minimum pressure is estimated to be 945 mb at landfall on the mainland of Florida.

After making landfall in southwestern Florida, hurricane conditions penetrated inland over portions of the peninsula. However, many weather stations near the path of Ian's center stopped transmitting observations prior to the arrival of the strongest winds. A WeatherFlow station in New Smyrna Beach, Florida, reported sustained winds of 63 kt and a peak gust of 83 kt at 0837 UTC 29 September. This station was located about 80 n mi from the center of Ian and is the basis for the 65-kt intensity at 0600 UTC 29 September.

A large portion of Florida experienced tropical-storm-force winds (Fig. 5). These winds arrived in the Florida Keys late on 27 September and extended as far north as Islamorada as Ian passed to the west. On the western side of Florida, there were sustained 35-kt winds as far north as Dunedin at 2005 UTC 28 September. As Ian moved off shore of the east coast of Florida at 1200 UTC 29 September, tropical-storm-force winds were reported as far north as Savannah, Georgia, and as far south as Pompano Beach, Florida.

North Carolina and South Carolina

An Air Force Reserve aircraft observed peak flight-level winds of 71 kt at 1355 UTC 30 September (reducing to 64 kt at the surface) and maximum SFMR winds of 72 kt at 1334 UTC 30 September. The highest reported sustained wind close to the landfall location from an instrument with a complete dataset was 69 kt at 1753 UTC 30 September with a peak gust of 73 kt from a WeatherFlow station (anemometer elevation 15 m) in Georgetown, South Carolina. These data support a landfall intensity of 70 kt.

Sustained tropical-storm-force winds were measured both north and south of the landfall location along the coast (Fig. 5). Inland, tropical-storm-force gusts were recorded along the track of Ian into northern portions of both North Carolina and South Carolina.

A dropsonde released by an Air Force Reserve aircraft measured 982 mb with a 53-kt surface wind speed at 1641 UTC 30 September. The minimum pressure recorded from a surface station was 978.7 mb by a WeatherFlow station located in Murrells Inlet, South Carolina, at

1934 UTC 30 September. This station and the dropsonde data were used as the basis for the minimum central pressure estimate of 978 mb at the time of landfall.

Storm Surge[5]

Cuba

The Instituto de Meteorología de Cuba reported that Ian produced a significant storm surge along the southwest coast of Cuba. East of the landfall location, in La Coloma, the sea penetrated 300 m (0.2 mi) inland and water levels reached a height between 2.5 and 3 m (~8 and 10 ft) (unknown reference level). Nearby in Playa Las Canas, water levels reached a height of 2.6 m (8.5 ft). In Artemisa, located farther to the east, water levels reached a height of 1.75 m (5.7 ft). These areas also had significant inland penetration of the sea, up to 1500 m (0.93 mi) inland in Majana and Cajío, and up to 5000 m (3.1 mi) inland in Guanimar. Minor-to-moderate coastal flooding also occurred on the northwest coast of Cuba.

United States

Ian produced a catastrophic storm surge along the southwest coast of Florida, impacting the barrier islands near Fort Myers, as well as rivers and bays such as the Caloosahatchee River, Estero Bay, the Imperial River, and Naples Bay. Peak storm surge inundation levels of 10 to 15 ft above ground level (AGL) occurred in Fort Myers Beach (Fig. 6). Ian made landfall in a region extremely vulnerable to storm surge, and the exact track, strong winds, and large storm size (e.g., 20 n mi RMW at landfall) contributed to the widespread devastating impacts. Ian also produced a significant storm surge on the northeast coast of Florida as it passed over the state, and along the South Carolina coast where it made a final landfall.

Several observing networks captured the storm surge event, including National Ocean Service (NOS) tide gauges (Fig. 7), deployed United States Geological Survey (USGS) water level sensors (Fig. 8), USGS stream gauges (not shown), and survey crews collecting post-storm high water marks (Fig. 9). Note that Mean Higher High Water (MHHW), an approximation for inundation at the immediate coastline, is reported herein at USGS sensors when a valid conversion from NAVD88 (a geodetic datum measured by the sensor) can be made using the NOAA VDatum conversion tool. These data were analyzed alongside the storm surge hindcast produced by the NHC Storm Surge Unit to create a final storm surge estimate. Figure 6 shows the NHC storm surge analysis, which represents the maximum inundation above ground level (AGL) during Hurricane Ian.

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[5] 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).

SOUTHWESTERN FLORIDA

Maximum inundation levels of 10 to 15 ft AGL occurred on Fort Myers Beach and Estero Island. A USGS water level sensor measured a wave-filtered water level of 12.70 ft above MHHW at Fort Myers Beach Pier (Fig. 8, Fig. 10), which was the highest water level measurement from this network. Nearby, a remote camera mounted by stormchaser Max Olson captured the evolution of the storm surge event on Fort Myers Beach. The camera was located less than 0.5 miles to the east on Estero Blvd relative to the USGS water level sensor. A timeline of images taken from this video footage is shown in Figure 11: (a) The onset of storm surge inundating the streets, (b) rapidly moving water carrying large floating debris, (c) a home in the view of the camera floating off its foundation with large waves crashing over it, (d) waves splashing over the camera, mounted approximately 12 ft above the road, and (e) receding waters revealing a barren landscape approximately 6.5 hours after the first image. Figure 10 shows the USGS hydrograph and the photo timeline overlaid to help relate the sensor measurements to on-the-ground impacts. These observations provide a glimpse of the life-threatening and destructive power of the storm surge and waves that occurred throughout the area. In addition, both the USGS and the NWS surveyed extensive stillwater high water marks on the island (Fig. 9). The agencies used differing approaches: the USGS surveyed a wider area including inland impacts, and estimated the water level above ground, while the NWS heavily surveyed coastal areas for peak impacts, and estimated the water level above the high tide line (MHHW). NWS survey crews found the highest marks, approximately 15 ft above MHHW, inside the second story of beachfront structures (e.g. Fig. 12).

Elsewhere, maximum inundation levels of 9 to 13 ft AGL occurred on the eastern portion of Sanibel Island. A USGS water level sensor measured a wave-filtered water level of 12.58 ft above MHHW on Sanibel Island (Fig. 8), and USGS surveyed widespread high water marks of 6 to 9 ft AGL on the island (Fig. 9a). Significant structural damage was reported in these areas. For example, post-storm NOAA aerial imagery revealed large cuts, and portions of the Sanibel causeway were washed away by the storm surge (Fig. 13).

There was a sharp gradient in the most severe storm surge across the track of Ian's center. Figure 9a highlights a significant difference in the high water marks on the extreme eastern portion of Sanibel Island compared to Captiva. Additionally, a USGS water level sensor in Pirate Harbor, south of Punta Gorda, measured only 4.47 ft above MHHW, less than 30 miles from Sanibel Island and Fort Myers Beach. The majority of the sensors placed in Port Charlotte and Englewood, as well as northward through Tampa Bay, remained dry and did not measure storm surge due to offshore winds. Water levels in Tampa Bay receded below normal levels, where the NOS tide gauge at Old Port Tampa measured a minimum water level of 4.38 ft below Mean Lower Low Water (MLLW).

Maximum inundation levels of 6 to 9 ft AGL occurred in Pine Island, Cape Coral, and other communities along the mouth of the Caloosahatchee River. A USGS water level sensor in Punta Rassa, located at the east end of the Sanibel Causeway, measured a wave-filtered water level of 8.37 ft above MHHW. Two additional sensors in Matlacha and Cape Coral were lost/destroyed (Fig. 8). While only scattered high water marks were collected in these areas, the NHC storm surge hindcast suggests significant inundation occurred, especially along the immediate coast.

Maximum inundation levels of 5 to 8 ft AGL occurred up the Caloosahatchee River in Fort Myers. The NOS tide gauge near downtown Fort Myers measured 7.26 ft above MHHW (Fig. 7) where storm surge reversed the direction of the river flow and flooded the streets of the city. The USGS stream gauge network also recorded the impressive push of surge up the river, but several gauges failed prior to recording a peak water level. Along the southern bank of the river in downtown Fort Myers, USGS surveyed a high water mark of 4.4 ft AGL (Fig. 9a).

Maximum inundation levels of 8 to 12 ft AGL occurred in Estero, Bonita Beach, Bonita Springs, and North Naples. There were several USGS water level sensors that measured greater than 9 ft above MHHW from San Carlos Island southward through Delnor-Wiggins State Park in North Naples (Figure 5). Additional USGS stream gauges in the canals north and east of Estero Bay recorded significant inland surge, and USGS surveyed a high water mark of 8.3 ft AGL near Mullock Creek (Fig. 9a). Farther south in Bonita and North Naples, the most severe impacts were contained to the immediate coastline while inland high water marks ranged from 5 to 7 ft AGL.

Maximum inundation of 6 to 9 ft AGL occurred in Naples. The NOS tide gauge on Naples Pier measured 6.18 ft above MHHW before the station was destroyed due to significant wave action or debris (Fig. 7). Similarly, the USGS water level sensor placed nearby was lost/destroyed (Fig. 8). The USGS water level sensor located on the Gordon River Bridge in Naples Bay measured 7.1 ft NAVD88 (no conversion to MHHW). High water marks collected near the sensor measured between 4 and 5 ft AGL, and there were reports of flooding at the Naples airport.

Maximum inundation of 4 to 6 ft AGL occurred from Marco Island through Everglades City. Several USGS water level sensors measured 6 to 7 ft above MHHW (Fig. 8), and many of the USGS stream gauges along the Everglades reached the operational limit of the sensor prior to recording a peak water level. Only a few high water marks were collected, with a maximum of 4.7 ft AGL on Marco Island (Fig. 9a).

Storm surge inundation of 1 to 3 ft AGL occurred in the Florida Keys, with locally higher amounts of 2 to 4 ft AGL along extreme western Key West and the Dry Tortugas. The NOS tide gauge at Key West measured 2.46 ft above MHHW (Fig. 7), while eyewitness reports near the Southernmost Point buoy in Key West reported dangerous water levels on the ground.

ATLANTIC COASTLINE

Maximum inundation levels of 3 to 5 ft AGL occurred along the northeast coast of Florida from Volusia County to the Florida/Georgia border. USGS water level sensors placed along the northeast coast of Florida (not shown) recorded wave-filtered water levels of 3 to 6 ft above MHHW extending from Volusia County northward through St. Johns County. Several of these sensors remained dry and did not measure storm surge, while others are characteristically noisy, indicative of significant wave contamination. This evidence of wave contamination is further confirmed by post-storm NOAA aerial imagery that shows extensive beach erosion and damage to piers resulting from large and destructive breaking waves (not shown). Flooding of inland neighborhoods and intracoastal communities in Flagler and Volusia Counties was largely the result of heavy rainfall. Farther south along the coast of Brevard County, water levels reached 2 to 4 ft AGL.

Along the St. Johns River, water levels reached 2 to 4 ft AGL. The NOS tide gauge at Mayport, Florida, near the mouth of the St. Johns River, measured 2.48 ft above MHHW, while a gauge on the Buckman Bridge located south of downtown Jacksonville measured 3.06 ft above MHHW (Fig. 7).

Maximum inundation of 2 to 4 ft AGL occurred along the Georgia coast northward to Charleston, South Carolina. The NOS tide gauges at Fort Pulaski, Georgia, and Charleston measured maximum water levels of 2.01 ft and 1.89 ft above MHHW, respectively (Fig. 7).

Maximum inundation levels of 4 to 6 ft AGL occurred in Georgetown and Horry counties, South Carolina, just east of the landfall location. A tide gauge at Springmaid Pier, south of Myrtle Beach, measured a water level of 5.17 ft above MHHW (Fig. 7), and a USGS stream gauge near Georgetown captured the storm surge up the Pee Dee River, measuring 3.4 ft above MHHW. Additional high water marks collected in South Carolina by the NWS (not shown) were mostly qualitative, suggesting inundation up to 4 ft AGL in homes located in barrier island communities. The highest impact areas include Pawleys Island, Garden City, and Cherry Grove. South of Cape Fear, maximum inundation of 3 to 5 ft AGL occurred in coastal Brunswick County, North Carolina.

Maximum inundation levels of 2 to 4 ft AGL occurred from Cape Fear to Cape Lookout, North Carolina, including the Cape Fear River. NOS tide gauges at Wilmington and Wrightsville Beach measured 2.98 ft and 3.54 ft above MHHW, respectively (Fig. 7). Farther up the coast, the tide gauge at Beaufort measured 2.84 ft above MHHW. Maximum inundation of 1 to 3 ft AGL occurred on the Outer Banks, and 2 to 4 ft AGL occurred in the rivers, such as the Neuse River.

Rainfall and Flooding

Ian produced widespread rainfall and flooding along its track with four areas of impacts: 1) Florida, 2) Cuba, 3) the United States Mid-Atlantic states, and 4) the Bahamas (Fig. 14). The full rainfall dataset is available for readers in a separate file at https://www.nhc.noaa.gov/data/tcr/supplemental/ian.xlsx.

In Florida, Ian produced a wide swath of heavy rainfall that led to considerable and deadly freshwater flooding. The highest storm total rainfall recorded was 26.95 inches in Grove City, Florida, located just north of the landfall location on the western side of the state. Counties north of the track of Ian's center (including Charlotte, Sarasota, Hardee, DeSoto, Polk, and Manatee) experienced significant flooding when the Peace, Myakka, and Alafia Rivers, and Horse Creek all crested to record levels (Fig. 15).

In central and eastern Florida, rainfall totals of 10-20 inches caused major floods along the St. Johns River, Lake George, Crest Lake, the Little Wekiva River, and Dunns and Shingle Creek affecting Seminole, Orange, Lake, Putnam and Osceola Counties. Rainfall totals reached a secondary peak as Ian neared the Atlantic Ocean and brought 21.49 inches to Daytona Beach. A dry slot led to lower rainfall totals south of the track of Ian's center, though isolated totals of 9+ inches were still recorded in Broward County. The relatively lower rainfall totals south of Ian's track still resulted in flooded roadways in parts of Martin and St. Lucie Counties[6].

Rainfall totals in coastal regions of the Carolinas, Virginia, and Maryland ranged from 3 to over 10 inches, adding freshwater to the storm surge (in Horry and Georgetown counties in South Carolina). In Charleston, South Carolina, 10.75 inches of rain was observed. Farther inland along

[6] https://www.tcpalm.com/story/weather/hurricanes/2022/10/01/hurricane-ian-treasure-coast-reported-limited-flooding-wind-damage/10459252002/

Ian's track, rainfall totals generally ranged from under 2 to 6 inches and were accompanied by reports of streets flooding (such as in York County, South Carolina) and uprooted trees due to gusty winds in areas with saturated soils.

Media outlets reported maximum rainfall totals of over 20 inches (over 500 mm) occurred in the western portion of Cuba. The Instituto de Meteorología de Cuba surface stations in western Cuba reported rainfall totals ranging from 151.7 to 338 mm (6 to 13+ inches). Severe flooding was also reported with this excessive rainfall.

In the Bahamas, over 9 inches of total rainfall were recorded on both Great Abaco and Bimini Islands. An interview with a local resident revealed some associated flooding, impassible roadways, and damaged buildings[7].

Tornadoes

Ian produced 15 tornadoes in the United States. Fourteen of the tornadoes occurred in Florida on 27–28 September in Ian's outer rain bands. The magnitude of the tornadoes ranged from EF 0–2, some of which caused injuries and considerable property damage. An EF–2 tornado at 0059 UTC 28 September with a 6-n mi track in Palm Beach County injured 2 when it caused the roof of a house to collapse. An EF-1 tornado that formed at 2317 UTC 27 September at the North Perry Airport in Pembroke Pines damaged several buildings and aircraft, causing an estimated $2 million in property damage. The final tornado associated with Ian occurred in an outer rain band on the coast of North Carolina on 30 September.

CASUALTY AND DAMAGE STATISTICS

In the United States, Ian was responsible for at least 156 fatalities, 66 of which were considered deaths[8] directly caused by the storm. All direct deaths in the United States occurred in Florida (Fig. 16). Storm surge was the deadliest hazard, claiming 41 lives, with 36 of the 41 surge fatalities occurring in Lee County, Florida. There were 12 direct fatalities attributed to freshwater flooding in central and eastern Florida, 8 were categorized as marine fatalities, 4 were related to wind, and 1 was due to rough surf. A boat carrying a reported 27 migrants travelling from Cuba to the United States capsized just off the coast of the Florida Keys in rough waters generated by Ian. While four passengers swam to shore and five were rescued, only seven bodies were recovered (accounting for 7 of the 8 marine deaths). It should be noted that the 11 other people missing from the boat are not represented in the total fatalities of this report. A couple living on a separate boat that was set adrift from the Florida Keys are also still missing.

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[7] https://supicket.com/readyfight-how-the-bahamas-is-faring-against-hurricane-ian/

[8] 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.

Ian was also indirectly responsible for 90 casualties in the United States. Most of the victims (84 in total) were located in Florida, with 5 in North Carolina, and 1 in Virginia (Fig. 16). The leading causes of death were lack of access to timely medical care (18), accidents (such a trip-and-fall during power outages; 16), and cardiac events (16). Other causes included vehicular accidents, accidents related to storm preparations or clean up, carbon monoxide poisoning, suicide, and homicide.

A distribution of all the fatalities (Fig. 17) shows a wide range of ages, from 6 to 101 years old. However, the peak of the distribution is skewed towards the elderly population. It is possible this a reflection of demographics in the counties of southwest Florida but is consistent with other hurricane landfalls where the oldest die at the highest rates.

Cuba reported a total of 5 deaths[9]. Three were directly related to Ian's hazards (two due to wind and one unknown), and two were indirect deaths due to accidents that occurred during clean up.

According to the NOAA National Centers for Environmental Information[10], Ian caused an estimated $112.9 billion worth of total damage in the United States (with a 90% confidence interval of $86.8 to $135.9 billion), making Ian the third-costliest United States hurricane on record. Of that total, $109.5 billion occurred in Florida, making Ian the costliest hurricane to ever affect that state. In southwestern Florida, the catastrophic storm surge and wind left a huge swath of complete destruction. In Fort Myers Beach alone, an estimated 900 structures were totally destroyed (Fig. 18), and 2,200 were damaged. In Lee County, at least 52,514 structures were impacted, of which 5,369 were destroyed and 14,245 received major damage. Bridges and roadways were also severely damaged or destroyed. Roads and bridges to Sanibel and Pine Islands were washed away, limiting access to either by boat or helicopter. A portion of Interstate 75 in southern Sarasota County was shut down due flooding from the Myakka River. In Collier County, 33 buildings were destroyed, and over 3,500 buildings sustained major damage while at least 200 homes were destroyed in Charlotte County.

In central and eastern Florida, widespread historic freshwater flooding caused destruction and significant damage to many structures and roadways, leading to over 250 water rescues (Fig. 19). In Volusia County, 40 buildings were destroyed, and 1,378 structures were damaged. Ian damaged an estimated 4,100 structures in Osceola County and 1,656 structures in Seminole County. The Florida Department of Agriculture and Consumer Services estimated $1.1 to $1.8 billion in losses due to flooding and wind damage to the state's crops and infrastructure.[11]

An estimated 4.45 million customers[12] (about 9.62 million people) lost power in the United States due to Ian between 28 September and 1 October. Florida experienced the largest loss of power with ~3.28 million customers total and maximum outage count of 2.78 million at once

[9] https://eldiariony.com/2022/10/02/huracan-ian-causo-estragos-en-cuba-con-cinco-muertos-y-mas-de-100000-viviendas-destruidas/
[10] NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2023). https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73
[11] https://www.agri-pulse.com/ext/resources/pdfs/Hurricane-Ian-Damage-Report_FDACS.pdf
[12] Estimate is based on PowerOutage.US storm summary. https://poweroutage.us/about/majorevents

(Fig. 20). North Carolina, South Carolina, and Virginia had an estimated 579,000, 378,000, and 211,000 affected customers, respectively.

In South Carolina, storm surge inundated the city of Georgetown, flooding streets and businesses in the downtown area (Fig. 21). In Horry County, the U.S. Coast Guard rescued crews from a stranded commercial shrimp boat. Roadway and beach flooding were also reported along the North Carolina and South Carolina coastal areas.

Stormwaters exiting back into the Gulf of Mexico carried debris, fertilizer, and other pollutants (Fig. 22). Scientists from NOAA's National Centers for Coastal Ocean Science tracked a harmful algal bloom in the days following Ian off the coast of southwestern Florida. Researchers from Florida Gulf Coast University also noted significant damage to artificial reefs in the region[13].

More than 100,000 homes were damaged or destroyed in Cuba due to Ian. According to news reports, this represents 60% of all the homes in the Pinar del Río province. It was also reported that while the hurricane made landfall in western Cuba, the entire island lost power for a few days. At the time of this report, there is no monetary damage estimate available for Cuba.

FORECAST AND WARNING CRITIQUE

Genesis

The genesis of Ian was reasonably well forecast. The tropical wave from which Ian developed was introduced in the Tropical Weather Outlook (TWO) with a low (<40%) 5-day probability of formation 84 h prior to genesis (Table 4). At 72 h prior to genesis, the system was first given a low 2-day chance of development, and the 5-day genesis probability was raised to the medium (40%–60%) category. A Special TWO was issued just before 1500 UTC 20 September, 63 h before genesis, where the 2- and 5-day probabilities of development were raised to the medium and high (>60%) categories, respectively. Finally, the 2-day probabilities were increased to the high category 54 h before development. In terms of the location of genesis, NHC forecasters did a good job of highlighting the correct area. Ian's genesis location occurred in 100% of the areas shown in the outlooks issued, roughly in the center of the summed areas (Fig. 23).

Track

A verification of NHC official track forecasts for Ian is given in Table 5a. The average official track forecast errors were lower than the mean official errors for the previous 5-yr period at 12, 24, and 120 h, comparable to the 5-yr means at 36 and 48 h, and higher than the 5-yr means at 72 and 96 h. A homogeneous comparison of the official track errors with selected

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[13] https://wusfnews.wusf.usf.edu/environment/2022-11-02/hurricane-ian-ruined-man-made-reefs-brought-algae-blooms-to-florida

guidance models is given in Table 5b and Figs. 24 and 25. While the official track forecast through 60 h had errors lower than or comparable to the 5-yr mean errors, most of the consensus models outperformed the NHC forecast at these lead times. The best performing model in the short-term forecast (through 36 h) was the Florida State Superensemble (FSSE). The consensus model HCCA, the United Kingdom Met Office global model (EGRI), and the COAMPS-TC model (CTCI) provided the best guidance at 48, 60, and 72 and 96 h, respectively. Of the dynamical models, the Canadian model (CMCI), the GFS ensemble mean (AEMI), and HWRF (HWFI) tended to have the greatest track errors. Examination of the individual official forecasts revealed the cross-track error to be the largest source of error with a consistent westward bias noted (Fig. 26). While the left-of-track bias made forecasting the exact landfall location of the Ian in southwestern Florida difficult, the forecast track cone of uncertainty did contain the landfall location for all advisory cycles (Fig. 27). In general, storms that parallel a coastline tend to be more challenging to predict because a small change in heading can cause large differences in the landfall location. Ian was an example of this particular challenge.

Intensity

A verification of the NHC official intensity forecasts for Ian is given in Table 6a. Official intensity forecast errors were greater than the mean official errors for the previous 5-yr period largely due to Ian's rapid intensification. The climatology-persistence (OCD5) errors were also higher than the corresponding 5-yr average values at all forecast periods, indicating Ian's intensity was more difficult than normal to predict. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b and Figs. 28 and 29. While the NHC forecast was very hard to improve upon through 48 h, the regional dynamical model HMON (HMNI) had the best predictions at 36-60 h, while the CTCI had the best predictions at 72 and 120 h. The statistical model LGEM had the lowest errors at 96 h. The greatest challenge for the official forecast was an inability to predict the second instance of rapid intensification after Ian moved north of Cuba, leading to the peak intensity of 140 kt (Fig. 30). Both HMNI and CTCI had forecasts with intensities closer to the observed peak. It is also worth noting that there was a low bias in the NHC intensity forecasts at longer lead times when Ian emerged over the Atlantic Ocean. This was due to several official track forecasts that showed the storm remaining over the southeastern U.S. and not emerging over the western Atlantic.

Storm Surge Forecasts and Warnings

Storm surge watches and warnings associated with Ian are given in Table 7 and shown in Fig. 7. A Storm Surge Watch was first issued at 0300 UTC 26 September for the Florida Keys from the Card Sound Bridge to Key West, including the Dry Tortugas, and for the west coast of Florida from Englewood to the Card Sound Bridge, including Florida Bay. Fort Myers Beach and Estero Island, which experienced the worst of the storm surge event, were included in this first storm surge watch area. The initial peak storm surge forecast was 4 to 7 ft AGL from Englewood to Bonita Beach including Fort Myers Beach.

At 0900 UTC 26 September, the Storm Surge Watch was extended northward to the Anclote River, Florida, including Tampa Bay. A Storm Surge Warning was issued at 2100 UTC 26 September from the Anclote River southward to Flamingo, Florida. At the time the warning was issued, the peak storm surge forecast was 5 to 10 ft AGL from the Anclote River to the Middle of Longboat Key including Tampa Bay, 5 to 8 ft AGL from the Middle of Longboat Key to Englewood, and 4 to 7 ft AGL from Englewood to Bonita Beach including Fort Myers Beach.

The Storm Surge Warning did not verify north of Englewood due to a southward shift in the track of Ian. As previously noted, sharp gradients in the water level measurements (e.g. Fig. 8, Fig. 9a) demonstrate the sensitivity of storm surge to the exact track of the storm. The track forecast uncertainty during the warning phase (i.e., within 36 h of the onset of hazardous conditions) warranted the issuance of the storm surge warning for this large area however, as only a small northward shift of the track could have caused extreme storm surge flooding in places that were dry during Ian (not shown).

Figure 31 depicts the timeline of the storm surge watch/warning and peak storm surge forecast ranges at Fort Myers Beach. It also shows the time of maximum wave-filtered water level (12.70 ft above MHHW) from the USGS water level sensor located at Fort Myers Beach. The storm surge watch and warning for this location were issued 48 and 30 h prior to the onset of tropical-storm-force winds. On the morning of 27 September, the peak storm surge forecast range increased from 4 to 7 ft AGL to 8 to 12 ft AGL as the forecast track of Ian shifted southward. On the morning of 28 September, additional changes to the peak storm surge forecast were made as a result of the intensification of Ian found by the hurricane hunter aircraft. The final peak storm surge forecast range (12 to 18 ft AGL) captures the peak USGS water level sensor measurement and is consistent with the NHC storm surge analysis of 10 to 15 ft AGL.

Along the Florida east coast, a Storm Surge Watch was first issued at 2100 UTC 26 September, extending from the Flagler/Volusia County line through the Florida/Georgia border including the St. Johns River. The Storm Surge Watch was later upgraded to a Storm Surge Warning as Ian was forecast to traverse the Florida Peninsula and emerge into the western Atlantic Ocean as a tropical storm. Many portions of the warning area verified, including the St. Johns River, with observed water levels reaching in excess of 3 ft AGL (which NHC uses as a first-cut threshold for the storm surge watch/warning). The NHC storm surge analysis indicates peak water levels of 3 to 5 ft AGL did extend southward into portions of Volusia County, which was marginally outside of the storm surge watch/warning area. As previously noted, the storm surge impacts in this area were contained to the wave action at the immediate beach.

In the storm surge warning area along the coast of Georgia through Charleston, South Carolina, water levels reached 2 to 4 ft AGL, marginally meeting the criteria for the warning. The track uncertainty at the time of the forecast supported the issuance of the warning. Ultimately, the track shifted to the east and there were fewer storm surge impacts in this area.

In South Carolina, a Storm Surge Watch was first issued at 2100 UTC 28 September from the South Santee River to Little River Inlet, including locations such as Georgetown and Myrtle Beach. At the watch issuance time, the peak storm surge forecast was 2 to 4 ft AGL. The same area was upgraded to a warning at 1500 UTC 29 September with a peak storm surge forecast of 3 to 5 ft AGL. The peak storm surge forecast increased to 4 to 7 ft AGL in subsequent advisories as the forecast track of Ian shifted eastward. The warning area verified well with observations of greater than 3 ft AGL. The final storm surge forecast range is consistent with the NHC storm surge analysis of 4 to 6 ft in this area.

Storm surge watches/warnings were issued along the North Carolina coast at 1500 UTC 29 September with a peak storm surge forecast of 2 to 4 ft AGL. At this time, a small warning area was also issued along the Neuse River where there was a favorable angle for strong onshore flow from a frontal gradient. Six hours later, an additional portion of the watch between Little River Inlet and Cape Fear was upgraded to a warning with a peak storm surge forecast of 3 to 5 ft AGL. The forecast values in this area are consistent with the NHC storm surge analysis. In the storm surge watch area between Cape Lookout and Cape Fear, water levels reached 2 to 4 ft AGL.

Wind Watches and Warnings

Coastal wind watches and warnings associated with Ian are given in Table 8. A verification of select coastal watches and warnings is provided below.

For the United States, a Tropical Storm Watch was first issued for the Florida Keys and Dry Tortugas at 2100 UTC 25 September. Tropical-storm-force winds are estimated to have begun in the Florida Keys around 1500 UTC 27 September, about 42 h after the issuance of the Tropical Storm Watch. The watch was upgraded to a Tropical Storm Warning at 0300 UTC 25 September, about 36 h before the onset of tropical-storm-force winds. A Hurricane Warning was issued for the Dry Tortugas about 18 h before the arrival of tropical-storm-force winds.

A Tropical Storm Watch was first issued for the coastal region of southwestern Florida about 48 h before the arrival of tropical-storm-force winds (estimated to be 0300 UTC 28 September). A Tropical Storm Warning and a Hurricane Watch were issued for the Fort Myers area at 2100 UTC 26 September, about 30 h before the arrival of tropical-storm-force winds. A Hurricane Warning was issued for this area at 0900 UTC 27 September, about 18 h before the onset of tropical-storm-force winds on the barrier islands.

For Georgetown County, South Carolina, where Ian made landfall, a Tropical Storm Watch was not issued, but a Tropical Storm Warning was issued at 1500 UTC 28 September, about 39 h before the arrival of tropical-storm-force winds. The Tropical Storm Warning was upgraded to a Hurricane Warning at 1500 UTC 29 September, about 15 h before the onset of tropical-storm-force winds.

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

The NHC began communication with emergency managers on Friday, 23 September as Ian was forming over the east-central Caribbean Sea. Twenty-four decision support briefings were provided to emergency managers and coordinated through the FEMA Hurricane Liaison Team embedded at the NHC. These briefings continued until the storm became extratropical over North Carolina on Friday, 30 September and included 12 Federal video-teleconferences with FEMA HQ and FEMA Region 4, and 11 webinar briefings for the Florida Division of Emergency Management and counties in Florida. In addition, the NHC acting director maintained direct communications with senior federal and state emergency management officials to discuss the evolving threat to the southeast United States, including in-person briefings for FEMA Administrator Deanne Criswell at the NHC on 26 September.

The Tropical Analysis and Forecast Branch of NHC provided 16 live briefings on Ian from 23 September to 1 October to the U.S. Coast Guard Districts 7 and 8 in support of their life-saving mission.

During Hurricane Ian, the NHC media pool was activated from 7 AM to 7 PM EDT on 24 September with hours extended until 11 PM EDT as necessary. The media pool closed on 30 September at 6 PM EDT. A total of 282 interviews were conducted. These included: 1) 56 network broadcast/cable outlets; 2) 42 cable weather outlets; 3) 50 local affiliate outlets; 4) 81 English and Spanish virtual interviews; and 5) 40 radio and print.

NHC provided 13 live stream broadcasts via YouTube Live, Facebook, and Twitter during the seven-day span of this media pool. These videos received more than two million views during the seven-day period on all three platforms, with a peak total of 334,000 views during the 26 September broadcast as Ian approached the southwestern coast of Florida. The total views reached through the live streams for the event was 1.1 million through Facebook and 500,000 through YouTube.

The NHC web pages were accessed approximately 224 million times between 23 September and 1 October resulting in approximately 4.2 billion hits (Ian generated most of the traffic during this period). A majority of the page views went to graphical products such as the key messages, cone graphic, and the wind speed probabilities. The key messages graphics for Ian were viewed approximately 26 million times on the NHC website. Non-automated tweets about Ian garnered 38.9 million views during the storm, with about 12.4 million views of the Key Message graphics.

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TABLES

Table 1. Best track for Hurricane Ian, 23–30 September 2022.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
22 / 1800	12.3	66.3	1006	30	low
23 / 0000	12.9	67.2	1006	30	"
23 / 0600	13.7	68.1	1006	30	tropical depression
23 / 1200	14.2	69.3	1006	30	"
23 / 1800	14.6	70.6	1006	30	"
24 / 0000	14.7	71.7	1005	35	tropical storm
24 / 0600	14.7	72.9	1005	35	"
24 / 1200	14.5	74.4	1003	40	"
24 / 1800	14.4	75.8	1003	40	"
25 / 0000	14.6	77.2	1003	40	"
25 / 0600	14.6	78.3	1003	40	"
25 / 1200	15.0	79.4	1003	40	"
25 / 1800	15.8	80.1	1003	40	"
26 / 0000	16.8	80.9	991	50	"
26 / 0600	17.7	81.7	985	65	hurricane
26 / 1200	18.7	82.4	981	70	"
26 / 1800	19.7	83.0	976	80	"
27 / 0000	20.8	83.3	965	85	"
27 / 0600	21.8	83.6	956	100	"
27 / 0830	22.2	83.7	947	110	"
27 / 1200	22.6	83.6	963	100	"
27 / 1800	23.5	83.3	951	105	"
28 / 0000	24.4	83.0	947	105	"
28 / 0200	24.6	82.9	952	110	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
28 / 0600	25.2	82.9	945	120	"
28 / 1200	26.0	82.7	937	140	"
28 / 1800	26.6	82.4	938	135	"
28 / 1905	26.7	82.2	941	130	"
28 / 2035	26.8	82.0	945	125	"
29 / 0000	27.2	81.7	960	100	"
29 / 0600	27.7	81.1	985	65	"
29 / 1200	28.4	80.6	987	60	tropical storm
29 / 1800	28.9	80.1	986	65	hurricane
30 / 0000	29.6	79.4	986	70	"
30 / 0600	30.3	79.1	984	75	"
30 / 1200	31.5	79.0	980	75	"
30 / 1800	33.3	79.2	978	70	"
30 / 1805	33.3	79.2	978	70	"
01 / 0000	34.4	79.3	990	50	extratropical
01 / 0600	35.3	79.7	999	30	"
01 / 1200					dissipation
28 / 1200	26.0	82.7	937	140	minimum pressure & maximum wind
27 / 0830	22.2	83.7	947	110	Landfall near La Coloma in the Pinar Del Rio Province of Cuba
28 / 0200	24.6	82.9	952	110	Landfall in the Dry Tortugas, Florida
28 / 1905	26.7	82.2	941	130	Landfall near Cayo Costa, Florida
28 / 2035	26.8	82.0	945	125	Landfall near Punta Gorda, Florida
30 / 1805	33.3	79.2	978	70	Landfall near Georgetown, South Carolina

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Ian, 23–30 September 2022.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
27 / 1100	9V3143	22.6	78.1	110 / 45	1022.4
27 / 1900	V7IJ2	23.4	82.6	150 / 45	1002.0
27 / 2000	V7IJ2	23.4	82.1	150 / 45	
27 / 2100	V7IJ2	23.4	82.1	150 / 55	1001.0
27 / 2100	WHIA	23.4	81.6	150 / 35	1002.2
27 / 2200	WHIA	23.4	81.7	170 / 39	1001.5
27 / 2300	WHIA	23.4	81.8	180 / 38	1000.9
28 / 0000	V7IJ2	23.4	81.6	180 / 50	1001.0
28 / 0200	WHIA	23.4	81.2	180 / 38	1007.0
28 / 0300	V7IJ2	23.4	82.1	200 / 45	1002.0
28 / 0300	ELVQ7	24.5	79.4	140 / 42	1008.0
28 / 0600	WOTA	25.7	79.8	120 / 42	1007.6
28 / 1000	WMCU	25.8	79.4	140 / 35	1006.6
28 / 1200	TBWUK8	28.9	89.3	110 / 35	1017.3
28 / 1300	WOTA	24.8	79.6	170 / 45	1007.3
28 / 1500	ELVQ7	24.2	80.1	160 / 38	1008.0
28 / 1500	WMCU	25.0	79.5	180 / 35	1008.0
28 / 1600	D5BF7	31.8	79.6	050 / 36	1014.0
28 / 1700	WMCU	24.6	79.7	180 / 35	1007.4
28 / 1800	KPSJ	26.2	79.7	180 / 35	1004.9
28 / 2100	KS1059	29.0	80.4	050 / 35	1007.2
28 / 2200	9HA540	31.9	78.1	020 / 42	1016.0
29 / 0000	KS1059	29.0	80.4	040 / 41	1004.9
29 / 1700	A8SI7	31.3	77.3	050 / 42	1008.3
29 / 2000	KS1059	29.0	80.2	310 / 35	990.9
29 / 2100	KS1059	29.0	80.2	320 / 44	990.6
29 / 2200	KS1059	29.0	80.1	320 / 40	991.4
29 / 2300	KS1059	29.0	80.1	340 / 50	992.1
29 / 2300	WDM218	32.9	77.6	230 / 43	1009.9

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
30 / 0000	KS1059	29.0	80.1	330 / 50	993.8
30 / 0100	KS1059	29.0	80.0	320 / 45	995.7
30 / 0200	KS1059	28.9	80.0	320 / 39	997.7
30 / 0300	KS1059	28.9	80.0	310 / 46	998.6
30 / 0400	KS1059	28.9	80.0	290 / 35	999.9
30 / 0400	A8SI7	31.1	74.8	180 / 35	1007.3
30 / 0700	OUJK2	36.5	75.2	050 / 35	1011.0
30 / 1200	H3BL	32.0	72.4	090 / 35	1011.9
30 / 1500	WDM218	32.4	75.6	150 / 44	1004.3
30 / 1800	WDM218	32.3	75.7	160 / 44	1004.1
30 / 1800	9HA564	36.5	75.2	050 / 45	1011.2
30 / 1900	OUJK2	36.6	75.1	050 / 55	1004.0

Table 3. Selected storm surge observations for Hurricane Ian, 23–30 September 2022.

Location	Storm surge (ft)[a]	Storm tide (ft)[b]	Estimated Inundation (ft)[c]
Florida			
National Ocean Service (NOS) Sites			
Old Port Tampa (OPTF1) (27.85N, 82.55W)	1.09	2.12	1.34
Fort Myers (FMRF1) (26.64N, 81.87W)	7.25	7.53	7.26
Naples (NPSF1) (26.13N, 81.8W)	6.28*	6.79*	6.18*
Key West (KYWF1) (24.55N, 81.8W)	2.12	2.5	2.46
Mayport (Bar Pilots Dock) (MYPF1) (30.39N, 81.42W)	3.71	4.45	2.48
I-295 Buckman Bridge (BKBF1) (30.19N, 81.69W)	2.85	3.45	3.06
US Geological Survey (USGS) Water Level Sensors			
Fort Myers Beach (FLLEE03382) (26.45N, 81.95W)		13.23	12.70
Sanibel Island (FLLEE26290) (26.42N, 82.08W)		13.09	12.58
Pirate Harbor (FLCHA03379) (26.8N, 82.05W)		4.69	4.47
Punta Rassa (FLLEE03246) (26.48N, 82.01W)		8.83	8.37
San Carlos Island (FLLEE03284) (26.45N, 81.95W)		12.06	11.62
Delnor-Wiggins State Park (FLCOL03294) (26.27N, 81.82W)		10.24	9.73

Location	Storm surge (ft)[a]	Storm tide (ft)[b]	Estimated Inundation (ft)[c]
Naples Bay (FLCOL03297) (26.14N, 81.79W)		7.10	
Marco Island (FLCOL03171) (25.94N, 81.74W)		7.38	6.74
Everglades City (FLCOL03237) (25.84N, 81.38W)		7.33	6.51
USGS High Water Marks			
Lee County (FLLEE32905) (26.65N, 81.86W)		7.7	4.43
Lee County (FLLEE33028) (26.48N, 81.85W)		10.8	8.31
Collier County (FLCOL03170) (25.96N, 81.71W)		6.99	4.71
NWS High Water Marks			
Lee County (26.45N,81.96W)			15.0
Georgia			
National Ocean Service (NOS) Sites			
Fort Pulaski (FPKG1) (32.03N, 80.9W)	3.85	5.47	2.01
South Carolina			
National Ocean Service (NOS) Sites			
Charleston (CHTS1) (32.78N, 79.92W)	2.56	4.51	1.89
Springmaid Pier (MROS1) (33.65N, 78.91W)	6.41	7.62	5.17

Location	Storm surge (ft)[a]	Storm tide (ft)[b]	Estimated Inundation (ft)[c]
USGS Stream Gauges			
Pee Dee River, Georgetown (2136350) (33.37N,79.26W)		5.47	3.36
North Carolina			
National Ocean Service (NOS) Sites			
Wrightsville Beach (JMPN7) (34.21N, 77.78W)	4.03	5.27	3.54
Wilmington (WLON7) (34.22N, 77.95W)	5.06	5.06	2.98
Beaufort, Duke Marine Lab (BFTN7) (34.71N, 76.67W)	3.3	4.3	2.84

[a] Storm surge is water height above normal astronomical tide level.
[b] Storm tide is water height above the North American Vertical Datum of 1988 (NAVD88).
[c] Estimated inundation is the maximum height of water above ground. For USGS water level sensors and stream gauges, inundation is estimated by converting the NAVD88 measurement to Mean Higher High Water (MHHW) using the NOAA VDatum tool. For USGS high-water marks, estimated inundation is the direct above ground measurement. For NWS high-water marks, estimated inundation is approximated as the water level height above the high tide line (MHHW). For NOS tide gauges, the height of the water above MHHW is used as a proxy for inundation.
* Incomplete

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%)	72	84
Medium (40%-60%)	63	72
High (>60%)	54	63

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Ian, 23–30 September 2022. 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	**18.3**	**32.0**	50.9	67.8	87.6	110.5	140.3	**141.8**
OCD5	39.3	90.6	147.7	195.8	248.7	303.1	442.4	589.7
Forecasts	29	27	25	23	21	19	15	11
OFCL (2017-21)	23.6	35.5	47.6	61.4	78.2	91.3	125.6	172.1
OCD5 (2017-21)	45.5	98.3	156.7	213.7	252.4	316.9	403.6	484.6

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Ian, 23–30 September 2022. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	18.7	32.8	50.2	66.9	87.5	115.6	151.8	152.7
OCD5	37.3	82.3	131.8	173.5	230.4	290.9	468.0	719.6
GFSI	**18.2**	36.4	60.5	86.9	113.0	158.9	228.2	266.7
EMXI	22.6	39.7	56.7	73.0	90.1	**112.8**	**136.5**	**128.9**
EGRI	19.3	34.0	**41.0**	**48.2**	**67.1**	**94.3**	164.7	203.3
CMCI	24.9	49.6	76.9	105.5	133.6	162.1	207.3	271.3
HWFI	23.5	44.8	69.8	91.9	117.1	156.8	238.7	252.0
HMNI	23.2	39.1	54.0	**63.1**	**74.5**	**95.2**	156.0	195.4
CTCI	21.9	36.8	**48.9**	**59.6**	**72.2**	**87.2**	**98.5**	187.5
AEMI	22.2	46.2	73.3	102.8	132.2	173.0	228.5	247.7
HCCA	**16.9**	**30.2**	**43.1**	**54.6**	**71.5**	**97.1**	**141.8**	**146.9**
FSSE	**16.0**	**26.6**	**40.0**	**55.5**	**73.5**	**98.0**	160.6	186.4
GFEX	19.2	35.6	56.6	76.2	98.5	131.8	176.2	186.2
TVCA	**17.9**	33.0	**49.0**	**63.6**	**81.3**	**109.9**	154.0	165.7
TVCX	**18.4**	**32.6**	**49.1**	**64.3**	**81.2**	**108.7**	152.6	161.9
TVDG	**17.5**	**32.4**	**47.7**	**63.6**	**83.0**	**112.1**	159.9	170.3
TABD	27.0	46.4	67.4	81.6	103.6	131.9	245.0	367.7
TABM	27.6	59.4	86.9	108.8	126.7	163.6	241.0	306.2
TABS	54.5	125.1	180.7	213.5	220.8	228.3	279.2	340.1
Forecasts	24	22	20	18	16	14	10	6

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Ian, 23–30 September 2022. 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	7.6	9.3	11.0	12.4	15.2	12.9	18.7	20.9
OCD5	11.4	16.7	21.1	25.3	31.8	40.7	43.4	41.2
Forecasts	29	27	25	23	21	19	15	11
OFCL (2017-21)	5.4	8.0	9.5	10.9	11.0	12.1	13.1	14.7
OCD5 (2017-21)	7.0	11.1	14.5	17.1	18.0	20.2	21.9	22.1

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Ian, 23–30 September 2022. 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	60	72	96	120
OFCL	8.1	10.7	12.8	14.4	17.2	15.4	17.5	19.2
OCD5	13.0	19.2	23.6	26.9	34.9	38.9	45.7	25.2
HWFI	10.4	11.0	14.6	17.1	18.3	**15.0**	17.6	32.2
HMNI	11.2	14.0	**11.1**	**13.9**	**14.1**	19.0	20.6	20.0
CTCI	12.5	14.7	13.4	17.2	**16.9**	**14.0**	20.6	**10.2**
DSHP	10.5	15.0	19.0	20.4	21.8	22.0	**17.4**	19.2
LGEM	11.5	15.7	19.6	18.7	22.2	22.4	**14.0**	**16.7**
ICON	10.1	11.5	14.8	15.6	17.3	17.4	**16.4**	**17.0**
IVCN	10.4	11.5	14.1	15.9	**16.9**	16.0	**16.7**	**15.2**
IVDR	10.4	11.3	**12.4**	14.6	**15.8**	**14.5**	**16.9**	**15.7**
HCCA	9.2	12.3	17.6	18.1	18.0	16.7	**15.3**	**16.0**
FSSE	10.0	13.6	19.6	23.1	24.7	25.5	**17.2**	20.7
GFSI	11.3	13.7	15.2	15.1	**15.2**	**12.9**	**14.4**	**17.0**
EMXI	11.9	15.5	20.6	23.5	31.9	30.2	33.2	20.5
Forecasts	24	22	20	18	16	14	10	6

Table 7. Storm Surge watch and warning summary for Hurricane Ian, 23–30 September 2022.

Date/Time (UTC)	Action	Location
26/0300	Storm Surge Watch issued	Florida Keys from the Card Sound Bridge westward to Key West, including the Dry Tortugas, and for the west coast of Florida from Englewood southward to the Card Sound Bridge, including Florida Bay
26/0900	Storm Surge Watch issued	Englewood FL to the Anclote River FL
26/2100	Storm Surge Warning issued	Anclote River FL southward to Flamingo FL, including Tampa Bay
26/2100	Storm Surge Watch issued	Anclote River FL to Aucilla River FL
27/1500	Storm Surge Warning issued	Marineland FL to the mouth of St. Mary's River including the St. Johns River, the Dry Tortugas, and the Suwanee River FL to Anclote River FL
27/1500	Storm Surge Watch issued	St. Mary's River to South Santee River SC
27/2100	Storm Surge Warning issued	Marineland FL to the Flagler/Volusia County Line
27/2100	Storm Surge Watch discontinued	Aucilla River FL to the Suwannee River FL
28/0430	Storm Surge Warning issued	Lower Florida Keys from Big Pine Key westward to Key West
28/1500	Storm Surge Warning issued	St. Mary's River to South Santee River SC
28/2100	Storm Surge Watch issued	South Santee River SC to Little River Inlet

Date/Time (UTC)	Action	Location
28/2100	Storm Surge Warning discontinued	Lower Florida Keys
28/2100	Storm Surge Watch discontinued	Middle and Upper Florida Keys
29/0300	Storm Surge Watch discontinued	Flamingo eastward to the Card Sound Bridge, including Florida Bay
29/0900	Storm Surge Warning discontinued	Suwannee River FL to the Middle of Longboat Key including Tampa Bay
29/1200	Storm Surge Warning discontinued	Middle of Longboat Key to Flamingo FL including Charlotte Harbor
29/1500	Storm Surge Warning issued	South Santee River SC to Little River Inlet and for the Neuse River in NC
29/1500	Storm Surge Watch issued	Little River Inlet to Duck NC, including the Pamlico River
29/2100	Storm Surge Warning issued	Little River Inlet to Cape Fear NC
29/2100	Storm Surge Watch issued	Cape Fear River
30/1500	Storm Surge Warning discontinued	Savannah River to Marineland FL, including the St. Johns River
30/2100	Storm Surge Warning discontinued	South Santee River SC to the Savannah River
01 / 0000	Storm Surge Warning discontinued	Cape Fear NC to South Santee River SC
01 / 0000	Storm Surge Watch discontinued	Cape Fear to Surf City, including the Cape Fear River

Date/Time (UTC)	Action	Location
01 / 0300	Storm Surge Watch/Warning discontinued	All

Table 8. Wind watch and warning summary for Hurricane Ian, 23–30 September 2022.

Date/Time (UTC)	Action	Location
23 / 2100	Tropical Storm Watch issued	Jamaica
23 / 2100	Hurricane Watch issued	Cayman Is
24 / 1800	Tropical Storm Watch issued	Little Cayman to Cayman Brac
24 / 1800	Hurricane Watch discontinued	All
24 / 1800	Hurricane Warning issued	Grand Cayman
24 / 2100	Tropical Storm Watch discontinued	Jamaica
25 / 0300	Tropical Storm Watch issued	Matanzas to La Habana
25 / 0300	Hurricane Watch issued	Isla de Juventud
25 / 0300	Hurricane Watch issued	Artemisa to Pinar del Rio
25 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Matanzas to La Habana
25 / 1500	Hurricane Watch changed to Hurricane Warning	Isla de Juventud
25 / 1500	Hurricane Watch changed to Hurricane Warning	Artemisa to Pinar del Rio
25 / 1500	Tropical Storm Watch discontinued	All
25 / 1800	Tropical Storm Watch issued	Little Cayman to Cayman Brac
25 / 2100	Tropical Storm Watch issued	Dry Tortugas to Seven Mile Bridge

Date/Time (UTC)	Action	Location
26 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Dry Tortugas to Seven Mile Bridge
26 / 0300	Tropical Storm Watch issued	Englewood to Chokoloskee
26 / 0900	Hurricane Watch issued	Anclote River to Englewood
26 / 1500	Tropical Storm Watch modified to	Englewood to Flamingo
26 / 1500	Tropical Storm Watch issued	Seven Mile Bridge to Channel 5 Bridge
26 / 1800	Hurricane Warning changed to Tropical Storm Warning	Grand Cayman
26 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Englewood to Flamingo
26 / 2100	Tropical Storm Warning changed to Hurricane Warning	Dry Tortugas
26 / 2100	Hurricane Watch changed to Hurricane Warning	Anclote River to Englewood
26 / 2100	Tropical Storm Watch discontinued	Little Cayman to Cayman Brac
26 / 2100	Tropical Storm Watch issued	Indian Pass to Suwannee River
26 / 2100	Tropical Storm Watch issued	Jupiter Inlet to Altamaha Sound
26 / 2100	Tropical Storm Warning discontinued	Grand Cayman
26 / 2100	Tropical Storm Warning issued	Key West to Seven Mile Bridge
26 / 2100	Hurricane Watch issued	Suwannee River to Anclote River
26 / 2100	Hurricane Watch issued	Englewood to Bonita Beach

Date/Time (UTC)	Action	Location
27 / 0900	Tropical Storm Watch discontinued	Seven Mile Bridge to Channel 5 Bridge
27 / 0900	Tropical Storm Watch modified to	Deerfield Beach to Jupiter Inlet
27 / 0900	Tropical Storm Warning modified to	Key West to Channel 5 Bridge
27 / 0900	Tropical Storm Warning modified to	Bonita Beach to Flamingo
27 / 0900	Tropical Storm Warning issued	Suwannee River to Anclote River
27 / 0900	Tropical Storm Warning issued	Jupiter Inlet to Volusia/Brevard CL
27 / 0900	Hurricane Watch discontinued	Englewood to Bonita Beach
27 / 0900	Hurricane Warning modified to	Anclote River to Bonita Beach
27 / 1500	Tropical Storm Watch discontinued	Deerfield Beach to Jupiter Inlet
27 / 1500	Tropical Storm Watch modified to	Altamaha Sound to South Santee River
27 / 1500	Tropical Storm Watch issued	Flamingo to Blackwater Sound
27 / 1500	Tropical Storm Watch issued	Channel 5 Bridge to Boca Raton
27 / 1500	Tropical Storm Warning discontinued	Jupiter Inlet to Volusia/Brevard CL
27 / 1500	Tropical Storm Warning issued	Boca Raton to Altamaha Sound
27 / 1500	Hurricane Watch issued	Bonita Beach to Chokoloskee
27 / 2100	Hurricane Warning changed to Tropical Storm Warning	Isla de Juventud

Date/Time (UTC)	Action	Location
27 / 2100	Tropical Storm Watch discontinued	Indian Pass to Suwannee River
27 / 2100	Tropical Storm Watch discontinued	Flamingo to Blackwater Sound
27 / 2100	Tropical Storm Watch discontinued	Channel 5 Bridge to Boca Raton
27 / 2100	Tropical Storm Warning modified to	Matanzas to Pinar del Rio
27 / 2100	Tropical Storm Warning modified to	Indian Pass to Anclote River
27 / 2100	Tropical Storm Warning discontinued	Bonita Beach to Flamingo
27 / 2100	Tropical Storm Warning modified to	Key West to Altamaha Sound
27 / 2100	Tropical Storm Warning issued	Chokoloskee to Blackwater Sound
27 / 2100	Tropical Storm Warning issued	Bimini to Grand Bahama Island
27 / 2100	Hurricane Watch discontinued	All
27 / 2100	Hurricane Warning discontinued	Artemisa to Pinar del Rio
27 / 2100	Hurricane Warning modified to	Anclote River to Chokoloskee
28 / 0300	Tropical Storm Watch discontinued	All
28 / 0300	Tropical Storm Warning modified to	Key West to South Santee River
28 / 1500	Tropical Storm Warning discontinued	Isla de Juventud
28 / 1500	Tropical Storm Warning discontinued	Matanzas to Pinar del Rio

Date/Time (UTC)	Action	Location
28 / 1500	Tropical Storm Warning modified to	Key West to Sebastian Inlet
28 / 1500	Tropical Storm Warning issued	Flagler/Volusia CL to Little River Inlet
28 / 1500	Hurricane Watch issued	Flagler/Volusia CL to South Santee River
28 / 1500	Hurricane Warning issued	Sebastian Inlet to Flagler/Volusia CL
28 / 1800	Hurricane Warning discontinued	Dry Tortugas
28 / 2100	Tropical Storm Watch issued	Surf City to Cape Lookout
28 / 2100	Tropical Storm Warning modified to	Card Sound Bridge to Sebastian Inlet
28 / 2100	Tropical Storm Warning modified to	Flagler/Volusia CL to Surf City
29 / 0300	Tropical Storm Warning modified to	Chokoloskee to Flamingo
29 / 0300	Tropical Storm Warning modified to	Boca Raton to Sebastian Inlet
29 / 0600	Tropical Storm Warning discontinued	Chokoloskee to Flamingo
29 / 0600	Hurricane Warning modified to	Anclote River to Bonita Beach
29 / 0900	Tropical Storm Watch discontinued	All
29 / 0900	Tropical Storm Warning discontinued	Bimini to Grand Bahama Island
29 / 0900	Tropical Storm Warning modified to	Indian Pass to Bonita Beach
29 / 0900	Tropical Storm Warning modified to	Boca Raton to Cape Lookout

Date/Time (UTC)	Action	Location
29 / 0900	Tropical Storm Warning discontinued	Flagler/Volusia CL to Surf City
29 / 0900	Hurricane Warning discontinued	All
29 / 1200	Tropical Storm Warning modified to	Jupiter Inlet to Cape Lookout
29 / 1500	Tropical Storm Warning discontinued	Indian Pass to Bonita Beach
29 / 1500	Tropical Storm Warning modified to	Jupiter Inlet to Savannah River
29 / 1500	Tropical Storm Warning issued	Little River Inlet to Duck
29 / 1500	Hurricane Watch modified to	Flagler/Volusia CL to Savannah River
29 / 1500	Hurricane Warning issued	Savannah River to Little River Inlet
29 / 1800	Tropical Storm Warning modified to	Vero Beach to Savannah River
29 / 2100	Tropical Storm Warning modified to	Cape Fear to Duck
29 / 2100	Hurricane Watch issued	Cape Fear to Surf City
29 / 2100	Hurricane Warning modified to	Savannah River to Cape Fear
30 / 0000	Tropical Storm Warning modified to	Sebastian Inlet to Savannah River
30 / 0300	Hurricane Watch changed to Tropical Storm Warning	Flagler/Volusia CL to Savannah River
30 / 0300	Tropical Storm Warning modified to	Flagler/Volusia CL to Savannah River
30 / 0900	Tropical Storm Warning modified to	Altamaha Sound to Savannah River

Date/Time (UTC)	Action	Location
30 / 2100	Tropical Storm Warning discontinued	Altamaha Sound to Savannah River
30 / 2100	Tropical Storm Warning modified to	Edisto Beach to Duck
30 / 2100	Hurricane Watch discontinued	All
30 / 2100	Hurricane Warning discontinued	All
1 / 0000	Tropical Storm Warning modified to	South Santee River to Duck
1 / 0300	Tropical Storm Warning discontinued	All

FIGURES

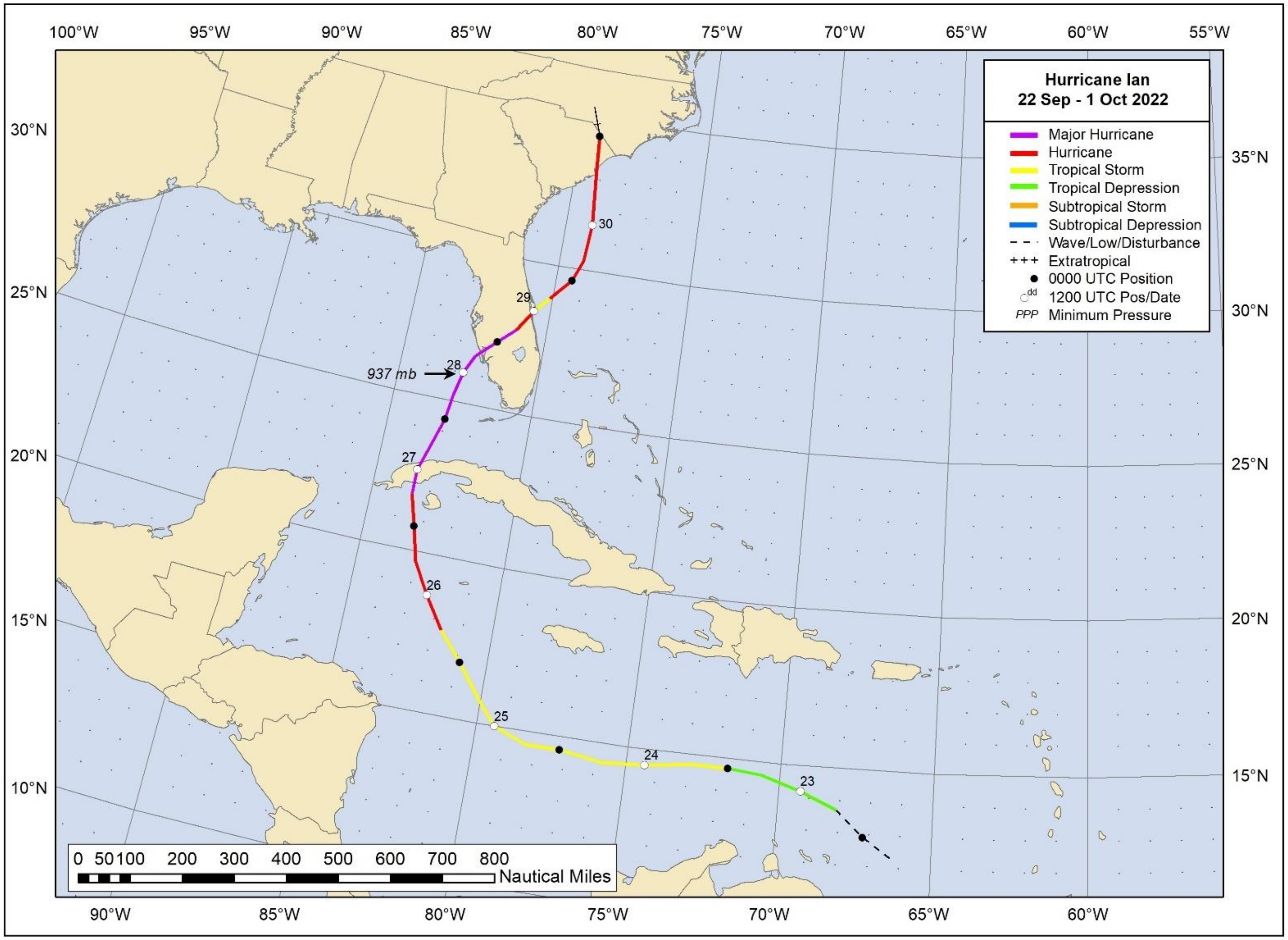


Figure 1. Best track positions for Hurricane Ian, 23–30 September 2022. Tracks during the extratropical stage are partially based on analyses from the NOAA Weather Prediction Center.

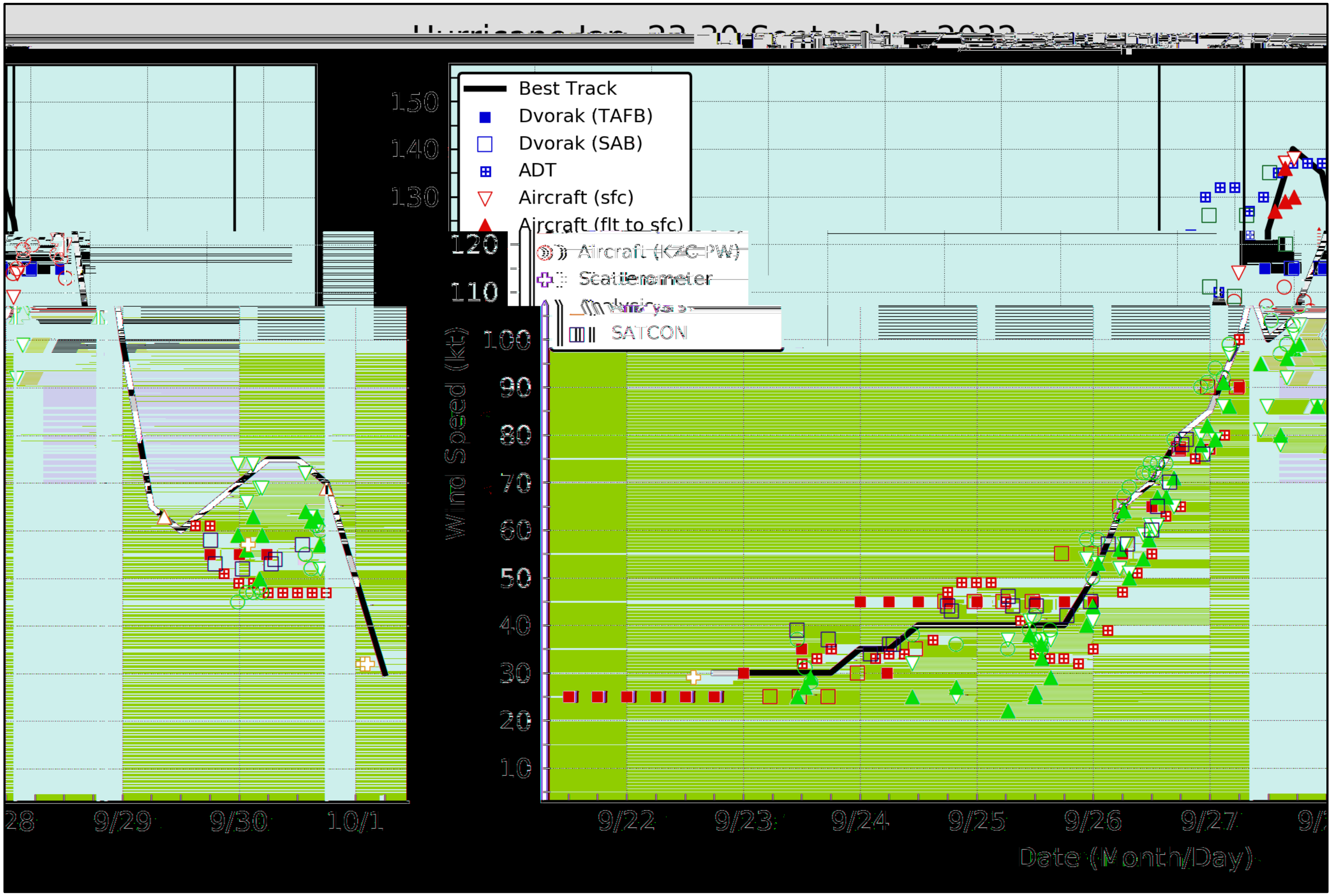


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Ian, 23–30 September 2022. Aircraft observations have been adjusted for elevation using 90%, 80%, and 75% adjustment factors for observations from 700 mb, 850 mb, and 925 mb, respectively. SATCON 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.

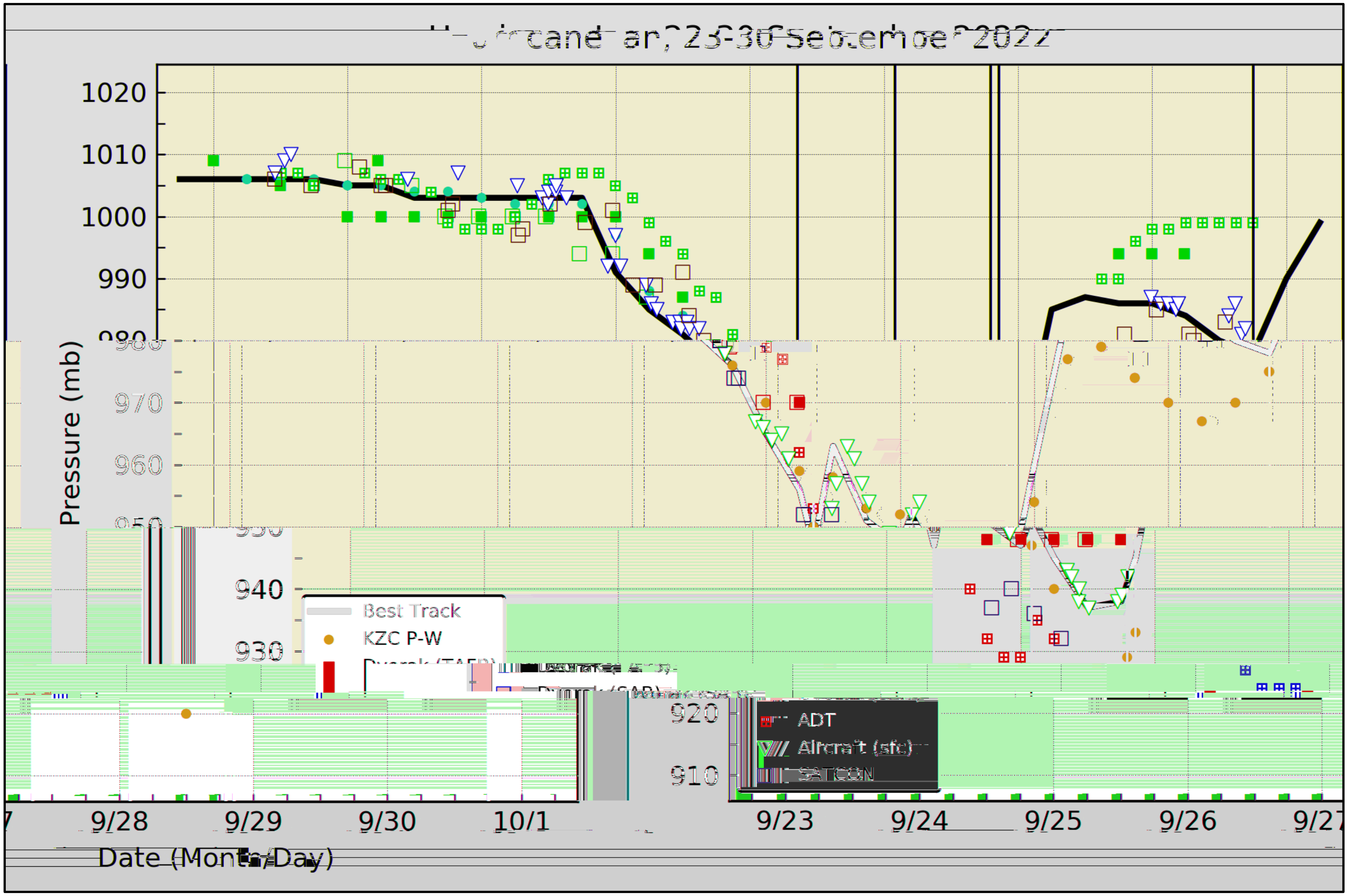


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Ian, 23–30 September 2022. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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.

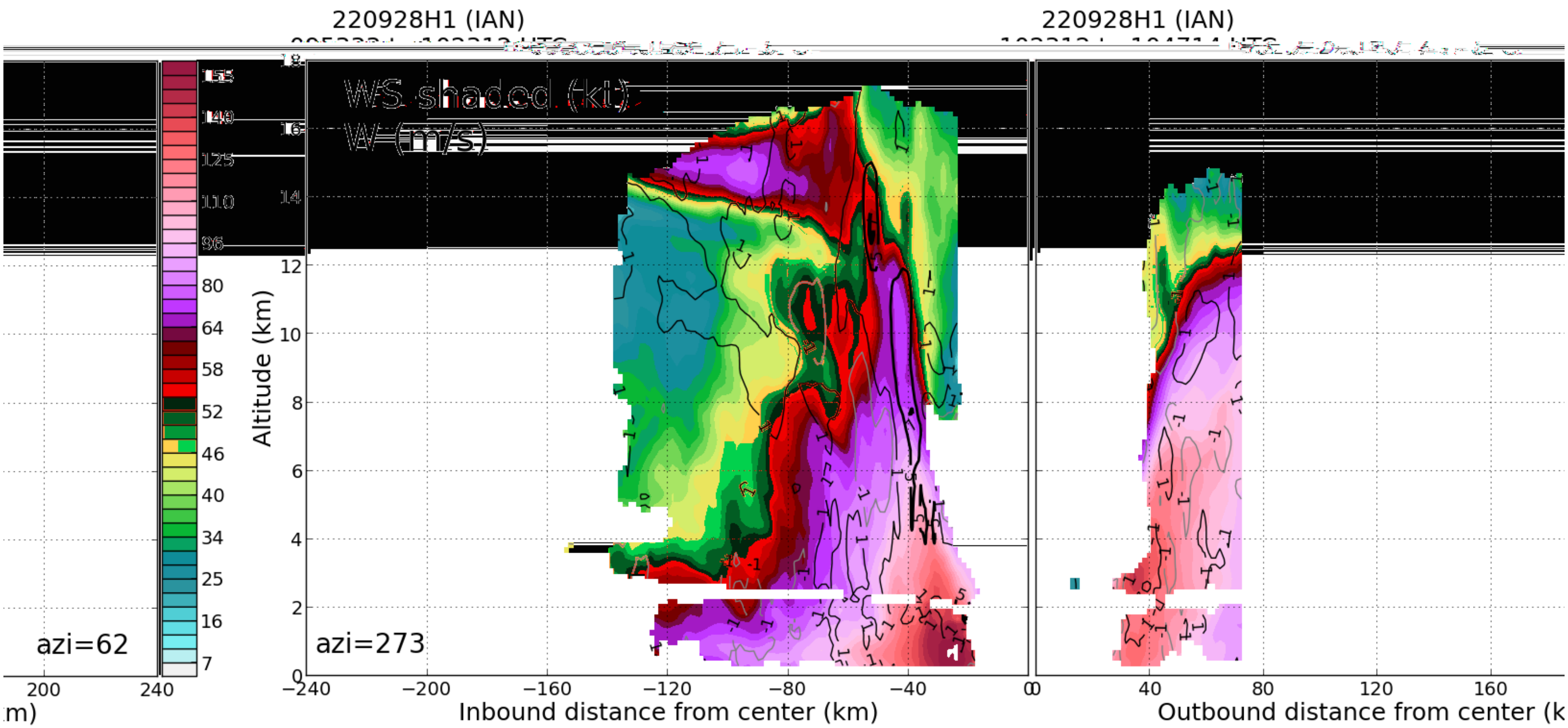


Figure 4. Tail Doppler Radar wind speeds (shaded, kt) and vertical motion (black contour, m/s) along the flight track of the NOAA P-3 in Hurricane Ian on 28 September 2022. Courtesy of Michael Fischer and Paul Reasor, Hurricane Research Division.

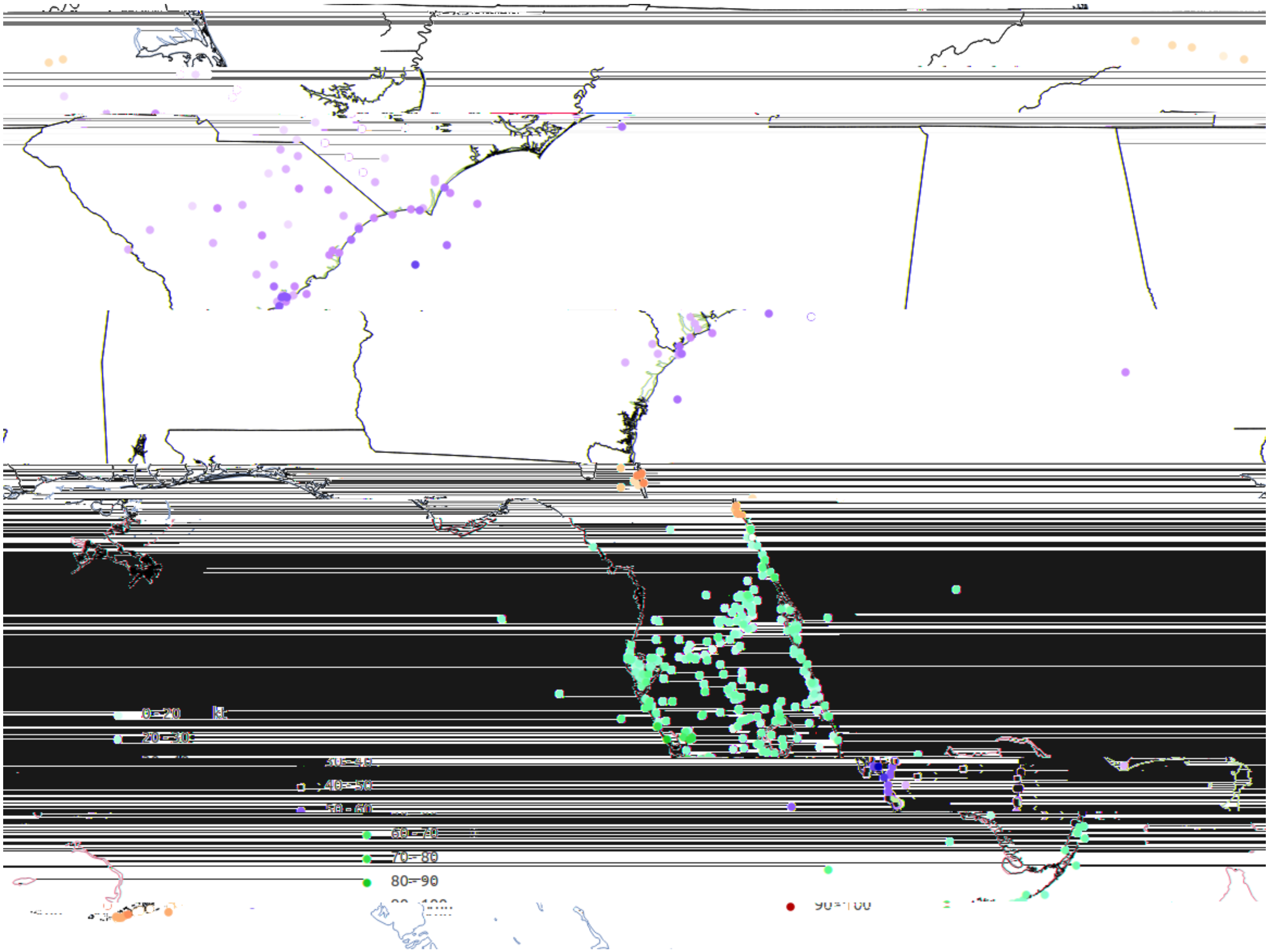


Figure 5. Selected sustained surface or near-surface wind observations associated with Hurricane Ian, 23–30 September 2022. Courtesy of Matt Onderlinde.

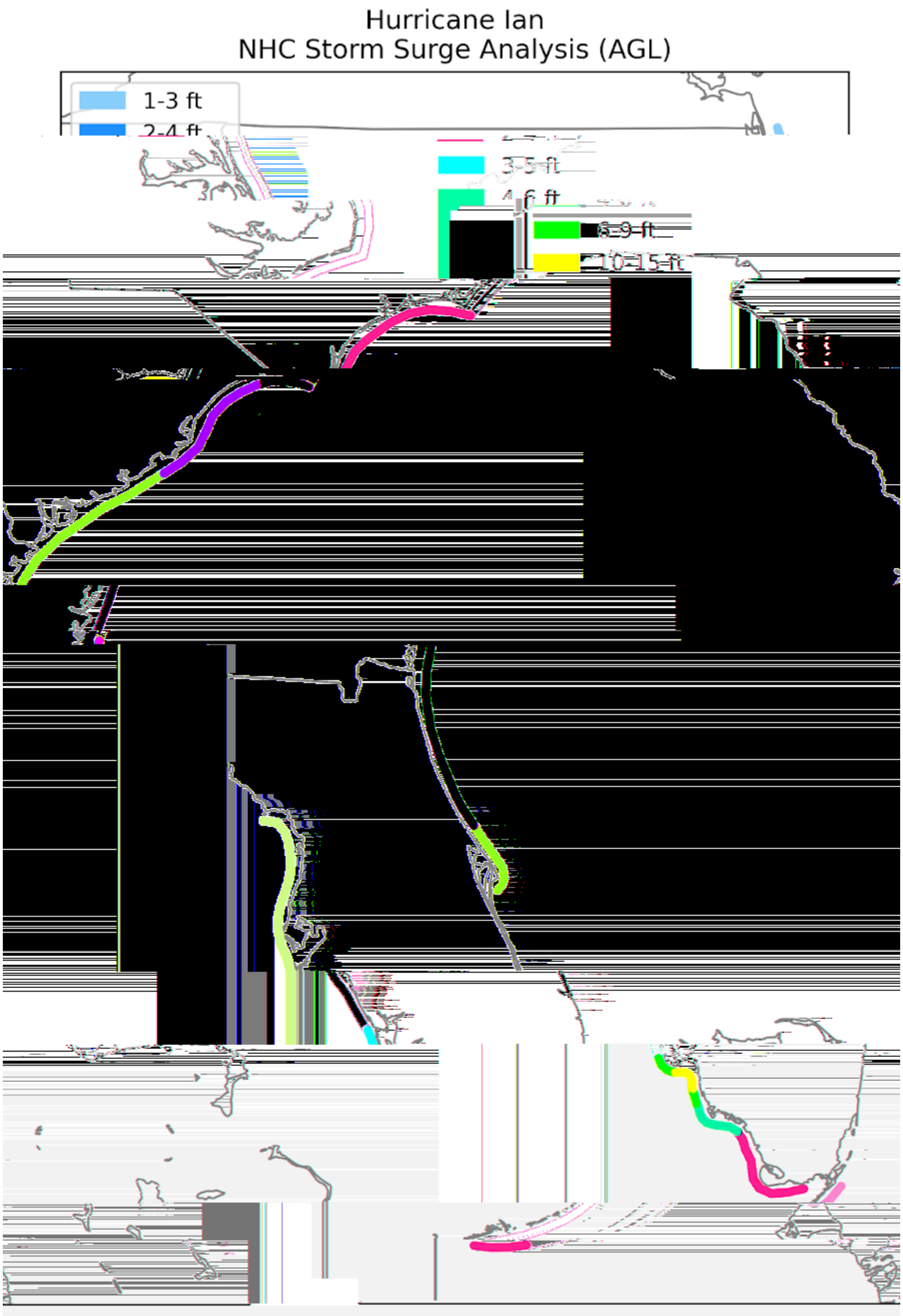


Figure 6. Analyzed storm surge inundation (feet above ground level) along the coasts of Florida, Georgia, South Carolina, and North Carolina from Hurricane Ian.

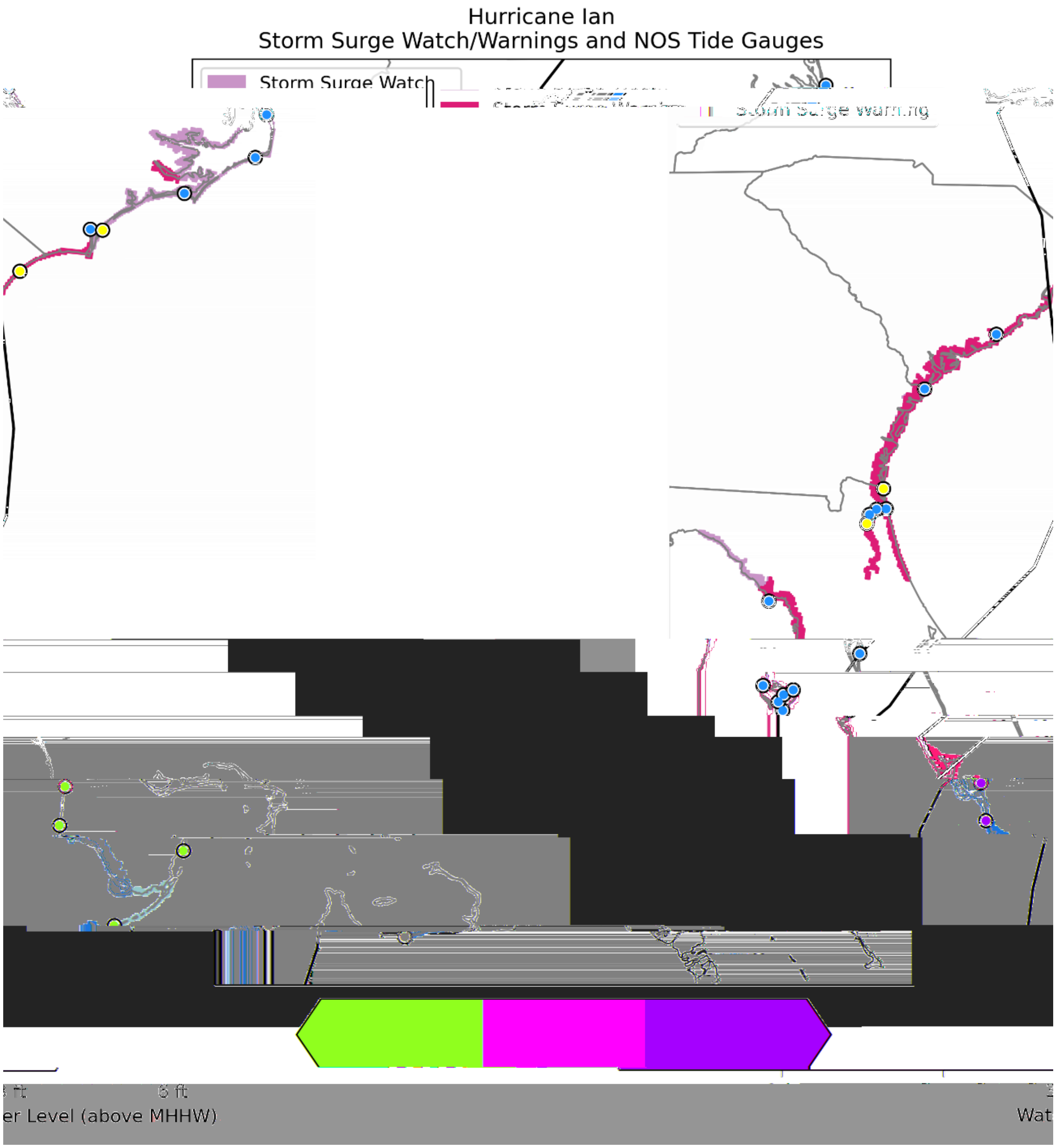


Figure 7. Maximum water levels (ft above MHHW) during Hurricane Ian measured by NOS tide gauge network and the maximum extent of the storm surge watches (lavender) and warnings (magenta). Ian's track is overlaid (black line).

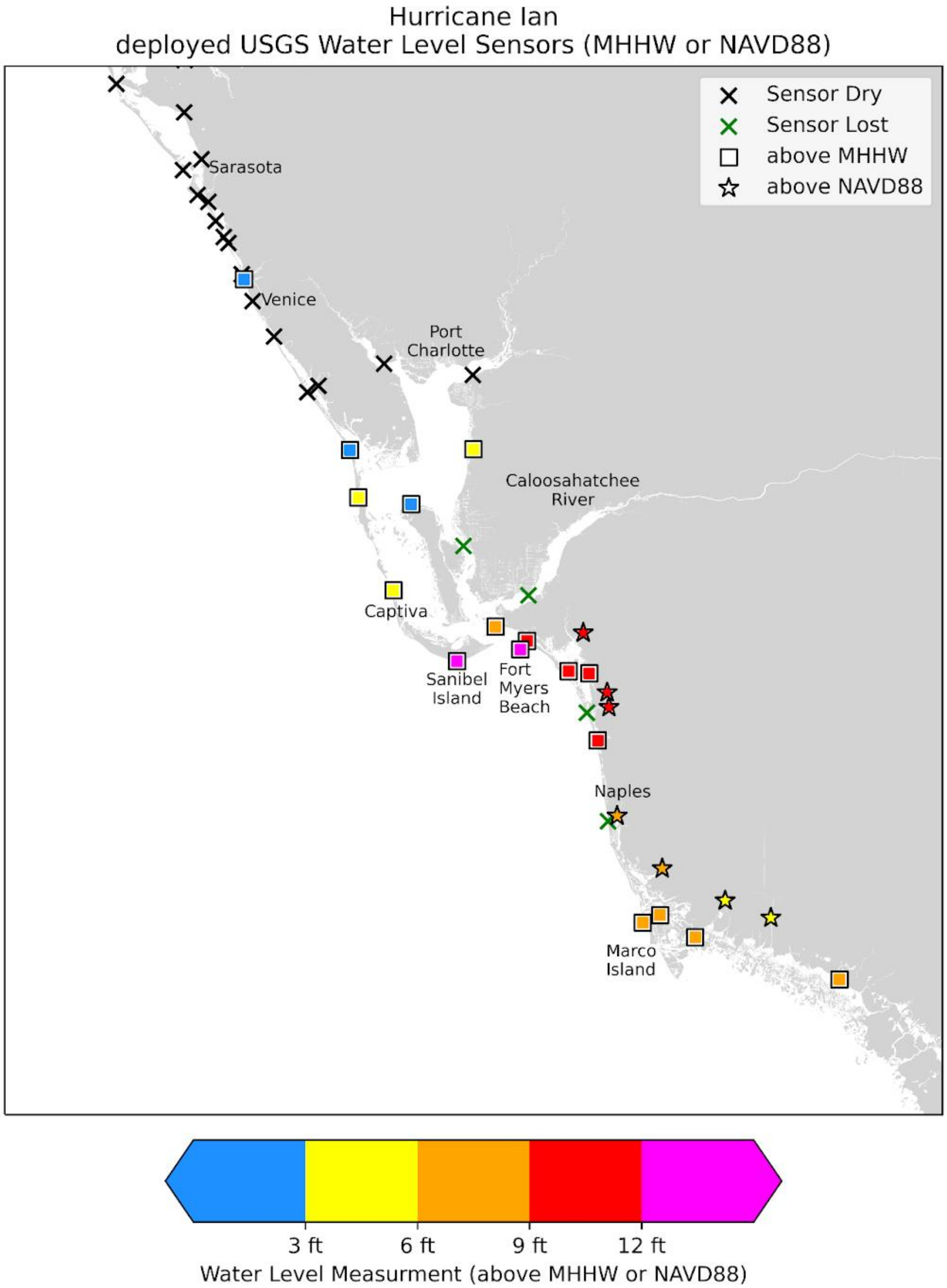
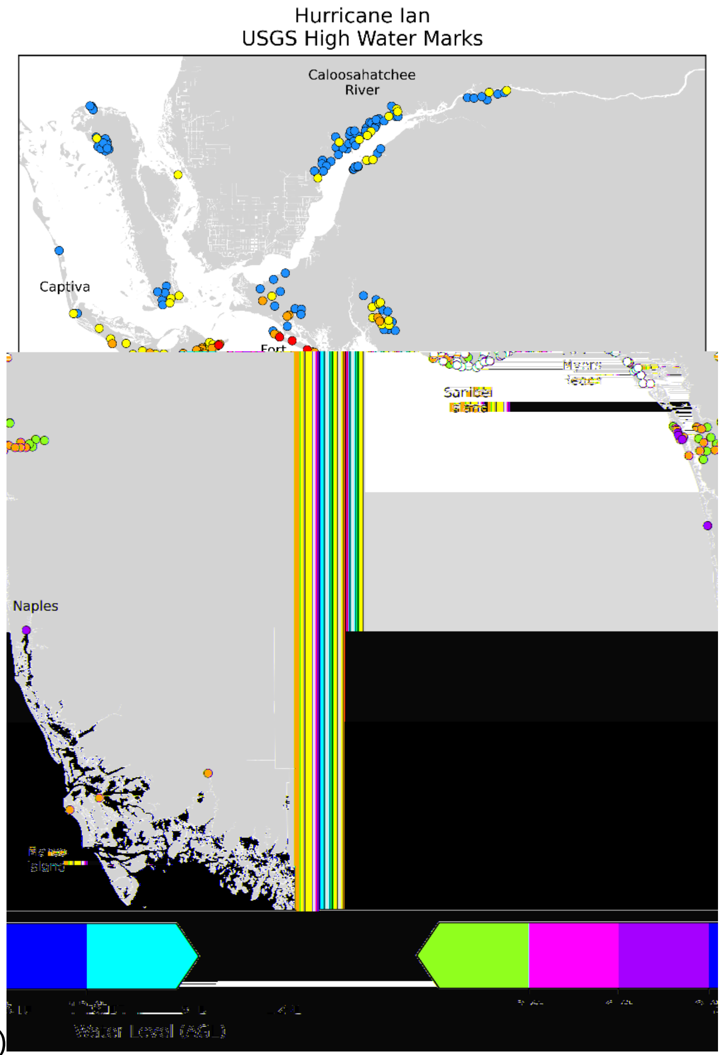


Figure 8. Maximum wave filtered water level measurements (ft above MHHW or NAVD88) from USGS water level sensors deployed along the west coast of Florida. NHC uses MHHW (displayed as squares) as an approximation for inundation at USGS sensors when a valid conversion from NAVD88 can be made using the NOAA VDatum tool. Sensors outside the valid conversion are given in NAVD88 (displayed as stars).

(a)



(b)

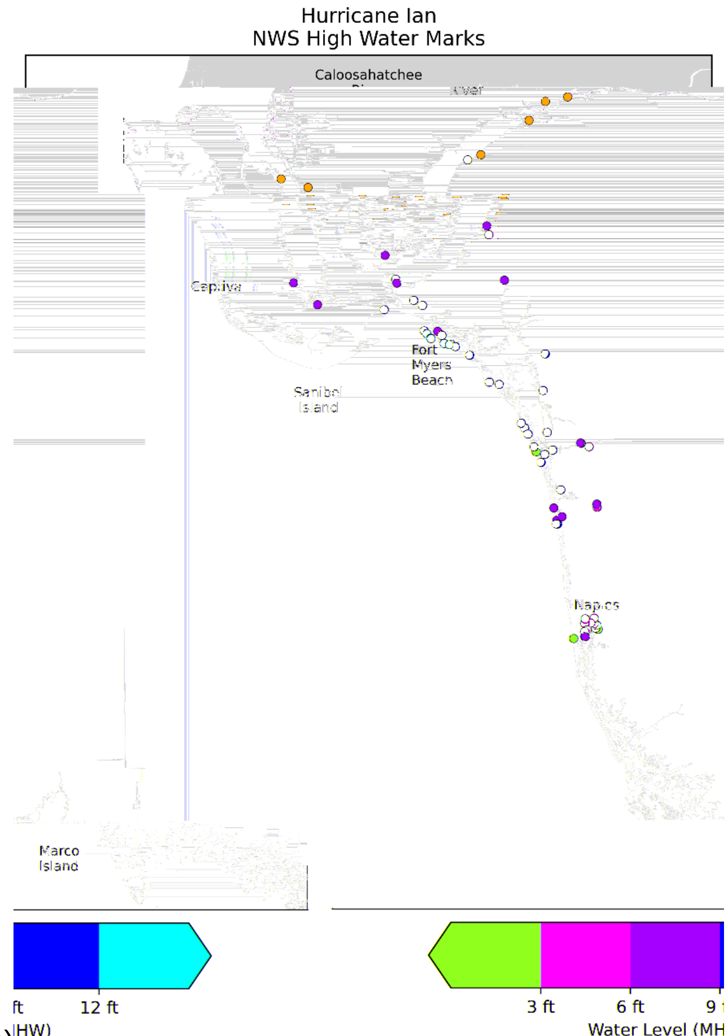


Figure 9. (a) USGS and (b) NWS high water marks collected in Southwest Florida estimating the storm surge impacts during Hurricane Ian. USGS surveyed a wider area including inland impacts, and estimated the water level above ground level (AGL). NWS heavily surveyed coastal areas for peak impacts, and estimated the water level above the high tide line (MHHW).

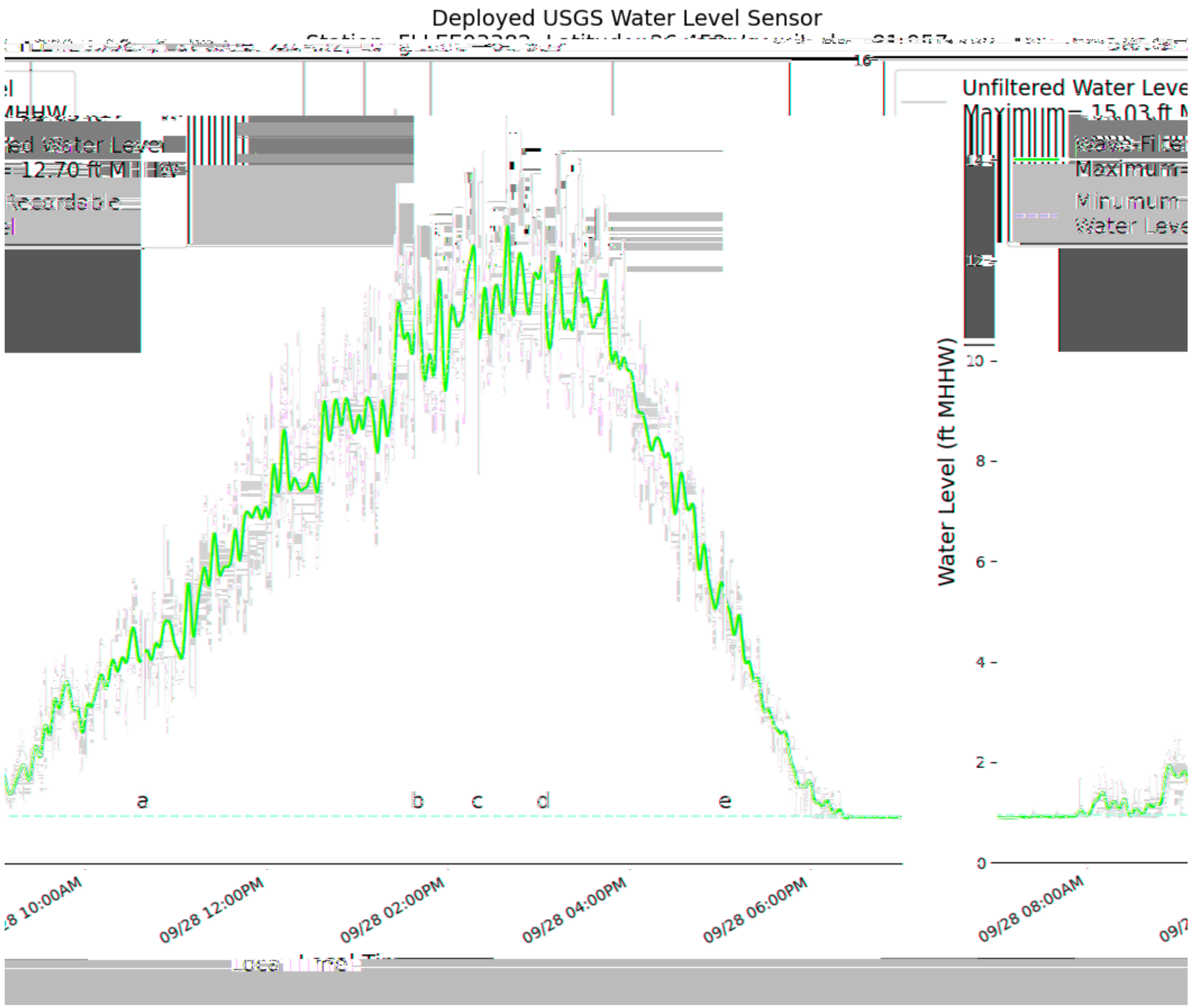


Figure 10. Unfiltered water level (gray) and wave-filtered water level (red) (ft above MHHW) measured during Hurricane Ian from a USGS sensor located in Fort Myers Beach. Vertical black lines (labeled as a to e) represent the still image times from Max Olson's remote camera in Figure 11.

Figure 11. Series of still images and the approximate local times from a remote camera that recoded a timelapse video of storm surge inundation and destruction in Fort Myers Beach. Credit: Max Olson.

(a) 

(b) 

Figure 12. (a) Storm surge high water mark in bathroom cabinet on the second-story of a beachfront structure in Fort Myers Beach. (b) NWS survey team extrapolating the high water mark to the outside of the home to survey its elevation of approximately 12 ft above the brick foundation and 15 ft above MHHW. Images courtesy of the NWS.

(a)

(b)

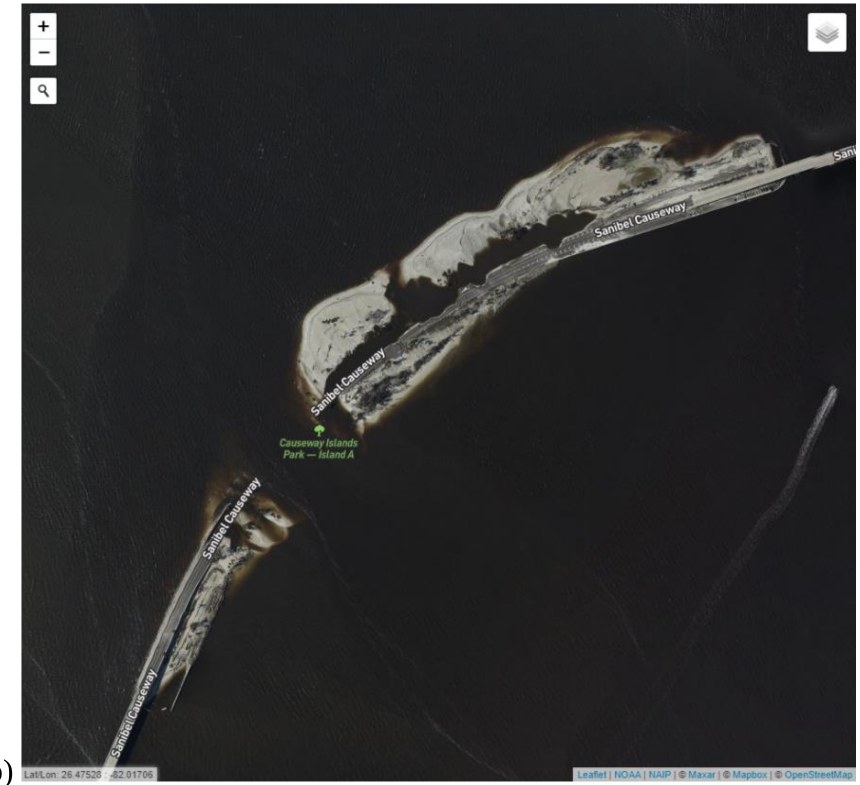


Figure 13. Before (a) and after (b) imagery of a portion of the Sanibel Causeway, showing the damage caused by Hurricane Ian. Imagery courtesy of the NOAA Remote Sensing Division at https://storms.ngs.noaa.gov/storms/ian/index.html#17/26.47970/-82.02219

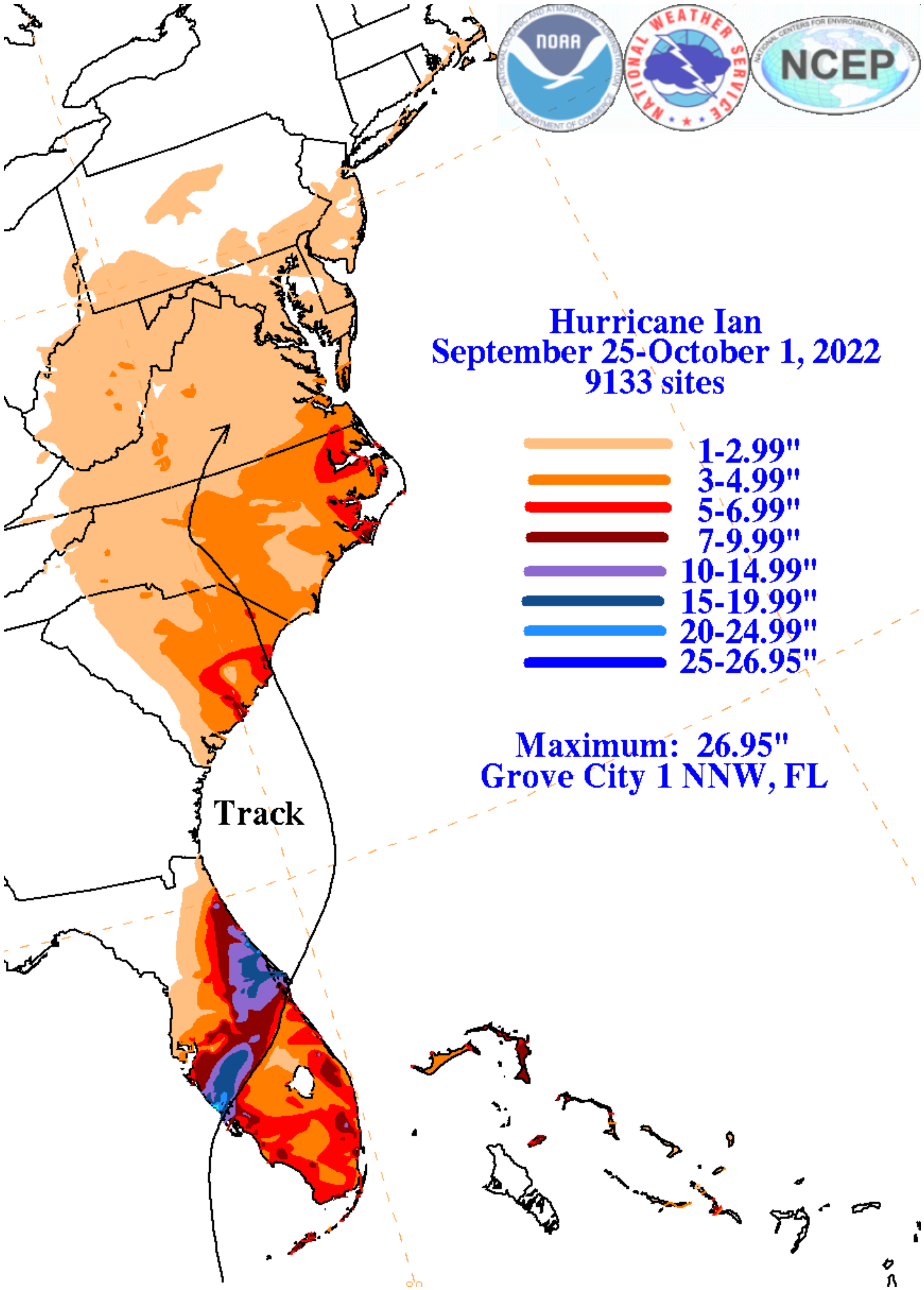
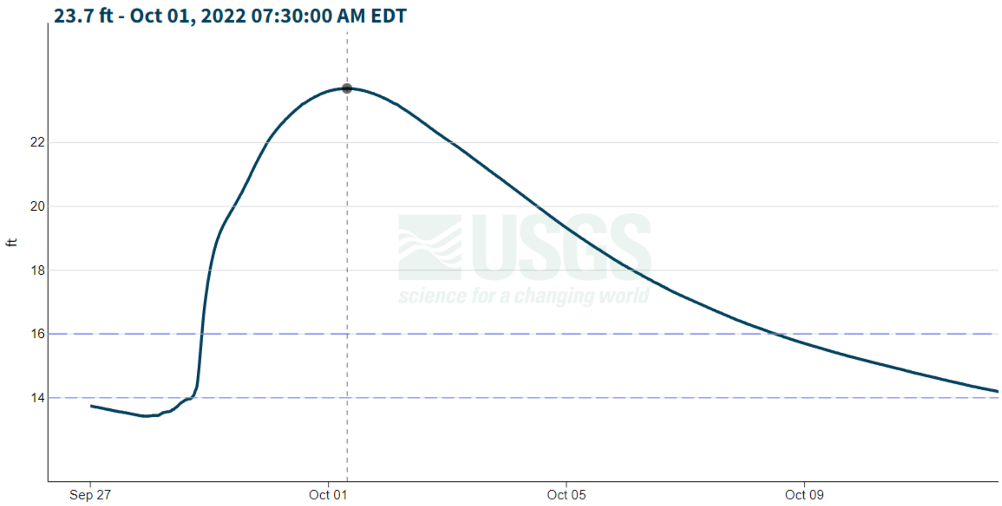
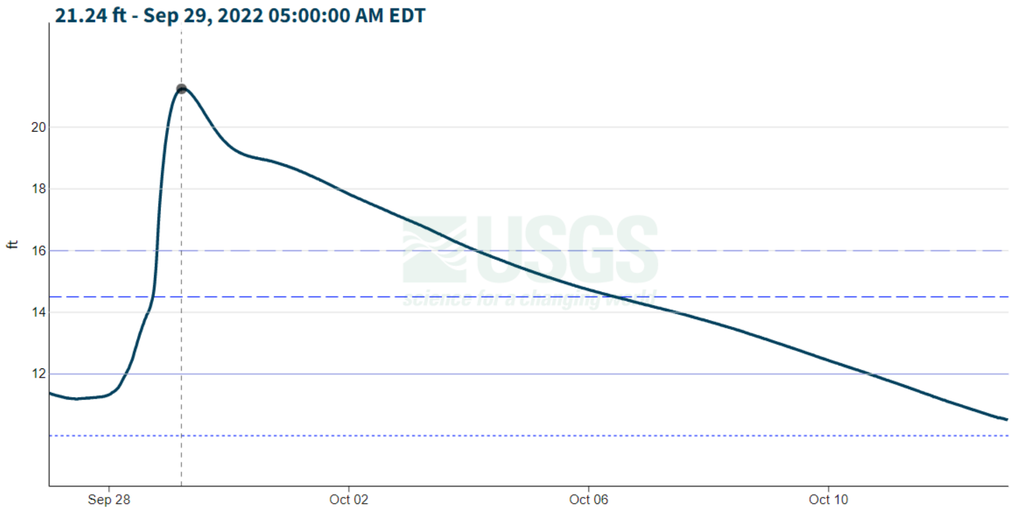


Figure 14. Analysis of storm total rainfall (inches) for Hurricane Ian courtesy of David Roth of the NOAA Weather Prediction Center.



(a)



(b)

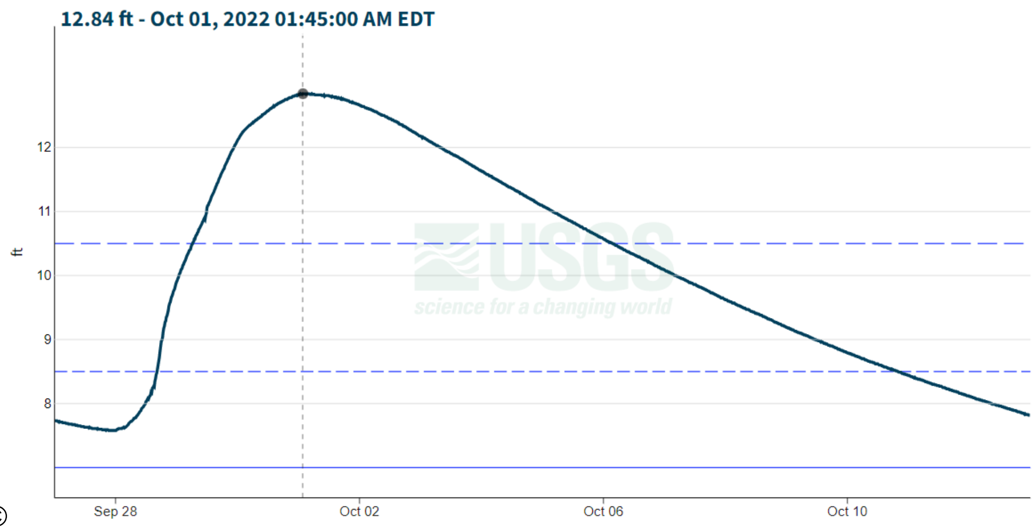


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Figure 15. USGS River Gauges measurements (ft) between 28 September–12 October 2022 at (a) Peace River at SR 70 at Arcadia, Florida, (b) Horse Creek at SR 72 near Arcadia, and (c) the Myakka River near SR 72 near Sarasota, Florida.

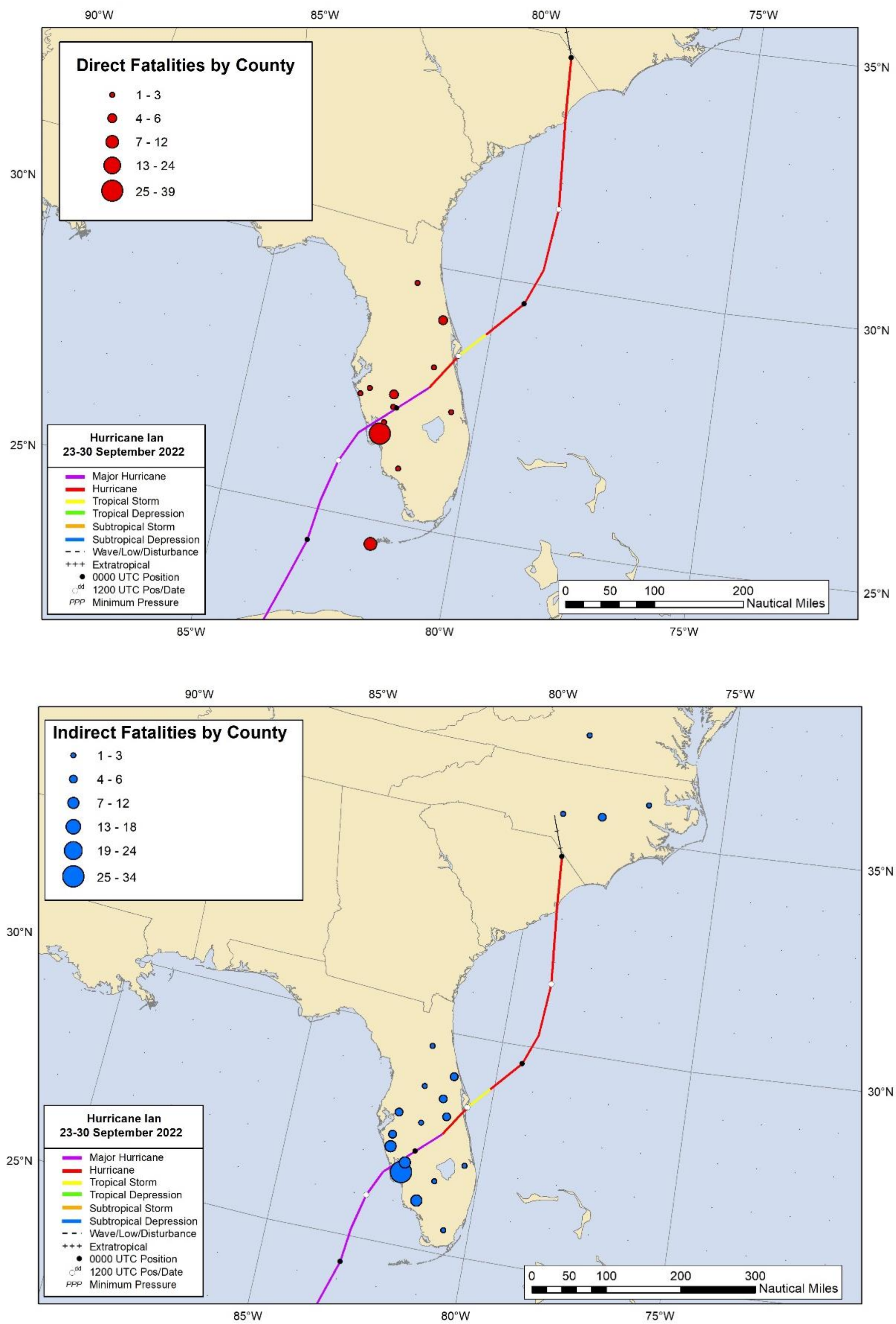

Figure 16. Locations of deaths directly (top) and indirectly (bottom) caused by Hurricane Ian, 23–30 September 2022.

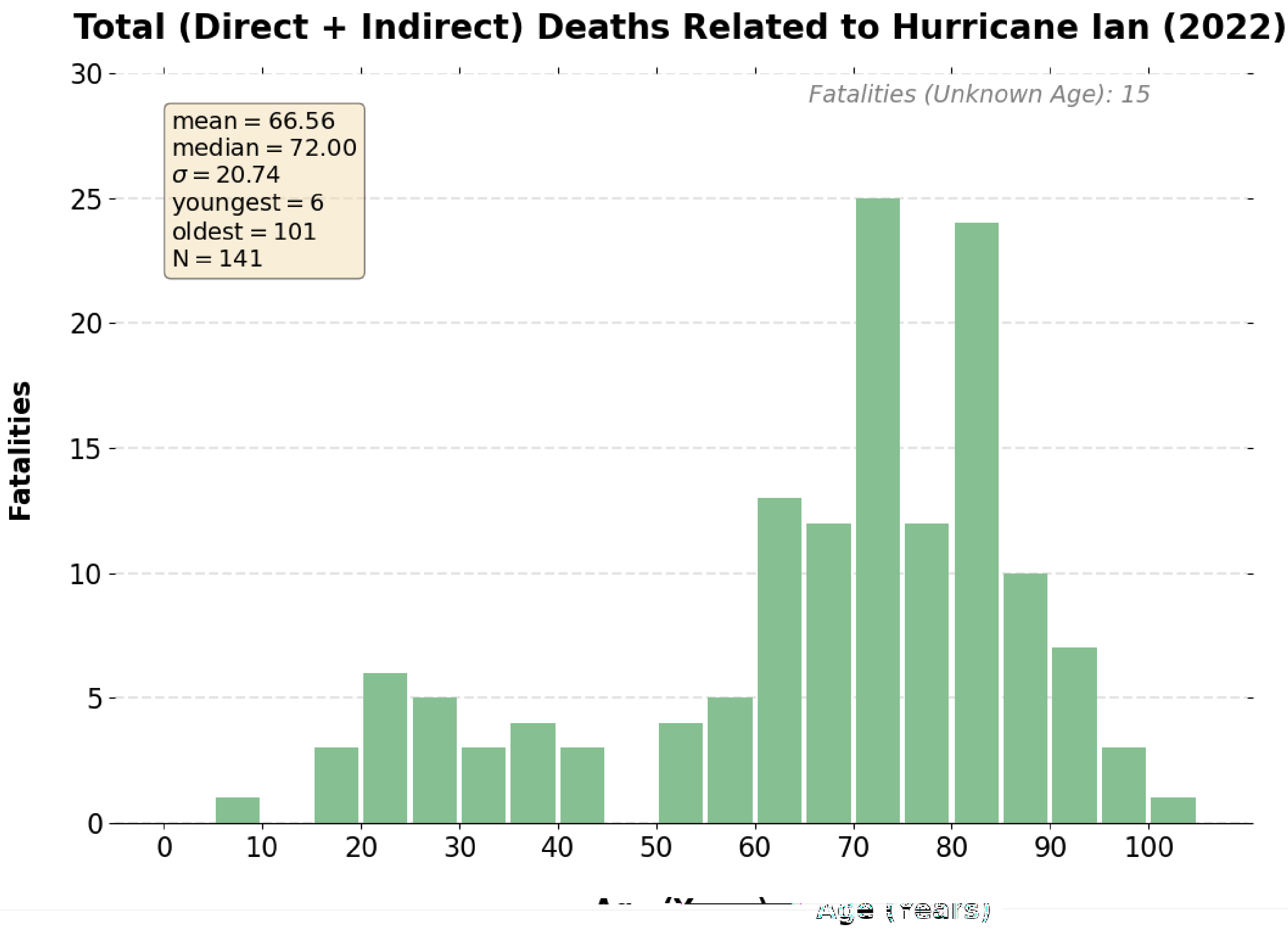

Figure 17. Age distribution of fatalities (both direct and indirect) in the United States during Hurricane Ian, 23–30 September.

Figure 18. Destruction caused by Hurricane Ian in Fort Myers Beach, Florida.

Figure 19. Images showing the freshwater flooding from Ian. **[Top left]** Rescue workers in Orlando, Florida, on Thursday, 29 September. Credit: Phelan M. Ebenhack/EBENP, via Associated Press. **[Top right]** Screen capture from drone footage in Daytona Beach, Florida. Credit: Daytona Beach Police Department. **[Bottom left]** Flooded buildings in Good Samaritan Society, Kissimmee, Florida. Credit: US Representative Darren Soto **[Bottom right]** Flooding from the Peace River washes out the road along NW Brownville Street in Brownville, outside of Arcadia, Friday. Credit: Luis Santana, Tampa Bay Times

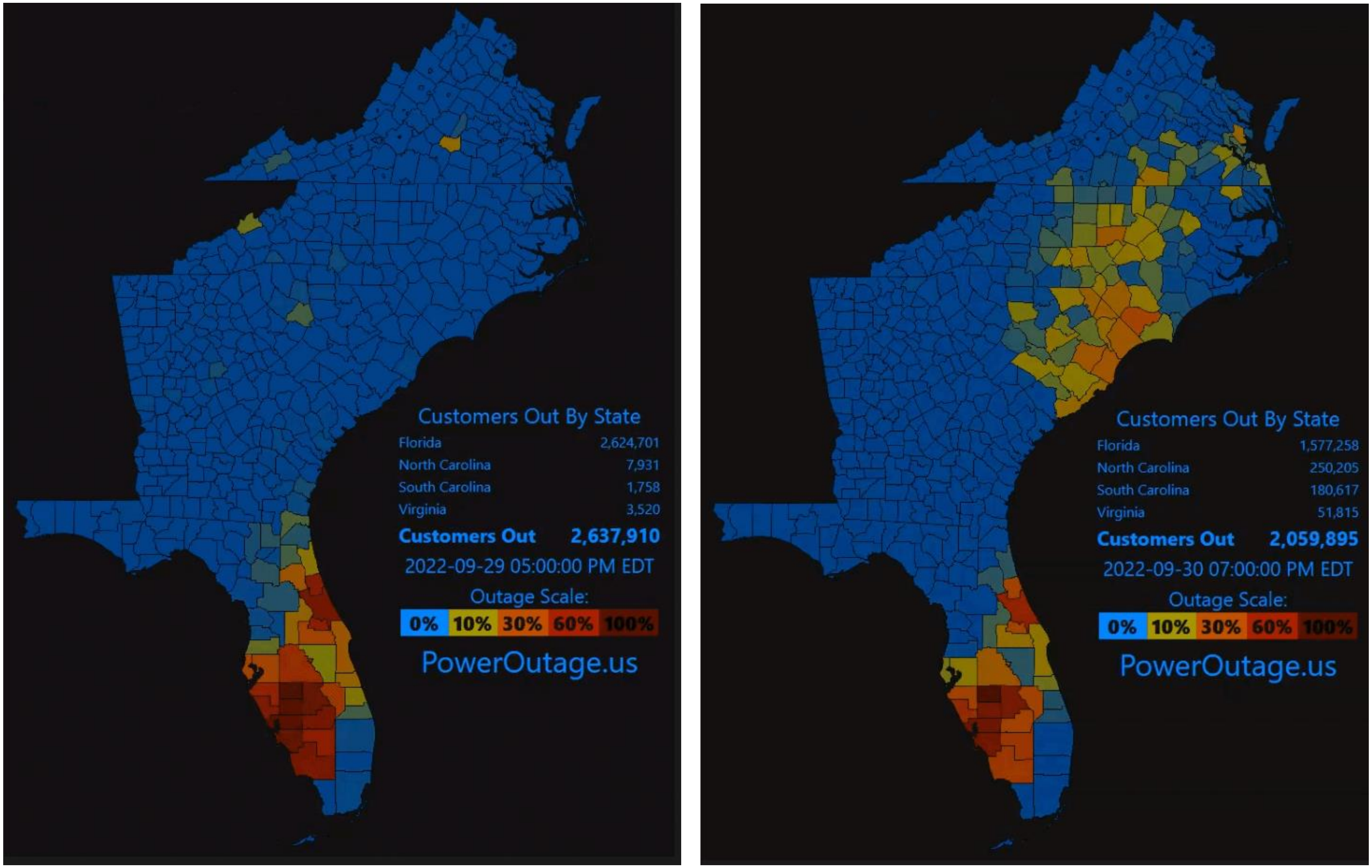

Figure 20. Power outage map for 2100 UTC 29 September (left) and 2300 UTC 30 September (right). Photo credit: PowerOutage.us

Figure 21. Storm surge inundation in historic Georgetown, South Carolina, between 2:35 and 2:50 pm EDT 30 September. Photo credit: Josh Morgerman, iCyclone.

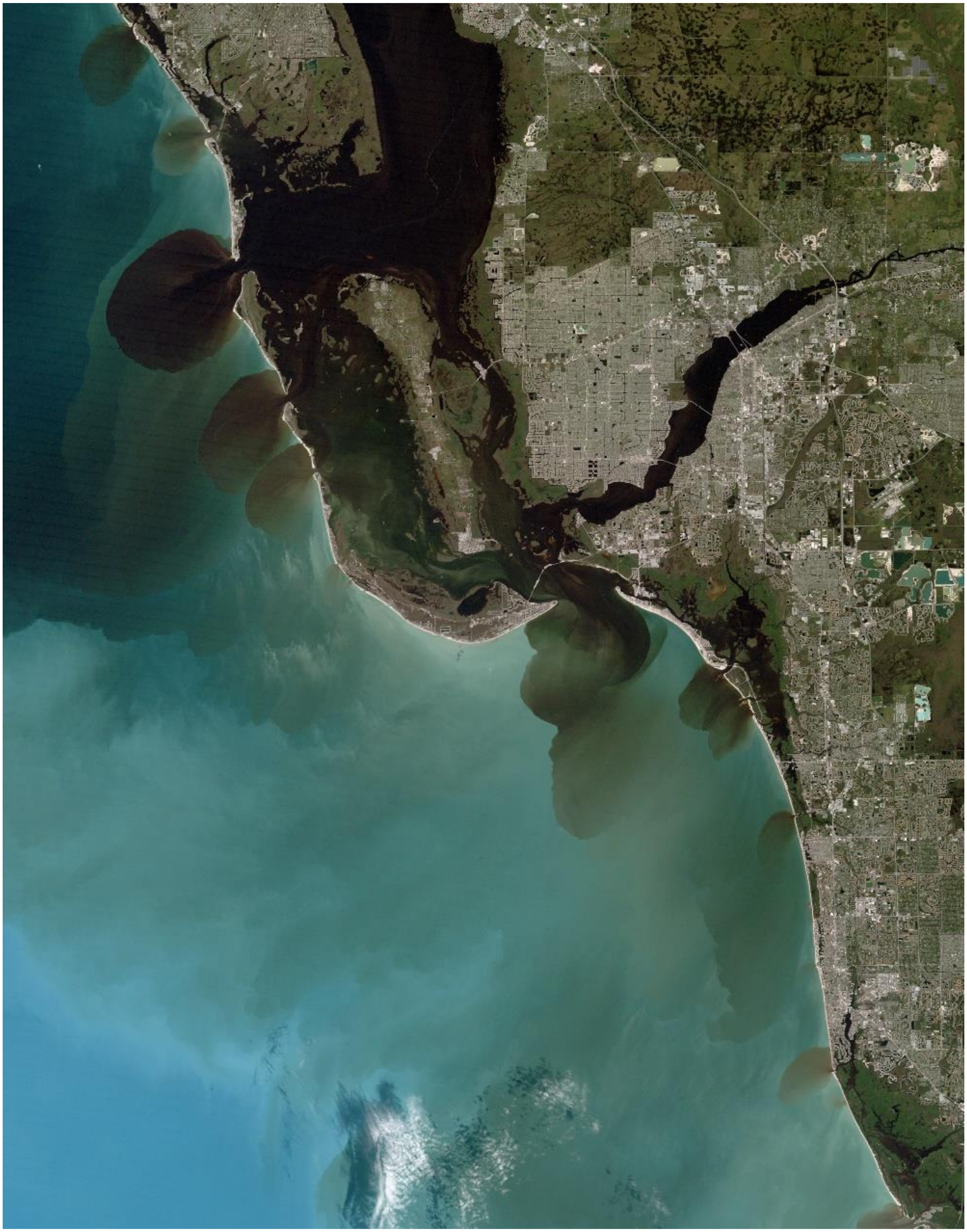

Figure 22. Gap-filled Landsat-7 image taken 2 October 2022 of the southwestern coast of Florida in the Fort Myers area. Photo credit: Michelle Bouchard using Landsat data from the U.S. Geological Survey

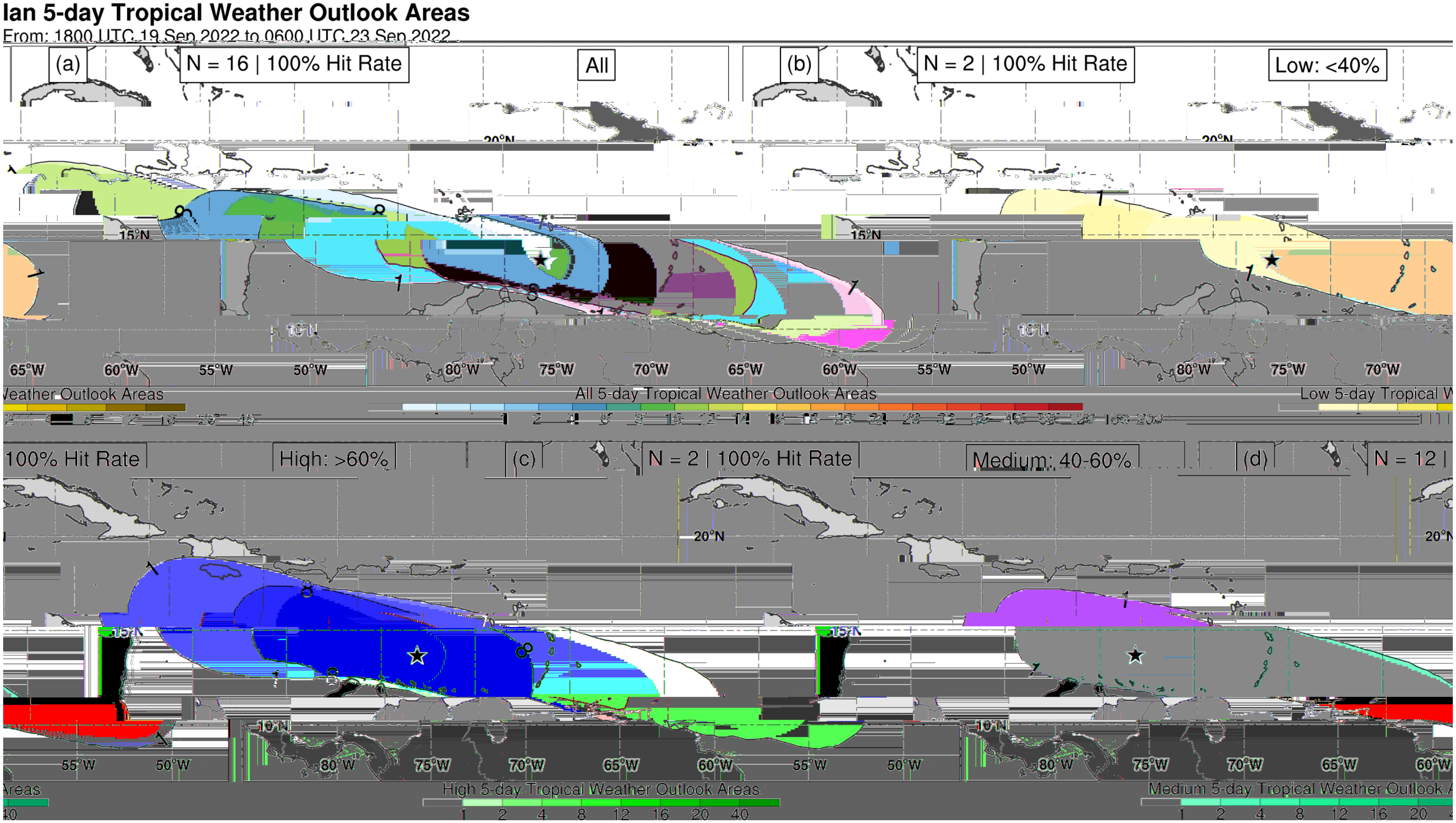

Figure 23. 5-day Tropical Weather Outlook genesis areas associated with the disturbance that developed into Hurricane Ian for (a) all probability areas (10–100%, multi-color shading), (b) low probability areas (< 40%, yellow shading), (c) medium probability areas (40–60%, orange shading), and (d) high probability areas (> 60%, red shading). The black star in each panel indicates the genesis location of Ian. Hit rate indicates the percentage of outlook areas where the genesis location was captured within.

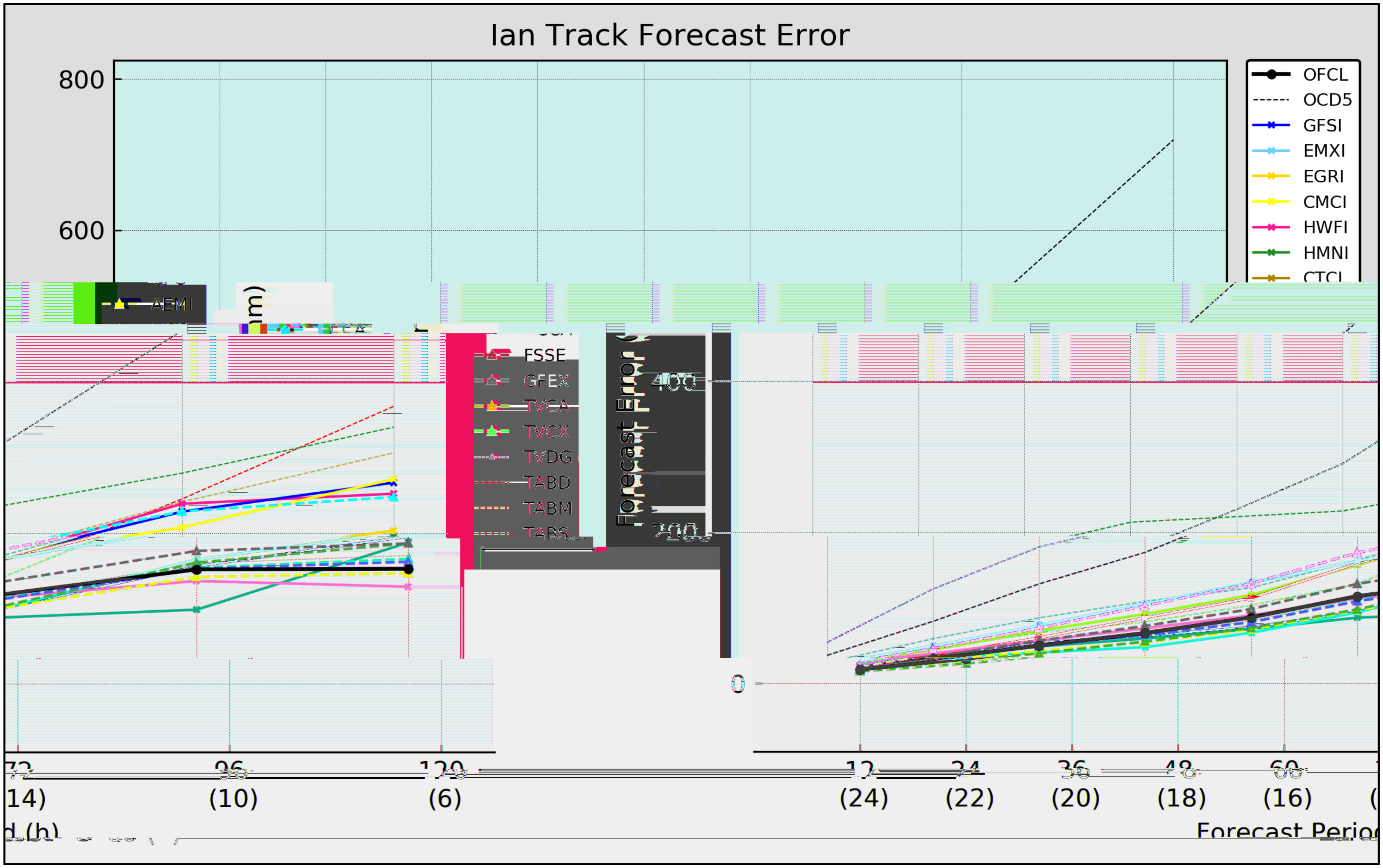

Figure 24. Track forecast error (n mi) of the official forecasts and selected models for Hurricane Ian, 23–30 September 2022.

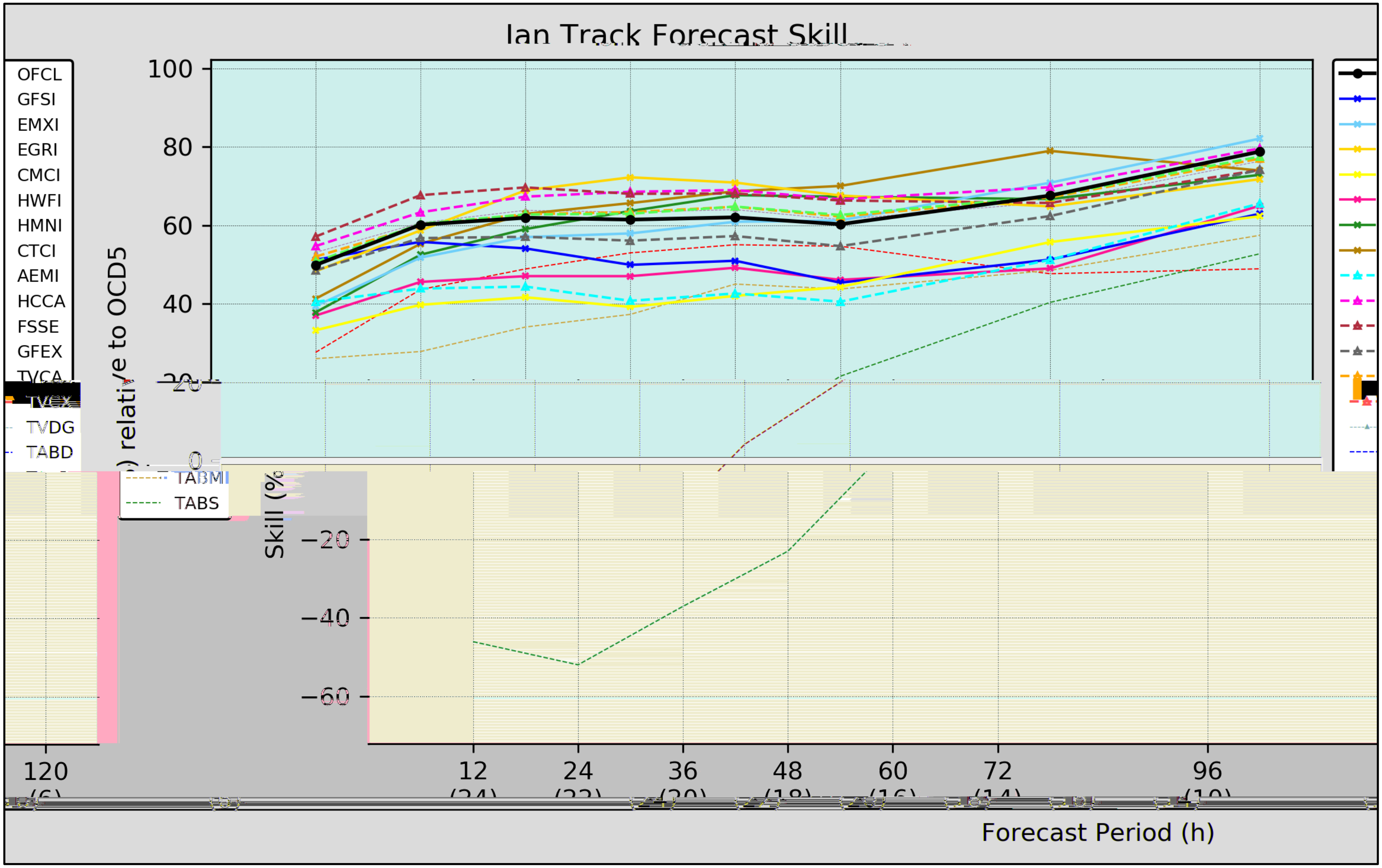

Figure 25. Track forecast skill of the official forecasts and selected models for Hurricane Ian, 23–30 September 2022.

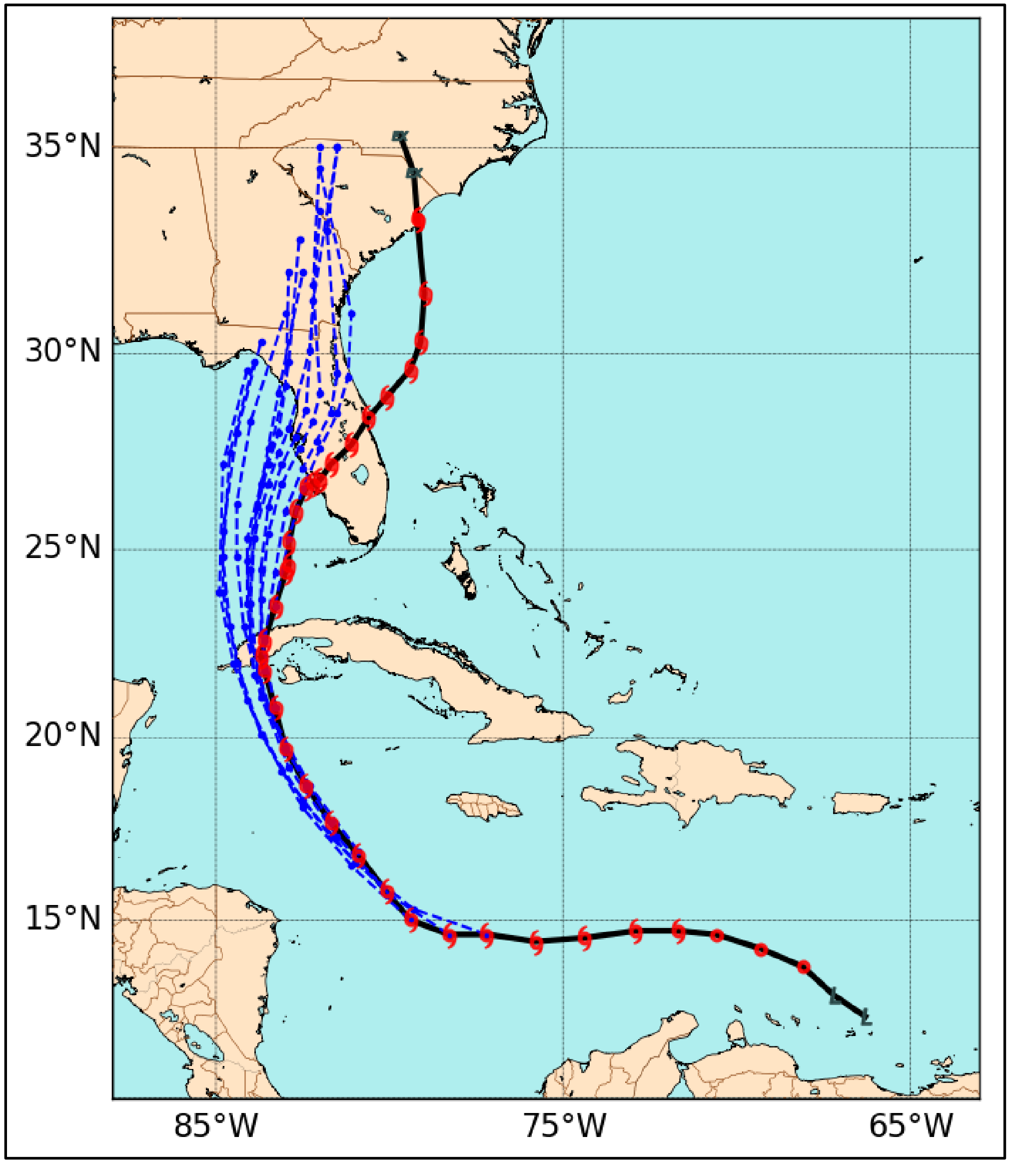

Figure 26. Selected official track forecasts between 00 UTC 25 September and 18 UTC 27 September (dashed lines, with 0, 12, 24, 36, 48, 60, 72, 96, and 120 h positions indicated) for Hurricane Ian, 23–30 September 2022. The best track is given by the thick solid black line with positions given by red symbols at 6-h intervals.

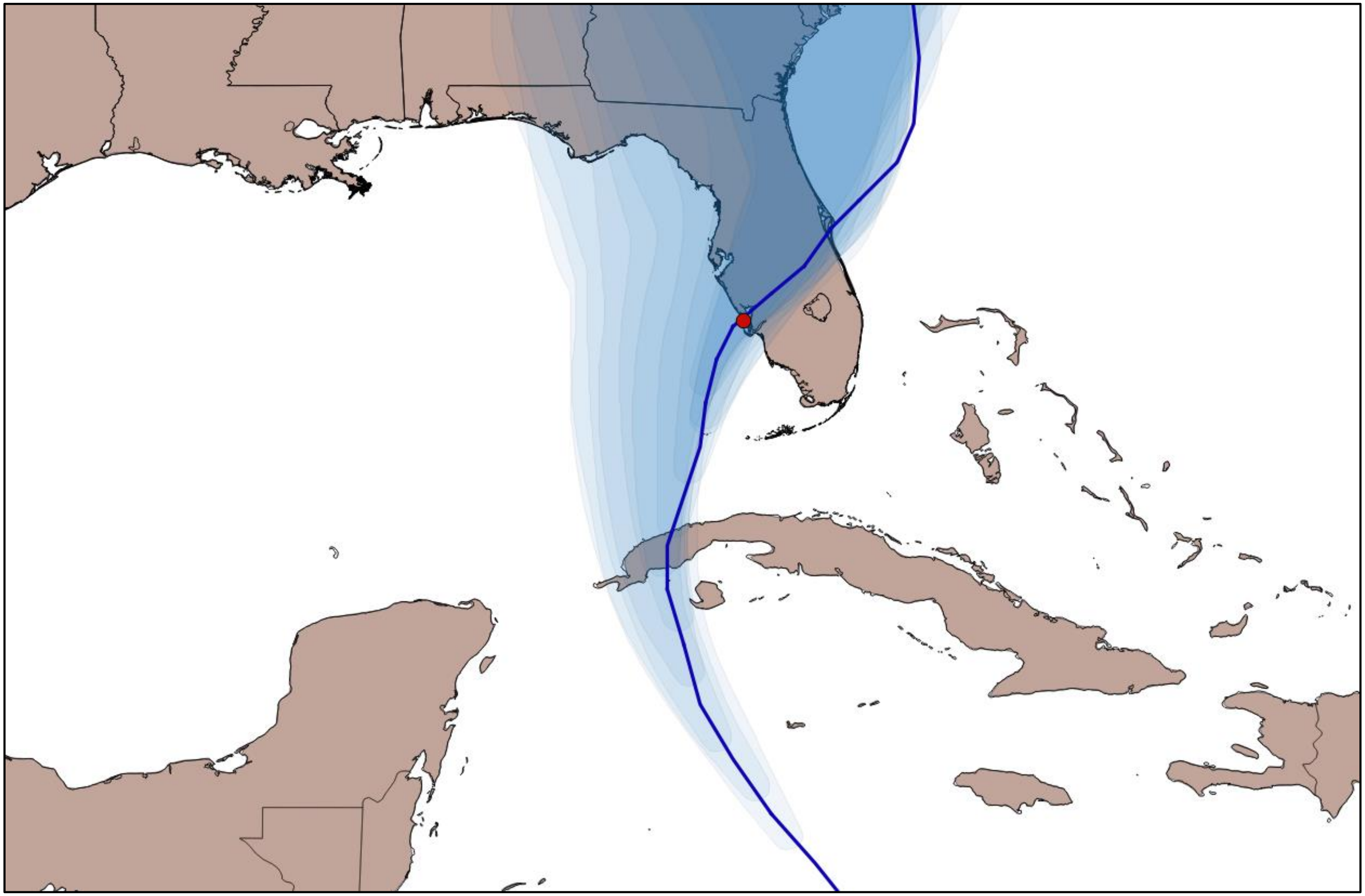

Figure 27. Select official NHC forecast track cones (light shaded blue) from 00 UTC 26 September through 06 UTC 28 September (advisories 12 through 22) with the best track (solid blue line) and Cayo Costa, Florida landfall location (red dot).

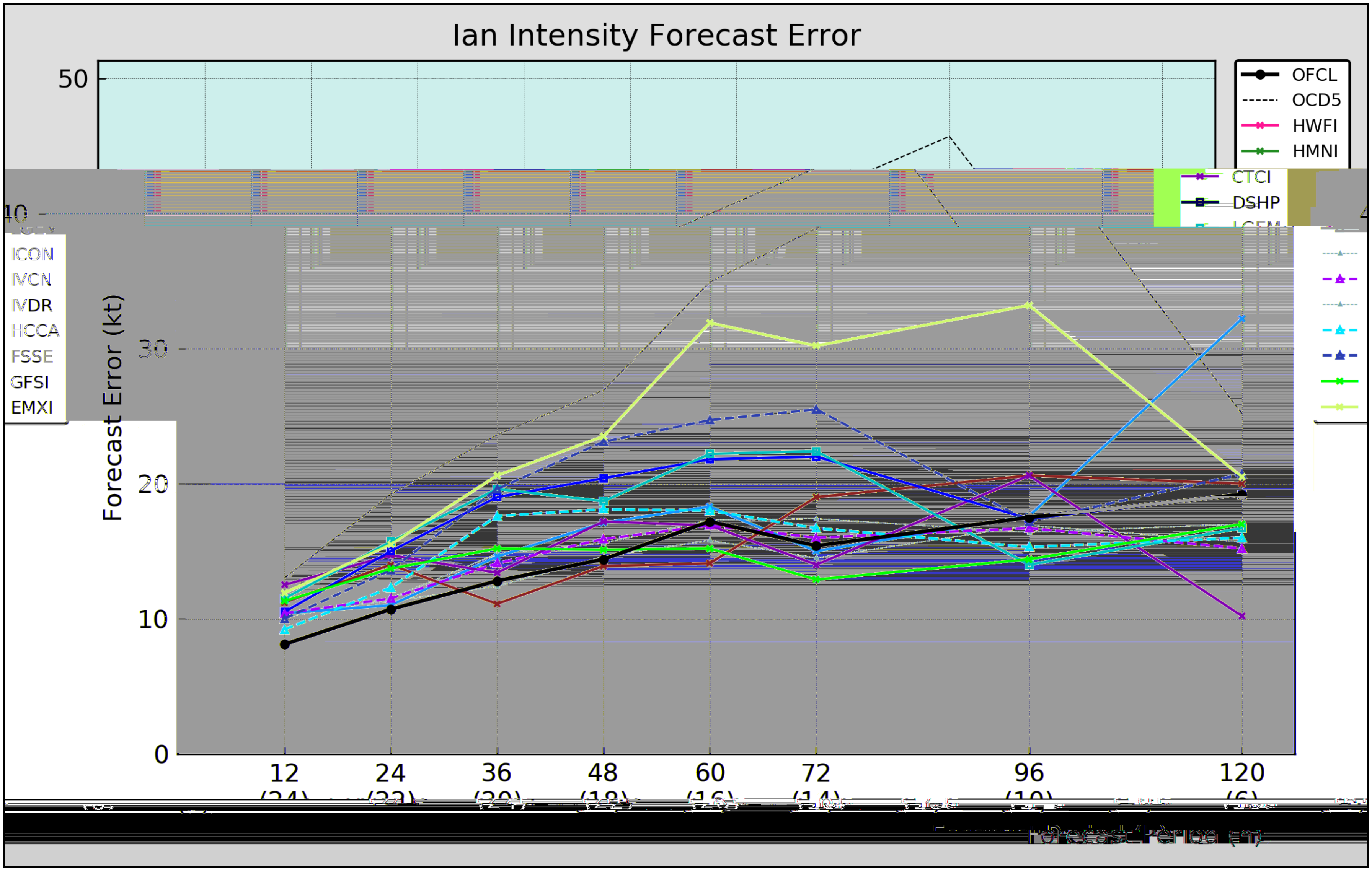

Figure 28. Intensity forecast error (kt) of the official forecasts and selected models for Hurricane Ian, 23–30 September 2022.

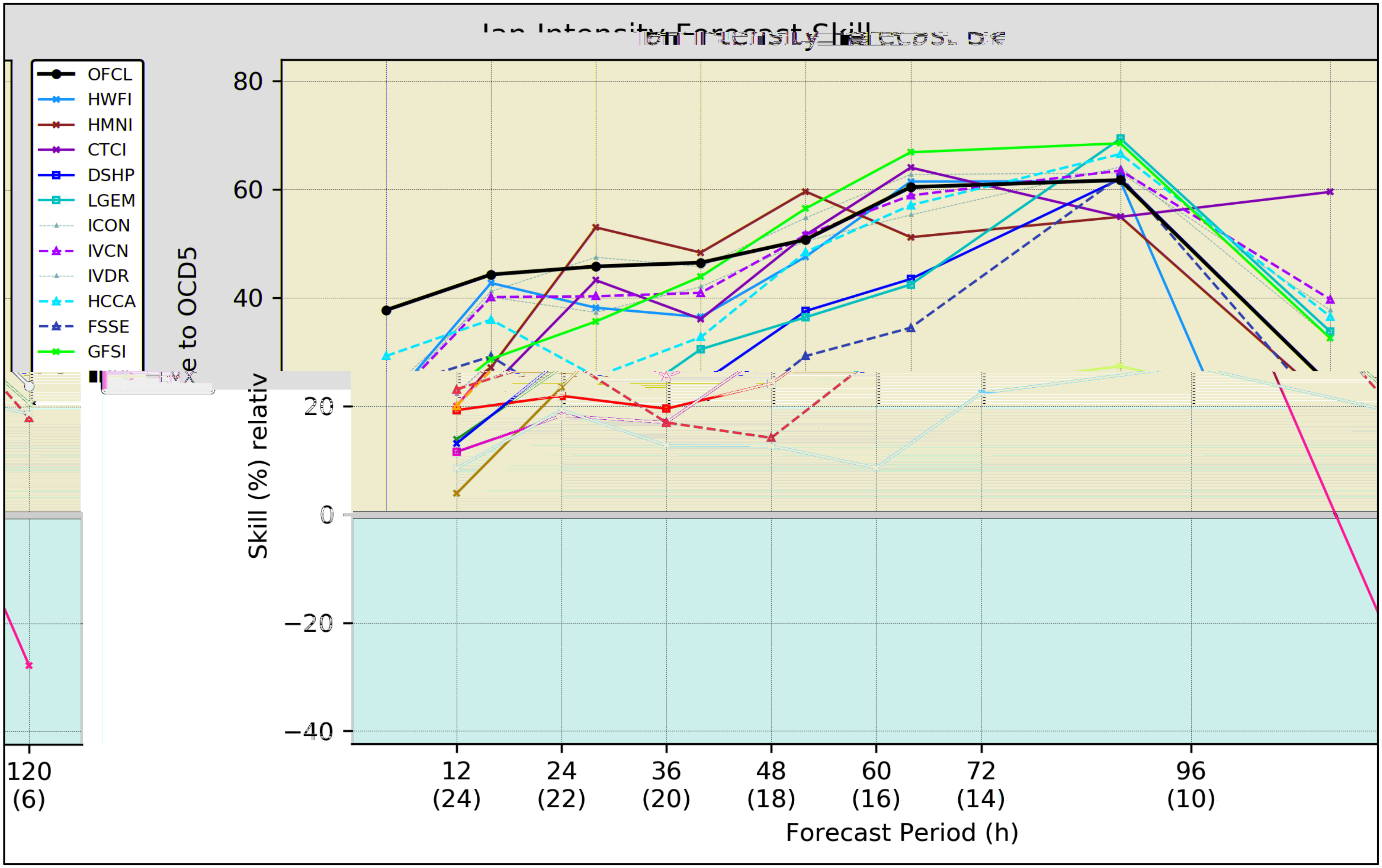

Figure 29. Intensity forecast skill of the official forecasts and selected models for Hurricane Ian, 23–30 September 2022.

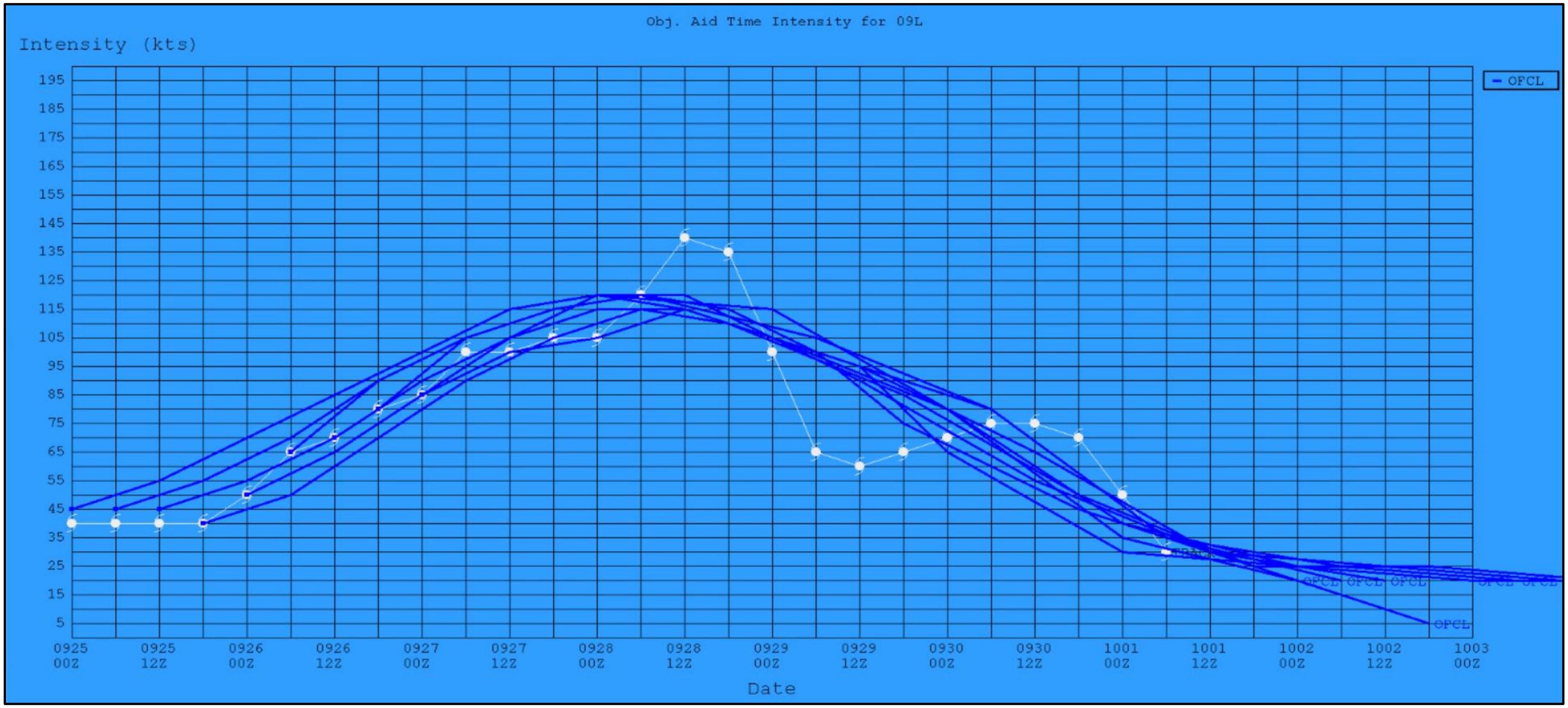

Figure 30. Selected official intensity forecasts between 00 UTC 25 September and 00 UTC 27 September (dashed lines, with 0, 12, 24, 36, 48, 60, 72, 96, and 120 h intensities indicated) for Hurricane Ian, 23–30 September 2022. The best track is given by the white solid line with intensities given at 6-h intervals.

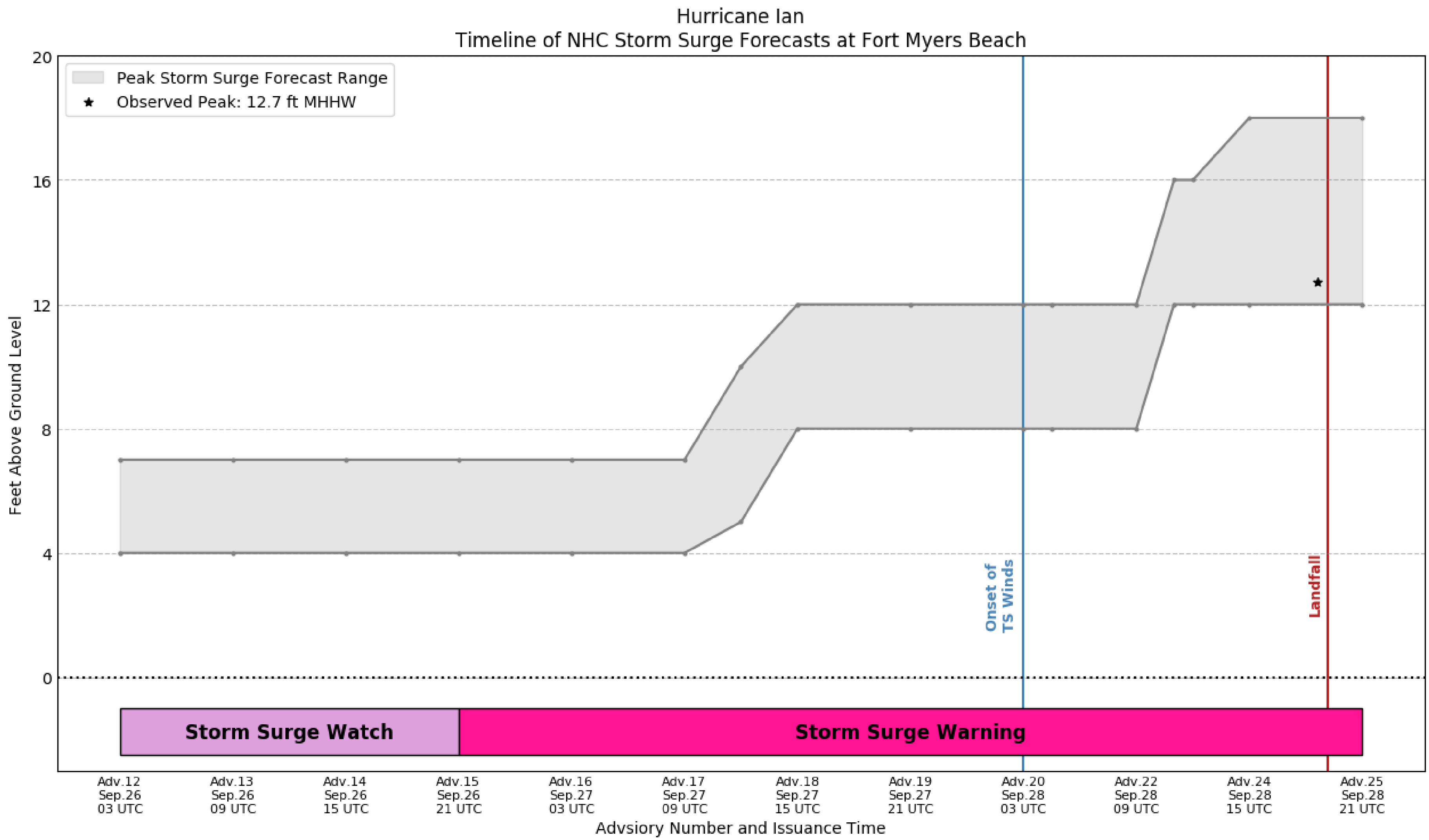

Figure 31. Timeline of NHC storm surge forecasts for Hurricane Ian compared with verifying onset time of tropical-storm-force winds, landfall, and the wave-filtered maximum water level measurement from the USGS sensor at Fort Myers Beach (shown as a star).

ADDITIONAL NWS RESOURCES

Note that the storm overviews in these reports were generated using the preliminary Best Track data for Hurricane Ian.

https://storymaps.arcgis.com/stories/2d5269a0866d436fb70677b0a3c1de3a (Tampa Bay WFO)

https://storymaps.arcgis.com/stories/4a242bae868140a394c96bc2d9415e86 (Melbourne WFO)

https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=ec1990ce72d444b99e58d1553f7775b1 (Miami WFO)

https://storymaps.arcgis.com/stories/bd0750c3c312476ba9c8c59eb7cb3cce (Charleston WFO)

https://www.weather.gov/ilm/hurricaneian (Wilmington WFO)