NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE HILARY

(EP092023)

16–20 August 2023

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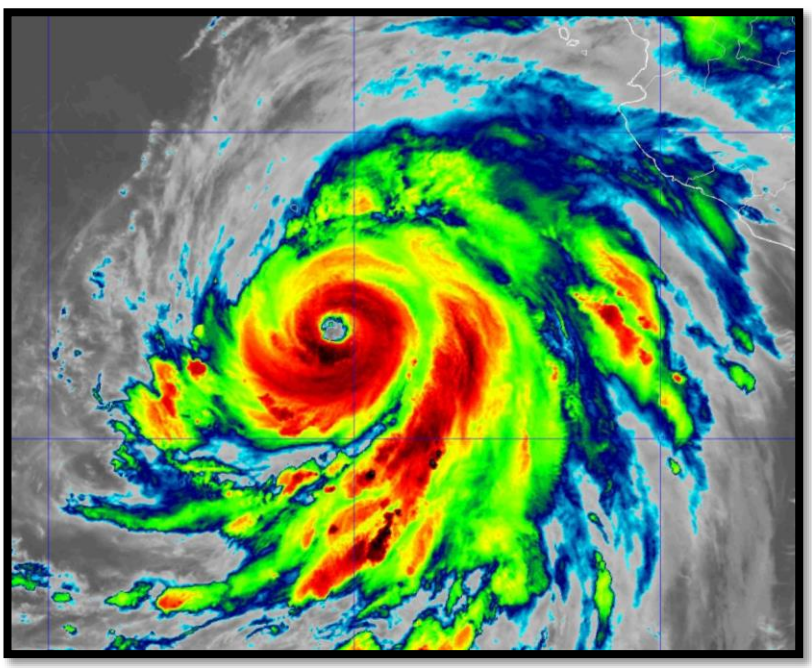

GOES-18 INFRARED SATELLITE IMAGE OF CATEGORY FOUR HURRICANE HILARY AT 0600 UTC 18 AUGUST 2023.
IMAGE COURTESY OF NOAA/NESDIS/STAR.

Hilary reached category 4 intensity (on the Saffir-Simpson Hurricane Wind Scale) while it passed well offshore of the coast of southwestern Mexico. Hilary weakened as it approached land and made landfall as a tropical storm in the Mexican state of Baja California. Hilary brought historic rainfall totals and catastrophic flooding impacts to portions of the Baja California peninsula and the southwestern United States. Hilary is responsible for 3 fatalities and over $900 million (USD) in damage in the U.S. and Mexico.

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16–20 AUGUST 2023

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SYNOPTIC HISTORY

Hilary appears to have originated from a tropical wave that moved off of the west coast of Africa on 3–4 August and reached the Lesser Antilles on 9 August. The wave moved quickly westward across the Caribbean Sea during the next few days and crossed Central America into the eastern Pacific basin late on 12 August. Shower and thunderstorm activity gradually increased in association with the wave, resulting in the formation of a broad area of low pressure several hundred miles to the south of the Gulf of Tehuantepec on 14 August. As the broad disturbance moved westward and passed well offshore of the coast of southern Mexico on 15 August, showers and thunderstorms began to show increased signs of organization, although the system lacked a well-defined center. Satellite data indicate the low-level circulation became better defined late that night, and it is estimated that a tropical depression formed by 0600 UTC 16 August, about 300 n mi south of Acapulco, Mexico. Six hours later, the depression strengthened into Tropical Storm Hilary. The "best track" chart of Hilary'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].

Hilary moved generally west-northwestward for the first couple of days after formation while being steered by a mid-level ridge over the southwestern United States and northern Mexico. The oceanic and atmospheric conditions were primed to support significant strengthening, with sea surface temperatures (SSTs) warmer than 30°C, weak vertical wind shear, abundant mid-level moisture, and a strongly diffluent upper-level environment. The storm began to rapidly intensify, with an eye becoming evident in passive microwave and conventional satellite images on 17 August. Hilary strengthened to a 75-kt hurricane by 1200 UTC that day, when it was centered about 285 n mi southwest of Manzanillo, Mexico. The strengthening hurricane was also quite large, with tropical-storm-force winds that extended over 200 n mi from the center. The satellite presentation of Hilary continued to improve that night, with a warm and symmetric eye surrounded by a ring of very cold cloud tops associated with intense convection. It is estimated that Hilary reached a peak intensity of 120 kt at 0600 UTC 18 August (cover photo), when it was centered about 375 n mi west-southwest of Manzanillo. This marked the end of a 48-h period in which Hilary rapidly strengthened by 90 kt, from a 30-kt tropical depression to a 120-kt category 4 hurricane.

A concentric eyewall structure became apparent in microwave data early on 18 August (Fig. 4a), suggesting that Hilary was undergoing an eyewall replacement cycle (ERC) while

[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.

turning northwestward along the southwestern periphery of the steering ridge. Some weakening occurred that day while the inner eyewall collapsed and the outer eyewall contracted. The completion of the ERC left Hilary with a larger eye (30–35 n mi diameter) and a broader wind field. A brief period of re-intensification occurred soon thereafter, and aircraft data early on 19 August revealed modest central pressure falls since the previous mission, along with flight-level winds that supported a second peak intensity of 115 kt from 0000 to 0600 UTC 19 August.

Rapid weakening commenced later that day as drier and more stable air wrapped around the western portion of the circulation and began eroding Hilary's inner core convection (Fig. 4b). Hilary turned north-northwestward and accelerated on 19–20 August within the flow between a subtropical ridge over the southern United States and a cutoff mid- to upper-level low offshore of the coast of California. This motion brought the hurricane over cooler SSTs and into an environment of stronger deep-layer southerly shear. As a result, the associated convection diminished and became displaced well to the north of the center. Hilary quickly weakened to a 55-kt tropical storm by 1200 UTC 20 August, when it was centered near Isla Cedros, about 20 n mi northwest of Punta Eugenia, Mexico. The storm continued to weaken and made landfall around 1700 UTC that day (Fig. 5) as a 50-kt tropical storm in a sparsely populated part of the state of Baja California near the community of San Fernando.

Satellite imagery, surface observations, and model analyses indicate that the low-level center of Hilary became less defined as it encountered the mountainous terrain of the northern Baja California peninsula. Additionally, convection became less organized and farther displaced from the elongated center due to increased shear associated with a deep-layer trough off the coast of California. As a result, the storm lost tropical characteristics and degenerated to a post-tropical cyclone over northern Baja California by 2100 UTC 20 August. Around this time, the aforementioned upper-level trough provided dynamic forcing that supported the development of a new, non-tropical area of low pressure farther to the northwest along a lee trough[2] near the coast of southern California (Fig. 6). This new system quickly absorbed the low- to mid-level remnants of Hilary by 0000 UTC 21 August. Heavy rainfall and gusty winds associated with this new system (which included the remnants of Hilary) continued over the southwestern United States on 21 August.

METEOROLOGICAL STATISTICS

Observations in Hilary (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) estimates and Satellite Consensus (SATCON) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from five flights of

[2] A lee trough is a pressure trough formed on the lee side of a mountain range in situations where the wind is blowing with a substantial component across the mountain ridge (American Meteorological Society *Glossary of Meteorology*).

the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command (Fig. 7). These missions provided 12 center fixes for Hilary from 18–20 August. 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 Hilary.

The cargo ship *Eminent Ace* (7JUL) reported tropical-storm-force winds between 0600–1000 UTC on 18 August over 300 n mi south of Hilary, but the ship's anemometer height (33.4 m) is well above the standard 10-m observing height. Selected surface observations from land stations and data buoys are given in Table 2.

Winds and Pressure

Hilary's peak intensity of 120 kt at 0600 UTC 18 August is based on a blend of objective and subjective satellite estimates. This peak is somewhat uncertain given the large spread in the various intensity estimates early on 18 August. The operational ADT and SATCON estimates at that time peaked between 130–135 kt, while TAFB and SAB provided consensus T6.0/115 kt subjective Dvorak classifications. The minimum central pressure of 940 mb is based on the Knaff-Zehr-Courtney (KZC) pressure-wind relationship.

Hilary's second peak intensity of 115 kt from 0000 to 0600 UTC 19 August is based on data from the Air Force Reserve Hurricane Hunters. The aircraft measured peak 700-mb flight-level winds of 128 kt at 0509 UTC that day, which reduces to a 115-kt surface intensity estimate using the standard 90% adjustment factor. A 0636 UTC center dropsonde on that mission reported a pressure of 944 mb with 15-kt surface winds, which supports the minimum pressure of 943 mb.

Hilary's estimated landfall intensity in Baja California at 1700 UTC 20 August is 50 kt. A dropsonde released by the Air Force Hurricane Hunters at 1433 UTC reported a mean boundary layer (0–500 m) wind of 65 kt and a wind of 58 kt in the lowest 150 meters of the atmosphere, and these data support a surface intensity of around 50 kt using standard reduction factors. The estimated landfall pressure of 990 mb is based on a blend of dropsonde data from around the time of landfall and the KZC pressure-wind relationship.

Mexico

Hilary's center passed well to the west of Socorro Island as a major hurricane on 18 August, and an automated station on the island reported a 10-minute average wind of 42 kt at 1340 UTC that day and a peak gust of 69 kt.

Hilary brought tropical-storm-force winds to numerous locations across the Baja California peninsula on 19–20 August. In Baja California Sur, an inland weather station at Sierra La Laguna (elev. 6395 ft) measured a sustained wind of 52 kt at 0830 UTC 19 August with a gust to 86 kt. Along the west coast of the peninsula, an automated station at Puerto Cortés Naval Base on Isla Santa Margarita reported a sustained wind of 40 kt at 1945 UTC 19 August with a peak gust of 55 kt. On the east coast of the peninsula, the Loreto International Airport (MMLT) reported a sustained wind of 50 kt with a gust to 60 kt at 0101 UTC 20 August. In Baja California, an automated weather station on Isla Cedros (ICDB1) measured a sustained wind of 48 kt at 1030 UTC 20 August and a gust of 58 kt. The Mexicali International Airport (MMML) reported a sustained wind of 37 kt later that day.

Surface observations indicate Hilary also brought tropical storm conditions to western portions of the state of Sonora. The Puerto Peñasco International Airport (MMPE) reported a sustained wind of 47 kt and a gust of 57 kt at 2041 UTC 20 August. Several other observing sites reported sustained winds of 30–40 kt, with peak gusts of 55 kt at San Luis Rio Colorado and 53 kt at El Pinacate.

The lowest reported sea level pressure in Mexico was 980.7 mb at 1130 UTC 20 August on Isla Cedros (ICDB1) while the center of Hilary passed near or over the island.

Southwestern United States

Operationally, Hilary was shown to have moved into southern California as a tropical storm. For each tropical cyclone, the NHC performs a routine post-analysis to analyze all available data (some of which were not available in real time) and determine if changes to a storm's location, intensity, or status are necessary. As Hilary approached land, significant interaction with an upper-level trough disrupted the convective organization of Hilary and caused the cyclone to lose tropical characteristics shortly after landfall. Thus, it is determined in post-analysis that Hilary degenerated to a post-tropical low over northern Baja California.

In real time, NHC forecasters noted that the center of Hilary was becoming diffuse and difficult to track as it approached the southwestern United States. Surface observations and analyses on 20 August showed a surface trough of low pressure that extended from Hilary's circulation northwestward along the coast of southern California. By around 2100 UTC that day, a non-tropical area of low pressure became evident in surface observations near San Diego. Operationally, it was unclear whether this feature was Hilary or a new system that developed in response to favorable upper-level dynamics associated with the deep-layer trough offshore of California. Closer examination indicates that this low formed outside of Hilary's radius of maximum wind and moved in a different direction than the low-level vorticity envelope that was tracked from Hilary's landfall position. Therefore, the low-pressure center near the California coast is considered a new feature that absorbed the remnants of Hilary by 0000 UTC 21 August.

Ultimately, these post-analysis changes do not diminish the significant wind impacts that Hilary and its remnants brought to the southwestern United States. Although the center of Hilary did not move into the United States, the large wind field associated with the tropical storm near the end of its life cycle resulted in sustained tropical-storm-force winds at some inland United States locations. Therefore, Hilary is still considered to have impacted the United States as a tropical storm. These observations generally occurred at higher elevations and may have been partially influenced by the topography of the region. A weather station at Big Black Mountain (elev. 4055 ft) in San Diego County reported a sustained wind of 63 kt at 1925 UTC 20 August and a peak gust of 73 kt. The Yuma International Airport (KNYL) in Arizona (elev. 207 ft) reported a sustained wind of 39 kt at 2057 UTC 20 August and a gust of 60 kt, along with blowing dust that reduced the visibility to as low as a quarter mile.

Several locations along the coast of southern California reported a brief period of sustained gale-force winds beginning around 0000 UTC 21 August. These winds appear to be associated with the new, non-tropical area of low pressure that absorbed the remnants of Hilary as previously described. A WeatherFlow station at the Imperial Beach Pier (XIMP) measured a sustained wind of 36 kt at 0003 UTC 21 August and a gust of 40 kt. A National Ocean Service station in La Jolla, California (LJAC1), reported a sustained wind of 35 kt and a gust of 44 kt at 0024 UTC 21 August. The enhanced pressure gradient that persisted over the mountainous terrain of the southwestern United States on 21 August resulted in strong and gusty winds that continued well after Hilary was absorbed.

Rainfall and Flooding

Mexico

Hilary produced areal average rainfall amounts of 2–4 inches (~50–100 mm) across large portions of the Baja California peninsula on 19–20 August as the tropical cyclone moved near and over the west coast of the peninsula (Fig. 8). The highest rainfall accumulations occurred in northern portions of Baja California Sur (Fig. 9), with a storm total maximum of 12.83 inches (326.0 mm) in San Lucas Norte. According to the National Meteorological Service of Mexico[3], this is around 1.8 times the average annual rainfall for Baja California Sur (180.8 mm). Elsewhere, 10.85 inches (275.5 mm) of rainfall was reported in Santa Águeda, and 9.58 inches (243.3 mm) of rain fell in Santa Rosalía. In the state of Baja California, 4.23 inches (107.4 mm) of rain was measured at the Observatorio de San Felipe. This heavy rainfall resulted in flash and riverine flooding and mudslides across the peninsula (Fig. 10).

Elsewhere, 1–3 inches (~ 25–75 mm) of rainfall occurred over western portions of the states of Sonora and Sinaloa. A storm total rainfall of 3.74 inches (95.0 mm) was reported in Vícam in the state of Sonora.

Southwestern United States

The interaction of deep tropical moisture associated with Hilary and its remnants and an upper-level trough offshore of California contributed to historic flooding rains over parts of the southwestern United States (Fig. 11). Several locations in the mountains of southern California received over 10 inches of rainfall from 19–21 August, with a storm total maximum of 13.07 inches reported at Upper Mission Creek. An automated weather station at Mount San Jacinto (elev. 8616 ft) received 11.75 inches of rain, and 10.34 inches of rain was reported by a CoCoRaHS observer near Crestline. Many locations in southern California set daily and/or monthly rainfall records as a result of Hilary. This includes the cities of Los Angeles and San Diego, with periods of record dating back to 1877 and 1875, respectively. Downtown Los Angeles broke daily (20 August: 2.48 in) and monthly (August: 2.99 in) rainfall records, while San Diego set a daily rainfall record (20 August: 1.82 in). Death Valley set its all-time daily rainfall record on 20 August (2.20 inches), which is more rainfall than it averages for an entire year (2.15 inches).

In advance of the event, the NOAA Weather Prediction Center issued a rare Day 2 High Risk for portions of southern California in their Excessive Rainfall Outlook product. The significant

[3] https://smn.conagua.gob.mx/tools/DATA/Ciclones%20Tropicales/Ciclones/2023-Hilary.pdf

threat of flash flooding prompted the evacuation of numerous vulnerable communities near burn scars in the region. As expected, the torrential rainfall across deserts, mountains, and burn scars resulted in significant flash and riverine flooding across portions of the state (Fig. 12).

Elsewhere, 2 to 4 inches of rain fell over southern portions of Nevada with locally higher storm total amounts at elevation. A maximum of 9.20 inches of rainfall was measured at Lee Canyon (elev. 8618 ft). An observing station near Mount Charleston (elev. 8906 ft) received 7.80 inches of rain, where major flooding occurred (Fig. 12). In Arizona, an automated weather station at Hilltop (elev. 5732 ft) received 2.10 inches of rainfall. Elsewhere, moisture related to the remnants of Hilary contributed to 1–3 inches of rainfall over portions of eastern Oregon, Idaho, and western Montana through 21 August.

CASUALTY AND DAMAGE STATISTICS

Hilary was responsible for at least three direct[4] deaths, two in Mexico and one in California. The government of Mexico reported that one person drowned on 19 August in Santa Rosalía, Baja California Sur, after his vehicle was swept away by floodwaters[5]. A 32-year-old woman was found dead after her vehicle was swept away by an overflowing stream near Cataviña, Baja California, on 20 August[6]. In San Bernardino County, California, a 74-year-old woman is presumed dead after her mobile home in Angelus Oaks was washed away by floodwaters, mud, and debris along the Santa Ana River on 20 August.[7]

Hilary produced about $900 million (USD) in damage in the United States, according to the NOAA National Centers for Environmental Information (NCEI). The government of Baja California Sur estimates that Hilary produced 250 million pesos (~ $14.5 million USD) in damage across the state. There are no damage estimates available for the state of Baja California.

Mexico

Damage to homes, roads, and infrastructure was reported across the Baja California peninsula (Fig. 13). Significant flooding was reported by the government of Mexico in the Baja California Sur municipalities of Loreto, Mulegé, and Comondú, and at least 87 homes were significantly damaged or destroyed. Floodwaters breached a protection wall in Santa Rosalía, where one person drowned and four others were rescued after a vehicle was swept away by an

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[4] 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.
[5] https://mexiconewsdaily.com/news/hurricane-hilary-leaves-at-least-1-dead-and-damage-in-baja-california/
[6] https://www.sandiegouniontribune.com/news/border-baja-california/story/2023-08-21/draft-danos-baja-california
[7] https://ktla.com/news/local-news/missing-elderly-socal-woman-was-swept-away-during-tropical-storm-hilary/

overflowing stream. Storm surge inundation damaged homes and grounded fishing boats in coastal communities along the west coast of the peninsula, including Punta Abreojos, La Bocana, and Bahía Asunción. Some damage to homes was reported in the fishing communities of Puerto Alcatraz, Isla San Lázaro, Puerto San Carlos, and on Magdalena Island.

Flash flooding also occurred across the state of Baja California, where officials reported 19 mud and rock slides and damage to about a dozen major roads, including the federal highway between Mexicali and Tijuana. A woman in the San Quintín municipality near Cataviña was swept away in her vehicle by a flooded stream and was later found deceased. Many cars were stranded on flooded roadways in and around Tijuana, and twelve people were rescued on a highway between Playas de Tijuana and Rosarito. Several portions of the Transpeninsular Highway (Federal Highway 1) were damaged. The roof of a school collapsed in Mexicali. In the state of Sonora, minor wind damage was reported in several locations including Puerto Peñasco. Large waves along the coast damaged homes and businesses in Bahía de Kino, including the partial collapse of a hotel.

Strong winds from Hilary downed trees and electric poles across the states of Baja California, Baja California Sur, and Sonora. The Federal Electricity Commission of Mexico reported that around 380,000 customers lost power during the event.

Southwestern United States

Southern California experienced significant damage from flooding and debris flows. Some roads and bridges were washed out in Riverside, San Bernardino, and San Diego Counties, and a train derailment occurred around the Whitewater River Channel. Several parts of Interstate 10 were closed due to flooding, including a 30-mile stretch in Riverside County between Bob Hope Drive and Indian Canyon Drive that was inundated by water, mud, and debris. All of the eastbound lanes of Interstate 8 near Ocotillo were closed due to large boulders and mud covering the roadway. At least 17 swiftwater rescues were performed across the region, with dozens of other rescues made as people became stranded by mud and floodwaters. A local state of emergency was declared in Palm Springs due to flooding and city officials performed 46 rescues, including 14 people from an assisted living facility in Cathedral City. A woman died in Angelus Oaks after her mobile home was swept away by floodwaters. About 30 people were rescued after the Santa Ana River flooded the nearby community of Seven Oaks, destroying several homes and vehicles. Rapid water rises also occurred along the San Diego River, which flooded portions of Mission Valley. Major flooding damaged or destroyed about 400 miles of roads in Death Valley National Park, resulting in an 8-week closure that was the longest in the park’s history. Residual floodwaters formed temporary lakes in Death Valley that persisted for months after the storm.

Generally minor wind damage was reported in southern California as strong winds brought down some trees and large branches (Fig. 14). Media reports indicate that tens of thousands of southern California customers lost power during the event, many in Riverside and San Bernardino Counties. Several trees were downed in the Los Angeles and San Diego metro areas. Although a few trees fell on homes or vehicles, no injuries were reported. Part of a roof blew off of a home near Twentynine Palms, and a downed eucalyptus tree damaged a home in Palm Desert. Some minor roof damage was reported to homes in Orange County. Gusty winds blew over a couple of semi-trucks on Interstate 8 in Imperial County. Along the coast, some beach erosion was reported at Redondo Beach and other vulnerable beaches in Los Angeles and Ventura Counties.

In Nevada, the small town of Mount Charleston and nearby areas in Clark County suffered extensive damage due to flash flooding (Fig. 14). Residents were forced to shelter in place after the town became cut off as a result of washed out roads. Floodwaters deposited mud in the local fire station and damaged homes and an elementary school in the Old Town subdivision. Strong wind gusts downed trees in the area, and the community was left without power or water. A landslide damaged the nearby Lee Canyon Ski Resort. Elsewhere, several road closures were reported in Clark and Nye Counties due to flooding, but otherwise damage in the state was minimal.

FORECAST AND WARNING CRITIQUE

Genesis

The genesis of Hilary was very well forecast (Table 3). The wave from which Hilary developed was introduced in the 7-day Tropical Weather Outlook (TWO) with a low (< 40%) chance of formation almost one week (156 h) prior to formation. The 7-day formation chances were raised to the medium and high categories 138 h and 108 h, respectively, before genesis. For the 2-day outlook, the disturbance was given a low chance of formation 84 h prior to genesis. The 2-day formation chances reached the medium and high categories 48 h and 30 h, respectively, before formation. A consistent signal for genesis in the global model guidance gave NHC forecasters the confidence that Hilary would develop and contributed to the large formation lead times. The location of Hilary's genesis was also well forecast (Fig. 15), with all of the genesis areas highlighted in the 7-day Graphical TWO capturing the location where Hilary formed.

Track

A verification of NHC official track forecasts for Hilary is given in Table 4a. Official track forecast errors at 12–60 h were lower than the mean official errors for the previous 5-year period. The 72–96 h NHC track forecast errors for Hilary were higher than the 5-year mean errors. The climatology-persistence (OCD5) errors were greater than their respective 5-year means at all forecast times, which suggests that Hilary's track was more challenging to forecast than an average eastern Pacific tropical cyclone. There was very little cross-track spread in the NHC forecasts for Hilary (Fig. 16), which consistently and correctly highlighted that the center of Hilary would move near or over the northern Baja California peninsula and approach southern California. The NHC track errors were more related to timing, with early forecasts too slow compared to Hilary's actual track. Given how infrequently tropical cyclones approach this region, consistent and accurate track forecasts likely played a critical role in effective risk communication for the affected areas.

A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b and Fig. 17. The NHC track forecast outperformed the individual global and regional models and simple consensus aids at most time periods. Only the Florida State Superensemble (FSSE) had lower errors than the NHC forecast for a majority of forecast times.

Intensity

A verification of NHC official intensity forecasts for Hilary is given in Table 5a. Official intensity forecast errors were greater than the mean official errors for the previous 5-yr period at all forecast periods. The OCD5 errors were greater than their respective 5-year means at 12–72 h, which suggests the intensity forecast for Hilary was more difficult than for an average eastern Pacific tropical cyclone. Hilary's rapid intensification (RI) and rapid weakening phases both contributed to the larger-than-average errors (Fig. 18). NHC forecasters recognized early on that the environmental and oceanic conditions appeared favorable for RI. In fact, the first NHC advisory explicitly forecast RI to occur and showed Hilary becoming a major hurricane in just 60 h. Despite being a large tropical cyclone, Hilary strengthened at an even faster rate than was expected and reached its peak intensity earlier than forecast. Later in Hilary's life cycle, significant intrusions of dry air, stronger shear, and interaction with the terrain of the Baja California peninsula contributed to an even faster rate of weakening than was anticipated.

A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b and Fig. 19. The HCCA aid outperformed the NHC forecast at all time periods. The HAFS-B (HFBI) and Naval Research Laboratory COAMPS-TC (CTCI) models were among the most skillful individual intensity models for Hilary, with lower errors than the NHC forecast at most forecast times. The SHIPS (DSHP) guidance had some of the largest errors, especially beyond 48 h.

Wind Watches and Warnings

Coastal watches and warnings issued by the government of Mexico in association with Hilary are given in Table 6. United States coastal watches and warnings for Hilary are provided in Table 7.

Hilary resulted in the first ever issuance of coastal and inland Tropical Storm Watches and Tropical Storm Warnings for southern California. A Tropical Storm Watch was issued for the coast of southern California from the California/Mexico border to the Orange/Los Angeles County Line, including Catalina Island, at 1500 UTC 18 August. The watch was extended northward to Point Mugu at 2100 UTC that day. Later, the entire watch area was upgraded to a Tropical Storm Warning at 0300 UTC 19 August. Hilary was absorbed by a new, non-tropical area of low pressure shortly before reaching southern California. However, some coastal locations in the watch and warning areas did report sustained gale-force winds associated with this new system beginning around 0000 UTC 21 August. These conditions occurred about 57 h and 45 h after the issuance of the watch and warning, respectively.

IMPACT-BASED DECISION SUPPORT SERVICES (IDSS) AND PUBLIC COMMUNICATION

The NHC began communication with emergency managers in the United States on 18 August as Hilary was rapidly strengthening south of the Baja California peninsula. Five decision support briefings were provided to emergency managers and coordinated through the Federal Emergency Management Agency (FEMA) Hurricane Liaison Team embedded at the NHC. The briefings were federal video-teleconferences with FEMA HQ, FEMA Region 9, California, Arizona, and Nevada. These briefings continued through 21 August.

The NHC conducted eight live stream broadcasts from 17–21 August that were disseminated via YouTube and Facebook Live. Key messages for Hilary were included in NHC forecast discussions and on the NHC website in graphical format from 16–21 August. These key messages were translated into Spanish and disseminated in both English and Spanish through official NHC social media accounts.

ACKNOWLEDGEMENTS

Data in Table 2 and damage summaries were compiled using reports issued by NWS Weather Forecast Offices in San Diego and Los Angeles, California; Phoenix, Arizona; and Las Vegas, Nevada. Data from the National Data Buoy Center, National Ocean Service Center for Operational Oceanographic Products and Services, and NOAA Weather Prediction Center were also used in this report. Some data and observations from Mexico were provided by the National Meteorological Service of Mexico. Lisa Bucci produced the aircraft reconnaissance graphic (Fig. 7) and the forecast track and intensity analysis graphics (Figs. 16 and 18). David Roth of the NOAA Weather Prediction Center provided the U.S. rainfall graphic (Fig. 11). Philippe Papin created the ECMWF Reanalysis v5 analysis graphic (Fig. 6) and the Graphical TWO verification figure (Fig. 15). Michael Spagnolo, Matthew Green, and Maria Torres contributed to the IDSS summary.

Table 1. Best track for Hurricane Hilary, 16–20 August 2023.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
16 / 0600	11.9	100.8	1003	30	tropical depression
16 / 1200	12.6	102.3	1002	35	tropical storm
16 / 1800	12.9	103.8	1000	40	"
17 / 0000	13.5	104.9	997	45	"
17 / 0600	14.4	105.8	989	60	"
17 / 1200	15.2	107.2	978	75	hurricane
17 / 1800	15.8	108.4	965	90	"
18 / 0000	16.4	109.5	952	105	"
18 / 0600	16.8	110.4	940	120	"
18 / 1200	17.3	111.1	944	115	"
18 / 1800	18.2	111.9	947	110	"
19 / 0000	19.2	112.6	943	115	"
19 / 0600	20.2	113.1	943	115	"
19 / 1200	21.5	113.5	952	100	"
19 / 1800	22.9	113.9	960	85	"
20 / 0000	24.3	114.3	968	75	"
20 / 0600	26.3	114.9	974	65	"
20 / 1200	28.1	115.3	981	55	tropical storm
20 / 1700	29.7	115.6	990	50	"
20 / 1800	30.3	115.7	992	50	"
20 / 2100	31.4	116.1	995	45	low
21 / 0000					absorbed by new low-pressure system
18 / 0600	16.8	110.4	940	120	maximum wind and minimum pressure
20 / 1700	29.7	115.6	990	50	landfall near San Fernando, Baja California, Mexico

Table 2. Selected surface observations for Hurricane Hilary, 16–20 August 2023, and its remnants which were absorbed by a new low-pressure system on 21 August 2023. A detailed list of observations can be found at https://www.nhc.noaa.gov/data/tcr/supplemental/hilary.zip.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)	
Mexico						
Colima						
Isla Socorro (ISOC8) (18.73N 110.95W)	18/1720	992.6	18/1340	42 (10 min)	69	6.86
Baja California Sur						
Sierra La Laguna (SLGB7) *elev. 6395 ft* (23.56N 110.00W)			19/0830	52 (10 min)	86	
Loreto Intl. AP (MMLT) (25.99N 111.35W)			20/0101	50	60	
Cabo San Lucas (CSLB7) *elev. 735 ft* (22.88N 109.93W)	19/1120	1001.4	19/1120	44 (10 min)	64	
Puerto Cortés (PCRB7) (24.48N 111.82W)	19/2300	997.1	19/1945	40	55	
La Paz Intl. AP (MMLP) (24.07N 110.37W)			19/2245	36 I		
Cabo Pulmo (CPLB7) (23.45N 109.42W)			19/2220	35 (10 min)	51	
San Juanico (SJUB7) (26.26N 112.48W)	20/0740	1000.9	20/0740	35 (10 min)	57	
Gustavo Diaz Ordaz (GDOB7) (27.64N 113.46W)	20/0840	994.9	20/0950	29 (10 min)	61	
San Lucas Norte						12.83
San Bruno						11.22
Santa Águeda						10.85
Baja California						
Isla Cedros (ICDB1) (28.03N 115.19W)	20/1130	980.7	20/1030	48	58	
Mexicali Intl. AP (MMML) (32.63N 115.24W)			20/2147	37 I		
Constitucion de 1857 (RUMB1) *elev. 5170 ft* (32.27N 116.21W)			20/1900	36 (10 min)	77	
Observatorio de San Felipe (31.03N 114.85W)						4.23
Colonia Vicente Guerrero						4.00

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)	
Sonora						
Puerto Peñasco Intl. AP (MMPE) (31.35N 113.52W)			20/2041	47[I]	57[I]	
Caborca (CABS6) *elev. 617 ft* (30.77N 112.44W)	20/1120	1004.4	20/2000	38 (10 min)		
Puerto Peñasco (E1610) (31.30N 113.51W)	20/1145	1002.4	20/1845	36[I]	48[I]	
San Luis Rio Colorado (SLRS6) (32.42N 114.80W)	20/1930	1001.4	20/1910	34 (10 min)	55	
El Pinacate (PNCS6) *elev. 327 ft* (31.68N 113.30W)	20/1200	1002.7	20/2250	33 (10 min)	53	
Bahía Kino (KNOS6) (28.81N 111.92W)	20/1220	995.0	20/1250	31 (10 min)	45	
Vicam (27.64N 110.29W)						3.74
United States						
California						
National Ocean Service Sites						
La Jolla (LJAC1) (32.87N 117.26W)	20/2118	997.1	21/0024	35 (8 m)	44	
San Diego (SDBC1) (32.71N 117.17W)	20/2048	997.0				
WeatherFlow Sites						
Camp Pendleton (XPEN) (33.26N 117.44W)			21/0052	41	45	
Imperial Beach (XIMP) (32.58N 117.14W)			21/0003	36	40	
Dana Point Light 3 (XDPT) (33.45N 117.69W)			21/0559	35	38	
Mission Bay (XMIS) (32.78N 117.21W)			21/0019	35	41	
Zuniga Jetty (XZUN) (32.67N 117.22W)			21/0340	35	39	
Other Sites						
Big Black Mountain (HP016) *elev. 4055 ft* (33.16N 116.81W)			20/1925	63	73	
SCE Silverwood West (711SE) *elev. 4192 ft* (34.30N 117.36W)			21/0800	55 (6 m)	69	
Magic Mountain Truck Trail (SE678) *elev. 4483 ft* (34.39N 118.34W)			21/1000	51 (6 m, 1 min)	76	
Upper Mission Creek (UMCC1) (34.12N 116.73W)						13.07
Mt. San Jacinto (MSJC1) (33.82N 116.64W)						11.75

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)	
Crestline 1.4 ESE (CA-SR-84) (34.24N 117.27W)						10.34
Arizona						
Yuma Intl. AP (KNYL) (32.66N 114.59W)	20/2057	1001.0	20/2057	39	60	
Hilltop (QHTA3) *elev. 5732 ft* (33.61N 110.41W)						2.10
Tweeds Point (QTWA3) (36.58N 113.73W)						1.67
Lindbergh Hill (QLBA3) (36.29N 112.08W)						1.54
Nevada						
Lee Canyon (LCAN2) *elev. 8618 ft* (36.31N 115.68W)						9.20
Bristlecone Trail (BRSN2) *elev. 8906 ft* (36.31N 115.69W)						7.80
Lower Angel Peak (NV033) (36.33N 115.54W)						6.52
Offshore						
NOAA Buoys						
46086 – San Clemente Basin (32.50N 118.05W)	20/2230	997.1	20/1917	23 (4 m, 1 min)	27	
46047 – Tanner Bank (32.39N 119.53W)	20/2230	1000.8	20/2258	23 (4 m, 1 min)	27	
46069 – South Santa Rosa (33.68N 120.21W)	20/2320	1000.2	20/1557	23 (4 m, 1 min)	26	

[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.
[I] Incomplete

Table 3. Number of hours in advance of formation of Hilary 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%)	84	156
Medium (40%-60%)	48	138
High (>60%)	30	108

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Hilary, 16–20 August 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	**20.1**	**25.4**	**29.2**	**40.5**	**57.0**	85.8	149.4	
OCD5	44.3	101.6	175.7	254.3	328.8	408.6	604.4	
Forecasts	16	14	12	10	8	6	2	
OFCL (2018-22)	22.1	34.0	45.4	56.0	70.9	78.7	100.5	117.8
OCD5 (2018-22)	36.7	73.4	114.0	156.9	193.2	244.5	317.0	376.0

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Hilary, 16–20 August 2023. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	20.6	26.3	31.1	41.6	53.6	81.1	149.4	
OCD5	46.9	106.8	182.2	257.3	321.0	372.9	604.4	
GFSI	22.5	32.5	45.2	66.1	91.2	105.1	176.7	
HWFI	25.4	45.1	74.6	99.7	118.5	139.5	**144.6**	
HMNI	28.1	45.1	51.1	56.3	69.5	96.2	159.8	
HFAI	25.0	38.8	44.9	70.9	105.3	137.7	186.3	
HFBI	27.3	40.5	50.6	72.4	101.3	121.2	158.7	
EMXI	21.0	31.4	**30.3**	44.3	81.4	134.2	255.7	
NVGI	27.0	39.5	40.6	57.2	74.0	81.6	**99.0**	
CMCI	26.0	45.4	57.1	65.5	74.1	113.0	**96.5**	
CTCI	21.9	31.5	37.0	56.5	63.9	**45.5**	**55.8**	
TVCE	**20.5**	32.2	41.1	60.9	85.1	112.2	173.1	
TVCX	20.8	31.4	39.0	58.3	84.4	114.5	175.6	
GFEX	21.5	30.8	35.5	48.3	75.2	109.9	201.4	
TVDG	21.4	32.3	39.9	60.4	87.6	118.2	188.0	
HCCA	24.2	32.8	**28.9**	**30.5**	53.9	87.1	**121.0**	
FSSE	22.2	30.2	**29.6**	**30.9**	**45.2**	**71.9**	151.1	
AEMI	21.9	29.7	43.9	55.1	69.9	**79.0**	174.5	
TABS	38.4	63.5	82.5	99.3	134.7	169.3	179.5	
TABM	22.5	**26.2**	**27.6**	**37.0**	73.8	102.9	**135.4**	
TABD	21.8	32.9	38.3	**40.6**	67.8	111.8	190.3	
Forecasts	15	13	11	9	7	5	2	

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Hilary, 16–20 August 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	11.9	15.4	18.8	19.5	18.8	23.3	22.5	
OCD5	14.5	21.7	28.3	31.2	31.9	23.0	9.5	
Forecasts	16	14	12	10	8	6	2	
OFCL (2018-22)	5.4	8.9	11.0	12.8	14.3	15.8	17.0	17.6
OCD5 (2018-22)	6.9	12.1	15.9	18.6	18.7	21.0	22.3	22.1

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Hilary, 16–20 August 2023. 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	12.0	15.8	20.0	18.3	15.7	21.0	22.5	
OCD5	14.5	23.2	30.5	32.6	32.1	**20.6**	**9.5**	
HWFI	13.5	24.5	28.8	28.3	24.3	**10.6**	**13.5**	
HMNI	14.9	24.7	27.3	27.8	23.9	**12.6**	**12.0**	
HFAI	13.0	23.1	26.3	24.2	17.7	**12.2**	**12.5**	
HFBI	**11.9**	19.5	**19.1**	**14.3**	**15.1**	**11.8**	**13.0**	
DSHP	**11.9**	18.5	23.5	21.2	29.1	40.0	47.0	
LGEM	**10.3**	16.3	20.5	19.0	28.6	36.2	**19.5**	
ICON	**11.6**	17.6	20.3	18.7	**15.3**	**15.4**	23.0	
IVCN	**11.7**	18.1	20.5	**17.7**	**15.1**	**10.0**	**18.5**	
IVDR	12.3	19.8	21.9	19.2	16.1	**8.4**	**16.0**	
CTCI	**10.6**	17.5	**19.0**	**16.1**	**13.9**	**5.4**	**8.5**	
GFSI	14.2	23.4	28.3	26.2	21.1	**9.0**	**17.0**	
EMXI	15.6	27.5	34.9	36.9	35.4	23.2	**9.5**	
HCCA	**9.4**	**13.2**	**13.5**	**15.2**	**12.9**	**11.2**	**10.5**	
FSSE	**11.1**	16.3	21.9	21.7	18.4	**12.8**	31.5	
Forecasts	15	13	11	9	7	5	2	

Table 6. Coastal watch and warning summary for Mexico during Hurricane Hilary.

Date/Time (UTC)	Action	Location
17 / 0900	Tropical Storm Watch issued	Baja California peninsula from San Evaristo to Cabo San Lazaro
17 / 1500	Tropical Storm Watch modified to	Baja California peninsula from San Evaristo to Los Barriles
17 / 1500	Tropical Storm Watch modified to	Baja California peninsula from Puerto San Andresito to Cabo San Lazaro
17 / 1500	Tropical Storm Warning issued	Baja California peninsula from Los Barriles to Cabo San Lazaro
17 / 2100	Tropical Storm Watch modified to	Baja California peninsula from Loreto to Los Barriles
17 / 2100	Tropical Storm Watch modified to	Baja California peninsula from Cabo San Lazaro to Punta Abreojos
18 / 0300	Tropical Storm Watch modified to	Baja California peninsula from Bahia San Juan Bautista to Los Barriles
18 / 0300	Hurricane Watch issued	Baja California peninsula from Punta Abreojos to Punta Eugenia
18 / 0900	Tropical Storm Watch issued	Mainland Mexico from Huatabampito to Bahia Kino
18 / 0900	Tropical Storm Watch modified to	Baja California peninsula from Bahia de Los Angeles to Loreto
18 / 0900	Tropical Storm Warning modified to	Baja California peninsula from Loreto to Punto Abreojos
18 / 0900	Hurricane Watch modified to	Baja California peninsula from Punta Abreojos to San Jose de Las Palmas
18 / 1500	Tropical Storm Watch modified to	Mainland Mexico north of Huatabampito
18 / 1500	Tropical Storm Watch modified to	Baja California peninsula north of Loreto
18 / 1500	Tropical Storm Watch issued	Baja California peninsula from Ensenada to the Mexico/California border
18 / 1500	Hurricane Watch modified to	Baja California peninsula from Punta Eugenia to Ensenada
18 / 1500	Hurricane Warning issued	Baja California peninsula from Punta Abreojos to Punta Eugenia
18 / 2100	Tropical Storm Watch modified to	Mainland Mexico from Huatabampito to Guaymas

Date/Time (UTC)	Action	Location
18 / 2100	Tropical Storm Warning modified to	Mainland Mexico north of Guaymas
18 / 2100	Tropical Storm Warning modified to	Baja California peninsula entire east coast
18 / 2100	Hurricane Watch modified to	Baja California peninsula from Cabo San Quintin to Ensenada
18 / 2100	Hurricane Warning modified to	Baja California peninsula from Punta Abreojos to Cabo San Quintin
19 / 0300	Tropical Storm Warning issued	Baja California peninsula from Cabo San Quintin to the Mexico/California border
20 / 0300	Tropical Storm Warning discontinued	East coast of the Baja California peninsula south of Los Barilles West coast of the Baja California peninsula south of Todos Santos
20 / 0900	Tropical Storm Warning discontinued	East coast of the Baja California peninsula south of San Evaristo West coast of the Baja California peninsula south of Santa Fe
20 / 0900	Tropical Storm Watch discontinued	Mainland Mexico from Huatabampito to Guaymas
20 / 1500	Hurricane Watch discontinued	All of Mexico
20 / 1500	Hurricane Warning changed to Tropical Storm Warning	Baja California peninsula from Punta Abreojos to Cabo San Quintin
20 / 1500	Tropical Storm Warning discontinued	East coast of the Baja California peninsula south of Loreto West coast of the Baja California peninsula south of Puerto San Andresito
20 / 2100	Tropical Storm Warning discontinued	East coast of the Baja California peninsula south of Bahia San Bautista West coast of the Baja California peninsula south of Punta Eugenia
21 / 0000	Tropical Storm Warning discontinued	East coast of the Baja California peninsula south of Isla San Luis West coast of the Baja California peninsula south of San Jose de las Palmas

Date/Time (UTC)	Action	Location
21 / 0000	Tropical Storm Warning discontinued	Mainland Mexico south of Puerto Libertad
21 / 0300	Tropical Storm Warning discontinued	East coast of the Baja California peninsula south of San Felipe Entire west coast of the Baja California peninsula
21 / 0300	Tropical Storm Warning discontinued	Mainland Mexico south of Puerto Peñasco
21 / 0600	Tropical Storm Warning discontinued	All of Mexico

Table 7. Coastal watch and warning summary for the United States during Hurricane Hilary.

Date/Time (UTC)	Action	Location
18 / 1500	Tropical Storm Watch issued	Southern California from the Mexico/California border to the Orange/Los Angeles County Line
18 / 1500	Tropical Storm Watch issued	Catalina Island
18 / 2100	Tropical Storm Watch modified to	Southern California from the Mexico/California border to Point Mugu
19 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Southern California from the Mexico/California border to Point Mugu
19 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Catalina Island
21 / 0900	Tropical Storm Warning discontinued	All of California

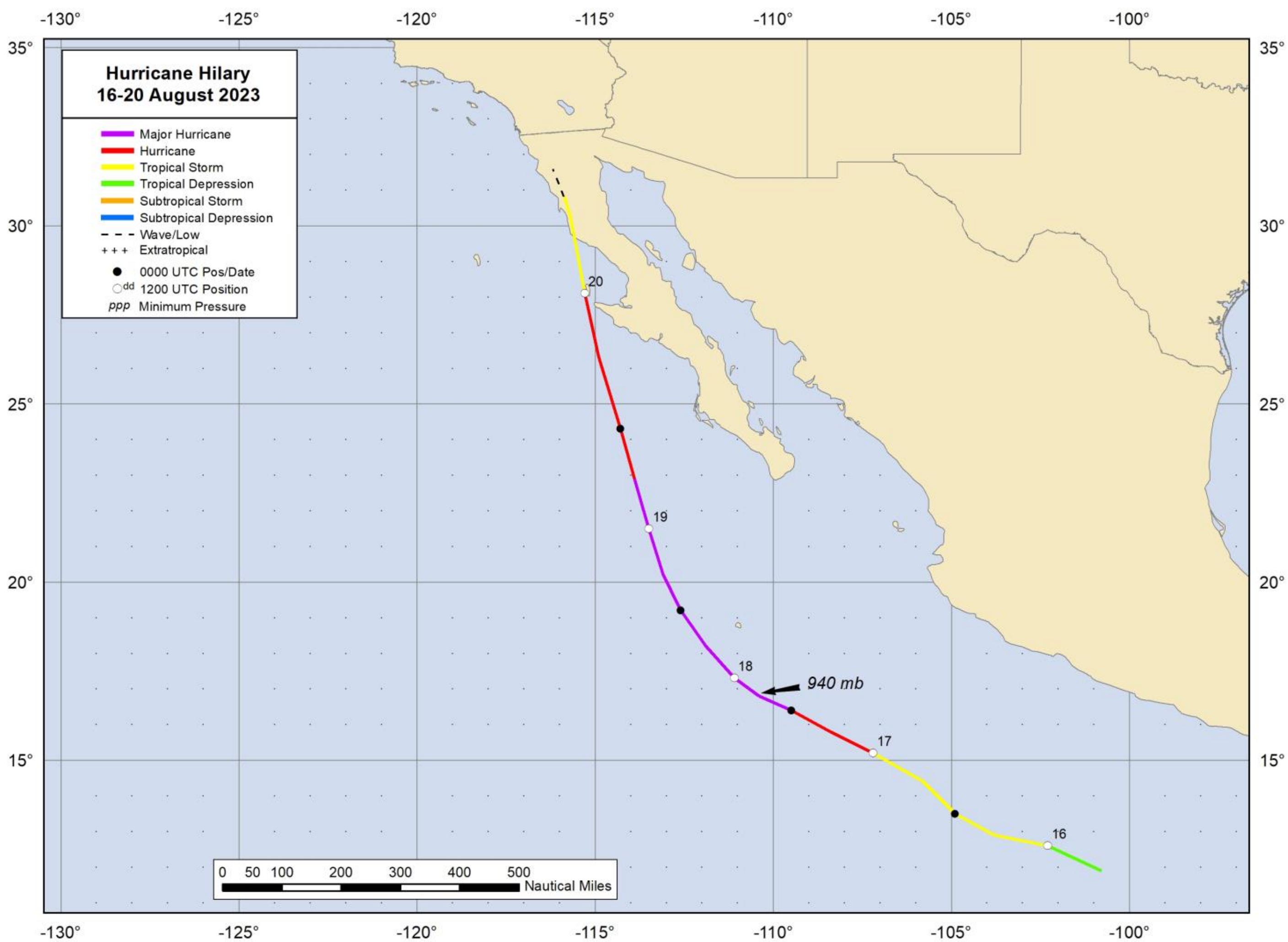


Figure 1. Best track positions for Hurricane Hilary, 16–20 August 2023.

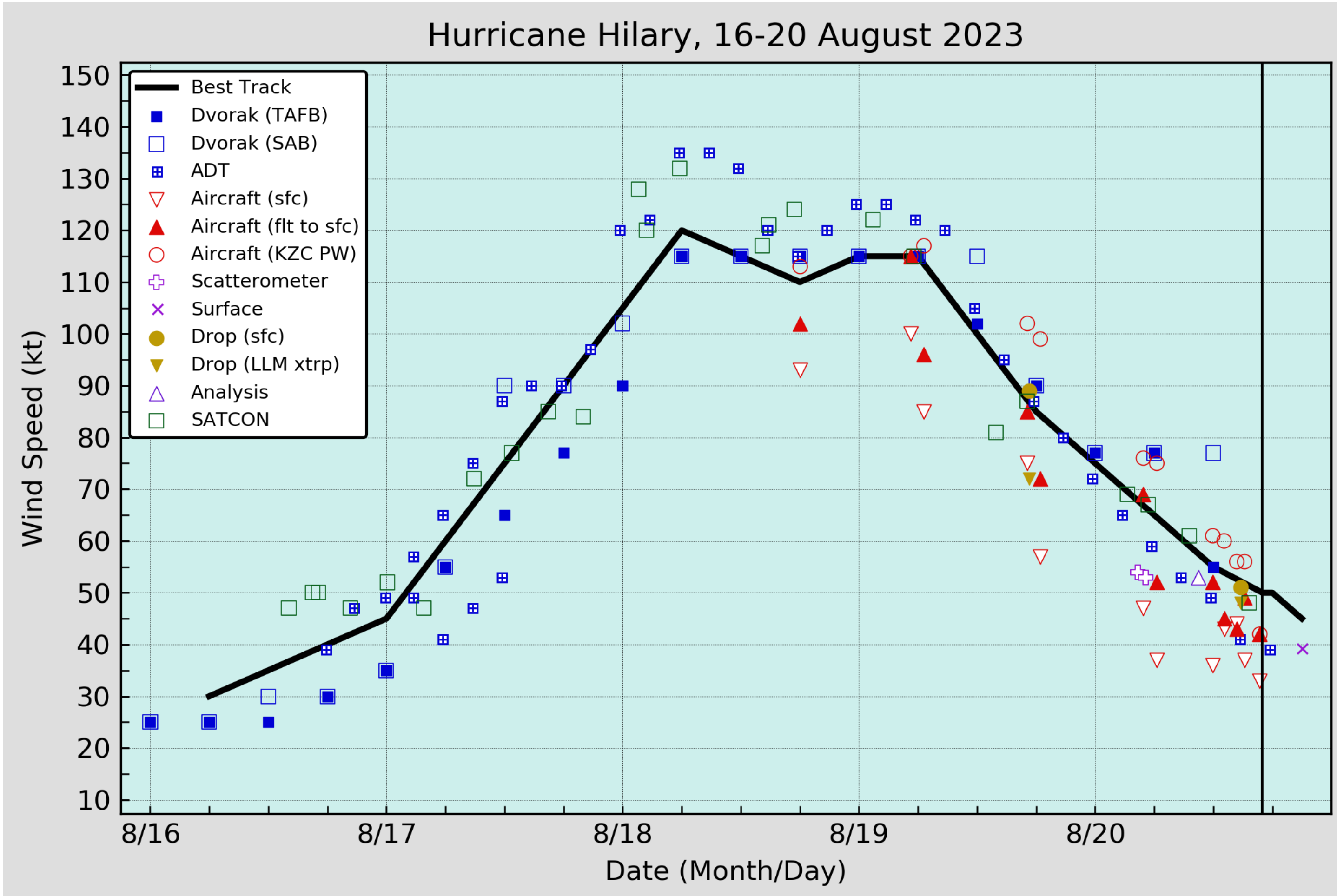


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Hilary, 16–20 August 2023. Aircraft observations have been adjusted for elevation using a 90% adjustment factor for observations from 700 mb. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). 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 the solid vertical line corresponds to landfall.

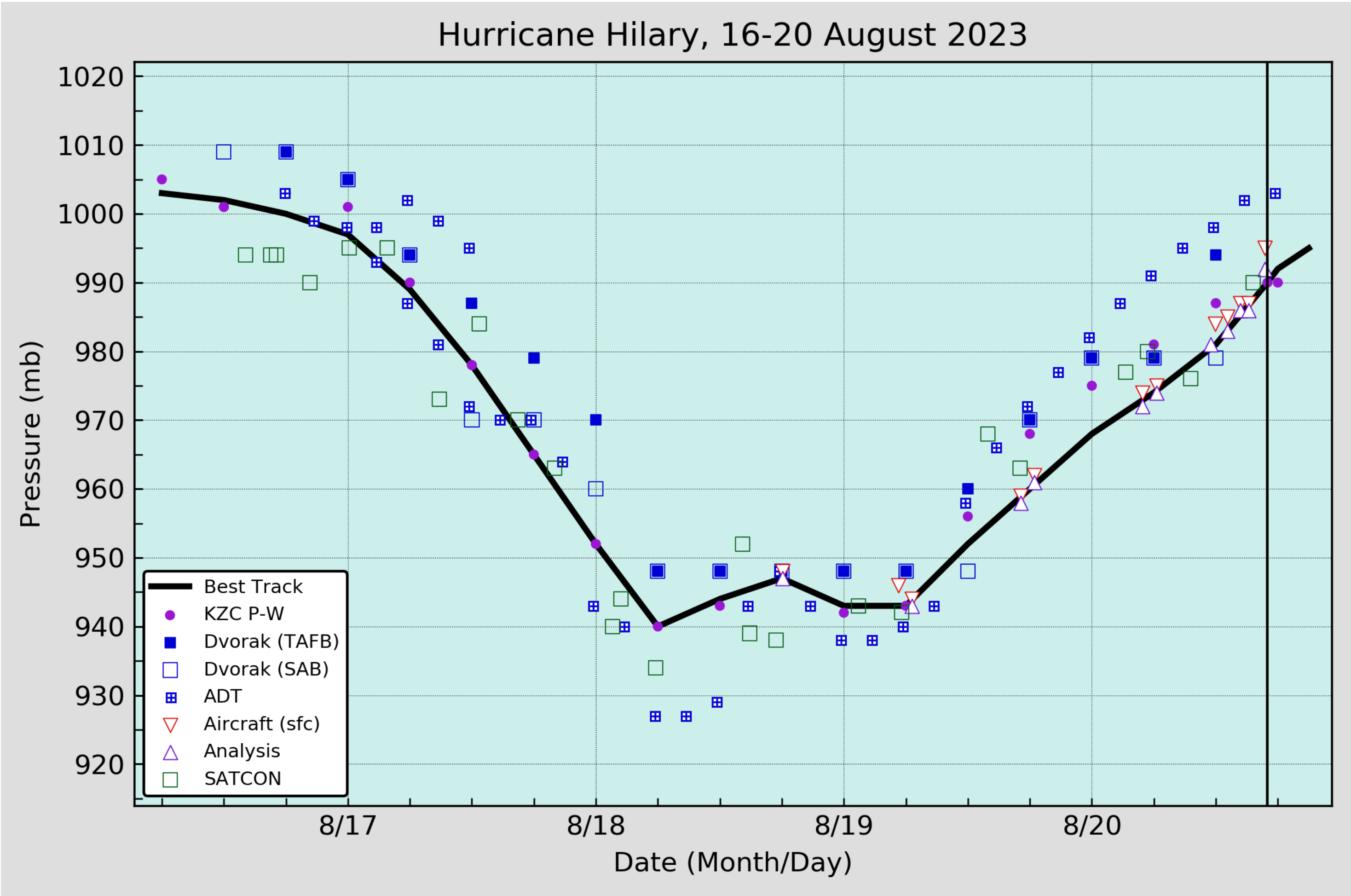


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Hilary, 16–20 August 2023. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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 the solid vertical line corresponds to landfall.

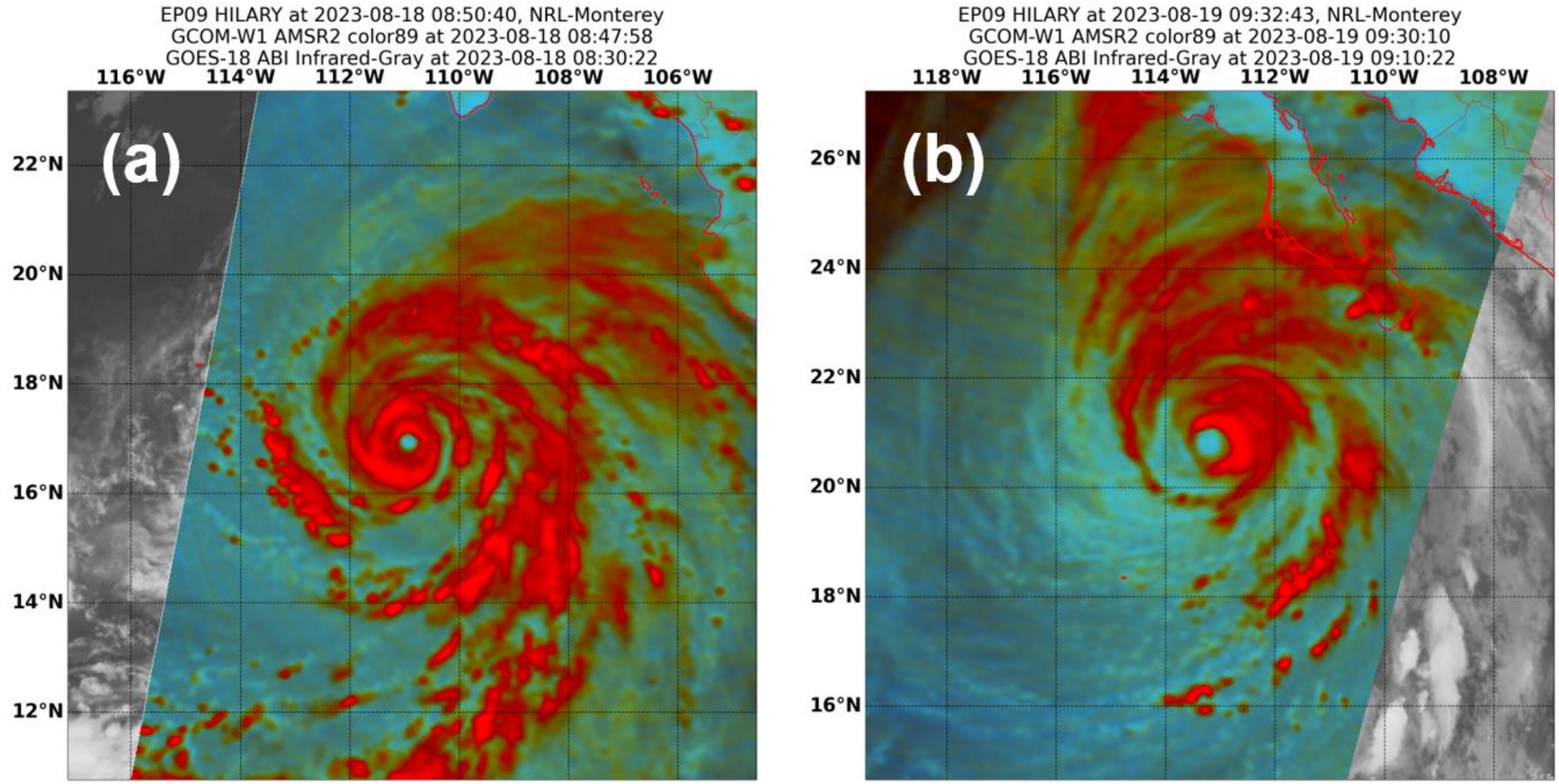


Figure 4. 89-GHz AMSR2 color composite images of Hurricane Hilary at (a) 0847 UTC 18 August, just after the hurricane reached its peak intensity, and (b) 0930 UTC 19 August, after completion of an eyewall replacement cycle and some erosion of the inner core convection by intrusions of dry air.

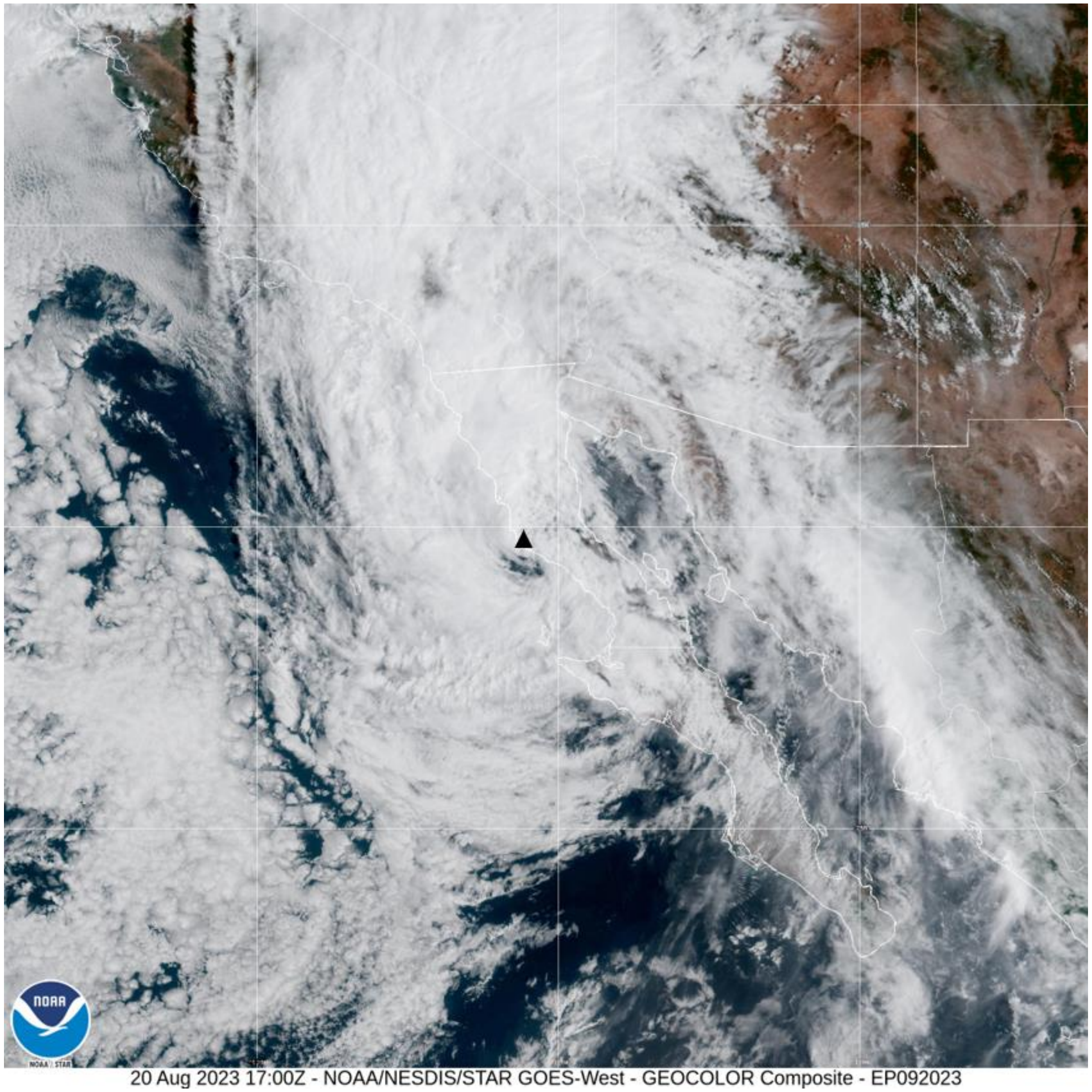


Figure 5. GOES-West GeoColor satellite image of Tropical Storm Hilary making landfall on the Baja California peninsula at 1700 UTC 20 August 2023. The black triangle denotes the estimated landfall location. Image courtesy NOAA/NESDIS/STAR.

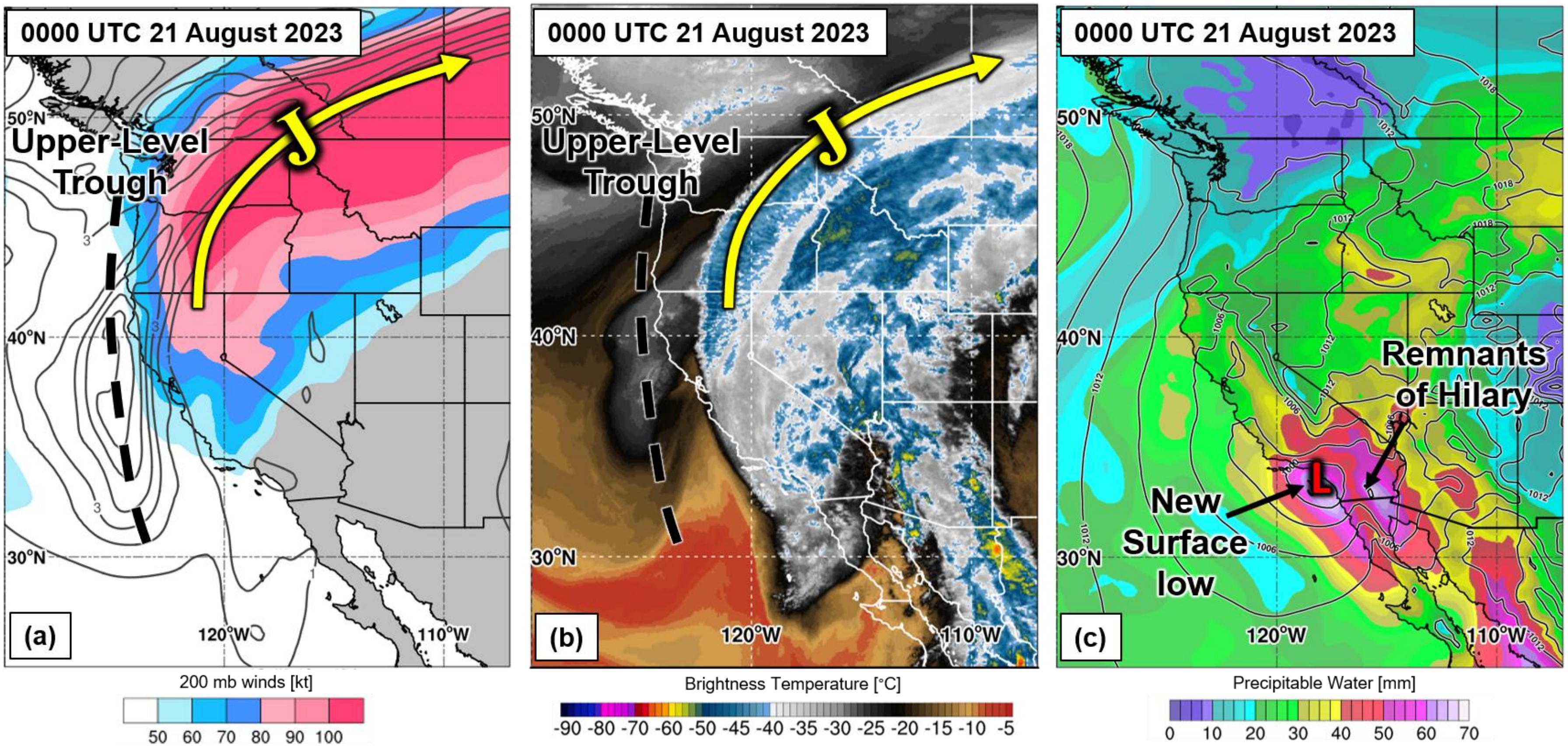


Figure 6. ECMWF Reanalysis v5 (ERA-5) and satellite analysis at 0000 UTC 21 August 2023. (a) 200-mb winds (shading, kt) and 200-mb Potential Vorticity (gray contours, every 1 PVU). (b) GOES-18 water vapor channel 9 (shaded, ºC). (c) Precipitable water (shading, mm) and sea-level pressure (black contours, every 2 mb). The upper-level trough axis is denoted as a black dashed line, and the 200-mb jet streak is denoted by a yellow arrow. In panel (c), the new surface low is shown as a red L, and the approximate location of Hilary's remnants are denoted by a black arrow.

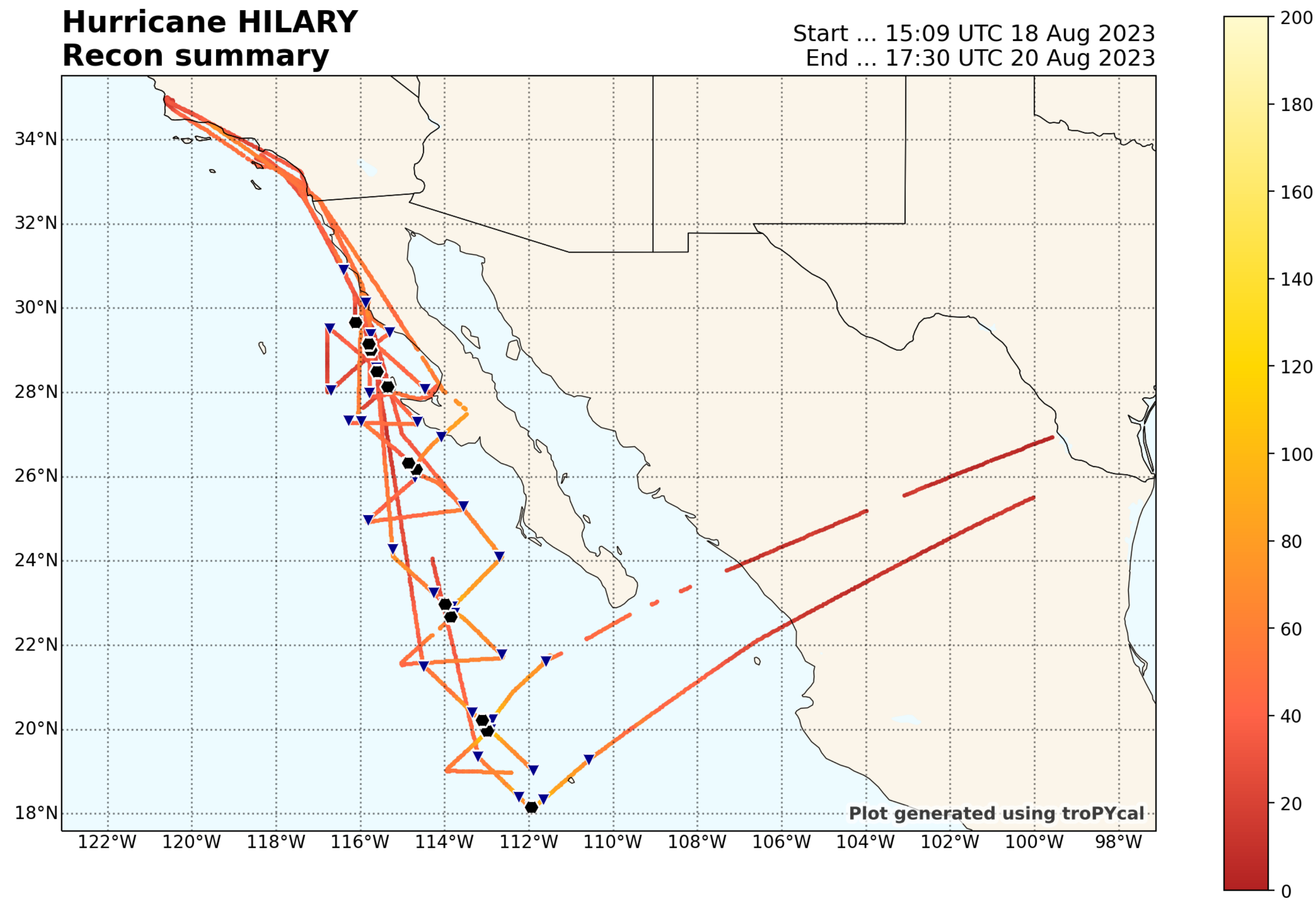


Figure 7. Air Force Reserve Hurricane Hunter aircraft flight tracks (colored lines) from reconnaissance missions into Hilary on 18–20 August 2023. The black markers denote center fixes and the blue triangles indicate dropsonde locations. The color of the flight track represents the observed flight-level wind speed in knots at that location (see legend).

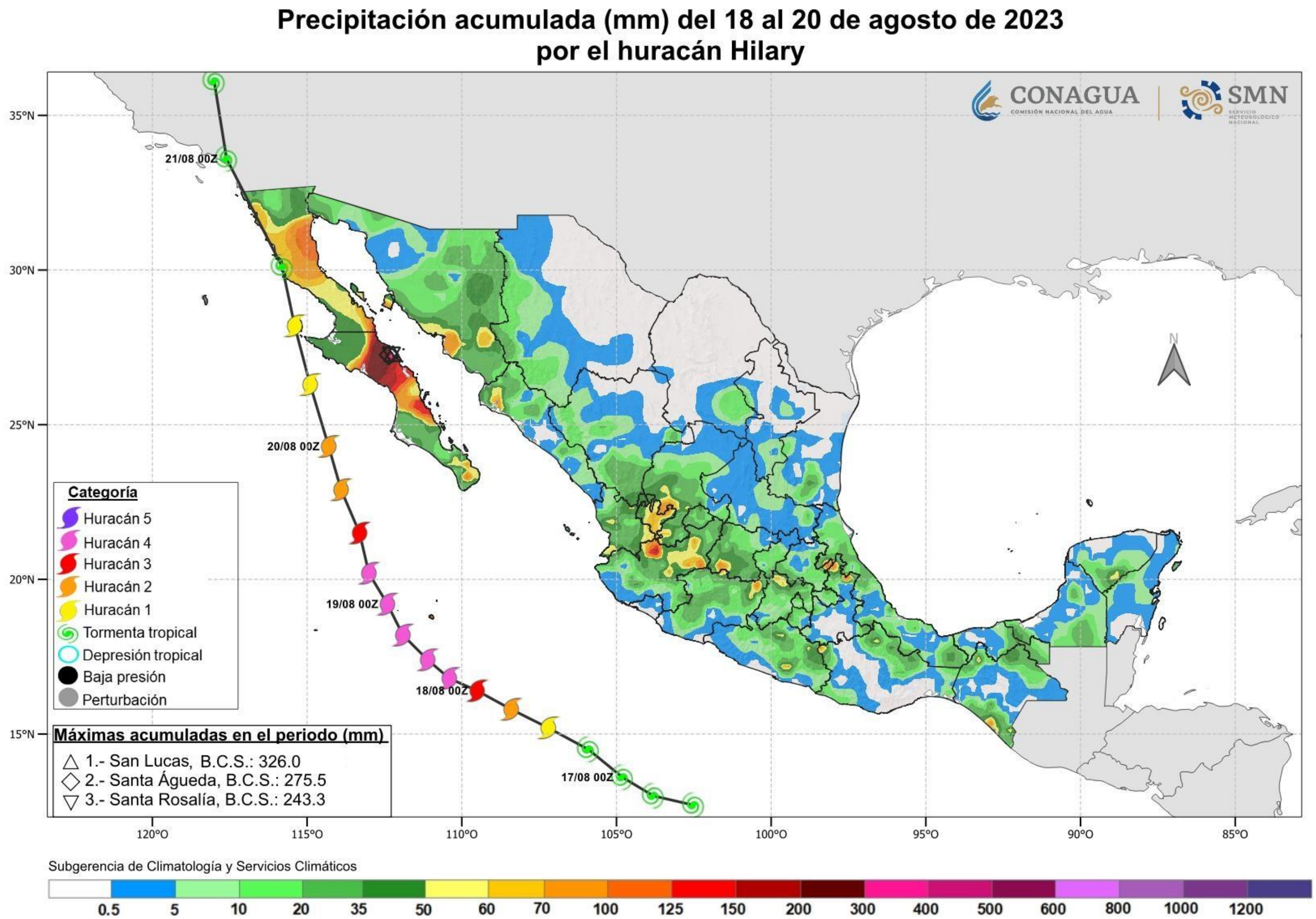
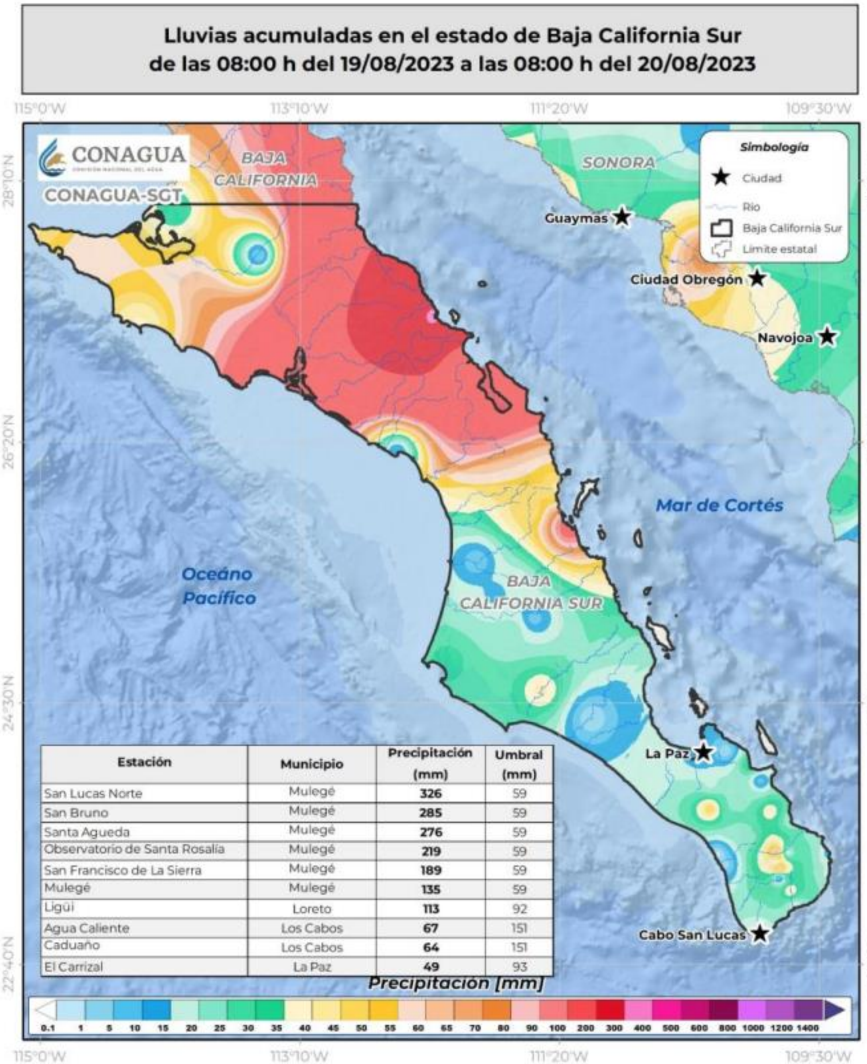


Figure 8. Rainfall accumulations (mm) in Mexico from 18–20 August 2023. Track and intensity are based on the operational NHC assessment. Not all of the rainfall depicted here is directly related to Hilary. Image courtesy of CONAGUA and the National Meteorological Service of Mexico.



Estación	Municipio	Precipitación (mm)	Umbral (mm)
San Lucas Norte	Mulegé	326	59
San Bruno	Mulegé	285	59
Santa Agueda	Mulegé	276	59
Observatorio de Santa Rosalía	Mulegé	219	59
San Francisco de La Sierra	Mulegé	189	59
Mulegé	Mulegé	135	59
Ligüí	Loreto	113	92
Agua Caliente	Los Cabos	67	151
Caduaño	Los Cabos	64	151
El Carrizal	La Paz	49	93

Figure 9. Rainfall accumulations (mm) in the Mexican state of Baja California Sur associated with Hilary from 19–20 August 2023. Image courtesy of CONAGUA and the National Meteorological Service of Mexico.

Figure 10. (Top left) Significant flash flooding in Santa Rosalía, Baja California Sur. Photo credit: Secretaría de Marina via Cuartoscuro. (Bottom left) Floodwaters cover a roadway near Cataviña, Baja California. Photo credit: La Jornada. (Right) Water rescue from a flooded vehicle on a highway in Rosarito, Baja California. Photo credit: Claudia Rioux via San Diego Union Tribune.

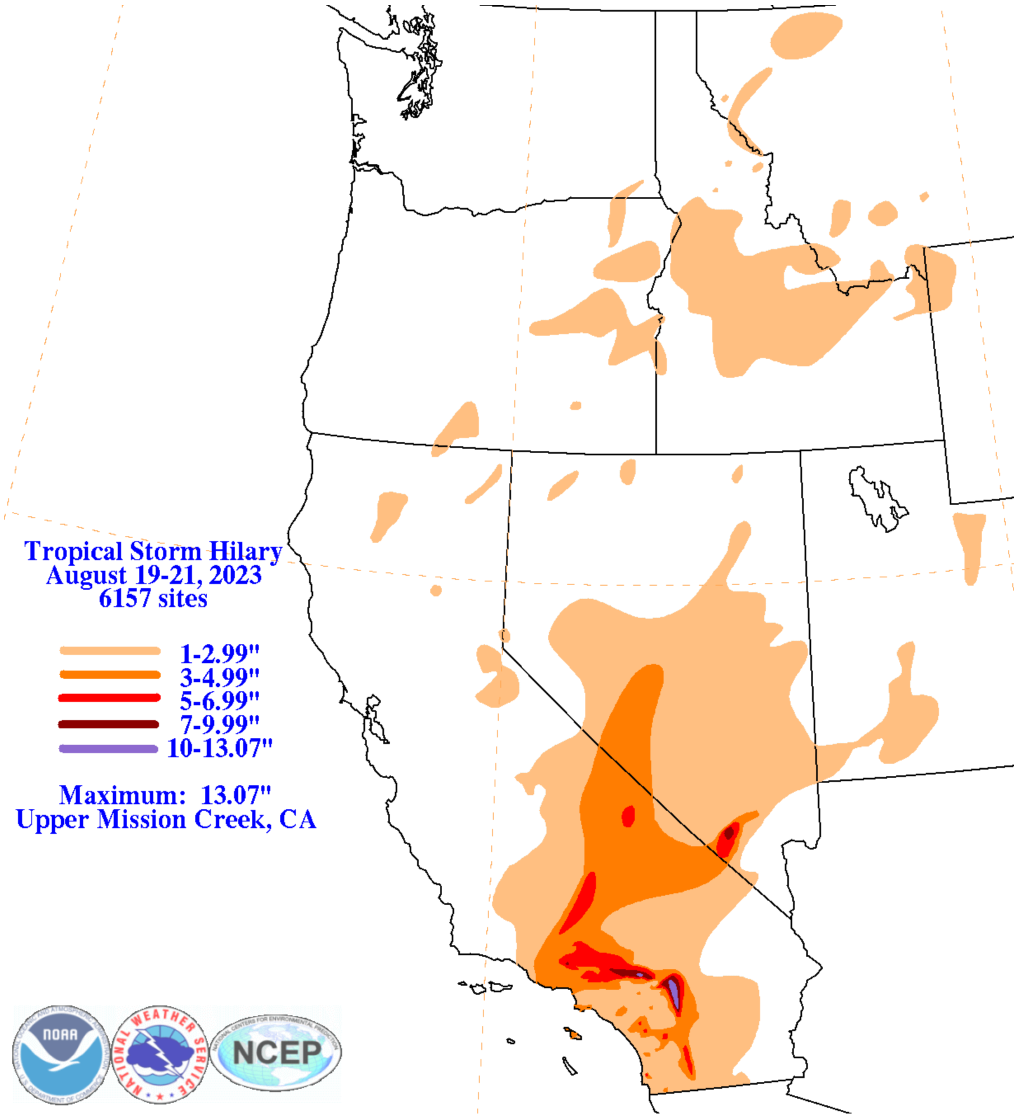


Figure 11. Rainfall accumulations (inches) in the United States from 19–21 August 2023 associated with Hilary and its remnants. Image courtesy of David Roth/NOAA Weather Prediction Center.

Figure 12. (Top left) Floodwaters forced a closure of Interstate 10 in Cathedral City, California. Photo credit: Josh Edelson/AFP via Getty Images. (Top right) Flooding of the Whitewater River in La Quinta, California. Photo credit: Jay Calderon/The Desert Sun/USA Today Network. (Bottom left) Rocks, mud and floodwaters being cleared from California State Route 190 during flash flooding in Death Valley National Park. Photo credit: California Highway Patrol. (Bottom right) Flash flooding caused a roadway collapse along Nevada State Road 157 in Clark County, Nevada. Photo credit: Nevada Department of Transportation.

Figure 13. (Top left) Collapsed roadway after flash flooding in Santa Rosalía, Baja California Sur. Photo credit: Edith Aguilar Villavicencio. (Top right) Damage to structures in Punta Abreojos, Baja California. Photo credit: Erick Zúñiga Rojas. (Bottom left) Downed power poles in Mexicali, Baja California. Photo credit: Reuters/Victor Medina. (Bottom right) Large waves damaged structures along the coast in Bahía de Kino, Sonora. Photo credit: Julián Ortega.

Figure 14. (Top left) A eucalyptus tree fell on a house in Palm Desert, California. Photo credit: Mark J. Terrill/Associated Press. (Top right) Uprooted tree blocking a roadway in San Diego, California. Photo credit: Elisabeth Frausto/La Jolla Light. (Bottom left) Debris from a damaged mobile home that was swept away by the overflowing Santa Ana River. Photo credit: San Bernardino County Fire Department. (Bottom right) Large debris field after flash flooding in Mount Charleston, Nevada. Photo credit: Jeff Scheid/The Nevada Independent.

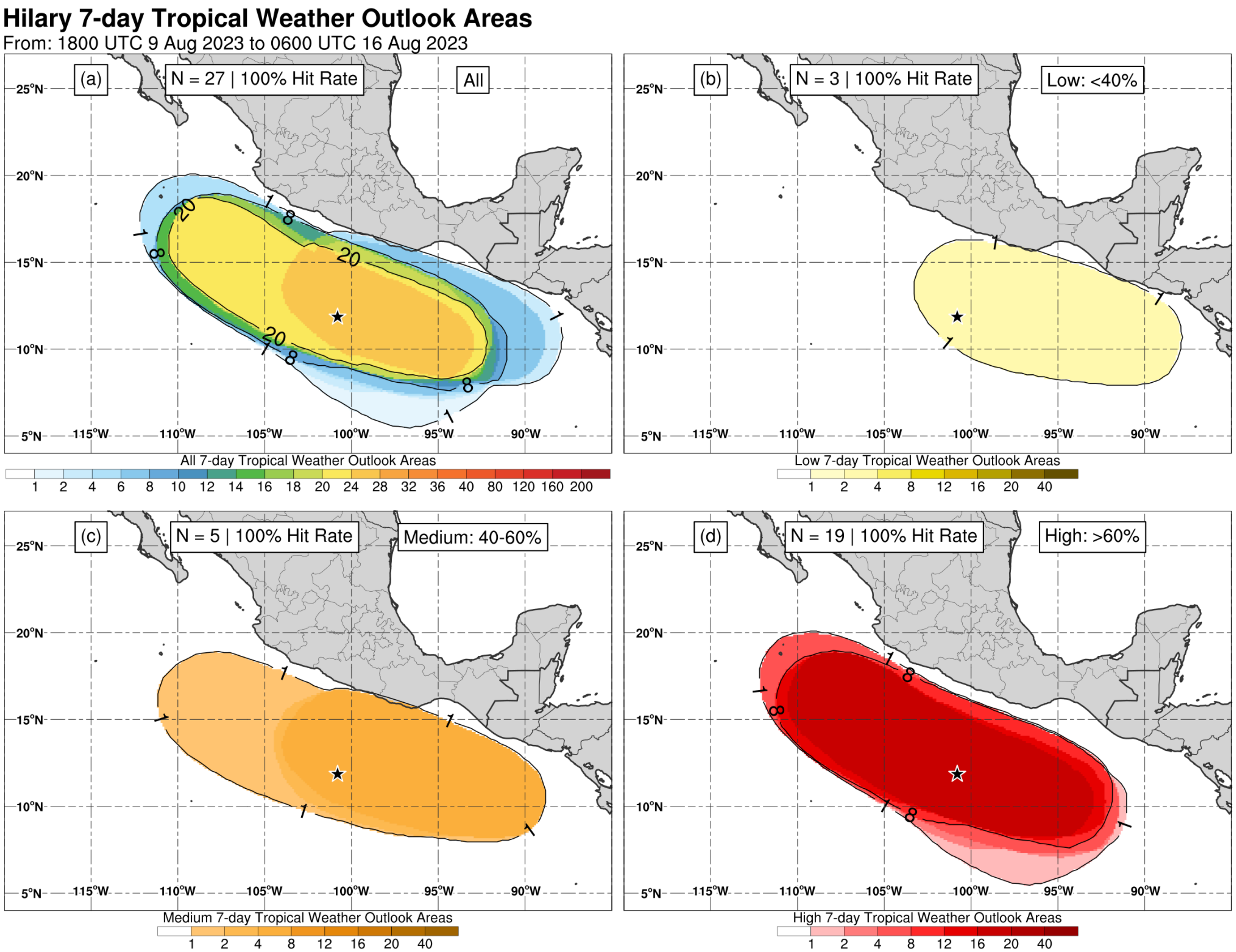


Figure 15. Composites of 7-day tropical cyclone genesis areas depicted in NHC's Tropical Weather Outlooks prior to the formation of Hilary for (a) all probabilistic genesis categories, (b) the low (<40%) category, (c) medium (40–60%) category, and (d) high (>60%) category. The location of genesis is indicated by the black star.

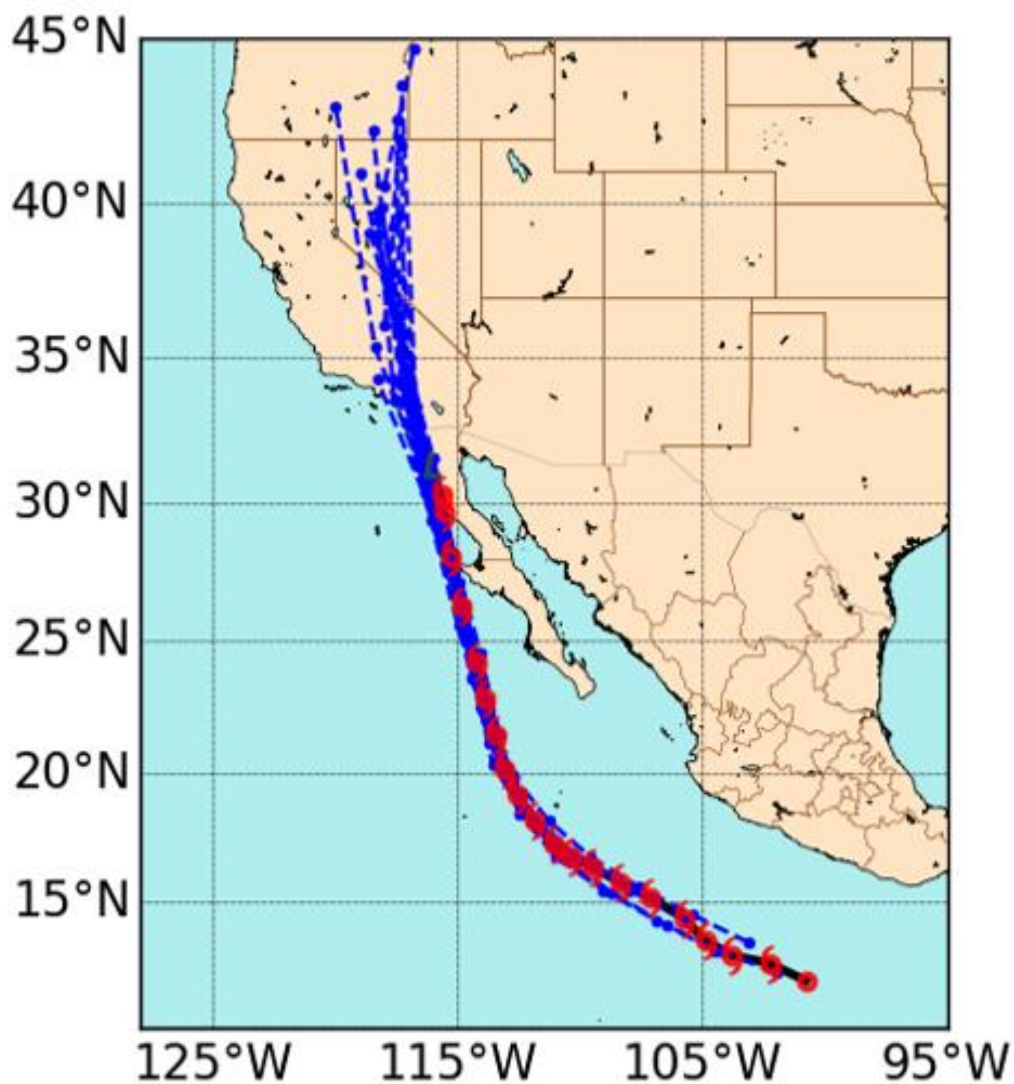


Figure 16. NHC official track forecasts (blue lines) for Hurricane Hilary. The best track of Hilary is indicated by the black line, with its position marked with a red symbol at 6-h intervals.

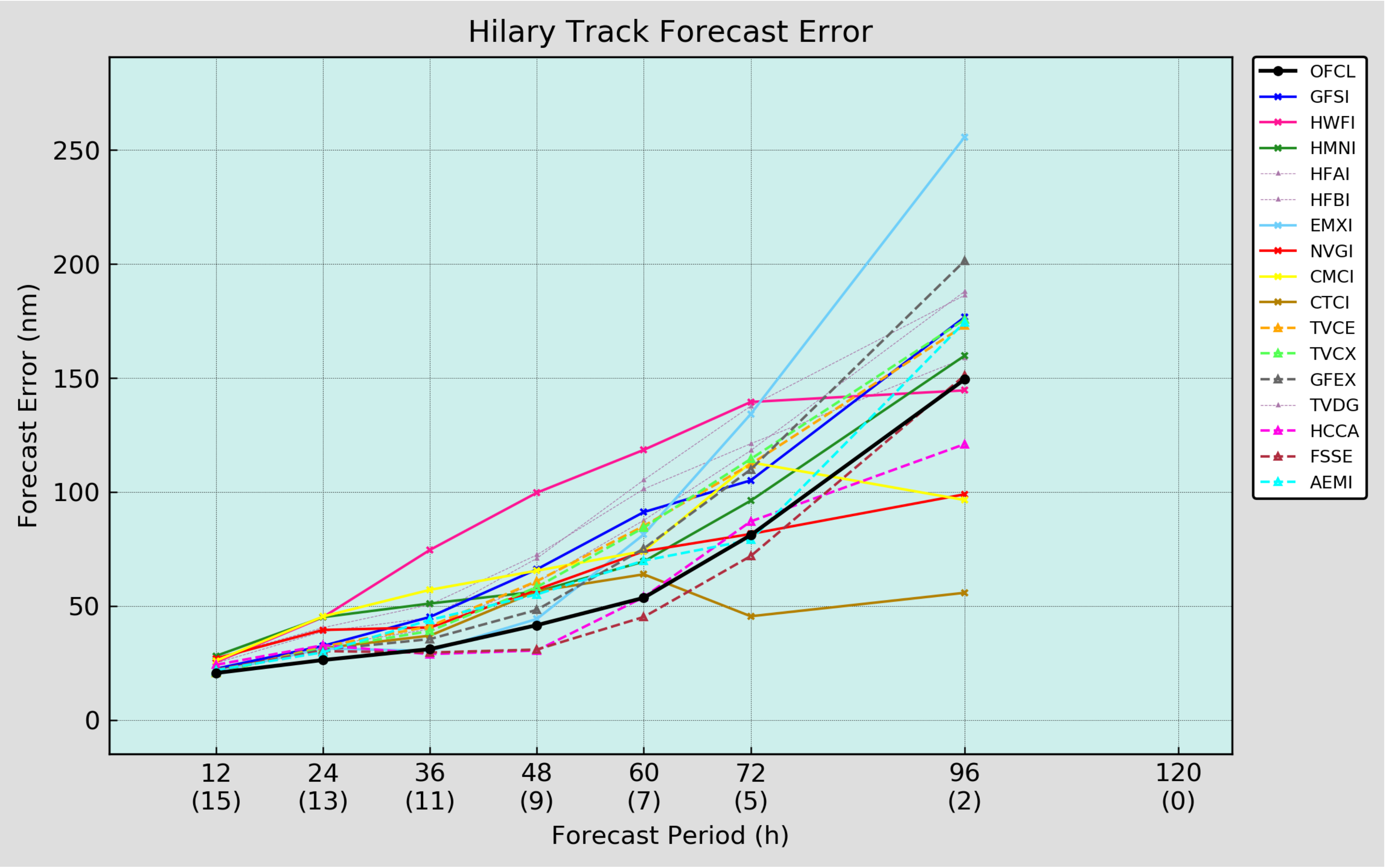


Figure 17. Homogenous comparison of NHC official track forecast errors (OFCL, black line) for Hurricane Hilary to select models and consensus aids.

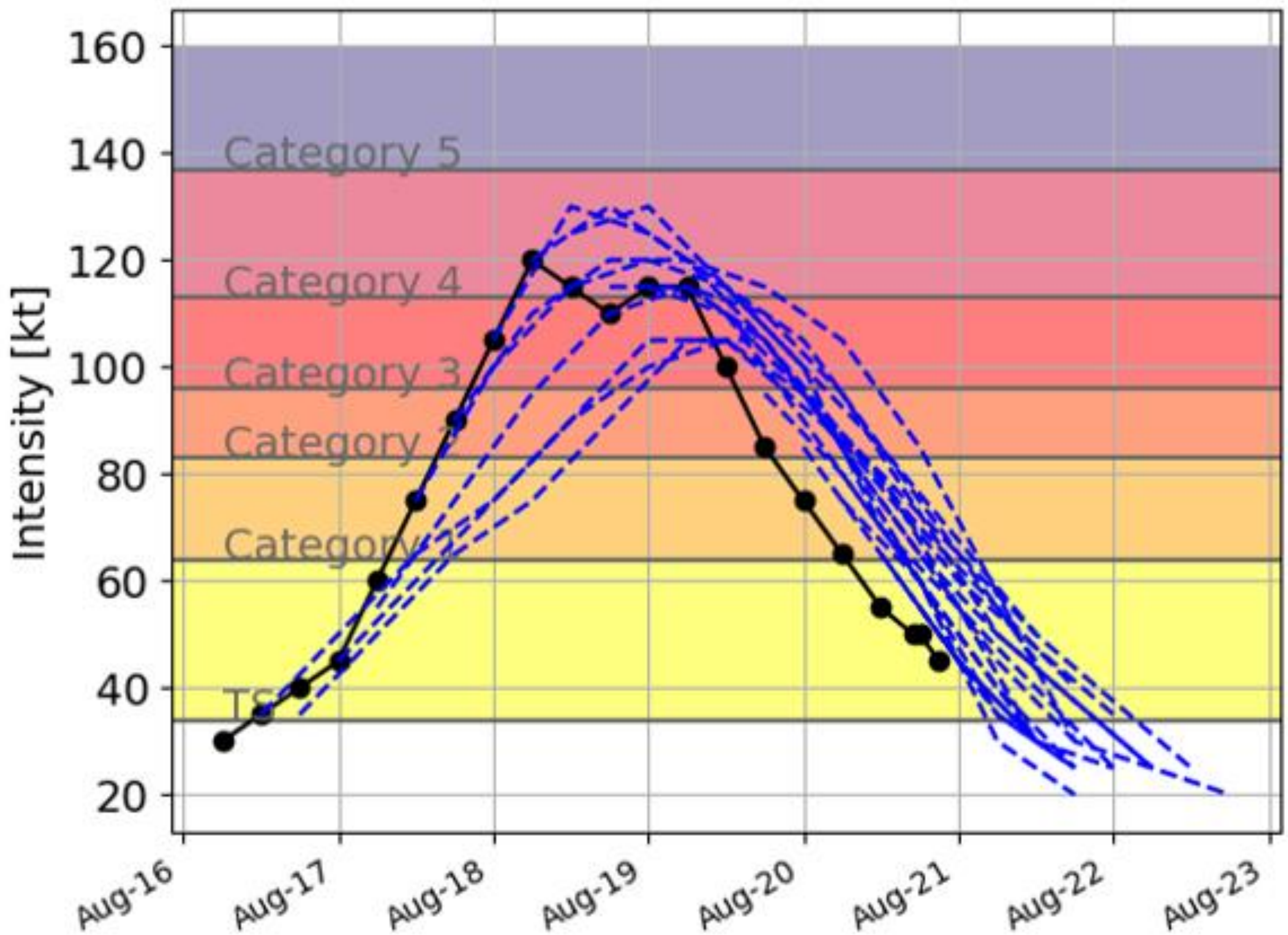


Figure 18. NHC official intensity forecasts (blue lines) for Hurricane Hilary. The best track intensity values are indicated by the black line with markers at 6-h intervals.

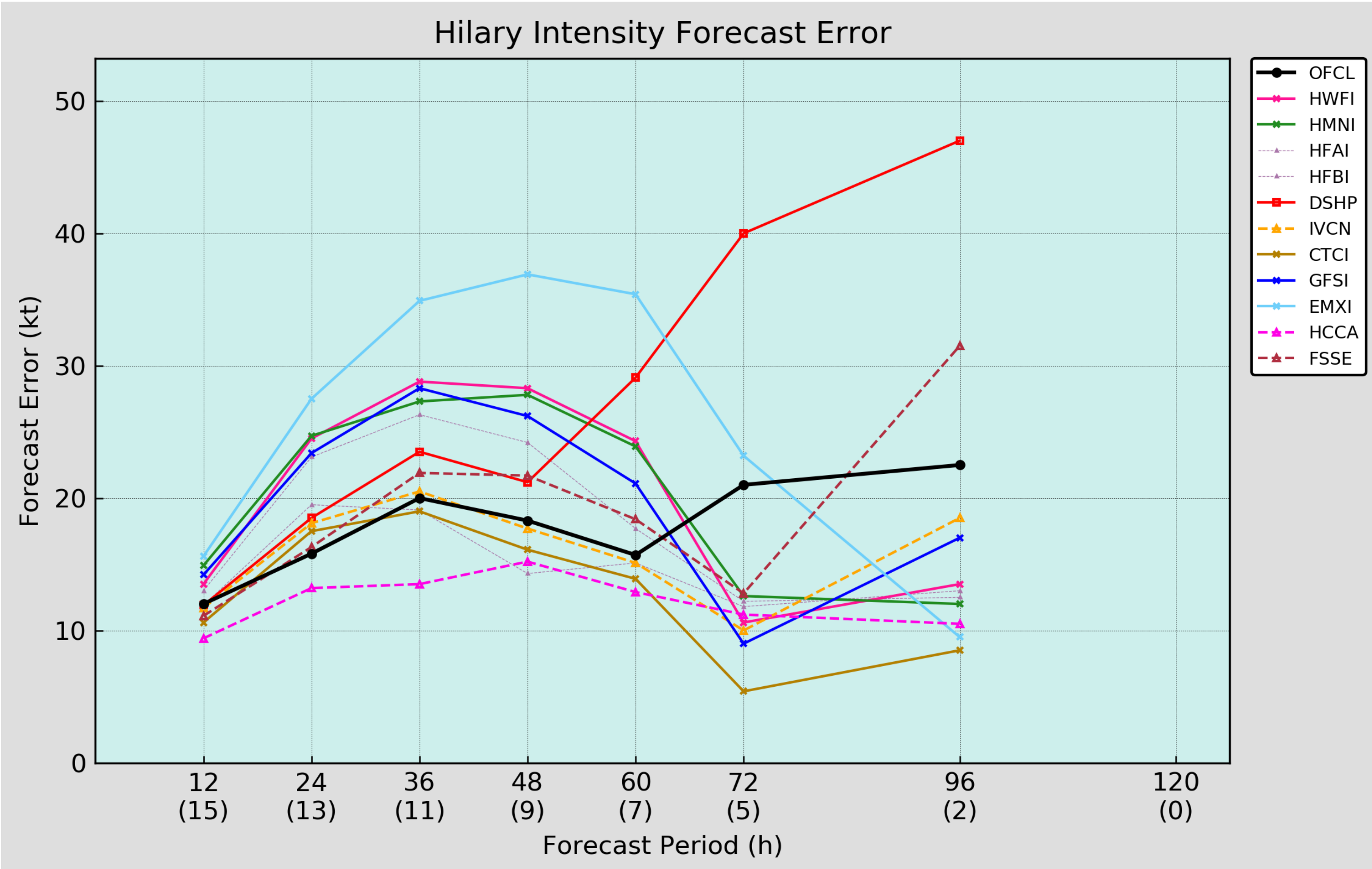


Figure 19. Homogeneous comparison of NHC official intensity forecast errors (OFCL, black line) for Hurricane Hilary to select models and consensus aids.