NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE KAY

(EP122022)

4–9 September 2022

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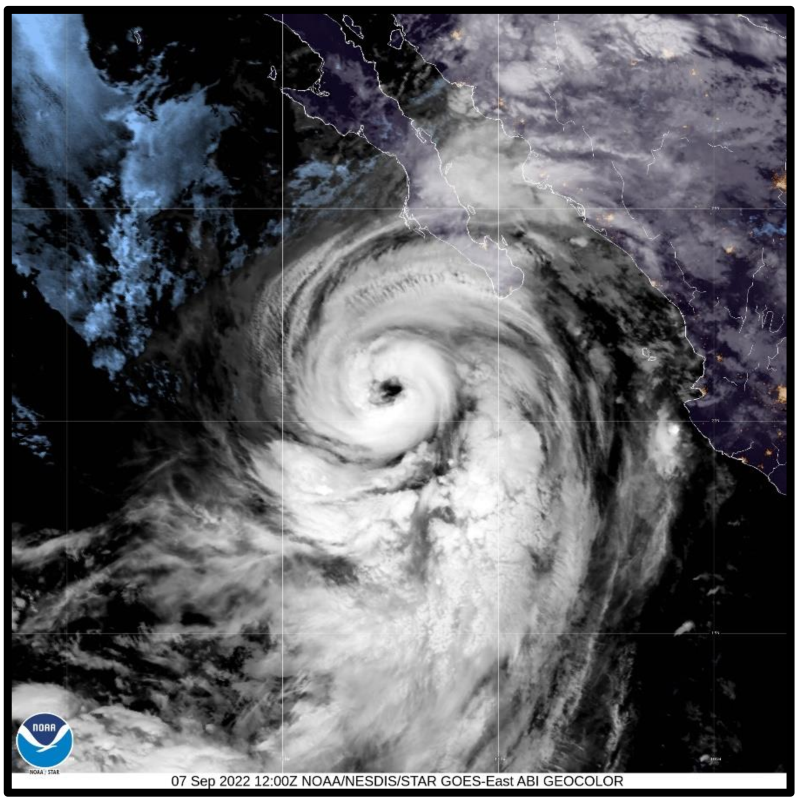

GOES-16 GEOCOLOR IMAGE OF KAY AT 1200 UTC 7 SEPTEMBER 2022. IMAGE COURTESY OF NOAA/NESDIS/STAR.

Hurricane Kay was a category 2 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that made landfall as a strong tropical storm in Baja California Sur and brought flooding rains and mudslides to Mexico and the southwestern United States.

Hurricane Kay

4–9 SEPTEMBER 2022

SYNOPTIC HISTORY

The origins of Kay are somewhat unclear. Between 30 August and 1 September, there seems to have been an interaction between the tail end of an upper-level trough extending from the northeastern United States into the Gulf of Mexico, a weak tropical wave that amplified in the western Caribbean, and the monsoon trough in the eastern Pacific. As the wave moved into the eastern Pacific later on 1 September, it was further invigorated by low-level convergence associated with the monsoon trough. After deep convection waned on 1 September, a broad low-level circulation became apparent on visible satellite imagery. The convection associated with the low remained disorganized for the next few days, but slowly became more persistent and grew in areal coverage with each diurnal cycle as the system moved generally west-northwestward. On 4 September, persistent deep convection became organized around a well-defined surface center, and it is estimated that a tropical depression formed by 1200 UTC that day when the system was located about 195 n mi south-southwest of Acapulco, Mexico. The "best track" chart of the tropical cyclone's path is given in Figure 1, with the wind and pressure histories shown in Figures 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1].

The cyclone steadily intensified after formation in a moist environment with moderate vertical wind shear and sufficiently warm sea surface temperatures. The depression became a tropical storm 6 h after genesis and turned toward the west along the south side of a mid-level ridge extending westward from Mexico. As the environmental wind shear relaxed slightly, Kay strengthened further and became a hurricane around 1800 UTC 5 September. The hurricane turned toward the northwest early on 6 September as it began to move along the southwestern periphery of the mid-level ridge centered over Mexico. Kay then turned toward the north-northwest when it was centered about 200 n mi southwest of the southern tip of the Baja California peninsula early on 7 September. Kay reached its estimated peak intensity of 85 kt around 1200 UTC that day as a large, 25 n mi-wide eye and nearly symmetric eyewall (cover photo) became apparent while the hurricane was in a low-shear environment.

By 0000 UTC 8 September, Kay accelerated toward the north around the western side of the mid-level ridge centered to the east of the hurricane. Environmental and oceanic conditions became less favorable as Kay moved over cooler sea-surface temperatures and the vertical wind shear gradually increased. Kay turned toward the north-northwest as the mid-level ridge built westward, and Kay weakened to a tropical storm just before it made landfall near San Rafael,

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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.

Baja California Sur, at 2035 UTC 8 September. A few hours later, around 0000 UTC 9 September, the center of Kay came back offshore and moved parallel to the coast of the peninsula. Kay lost organized deep convection and became a gale-force, post-tropical cyclone by 1800 UTC 9 September as it moved northwestward in the low-level flow. The system weakened to a remnant low when the winds dropped below gale force by 0600 UTC 10 September. The low gradually spun down over the next couple of days as it turned toward the southwest, then south and southeast. The remnant low dissipated early on 13 September about 315 n mi west of Punta Eugenia.

METEOROLOGICAL STATISTICS

Observations in Kay (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 six flights of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command that made 12 center fixes. 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 Kay.

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

Winds and Pressure

Kay's estimated peak intensity of 85 kt at 1200 UTC 7 September is based on a blend of satellite intensity estimates and observations from the Air Force Reserve Hurricane Hunters collected before and after this time. During the flight late on 6 September, maximum winds reported by the aircraft at 700 mb were 76 kt (reducing to 68 kt at the surface), and surface winds of 65 kt were measured by the SFMR. The following mission, centered at 1800 UTC 7 September, had peak flight-level winds of 82 kt (reducing to a surface intensity of 74 kt) and SFMR observations of 58 kt. Satellite imagery indicates Kay's inner core structure briefly became better organized between these two flights, and the subjective Dvorak estimates from both TAFB and SAB peaked at T5.0 (90 kt) 1200 UTC 7 September. Giving greater weight to the lower aircraft data over the satellite estimates but allowing for the possibility that the strongest winds were not sampled by the aircraft later on 7 September, the peak intensity has been estimated at 85 kt. It is important to note that the aircraft were very limited in the amount of on-station time to investigate the storm environment because of the distance from Keesler Air Force Base.

The minimum central pressure is estimated to be 968 mb at 1200 UTC 7 September based on measurements from dropsondes released during missions prior to and after this time period.

A dropsonde released in the center of Kay at 2034 UTC 6 September measured 976 mb with 6 kt of wind at the surface. At 1836 UTC 7 September, a dropsonde in the center measured 971 mb with 10-kt winds at the surface, but this was several hours after peak intensity when Kay was weakening. It assumed that some deepening occurred prior to 1200 UTC 7 September before weakening commenced shortly thereafter when the next aircraft flew into the storm.

In the hours prior to landfall on 8 September, a reconnaissance aircraft sampling Kay measured maximum 700-mb flight-level winds of 65 kt, which reduces to 59 kt and supports the estimated landfall intensity of 60 kt. A dropsonde released in the center at 1800 UTC 8 September measured a surface pressure of 982 mb with 2-kt winds.

Mexico

Kay brought tropical-storm-force winds to many locations along the Baja California Peninsula on 7–8 September, although no observations were available from the sparsely populated area where the cyclone made landfall (Table 3). In Baja California Sur, an automated weather station at Sierra La Laguna (elev. 6395 ft) measured a 10-minute average wind of 51 kt at 1600 UTC 7 September with a gust to 91 kt. An automated station at Puerto Cortés Naval Base on Isla Santa Margarita reported a sustained wind of 46 kt at 0545 UTC 8 September with a gust to 59 kt. A gust of 60 kt was recorded later that day at an automated weather station in San Juanico. A couple of stations in Baja California (Isla Cedros and Bahía de los Angeles) reported sustained tropical-storm-force winds with gusts over 50 kt.

Surface observations indicate Kay also brought tropical-storm-force wind gusts to coastal portions of the Mexican states of Guerrero, Colima, Sinaloa, and Sonora, as well as to the Islas Marías.

The lowest reported pressure on land was 984.7 mb at 2050 UTC 8 September from an inland weather station in Gustavo Díaz Ordaz (elev. 274 ft) about 50 n mi to the northeast of where Kay made landfall.

Southwestern United States

The pressure gradient associated with post-tropical Kay induced strong downslope winds in the mountains of southern California on 9–10 September, resulting in some extreme wind gusts that were not directly associated with the circulation of the cyclone. The strongest reported wind gust was 95 kt at Cuyamaca Peak (elevation 6500 ft) in San Diego County, with numerous other reports of 60–80-kt gusts at elevation in San Diego County. Gale-force wind gusts were reported at numerous stations along and offshore of the coast of southern California on 9–10 September. NOAA buoy 46086, located about 25 n mi southeast of San Clemente Island, California, measured a peak 1-minute wind speed of 32 kt at 0003 UTC 10 September with a gust to 37 kt.

Rainfall and Flooding

Mexico

Kay produced heavy rainfall over much of the Baja California Peninsula (Fig. 4), with areal averages of 3–6 inches (76–152 mm) and locally higher amounts greater than 8 inches (203 mm) likely influenced by the complex topography of the region. The highest reported rainfall totals occurred over the northern portion of Baja California Sur, with 15.08 inches (383 mm) measured in Guadalupe and 14.57 inches (370 mm) in San Francisco de la Sierra. Over southern portions of the peninsula, 9.45 inches (240 mm) fell in La Palmilla, and 9.29 inches (236 mm) was reported in San Bartolo.

Outer rainbands from Kay brought heavy rains to portions of southwestern, west-central, and northwestern mainland Mexico during the event. Eastern portions of the state of Guerrero received 2–4 inches (51–102 mm) of rainfall, with a daily maximum of 5.51 inches (140 mm) in Laguna de Coyuca on 4 September. Flooding was reported at several locations in the state, including Acapulco and Ixtapa (Fig. 5). Elsewhere, generally 1–3 inches (25–76 mm) of rain fell over portions of the states of Michoacan, Colima, Jalisco, Nayarit, Sinaloa, and Sonora.

Southwestern United States

Tropical moisture associated with Kay and its remnants resulted in showers and thunderstorms that produced instances of heavy rainfall over portions of the southwestern United States from 8–14 September (Fig. 6). In southern California, a weather station at Mount Laguna reported 5.85 inches of rain during this period, and 5.15 inches fell at Volcano Mountain. In Arizona, 4.60 inches of rain were reported near Green Valley, and 4.10 inches were measured in Dragoon. The peak storm-total rainfall in Nevada was 3.40 inches near the Berry Creek.

CASUALTY AND DAMAGE STATISTICS

Kay and its remnants were responsible for at least 4 direct deaths[2] in Mexico and 1 in California. Three fatalities occurred in the Mexican state of Guerrero, including two people who died in the town of Xaltianguis when their vehicles were swept away or submerged by floodwaters. In the town of Huamuchito, a 9-year-old boy was killed by an adobe fence that fell due to heavy rainfall. Elsewhere, a 50-year-old man died in Puerto Vallarta on 6 September after being caught in a rip current at a beachfront hotel. There were also 2 indirect deaths reported in a Baja California Sur vehicle accident on a highway between Guerrero Negro and Vizcaíno on 10 September. The vehicle fell into a collapsed roadway that was caused by prior heavy rainfall and flooding from Kay.

In California, a 62-year-old woman died in Forest Falls after heavy rainfall over burn scars in San Bernardino County on 12 September caused a debris flow that destroyed her home and buried the area underneath several feet of mud, rocks, and other debris.

A comprehensive damage estimate is unavailable at this time of this report.

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

Mexico

The most significant impacts in the Baja California Peninsula were from heavy rainfall and strong winds associated with Kay, especially in the Mulegé municipality in Baja California Sur where Kay made landfall. Heavy rainfall resulted in flash flooding that produced landslides and forced many road closures. Riverine flooding was reported in several Baja California Sur municipalities including Comondú, La Paz, and Mulegé, where several homes were inundated by flooding along the Mulegé River (Fig. 5). Rising waters forced road and bridge closures at several locations along Federal Highway 1, including near La Paz, Loreto, Mulegé, and Santa Rosalia. Water rescues were performed in Loreto when a passenger bus was swept away by floodwaters while trying to cross a stream. Flooded roads were also reported farther south near Cabo San Lucas.

There were media reports of downed trees and roof damage to homes in coastal communities from Punta Abreojos northward to Bahía Asuncion, as well as in San Ignacio and Santa Rosalía. In Baja California Sur, Kay damaged about 105 roads across the state, including 42 in Mulegé and 37 in Comondú municipalities (Fig. 7). Damage to infrastructure cut off some coastal communities, including Punta Abreojos, Bahía Tortugas, and San Juanico. The government of Mexico allocated 224 million pesos ($12 million [US]) to the Mulegé municipality to repair road damage caused by Kay and Tropical Storm Javier, which passed offshore the Baja California Peninsula the week before Kay made landfall. Kay and Javier also damaged more than 90 schools in Baja California Sur, mainly in the northern portion of the state. Farther north in Baja California state, about 140 homes were damaged in San Felipe, as well as a dock and several boat ramps at the port. Strong winds downed power lines across the region, and at least 187,000 customers lost power during the event, including over 128,000 in Baja California and 46,000 in Baja California Sur.

Kay also produced damage in coastal portions of southwestern Mexico as the center passed well offshore. Downed trees and power lines, flash flooding, and landslides were reported in the state of Guerrero, including Acapulco and surrounding areas. Gusty winds resulted in roof damage to around 20 structures in the state. In Puerto Vallarta, some flooding occurred at the regional hospital, and at least 12 homes were damaged by flooding and landslides. Several vehicles were swept away by floodwaters, and one person was injured by a falling fence. Large swells and battering waves caused additional damage along coastal portions of several states in southwestern and west-central Mexico (Fig. 8). In Bahía de Kino (Sonora), several homes suffered significant damage from battering waves along the coast, and a pier was destroyed. Elsewhere, the boardwalk in Puerto Vallarta (Jalisco) was damaged, and some beachfront restaurants on Playa El Borrego in San Blas (Nayarit) and Isla de la Piedra in Mazatlán (Sinaloa) suffered damage as well.

Southwestern United States

Post-tropical Kay and its remnants contributed to localized flash flooding, mudslides, and debris flows in numerous locations across the southwestern United States (Fig. 9). Significant debris flows caused by heavy rainfall over the Apple and El Dorado burn scars damaged or destroyed 30 homes in San Bernardino County, California, resulting in one fatality and about $6 million (USD) in damages. Numerous roadways were blocked by rocks and debris or closed due to flooding. Flash flooding along Interstate 8 west of Ocotillo, California, on 9 September sent rocks across portions of the westbound lanes. On 10 September, several roads were damaged or washed out in Death Valley National Park, and about 40 vehicles were stranded including a tour bus that became stuck in wet sand. Media reports indicate that over 50 people were rescued on 11 September after their vehicles were stranded in a mudslide near Lake Hughes, California. The following day, flash flooding in Mohave County, Arizona, required eight water rescues and inundated several homes near Getz, causing an estimated $100,000 in property damage. Multiple vehicles were stranded on 13 September due to flooding in Valley of Fire State Park in Nevada.

However, some of the rainfall actually proved beneficial for firefighters in the region. The rain associated with the remnants of Kay significantly helped to slow the spread of the Fairview Fire in southern California, which burned largely uncontrolled for several days after igniting on 5 September. After the rainfall, firefighters were able to achieve over 50% containment of the fire by 12 September.

In southern California, gusty downslope winds resulted in some downed trees, power lines, and highway signs. Over 63,000 power outages were reported in the state. Large swells produced some minor coastal flooding at Seal Beach in the Long Beach area, and two homes experienced minor flooding. Significant beach erosion was reported along the southern California coastline, with some locations losing up to five feet of sand in the vertical. Figure 10 shows some of the impacts and damage in California. There were also a few reports of downed trees and power lines by gusty winds in Arizona.

FORECAST AND WARNING CRITIQUE

The possibility of Kay's genesis was identified several days in advance, and the timing of formation was relatively well forecast. Table 4 provides the number of hours in advance of formation with the first NHC Tropical Weather Outlook (TWO) forecast in each likelihood category. A low chance (<40%) was introduced in the 5-day forecast period 126 h before Kay formed. The probabilities were raised to the medium (40-60%) and high (>60%) categories 102 h and 66 h before genesis, respectively. Regarding the 2-day forecast period, a low chance of genesis was introduced in the TWO three days (72 h) before formation, and the probability was raised to the medium category 60 h prior to formation. The 2-day probabilities reached the high category 36 h before genesis. The location of formation was very well predicted (Fig. 11) with a 100% hit rate.

A verification of NHC official track forecasts for Kay is given in Table 5a. Official track forecast errors were less than or comparable to the mean official errors for the previous 5-yr period from 12 to 60 h. The errors were greater than the means at 72 h and beyond, however the sample size is fairly small at these forecast periods. The climatology (OCD5) track errors were larger than the 5-yr average OCD5 errors, indicating that the system's track was more difficult than usual to forecast. Between the 60- and 120-h forecast lead times, the official errors were largely related to the along-track component of the motion, as the official forecast had a slow bias during this time. A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b and Fig. 12. At the 12-h forecast period, two consensus model aids (HCCA and TVCE) had the lowest errors, followed by the United States global dynamical model (GFSI) which had the lowest errors from 24 to 72 h and at 120 h. The ECMWF global model (EMXI) had the lowest errors at 96 h.

A verification of NHC official intensity forecasts for Kay is given in Table 6a. Official intensity forecast errors were lower than the mean official errors for the previous 5-yr period for 60–96 h but above the means for all other forecast periods. The climatology and persistence (OCD5) error values were smaller than the 5-yr averages, indicating that Kay's intensity should have been easier than average to forecast. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b and Fig. 13. Although the official intensity forecast errors were lower than the 5-yr means at a few forecast lead times, all the models had lower errors than the official forecast for at least one forecast period. In fact, many of the intensity consensus aids (ICON, IVCN, IVDR, HCCA) bested the official forecast at all forecast periods. The best predictions were generated by the consensus aids in the short to medium range forecast (HCCA at 12–24 h, ICON at 36–48 and 72 h, and IVDR at 60 h). The regional dynamical model HMON (HMNI) had the lowest intensity errors at 96 h, and the ECMWF global model (EMXI) had the lowest error at 120 h (but this forecast period had a sample size of one). The individual official forecasts between 1200 UTC 4 September and 1200 UTC 7 September tended to have a high bias because they predicted a higher peak intensity and as a result, slower weakening (Fig. 14). This could possibly be linked to the higher-than-average rapid intensification probabilities predicted by the statistical rapid intensification guidance and the slow bias of the track forecasts. One of the poorest performers for intensity prediction beyond 24 h was the SHIPS statistical-dynamical model (DSHP).

Coastal watches and warnings associated with Kay are given in Table 7.

ACKNOWLEDGEMENTS

Data in Table 3 and damage summaries were compiled from reports issued by the Weather Prediction Center and the NWS Weather Forecast Offices in San Diego and Los Angeles, California; Phoenix, Arizona; and Las Vegas, Nevada. Data and observations from Mexico were provided by the National Meteorological Service of Mexico. The United States rainfall data was provided by David Roth of the NOAA Weather Prediction Center.

Table 1. Best track for Hurricane Kay, 4–9 September 2022.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
04 / 1200	14.1	100.9	1005	30	tropical depression
04 / 1800	14.7	102.0	1004	35	tropical storm
05 / 0000	15.3	103.3	1002	35	"
05 / 0600	15.5	104.8	998	45	"
05 / 1200	15.5	106.0	990	55	"
05 / 1800	15.5	106.9	983	65	hurricane
06 / 0000	15.9	107.7	980	70	"
06 / 0600	16.7	108.6	980	70	"
06 / 1200	17.6	109.6	977	75	"
06 / 1800	18.4	110.6	976	75	"
07 / 0000	19.0	111.4	971	80	"
07 / 0600	19.8	111.8	971	80	"
07 / 1200	20.6	112.3	968	85	"
07 / 1800	21.5	112.8	971	80	"
08 / 0000	22.6	112.9	972	75	"
08 / 0600	23.9	113.2	975	70	"
08 / 1200	25.2	113.5	979	65	"
08 / 1800	26.6	114.1	982	60	tropical storm
08 / 2035	27.2	114.3	982	60	"
09 / 0000	27.9	114.6	985	55	"
09 / 0600	29.0	115.5	987	50	"
09 / 1200	30.0	116.4	991	40	"
09 / 1800	30.8	117.4	995	35	low
10 / 0000	31.2	118.5	996	35	"
10 / 0600	31.1	119.5	998	30	"
10 / 1200	30.9	120.2	998	30	"
10 / 1800	30.8	120.7	1003	25	"
11 / 0000	30.7	120.9	1003	25	"
11 / 0600	30.6	121.0	1004	25	"
11 / 1200	30.3	121.3	1006	20	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
11 / 1800	30.0	121.6	1007	20	"
12 / 0000	29.6	121.8	1007	20	"
12 / 0600	29.1	121.9	1007	20	"
12 / 1200	28.5	121.8	1008	15	"
12 / 1800	28.0	121.5	1010	15	"
13 / 0000	27.4	120.9	1011	15	"
13 / 0600					dissipated
07 / 1200	20.6	112.3	968	85	minimum pressure and maximum wind
08 / 2035	27.2	114.3	982	60	Landfall near San Rafael in Baja California Sur, Mexico

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Kay, 4–9 September 2022.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
06 / 1700	D5QE4	22.5	110.6	090 / 35	1007.0
06 / 2100	VROD3	20.8	106.4	170 / 45	1009.0

Table 3. Selected surface observations for Hurricane Kay, including the post-tropical phase after Kay degenerated into a remnant low.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)[b]
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
Mexico						
Guerrero						
Secretaría de Marina (SEMAR) Automated Stations						
Puerto Vicente (PVCG3) (17.27N 101.06W)			04/2215	34	53	
Servicio Meteorológico Nacional (SMN) Automated Stations						
Acapulco (16.76N 99.75W)			04/2320	18 (10 min)	34	
Other Sites						
Laguna de Coyuca						5.51[I]
Colima						
International Civil Aviation Organization (ICAO) Sites						
Manzanillo – Playa de Oro Intl. AP (MMZO) (19.15N 104.56W)			06/0110	30	40	
SEMAR Automated Stations						
Isla Socorro (ISOC8) (18.73N 110.95W)			07/1200	38	51	8.26
Nayarit						
SEMAR Automated Stations						
Isla María Madre (IMMR3) (21.63N 106.54W)			06/2315		33	
Baja California Sur						
ICAO Sites						
Loreto Intl. AP (MMLT) (25.99N 111.35W)			07/1940	40[I]		
Los Cabos Intl. AP (MMSD) (23.15N 109.72W)			07/2240	32[I]	36[I]	
Cabo San Lucas Intl. AP (MMSL) (22.95N 109.94W)			07/1155	25	37	
SMN Automated Stations						

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)[b]
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
Sierra La Laguna (SLGB7) *elev. 6395 ft* (23.56N 110.00W)			07/1600	51 (10 min)	91	
Santa Rosalia (76252) (27.34N 112.27W)	08/2000	994.4	08/1830	41 (10 min)	55	
Cabo San Lucas (CSLB7) *elev. 735 ft* (22.88N 109.93W)			07/1610	39 (10 min)	58	
San Juanico (SJUB7) (26.26N 112.48W)	08/1420	994.6	08/1420	36 (10 min)	60	3.91
Gustavo Díaz Ordaz (GDOB7) *elev. 274 ft* (27.64N 113.46W)	08/2050	984.7	08/2050	24 (10 min)	48	3.15
Loreto (LTOB7) (26.01N 111.35W)			06/1400	20 (10 min)	39	
SEMAR Automated Stations						
Puerto Cortés (PCRB7) (24.48N 111.82W)	08/0745	996.5	08/0545	46	59	
Isla Alijos (24.95N 115.73W)	08/1259	996.1[l]	08/1659	33[l]	41[l]	
Other Sites						
Guadalupe						15.08
San Francisco de la Sierra						14.57
La Palmilla						9.45
San Bartolo						9.29
Observatorio de Ciudad Constitución (25.01N 111.66W)						5.43
Sinaloa						
SMN Automated Stations						
Obispos (OSPS5) (24.25N 107.19W)			06/0520	28 (10 min)	40	
Baja California						
ICAO Sites						
Tijuana Intl. AP (MMTJ) (32.54N 116.97W)			09/1542	20	32	
SMN Automated Stations						
Bahía de los Angeles (BLAB1) (28.90N 113.56W)	09/0120	994.0	09/0010	40 (10 min)	51	
La Rumorosa *elev. 4140 ft* (RUMB1) (32.27N 116.21W)			09/1230	29 (10 min)	51	
Cataviña (CATB1) (29.73N 114.72W)			08/2040		44	2.41

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)[b]
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
SEMAR Automated Stations						
Isla Cedros (ICDB1) (28.03N 115.19W)			08/1645	40	52	
San Felipe (SFEB1) (30.99N 114.83W)	09/1030	996.4	09/0745	32	44	
Isla Coronado (ICRB1) (32.42N 117.25W)			09/1330	29	37	
Isla Guadalupe (IGPB1) (28.88N 118.29W)	09/0945	997.2	09/0645	26	33	
Sonora						
ICAO Sites						
Guaymas – General José Maria Yánez Intl. AP (MMGM) (27.97N 110.93W)			08/1641	26[l]	45[l]	
SMN Automated Stations						
Caborca (CABS6) *elev. 617 ft* (30.77N 112.44W)			09/1550	29 (10 min)	38	
Bahia de Kino (KNOS6) (28.82N 111.92W)			09/0550	27 (10 min)	34	
El Pinacate (PNCS6) *elev. 327 ft* (31.68N 113.30W)			09/1730	26 (10 min)	37	
Alamos (ALMS6) *elev. 1340 ft* (27.02N 108.94W)			06/0250	21 (10 min)	41	
Empalme (27.96N 110.80W)			06/0840		35	
SEMAR Automated Stations						
Puerto Penasco (PPCS6) (31.30N 113.55W)			09/1910	28	45	
Guaymas (27.90N 110.89W)	09/0045	1004.7	08/1530	25	37	
United States						
California						
ICAO Sites						
Catalina AP (KAVX) (33.40N 118.41W)			09/1942		41	
Ramona AP (KRNM) (33.04N 116.92W)			09/1553		41	
Palmdale Reg. AP (KPMD) (34.63N 118.08W)			09/2355		37	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)[b]
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
Long Beach AP (KLGB) (33.81N 118.15W)			09/2210		34	
Los Angeles Intl. AP (KLAX) (33.94N 118.39W)			09/2231		34	
Chino AP (KCNO) (33.98N 117.62W)			09/2105		34	
Ontario Intl. AP (KONT) (34.05N 117.58W)			09/1955		34	
Victorville AP (KVCV) (34.60N 117.38W)			09/2155		34	
National Ocean Service (NOS) Sites						
San Diego (SDBC1) (32.71N 117.17W)	09/1524	998.1				
La Jolla (LJAC1) (32.87N 117.26W)	09/1542	998.2				
WeatherFlow Sites						
Dana Point Light 3 (XDPT) (33.45N 117.69W)			09/1659		39	
Long Beach Breakwater E End (XLBB) (33.72N 118.14W)			09/2154		36	
San Clemente (XCLM) (33.40N 117.60W)			09/1907		35	
Anaheim Bay West Jetty L5 (XABJ) (33.73N 118.10W)			09/2059		34	
Long Beach Entrance Light (XLBL) (33.72N 118.18W)			09/2207		34	
Other Sites						
Cuyamaca Peak *elev. 6500 ft* (32.95N 116.61W)			09/1527		95	
Big Black Mountain *elev. 4055 ft* (33.16N 116.81W)			09/1725		83	
Laguna Launch *elev. 5711 ft* (32.94N 116.49W)			09/2115		81	
Sill Hill *elev. 3556 ft* (32.95N 116.64W)			09/1550		79	
Otay Mountain (OTYC1) *elev. 3283 ft* (32.60N 116.84W)			09/1714		70	
Hauser Mountain *elev. 3188 ft* (32.66N 116.56W)			09/1700		70	
Mount Laguna Observatory *elev. 6055 ft* (32.89N 116.42W)			09/1725		70	
Jamul *elev. 1105 ft* (32.71N 116.87W)			09/1700		69	
Toro Peak *elev. 8689 ft* (33.52N 116.43W)			09/1843		67	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)[b]
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
Pine Cove Rocky Point *elev. 6550 ft*			09/2045		66	
Pine Valley – Horse Launch *elev. 4399 ft* (32.78N 116.48W)			09/1745		65	
Mount Laguna (LGMC1) (32.86N 116.42W)						5.85
Mount Laguna RAWS (MLGC1) (32.88N 116.42W)						5.71
Volcano Mountain (VCNC1) (33.11N 116.58W)						5.15
Ranchita (RCHC1) (33.22N 116.50W)						4.65
Panorama Point (PPOC1) (34.23N 117.31W)						4.57
Raywood Flats (RWDC1) (34.05N 116.82W)						4.33
Crestline 1.4 ESE (34.24N 117.27W)						4.30
Forest Falls (YUCC1) (34.06N 116.89W)						4.09
Julian (JLNC1) (33.08N 116.60W)						4.09
Agua Caliente (AGUC1) (32.95N 116.28W)						4.08
Arizona						
Green Valley 1.2 SW (31.84N 111.01W)						4.60
Dragoon (DGNA3) (32.01N -110.00W)						4.10
Kingman (MHLA3) (35.18N 113.98W)						3.55
Bagdad (BDDA3) (34.60N 113.18W)						3.12
Nevada						
Berry Creek (39.32N 114.62W)						3.40
Cathedral Gorge State Park (37.80N 114.41W)						3.00
Valley of Fire State Park (36.43N 114.51W)						2.89
Caliente 0.3 SSE (37.61N 114.51W)						2.80[i]

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)[b]
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
Offshore						
NOAA Buoys						
46086 – San Clemente Basin (32.50N 118.05W)	09/1650	998.0	10/0003	32 (4 m, 1 min)	37	
46047 – Tanner Bank (32.39N 119.53W)	09/1140	997.9	10/0903	25 (4 m, 1 min)	29	

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] United States rainfall totals are from 8–14 September 2022, courtesy of the NOAA Weather Prediction Center.
[I] 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	126
Medium (40%-60%)	60	102
High (>60%)	36	66

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Kay, 4–9 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	23.8	34.2	**41.9**	58.7	**71.4**	87.0	112.2	182.6
OCD5	50.3	98.1	143.0	210.6	277.5	358.6	471.6	628.6
Forecasts	19	17	15	13	11	9	5	1
OFCL (2017-21)	21.9	33.8	45.6	56.9	74.8	79.9	99.5	121.3
OCD5 (2017-21)	35.8	72.3	112.7	155.0	198.7	239.0	309.2	372.2

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Kay, 4–9 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	24.1	34.2	41.9	58.7	71.4	87.0	112.2	182.6
OCD5	49.6	98.1	143.0	210.6	277.5	358.6	471.6	628.6
GFSI	25.6	**29.0**	**34.2**	**47.2**	**58.1**	**77.1**	**102.7**	**130.6**
EMXI	26.8	38.5	47.0	62.0	74.7	**86.3**	**85.9**	**162.9**
CMCI	27.3	38.2	58.9	84.6	109.6	134.6	190.7	310.8
HWFI	24.6	36.5	54.4	70.2	79.7	99.8	151.4	230.2
HMNI	**23.3**	40.7	58.8	79.4	101.7	130.9	154.7	262.4
CTCI	25.8	**32.0**	44.6	71.9	95.4	110.2	117.5	182.6
AEMI	25.3	**31.0**	**41.0**	64.2	85.9	120.8	172.5	249.7
GFEX	24.5	**32.2**	**37.6**	**51.9**	**64.1**	**78.9**	**93.4**	**144.7**
HCCA	**23.0**	**31.6**	**40.1**	**55.0**	**65.4**	**86.2**	120.8	194.3
TVCE	**23.0**	**33.9**	47.4	69.8	86.3	105.7	130.6	189.0
TVCX	**24.0**	**33.1**	44.9	67.2	82.9	99.7	117.6	**169.5**
TVDG	24.1	34.2	45.9	68.6	85.8	104.8	127.0	**164.2**
TABD	33.6	51.5	59.3	65.2	85.6	115.3	155.9	259.2
TABM	32.0	54.0	72.8	88.0	116.9	145.9	149.8	219.2
TABS	45.2	91.2	130.2	163.8	202.5	228.8	228.8	361.2
Forecasts	18	17	15	13	11	9	5	1

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Kay, 4–9 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	7.4	11.5	14.3	15.4	**13.6**	**12.8**	**16.0**	20.0
OCD5	6.4	9.2	9.0	9.8	12.6	14.9	7.2	21.0
Forecasts	19	17	15	13	11	9	5	1
OFCL (2017-21)	5.5	9.1	11.1	12.9	15.3	15.6	16.4	17.0
OCD5 (2017-21)	7.0	12.2	15.8	18.6	20.4	21.2	22.3	21.8

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Kay, 4–9 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	7.5	11.5	14.3	15.4	13.6	12.8	16.0	20.0
OCD5	**6.8**	**9.2**	**9.0**	**9.8**	**12.6**	14.9	**7.2**	21.0
HWFI	**6.8**	**8.8**	**10.7**	**11.2**	**11.4**	**9.4**	**4.0**	**12.0**
HMNI	8.2	**10.4**	**10.3**	**10.9**	**10.1**	**9.2**	**4.0**	**9.0**
CTCI	**5.0**	**8.0**	**9.3**	**12.7**	18.4	23.0	25.4	**11.0**
DSHP	**6.0**	**9.4**	16.3	22.5	26.8	29.9	36.0	38.0
LGEM	**5.6**	**6.5**	**6.8**	**8.2**	**11.3**	13.3	**11.8**	**8.0**
ICON	**5.9**	**5.7**	**6.3**	**7.2**	**7.4**	**8.3**	**12.8**	**17.0**
IVCN	**5.7**	**6.0**	**6.4**	**7.4**	**9.2**	**11.6**	**15.4**	**16.0**
IVDR	**5.9**	**6.8**	**7.1**	**7.8**	**7.1**	**9.3**	**13.8**	**15.0**
HCCA	**5.2**	**5.6**	**8.1**	**11.2**	**12.2**	**12.6**	**13.6**	**11.0**
GFSI	**7.3**	**10.4**	**11.7**	**10.2**	**8.2**	**10.7**	16.2	21.0
EMXI	8.9	14.3	16.6	17.8	18.2	17.3	**10.6**	**2.0**
Forecasts	18	17	15	13	11	9	5	1

Table 7. Watch and warning summary along the Pacific coast of Mexico for Hurricane Kay, 4–9 September 2022.

Date/Time (UTC)	Action	Location
5 / 1500	Tropical Storm Watch issued	Baja California peninsula from Loreto to Puerto San Andresito
6 / 0300	Tropical Storm Watch modified	Baja California peninsula from Loreto to Punta Abreojos
6 / 0900	Tropical Storm Warning issued	Baja California peninsula from San Evaristo to Cabo San Lazaro
6 / 1500	Tropical Storm Watch modified	Baja California peninsula from Santa Rosalia to San Evaristo
6 / 2100	Tropical Storm Watch modified	Mexico from Bahia De Los Angeles to Santa Rosalia
6 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Baja California peninsula from Cabo San Lazaro to Punta Abreojos
6 / 2100	Tropical Storm Watch issued	Baja California peninsula from Punta Eugenia to San Jose De Las Palomas
6 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Baja California peninsula from Santa Rosalia to San Evaristo
6 / 2100	Hurricane Watch issued	Baja California peninsula from Puerto Cortes to Punta Eugenia
7 / 0900	Tropical Storm Watch modified	Baja California peninsula from San Felipe to Bahia De Los Angeles
7 / 0900	Tropical Storm Watch modified	Baja California peninsula from San Jose De Las Palomas to Cabo San Quintin
7 / 0900	Tropical Storm Watch changed to Tropical Storm Warning	Baja California peninsula from Bahia De Los Angeles to Punta Abreojos
7 / 0900	Hurricane Watch modified	Baja California peninsula from Puerto Cortes to Punta Abreojos
7 / 0900	Hurricane Warning issued	Baja California peninsula from Punta Abreojos to San Jose De Las Palomas
7 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Baja California peninsula from San Jose De Las Palomas to Cabo San Quintin
7 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Baja California peninsula from San Felipe to Bahia De Los Angeles
7 / 1500	Tropical Storm Watch issued	Baja California peninsula from Cabo San Quintin to US/Mexican border

Date/Time (UTC)	Action	Location
7 / 1500	Tropical Storm Warning modified	Mainland of Mexico from Guaymas to Punta Abreojos on the western coast of the Baja California peninsula
8 / 0300	Tropical Storm Watch upgraded to a Tropical Storm Warning	Baja California peninsula from San Jose De Las Palomas to Ensenada
8 / 0900	Tropical Storm upgraded to a Tropical Storm Warning	Baja California peninsula from Ensenada to US/Mexican border
8 / 1500	Tropical Storm Warning discontinued	Eastern coast of the Baja California peninsula from La Paz to Cabo San Lucas
8 / 1800	Tropical Storm Warning discontinued	Western coast of the Baja California peninsula from Todos Santos to Cabo San Lucas
8 / 2100	Tropical Storm Warning discontinued	Eastern coast of the Baja California peninsula from San Evaristo to La Paz
8 / 2100	Tropical Storm Warning discontinued	Western coast of the Baja California peninsula from Puerto Cortes to Todos Santos
9 / 0000	Hurricane Watch discontinued	All
9 / 0000	Hurricane Warning modified to Tropical Storm Warning	All
9 / 0300	Tropical Storm Warning discontinued	Eastern coast of the Baja California peninsula from Loreto to San Evaristo
9 / 0300	Tropical Storm Warning discontinued	Western coast of the Baja California peninsula from Puerto San Andresito to Todos Santos
9 / 0900	Tropical Storm Warning discontinued	Mainland of Mexico from Bahia Kino to Guaymas
9 / 0900	Tropical Storm Warning discontinued	Eastern coast of the Baja California peninsula from Loreto to Santa Rosalia
9 / 1500	Tropical Storm Warning discontinued	Mainland of Mexico from Bahia Kino to Santa Rosalia
9 / 1500	Tropical Storm Warning discontinued	Western coast of the Baja California peninsula from Punta Eugenia to Puerto San Andresito
9 / 1500	Tropical Storm Warning discontinued	Mainland of Mexico from Puerto Libertad to Bahia Kino
9 / 1500	Tropical Storm Warning discontinued	Eastern coast of the Baja California peninsula from Puerto Libertad to Santa Rosalia

Date/Time (UTC)	Action	Location
9 / 2100	Tropical Storm Warning discontinued	Puerto Libertad to Bahia de Los Angeles
9 / 2100	Tropical Storm Warning discontinued	Western coast of the Baja California peninsula from Cabo San Quintin to Punta Eugenia
10 / 0300	Tropical Storm Warning discontinued	All

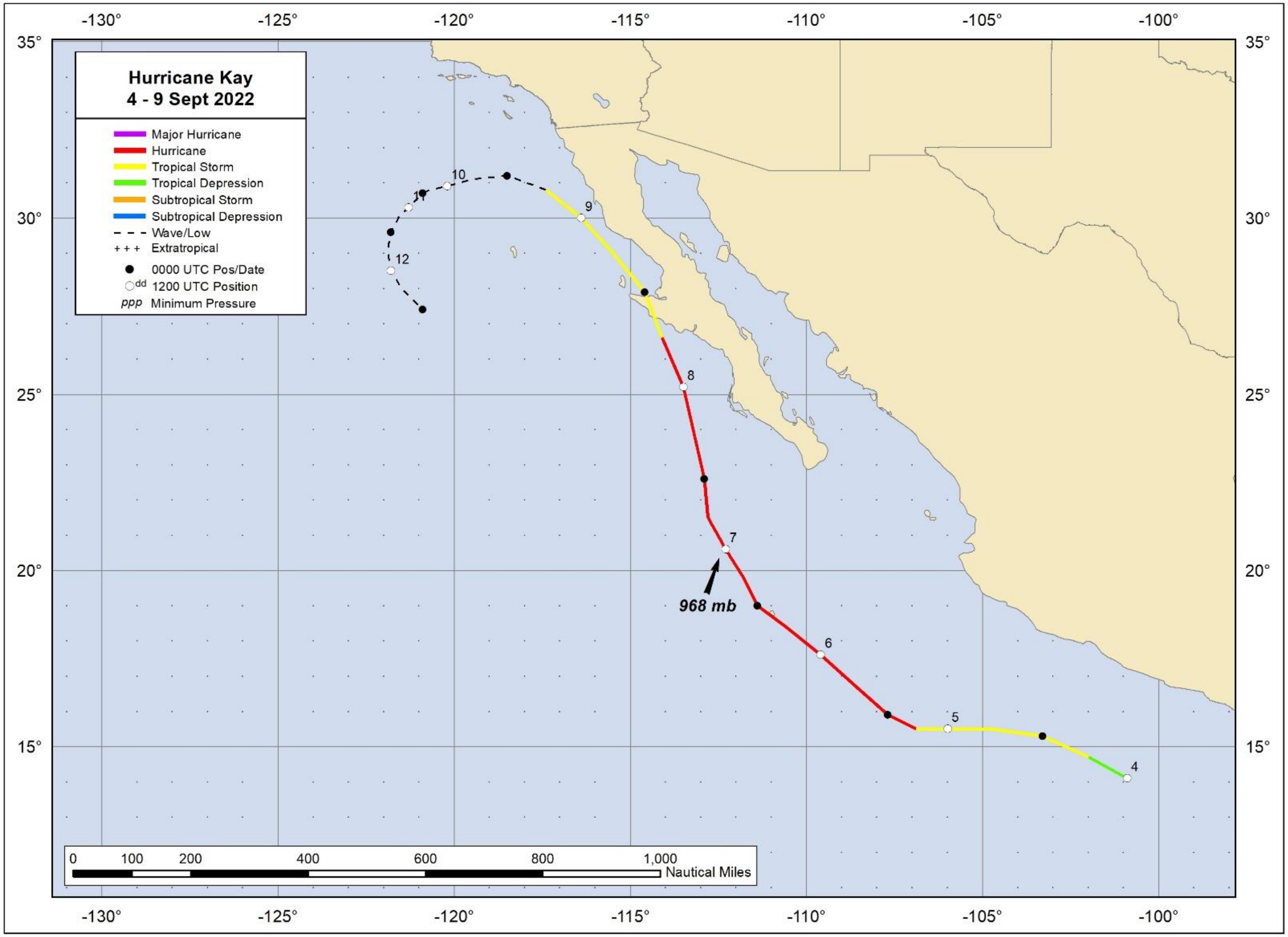

Figure 1. Best track positions for Hurricane Kay, 4–9 September 2022.

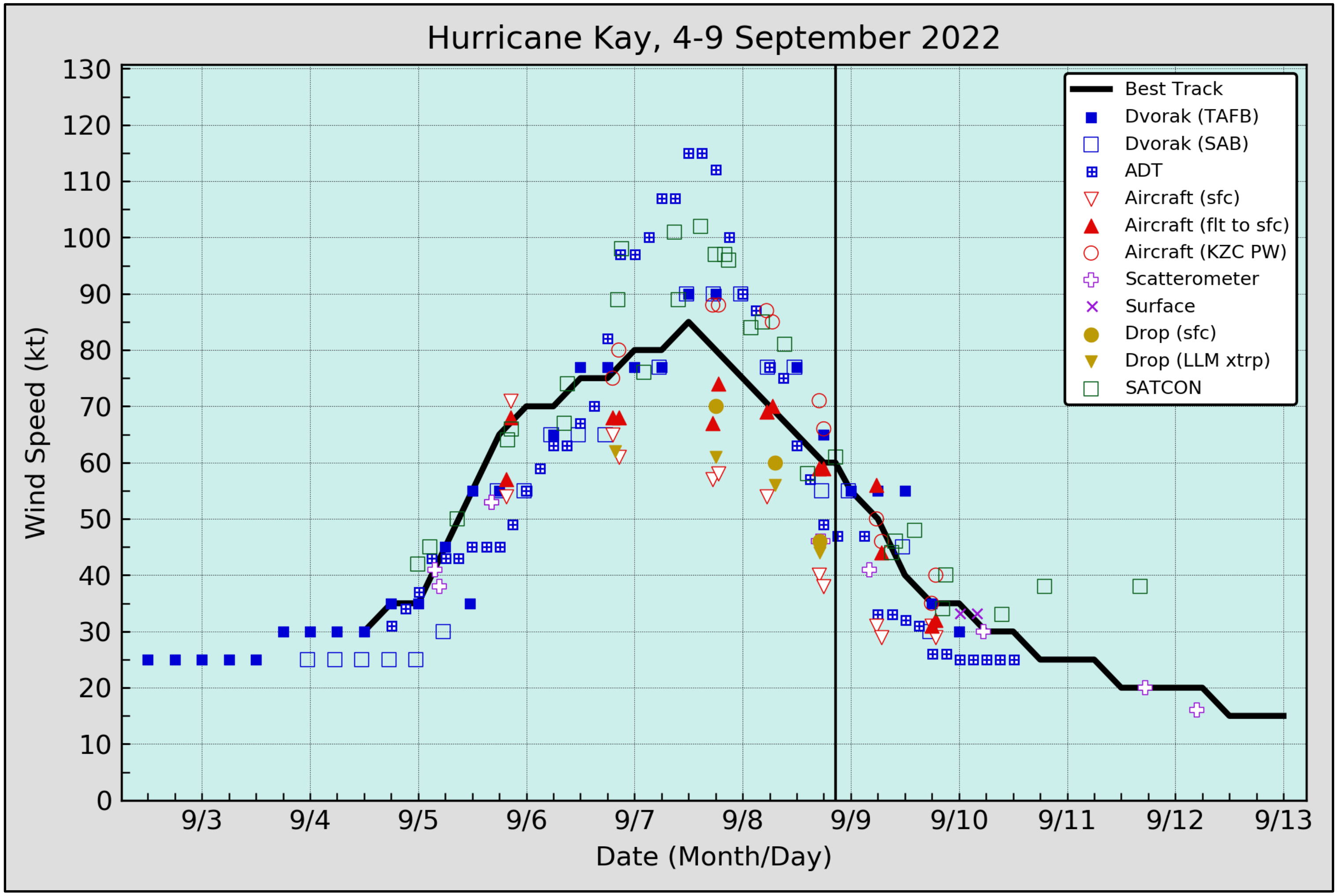

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Kay, 4–9 September 2022. Aircraft observations have been adjusted for elevation using 90%, 80%, and 75% adjustment factors for observations from 700 mb, 850 mb, and 925 mb, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC, and solid vertical line corresponds to landfall.

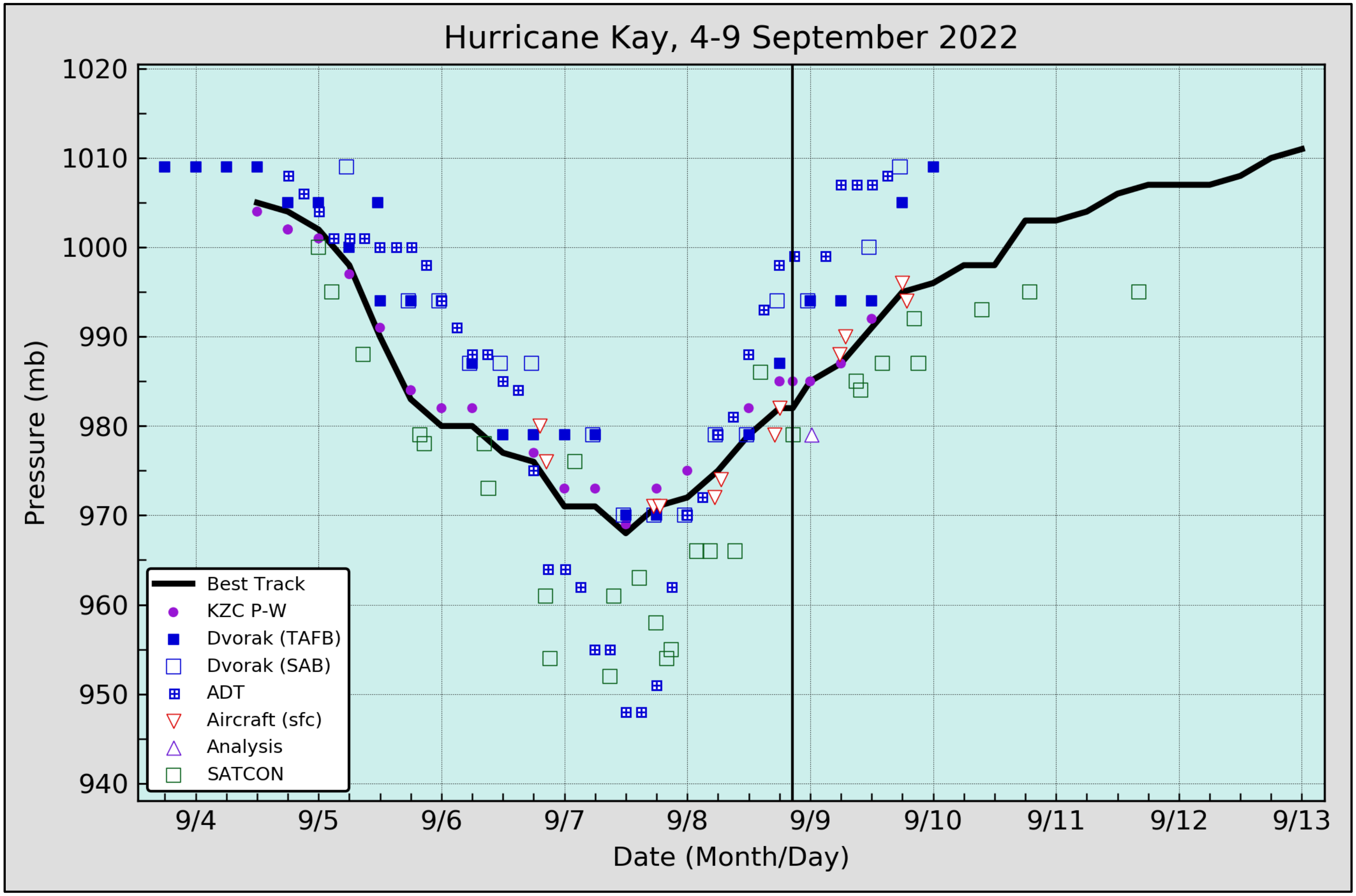

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Kay, 4–9 September 2022. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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 line corresponds to landfall.

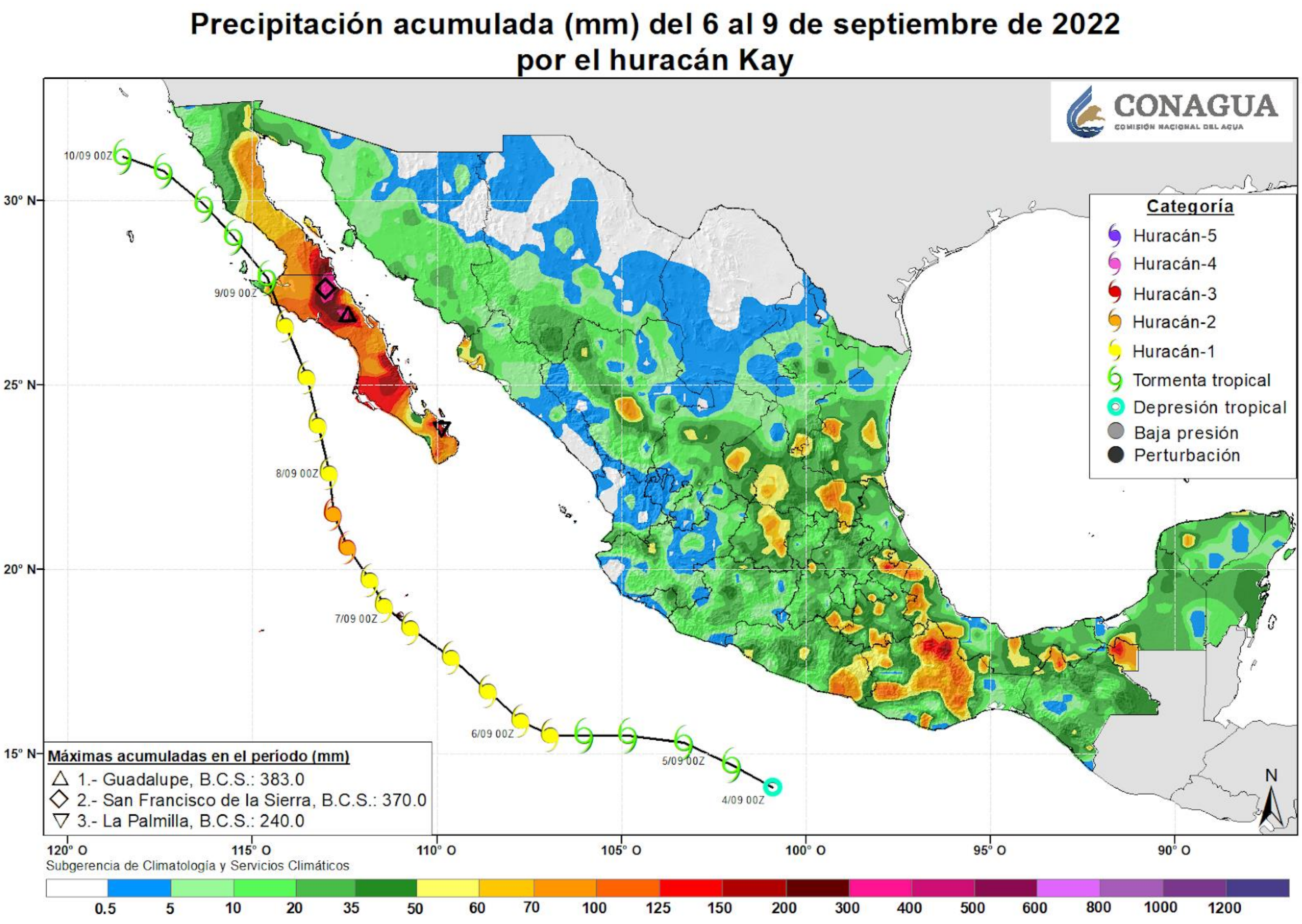

Figure 4. Rainfall accumulations (mm) from 6–9 September 2022 associated with Kay. Track and intensity are based on the operational NHC assessment. Image courtesy of CONAGUA and the National Meteorological Service of Mexico.

Figure 5. Flooding impacts in Mexico associated with heavy rainfall from Kay. (Left) Homes inundated by floodwaters along the Mulegé River in Baja California Sur. Image credit: Dans Vela via BCS Noticias. (Right) Street flooding near the port in Acapulco. Image credit: Martin Gomez / El Sol de Acapulco.

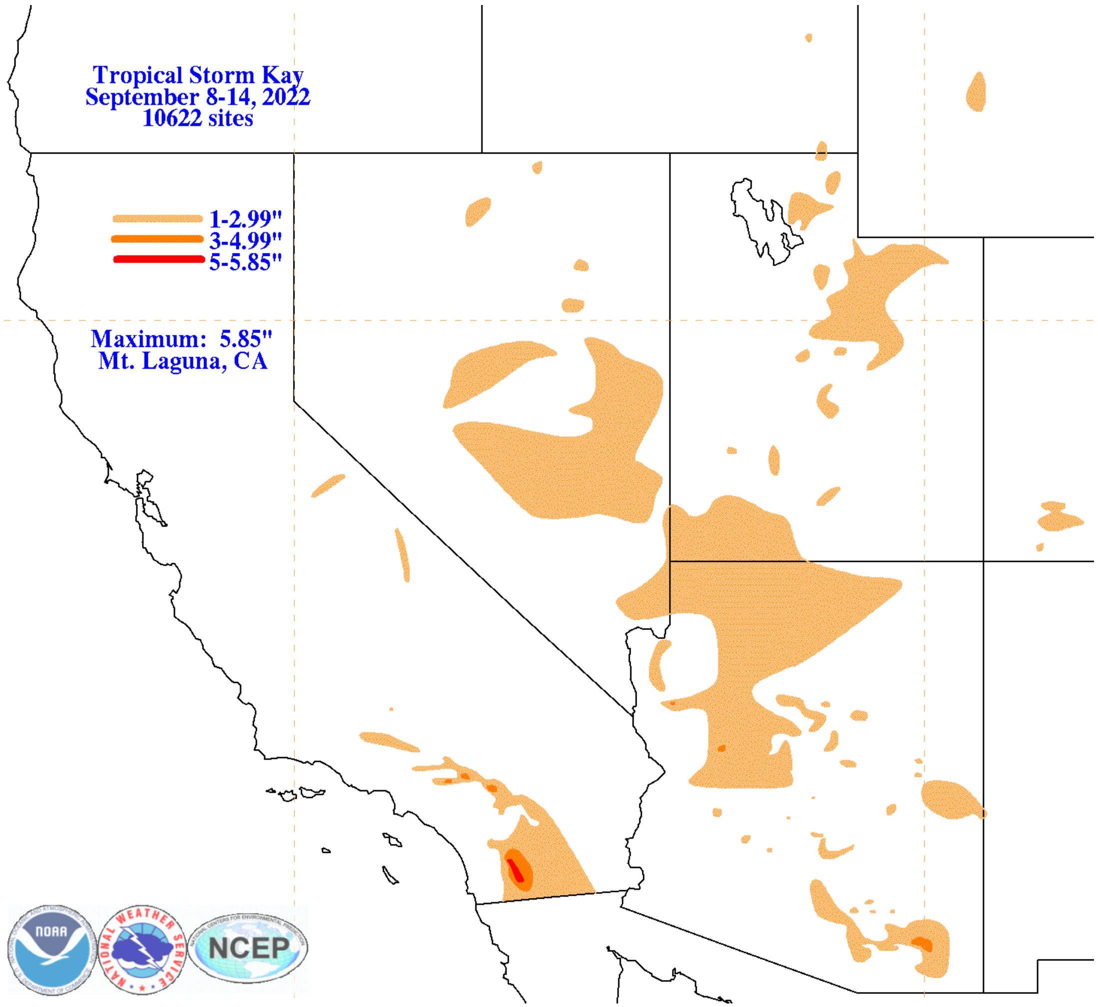

Figure 6. Rainfall accumulations (inches) in the southwestern United States from 8–14 September 2022, including the post-tropical phase of Kay. Image courtesy of David Roth, NOAA Weather Prediction Center.

Figure 7. Roads damaged by flooding in the Comondú municipality of Baja California Sur. Image credits: (left) BCS Noticias and (right) Scorpion Bay Hotel, San Juanico.

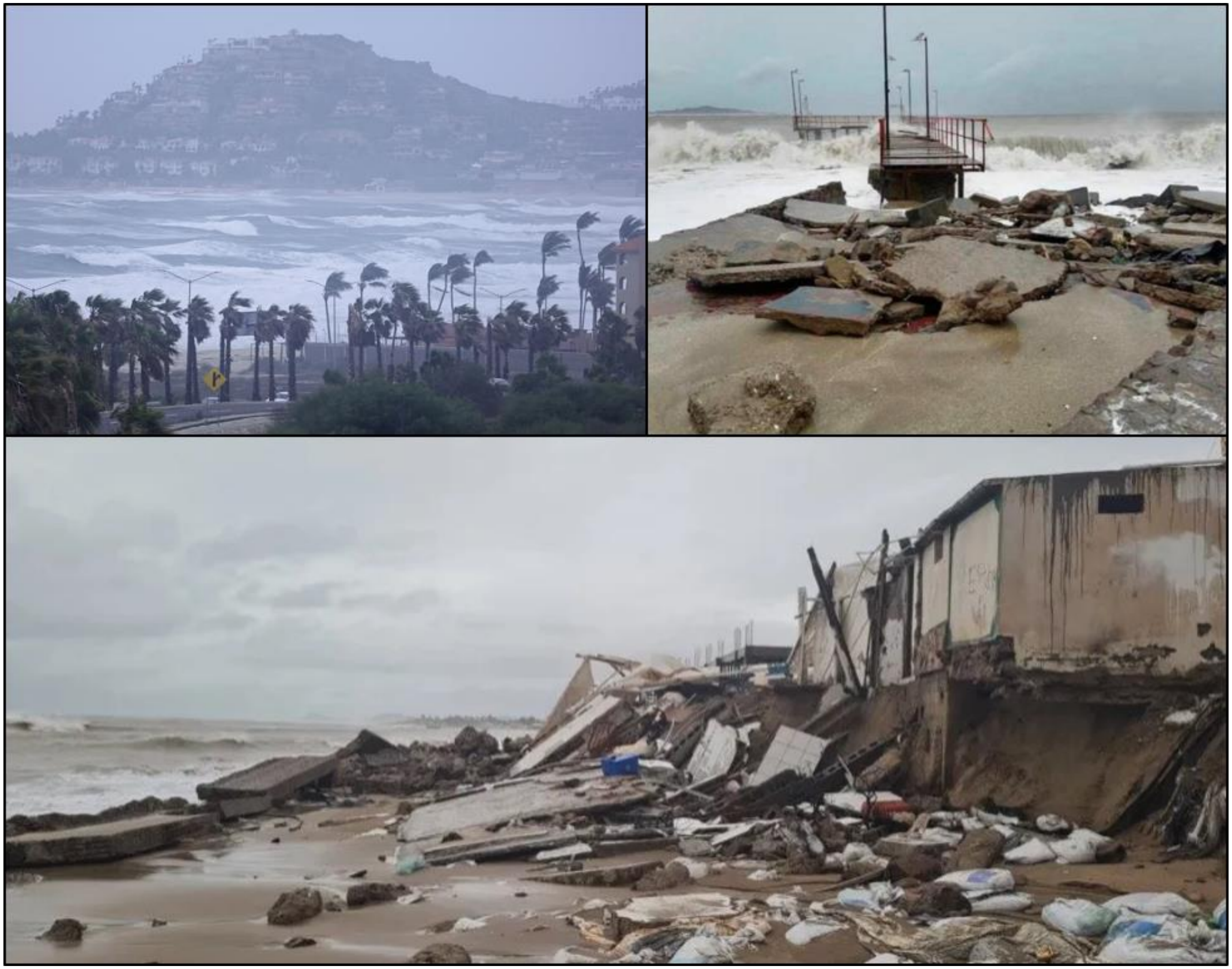

Figure 8. Impacts and damage from large swells associated with Kay. (Top left) Large waves in Los Cabos, Mexico, on 7 September. Image credit: Jorge Reyes / EPA-EFE / Shuttershock. (Top right) Large waves from Kay damaged a pier in Bahía de Kino. Image credit: Daniel Sanchez Dorame / Excelsior. (Bottom) Large waves caused severe damage to some homes along the coast in Bahía de Kino. Image credit: Julian Ortega / El Imparcial.

Figure 9. (Left) Stranded vehicle after a mudslide in Lake Hughes, California, on 11 September. Image credit: Los Angeles County Public Works via Twitter (@LACoPublicWorks). (Right) Flash flooding induced a mudslide that blocked a road in Forest Falls, California. Image courtesy of Gina Ferazzi / Los Angeles Times.

Figure 10. Damage and impacts from post-tropical Kay and its remnants. (Top left) Large waves crash in front of homes along Capistrano Beach in Dana Point, California, on 9 September. Image credit; Paul Bersebach / The Orange County Register via Associated Press (AP). (Top right) Downed tree blocking a road near San Diego, California, on 9 September. Image credit: Nelvin C. Cepada / The San Diego Union-Tribune via AP. (Bottom left) A large mudslide damaged a home in Forest Falls, California, on 12 September. Image credit: Will Lester / Inland Valley Daily Bulletin / SCNG. (Bottom right) Pavement damage to California State Route 190 in Death Valley National Park after flash flooding on 10 September. Image credit: National Park Service.

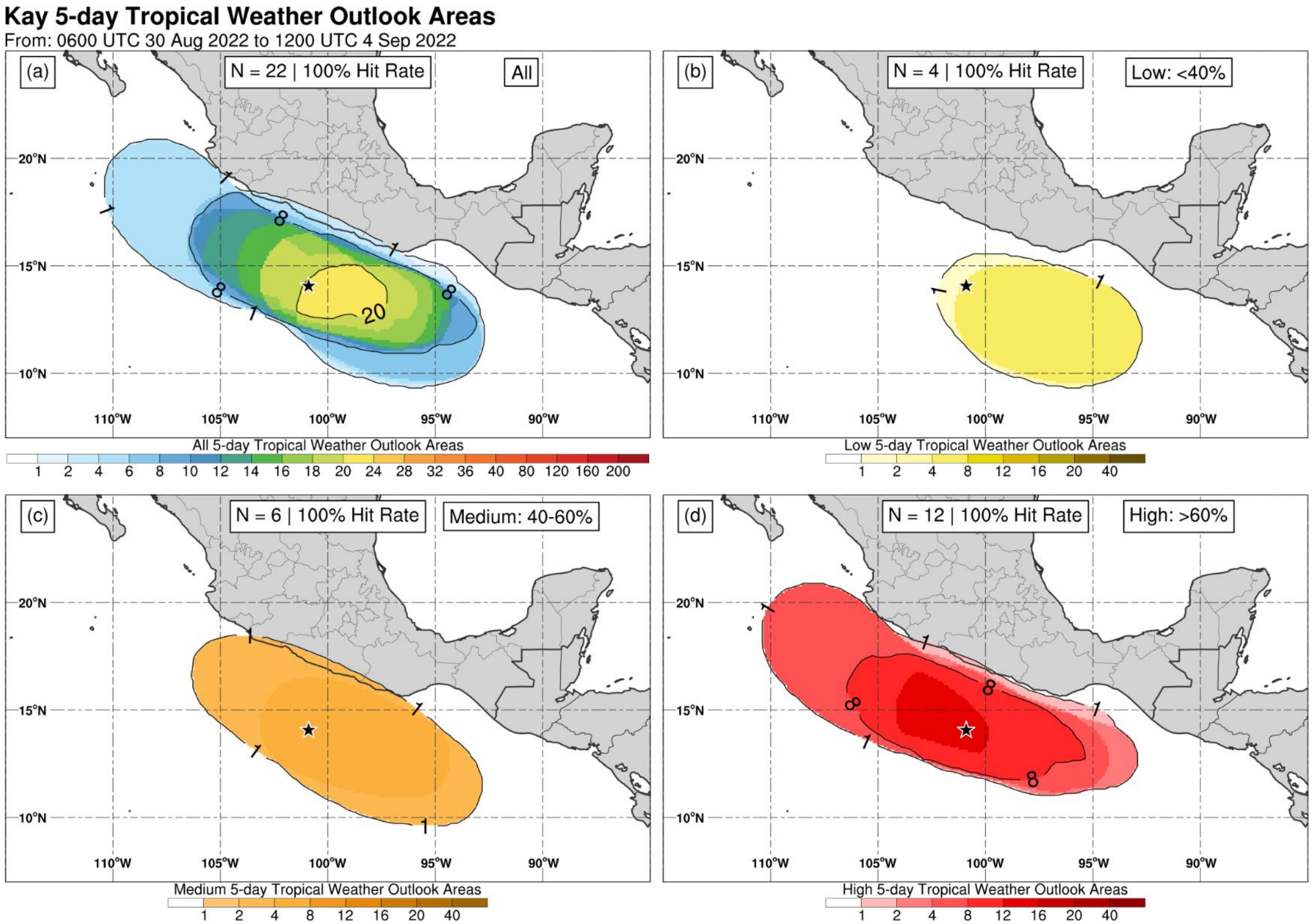

Figure 11. Five-day Tropical Weather Outlook genesis areas associated with the disturbance that developed into Hurricane Kay for (a) all probability areas (10–100%, multi-color shading), (b) low probability areas (< 40%, yellow shading), (c) medium probability areas (40–60%, orange shading), and (d) high probability areas (> 60%, red shading). The black star in each panel indicates the genesis location of Kay. Hit rate indicates the percentage of outlook areas where the genesis location was captured within.

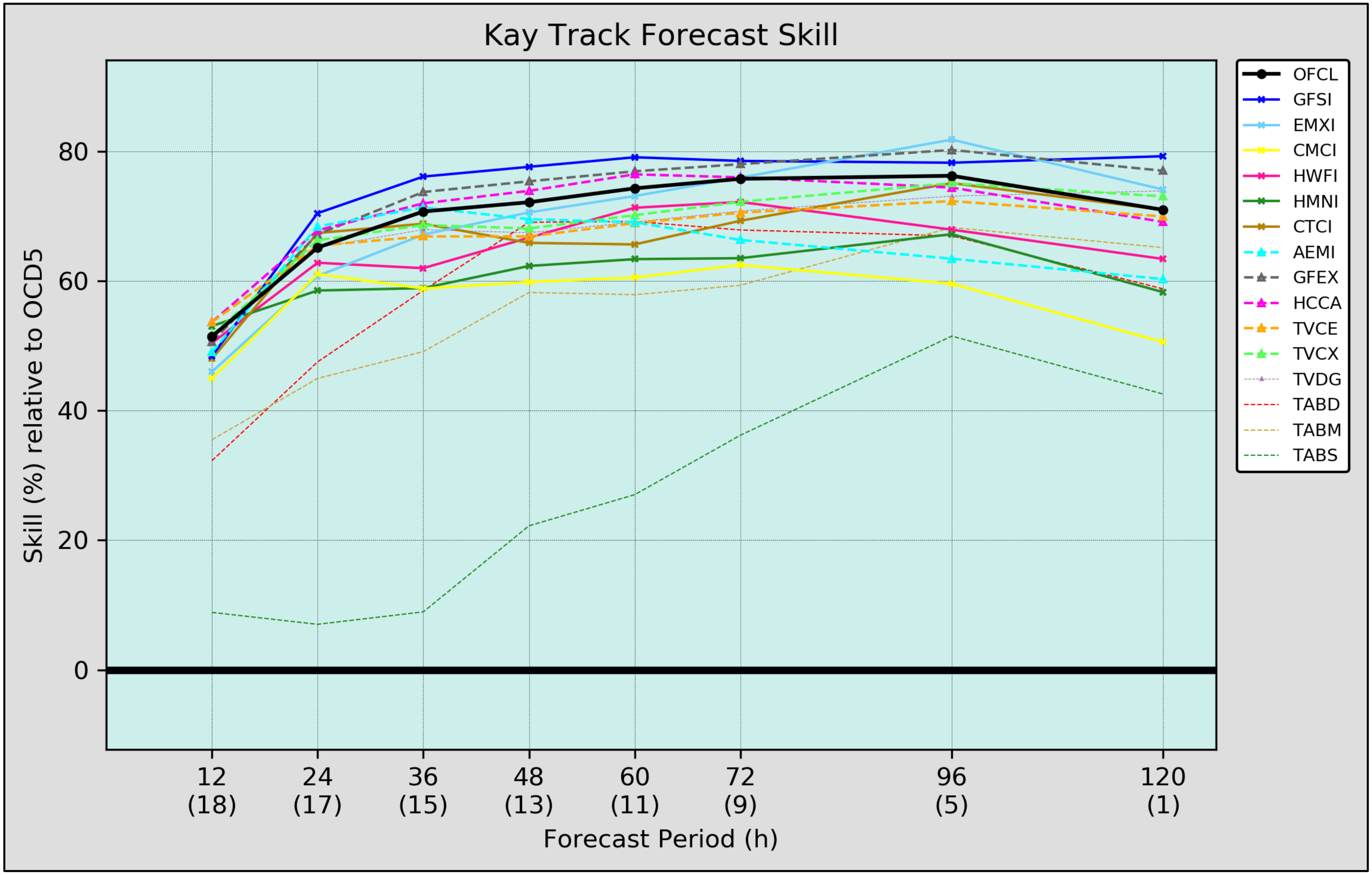

Figure 12. Track forecast skill of the official forecasts and selected models for Hurricane Kay, 4–9 September 2022.

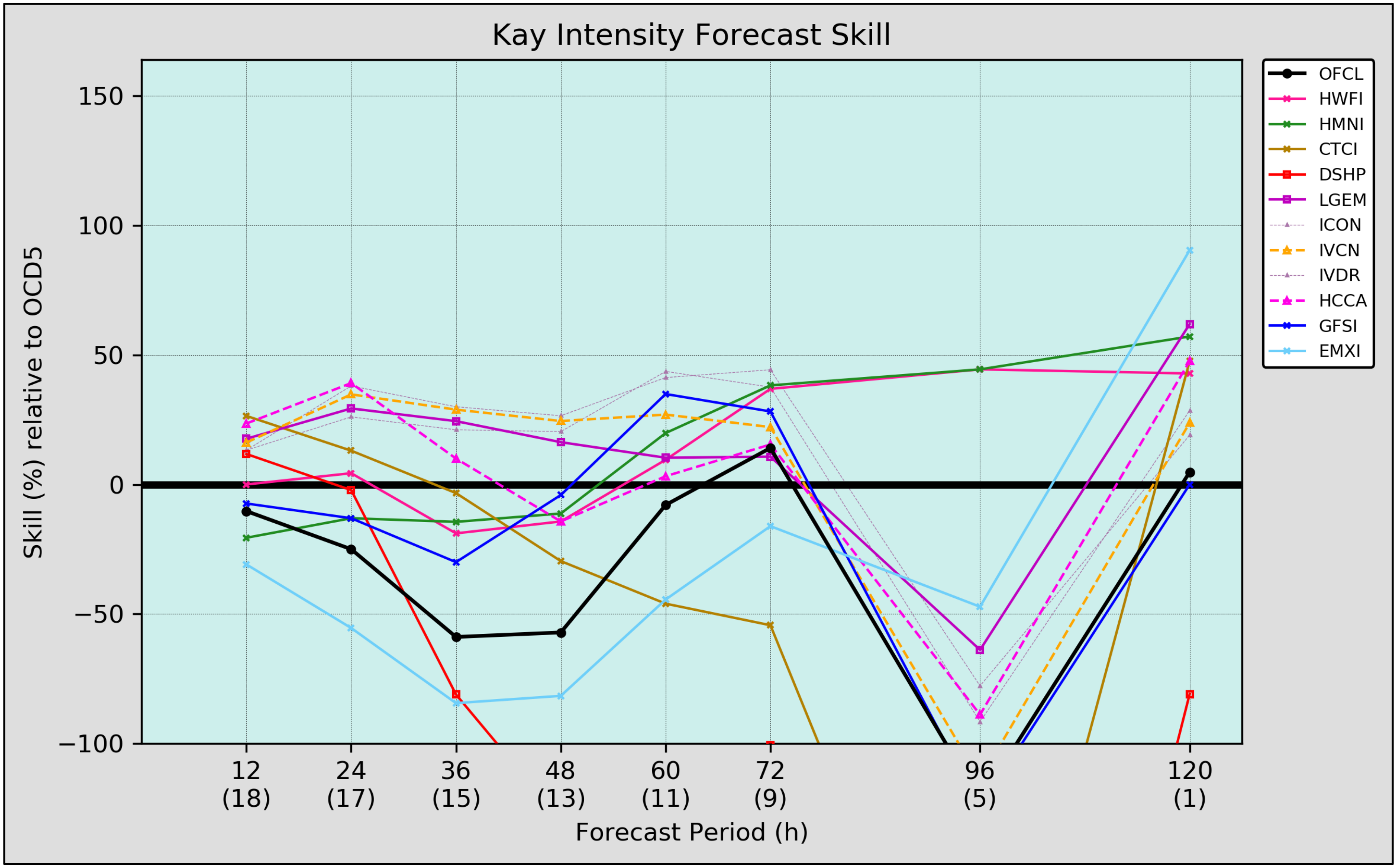

Figure 13. Intensity forecast skill of the official forecasts and selected models for Hurricane Kay, 4–9 September 2022.

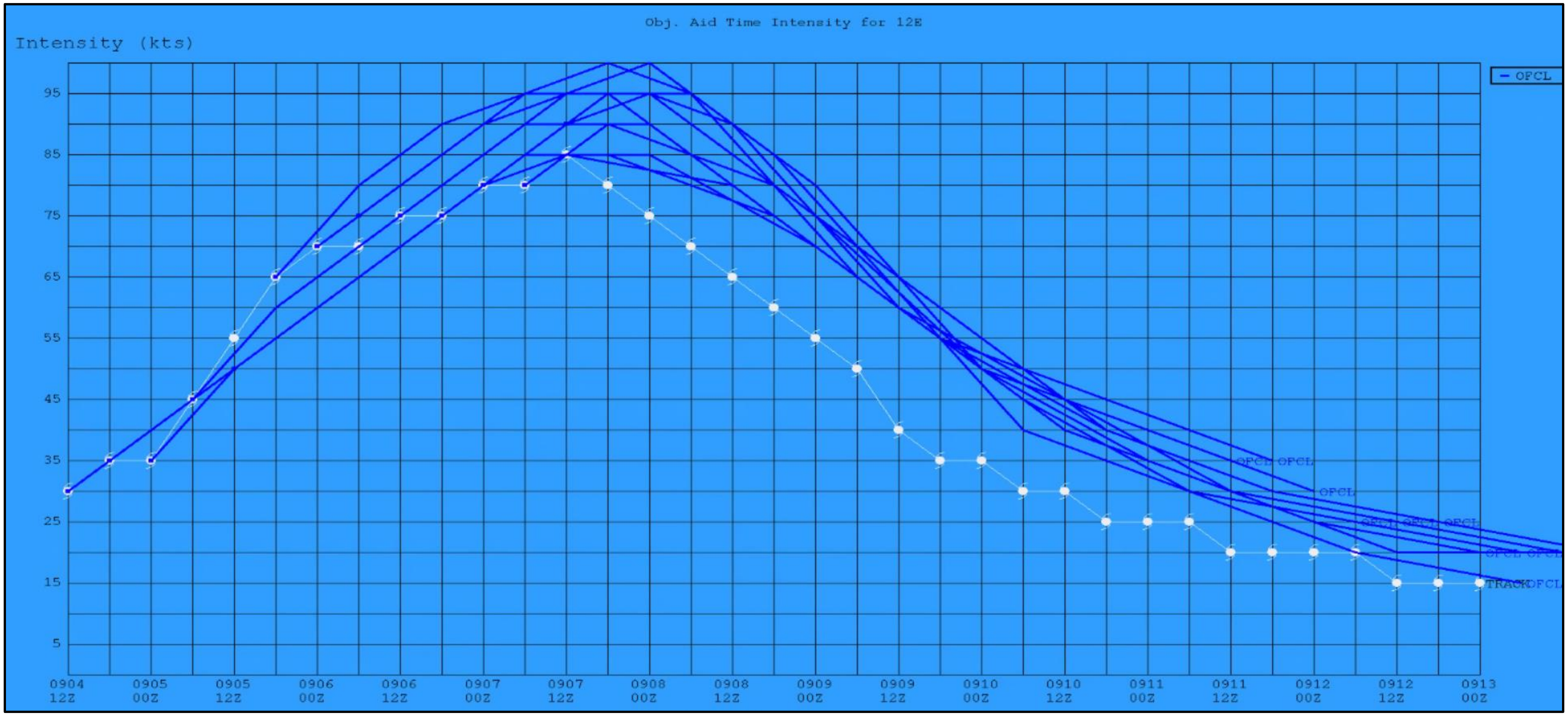

Figure 14. Select official intensity forecasts between 1200 UTC 4 September and 1200 UTC 7 September (solid blue lines, with 0, 12, 24, 36, 48, 60, 72, 96, and 120 h intensities indicated) for Hurricane Kay, 4–9 September 2022. The best track is given by the white solid line with intensities given at 6-h interval.