NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE BONNIE

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1–9 July 2022

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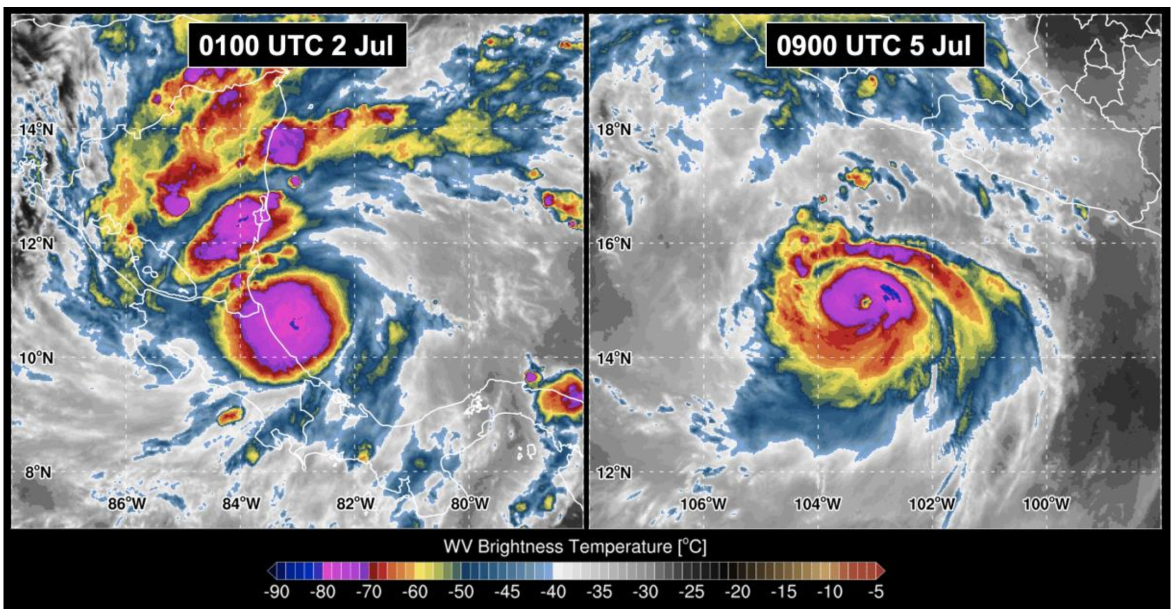

GOES-16 WATER VAPOR IMAGES, SHOWING BONNIE IN THE SOUTHERN CARIBBEAN SEA NEAR LANDFALL ON 2 JULY (LEFT) AND THEN NEAR PEAK INTENSITY IN THE EASTERN PACIFIC ON 5 JULY (RIGHT). DATA USED TO CREATE THESE IMAGES COURTESY OF THE NOAA BIG DATA PROJECT

Hurricane Bonnie was a rare Atlantic-to-Pacific basin-crossing tropical cyclone that developed over the southern Caribbean Sea, made landfall in southern Nicaragua, and then emerged into the far eastern North Pacific. Bonnie reached its peak intensity as a category 3 hurricane (on the Saffir-Simpson Hurricane Wind Scale) over the eastern Pacific south of Mexico. Bonnie caused significant flooding rainfall over Central America and was responsible for 5 deaths, and its precursor disturbance produced gusty winds and heavy rainfall over the Windward Islands and the northern coast of South America.

Hurricane Bonnie

1–9 JULY 2022

SYNOPTIC HISTORY

Bonnie originated from a low-latitude tropical wave that emerged off the coast of Africa on 22 June. The tropical wave was unusually convectively active for late June, and a large, but disorganized, area of showers and thunderstorms was maintained over the next several days as the system moved quickly westward in the trade wind flow. By 27 June, convection increased further, aided by a convectively coupled Kelvin Wave (Fig. 1), and the shower and thunderstorm activity appeared to become better organized near the wave axis. However, a NOAA reconnaissance aircraft on the afternoon of 27 June indicated that, despite the improved convective structure, the tropical wave had not developed a closed circulation. The aircraft did find an area of tropical-storm-force winds along the northern portion of the wave axis around 1800 UTC that day.

Environmental conditions between 28–30 June appeared favorable for development of the wave into a tropical cyclone, with low vertical wind shear and warm sea-surface temperatures (SSTs). However, the system moved quickly westward at 25–30 kt, steered by a climatologically strong low-level ridge, and this fast motion, possibly along with some mid-level shear, likely prevented the development of a closed circulation needed for tropical cyclone formation. During this period, the wave moved into the Caribbean Sea at low latitudes, and heavy rainfall with winds gusting up to tropical storm force affected the Lesser Antilles, spreading across the northern coast of South America. Visible satellite imagery late on 30 June began to show evidence of a developing low-level circulation as the wave's forward motion slowed, yet an Air Force Reserve reconnaissance aircraft was not able to close off a surface circulation at that time. However, surface pressures did fall 3–4 mb by 0000 UTC 1 July while the system entered the southwestern Caribbean Sea. Scatterometer data overnight finally showed evidence of a closed circulation, and Tropical Storm Bonnie is estimated to have developed by 0600 UTC 1 July, about 200 n mi east-southeast of the Columbian island of San Andres. The "best track" chart of Bonnie's path is given in Fig. 2, with the wind and pressure histories shown in Figs. 3 and 4, respectively. The best track positions and intensities are listed in Table 1[1].

Bonnie's forward motion continued to slow down while it turned a little south of due west, as it became steered by a weaker southwest-to-northeast oriented mid-level ridge centered over the Gulf of Mexico. This reduction in forward speed finally allowed the storm to take advantage of the favorable environmental conditions that had been in place, and Air Force reconnaissance aircraft data indicated that Bonnie intensified into a 50-kt tropical storm by 0000 UTC 2 July. Landfall at the same intensity occurred shortly thereafter at 0300 UTC 2 July in extreme southern

[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.

Nicaragua near the border with Costa Rica. Near landfall, Bonnie exhibited an improved structure in both satellite (left cover photo) and radar imagery, with a small formative inner core taking shape. After landfall, Bonnie weakened, but its circulation stayed intact while the storm crossed over Lake Nicaragua and moved back offshore into the far eastern Pacific Ocean by 1200 UTC 2 July (Fig. 5). Bonnie is the first tropical cyclone to maintain its surface circulation across Central America since Hurricane Otto in 2016.

Once back over open water, Bonnie began to slowly reintensify as vertical wind shear stayed low (under 10 kt) and SSTs remained just warm enough (26–27°C) to support intensification. Although Bonnie's structure remained a bit ragged (Fig. 6a), a faster rate of intensification started early on 3 July as SSTs along its track increased to above 28°C. Bonnie also turned west-northwestward by 3 July as the mid-level ridge that was steering it remained parked over the Gulf of Mexico and now was more oriented to the northeast relative to the cyclone. Bonnie steadily intensified, becoming a hurricane by 0000 UTC 4 July, and then 36 h later it peaked as a 100-kt major hurricane at 1200 UTC 5 July, while located about 240 n mi south of Manzanillo, Mexico. Bonnie possessed a small inner core during this period, with a pinhole eye surrounded by a circular central dense overcast as seen in both geostationary and microwave satellite imagery (right cover photo, Fig. 6b). The hurricane wind field also remained quite compact, with tropical-storm-force wind radii never extending beyond 90 n mi to the north of the center.

Bonnie's peak intensity was short lived, as an increase in northerly shear above 15 kt in combination with the start of an eyewall replacement cycle (Fig. 6c) led to gradual weakening. The cyclone weakened to an 80-kt category 1 hurricane by 6 July. Bonnie's forward motion also slowed during this period, as it approached a weakness in the mid-level ridging located to its north over the Baja California peninsula. On 7 July, the shear dropped once again to under 10 kt, and microwave imagery indicated that the eyewall replacement cycle had completed with Bonnie exhibiting a larger closed eyewall (Fig. 6d). In response, Bonnie was able to reintensify slightly by 1800 UTC 7 July. Mid-level ridging also built back to the north of Bonnie during this time frame, and the tropical cyclone started gradually accelerating west-northwestward.

This secondary peak also proved to be transient, as the cyclone soon crossed the 26°C SST isotherm over cooler waters and its convective structure began a pronounced decay. Bonnie weakened below hurricane intensity by 1800 UTC 8 July, and the remaining deep convection near the circulation center dissipated over the following 24 h. The lack of convection by 1800 UTC 9 July resulted in the storm degenerating to a 40-kt post-tropical cyclone when it was located about 1060 n mi west-southwest of the southern tip of the Baja California peninsula. As the system became vertically shallow, it turned westward following the low-level flow as the circulation continued to spin down. The low continued to spin down and finally degenerated into a trough axis by 0600 UTC 11 July, about midway between the Baja California peninsula and the Hawaiian Islands.

METEOROLOGICAL STATISTICS

Observations in Hurricane Bonnie (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 the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command and four flights from the NOAA Aircraft Operations Center, all when Bonnie was still in the Atlantic basin. 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 Bonnie.

Ship reports of winds of tropical storm force associated with Bonnie and its precursor disturbance are given in Table 2.

Winds and Pressure

Bonnie's 100-kt peak intensity in the eastern Pacific at 1200 UTC 5 July is based on a blend of a subjective satellite estimate from TAFB of T5.5/102 kt and objective satellite intensity estimates from SATCON between 95–105 kt around that period. The minimum central pressure of 964 mb is based primarily on the Knaff-Zehr-Courtney pressure-wind relationship, which is a bit higher than average for a category 3 hurricane, due to the estimated small size and tight gradient of Bonnie's wind field at that time.

Bonnie's secondary 85-kt peak at 1800 UTC 7 July and 0000 UTC 8 July is based on a blend of subjective satellite estimates of T5.0/90-kt from SAB and T4.0/65-kt from TAFB. The objective intensity estimates from ADT and SATCON favor the higher end of this intensity range, which is supported by the improved microwave structure observed during this period (Fig. 6d).

Bonnie's peak intensity of 50 kt while over the southeastern Caribbean Sea from 0000 UTC 2 July until landfall at 0300 UTC 2 July is based on aircraft data, with peak 850-mb flight-level winds of 61 kt measured at 0033 UTC 2 July (which reduces to 49 kt), and a peak SFMR wind of 49 kt measured at 0005 UTC 2 July. In addition, a blend of both subjective and objective satellite intensity estimates also supports an intensity around 50 kt during this time frame. Observations were very sparse near the location that Bonnie made landfall, which was in a biological and nature reserve, and as of this writing no surface observations of tropical-storm-force have been reported.

The intensity of the tropical wave that became Bonnie was initially assessed at 35 kt when its axis was still located to the southeast of the Windward Islands on 27 June based on believable SFMR surface winds of 30–35 kt from a NOAA Hurricane Hunter mission that afternoon. Even though it would be three days before the wave would become a tropical storm, wind observations from ships and surface observations over the Lesser Antilles, and several additional aircraft reconnaissance missions, indicate that the wave was able to maintain winds of tropical-storm-force as it moved into the Caribbean Sea. On the island of Grenada, a sustained wind of 35 kt was reported at 2000 UTC 28 June as the pre-Bonnie tropical wave moved across. In addition, a gust to 34 kt was reported at Scarborough in Trinidad and Tobago at 1817 UTC 28 June.

Rainfall and Flooding

Bonnie was responsible for significant flooding due to heavy rainfall that was observed in Nicaragua, Costa Rica, and El Salvador as the storm moved over the region on 2 July (Fig. 7). Detailed rainfall observations were available from Costa Rica, including a large area of 6 to 10 inches (150–250 mm) occurring along the northwestern coast of Costa Rica closest to where Bonnie's center traversed. General totals of 2 to 4 inches (50–100 mm) were reported over most of the country. Heavy rainfall also occurred in Nicaragua and El Salvador though detailed rainfall totals in these countries is not available as of the writing of this report.

CASUALTY AND DAMAGE STATISTICS

There were 5 direct deaths[2] associated with Bonnie, primarily due to heavy rainfall as it moved over Central America. Four of those deaths occurred in Nicaragua mainly due to people being swept away and drowning in rising rivers which had overflowed their banks, one of which died while attempting to save other passengers from a bus that had been swept away by floodwaters. Another fatality was reported in El Salvador, and there is still one missing person who has not been accounted for as of the writing of this report. In Costa Rica, more than 3,000 people were evacuated due to flooding and mudslides caused by Bonnie. More than 10,000 people were reported to have lost power in Nicaragua as well.

Monetary damage estimates are currently estimated to be more than 25 million (U.S.) dollars in damage, per a global catastrophe report from Aon, primarily due to flooding rainfall in Nicaragua, El Salvador, and Costa Rica. The pre-Bonnie tropical wave resulted in more modest impacts in Trinidad and Tobago, though at least 40 homes were flooded in a village along Grande Riviere, and nearly 200,000 customers nationwide lost clean drinking water due to storm impacts affecting water treatment facilities.

FORECAST AND WARNING CRITIQUE

Bonnie's genesis forecast was problematic, mainly due to the storm taking much longer to develop than initially anticipated, which led to an unusually long period of advisories as a

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[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.

Potential Tropical Cyclone. The wave from which Bonnie developed was first introduced in the 5-day Tropical Weather Outlook with a low chance (<40%) of development more than a week (186 h) prior to genesis at 1200 UTC 23 June (Table 3). The 5-day probabilities were increased to the medium (40–60%) category 174 h and then high (>60%) 120 h before the system ultimately developed. In a similar fashion, the 2-day probabilities were introduced well before Bonnie developed, with the low, medium, and high categories designated 174 h, 120 h, and 96 h before formation, respectively. Not surprisingly, the genesis area the 5-day outlooks depicted was located too far to the east with an overall hit rate of only 22%, and the highest concentration of outlooks were centered to the east of the Windward Islands (Fig. 8). Notably, the ECMWF (Fig. 9a–c) was consistently forecasting Bonnie to develop a closed circulation with near tropical-storm-force winds before reaching the Windward Islands on 28 June**.** Because the pre-Bonnie disturbance was initially expected to become a tropical cyclone before reaching the Windward Islands, NHC initiated Potential Tropical Cyclone advisories at 2100 UTC 27 June when the government of Trinidad and Tobago issued a Tropical Storm Warning for Trinidad, Tobago, and Grenada. Although the disturbance did not become a tropical cyclone before it impacted the Windward Islands and northern South America (Fig. 9d), the Potential Tropical Cyclone advisories and associated watches and warnings likely heightened the awareness of the wind and rainfall impacts from this system.

Since NHC's verification requires the system to be classified as a tropical cyclone at both the forecast's initial time and the projection's valid time, the first three days of forecasts of Bonnie while it was a Potential Tropical Cyclone are not included in the verification statistics below. In addition, while Bonnie initially developed in the Atlantic basin, the vast majority of forecasts were made while the storm was a tropical cyclone in the eastern Pacific basin, so the mean official errors use the 5-yr eastern Pacific averages.

A verification of NHC official track forecasts for Hurricane Bonnie is given in Table 4a. Official track forecast errors for Bonnie were lower than the mean official errors at all forecast times for a healthy sample size. The climatology and persistence (OCD5) model errors were somewhat lower than the 5-yr averages at all forecast times, suggesting that the track of Bonnie was easier than usual to predict at all forecast lead times.

A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. For the deterministic track guidance, only the ECMWF (EMXI) preformed slightly better than the NHC official forecast at 12, 24, and 120 h, while the HMON (HMNI) outperformed the official forecast at 96–120 h. The consensus track guidance fared a bit better with the Florida State Superensemble (FSSE), in addition to aids TCVX and TVDG, generally outperforming the official forecast for a larger set of forecast lead times. Of note, the HFIP Corrected Consensus Approach (HCCA) was unavailable for most forecast periods with Bonnie due to computational issues related to the tropical cyclone crossing into the eastern Pacific basin.

A verification of NHC official intensity forecasts for Bonnie is given in Table 5a. Official intensity forecast errors were lower than the mean official errors for the previous 5-yr period at all forecast lead times. However, OCD5 intensity errors were also lower than the 5-yr averages, suggesting that, like the track, Bonnie's intensity was easier than usual to forecast.

A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. Once again, there was not a whole lot of deterministic intensity guidance that outperformed the NHC intensity forecast, with only a few forecast time periods from the HWRF (HWFI), DSHP, and LGEM showing slightly lower intensity errors. However, the consensus aids FSSE, ICON, and IVCN did outperform the NHC intensity forecast at a few particular lead times (24 h, 60–96 h).

Coastal watches and warnings associated with Bonnie are given in Table 6. Note that although Bonnie did not become a tropical cyclone until it reached the southwestern Caribbean Sea, the pre-Bonnie tropical wave, as it moved across the Lesser Antilles, did bring gusts up to tropical-storm-force and heavy rainfall at locations across the Lesser Antilles where tropical storm warnings were in place.

Table 1. Best track for Hurricane Bonnie, 1–9 July 2022.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
27 / 1800	8.3	50.5	1009	35	disturbance
28 / 0000	8.7	52.2	1009	35	"
28 / 0600	9.1	54.2	1009	35	"
28 / 1200	9.6	56.5	1009	35	"
28 / 1800	10.2	58.9	1009	35	"
29 / 0000	10.7	61.6	1009	35	"
29 / 0600	11.1	64.0	1009	35	"
29 / 1200	11.4	66.2	1009	35	"
29 / 1800	11.7	68.0	1009	35	"
30 / 0000	11.9	69.7	1009	35	"
30 / 0600	12.0	71.4	1009	35	"
30 / 1200	12.0	73.1	1008	35	"
30 / 1800	12.0	74.9	1007	35	"
01 / 0000	11.9	76.7	1005	35	"
01 / 0600	11.6	78.5	1005	35	tropical storm
01 / 1200	11.3	80.2	1005	35	"
01 / 1800	11.2	81.8	1004	40	"
02 / 0000	10.9	83.1	996	50	"
02 / 0300	11.0	83.8	996	50	"
02 / 0600	11.1	84.5	1000	40	"
02 / 1200	11.2	85.9	1002	35	"
02 / 1800	11.2	87.4	999	45	"
03 / 0000	11.2	88.9	997	50	"
03 / 0600	11.5	90.4	997	50	"
03 / 1200	11.8	91.9	995	55	"
03 / 1800	12.2	93.4	993	60	"
04 / 0000	12.9	94.9	989	65	hurricane
04 / 0600	13.4	96.6	987	70	"
04 / 1200	13.6	98.2	984	75	"
04 / 1800	13.8	99.6	978	85	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
05 / 0000	14.4	100.9	974	90	"
05 / 0600	14.9	102.4	968	95	"
05 / 1200	15.1	103.8	964	100	"
05 / 1800	15.4	105.1	967	95	"
06 / 0000	15.6	106.4	970	90	"
06 / 0600	15.8	107.6	974	85	"
06 / 1200	16.0	108.5	975	85	"
06 / 1800	16.3	109.5	975	85	"
07 / 0000	16.6	110.6	980	80	"
07 / 0600	16.9	111.8	980	80	"
07 / 1200	17.2	113.1	980	80	"
07 / 1800	17.5	114.5	976	85	"
08 / 0000	17.8	116.1	976	85	"
08 / 0600	18.0	117.7	982	75	"
08 / 1200	18.2	119.3	989	65	"
08 / 1800	18.6	121.0	998	55	tropical storm
09 / 0000	19.0	122.8	1001	50	"
09 / 0600	19.2	124.7	1002	45	"
09 / 1200	19.4	126.6	1005	40	"
09 / 1800	19.5	128.6	1008	40	low
10 / 0000	19.6	130.5	1008	35	"
10 / 0600	19.5	132.3	1008	35	"
10 / 1200	19.4	134.0	1008	30	"
10 / 1800	19.4	135.5	1010	25	"
11 / 0000	19.4	136.9	1010	25	"
11 / 0600					dissipated
05 / 1200	15.1	103.8	964	100	Maximum wind and minimum pressure
02 / 0300	11.0	83.8	996	50	Landfall in southern Nicaragua (10 n mi northwest of the Nicaragua/Costa Rica border)

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Bonnie, 1–9 July 2022.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
27 / 1500	VRSG9	7.9	52.1	090 / 35	1010.0
29 / 0800	VRRX9	14.5	66.1	060 / 37	1015.0

Table 3. 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%)	174	186
Medium (40%-60%)	120	174
High (>60%)	96	120

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Bonnie, 1–9 July 2022. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	**18.9**	**25.1**	**33.7**	**40.0**	**47.3**	**56.0**	**88.3**	**117.7**
OCD5	33.6	63.1	101.5	133.0	159.5	184.0	256.8	347.3
Forecasts	32	30	28	26	24	22	18	14
OFCL (2017-21)[3]	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

[3] 5-yr means are based on the eastern Pacific averages.

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Bonnie, 1–9 July 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 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	18.6	23.7	30.4	35.0	41.0	48.2	88.4	122.1
OCD5	34.4	63.4	98.7	125.7	157.8	180.2	252.7	350.3
GFSI	19.9	32.6	46.5	58.8	70.2	84.4	126.4	204.1
EMXI	**18.2**	**23.3**	32.7	39.3	46.4	62.2	106.5	**116.6**
CMCI	19.9	33.6	53.5	72.2	93.0	107.5	142.1	172.0
NVGI	24.8	41.4	53.0	69.4	86.7	107.9	125.3	126.9
HWFI	26.8	41.0	52.0	57.7	63.4	73.9	118.0	173.8
HMNI	22.4	31.2	44.3	54.6	64.1	65.2	**73.0**	**93.7**
CTCI	22.1	37.3	56.8	73.4	87.8	100.2	145.1	176.3
FSSE	**17.5**	**23.0**	**29.3**	**33.8**	42.9	49.4	**83.2**	**110.7**
AEMI	20.3	31.6	45.1	57.5	69.8	86.8	135.9	206.8
GFEX	**18.1**	**23.0**	31.4	42.0	52.2	65.0	108.9	150.9
TVCE	**18.3**	23.7	32.5	37.2	42.3	**47.3**	**80.2**	**118.2**
TVCX	**17.3**	**22.8**	31.0	**34.9**	41.1	48.2	**87.3**	124.6
TVDG	**18.2**	**22.4**	30.5	**34.2**	**39.2**	**45.2**	**77.9**	**122.0**
TABS	40.9	93.6	152.7	209.9	261.6	316.8	424.3	547.6
TABM	29.9	57.8	89.6	119.0	142.8	166.8	214.2	245.0
TABD	27.5	52.6	83.5	115.1	146.3	179.9	260.6	352.4
Forecasts	28	26	24	22	21	19	15	11

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Bonnie, 1–9 July 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	**4.2**	**7.0**	**7.0**	**7.7**	**9.6**	**11.8**	**15.6**	**12.5**
OCD5	5.8	8.4	9.6	9.8	12.5	15.0	19.8	21.3
Forecasts	32	30	28	26	24	22	18	14
OFCL (2017-21)[4]	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

[4] 5-yr means are based on the eastern Pacific averages.

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Bonnie, 1–9 July 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	4.3	7.1	7.1	7.5	8.8	11.1	13.7	12.7
OCD5	5.6	8.6	9.9	9.1	10.8	12.8	15.6	16.4
HWFI	8.8	9.9	9.8	8.2	**6.9**	**10.3**	19.0	34.3
HMNI	6.1	8.2	9.9	13.6	14.3	12.7	23.9	32.4
CTCI	7.7	10.1	12.8	14.4	15.4	15.8	17.9	20.0
DSHP	5.2	**6.7**	7.8	8.9	10.2	12.7	**13.5**	**12.6**
LGEM	5.8	8.2	9.8	10.3	**8.6**	**8.6**	**8.5**	**10.1**
ICON	6.0	**6.9**	7.4	**6.7**	**6.2**	**8.7**	**13.5**	18.8
IVCN	5.8	**6.8**	7.4	7.5	**6.9**	**7.9**	**12.1**	18.1
IVDR	6.5	7.4	8.3	8.6	**8.0**	**8.3**	13.9	19.1
FSSE	5.6	**5.8**	**7.0**	8.3	**7.2**	**7.5**	**13.4**	17.1
GFSI	8.7	10.9	13.4	15.2	17.1	17.8	22.8	21.0
EMXI	6.3	9.1	11.5	14.0	17.6	21.2	21.9	19.1
CMCI	7.5	11.7	15.3	16.6	19.9	22.7	23.7	18.6
NVGI	7.9	10.5	11.2	13.0	16.1	18.8	19.5	15.5
Forecasts	28	26	24	22	21	19	15	11

Table 6. Watch and warning summary for Hurricane Bonnie, 1–9 July 2022.

Date/Time (UTC)	Action	Location
27 / 2100	Tropical Storm Warning issued	Trinidad, Tobago, and Grenada
28 / 0300	Tropical Storm Watch issued	Bonaire
28 / 0300	Tropical Storm Watch issued	Islas de Margarita, Coche, Cubagua
28 / 0300	Tropical Storm Watch issued	Pedernales to Cumana
28 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Bonaire
28 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Islas de Margarita, Coche, Cubagua
28 / 1500	Tropical Storm Warning issued	Curacao and Aruba
28 / 2100	Tropical Storm Watch issued	Peninsula de Paraguana to Columbia/Venezuela border
28 / 2100	Tropical Storm Watch issued	Columbia/Venezuela border to Santa Marta
29 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Peninsula de Paraguana to Columbia/Venezuela border
29 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Columbia/Venezuela border to Santa Marta
29 / 0300	Tropical Storm Warning discontinued	Trinidad and Tobago
29 / 0900	Tropical Storm Warning discontinued	Grenada
29 / 1500	Tropical Storm Watch discontinued	Pedernales to Cumana
29 / 1500	Tropical Storm Warning discontinued	Islas de Margarita, Coche, Cubagua
29 / 2100	Tropical Storm Watch issued	Laguna de Perlas to Sandy Bay Sirpi, Nicaragua
29 / 2100	Tropical Storm Watch issued	Limon to Nicaragua/Costa Rica border
29 / 2100	Hurricane Watch issued	Nicaragua/Costa Rica border to Laguna de Perlas, Nicaragua
30 / 0000	Tropical Storm Warning discontinued	Bonaire
30 / 0300	Tropical Storm Warning discontinued	Curacao and Aruba

Date/Time (UTC)	Action	Location
30 / 0900	Tropical Storm Warning issued	San Andres
30 / 1200	Tropical Storm Warning discontinued	Peninsula de Paraguana to Columbia/Venezuela border
30 / 1200	Tropical Storm Warning discontinued	Columbia/Venezuela border to Santa Marta
30 / 1500	Tropical Storm Watch issued	Cabo Blanco, Costa Rica to Puerto Sandino, Nicaragua
30 / 1500	Tropical Storm Warning issued	Limon, Costa Rica to Sandy Bay Sirpi, Nicaragua
1 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Cabo Blanco, Costa Rica to Puerto Sandino, Nicaragua
1 / 1500	Tropical Storm Warning issued	Puerto Sandino, Nicaragua to Nicaragua/Honduras border
1 / 1500	Hurricane Watch discontinued	All
2 / 0300	Tropical Storm Warning discontinued	San Andres
2 / 1500	Tropical Storm Warning discontinued	Limon, Costa Rica to Sandy Bay Sirpi, Nicaragua
2 / 2100	Tropical Storm Warning discontinued	All

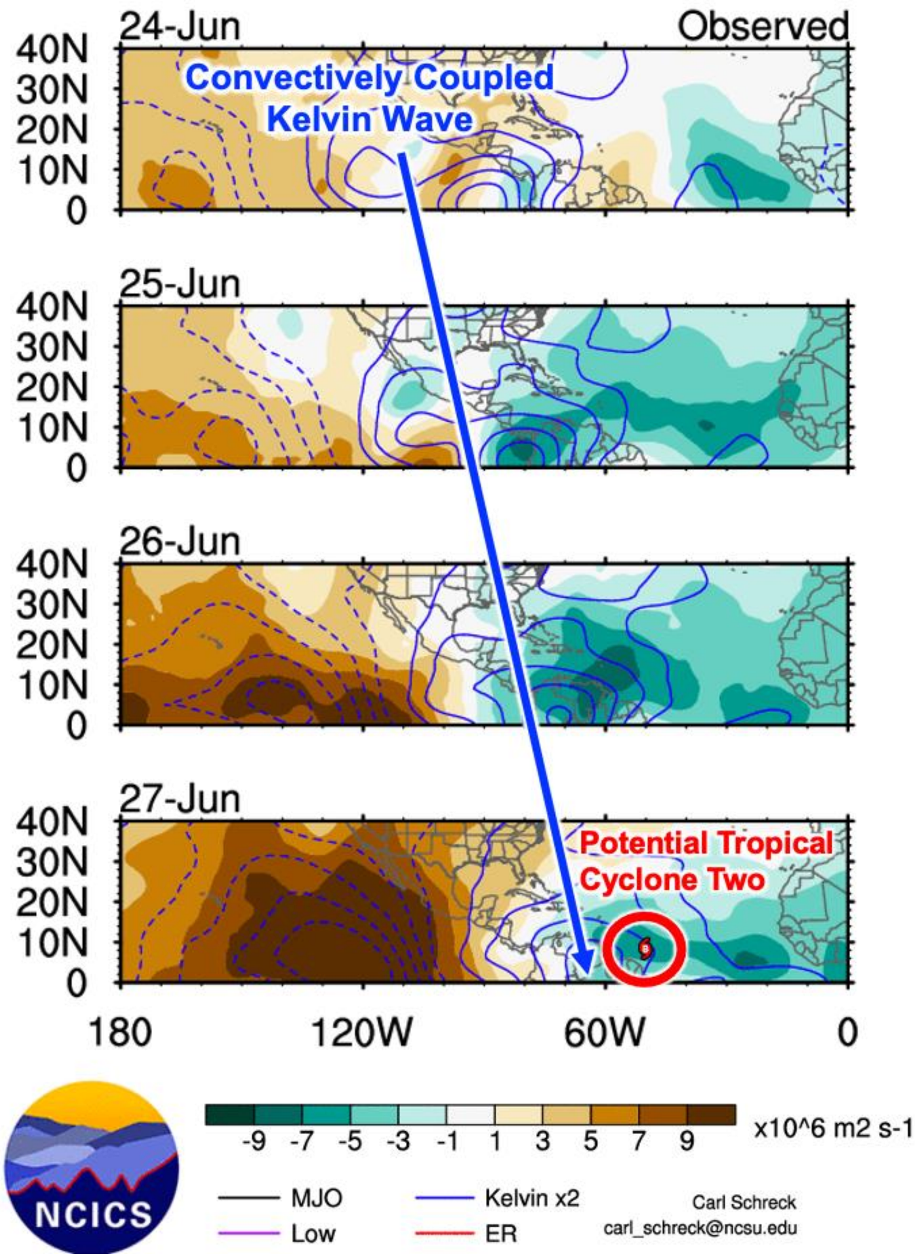

Figure 1. CFS model analysis unfiltered Velocity Potential Anomalies at 200 mb (shaded, x10^6 m^2 s^{-1}) over the Western Hemisphere covering the Atlantic basin from 24–27 June 2022, where green (brown) shading shows areas of upward (downward) motion favored by the upper-level velocity potential field. Blue solid (dashed) contours indicate where the velocity potential has been filtered for upward (downward) motion associated with Kelvin Waves, with annotations highlighting where a convectively coupled Kelvin Wave moved eastward and enhanced upward vertical motion near the pre-Bonnie tropical wave (Potential Tropical Cyclone Two). Image has been adapted from Carl Schreck of North Carolina Institute for Climate Studies, accessible at https://ncics.org/portfolio/monitor/mjo.

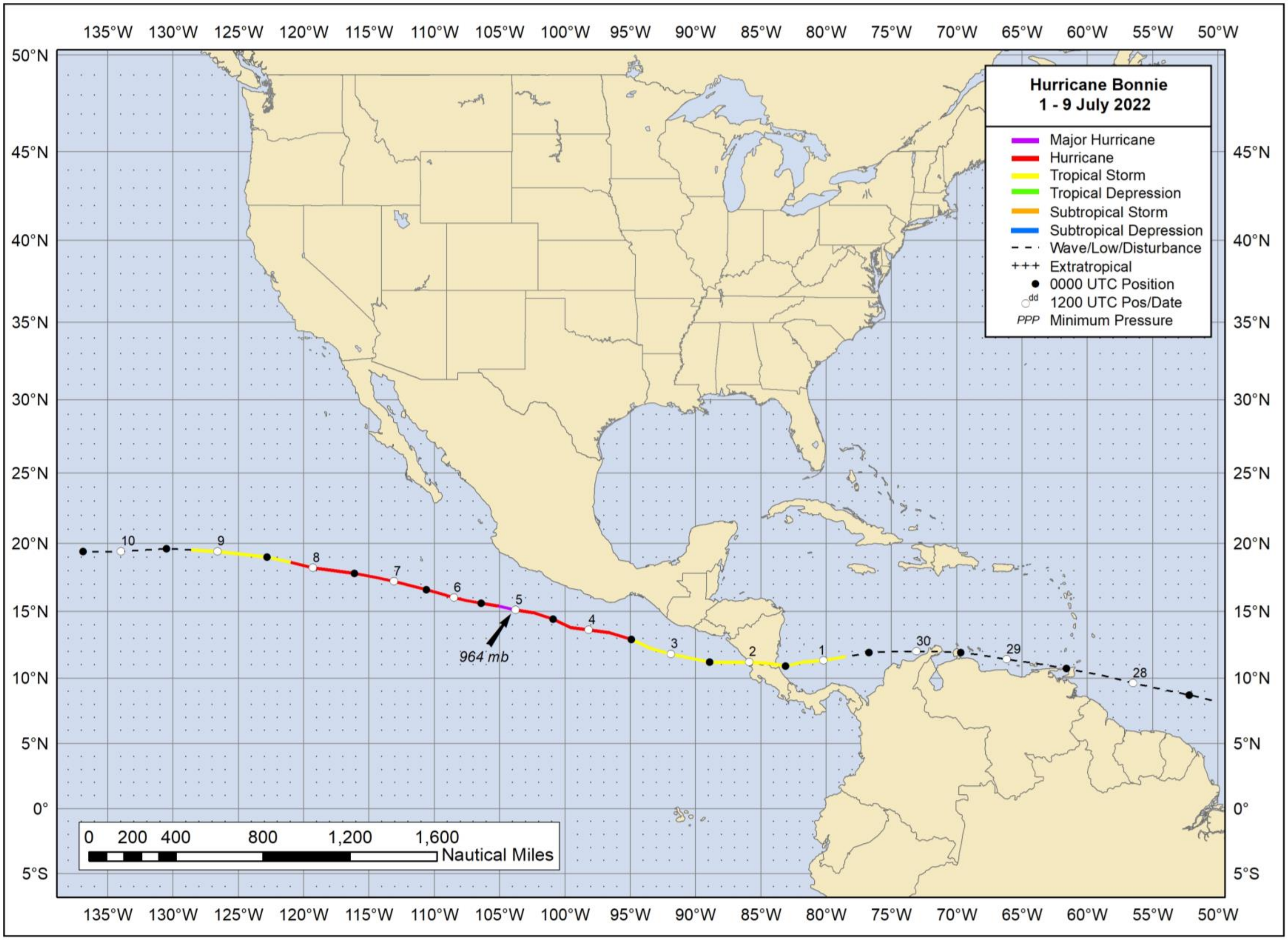

Figure 2. Best track positions for Hurricane Bonnie, 1–9 July 2022.

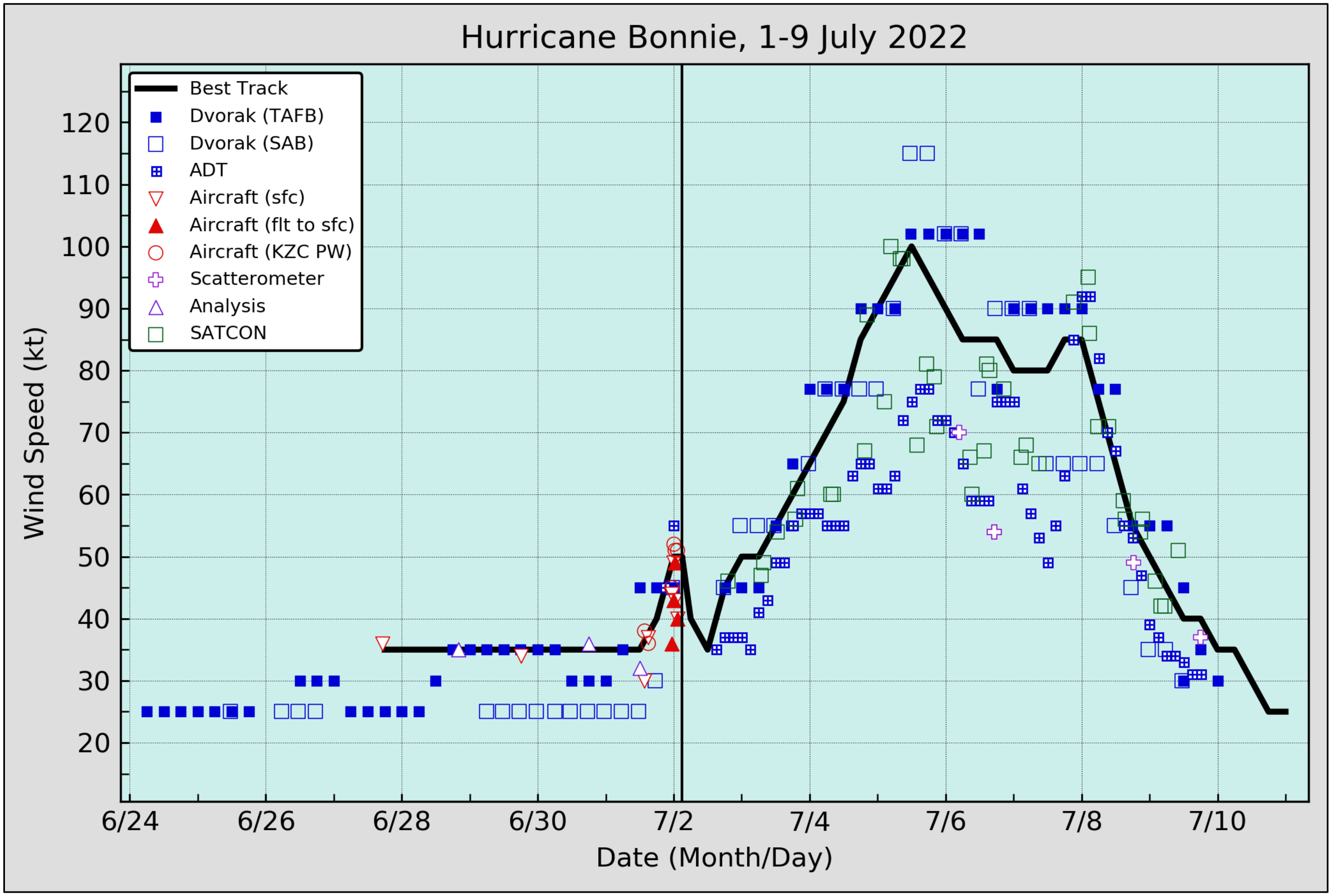

Figure 3. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Bonnie, 1–9 July 2022. Aircraft observations have been adjusted for elevation using 90%, 80%, and 75% adjustment factors for observations from 700 mb, 850 mb, and 925 mb, respectively. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

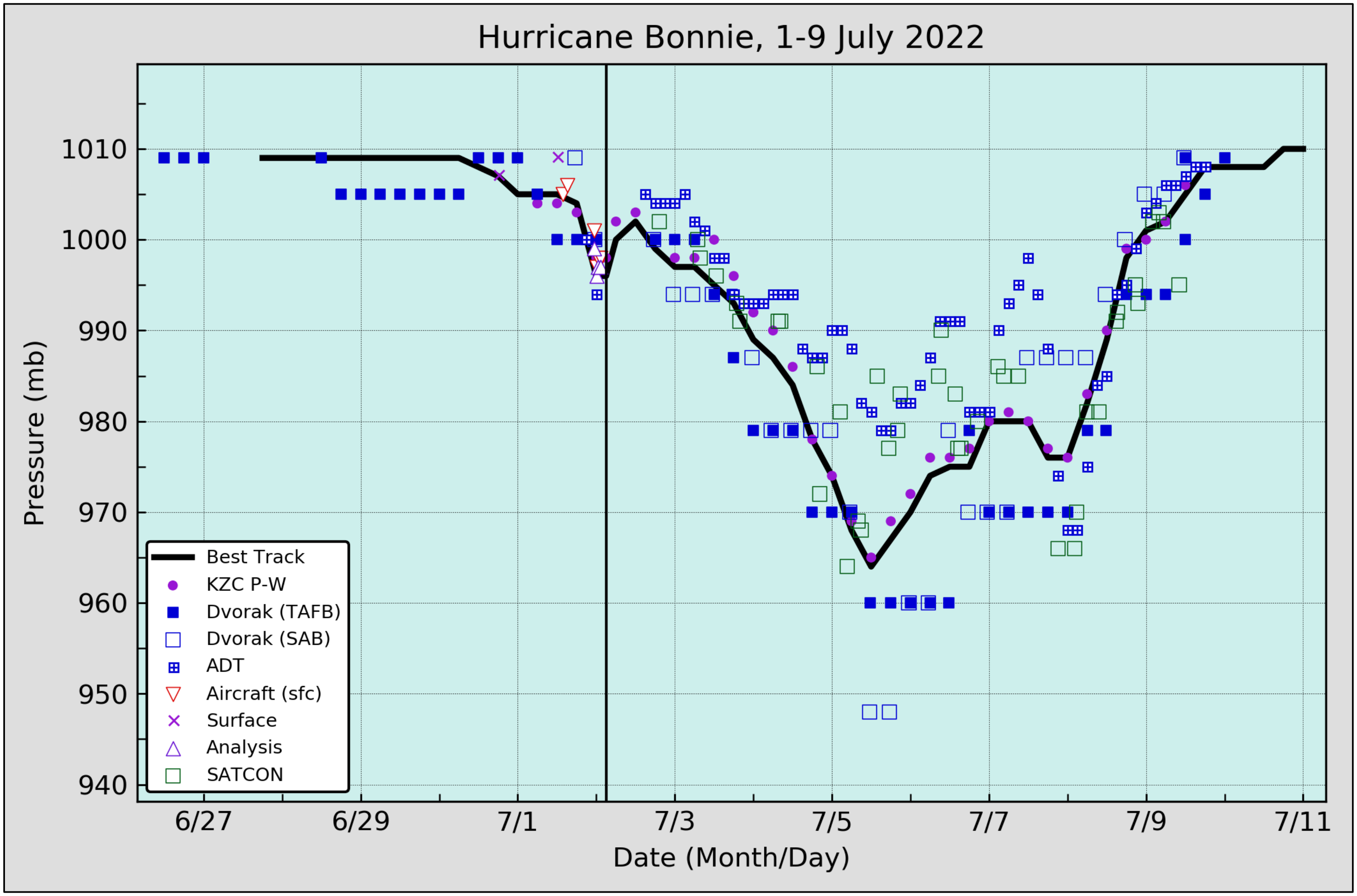

Figure 4. Selected pressure observations and best track minimum central pressure curve for Hurricane Bonnie, 1–9 July 2022. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

Figure 5. Radar reflectivity data from the Las Nubes, Nicaragua, radar valid at 1210 UTC 2 July 2022 as Bonnie was emerging from Central America over the far eastern Pacific Ocean. Note that the core of the tropical cyclone was largely intact as it moved back over open waters. Image courtesy the Nicaragua Institute of Territorial Studies.

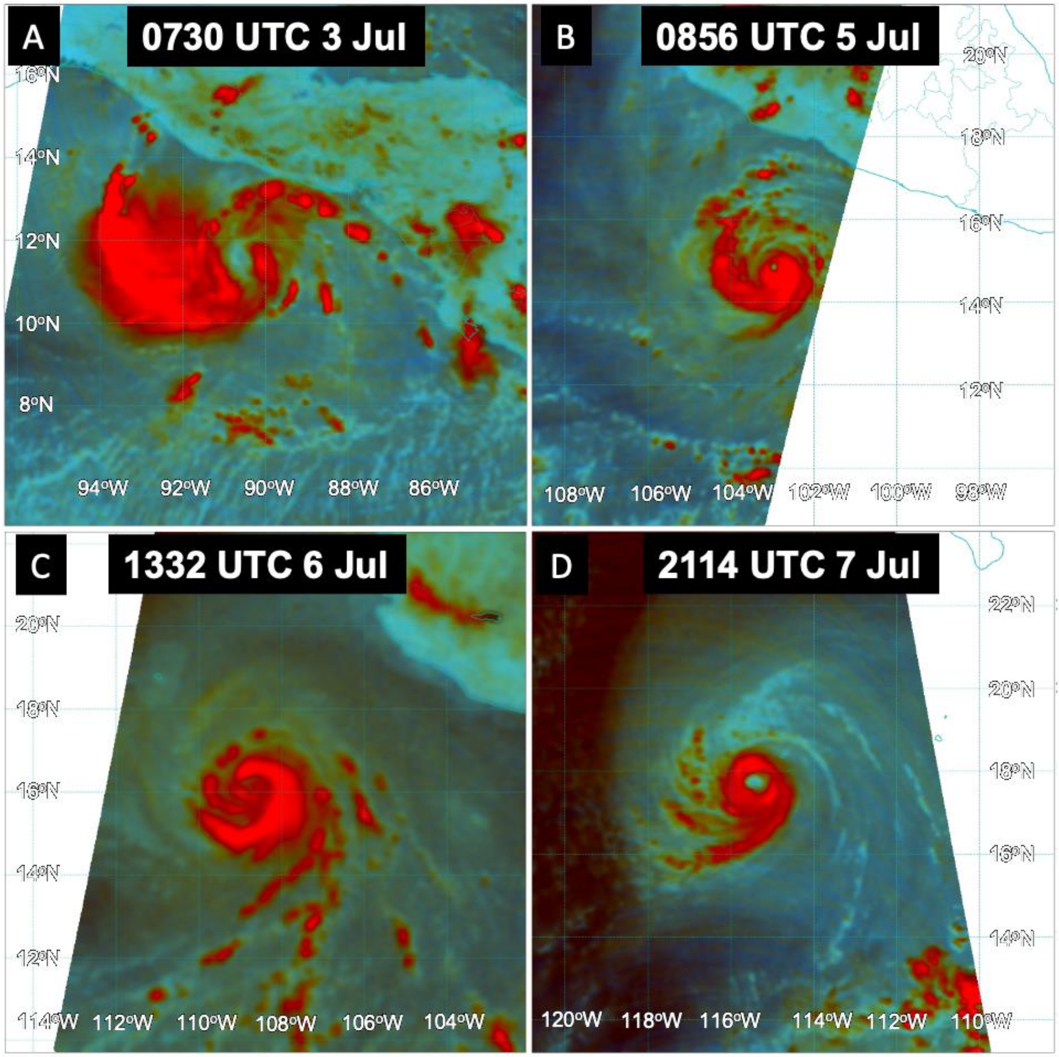

Figure 6. Passive microwave satellite 89–91-GHz color composite imagery showing Bonnie's structural evolution from 3–7 July 2022. (a) 0730 UTC 3 July AMSR2 pass showing Bonnie as a tropical storm slowly intensifying. (b) 0856 UTC AMSR2 pass depicting Bonnie near peak intensity with a small eye signature with surrounding single eyewall. (c) 1332 UTC 6 July SSMIS pass showing Bonnie weakening as it underwent structural changes related to an eyewall replacement cycle and dry air intrusion. (d) 2114 UTC 7 July AMSR2 pass showing a reorganized Bonnie with a larger closed eyewall corresponding to its secondary peak.

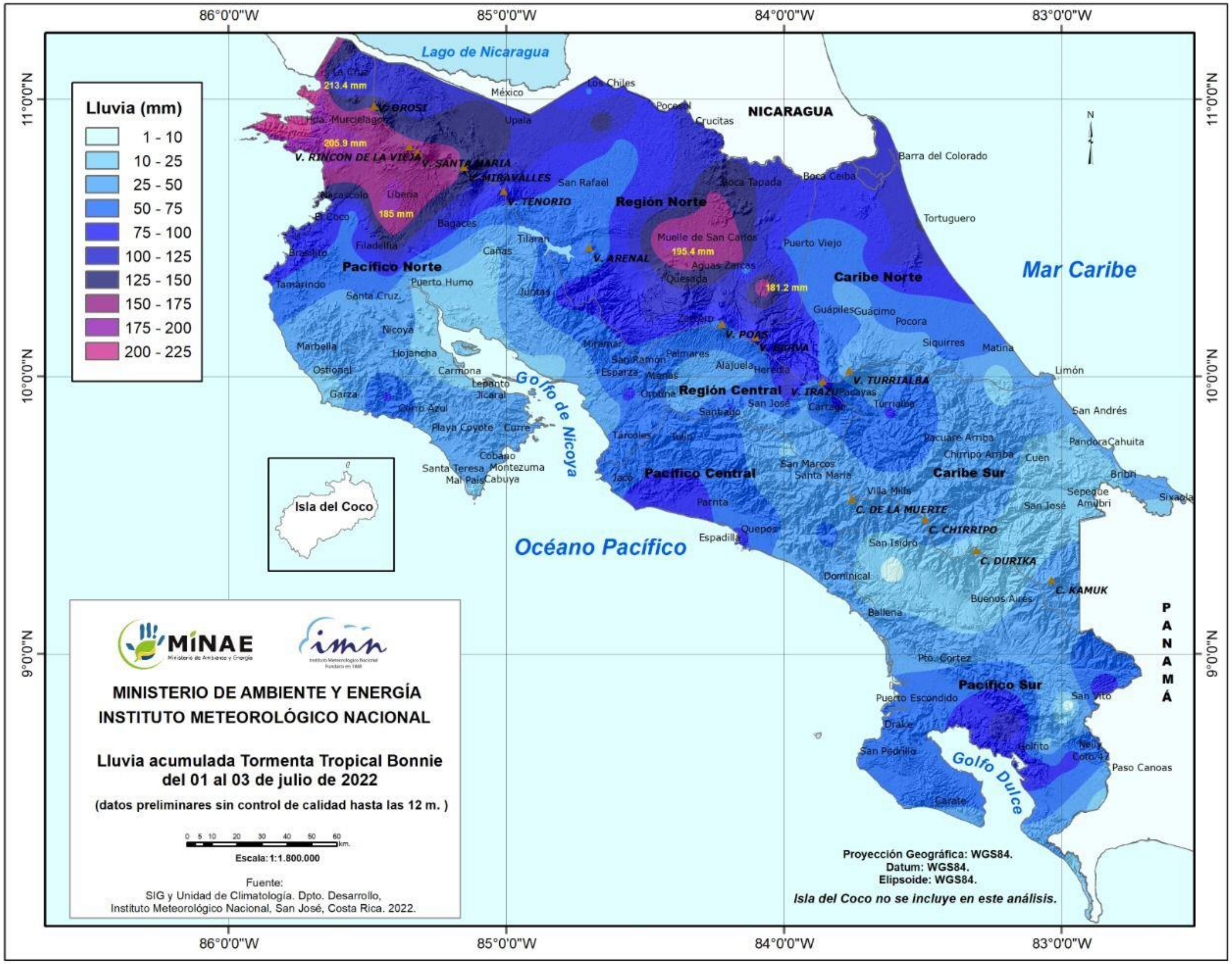

Figure 7. Rainfall observations between 1–3 July in Costa Rica associated with Bonnie as it crossed over this region as a tropical storm. Image courtesy of the Department of Climatology in San Jose, Costa Rica.

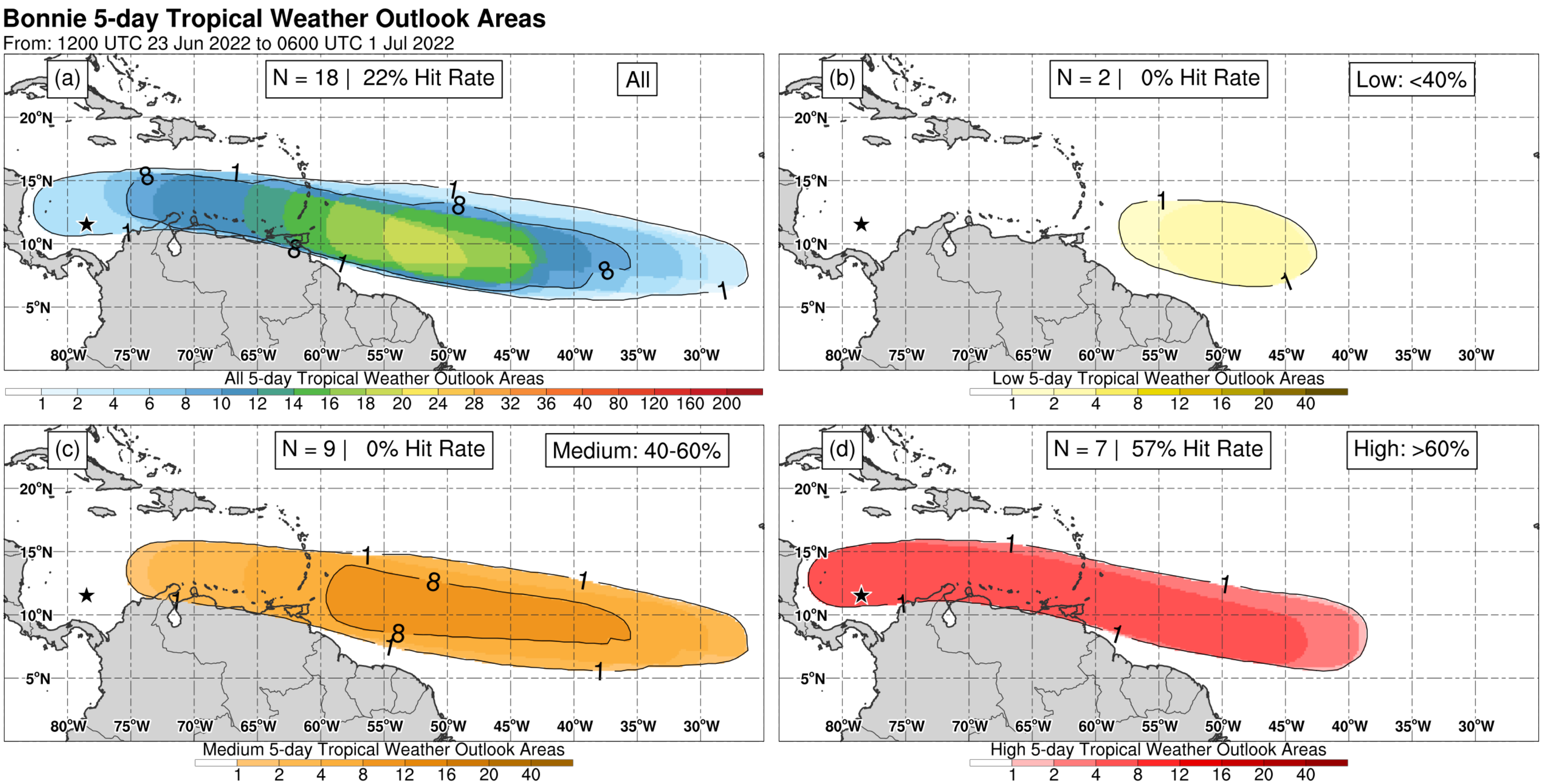

Figure 8. Composites of 5-day tropical cyclone genesis areas depicted in NHC's Tropical Weather Outlooks prior to the formation of Hurricane Bonnie for (a) all probabilistic genesis categories, (b) the low (<40%) category, (c) the medium (40–60%) category, and (d) the high (>60%) category. Bonnie's location of genesis is indicated by the black star. The hit rate in each plot indicates the percentage of outlook areas that capture the location of genesis.

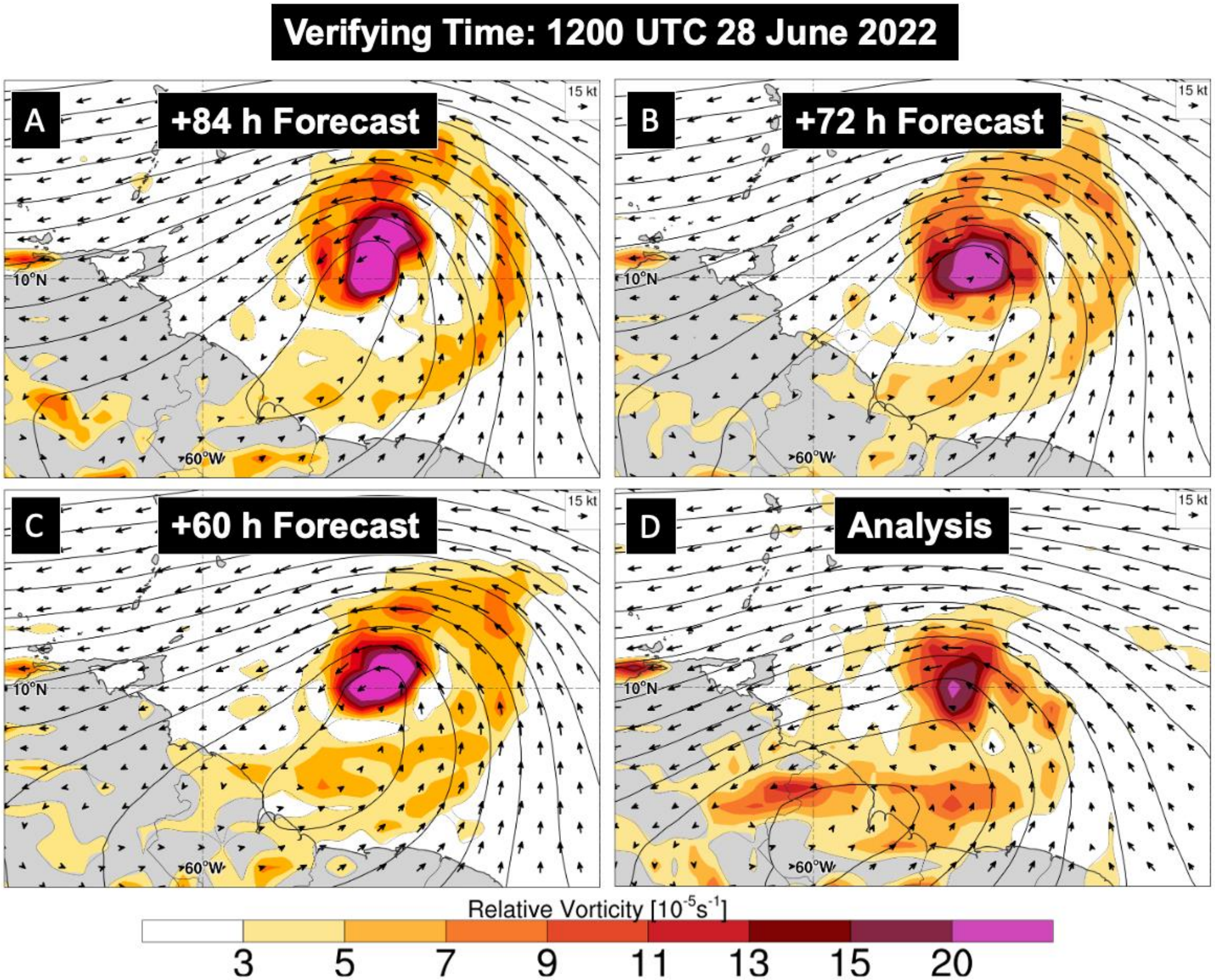

Figure 9. Three consecutive ECMWF forecasts of 850 mb relative vorticity (x 10^{-5} s^{-1}), streamfunction (black contours, every 1 x 10^6 m^2 s^{-1}), and winds (arrows, kt) for (a) 84 h, (b) 72 h, (c) 60 h, with verifying analysis at (d) 1200 UTC 28 June. Note the closed cyclonic flow the model is depicting with the pre-Bonnie tropical wave to the east of the Lesser Antilles in panels a–c while the system remained an open wave in the final model analysis (panel d).