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WEATHER ANALYSIS & FORECASTING REPORT ON HURRICANE NANA

The weather system that would eventually become Hurricane Nana formed from a tropical wave that emerged off the coast of Africa on Sunday, August 23, 2020 and tracked westward across the tropical Atlantic Ocean. The National Hurricane Center (NHC) started mentioning this system in their tropical weather outlook on Thursday, August 27, 2020 at 12:00 pm. At this time the system was over the Central Atlantic and was moving westward at around 15 to 20 mph with a 30% (low) chance of development in 5 days. See figure 1 below.

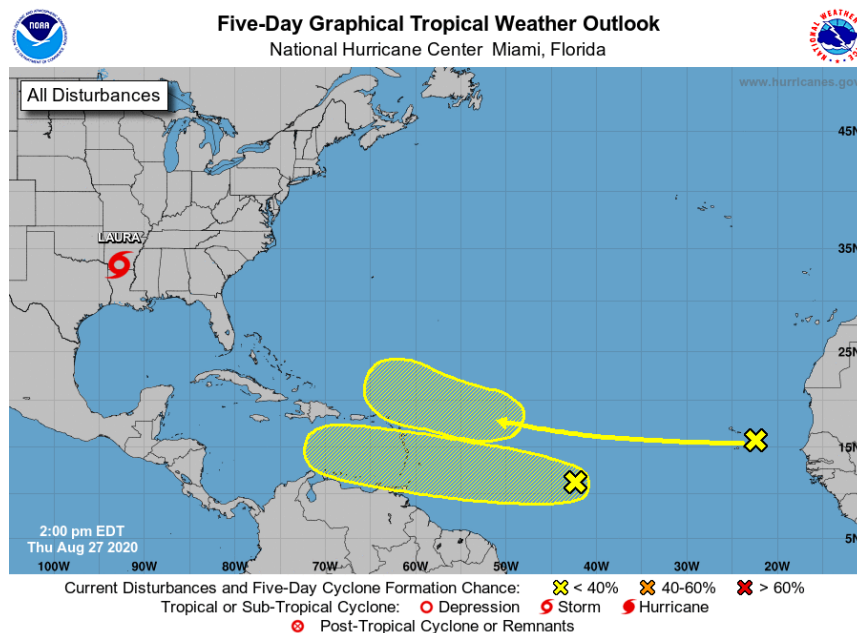


Figure 1: The yellow x closest to the bottom over the Central Atlantic Ocean shows the position of the tropical wave that would become Nana as of Thursday, August 27, 2020.



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WEATHER ANALYSIS & FORECASTING REPORT ON HURRICANE ETA

In late October 2020, global models began to indicate the possibility of an area of low pressure developing over the southwest Caribbean Sea from a tropical wave that was approaching the eastern Caribbean. The tropical weather outlook from the National Hurricane Center (NHC) issued at 12:00 pm on Wednesday October 28, 2020 indicated that the system had a 20% (low) chance of development in 5 days (See figure 1 below).

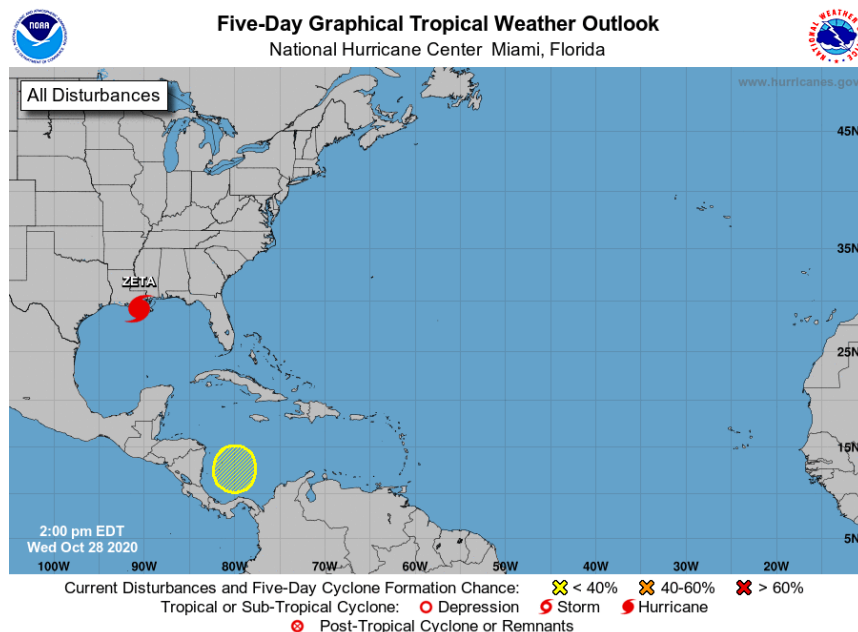


Figure 1: The yellow circle over the southwest Caribbean Sea shows the area where the broad low, which would eventually become hurricane Eta, was forecast by the National Hurricane Center to develop.

Chances of development increased gradually during the next few days and the system became tropical depression #29 at 3 pm local time on Saturday, October 31, 2020. This information was communicated to the National Emergency Management Organization (NEMO). The system was upgraded to tropical storm Eta six hours later at 9 pm on October 31st. At the time, the forecast was for Eta to continue moving westward and then turn toward the west-southwest with a decrease in forward speed. On that track, Eta was forecast to make landfall either over extreme eastern Honduras or northeastern Nicaragua some time on Tuesday, November 3, 2020 as a hurricane (see figure 2).

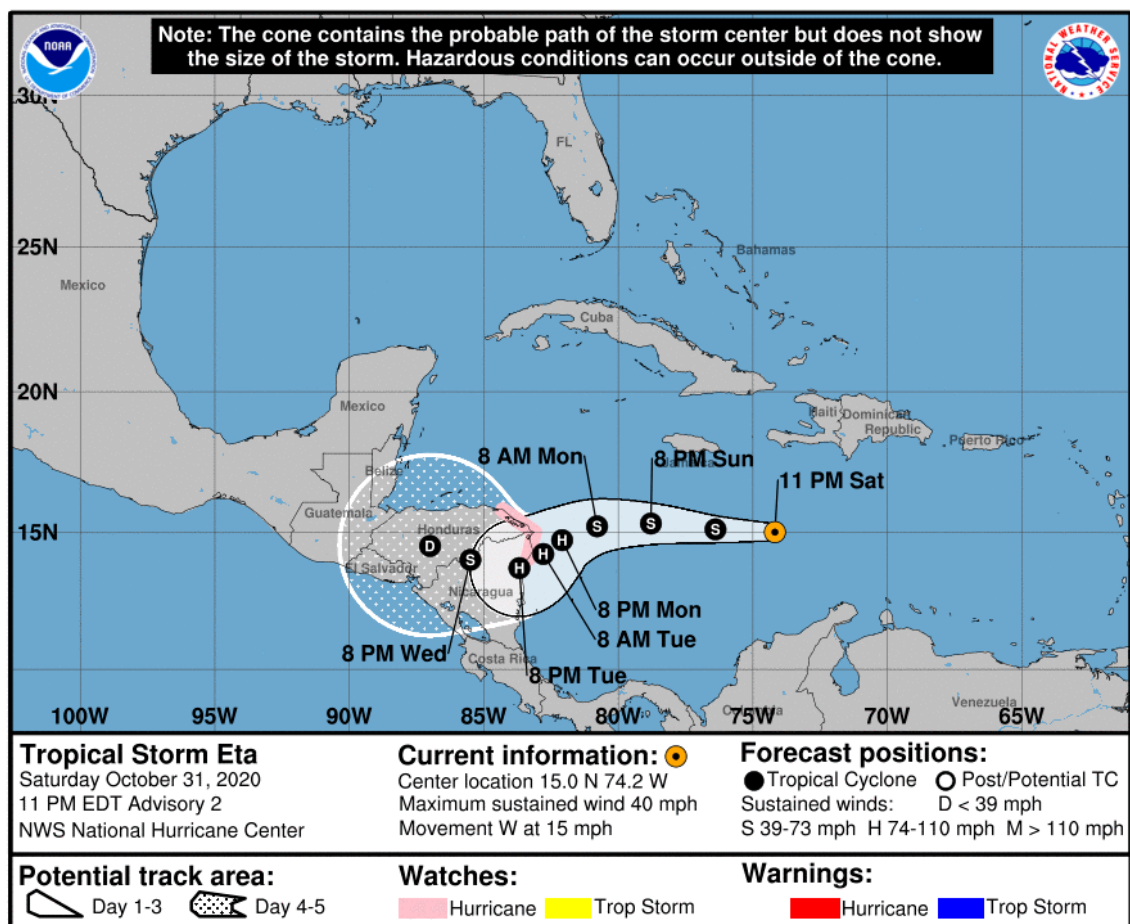


Figure 2: National Hurricane Center's forecast track for Tropical Storm Eta at 9 pm October 31, 2020.

A second update on Eta was sent from the National Meteorological Service (NMS) to the NEMO on the morning of Sunday, November 1, indicating the potential for heavy rainfall of up to 10-20 inches across Belize from this system. It was also indicated

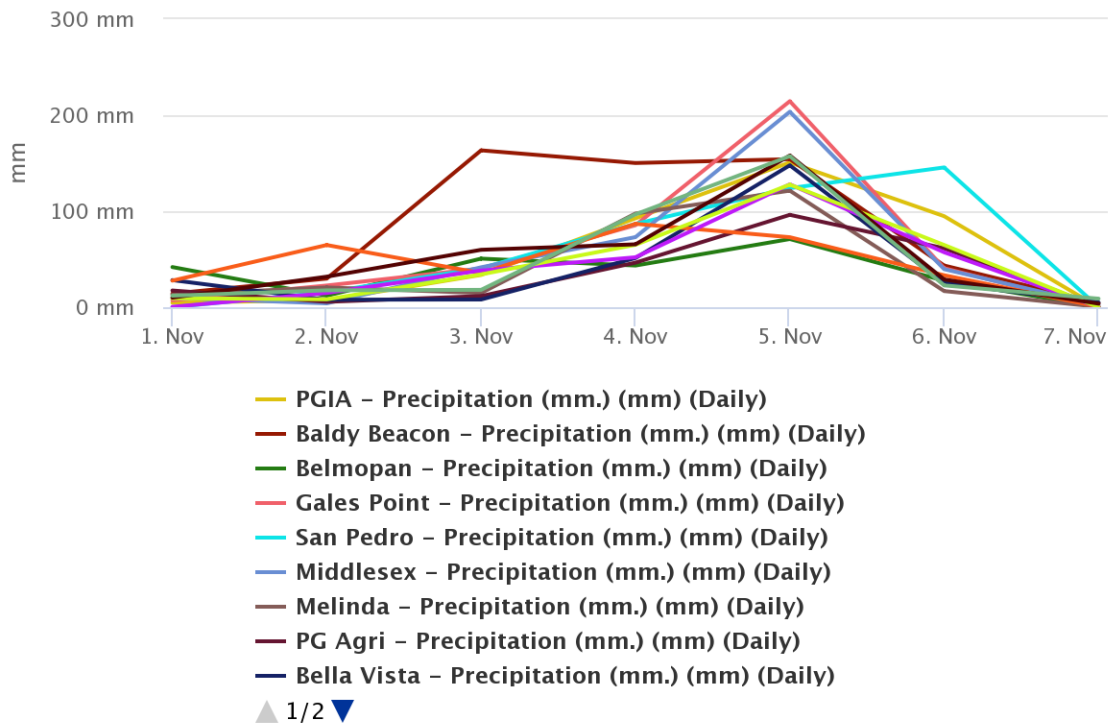
that there was considerable uncertainty in the forecast path of the system once it made landfall over Honduras or Nicaragua. Rainfall from the extreme outer bands of the system was already affecting the country on that day. Another update was sent later that evening indicating that Eta was starting to intensify rapidly. Winds had increased to 65 mph and the system was forecast to become a hurricane later that night with further rapid intensification expected within the following 24 to 36 hours. The NEMO issued advisory number 1 on Eta at 6:00 pm that evening.

As was forecasted, Eta continued its rapid intensification and was a major category 4 hurricane with winds of 150 mph by 9 pm on Monday, November 2. At that time, the system was slowing down as it approached the coast of Nicaragua moving in a west-southwesterly direction.

Rainfall from Eta gradually increased across Belize as the system tracked across Nicaragua and Honduras. Eta weakened to a tropical storm and eventually to a tropical depression on Wednesday, November 3 as it moved across the mountainous terrain of Nicaragua and Honduras. Heavy rains continued across Belize, peaking on Thursday, November 5 (See figure 3) and flooding was reported in the Cayo District.

Eta emerged off the coast of Honduras and moved northward, paralleling the coast of Belize late Thursday night into Friday morning (see figure 4). Torrential rain affected the country, with some central and northeastern areas recording over 5 inches of rainfall that night. This led to widespread flooding across the country, causing damage to several areas, including the road and highway networks..

Eta began to slowly move in a northeasterly direction away from Belize late Friday afternoon causing the rains to gradually decrease. By Friday night, the country recorded minimal rainfall and by Saturday, November 7, 2020 mainly fair and sunny conditions prevailed.



Highcharts.com

Figure 3: Time series of daily rainfall from Nov 1-6, 2020 for a few selected stations. Graph shows that rainfall peaked on November 5, 2020 at most stations.

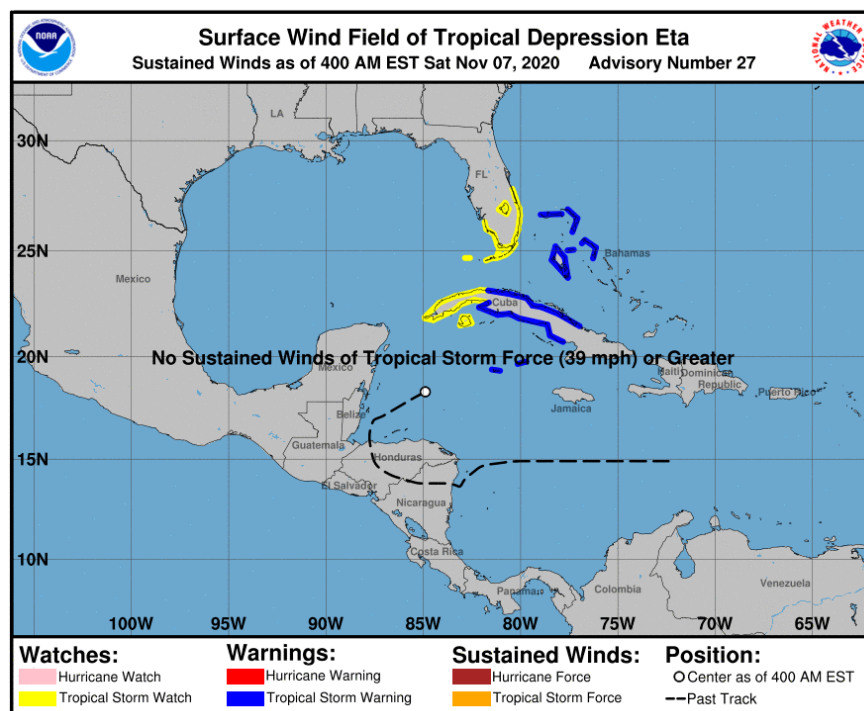


Figure 4: National Hurricane Center best track of Eta (black dotted line) from October 31 - November 7, 2020.

In Summary, although Eta was only a tropical depression at its nearest approach to Belize, the system dumped heavy rainfall across the country. These rains started well before the system made landfall on Nicaragua as moisture ahead of the system began affecting the country from as early as Sunday, November 1, 2020 (see figure 5). Rains continued through much of the week with storm total rainfall exceeding 20 inches (508 mm) over the Mountain Pine Ridge (figure 6). These rains resulted in severe flooding across the country. The damage assessment is still ongoing at the time this report is being compiled, but indications are that flooding from the system resulted in damage to residential homes, business, farms, road infrastructure, bridges and utility companies among others. Several persons have been displaced but up to this point there are no reports of fatalities.

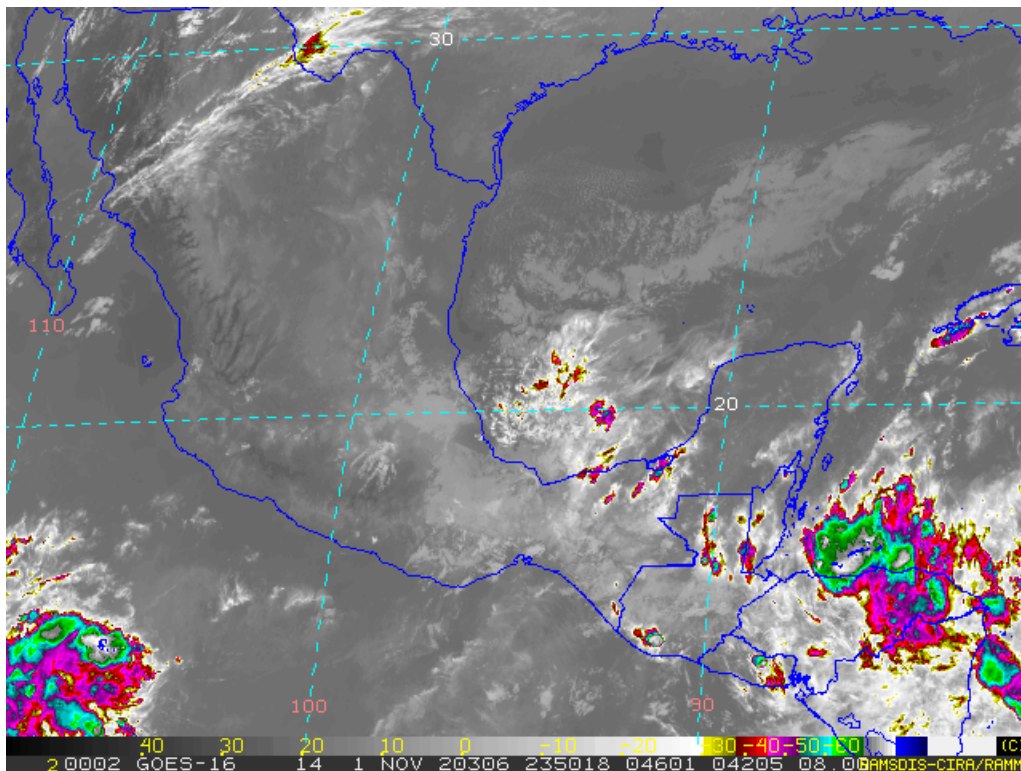


Figure 5: Infrared Satellite imagery on November 1, 2020 that shows moisture affecting the area well ahead of Eta.

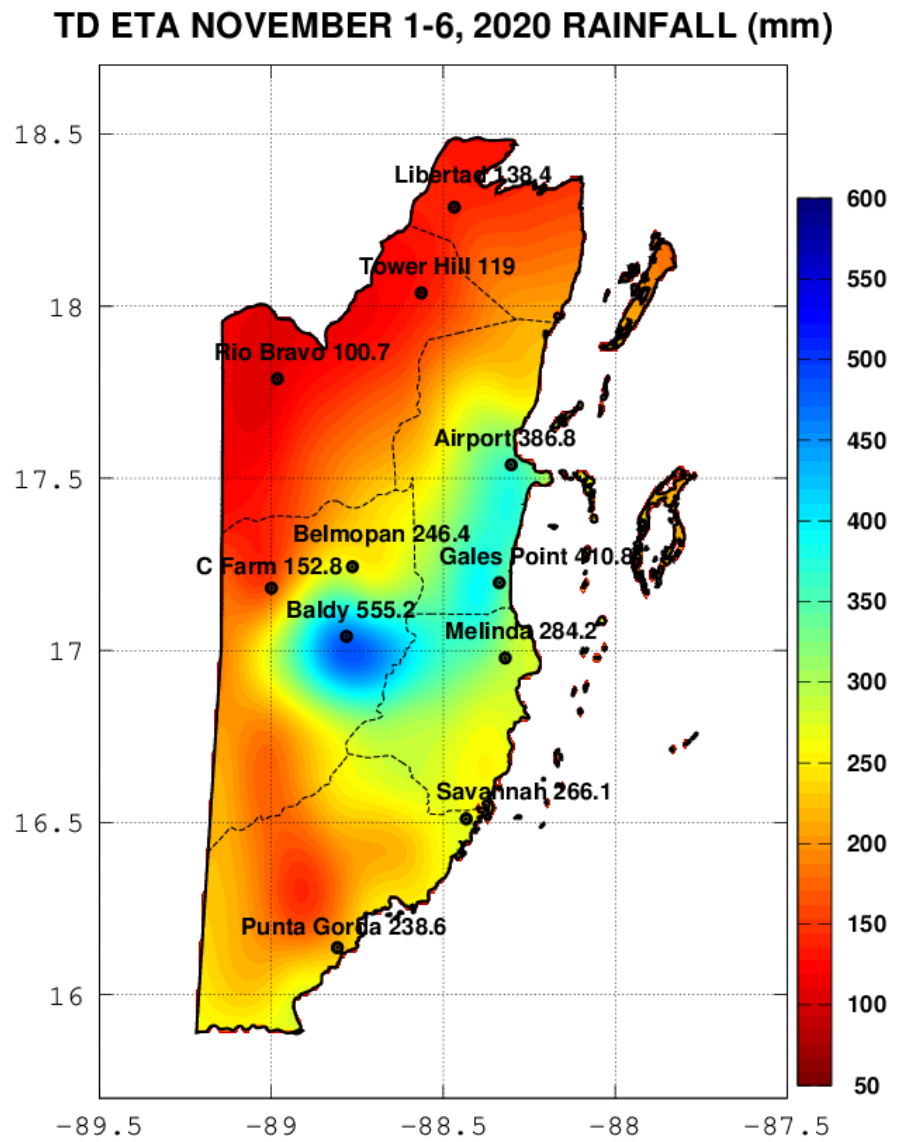


Figure 6: Total rainfall in mm for a few stations across the country from November 1 - 6, 2020 showing that the highest amounts occurred in Baldy Beacon in Mountain Pine Ridge and along the eastern Slopes of the Maya Mountains.

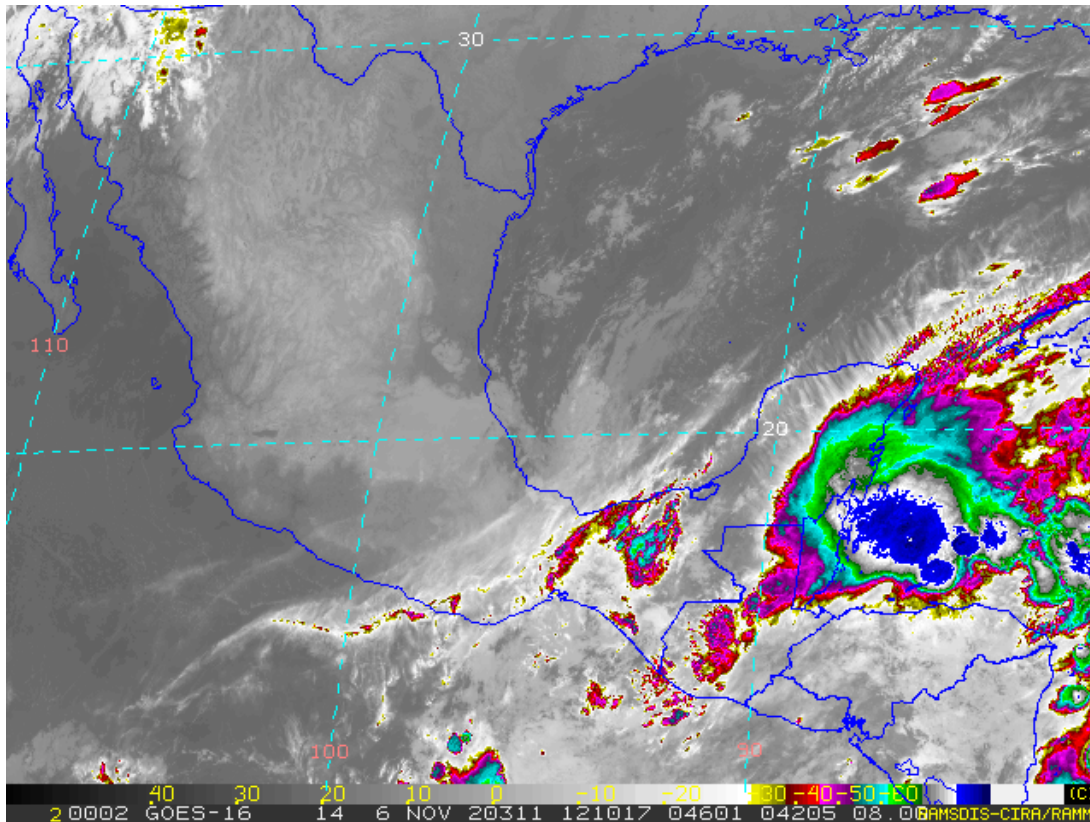


Figure 7: Infrared Satellite imagery on the early morning of November 6, 2020 showing intense shower and thunderstorm activity over northeastern Belize and offshore areas, as TD Eta tracked just east of Belize after emerging off the coast of Honduras overnight.

Rank	Station	Storm Total Rainfall (inches)
1	Baldy Beacon	21.9
2	Gales Point / San Pedro	16.2
3	International Airport	15.2
4	Middlesex	14.6
5	Hershey	13.9
6	Pomona	12.8
7	Santa Elena	12.6
8	Hattievile	12.2
9	Municipal (Belize City)	11.4
10	Melinda	11.2

Table 1.: Stations that recorded the top 10 highest storm total rainfall during the event.

The system continued moving rapidly westward during the next couple of days and entered the eastern Caribbean Sea on the morning of Sunday, August 30, 2020. It became better organized later that morning with a broad area of low pressure forming along the axis of the wave. By midday the NHC upgraded the 5-day chances of formation with the system to 60% (medium) and its potential track was suggesting a path directly towards Belize. The National Meteorological Service (NMS) of Belize communicated this information to the National Emergency Management Organization (NEMO) and Advisory #1 was released to the Belizean public later that evening.

The following morning of Monday, August 31, 2020, the chances of development was upgraded to 70% in 48 hours and 80% in 5 days (high). The system was now over the Central Caribbean Sea with the low pressure center located near latitude 14 N, longitude 69 W and it was still moving westward at around 15-20 mph.

On the following day, the chances of development increased further and an aircraft was sent in to investigate the system. The aircraft found a closed circulation with winds of tropical storm strength and as a result the system was upgraded to tropical Storm Nana at 10:05 am on Tuesday, September 1, 2020. At this point the Government of Belize declared a tropical storm watch for the entire coastline of the country. The position of tropical storm Nana at this point was near latitude 16.5 N, longitude 77.7 W and the system was moving to the west at 18 mph with maximum sustained winds of 50 mph. See figure 2.

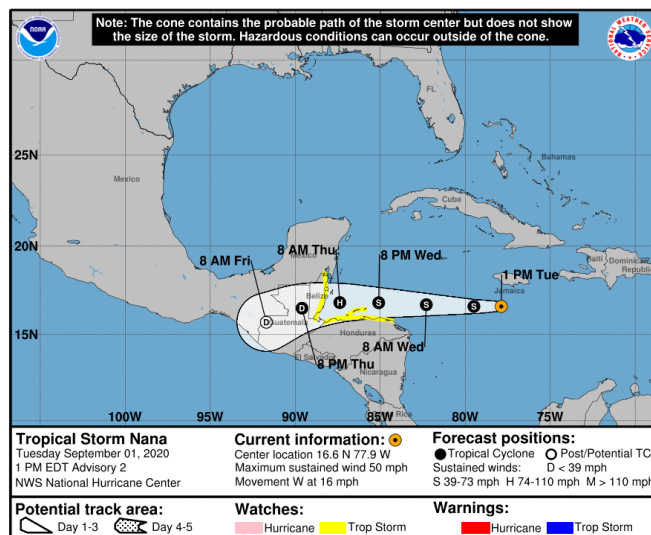


Figure 2: Projected path of tropical storm Nana on Sept 1, 2020.

Nana continued westward that day with no significant change in strength. However, the official forecast from the NHC was calling for the system to become a hurricane before landfall. Therefore later that evening at 4:15 pm the Government of Belize issued a hurricane watch for the entire coastline of the country. Maximum sustained winds with the system increased to 60 mph later that night at 9:00 pm.

On Wednesday, September 2, 2020 at 9:00 am the Hurricane watch for Belize was upgraded to a hurricane warning from Belize City southward as it was becoming more evident that the system would make landfall in southern Belize within 24 hours as a category 1 hurricane. At this point Nana was near latitude 17.1 N, longitude 84.6 W or about 240 miles east of Belize City. Maximum sustained winds remained at 60 mph and the system was moving westward at around 17 mph. The system continued moving westward that day with little change in strength as it was encountering moderate vertical wind shear on its north side along with some dry air at the mid-levels of the troposphere.

Effects from tropical storm Nana started to be felt on Belize late in the evening of Wednesday, September 2, 2020. Light to moderate rainfall began across the country and winds gradually started to pick up. At 6:00 pm on that day the system was about 100 miles east-southeast of Belize City. Nana was finally upgraded to a hurricane a few hours later at 9:00 pm. Maximum sustained winds were 75 mph and minimum central pressure was 994 hpa. The system was about 48 miles east of Dangriga Town and about 60 miles southeast of Belize City. Movement was still westward at 16 mph. At this point, winds were gusting to near tropical storm strength in Belize City. The projected landfall location had been narrowed down to the Stann Creek District, south of Dangriga and near the Hopkins area. Landfall occurred at around 11:45 pm. Reports from residents in Hopkins suggest winds of possible hurricane strength. A weather station at Carrie Bow Caye, just offshore, reported sustained winds of 61 mph with gusts of up to 75 mph at 11:42 pm. The wind direction from this station as the storm passed suggest that the center passed just to the south of its location. The atmospheric pressure reading suggests that the storm passed this station at around 11:30 pm when the pressure dipped to its lowest value of 997.5 hpa (see figure 3).

Nana weakened and was downgraded to a tropical storm with winds of around 70 mph after landfall and continued on a west to west-southwesterly path across Belize (see

figure 4). Gusty winds continued inland but the major impact after landfall was heavy rainfall.

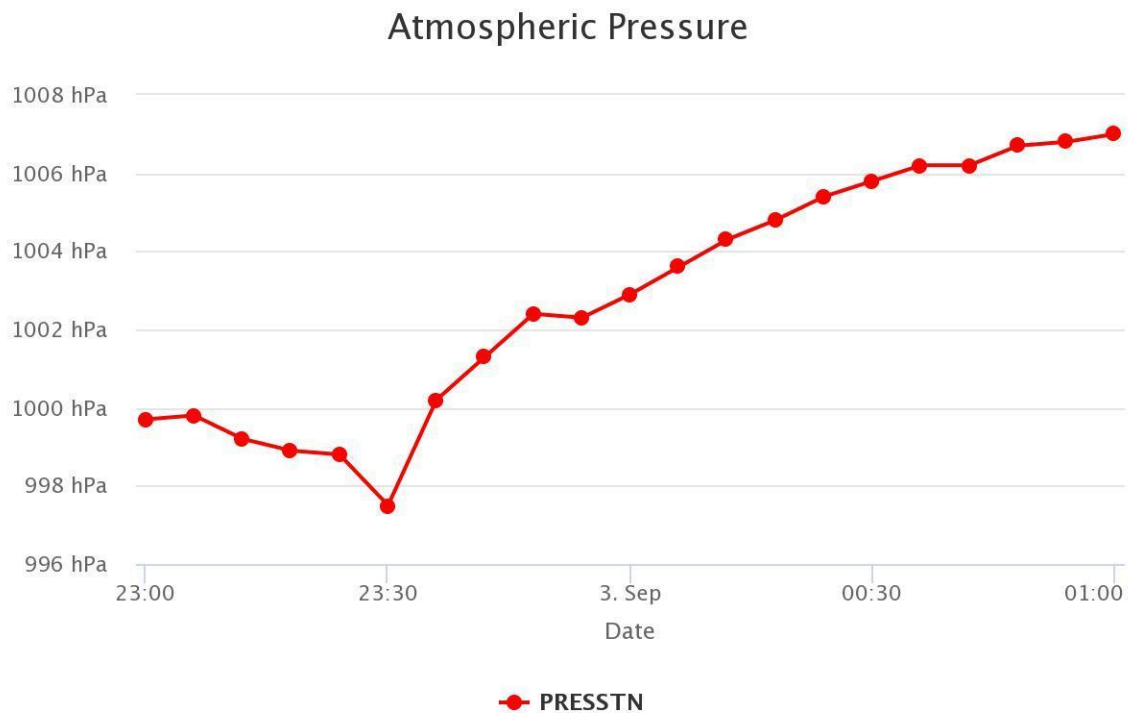


Figure 3: Time series of atmospheric pressure reading recorded at Carrie Bow Caye Between 11 pm September 2 and 1 am September 3. Lowest pressure of around 997.5 hpa occurred at 11:30 pm September 2 suggesting that this is the point at which the storm was closest to this station.

The heaviest rainfall occurred over the Toledo district. Highest amounts were recorded at the weather station at Corazon where a total of 144 mm (5.7 inches) fell (see table 1 and figure 5).

Although winds had subsided by 6:00 am on the morning of the 3rd, heavy rains continued. The coastal watches and warnings were lifted for the country but the All Clear was issued for all districts except the Toledo district as heavy rainfall continued. Therefore, The NMS maintained a flood warning for that district. The All Clear was issued for all of the country at 9:00 am on Thursday, September 3, 2020.

Table 1 below shows data on rainfall and wind speeds from some of the automatic weather stations around the country in association with Nana. As can be seen, most of the stronger winds occurred north of the center. In contrast the heaviest rainfall occurred south of the center over the Toledo district.

Station	Rainfall mm	Rainfall inches	Max Average Winds mph	Max Average Winds knots	Wind Gust mph	Wind Gust kts	Time (Wind speeds)
Carrie Bow	46.5	1.8	61	53	75	65	11:42 PM
Baldy Beacon	22.8	0.9	38.5	44	59	51.1	12:00 AM
Dangriga	13.0	0.5	37	32.2	52	45.5	11:35 PM
Placencia	53.8	2.1	25	21.3	49	42.6	12:25 AM
Corazon	144	5.7	-	-	-	-	-
Blue Creek	106.6	4.2	-	-	-	-	-
PG Agric	98.4	3.9	-	-	-	-	-
Bella Vista	69.8	2.7	-	-	-	-	-
Golden Stream	35.8	1.4	-	-	-	-	-
Belize City	17.4	0.7	38	32.8	47	40.9	11:00 PM
PGIA	16.8	0.7	22.5	19.6	34.3	29.8	11:20 PM

Table 1. Total rainfall accumulated between 12 am Sept 2 and 12 am Sept 4 and wind speed (average and gusts) in association with Hurricane Nana.

Figure 4 shows the estimated wind field and path of Nana as it crossed Belize. As can be seen, the hurricane force winds of 75 mph and above (area shaded in red) only extended about 10 miles from the center and dissipated rapidly after the system made landfall. Strong tropical storm force winds of around 58 - 73 mph extended to about 30 miles from the center but mostly on the north side, while weak tropical storm force winds of 39-57 mph extended to around 70 miles mostly north of the center. As indicated by the measurements in table 1, tropical storm force winds were felt in Belize City, but only in gusts. The highest sustained wind speed observed was 38 mph which is just below the threshold for weak tropical storm force winds. This would suggest that the actual tropical storm force winds were confined to an area less than the 70-mile north of the center contrary to what was estimated. As a matter of fact, the weather station at San Pedro, Ambergris Caye (not shown) only recorded maximum sustained winds of 27 mph and gusts of 35 mph.

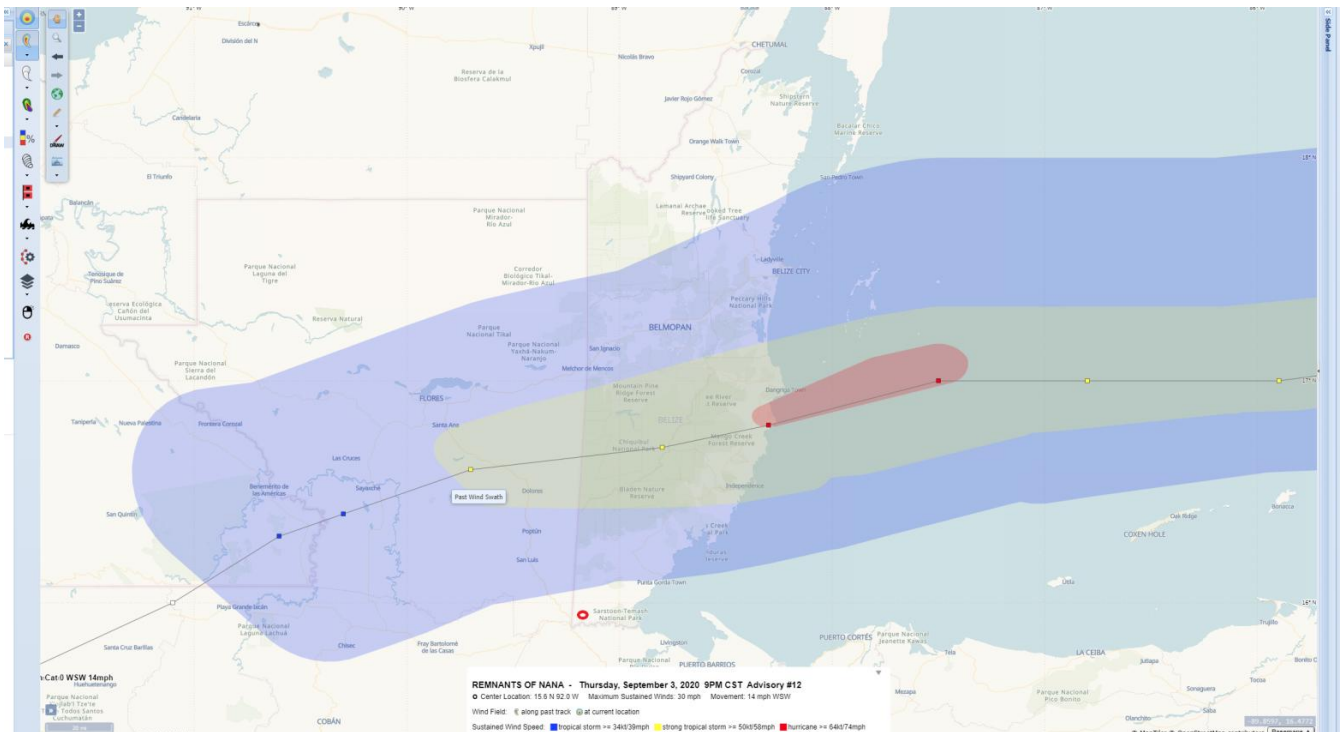


Figure 4. The wind field (shaded area) and path (thin black line) of Nana as it approached and crossed Belize into Guatemala. The area shaded in light blue represents the extent of Weak Tropical Storm force winds of 39-57 mph. The area shaded in yellow represents the extent of Strong Tropical Storm force winds of 58-73 mph while the area shaded in red represents the extent of category 1 hurricane force winds of 74-95 mph

Figure 5 shows an infrared satellite imagery taken at around 12:55 am on September 3 when the storm had already made landfall. The white-grey colors that fall inside the red colors indicate very cold cloud tops and areas of possible heavy rainfall across the country. Figure 6 shows the rainfall measured between 12:00 am on the 2nd and 12:00 am on the 4th. It confirms that the heaviest rainfall associated with the system occurred over the Toledo District.

In summary, hurricane Nana made landfall on Belize at around 11:45 pm on Wednesday, September 2, 2020 as a category 1 hurricane with maximum sustained winds of 75 mph. The storm weakened rapidly after landfall and continued on a west to west-southwesterly track across the country, exiting Belize into Guatemala during the early morning hours of Thursday September 3. Damage from winds were limited to the immediate area of landfall which was just south of Hopkins Village in the Stann Creek district. Preliminary data indicate that there were some damage to roofs and other structural damages to residences in that village from the storm. Further inland, gusty winds resulted in damage in the agricultural sector primarily to crops such as banana and corn. There was also reports of damage sustained by the aquaculture sector. Although no storm surge was reported to the NMS, there were reports of increased surf and high waves which resulted in minor damage to some piers in the Placencia area. Finally, there were some reports of localized flooding over the Toledo district.