NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE OTTO

(AL162016, EP22016)

20 – 26 November 2016

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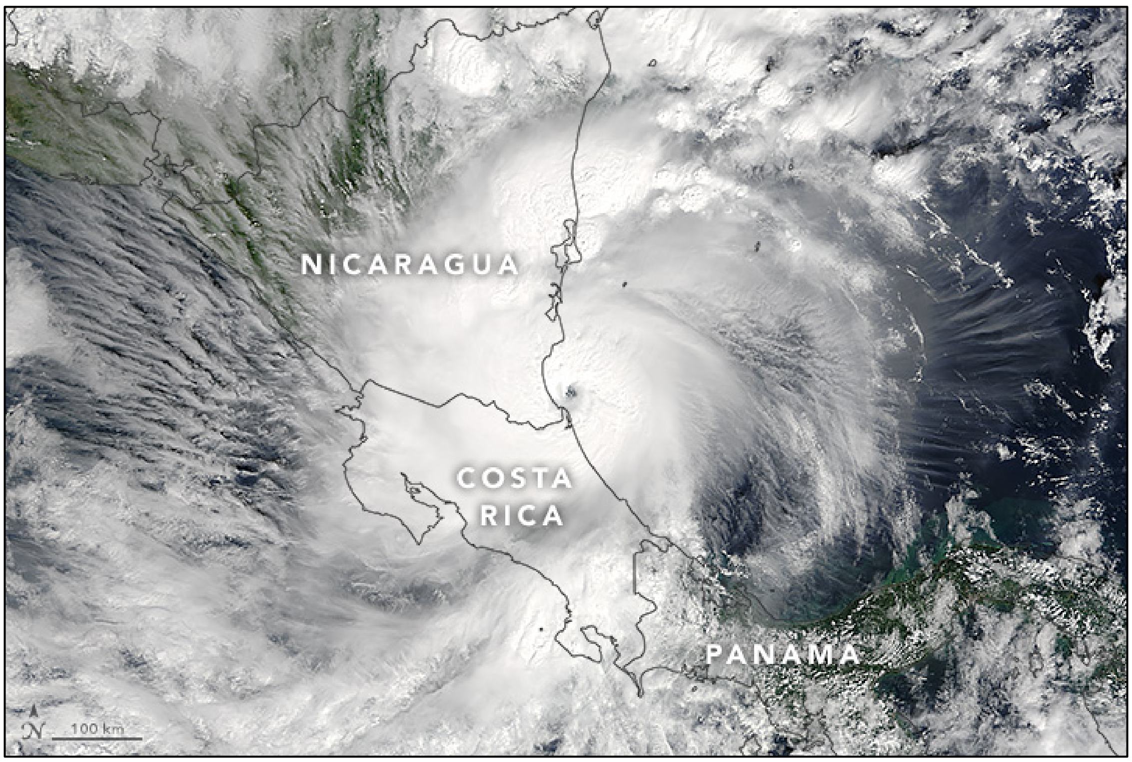

NASA TERRA MODIS VISIBLE SATELLITE IMAGE OF HURRICANE OTT0 AT 1605 UTC 24 NOVEMBER 2016 JUST BEFORE LANDFALL AS A CATEGORY 3 HURRICANE IN SOUTHERN NICARAGUA. IMAGE COURTESY OF NASA'S EARTH OBSERVATORY.

Otto was a late-season tropical cyclone over the southwestern Caribbean Sea that rapidly intensified to a category 3 hurricane (on the Saffir-Simpson Hurricane Wind Scale) before making landfall in southern Nicaragua. Otto became a rare Atlantic-to-Pacific basin-crossing tropical cyclone when it moved across southern Nicaragua and northern Costa Rica and emerged over the far eastern North Pacific as a tropical storm. Heavy rainfall and flooding from the hurricane caused 18 fatalities in Central America.

Hurricane Otto

20 – 26 NOVEMBER 2016

SYNOPTIC HISTORY

Otto formed from a broad cyclonic gyre that developed over the southwestern Caribbean Sea. The gyre appears to have formed from the combination of an eastward-moving convectively coupled Kelvin wave and a couple of tropical waves that passed through the area in mid-November. The passage of the tropical waves caused an increase in cloudiness and thunderstorms over the southwestern Caribbean Sea, and a broad surface low pressure area formed a few hundred n mi northwest of Colombia by early on 15 November. The low produced disorganized cloudiness and thunderstorms over the next couple of days while it drifted westward, and satellite data during this time showed that the winds associated with the low remained very light. Although the circulation became a little better defined on 17-18 November, the associated thunderstorm activity became less organized when the upper-level winds over the system became slightly less conducive for tropical cyclone formation. Early on 20 November, a surge of northerly low-level winds associated with a cold front and high pressure ridge over the Gulf of Mexico moved across the northwestern Caribbean Sea and pushed southward along the east coast of Nicaragua. This northerly surge appears to have helped to concentrate the low-level vorticity within the pre-existing low pressure area, which led to the low becoming better defined. The associated thunderstorm activity increased in organization later that day, resulting in the formation of a tropical depression at 1800 UTC 20 November about 105 n mi north of Colon, Panama. The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1].

The tropical cyclone drifted eastward, and then southward on 21-22 November while it was located within a col between two mid-level ridges. Steady strengthening occurred within an environment of moderate south-southeasterly shear and over warm 29°C waters. The tropical depression strengthened into a tropical storm by 0600 UTC 21 November, and Otto reached an intensity of 60 kt at 1200 UTC 22 November, while it was centered about 75 n mi north-northeast of Colon. Around that time, Otto began moving slowly west-northwestward to the south of a building mid-level ridge. Later that day, Otto's development ceased when a slight increase in southeasterly shear and the entrainment of dry-mid level air caused the inner-core structure of the tropical cyclone to become less organized. Although reconnaissance aircraft data indicate that Otto's minimum pressure rose by about 8 mb during the 24-h period ending at 1200 UTC 23 November, flight-level wind observations suggest that Otto's intensity remained nearly steady.

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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.

Around 1800 UTC 23 November, a burst of deep convection developed over the center of the tropical cyclone and it is estimated that Otto became a hurricane at that time, while located about 150 n mi east of the Nicaragua/Costa Rica border. Shortly after that time, the 850–200-mb wind shear over the cyclone decreased to around 10 kt, and a period of rapid intensification ensued while Otto began moving more quickly westward toward the coast of Central America. Microwave satellite data (Fig. 4) at 0943 UTC 24 November revealed a well-defined eye that became discernible in geostationary satellite data shortly before 1200 UTC that day. United States Air Force Reserve Hurricane Hunter aircraft data and satellite imagery indicate that Otto reached its estimated peak intensity of 100 kt at 1200 UTC while located about 40 n mi east of the Nicaragua/Costa Rica border (Fig. 5 and cover photo). Otto continued moving westward and made landfall in the Indio Maíz Biological Reserve in extreme southern Nicaragua about 10 n mi northwest of the Nicaragua/Costa Rica border around 1730 UTC 24 November with an estimated intensity of 100 kt (category 3 on the Saffir-Simpson Hurricane Wind Scale).

The hurricane rapidly weakened while moving inland over southern Nicaragua, and by 0000 UTC Otto had become a category one hurricane when it turned west-southwestward, and began to pass over extreme northwestern Costa Rica. Radar data from Las Nubes, Nicaragua (Fig. 6), and microwave satellite imagery (Fig. 4) show that the eye of Otto remained intact while the storm traversed Central America. Otto weakened to a tropical storm just before it exited the Pacific coast of northwestern Costa Rica near the Gulf of Papagayo around 0330 UTC 25 November. The tropical cyclone encountered less favorable atmospheric conditions over the far eastern Pacific Ocean that included stronger southeasterly shear and dry mid-level air. This caused the tropical storm to gradually weaken while it moved west-southwestward at an increasingly faster forward speed. Deep convection associated with Otto quickly decreased in organization on 26 November, and the system weakened to a tropical depression by 1200 UTC that day. Shortly after that time, Otto degenerated into a trough of low pressure about 425 n mi south of Salina Cruz, Mexico. The remnants of Otto continued to produce disorganized showers during the next few days while remaining well south of the southern coast of Mexico.

METEOROLOGICAL STATISTICS

Observations in Otto (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), and objective Advanced Dvorak Technique (ADT) 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. 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 Otto.

The 100-kt estimated peak intensity of Otto at landfall on 24 November is based on a blend of aircraft data with subjective and objective Dvorak intensity estimates. A U.S. Air Force Reserve Hurricane Hunter aircraft measured peak SFMR winds of 90 kt and a 700-mb flight-level wind of 108 kt during the final eyewall penetration around 1117 UTC 24 November. The satellite presentation of the hurricane continued to improve after the final aircraft fix and ADT estimates peaked at 110 kt (T5.8) at 1545 UTC. Subjective Dvorak data T-numbers also reached T5.5 (102 kt) by about 1500 UTC. Based on these data Otto is estimated to have made landfall as a 100-kt category 3 hurricane; this value is slightly higher than the operational assessment.

Otto's analyzed 80-kt intensity and 980 mb minimum pressure at 0000 UTC 24 November are based on a blend of flight-level and SFMR winds, and dropwindsondes from three eyewall penetrations by the aircraft that evening. During the second penetration, the aircraft measured a peak 850-mb flight-level wind of 103 kt and SFMR winds of 88 kt, however it appears that the aircraft flew through a transient eyewall mesovortex and these winds were likely unrepresentative of Otto's intensity. The minimum pressure reported by the aircraft on the final fix at 0044 UTC 24 November was 4-5 mb higher than what was supported by dropsonde data during the previous penetration.

Selected surface observations from land stations are given in Table 2. There were no reliable ship reports of winds of tropical storm force in association with Otto.

Otto was a small hurricane, with hurricane-force winds extending only 10-20 n mi from the center when the cyclone made landfall in a sparsely populated area of southern Nicaragua. Although there have been no observations of hurricane-force winds received, hurricane-force winds occurred over portions of the Indio Maíz Biological Reserve in southeastern Nicaragua, and also likely occurred over portions of northern Costa Rica. A research team with the National Geographic Society in the Indio Maíz Biological Reserve reported that within portions of the reserve very few trees were left unscathed by the wind, and that defoliation of the rainforest canopy was extensive (Jordon 2016) (Fig. 7). The highest wind gust reported over land was 58 kt (Table 2) on Isla San José off the Pacific coast of Costa Rica.

The hurricane likely produced significant storm surge inundation along portions of the coasts of southern Nicaragua and possibly extreme northeastern Costa Rica, but no observations of storm surge flooding have been received.

Otto produced very heavy rainfall over portions of Panama, Costa Rica, and Nicaragua. In Costa Rica, the heaviest rainfall occurred over the mountainous area of the northern and northwestern portions of that country. Figure 8 shows the rainfall accumulations over Costa Rica on 24 November, and 3-day rainfall totals from that country are given in Table 2. Several observing sites reported more than 8 inches of rainfall during the event, with the majority of the rain occurring on 24 November. An observing site near the Miravelles Volcano reported 11.77 inches on 24 November, and a 3-day total of 12.11 inches, which was the highest total reported in Costa Rica. Rainfall amounts of 3 to 6 inches were reported over southern and southwestern Nicaragua (Table 2). The highest rainfall total in Nicaragua was 6.35 inches at El Castillo in the extreme south-central portion of the country. No rainfall totals have been received from Panama.

The late-season hurricane set several historical records. When Otto became a hurricane at 1800 UTC 23 November, it surpassed by one day Hurricane Martha of 1969 as the latest hurricane formation in a calendar year in the Caribbean Sea. Otto became the strongest hurricane on record[2] so late in the year, the latest hurricane on record to be located in the Caribbean Sea, and Otto's landfall on 24 November is the latest hurricane landfall in the Atlantic basin within a calendar year. Otto's landfall is also the southernmost hurricane landfall in Central America, surpassing Hurricane Irene (1971), which also made landfall in southern Nicaragua but about 25-30 n mi north of where Otto crossed the coast. Otto is also the only known hurricane to move over Costa Rica.

Otto is one of a small number of tropical cyclones that maintained tropical cyclone status throughout the crossing from the Atlantic to the eastern North Pacific basin. The last tropical cyclone to do so was Hurricane Cesar, which made landfall in Nicaragua as a hurricane in late July 1996 but was still a tropical depression when it entered the far eastern Pacific basin. The depression later re-strengthened into Hurricane Douglas south of Mexico. (World Meteorological Organization operational protocols at that time required the renaming of tropical cyclones that moved from the Atlantic basin into the eastern North Pacific. In 2000, the World Meteorological Region IV Hurricane Committee decided that tropical cyclone names should be retained when a tropical cyclone moves from one basin to another within region IV while maintaining its status as a tropical cyclone.) As a result, Otto became the first tropical cyclone to retain its Atlantic basin name when it maintained tropical cyclone status during the basin crossing.

CASUALTY AND DAMAGE STATISTICS

Hurricane Otto is responsible for 18 direct deaths[3] in Central America. The United Nations Office for the Coordination of Humanitarian Affairs reported eight deaths in Panama in association with Otto. Although the center of the tropical cyclone remained well north of Panama, heavy rainfall and gusty winds associated with Otto appeared to be directly responsible for the fatalities. Three people died in landslides, a young boy perished when a tree fell on his mother's truck, and two youths were swept to their deaths in a swollen river in the eastern portion of Panama City. Two sailors went missing and are presumed to have died when their ship *Jessica* sank off the coast of Colon, Panama. The sailors that perished departed the sinking vessel on a raft with one other person who was rescued by the United States Coast Guard after four days drifting at sea. Three other crew members onboard *Jessica* were rescued by the National Air Service of Panama at the time of the incident.

The National Meteorological Institute of Costa Rica reported that ten people perished in flooding in that country as result of Otto. Most of the deaths occurred from flash flooding and landslides over the northern and northwestern portions of Costa Rica.

Officials in Nicaragua reported that there were no storm-related deaths in that country.

[2] Prior to the satellite era (1966) records for the entire Atlantic basin may not complete.

[3] 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.

Media reports indicate that extensive freshwater flood damage occurred in portions of Panama, Costa Rica, and Nicaragua, with damage more widespread across northern Costa Rica and extreme southern Nicaragua. Red Cross officials reported that numerous homes, roads, and bridges were damaged in Costa Rica (Fig. 9). Extensive power outages occurred in that country and tens of thousands were left without fresh water after the storm due power outages and damage to numerous water systems. In Panama, Otto had a large effect on the agricultural and livestock industry and media reports indicate that about 500 people were displaced by the storm. More than 10,000 people in Nicaragua were evacuated prior to the hurricane.

There have been no official monetary damage estimates received from the affected countries as of this writing. The meteorological service of Costa Rica reported that economic losses are still being calculated, but the report indicated that most of the damage occurred within the agricultural, forestry, and livestock industries. Recent media reports indicate that Otto caused about $15 million USD in damage to the coffee industry in Costa Rica.

FORECAST AND WARNING CRITIQUE

The formation of Otto was anticipated, but uncertainty in the timing of genesis resulted in very poor short-range (48 h) predictions. The potential for tropical cyclone development was introduced into the Tropical Weather Outlook (TWO) at 0600 UTC 12 November, more than eight days before genesis occurred. The 5-day probability of formation was increased to the medium (40%-60%) and high (>60%) categories 186 h and 138 h before formation, respectively (Table 3). After the 5-day probability of formation reached the high category, the numerical models began to delay development. As a result, the 48-h formation chance remained in the low category and the 5-day formation probability was lowered to the medium category at 0600 UTC 18 November. After the system began showing signs of organization the next day, the 48-h probability was raised to the medium category in a Special TWO that was issued around 1400 UTC 19 November, a little more than a day before formation occurred. The 5-day probabilities were once again increased to the high category at 1800 UTC that day. The 48-h probability of development did not reach the high category until after development occurred in post-analysis.

A verification of NHC official track forecasts for Otto is given in Table 4a. Official forecast track errors were much lower than the mean official errors for the previous 5-yr period through 72 h, but were near the long-term mean at 96 h, and much larger than the mean at 120 h, albeit for only 2 verifying forecasts. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. The NHC track forecasts had lower mean errors than most of the individual track models through 72 h, but several of the consensus models (HCCA, TVCX, GFEX, and TVCA) had lower mean errors at several forecast lead times. The TVCX consensus model beat the NHC track forecasts through 36 h, and the GFEX consensus model outperformed the official forecast at 72 h and beyond. The NHC track forecasts (Fig. 10) and most of the numerical model guidance (not shown) were very consistent in predicting that Otto would make landfall in southern Nicaragua. The larger than average NHC long-range track errors were primarily along-track (timing) errors that occurred due to Otto's faster than anticipated west-southwestward motion after landfall.

A verification of NHC official intensity forecasts for Otto is given in Table 5a. Official forecast intensity errors were generally comparable to the mean official errors for the previous 5-yr period. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. The NHC intensity forecasts performed better than nearly all of the intensity model guidance through 72 h, but most of the guidance models had lower errors than the official forecast at 96 and 120 h. All of the NHC intensity forecasts, including the first one issued about 84 h before landfall, correctly predicted that Otto would become a hurricane before reaching the coast of Central America; however, the rapid strengthening of Otto to category 3 intensity was not anticipated. The official intensity forecasts never explicitly predicted an intensity higher than 80 kt. Otto's quick demise over the eastern Pacific Ocean was also not foreseen. The NHC intensity forecasts correctly predicted that Otto would weaken due to shear and dry air, but Otto's dissipation as a tropical cyclone occurred much sooner than anticipated.

Watches and warnings associated with Otto are given in Table 6. A Hurricane Watch was first issued by the governments of Costa Rica and Nicaragua at 1500 UTC 22 November, a little more than two days before landfall occurred. The Hurricane Warning was issued at 0300 UTC 23 November, a little more than 36 h before landfall. Since Otto was forecast to exit the west coast of Central America as a tropical storm, tropical storm warnings were issued for a portion of the Pacific coasts of Costa Rica and Nicaragua.

REFERENCES

Jordan, Chris. "Rebounding from Hurricane Otto in Nicaragua's Most Ecologically Sensitive Rainforests." Web blog post. *Water Currents.* National Geographic,12 Dec. 2016. Web. 11 Jan. 2017.

Jordan, Chris. "From the Field: Hurricane Otto Tears Through Indio Maíz." Web blog post. *Blog.* Global Wildlife Conservation, 12 Dec. 2016. Web. 11 Jan. 2017.

Table 1. Best track for Hurricane Otto, 20-26 November 2016.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
17 / 1800	12.5	80.7	1006	20	low
18 / 0000	12.3	81.3	1005	20	"
18 / 0600	11.8	81.7	1005	20	"
18 / 1200	11.4	82.0	1005	20	"
18 / 1800	11.2	82.0	1005	20	"
19 / 0000	11.1	82.0	1005	25	"
19 / 0600	11.0	81.8	1005	25	"
19 / 1200	10.9	81.5	1005	25	"
19 / 1800	10.8	81.2	1005	25	"
20 / 0000	10.7	80.8	1005	25	"
20 / 0600	10.7	80.4	1005	25	"
20 / 1200	10.9	80.0	1004	25	"
20 / 1800	11.1	79.7	1002	30	tropical depression
21 / 0000	11.3	79.4	1002	30	"
21 / 0600	11.3	79.3	1002	35	tropical storm
21 / 1200	11.3	79.2	1001	40	"
21 / 1800	11.1	79.1	1000	45	"
22 / 0000	10.8	79.1	998	50	"
22 / 0600	10.6	79.1	992	55	"
22 / 1200	10.4	79.2	986	60	"
22 / 1800	10.5	79.4	986	60	"
23 / 0000	10.6	79.6	987	60	"
23 / 0600	10.8	80.0	991	60	"
23 / 1200	11.0	80.4	994	60	"
23 / 1800	11.2	81.1	990	65	hurricane
24 / 0000	11.2	81.8	980	80	"
24 / 0600	11.1	82.4	978	90	"

24 / 1200	11.0	83.0	975	100	"
24 / 1730	11.0	83.8	975	100	"
24 / 1800	11.0	83.9	978	95	"
25 / 0000	10.9	84.9	992	65	"
25 / 0330	10.7	85.6	993	60	tropical storm
25 / 0600	10.6	86.2	994	60	"
25 / 1200	10.3	87.5	995	55	"
25 / 1800	10.0	88.8	997	50	"
26 / 0000	9.7	90.2	1000	45	"
26 / 0600	9.4	91.7	1003	40	"
26 / 1200	9.1	93.3	1005	30	tropical depression
26 / 1800					dissipated
24 / 1200	11.0	83.0	975	100	Maximum winds and minimum pressure
24 / 1730	11.0	83.8	975	100	landfall in southern Nicaragua (10 n mi northwest of the Nicaragua/Costa Rica border)
25 / 0330	10.7	85.6	993	60	last best-track point before entering the eastern North Pacific basin

Table 2. Selected surface observations for Hurricane Otto, 20-26 November 2016.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
Costa Rica						
Volcan Turrialba 9.56°N 83.77°W			24/0752		46	3.96
Volcan Irazú 9.98°N 83.84°W			24/0630		40	6.56
Copalchi, Peñas Blancas 11.20°N 85.62°W						10.12
Liberia 10.59°N 85.55°W			24/2157		34	4.40
Mangarica 10.60°N 85.45°W			24/2111		35	3.83
La Maritza 10.96°N 85.50°W			24/1001		41	8.59
Isla San José 10.85°N 85.91°W					58	3.65
Limón 9.95°N 83.02°W						6.94
Santa Rosa 10.83°N 85.62°W			24/2200		32	4.75
Piñales Las Delicias 10.44°N 84.32°W						3.61
La Selva, Sarapiquí 10.42°N 84.00°W		1002.3				3.85
Comando Los Chiles 11.02°N 84.70°W			24/1811		36	5.26
La Rebusca 10.48°N 84.02°W					30	4.58
Comando Sarapiqui 10.45°N 84.01°W						4.40
Laguna, Caño Negro 10.90°N 84.78°W						7.26
Upala 10.87°N 85.07°W			24/1947		32	6.49
Sta Elena, La Cruz 10.92°N 85.61°W						4.85
Esta. Biol. Pitilla 10.98°N 85.42°W						10.55

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
Hda Verdum, Sta Cecilia 11.08°N 85.45°W						10.62
Fca Brasilia del Oro 10.97°N 85.33°W			24/1912		34	9.07
Veracruz, Caño Negro* 10.85°N 84.87°W		995.6				4.99
El Sábalo 10.60°N 85.00°W						7.54
Canalete 10.84°N 85.04°W						7.58
Bijagua 10.73°N 85.05°W						10.41
Las Pailas 10.76°N 85.37°W						7.05
P.N. Rincón de la Vieja 10.78°N 85.35°W						8.07
Río Naranjo 10.68°N 85.17°W						8.01
Fortuna 10.68°N 85.20°W						8.97
C.M. Miravalles 10.70°N 85.19°W						12.11
Pozo 29 10.68°N 85.17°W						9.00
Nicaragua						
San Carlos	25/0100	1007.0				4.11
Rivas	25/0000	1008.0				3.54
El Ostional (San Juan del Sur)						4.21
San Carolos (Río Frio)						3.79
El Castillo (Las Maravillas)						6.35
El Castillo (Las Maravillas)						4.54

[a] Date/time is for sustained wind when both sustained and gust are listed.

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%)	138	204
Medium (40%-60%)	28	186
High (>60%)	-	138

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Otto. 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	72	96	120
OFCL	**18.4**	**21.4**	**27.7**	**30.9**	**53.6**	158.0	272.1
OCD5	40.2	85.2	129.2	195.1	402.0	624.1	892.1
Forecasts	20	18	16	14	10	6	2
OFCL (2011-15)	28.4	45.0	60.4	77.1	113.1	157.8	210.0
OCD5 (2011-15)	48.3	101.5	161.5	222.6	329.8	412.6	483.9

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Otto. 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	72	96	120
OFCL	19.7	23.5	30.1	29.7	43.9	150.3	238.7
OCD5	46.1	96.2	138.5	192.4	345.6	571.3	873.1
GFSI	**18.3**	30.7	35.4	42.2	72.4	203.6	**232.5**
GHMI	26.6	43.4	81.8	143.6	271.6	462.7	633.3
HWFI	21.5	37.2	54.8	68.6	112.2	233.2	400.6
EMXI	26.6	43.0	60.8	74.6	46.7	**78.8**	**170.5**
CMCI	41.4	72.1	112.1	133.9	176.0	152.4	**97.6**
NVGI	37.0	59.8	81.9	65.4	93.0	247.6	507.4
GFNI	19.9	38.8	74.4	91.1	145.0	242.7	465.3
AEMI	**18.6**	28.0	36.1	45.4	81.2	231.2	324.0
HCCA	**17.6**	**23.0**	30.9	35.4	60.6	180.9	278.4
TVCX	**18.2**	**22.9**	**28.5**	38.8	79.8	205.0	307.7
GFEX	**18.8**	30.1	39.2	41.6	**38.0**	**141.4**	**198.4**
TVCA	**18.7**	23.8	**27.0**	40.3	94.6	227.3	340.6
LBAR	49.9	123.5	212.3	289.1	427.6	662.5	1046.7
BAMD	41.5	75.5	116.0	162.0	276.2	259.9	**204.0**
BAMM	30.6	53.7	76.8	86.6	98.7	**91.3**	**102.2**
BAMS	28.6	42.5	57.6	77.8	117.3	166.7	**170.4**
Forecasts	15	13	11	9	6	4	1

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Otto. 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	72	96	120
OFCL	8.8	11.7	**10.6**	**10.4**	**12.0**	16.7	**10.0**
OCD5	11.1	13.7	13.8	14.2	21.6	14.2	12.0
Forecasts	20	18	16	14	10	6	2
OFCL (2011-15)	6.2	9.4	11.5	13.3	14.6	14.6	15.8
OCD5 (2011-15)	7.3	10.8	13.3	15.3	17.7	17.8	17.6

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Otto. Errors smaller than the NHC official forecast are shown in boldface type.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	8.8	11.7	10.6	10.4	12.0	16.7	10.0
OCD5	11.1	13.7	13.8	14.2	21.6	**14.2**	12.0
GFSI	12.9	16.9	18.0	15.1	14.2	**11.0**	15.0
GHMI	13.9	19.1	20.3	21.8	20.2	**9.8**	20.0
HWFI	12.9	16.0	21.4	17.7	**9.7**	**6.5**	**7.0**
EMXI	12.6	16.7	17.7	22.1	32.7	24.3	**4.5**
GFNI	12.8	17.4	17.1	23.0	30.2	14.8	**6.0**
DSHP	10.0	13.1	13.2	11.0	12.7	**6.8**	**6.0**
LGEM	10.1	14.4	17.1	17.8	18.5	**9.2**	**7.5**
ICON	11.2	14.9	15.4	14.4	12.6	**5.2**	**4.5**
IVCN	11.4	14.5	15.3	14.3	13.0	**7.0**	**2.5**
HCCA	10.1	14.1	14.9	13.4	**10.1**	**5.8**	**5.5**
Forecasts	20	18	16	14	10	6	2

Table 6. Watch and warning summary for Hurricane Otto, 20-26 November 2016.

Date/Time (UTC)	Action	Location
22 / 0300	Tropical Storm Watch issued	San Andres Island
22 / 1500	Tropical Storm Warning issued	Coast of Panama from Nargana to Colon
22 / 1500	Hurricane Watch issued	Costa Rica/Panama border to south of Bluefields, Nicaragua
22 / 1500	Tropical Storm Watch issued	Coast of Panama from Colon to the Costa Rica/Panama border
22 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	San Andres Island
22 / 2100	Tropical Storm Watch issued	Coast of Nicaragua from Bluefields to Sandy Bay Sirpi
23 / 0300	Hurricane Warning issued	Limon, Costa Rica to Bluefields, Nicaragua
23 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Bluefields to Sandy Bay Sirpi
23 / 0300	Hurricane Watch modified to	Bluefields to Sandy Bay Sirpi and Limon to Costa Rica/Panama border
23 / 0900	Tropical Storm Watch issued	Pacific coast of Nicaragua and Costa Rica from Puerto Sandino to Puntarenas
23 / 1200	Tropical Storm Warning discontinued	Coast of Panama from Nargana to Colon

Date/Time (UTC)	Action	Location
23 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Pacific coast of Nicaragua and Costa Rica from Puerto Sandino to Puntarenas
24 / 0300	Tropical Storm Watch discontinued	Coast of Panama from Colon to the Costa Rica/Panama border
24 / 0900	Tropical Storm Warning discontinued	San Andres Island
24 / 2100	Hurricane Watch discontinued	Bluefields to Sandy Bay Sirpi and Limon to Costa Rica/Panama border
25 / 0300	Hurricane Warning discontinued	All
25 / 0300	Tropical Storm Warning discontinued	Bluefields to Sandy Bay Sirpi
25 / 1200	Tropical Storm Warning discontinued	All

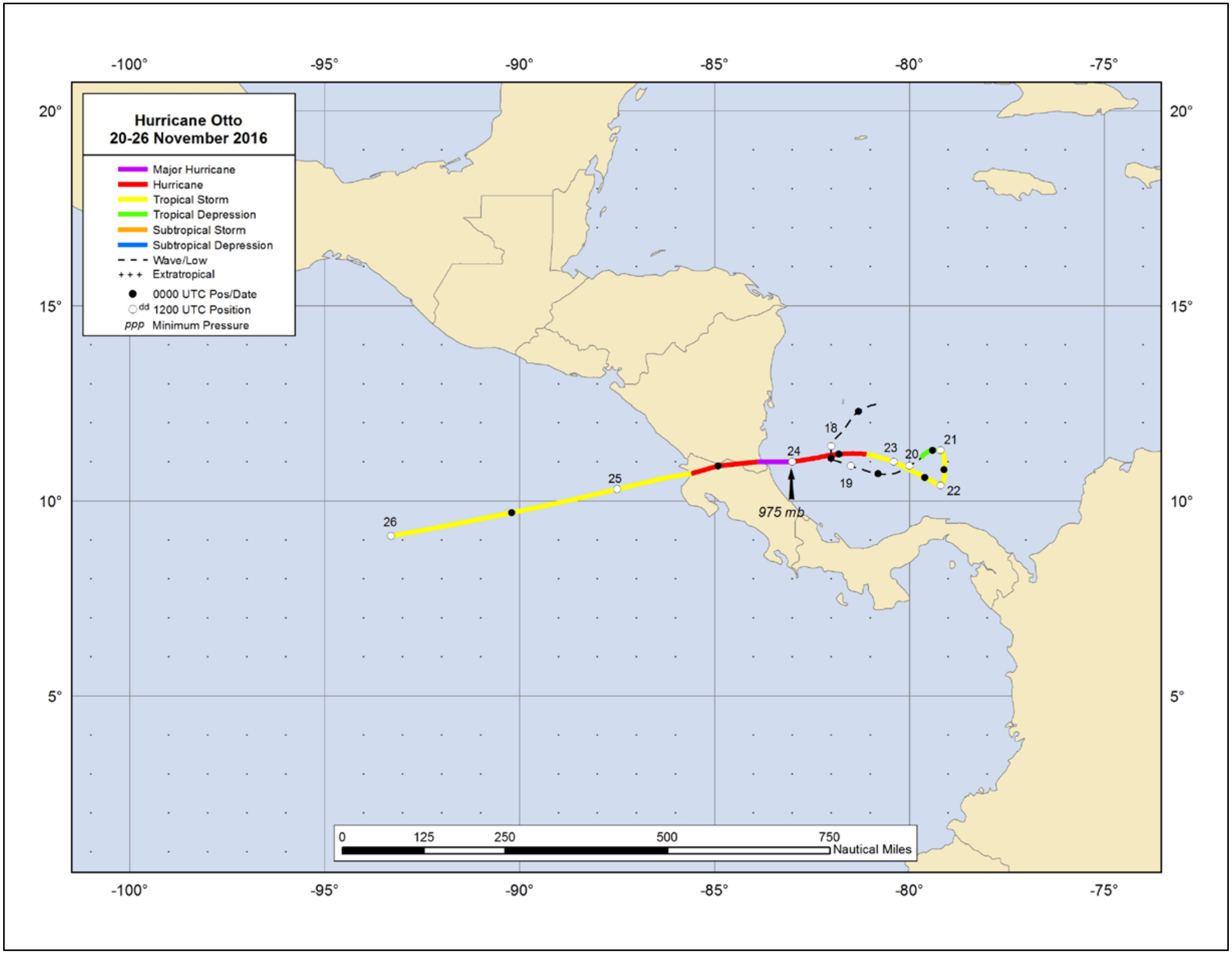

Figure 1. Best track positions for Hurricane Otto, 20-26 November 2016.

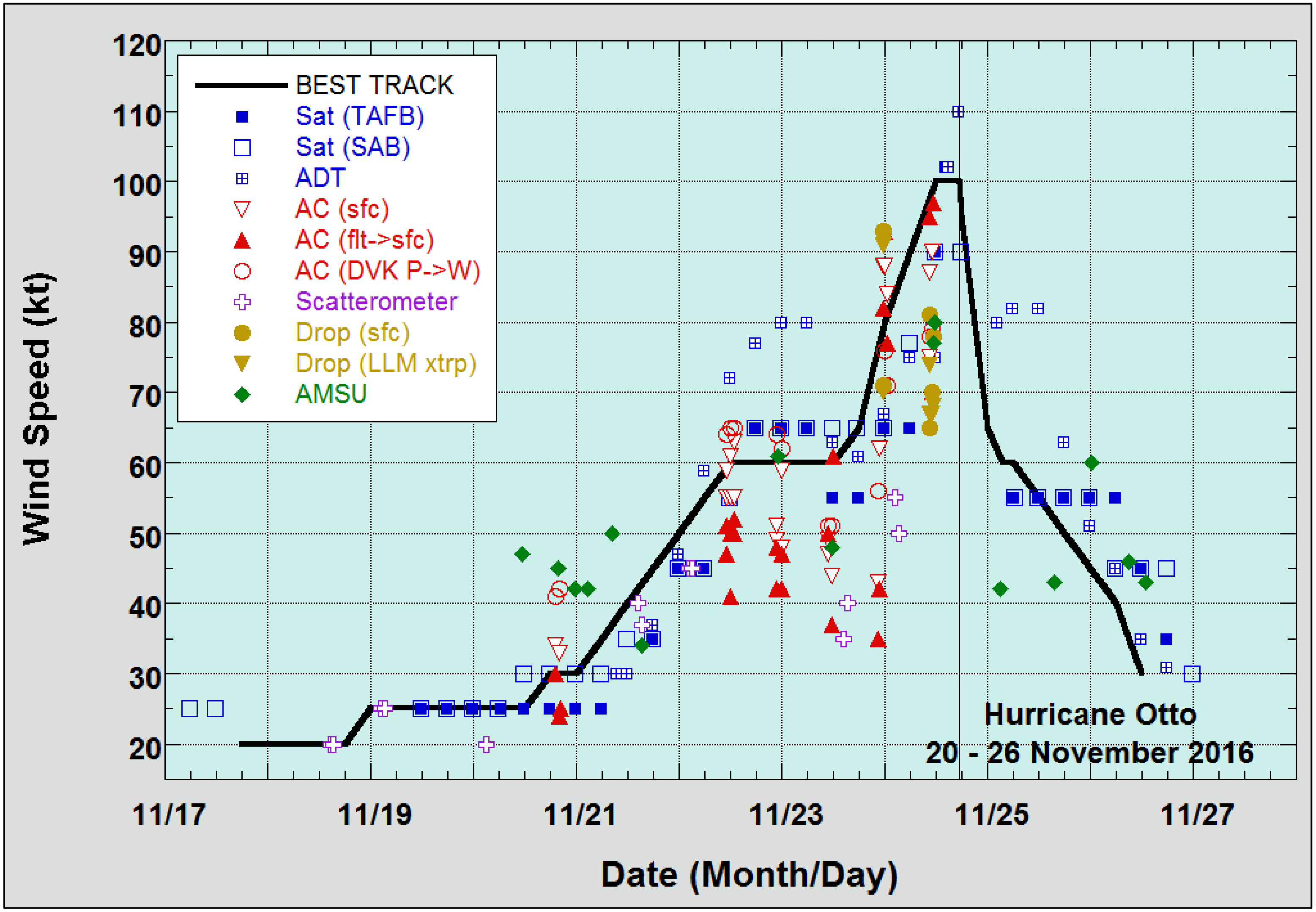

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Otto, 20-26 November 2016. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC, and solid vertical line corresponds to landfall.

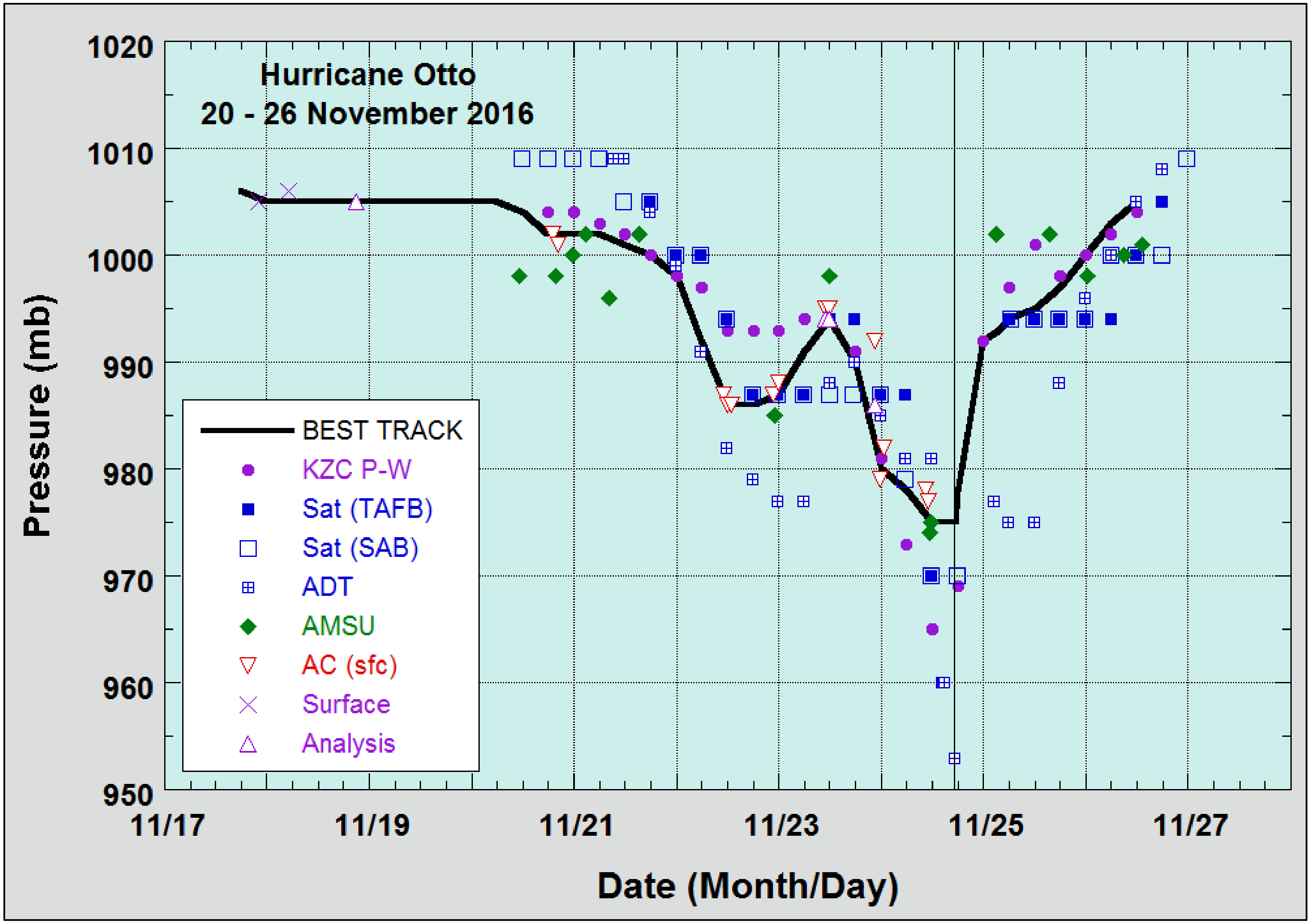

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Otto, 20-26 November 2016. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. 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.

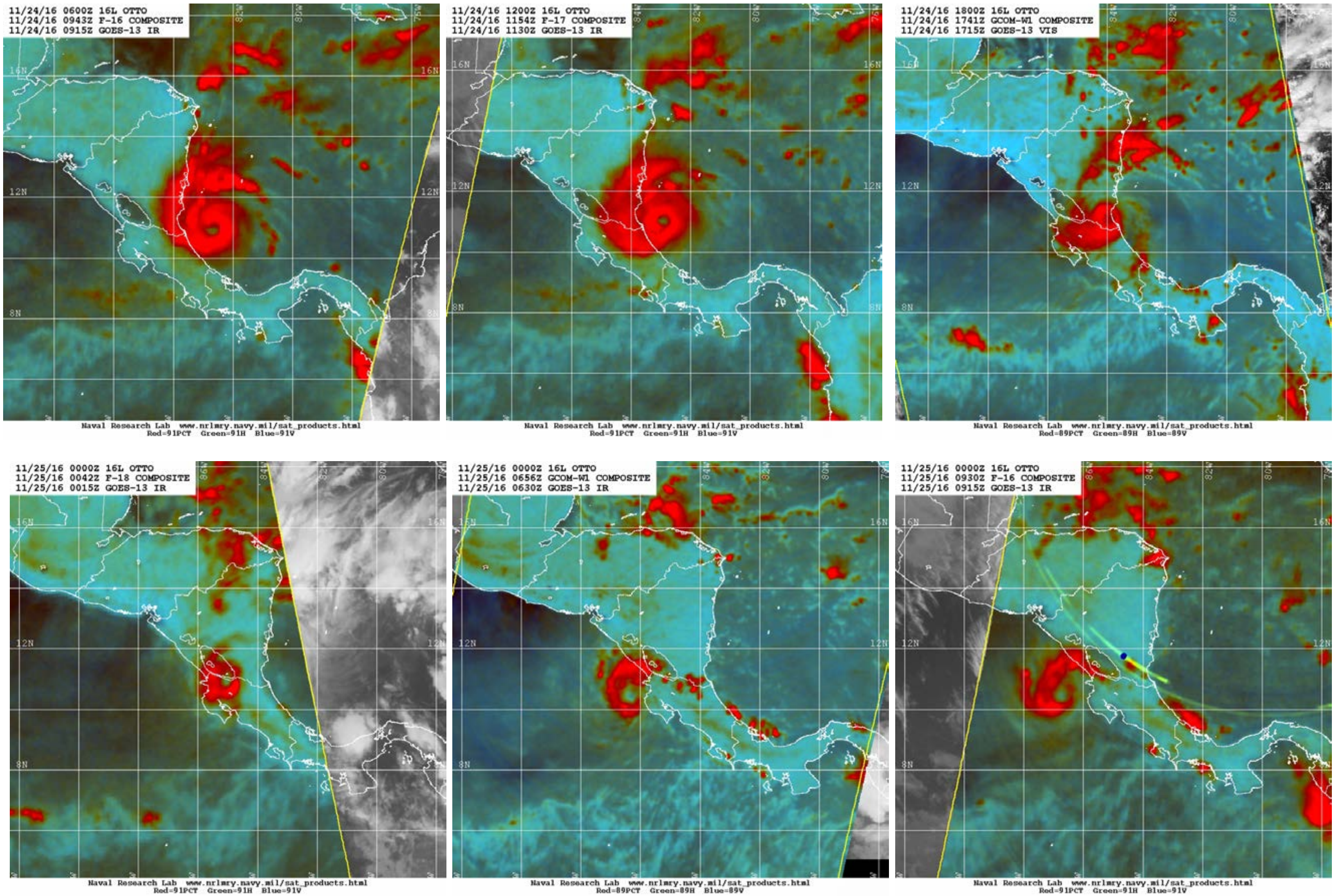

Figure 4. Series of 89- to 91-GHz color composite microwave satellite images of Otto between 0943 UTC 24 November (top left) and 0930 UTC 25 November (bottom right) that show the passage of Otto over Central America. Note the persistence of the eye during its trek from the Caribbean Sea to the eastern North Pacific basin. Images courtesy of the Naval Research Laboratory.

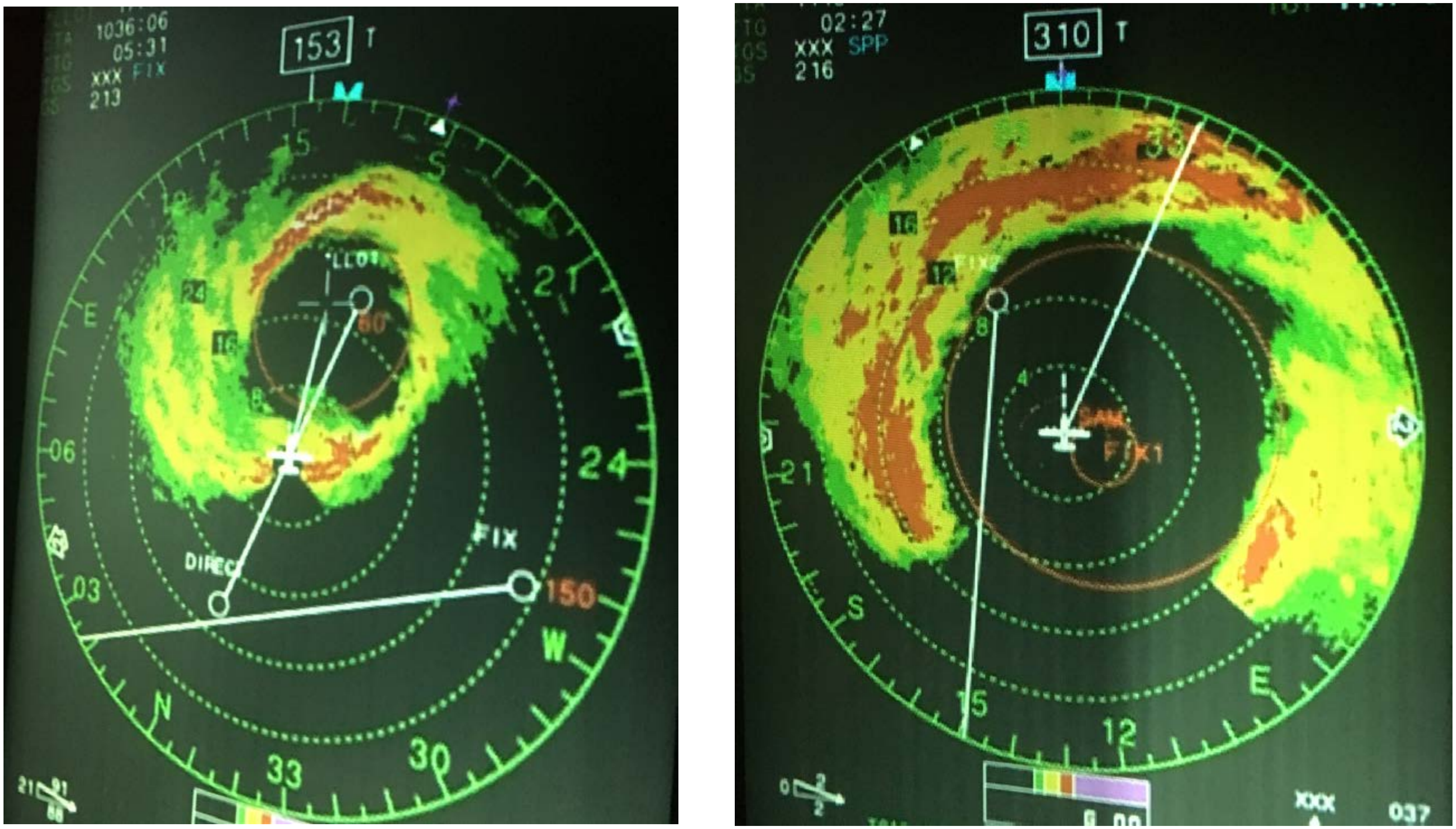

Figure 5. United States Air Force Reserve Hurricane Hunter C-130 aircraft radar images of the eye of Hurricane Otto on the final two aircraft penetrations into the hurricane around 1030 UTC (left) and 1115 UTC (right) 24 November 2016. Note the distance scale of the images is not the same. Range rings are in n mi. Images courtesy of the United States Air Force Reserve 53rd Weather Reconnaissance Squadron.

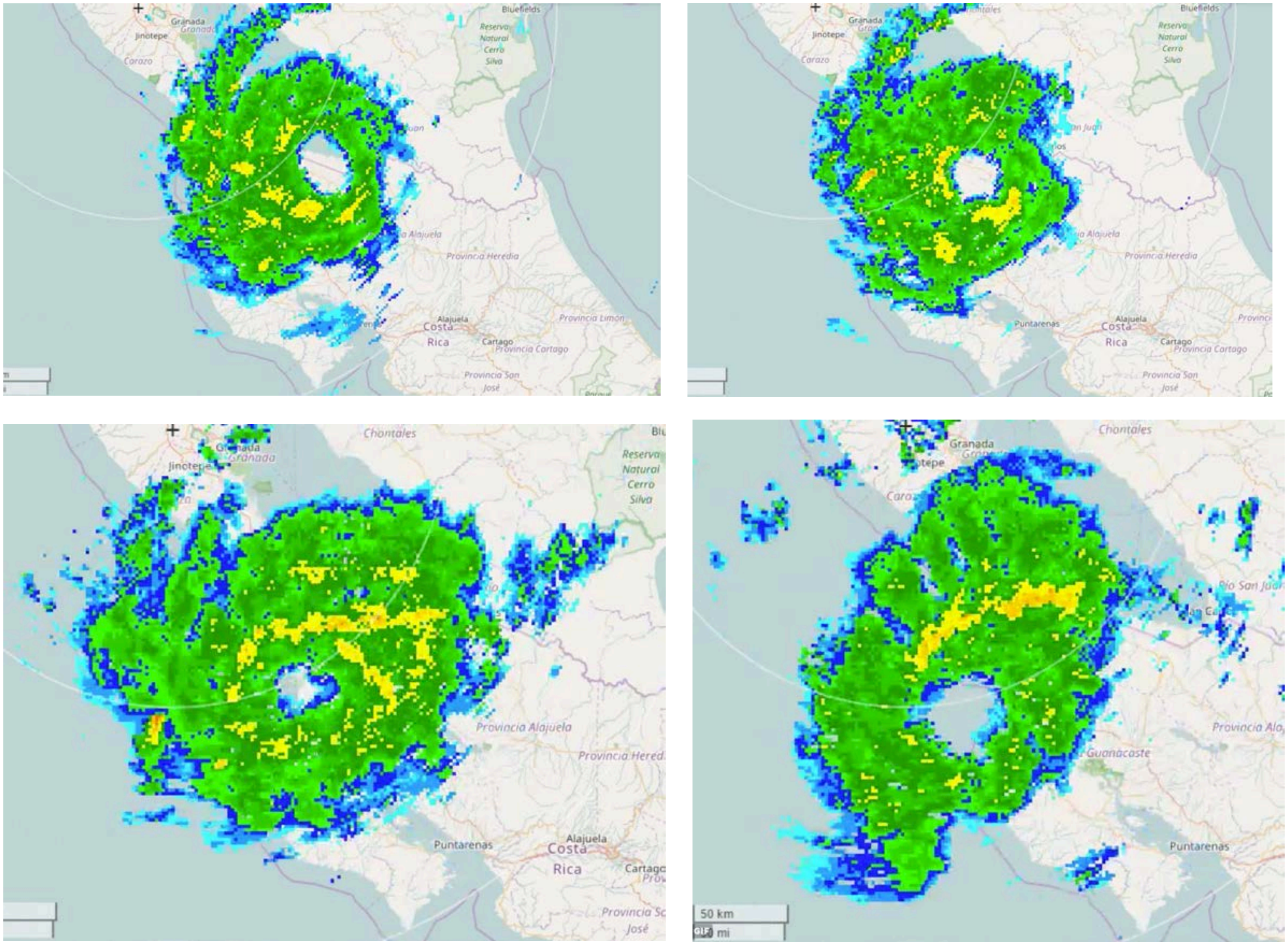

Figure 6. Series of radar images form the Las Nubes, Nicaragua, radar showing Otto moving over Central America early on 25 November. Images courtesy of the Nicaragua Institute of Territorial Studies. Note that the distance scale of the images changes between the panels.

Figure 7. Photos showing the extensive tree damage and defoliation of the rain forest canopy in the Indo Maíz Biological Reserve in southeastern Nicaragua. Photos courtesy of Camilo de Castro Belli of the National Geographic Society.

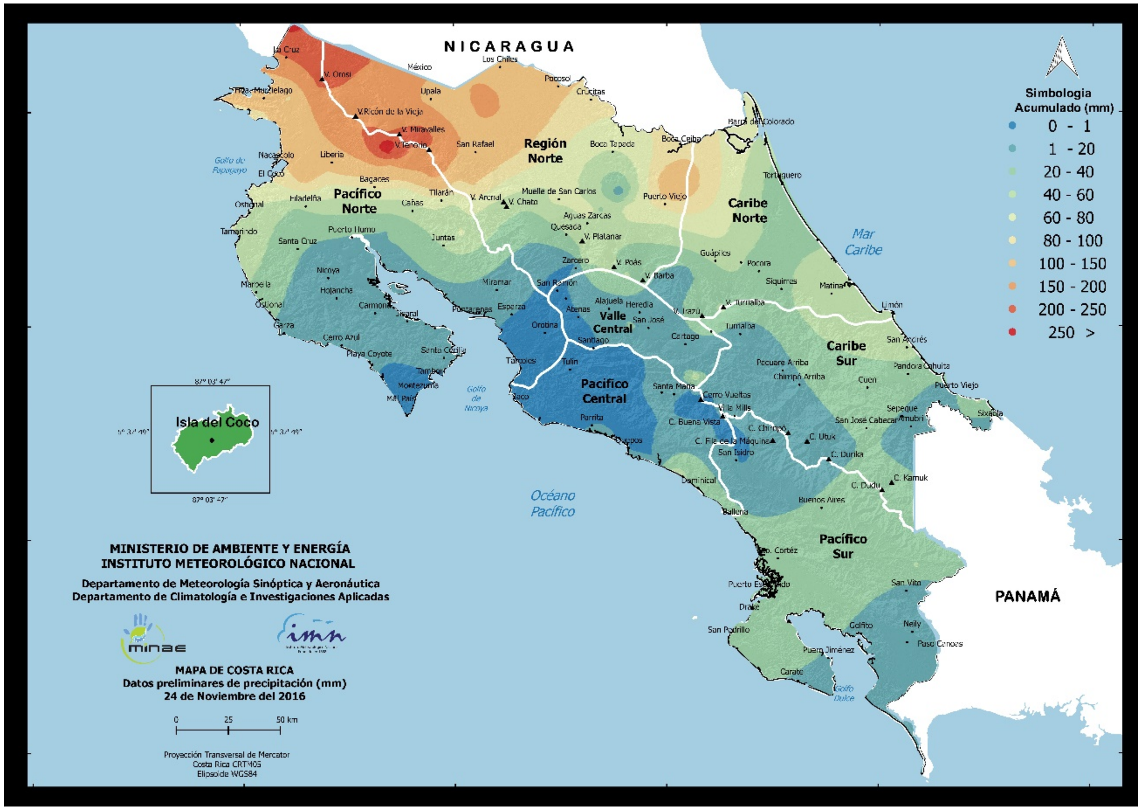

Figure 8. Map of rainfall accumulations (mm) in Costa Rica on 24 November 2016. Note that the rainfall amounts shown in Table 2 cover a 3-day period. Map courtesy of the National Meteorological Institute of Costa Rica.

Figure 9. Photo of damage to a bridge (left photo) over the Blanco River, in Guayabo de Bagaces, Costa Rica. Image courtesy of La Nacion. Photo of damage to a home (right photo) caused by a landslide near Guayabo de Bagaces. Image courtesy of Reuters (Juan Carlos Ulate).

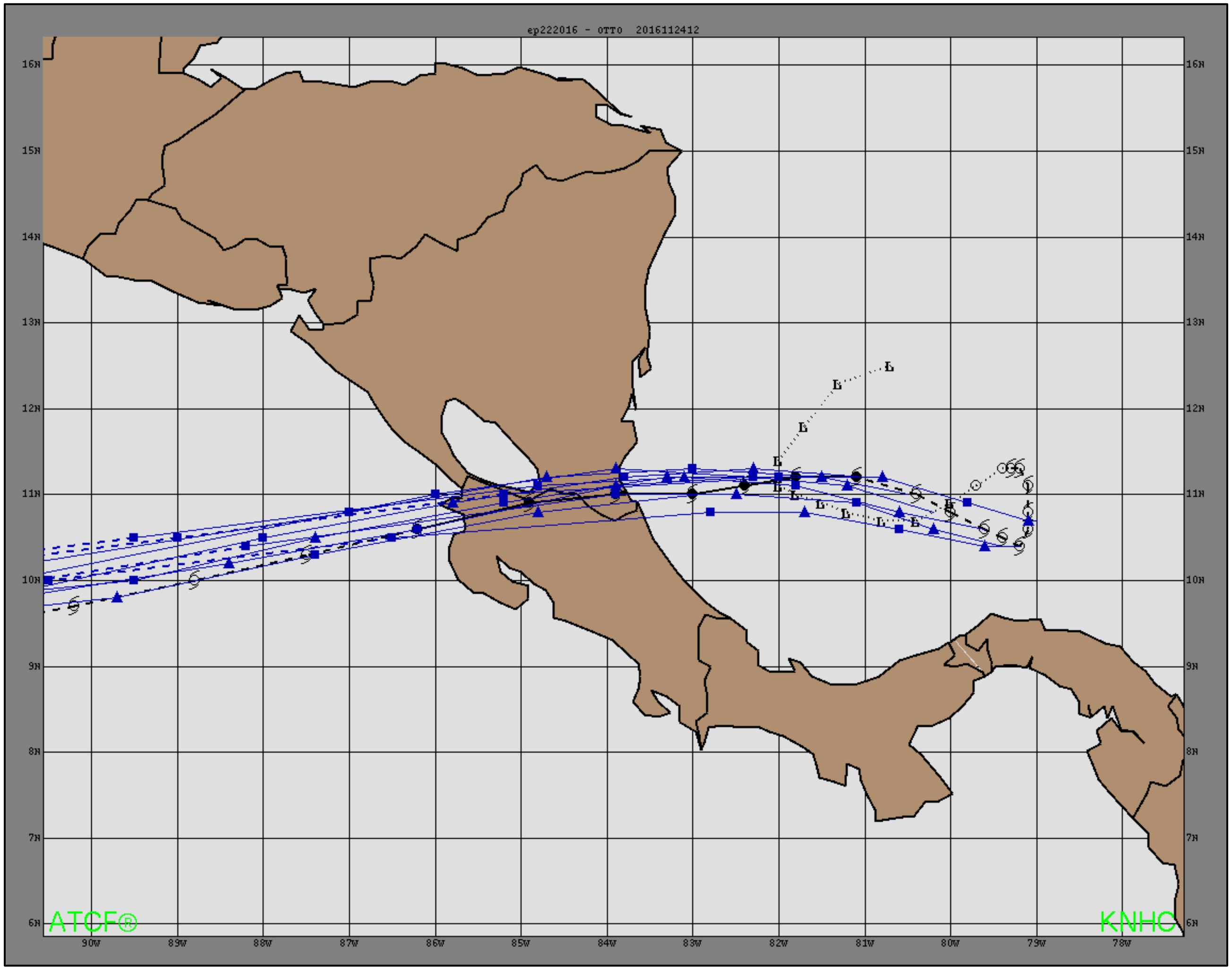

Figure 10. NHC track forecasts (dark blue) between 0600 UTC 21 November and 1200 UTC 24 November and the actual track of Otto (black). Note the consistency in the NHC forecasts of showing landfall in southern Nicaragua.