

# Irene Sweeps across Puerto Rico and the U.S. Virgin Islands

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## a. Synoptic History

Irene was a quite large and impressive tropical wave during most of its journey across the Atlantic Ocean during the week of August 14-20, 2011. For most of this time the wave was nearly surrounded by dry air and with enough vertical wind shear to ensure that any intensification would be slow. Its forward speed of 20 mph somewhat aided the shear in keeping it weak.

After the tropical wave reached a position near latitude 14°N and longitude 52°W on August 19 (Friday) at 600 pm AST (2200 UTC) its upper level circulation (outflow) was growing rapidly, becoming almost twice the size that Tropical Storm Emily had at approximately the same location barely 2 weeks before. To the north was a deep high pressure ridge at latitude 25°N and to the northwest a remnant upper level tropospheric

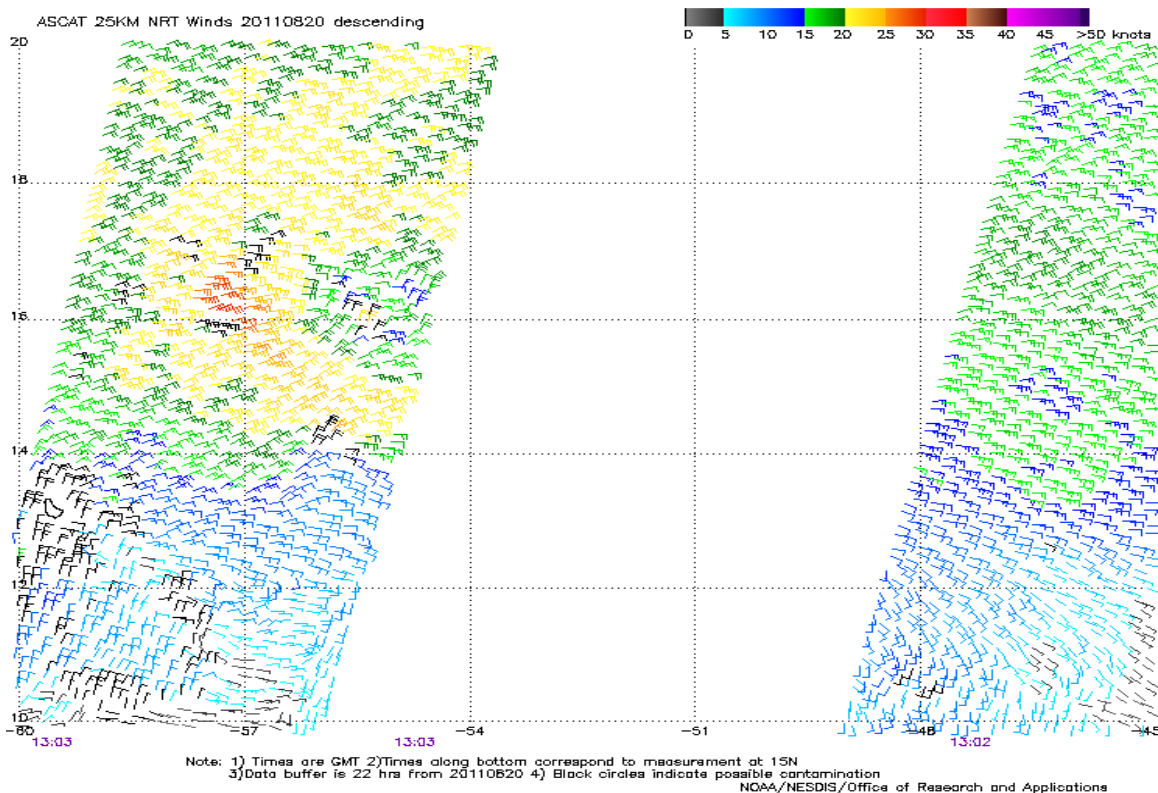


Fig. 1. Descending pass of the advanced scatterometer (ASCAT) from satellite on August 20.

trough which continued to weaken. The growing size and influence of the wave decreased the effect of dry air being entrained while the available dry air surrounding it decreased as well. The system was moving into an area of less vertical shear, eventually slowing its forward speed, and over warmer water.

Early on August 20 the advanced scatterometer (ASCAT) showed that, although the winds were strengthening, only a small area had surface winds reaching 30 knots and the circulation near 57°W was far from being closed (Fig. 1).

By the time the wave was approaching the Lesser Antilles an Air Force Reserve Hurricane Hunter aircraft had found a low level circulation and 53 knots of sustained wind 1,400 feet above the ocean surface. The system was located at 14.9°N, 58.5°W at 700 pm AST (2300 UTC) on August 20 and the National Hurricane Center (NHC) issued its initial warnings, including a tropical storm warning for Puerto Rico, Vieques, Culebra, and the U.S. Virgin Islands (Fig. 2). Most of the model guidance was showing the system moving west-northwest, eventually south of Puerto Rico and the U.S. Virgin Islands. Both initial position and motion would continue to be uncertain for the next day due in part to difficulty in locating the center.

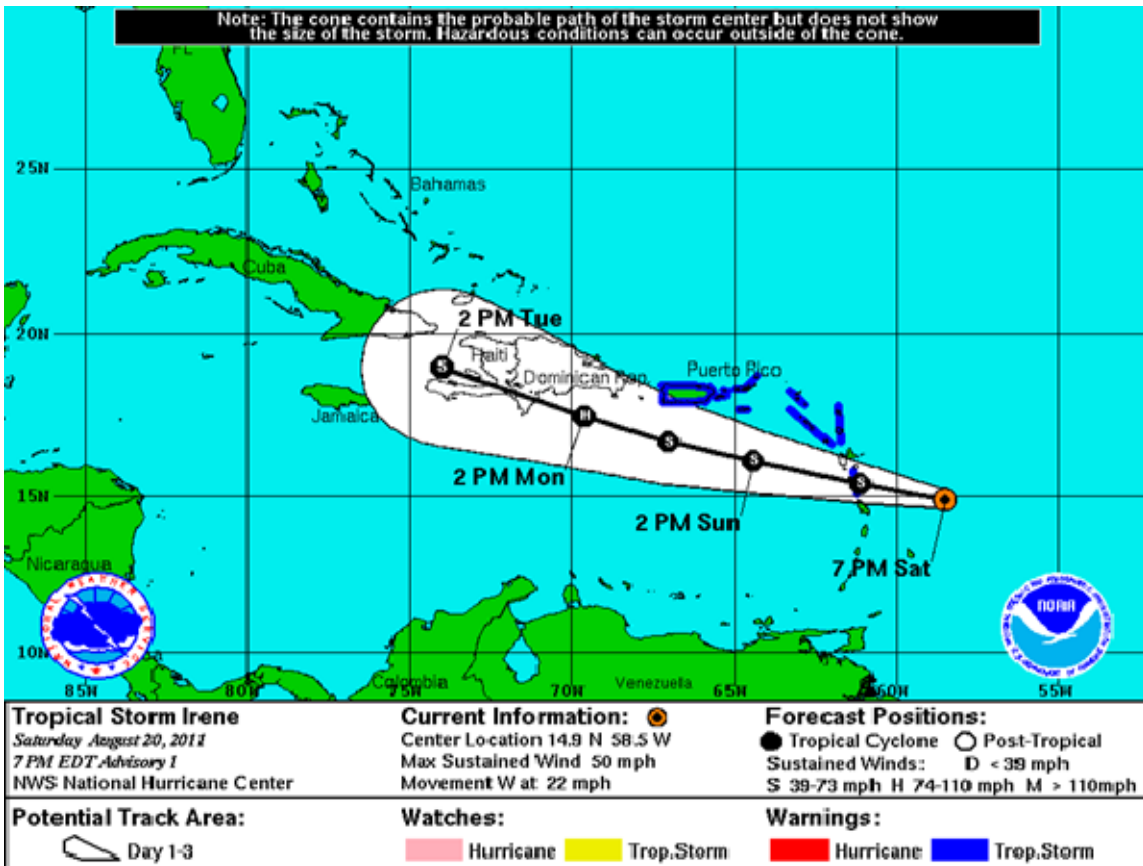


Fig. 2. Initial watches, warnings, and position forecast issued for Irene on August 20.

At 1100 am AST (1500 UTC) on Sunday, August 21 the forecast track and uncertainty of Irene had shifted slightly north and was close enough to Puerto Rico for NHC to upgrade

the tropical storm warning to a hurricane warning for Puerto Rico, Vieques, and Culebra though it was kept a storm warning for the U.S. Virgin Islands. The best forecast estimate for the center of Irene was still to pass south of St. Croix, across the Puerto Rico coastal waters in the Caribbean Sea and then over the southwest corner of mainland Puerto Rico.

The ASCAT image at this time indicated stronger winds in a circulation becoming better defined (Fig. 3).

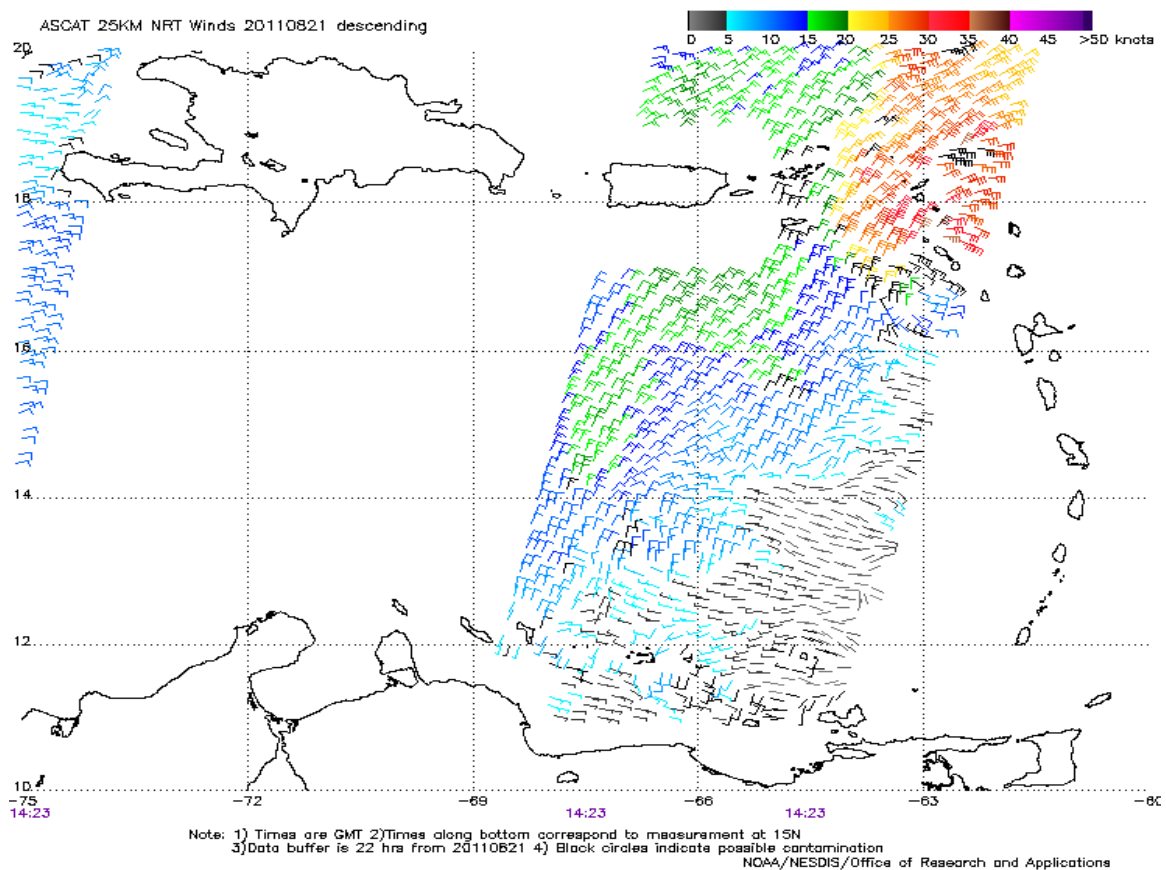


Fig. 3. Descending pass of scatterometer showing several locations of winds exceeding 35 knots about noon on August 21.

Later that day the center was still moving north of the forecast track. At about 600 pm AST the center passed over St. Croix while the strongest winds were farther north. At 556 pm AST (2156 UTC) Cyril E. King Airport at Charlotte Amalie, St. Thomas recorded a wind gust to 60 knots (69 mph), also when the WSR-88D radar in Puerto Rico showed the strongest winds over and just south of St. Thomas (Fig. 4).

By 1236 am AST August 22 sustained winds were reported over Vieques of 52 mph with a gust to 71 mph, while a buoy near Esperanza, PR (Vieques) reported a gust to 66 knots (76 mph) at 106 am AST (Fig. 5).

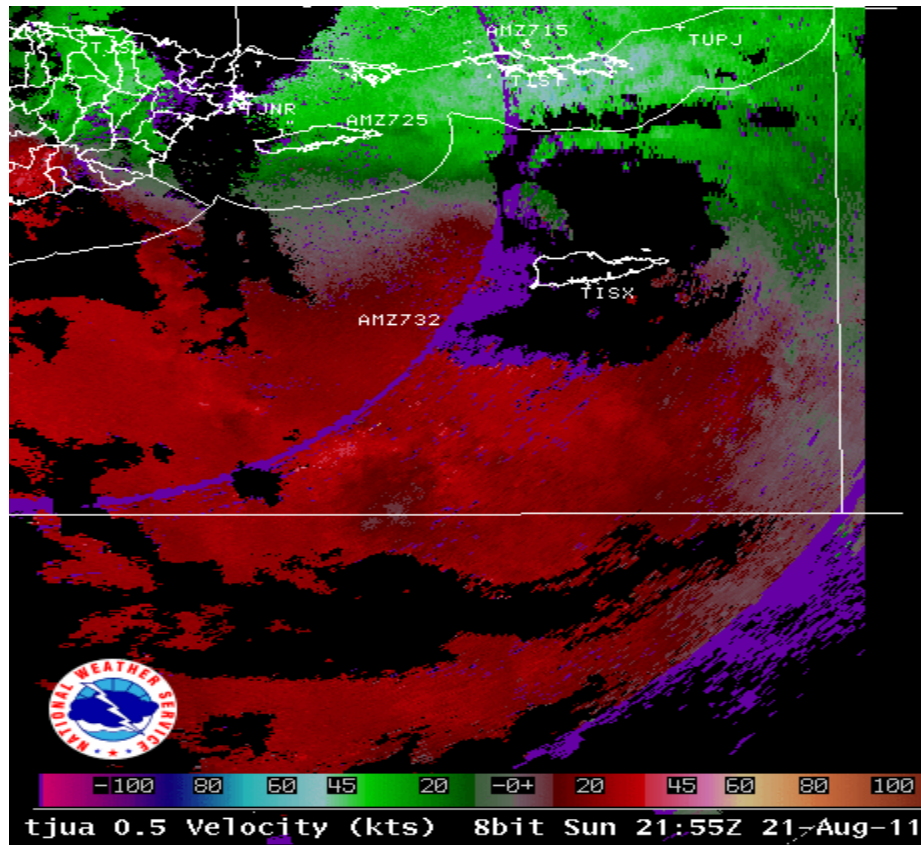


Fig. 4. TJUA WSR 88D Doppler Radar image of velocity at 2155z on August 21. Irene's center was over St. Croix (TISX) and the strongest winds (inbound, green) were over St. Thomas (TIST).

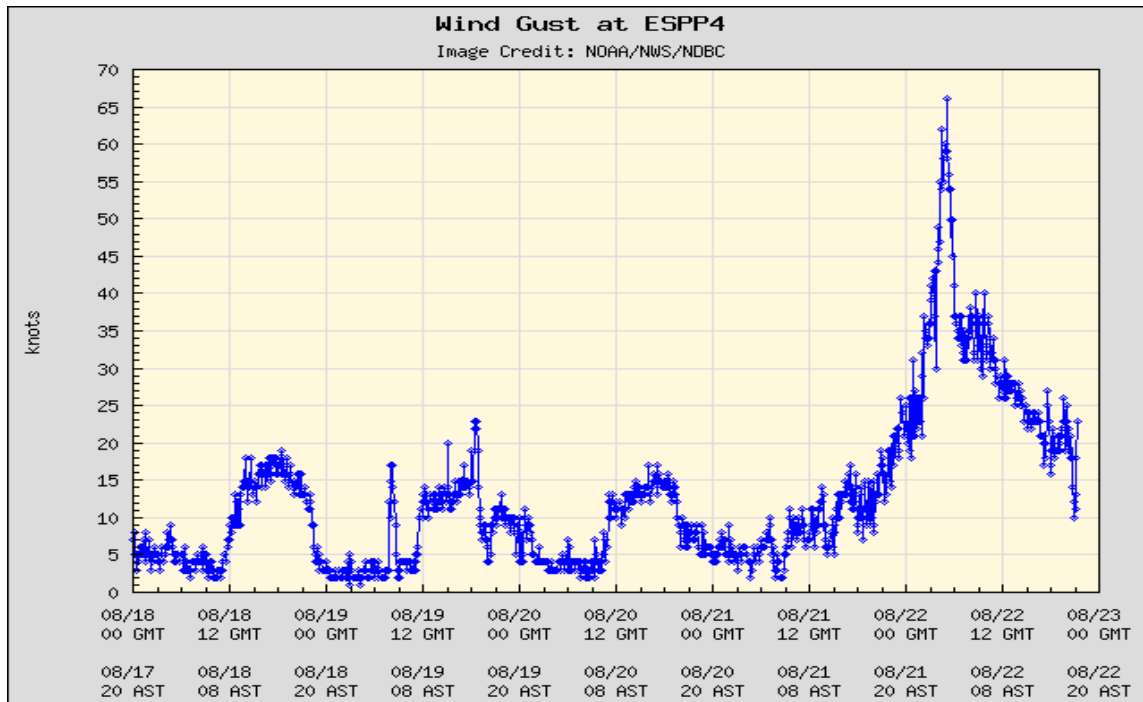
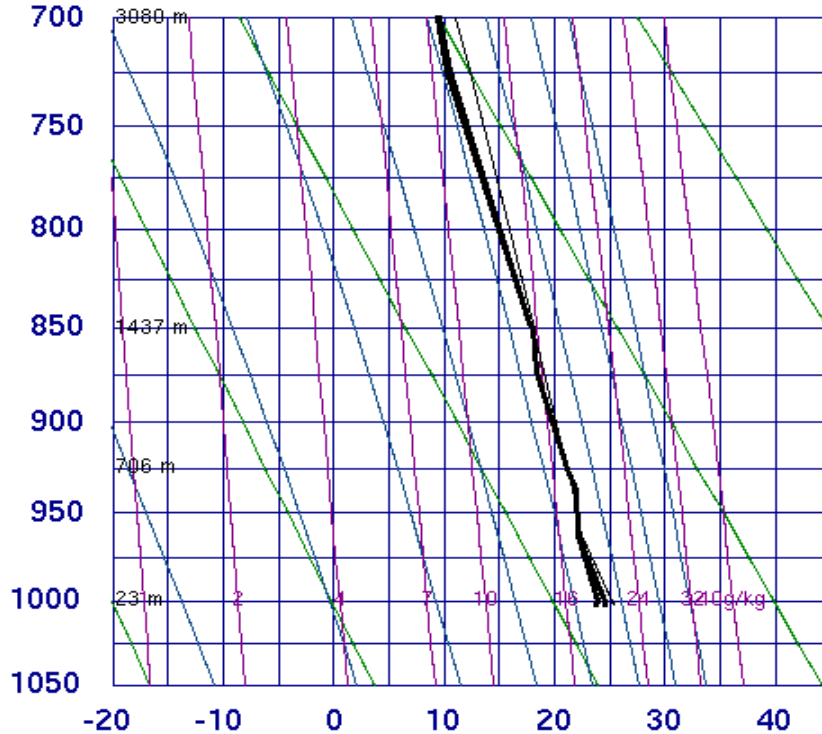


Fig. 5. Wind history at ESPP4 (Esperanza) buoy.

### 78526 TJSJ San Juan



	SLAT	18.43
	SLON	-66.00
	SELV	3.00
	SHOW	-0.79
	LIFT	-0.98
	LFTV	-1.10
	SWET	324.9
	KINX	39.10
	CTOT	21.30
	VTOT	21.30
	TOTL	42.60
	CAPE	361.4
	CAPV	432.1
	CINS	0.00
	CINV	0.00
	EQLV	138.8
	EQTV	138.8
	LFCT	971.0
	LFCV	971.0
	BRCH	123.8
	BRCV	140.3
	LCLT	295.9
	LCLP	971.0
	MLTH	298.4
	MLMR	18.39
	THCK	5797.
	PWAT	69.75

06Z 22 Aug 2011

University of Wyoming

Fig. 6. 0600 UTC August 22, 2011 sounding at TJSJ shows 51 knots at 305 m above msl.

Irene made landfall over mainland Puerto Rico at 125 am AST on August 22, near Punta Santiago then Luis Munoz Marin International Airport at San Juan recorded its highest wind gust of 59 mph at 218 am AST. A special atmospheric sounding done just before the center passed across the south portion of metropolitan San Juan revealed 51 knots of wind only 1,000 feet (305 m) above sea level (Fig. 6). At 300 am AST (0700 UTC) the center was estimated to be 10 miles southwest of San Juan with 70 mph sustained winds, mainly over the Atlantic waters north of the city. Figure 7 shows some areas of 70 knot winds only 600 to 700 feet above the water north of Carolina, PR at 256 am AST.

By 500 am AST the TJSU Doppler radar had indicated winds sustained up to 72 knots only 500 to 600 feet above the ocean surface. Irene was then officially upgraded to hurricane status though a hurricane warning had already been issued for the region. With the hurricane center moving offshore about this time the strongest wind (north of the center) also moved away from shore. At 536 am AST the buoy near Arcibo recorded its highest wind gust of 37 knots (43 mph). At 900 am AST the center of Irene was directly north of the west coast of Puerto Rico but the hurricane force winds were well offshore with a well developed center noted on radar (Fig. 8). The GOES satellite near this time still showed clouds covering the hurricane center (Fig. 9), and as viewed from the International Space Station (Fig. 10).

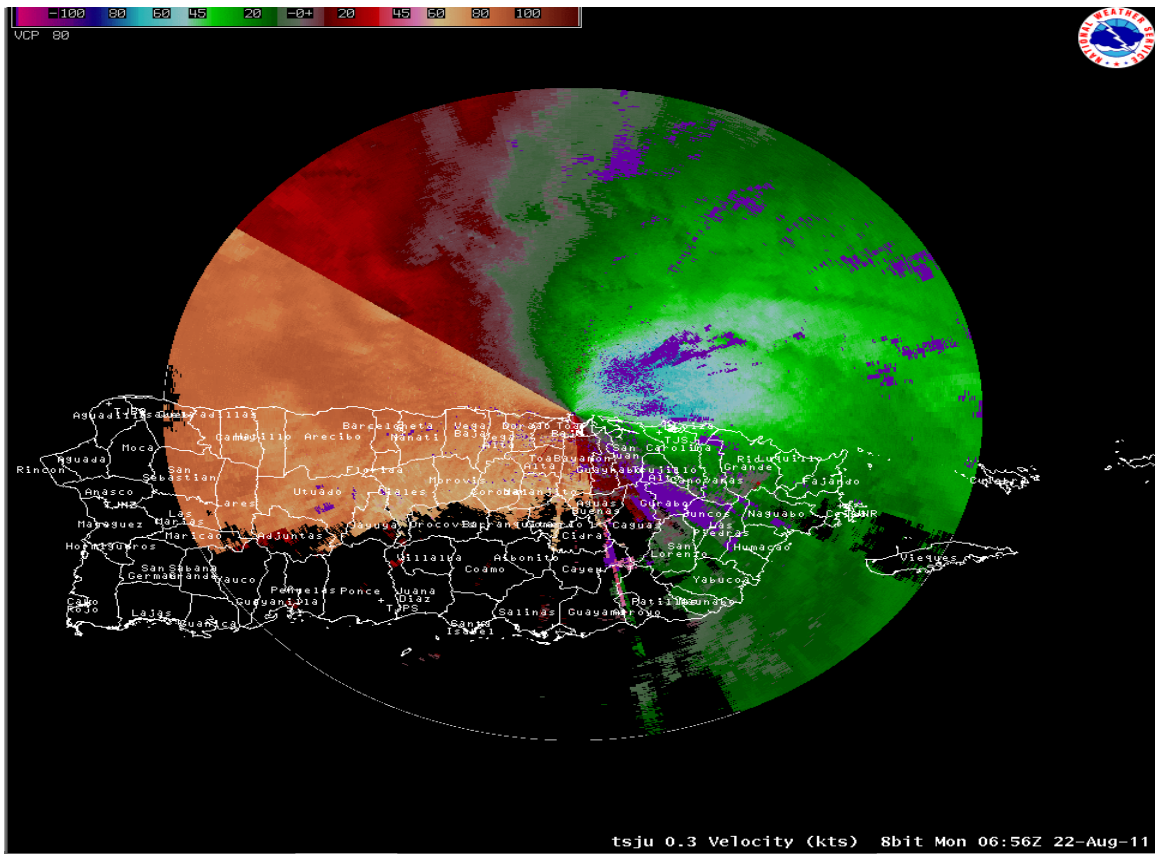


Fig. 7. Terminal Doppler Radar (TSJU) image at 256 am AST (0656 UTC) on August 22. Areas of inbound (blue) velocity showed 70 knots north of Carolina (E. San Juan Metro).

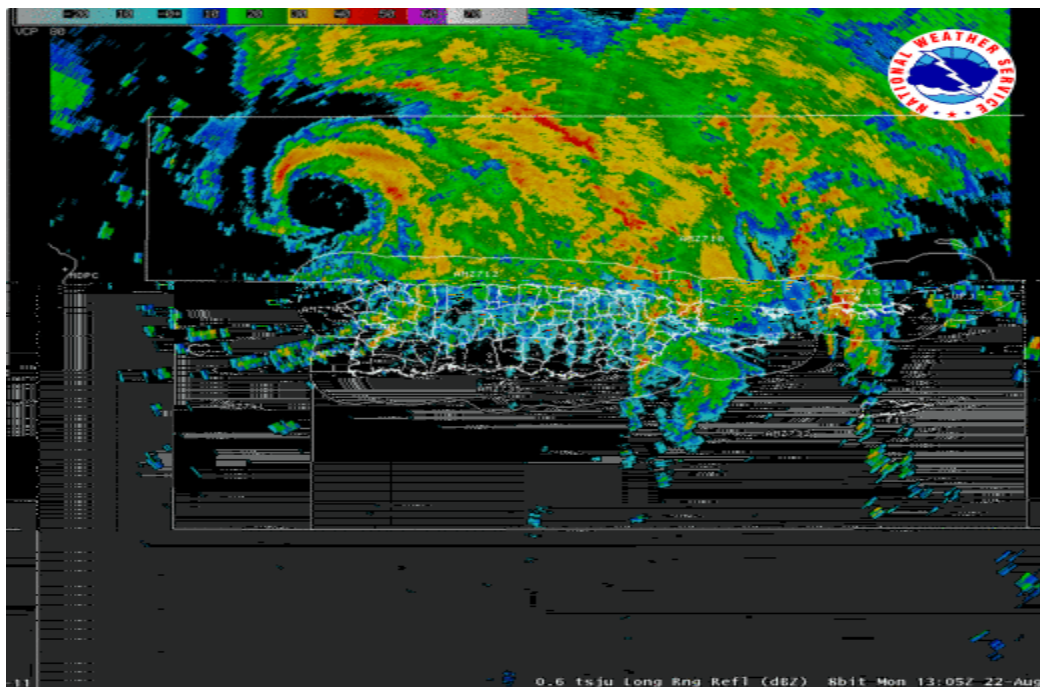


Fig. 8. Terminal Doppler Radar (TSJU) shows the center of Irene north of the west edge of mainland Puerto Rico.



Fig. 9. Hurricane Irene visual GOES satellite view about 1000 am AST (1400 UTC).

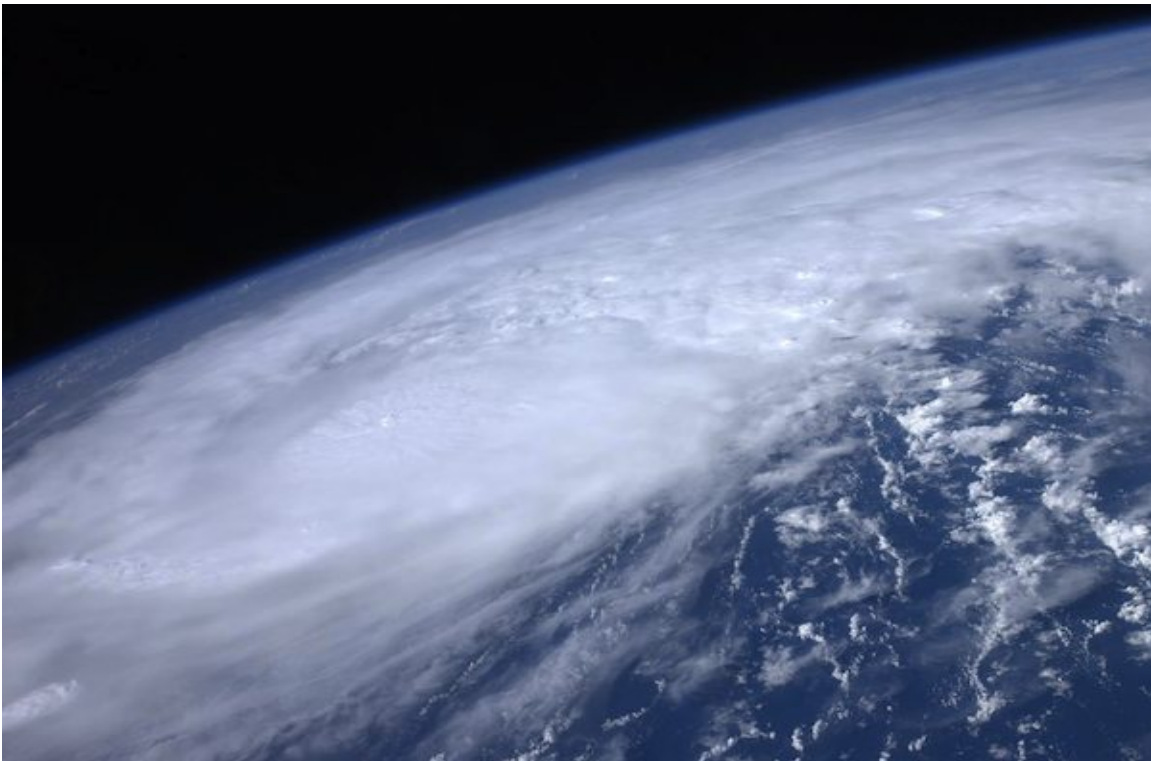


Fig. 10. Hurricane Irene over Puerto Rico as viewed from the International Space Station.

Figure 11 from NHC shows the wind history of Irene updated through Tuesday morning (August 23) and indicated that winds increased to hurricane force as it reached the north central coast of Puerto Rico.

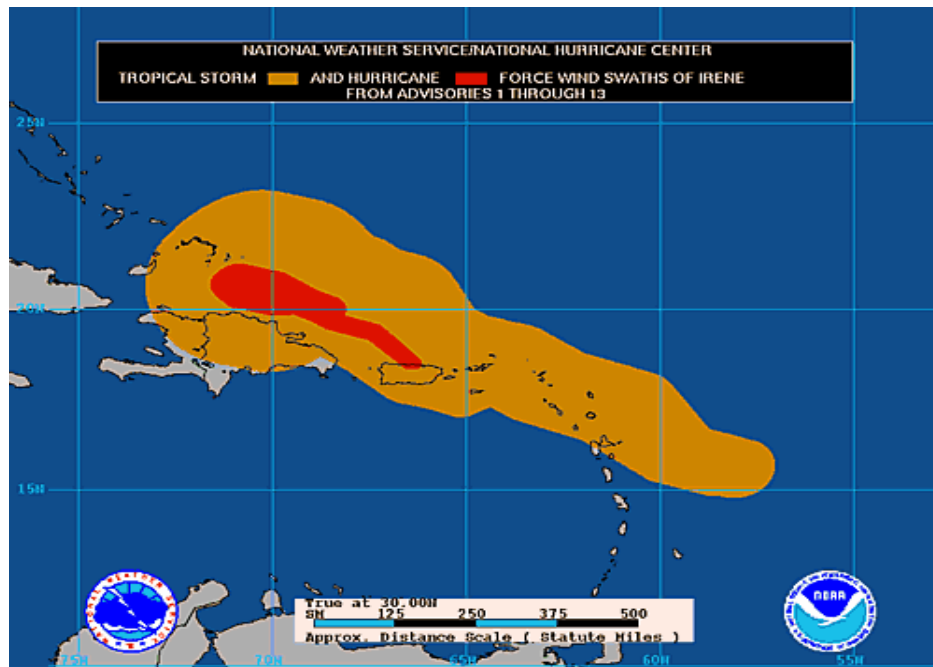


Fig. 11. Wind history for Irene through 1100 am AST Tuesday morning.

## b. Rainfall and Rivers

Heavy rainfall from Irene was widespread, especially over Eastern Puerto Rico. The Southeast River Forecast Center's graphical estimation of rainfall from Doppler radar, quality controlled with rain gages, is shown in Figure 12 followed by the highest recorded 3-day and 5-day rain gage amounts above 20 inches, as shown in Table 1.

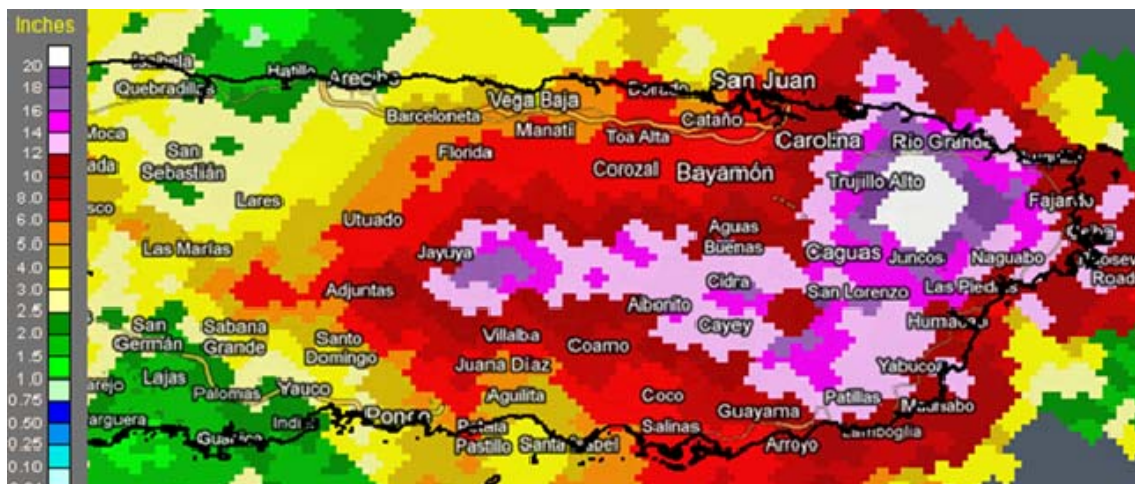


Fig. 12. Total rainfall during Irene from Southeast River Forecast Center, estimated from radar and rain gages.



Location	08/22	08/23	08/24	3-Day SUM	5-Day
GURABO ABAJO RAINGAG PR	4.91	7.28	9.85	22.05	24.51
R CANOVANAS-CAMPO RI PR	5.78	5.60	9.20	20.58	22.17
QUEB GUABA/NAGUABO PR	10.51	3.90	4.41	18.82	20.24
QUEB BLANC/SAN LOREN PR	4.45	6.99	6.57	18.01	19.29
LAGO DE MATRULLAS PR	5.31	6.66	5.86	17.83	18.40
PUEBLITO DEL R RAING PR	7.77	3.21	6.46	17.44	
BISLEY MET STATION PR	8.34	5.71	3.16	17.22	
R BAYAMON @ ARENAS PR	3.04	8.70	4.97	16.71	17.51
R CAYAGUAS@CERRO GOR PR	4.01	5.72	6.85	16.58	18.25
RIO GR DE PATILLAS PR	2.97	4.21	7.81	14.99	15.85
LAGO ICACOS DAMSITE PR	7.94	2.42	4.46	14.83	15.37
BARRIO BEATRIZ PCPN PR	2.45	6.20	4.88	13.53	
LAGO CIDRA NR CIDRA PR	3.00	6.67	3.35	13.03	13.29
QUEB ARENAS RAINGAGE PR	4.68	3.44	4.50	12.63	14.51
R BAYAMON BL L CIDRA PR	2.48	6.49	3.57	12.54	13.05
YABUCOA PR	5.20	5.20	2.14	12.55	13.63
BO MARIN/PATILLAS 4N PR	3.67	2.99	5.79	12.45	14.06
VILLALBA 3NE/BAR APE PR	3.72	3.17	4.58	11.48	12.38
LAGO PATILLAS AT DAM PR	2.38	2.36	6.64	11.38	11.86
PLATA AT COMERIO PR	4.55	4.17	2.50	11.23	11.61
REPRESA DE COMERIO PR	4.49	4.54	2.02	11.05	11.28
NSSR/CEIBA 3SE PR	7.87	1.98	0.91	10.77	11.02
de LOIZA @ CAGUAS PR	2.06	5.40	2.89	10.36	11.93
PIEDRAS@ HATO REY PR	2.30	3.03	4.87	10.20	10.35
RIO SALIENTE@COABEY PR	3.20	4.01	2.98	10.20	10.20
RIO INABON NR PONCE PR	1.32	4.51	4.26	10.10	11.99
R GR D LOIZA/SAN LOR PR	2.00	4.78	3.26	10.05	10.05

Table 1. Recorded rainfall at stations across Puerto Rico, from 800 am on August 21 through 800 am on August 24. The 5-Day totals include data on 08/21 and 08/25.

The 24 hour values begin and end at 800 am. For example 08/22 rainfall refers to rain that began 08/21 at 800 am and ended at 08/22 at 800 am. Officially, the sum of total rainfall for Irene ends at 800 am Wednesday 08/24. The remaining rainfall was just local effects and unstable atmosphere.

Table 2 shows many of the river forecast gage locations in Puerto Rico that exceeded flood stage during August 22-24, arranged according to basin. The crest value at the gage on the Rio Grande de Manati at Manati (MANP4) was the third highest level reached in its history, behind only the crests reached during Hurricane Hortense (1996) and Hurricane Georges (1998). The crest on the Rio Puerto Nuevo, Rio Piedras at Metro-R Piedras (Hato Rey) was the fourth highest gage height, behind only the level recorded during Hurricane Hortense (1996) and after non-tropical storm related rainfalls in December, 1975 and November, 1977.

#Questionable Data *Moderate Flooding **Major Flooding						
<b>Flood Summary at River            Forecast Points (Puerto Rico)</b>						
Basin	River and Station	Flood Stage (ft)	Above flood stage (date/time UTC)		Crest (ft) date/time (UTC)	
			From	To		
<b>Rio Cibuco</b>	Rio Cibuco at Vega Baja (VGBP4)	15.0	23/0240	24/0714	16.47	24/0230
<b>Rio de La Plata</b>	Rio de La Plata at Hwy 2 Toa Alta (TOAP4)	16.0	22/0902	24/1134	*21.25	23/2000
			23/0854	24/0103	16.08	24/1600
	Rio de La Plata below La Plata Dam (NASP4)	16.0	22/0528	24/0627	23.68	24/0615
	Rio de La Plata at Proyecto La Plata (AIBP4)	14.0	22/1047	24/1058	*20.29	23/1145
	Rio de La Plata at Comerio (COMP4)	11.0	N/A	24/0539#	20.67	23/1715
<b>Rio Grande de Loiza</b>	Rio Grande de Loiza at Caguas (CAGP4)	16.0	22/1239	22/1356	16.52	22/1315
			23/0057	23/0303	17.81	23/0200
			23/2141	24/0148	18.51	24/0215
	Rio Grande de Loiza at Highway 183 (SLNP4)	14.0	22/1117	24/1028	17.41	23/0115
<b>Rio Gurabo</b>	Rio Gurabo at Gurabo (GURP4)	18.0	22/1302	24/1111	*28.94	23/1600
<b>Rio de Arecibo</b>	Rio de Arecibo at San Pedro (AREP4)	11.0	N/A	N/A	*14.11	24/0000
	Rio de Arecibo at Lago Dos Bocas near Utuado (ARGP4)	297.0	22/2015	N/A	301.45	23/2230
	Rio de Arecibo below Utuado (UTXP4)	14.0	23/2037	23/2111	15.48	23/2056
<b>Rio Grande de Manati</b>	Rio Grande de Manati at Ciales (CIAP4)	10.00	22/1134	24/0151	**17.98	23/2006
	Rio Grande de Manati at Manati (MANP4)	25.0	22/1102	24/1737	**34.77	23/2245
<b>Rio Guanajibo</b>	Rio Guanajibo near Hormigueros (HORP4)	20.0	24/0130	24/0300	20.06	24/0230
<b>Rio Puerto Nuevo</b>	Rio Piedras at Metro-R Piedras (Seniorial)	11.0	23/0113	23/2219	*13.17	23/2015
	Rio Piedras at Metro-R Piedras (Hato Rey)	15.0	23/0138	23/0251	16.47	23/0215
			23/2008	23/2355	**20.43	23/2200

Table 2. River gages at selected forecast points that exceeded flood stage, arranged by basin.

### **c. Damage and other Impacts**

Across the U.S. Virgin Islands Tropical Storm Irene downed trees and branches which blocked roads, sent debris across roadways, and some minor rock slides. Irene's winds and rains left many residents without power. Saint Croix was hit the worst since the center of the storm crossed the island. Downed trees and flooding were reported along Melvin Evans Highway and roadway Queen Mary, and at Good Hope, Carlton, Williams Delight, Lagoon Fredericksted, Melvin Evans Airport road, and the rear of Sunny Isles.

Damage from flooding was extensive across Puerto Rico from Irene, however, though wind caused widespread damage it was relatively minor compared to what might have occurred in a stronger hurricane. After tree damage occurred on Sunday night (August 21-22) in St. Thomas and St. John, many trees were blown down very early on Monday morning from Fajardo to San Juan Metro. Downed trees blocked highways in Gurabo, Adjuntas, and Caguas while a down power pole lay on Highway PR-176 in Cupey.

The following is a summary of reported inland flooding for Puerto Rico, by municipality.

Arecibo: Routes PR-605 and PR-612 closed due to flooding.

Arroyo: Highway PR-3 KM 130 flooded.

Barceloneta: sections of Highways PR-2, PR-666, and PR-684 flooded due to Manati River out of its banks.

Canovanas: Route 907 in sector Cubuy washed out from flooding.

Carolina: urban flooding at the junction of Baldority de Castro and Campo Rico Avenue.

Cayey: Highways PR-1 and PR-743 flooded.

Cidra: Highway PR-173 KM 6.5 flooded due near "Ceiba" neighborhood.

Coamo: Highway PR-556 KM 1.0 flooded due to Coamo River out of its banks.

Dorado: PR-659 flooded at the junction with PR-694 due to the flooding La Plata River.

Fajardo: PR-53 flooded due to Fajardo River out of its banks.

Guayama: sections of PR-3 and PR-179 flooded due to Guamani River out of its banks.

Manati: flooding on PR-2, PR-667, and PR-6635 due to Manati River out of its banks.

Orocovis: flooding on Routes PR-568 and PR-155 in sector Los Sandovalos.

Patillas: flooding on Highway PR-3 due to the small stream "Guardarraya" out of its banks.

Ponce: flooding on Highway PR-1 due to Inabon River out of its banks.

San Juan: urban flooding on Baldorioty Ave. at the entrance of Minillas Tunnel. Avenue Jesus T. Pinero also closed due to Puerto Nuevo River out of its banks. Route PR-865 at KM 4.6 sector El Hoyo flooded.

San Lorenzo: expressway "Chayanne" flooded.

Toa Alta: PR-824 sector Los Cocos flooded.

Toa Baja: PR-2 at junction with PR-165 sector la Virgencita flooded due to La Plata: River out of its banks.

Trujillo Alto: Routes PR-175, PR-848, and PR-881 closed due to flooding.

Utuado: PR-611, 6 meter landslide due to the water laden hill.

Vega Alta: Highways PR-2, PR-620, PR-647, PR-675, PR-676, and PR-690 closed due to Cibuco River out of its banks.

One woman died on August 23 after her vehicle was swept away while trying to drive across PR-857 in Barrio Canovanillas, cohitre sector. There were no major injuries reported, however, there were significant numbers of people evacuated or placed in shelters. Table 3 summarizes these by municipality.

<b>Municipality</b>	<b>Placed in Shelter</b>	<b>Evacuated</b>
<b>Canovanas</b>	N/A	211
<b>Carolina</b>	344	344
<b>Coamo</b>	N/A	12
<b>Fajardo</b>	566	566
<b>Humacao</b>	N/A	11
<b>Juncos</b>	N/A	43
<b>Loiza</b>	N/A	125
<b>Ponce</b>	21	21
<b>San Juan</b>	113	113

Table 3. Numbers of people placed in shelters and/or evacuated, by municipality.

Shortly after Irene’s center passed by San Juan on August 22 there were 800,000 homes without electric power and 118,000 without water service.

The storm surge from Irene, as expected, was very minor. The highest surges measured were at Esperanza (Vieques) and Fajardo and reached 1.6 feet between 100 am and 200 am (0506 UTC and 0530 UTC respectively). This was during the time that the center of Irene was moving inland over eastern Puerto Rico.

#### **d. Watches/Warnings**

The NHC issued a tropical storm warning for all of Puerto Rico and the U.S. Virgin Islands approximately 22 hours before winds of that force were experienced there, and

<b>Warning Type</b>	<b>Location</b>	<b>Date/Time (AST)</b>
<b>Tropical Storm Warning</b>	Puerto Rico, Vieques, Culebra, U.S. Virgin Islands	20th / 700 pm
<b>Hurricane Watch with Tropical Storm Warning</b>	Puerto Rico, Vieques, Culebra	21st / 500 am
<b>Hurricane Warning</b>	Puerto Rico, Vieques, Culebra	21st / 1100 am
<b>Hurricane Watch with Tropical Storm Warning</b>	U.S. Virgin Islands	21st / 1100 am
<b>Hurricane Watch Ended</b>	U.S. Virgin Islands	22nd / 500 am
<b>Tropical Storm Warning replaces Hurricane Warning</b>	Puerto Rico, Vieques, Culebra	22nd / 900 am
<b>Tropical Storm Warning Ended</b>	U.S. Virgin Islands	22nd / 1100 am
<b>Tropical Storm Warning Ended</b>	Puerto Rico, Vieques, Culebra	22nd / 200 pm

Table 4. History of Tropical Storm and Hurricane Watch and Warning issuances from the National Hurricane Center for Puerto Rico/U.S. Virgin Islands during Irene.

about 30 hours before it occurred across the San Juan Metro area. The upgrade to Hurricane Warning was done 18 hours before such winds occurred westward from San Juan. Table 4 summarizes the Center’s warning issuances for the region.

In expectation of the major flood problems that were to come with Irene the National Weather Service at San Juan issued the first flash flood watch for the entire area at 328 pm AST (August 20). It encompassed all of Puerto Rico and the U.S. Virgin Islands. The watch was in effect beginning Sunday morning (August 21) and remained in effect until cancelled for Culebra, Vieques and the U.S. Virgin Islands by 235 am on August 23. However, the watch was then extended for mainland Puerto Rico and remained in effect until 326 pm on August 24.

August 21	August 22		August 23		August 24
St. John	Aibonito	Luquillo	Aguas Buenas	Juncos	Arrovo
St. Thomas	Arroyo	Manati	Aibonito	Las Piedras	Canovanas
	Barceloneta	Maunabo	Arecibo	Loiza	Carolina
	Barranquitas	Morovis	Arroyo	Luquillo	Ceiba
	Bayamon	Naguabo	Barranquitas	Maunabo	Fajardo
	Caguas	Naranjito	Bayamon	Morovis	Guaynabo
	Canovanas	Orocovis	Caguas	Naguabo	Humacao
	Carolina	Patillas	Canovanas	Naranjito	Juncos
	Cayey	Rio Grande	Carolina	Orocovis	Las Piedras
	Ceiba	San Lorenzo	Cayey	Patillas	Loiza
	Ciales	St. Croix	Ceiba	Penuelas	Luquillo
	Cidra	St. John	Ciales	Ponce	Maunabo
	Comerio	St. Thomas	Cidra	Rio Grande	Naguabo
	Corozal	Toa Alta	Coamo	Salinas	Patillas
	Culebra	Toa Baja	Comerio	San Juan	Rio Grande
	Fajardo	Trujillo Alto	Corozal	San Lorenzo	San Juan
	Gurabo	Vega Alta	Dorado	Santa Isabel	Trujillo Alto
	Humacao	Vega Baja	Fajardo	Toa Alta	Yabucoa
	Juncos	Vieques	Florida	Toa Baja	
	Las Piedras	Yabucoa	Guayama	Trujillo Alto	
	Loiza		Guayanilla	Utado	
			Guaynabo	Vega Alta	
			Gurabo	Vega Baja	
			Humacao	Villalba	
			Jayuya	Yabucoa	
			Juana Diaz		

Table 5. Municipalities where a flash flood warning was issued, August 21-24. Those municipalities that disaster assistance would soon be available (Table 6) are colored rose.

There were flash flood warnings issued for numerous municipalities (Table 5) during the time that Irene passed by, including all of the U.S. Virgin Islands and 55 of the 78 municipalities (51 of those on the 23rd alone) in Puerto Rico. For most of these there were multiple issuances or extensions of the warnings. Overall, during the extreme rainfall there were 23 flash flood warnings issued on August 22, 24 more on August 23,

and 5 on August 24 (though each warning covered multiple municipalities). Also, there were many longer term river or areal flood warnings issued (Table 6).

August 22		August 23		August 24
Aguas Buenas	Guaynabo	Aguas Buenas	Juncos	Aibonito
Aibonito	Gurabo	Aibonito	Las Piedras	Arecibo
Arecibo	Juncos	Arroyo	Loiza	Barranquitas
Barranquitas	Manati	Barranquitas	Manati	Bayamon
Bayamon	Morovis	Bayamon	Morovis	Caguas
Caguas	Naranjito	Caguas	Maunabo	Canovanas
Canovanas	Orocovis	Canovanas	Naranjito	Carolina
Carolina	Rio Grande	Carolina	Orocovis	Cayey
Catano	San Lorenzo	Cayey	Patillas	Cidra
Cayey	Toa Alta	Ciales	Rio Grande	Comerio
Ciales	Toa Baja	Cidra	San Lorenzo	Dorado
Cidra	Trujillo Alto	Comerio	Toa Alta	Guayama
Comerio	Utuado	Dorado	Toa Baja	Gurabo
Dorado		Florida	Trujillo Alto	Loiza
		Guayama	Utuado	Naranjito
		Gurabo	Vega Alta	Patillas
		Humacao	Vega Baja	Rio Grande
		Jayuya	Yabucoa	Toa Alta
				Toa Baja
				Trujillo Alto

Table 6. Municipalities where a flood warning was issued, August 22-24. Those municipalities that disaster assistance would soon to be available are rose colored.

Four severe thunderstorm warnings and one tornado warning were issued during the morning and early afternoon of August 23 as multiple rain bands passed over. These highlighted more specific damage that was expected.

### e. Federal Disaster Declaration

On August 27 Puerto Rico was declared a major disaster area. By September 3 additional municipalities were added to provide aid to those impacted, and then still more on September 13. Table 7 shows the municipalities approved for federal assistance. In all, there were 29 municipalities approved for individual assistance (IA) to individuals and households while 37 municipalities were designated for public assistance (PA) to state and local governments and certain private nonprofit organizations for emergency work and the repair or replacement of disaster-damaged facilities. Figures 13 and 14 show some of the damage caused by rainfall in Irene.

Individual Assistance		Public Assistance			
Aguas Buenas	Loiza	Adjuntas	Cayey	Jayuya	Rio Grande
Arroyo	Luiquillo	Aguada	Ceiba	Juana Diaz	Sabana Grande
Caguas	Naguabo	Aguas Buenas	Ciales	Juncos	Salinas
Canovanas	Naranjito	Aibonito	Cidra	Las Marias	San Lorenzo
Carolina	Orocovis	Anasco	Coamo	Las Piedras	Santa Isabel
Cayey	Patillas	Arecibo	Comerio	Luquillo	Trujillo Alto
Cidra	Ponce	Arroyo	Corozal	Maricao	Utua
Coamo	Rio Grande	Barranquitas	Culebra	Maunabo	Vega Baja
Comerio	San Juan	Bayamon	Fajardo	Morovis	Vieques
Fajardo	San Lorenzo	Caguas	Guayama	Naguabo	Villalba
Gurabo	Trujillo Alto	Canovanas	Guaynabo	Naranjito	Yabucoa
Humacao	Vega Baja	Carolina	Gurabo	Orocovis	Yauco
Jayuya	Vieques	Catano	Humacao	Rincon	
Juncos	Villalba				
Las Piedras					

Table 7. Municipalities where the federal disaster declaration made federal funds available.



Fig. 13. Cayey, PR, August 28, 2011 -- The entrance to this house in Barrio Beatriz in Cayey was severely affected by the rains of Hurricane Irene. FEMA declared a major disaster for this municipality and offered Individual and Public Assistance to families and communities. (FEMA/Ashley Andújar)



Fig. 14. Juncos, PR, August 25, 2011 -- This house located in Juncos was completely destroyed by a landslide, caused by the rain from Hurricane Irene. FEMA conducted preliminary damage assessments in various municipalities affected by the hurricane. (Photo by Yuisa Rios/FEMA)

## **f. Conclusion**

Puerto Rico was under the effects of Tropical Cyclone Irene from early Sunday August 22 through late Wednesday August 24. Irene made landfall as a tropical storm during the early morning hours of Monday August 22, intensified overland and became a hurricane over northern Puerto Rico around 500 am AST Monday, before exiting into the Atlantic later that morning. Irene's most significant impact was in flooding from rainfall. The first rainbands entered eastern Puerto Rico early Sunday and persisted through midnight on Wednesday, although additional rainfall was received across some of the eastern municipalities through Thursday morning August 25. Locations like Gurabo across eastern interior Puerto Rico experienced significant 48 hour rainfall accumulations, with an estimated return period of around 50 years.

Though the early storm forecast track was too far south, the tropical storm warnings, hurricane watches and hurricane warnings were issued for the islands with easily ample time to prepare for the resulting impacts. Widespread flash flood watches, flash flood warnings and flood warnings were also done with no known unwarned hazards.

As Irene would do later in the Eastern United States, more damage occurred due to flooding than from its other hazards, and caused the lone death. Warnings could not prevent significant damage from occurring, however it is very likely that careful attention to the warnings that were issued saved many lives and reduced the damage that Irene brought to Puerto Rico and the U.S. Virgin Islands.