

PRELIMINARY REPORT

Hurricane Irene
13-19 October, 1999

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Irene was a typical wet October tropical cyclone that moved over the Florida Keys and southeast Florida dumping from 10 to 20 inches of rain. This resulted in severe flooding conditions. This type of tropical cyclone was a common phenomena during the 30's and 40's. Figure 1 shows the track of Irene over Cuba and Florida.

a. Synoptic History

A broad area of low pressure prevailed over the southwestern Caribbean from the 8th to the 10th of October, accompanied by disorganized clouds and thunderstorms. This system did not show signs of tropical cyclone development until a tropical wave reached the western Caribbean Sea on 11 October. On the 12th, a U.S. Air Force Reserve reconnaissance plane was dispatched to the region and found an incipient low-level circulation and a broad low pressure area of 1006 mb just to the northeast of the coast of Honduras.

However, the circulation was too disorganized to be classified as a tropical depression. Satellite imagery during the night showed that the thunderstorm activity increased and both banding features and upper-level outflow became quite distinct. Post-analysis of surface and upper-air data from Grand Cayman, and satellite Dvorak T-numbers indicate that Tropical Depression Thirteen formed in the northwestern Caribbean Sea about 0600 UTC 13 October. It reached tropical storm status by 1200 UTC on the 13th. Data from a reconnaissance aircraft later in the day confirmed Irene was a strengthening tropical storm. Irene moved on a general northward track and slowed down considerably before curving to the north-northeast just to the southwest of the Isle of Youth, Cuba, where it made its first landfall at 1200 UTC 14 October. Radars from Cuba and Key West showed the center of Irene moving on a north-northeast track over western Cuba. The center of the tropical cyclone then crossed the Havana and Ciudad Havana provinces between 2100 and 2300 UTC on the 14th. Irene reached hurricane status over the Florida Straits and the

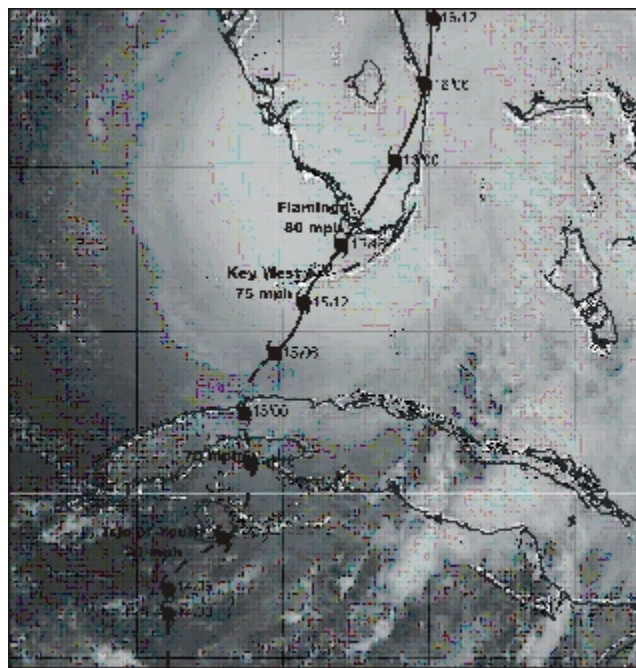


Figure 1. Detailed track of Irene showing the landfall points and a GOES 8 visible satellite image at the time of landfall near Flamingo, Florida.

calm of the center moved over Key West near 1300 UTC 15 October. Most of the hurricane force winds were confined to the east of Irene's center over the lower to middle Florida Keys. Irene made its 4th landfall near Cape Sable, Florida and then moved across southeast Florida bringing tropical storm conditions (sustained 39-73 mph winds) and torrential rains (10 to 20 inches). Figure 1 is a visible satellite image of Irene near landfall. During the period while Irene was crossing Florida, sustained hurricane force winds appeared to be limited to squalls offshore the east coast of Florida, as reported by reconnaissance aircraft and indicated by available National Weather Service (NWS) surface observations and Doppler radar.

Irene moved back over water in northern Palm Beach County near Jupiter a little after 0000 UTC on the 16th. It retained hurricane strength and moved on a general northward track paralleling the Florida east coast heading for the Carolinas. An upper-level trough, sweeping eastward across the eastern United States, forced Irene on a fast northeast track. The core of Irene missed the mainland Carolinas but produced very heavy rains inland. It then brushed North Carolina's Outer Banks before moving out to sea.

During a 12-hour period beginning on the evening of the 18th, Irene went through a rapid intensification phase. The central pressure dropped from 978 to 958 mb and the winds increased from 70 to 95 knots. This may be attributable to a combination of a trough interaction and the tropical cyclone moving over very warm water. These two factors together have been known to be the cause of explosive deepening. Hurricane Opal (1995), while located in the Gulf of Mexico, was an example.

Thereafter, Irene continued to accelerate and finally became absorbed by a much larger extratropical low near Newfoundland. The system as a whole became an intense extratropical storm over the North Atlantic.

Irene's track is shown in Fig. 2. Table 1 is a listing, at six-hourly intervals, of the best-track position, estimated minimum central pressure and maximum 1-minute surface wind speed.

b. Meteorological Statistics

The best track pressure and wind curves as a function of time are shown in Fig. 3 and are primarily based on data provided from numerous reconnaissance missions flown into Irene by U.S. Air Force (Reserve) and NOAA Aircraft Operations Center aircraft. Satellite intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB) and the Air Force Weather Agency, (AFGWC in figures) were also included in this analysis. Irene was under constant surveillance by three Cuban Weather Radars located at Havana, Isle of Youth and Pinar del Rio, respectively. Radar fixes were relayed to the National Hurricane Center by the Cuban Weather Service and then combined with fixes from Key West radar.

Irene was upgraded to tropical storm status based on a satellite intensity estimate from TAFB and upper-air data from Grand Cayman, which reported 38 knots at the 5,000-foot level and 31 knots near the surface when the tropical cyclone was about 150 n mi from

that island. Operationally, Irene was upgraded to hurricane status just before landfall over the Isle of Youth. However, numerous observations from Cuba and a post-analysis of satellite imagery indicate that Irene was most likely a tropical storm while crossing Cuba. Peak winds reported from Cuba were 68 knots at the Havana forecast office.

In addition to National Weather Service (NWS) reports, observations from the South Florida Water Management District, shown in Table 2, indicate that gusts to hurricane force were experienced near Lake Okeechobee. Based on the Miami WSR-88D (Weather Surveillance Radar -1988 Doppler) signatures, these gusts were likely produced by small-scale mesocyclone-induced downbursts. Four weak tornadoes occurred in Broward and Palm Beach counties.

The rapid intensification of Irene on the 18th off the North Carolina coast was documented by a reconnaissance plane investigating the hurricane during that period. The report indicated a very small closed eyewall of about 3 n mi in diameter and 114 knot winds at 850-mb. A dropsonde in the eyewall measured 129 knots at the 902-mb level. The wind field was very small and highly asymmetric.

c. Casualty and Damage Statistics

There were 8 *indirect* casualties associated with Irene. They were five people electrocuted (four in Broward and one in Dade counties). There were three drowning in vehicles driving into canals (one in Palm Beach and two in Broward). In addition, there were three injured by tornadoes in Broward.

Irene caused considerable damage due to flooding in South Florida. In some residential areas. Flooding lasted for a week, displacing several hundred people and isolating thousands more. The total losses (agricultural and property) were estimated near \$600 million mostly in Dade, Broward and Palm Beach counties. Additional losses to near \$200 million occurred in the rest of the state of Florida. An estimated 700,000 customers lost electricity.

d. Forecast and Warning Critique

The average official track errors during Irene's life as a tropical storm or hurricane were 54 n mi at 12 hours (21 cases), 92 n mi at 24 hours (19 cases), 104 n mi at 36 hours (17 cases), 127 n mi at 48 hours (15 cases) and 221 n mi at 72 hours (11 cases). With the exception of the 12- to 24-hour forecasts, these errors are lower than the previous 10-year averages of the official track errors. These 10-year average errors are 48, 89, 128, 164 and 242 n mi for 12, 24, 36, 48 and 72 hours, respectively.

Table 3 lists the numerous watches and warnings issued. Some residents of southeast Florida expressed displeasure with the NWS forecasts. Although a tropical storm warning was issued for a portion of southeast Florida (meaning sustained winds between 39 and 73 mph) as indicated in Table 3, and torrential rains of 10 to 20 inches with locally higher amounts were forecast, some residents, especially in southeast Florida claimed that such

conditions were “unexpected” or “surprising”. There is an apparent disconnect between an accurate forecast issued some 36 hours in advance and a public perception of “surprise”. The remedial challenge in this case appears to be related to communications and not to the forecast. The combined resources of NWS, the emergency management community and the local media apparently did not adequately convey the message to the public that: (a) track forecasts are not exact; (b) hurricanes are not a point but cover a broad area; and (c) serious effects usually extend for hundreds of miles from the center. Instead, some residents, as well as isolated TV reporting, focused on the center of Irene.

Indeed, the center of Irene was forecast to move along the west coast of Florida as indicated by most of the reliable and state-of-the-art track models shown in Fig. 4a. Instead, the center of Irene kept moving toward the north-northeast. The NHC nevertheless factored uncertainties into its forecast advisories and issued warnings appropriately as shown in Fig. 4b.

Table 1. Preliminary best track, Hurricane Irene, 13-19 October, 1999

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
12/1200	15.9	82.0	1006	20	low
1800	16.4	83.0	1006	20	"
13/0000	16.7	83.2	1005	20	"
0600	17.3	83.3	1004	30	tropical depression
1200	18.5	83.4	1003	35	tropical storm
1800	19.8	83.6	1001	45	"
14/0000	20.7	83.6	999	55	"
0600	21.0	83.6	999	60	"
1200	21.3	82.9	997	60	"
1800	22.4	82.4	995	60	"
15/0000	23.1	82.6	988	60	"
0600	23.8	82.2	988	65	hurricane
1200	24.4	81.8	987	65	"
1800	25.1	81.3	986	65	"
16/0000	26.1	80.6	986	65	"
0600	27.0	80.2	985	65	"
1200	27.8	80.1	982	65	"
1800	28.6	79.9	984	65	"
17/0000	29.4	79.8	984	65	"
0600	30.2	79.8	985	65	"
1200	31.2	79.7	984	65	"
1800	32.2	79.0	978	70	"
18/0000	33.4	77.4	976	80	"
0600	34.8	75.2	964	95	"
1200	36.8	71.6	960	90	"
1800	39.0	67.4	968	80	"
19/0000	41.5	61.0	968	80	"
0600	44.9	51.5	968	80	extratropical
1200	48.0	48.0	968	80	"
1800	51.0	45.0	968	80	being absorbed by a low
14/1200*	21.7	83.0	997	60	western Isle of Youth, Cuba
14/1900*	22.7	82.5	986	60	Batabano Cuba
15/1300*	24.6	81.6	987	65	Key West Fl.
15/2000*	25.3	81.1	987	70	Cape Sable Fl.
18/0600	34.8	75.2	964	95	brushed the Outer Banks NC.
18/0756	35.4	74.4	958	95	minimum pressure

*landfall points

Table 2.
Hurricane Irene selected surface observations, October 1999.

L o c a t i o n	Pres. (mb)	Date/ Time (UTC)	Sust. Wind (kt)^a	Peak Gust (kt)	Date/ Time (UTC)^b	Storm Surge (m)^c	Storm Tide (m)^d	Total Rain (in)
<i>Cuba</i>								
Havana Casablanca				68	14/2020			4.80
Playa Giron								10.7
Topes de Collantes								8.70
Jaguey Grande								8.70
Jovellanos								7.10
Melena del Sur								7.20
Union de Reyes								7.10
Batabano								6.40
Guines								6.20
Cienfuegos								5.50
Nueva Gerona								5.40
Colon								4.80
<i>Florida</i>								
Big Pine Key			69	89	15/0000			
Sombrero Key C-Man	990.5	15/1700	57	69	15/1530			
Molasses Reef C-MAN	991.5	15/2100	53	64	15/2020			
Long Key C-MAN	988.7	15/2000	50	61	15/2000			
Sand Key C-MAN	987.0	15/1200	43	57	15/0610			
Dry Tortugas C-MAN			41	51	15/0850			
Key West Intl. Airp.	987.6	15/1010	38	47	15/0518			8.85
Marathon Airp.	989.6							7.18
Key West			38	47	15/1630	1.5		
Vaca Key					15/0800	2.3		
Tavernier								9.82
Fowey Rock Lt C-Man	991.9	15/2300	57	73	15/2200			
Miami Beach			52		15/1950			9.49
Tamiami Airp.	990.9	15/2353	45	60	15/2130			
Lake Worth C-MAN		16/0300	44	53	16/0300			
Homestad AF	990.9	15/2257	42	74*	15/1809			14.57
Miami Int. Airp.	990.1	15/2256	41	61	15/2008			10.99
Pompano Beach Airp.	991.0	16/0253	40	50	15/2202			
Ft. Lauderdale Exec.	909.5	16/0153	40	50	15/2048			
Ft. Lauderdale Int. Airp.	990.9	16/0123						13.38
Opalocka Airp.	989.9	16/0053	39	49	15/2257			
West Palm Beach Airp.	990.9	16/0453	37	53	16/0211			10.88
North Perry Airp.		15/2029	37	50	15/2029			
Winter Heaven	1003.1	16/1927		42	15/2033			
Fort Myers (FMY)	1000.1	15/2328		38	16/0228			
Fort Myers (RSW)	1000.0	16/0017		38	15/2305			
Bunnell (X47)				38	16/2222			

**Table 2. (Cont.)
Hurricane Irene selected surface observations, October 1999.**

L o c a t i o n	Pres. (mb)	Date/ Time (UTC)	Sust. Wind (kt)^a	Peak Gust (kt)	Date/ Time (UTC)^b	Storm Surge (m)^c	Storm Tide (m)^d	Total Rain (in)
Opa-locka								7.60
Sawgrass Mills								7.41
North Palm Beach								7.55
Leisure City								7.08
Jupiter								6.44
South Florida Water Management								
Belle Glade				81	16/2303			
20-25 miles SW of Clewinston				79	15/2226			
Lake Ockeechobee (middle)				70	16/0522			
25 mi west of Palm Beach				59	15/0055			
west of Lake Ockeechobee				56	15/2239			
35 mi west of Boca Raton				50	15/2314			
Krome Ave (near Homestead)				50	15/2003			
La Belle				43	15/1712			
Kissimee				40	16/1510			

^a ASOS and C-MAN are 2 min; buoys are 8 min.

^b Date/time is for sustained wind when both sustained and gust are listed.

^c Storm surge is water height above normal astronomical tide level.

^d Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).

* This type of anemometer has been unreliable in the past.

Table 3. Tropical Cyclone watch and warning summary for Hurricane Irene

Date/Time (UTC)	Action	Location
13/1500	Tropical Storm Warning	Cayman Islands.
13/1500	Hurricane Watch	Cuban provinces of Pinar del Río, Havana, Ciudad Havana and Isle of Youth.
13/2100	Hurricane Warning	Cuban provinces of Pinar del Río, Havana, Ciudad Havana, Matanzas and Isle of Youth.
13/2100	Hurricane Watch	Lower and Middle Florida Keys, West of Craig Key including Dry Tortugas.
14/1200	Tropical Storm Warning	Discontinued for Cayman Islands.
14/1500	Hurricane Warning	Dry Tortugas.
14/1500	Hurricane Watch	West coast of Florida from Flamingo to Boca Grande.
14/1500	Tropical Storm Warning	Lower and Middle Florida Keys, West of Craig Key.
14/2100	Hurricane Warning	South of Florida City around the Florida peninsula to Boca Grande, including all Florida Keys and Dry Tortugas
14/2100	Tropical Storm Warning & Hurricane Watch	From Florida City to Jupiter Inlet and Lake Okeechobee.
14/2100	Hurricane Watch	North of Boca Grande to Longboat Key.
15/0300	Hurricane Warning	Extended Northward along Florida West Coast to Anclote Keys.
15/0300	Hurricane Watch	From North of Anclote Keys to Yankeetown
15/0300	Hurricane Warning	Discontinued for Cuban provinces of Pinar del Río, Matanzas and Isle of Youth.
15/0900	Tropical Storm Warning & Hurricane Watch	Extended Northward along Florida East coast to South of Flagler Beach.
15/0900	Hurricane Warning	Discontinued for all Cuban provinces
15/1200	Tropical Storm Watch	Bimini, Grand Bahama and Abaco Islands in Bahamas.
15/2100	Tropical Storm Warning (Downgraded from Hurricane Warning)	North of Bonita Beach to the Anclote Keys.
15/2100	Tropical Storm Warning	Extended Northward from Florida City to Fernandina Beach and Lake Okeechobee.
15/2100	Tropical Storm Watch	North of Fernandina Beach to Savannah, Georgia.
15/2100	Hurricane Watch	All discontinued.
16/0300	All Warnings	Discontinued South of Florida City, the Florida Keys, the Dry Tortugas and the Florida West coast.

16/0300	Tropical Storm Watch	Extended Northward from North of Fernandina Beach to Little River Inlet, South Carolina.
16/0300	Tropical Storm Watch	Discontinued for Abaco Islands, Bahamas.
16/0900	Tropical Storm Warning	Extended North of Fernandina Beach, Florida to Edisto Beach, South Carolina.
16/0900	Hurricane Watch	North of Edisto Beach to Cape Hatteras, North Carolina including Pamlico Sound.
16/0900	Tropical Storm Warning	Discontinued along the Florida East coast from Jupiter Inlet Southward, including Lake Okeechobee.
16/1500	Hurricane Warning	From Edisto Beach, South Carolina to Surf City, North Carolina.
16/1500	Tropical Storm Watch	Discontinued for Bimini and Grand Bahama Island.
16/2100	Hurricane Warning	Expanded from Savannah, Georgia to Cape Hatteras, North Carolina including Pamlico Sound
16/2100	Hurricane Watch	North of Cape Hatteras to the North Carolina/Virginia border, including Albemarle Sound.
16/2100	Tropical Storm Warning	Discontinued South of Vero Beach, Florida.
17/0300	Tropical Storm Warning (Replacing Hurricane Watch)	North of Cape Hatteras to the North Carolina/Virginia border, including Albemarle Sound.
17/0300	Tropical Storm Warning	Discontinued South of New Smyrna Beach, Florida.
17/0900	Tropical Storm Warning	Discontinued South of St. Augustine Beach, Florida.
17/1500	Tropical Storm Warning	Discontinued South of Fernandina Beach, Florida.
17/2100	All Warnings	Discontinued from Edisto Beach, South Carolina Southward.
18/0000	Hurricane Warning	Discontinued South of Santee River, South Carolina.
18/0300	All Warnings	Discontinued from Surf City, North Carolina Southward.
18/0300	Tropical Storm Warning (downgraded from Hurricane Warning)	North of Surf City, North Carolina to North Carolina/Virginia border, including Pamlico and Albemarle Sounds.
18/0600	All Warnings	Discontinued from Bogue Inlet, North Carolina Southward.
18/0900	All Warnings	Discontinued everywhere they had still been in effect.

* Tropical Cyclone watches and warnings are issued by respectively countries in coordination with the National Hurricane Center.

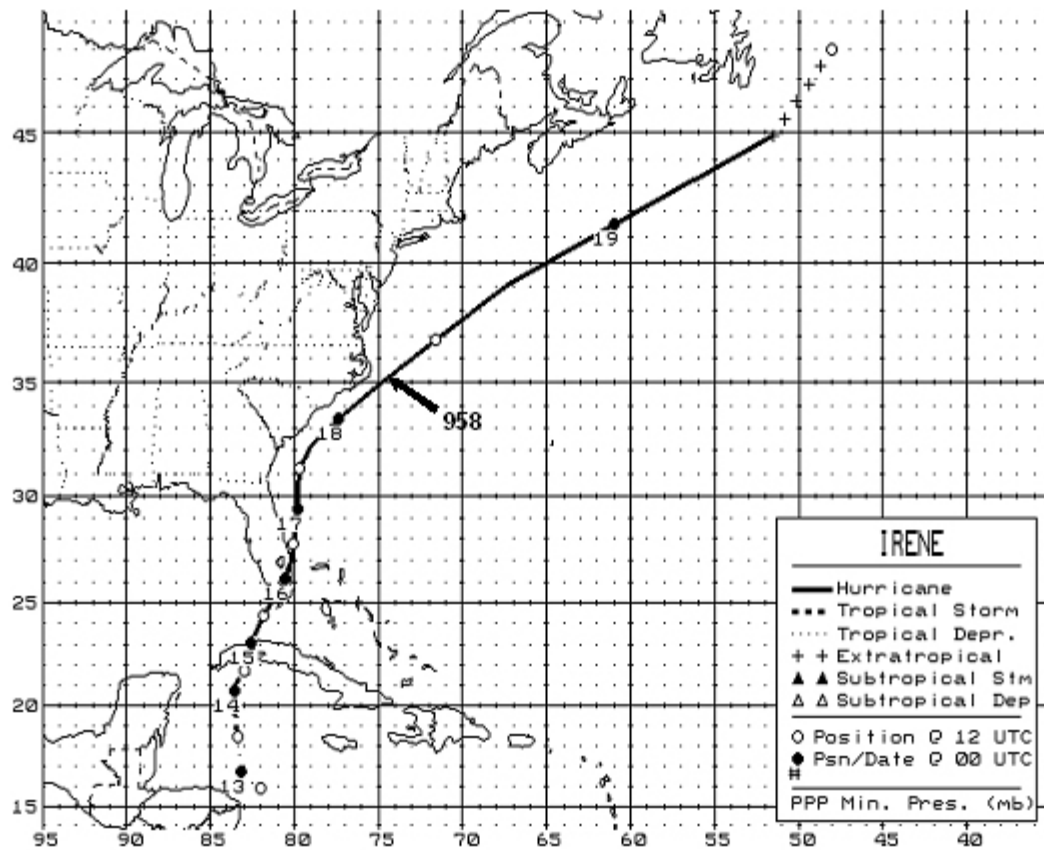


Figure 2. Best track positions for Hurricane Irene, 13-19 October, 1999.

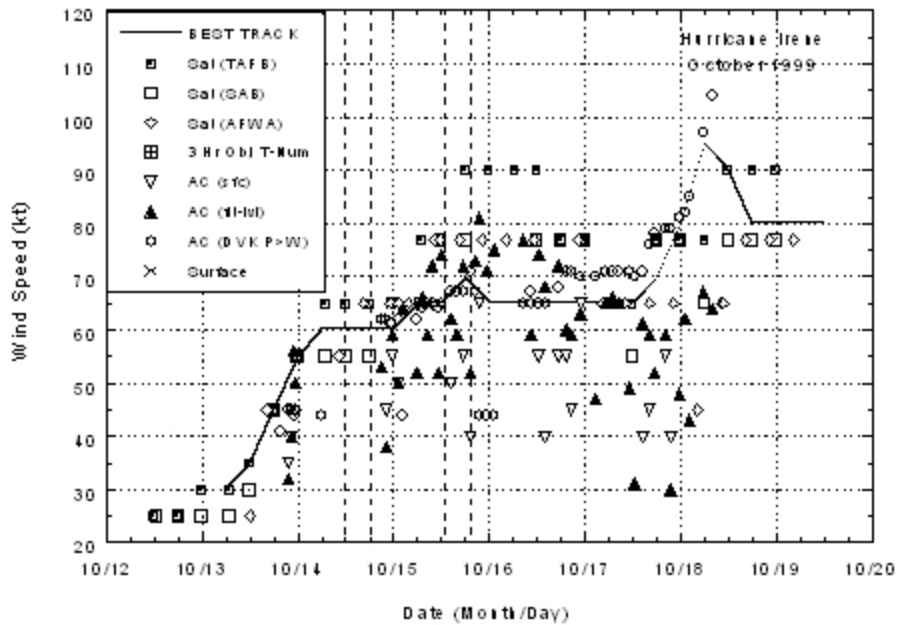
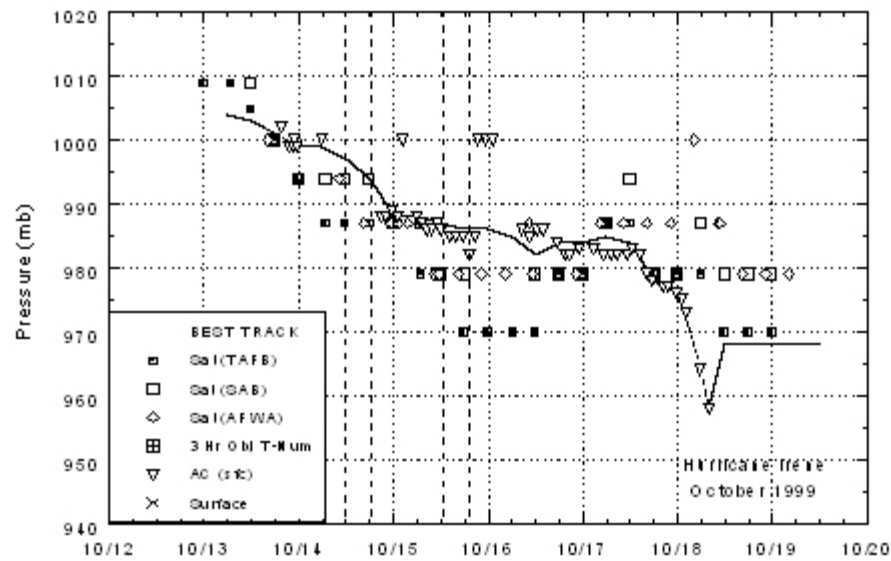
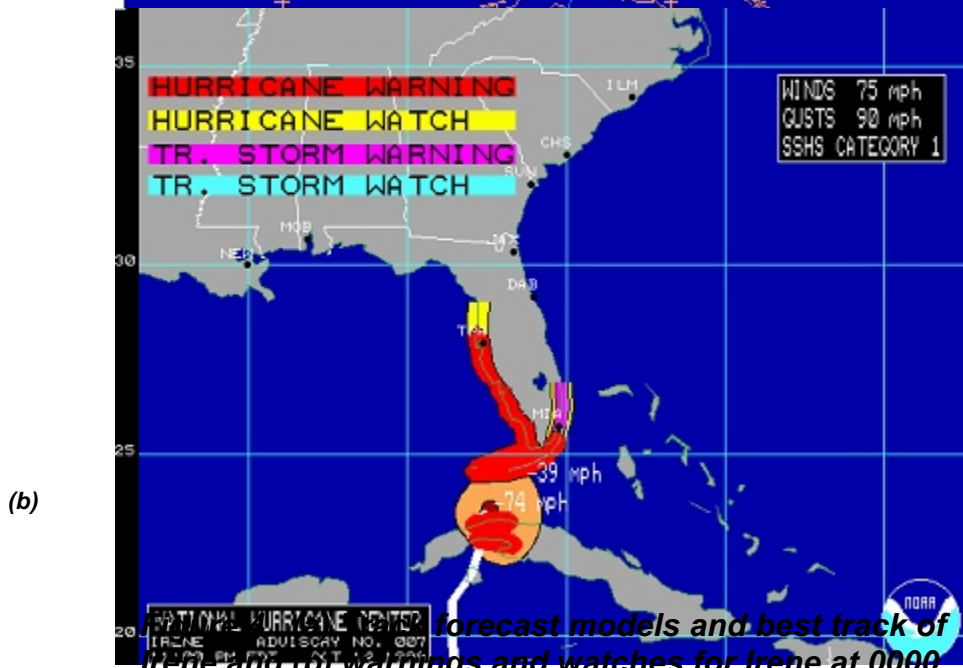
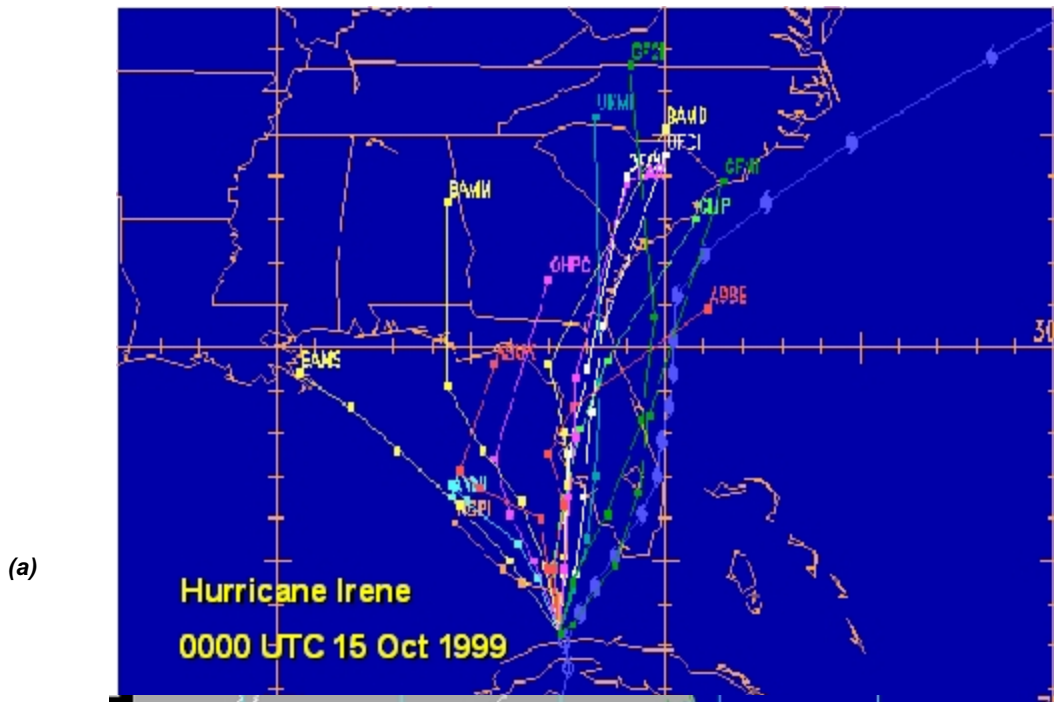


Figure 3. Preliminary best track minimum central pressure and maximum sustained wind speed curves for Hurricane Irene. Vertical dashed lines denote landfalls.



forecast models and best track of Irene and (b) warnings and watches for Irene at 0000 UTC 14 October, 1999.