

Preliminary Report
Hurricane Lili
14 - 27 October 1996

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Lili was the sixth category 3 Atlantic hurricane on the Saffir/Simpson hurricane scale during 1996. It moved across central Cuba and the central Bahamas with sustained winds in the 80 to 90 knot range.

a. Synoptic History

A tropical wave moved from Africa to the Atlantic Ocean on 4 October accompanied by a large cyclonic rotation of low clouds and a mid-tropospheric jet. The wave moved westward under an unfavorable strong vertical shear environment and, on 11 October, passed through the Windward Islands where a marked wind shift and large 24-hour pressure changes were observed. It reached the southwestern Caribbean on the 13th, where a pre-existing area of low surface pressure was located.

The system developed a well-defined low-level circulation and became a tropical depression at about 1200 UTC on the 14th, just east of Nicaragua, and began moving northwestward at about eight knots. The track in Fig. 1 and Table 1 begins at this time.

Over the next two days, the depression turned north and then north-northeastward in response to a weak mid- to upper-level low over the Gulf of Mexico. Although there appeared to be considerable convective banding and falling surface pressures, aircraft data showed that the depression did not strengthen to a storm until early on the 16th, when the center was close to Swan Island. With a well-established outflow over the circulation, Lili strengthened to a hurricane on the 17th.

Moving slowly, the center executed a small cyclonic loop just north of Swan Island on the 16th and wobbled again on the 17th as it approached the Isle of Youth, Cuba. The center passed over the eastern side of the Isle of Youth near 0100 UTC on the 18th and made landfall on the south coast of mainland Cuba in Matanzas Province at 0930 UTC. The maximum sustained surface winds had strengthened to near 85 knots at landfall as Lili turned eastward for a twelve-hour crossing of central Cuba on the 18th.

A major trough in the westerlies moved to the eastern United States as Lili approached Cuba and this resulted in the hurricane accelerating mostly northeastward to a forward speed of near 25 knots by late on the 19th.

The hurricane maintained its strength over Cuba. The pressure was measured by aircraft at 975 millibars just before landfall and the same pressure was measured again when the eye moved back over water. Accelerating toward the Bahamas, there was further strengthening and Lili went through the central Bahamas early on the 19th with sustained winds of near 90 knots. The eye, 30 to 40 nautical miles wide, moved over Great Exuma and San Salvador and the eye wall affected portions of Long Island, Rum Cay, and Cat Island.

Shortly thereafter, at 0000 UTC on the 20th and just east of the Bahamas, the hurricane reached its peak strength, with an estimated 100-knot maximum sustained wind and a central surface pressure of 960 mb. This is a category 3 on the Saffir/Simpson hurricane intensity scale and Lili is the sixth category 3 or higher hurricane in the Atlantic basin in 1996.

Lili continued moving northeastward, its center passing about 130 n mi southeast of Bermuda on the 20th. By now, the strongest winds were on the southeast side of the center and Bermuda's sustained winds did not reach tropical storm force. Lili's winds gradually decreased from the 100-knot maximum on the 20th to 65 knots on the 21st.

On the 22nd, having turned eastward, the forward motion decelerated to almost stationary as a mid-level short-wave high pressure ridge came into longitudinal phase with Lili. Lili drifted erratically eastward across the central north Atlantic until the 24th, when another acceleration toward the northeast began. Lili reintensified to 85 knots on the 25th and finally weakened to a tropical storm on the 26th, as the center was passing about 300 n mi northwest of the Azores. Lili is estimated to have become extratropical on the 27th. It remained a 55-knot extratropical storm until crossing Great Britain on the 28th. Its remnants crossed the northern European mainland on the 29th.

b. Meteorological Statistics

Figures 2 and 3 show curves of minimum sea-level pressure and maximum one-minute surface wind speed, respectively, as a function of time. Satellite data plotted in these figures is based on the Dvorak satellite intensity estimating technique as applied at the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB) and the U.S. Air Force Global Weather Center (AFGWC).

Aircraft data is from eleven aircraft reconnaissance missions into Lili over a five-day period, from the 15th to the 20th, resulting in 37 center penetrations. Seven of the missions were performed by the U.S. Air Force Reserve Unit out of Keesler AFB, Mississippi. The other four missions were performed by the NOAA research aircraft when Lili's center was near Cuba. The maximum wind speed measured by aircraft was 112 knots at the 700 mb level, at 0855 UTC on the 19th in the southeast quadrant. The minimum surface pressure from the aircraft was 960 millibar at 1218 UTC on the 19th.

Table 2 lists a selection of significant surface observations. The highest sustained wind from

Cuba was a 10-minute average of 80 knots reported from Cayo Largo del Sur, an island located about 50 nautical miles east of the Isle of Youth. The center was over mainland Cuba and about 40 nautical miles north of the island at the time of the report. An 80-knot 10-minute wind was also reported from San Salvador in the central Bahamas at the time that the center was located about 15 nautical miles to its north-northwest.

Table 3 lists selected ship reports of winds greater than 33 knots that were caused by Lili. Two hours after the report from San Salvador, at 1200 UTC on the 19th, a ship with call sign ZCBC3 reported an estimated wind speed of 99 knots, while located about 20 nautical miles south of the center. The 112-knot aircraft wind was measured only a few hours earlier and the hurricane's estimated maximum sustained wind speed of 100 knots is based on these measurements.

There was heavy rainfall over portions of Cuba with over 26 inches accumulated at La Moza.

Sustained wind speeds to about 45 knots with gusts to as high as 78 knots (from Alderney, a Channel island) were reported from Great Britain, when Lili was extratropical, on the 28th and 29th.

c. Casualty and Damage Statistics

During the formative state of the tropical cyclone, heavy rain occurred over portions of Central America. The Associated Press reported five drowning deaths in Honduras and three deaths in Costa Rica. In addition, thousands were left homeless in both of these countries and there was flooding in Nicaragua as well.

In Cuba, there was extensive damage to agriculture and thousands were made homeless according to Reuters news. Reuters also reported that six were killed in Great Britain from Lili as an extratropical storm. Four died in traffic accidents and two fishermen were swept into the sea.

In the Bahamas, reports from Georgetown on Great Exuma island suggest that many houses were substantially damaged and many boats were sunk. A storm tide of 15 feet above mean sea level was estimated on the north side of Great Exuma.

d. Forecast and Warning Critique

Table 4 lists the various watches and warnings along with their issuance times. Hurricane warnings were issued for the Isle of Youth, Cuba, almost 24 hours before hurricane conditions began. The lead time for the mainland Cuba landfall was 30 hours. The hurricane warning lead time for the central Bahamas was somewhat less...15 to 18 hours. The hurricane watch was issued for Cuba 52 hours before the center reached the Isle of Youth and Lili was only a tropical depression at the time of issuance.

The average official track forecast errors for Lili, in nautical miles, ranged from 57 at 12 hours, 88 at 24 hours, 119 at 36 hours, 142 at 48 hours, to 200 at 72 hours. The 12-hour official errors are larger than the previous 10-year average and the rest are smaller, considerably so at 48 and 72 hours, than the previous 10-year averages.

Once again, a good track forecast performance is attributed to excellent numerical model guidance. For example, the looping motion on the 16th followed by another wobble on the 17th were both forecast by the 0000 UTC GFDL model run on the 16th. Another point of interest is at 1200 UTC on the 18th, when the center had just made landfall in Cuba and was accelerating in the general direction of southeast Florida and perhaps less than 24 hours away. No warnings were issued for the Miami and Fort Lauderdale metropolitan areas and this was possible because of the confidence in the guidance models which showed the hurricane turning northeastward and missing south Florida. Tropical storm warnings were issued for the Florida Keys however and Table 2 shows that sustained winds did not quite reach tropical storm force there.

The GFDL model absolute wind speed forecast errors at 72 hours averaged 11 knots for 16 cases during Lili. This is considerably smaller than the 1995 average GFDL error at 72 hours of 20 knots and is also smaller than the average official error of 22 knots for the same 16 Lili cases.

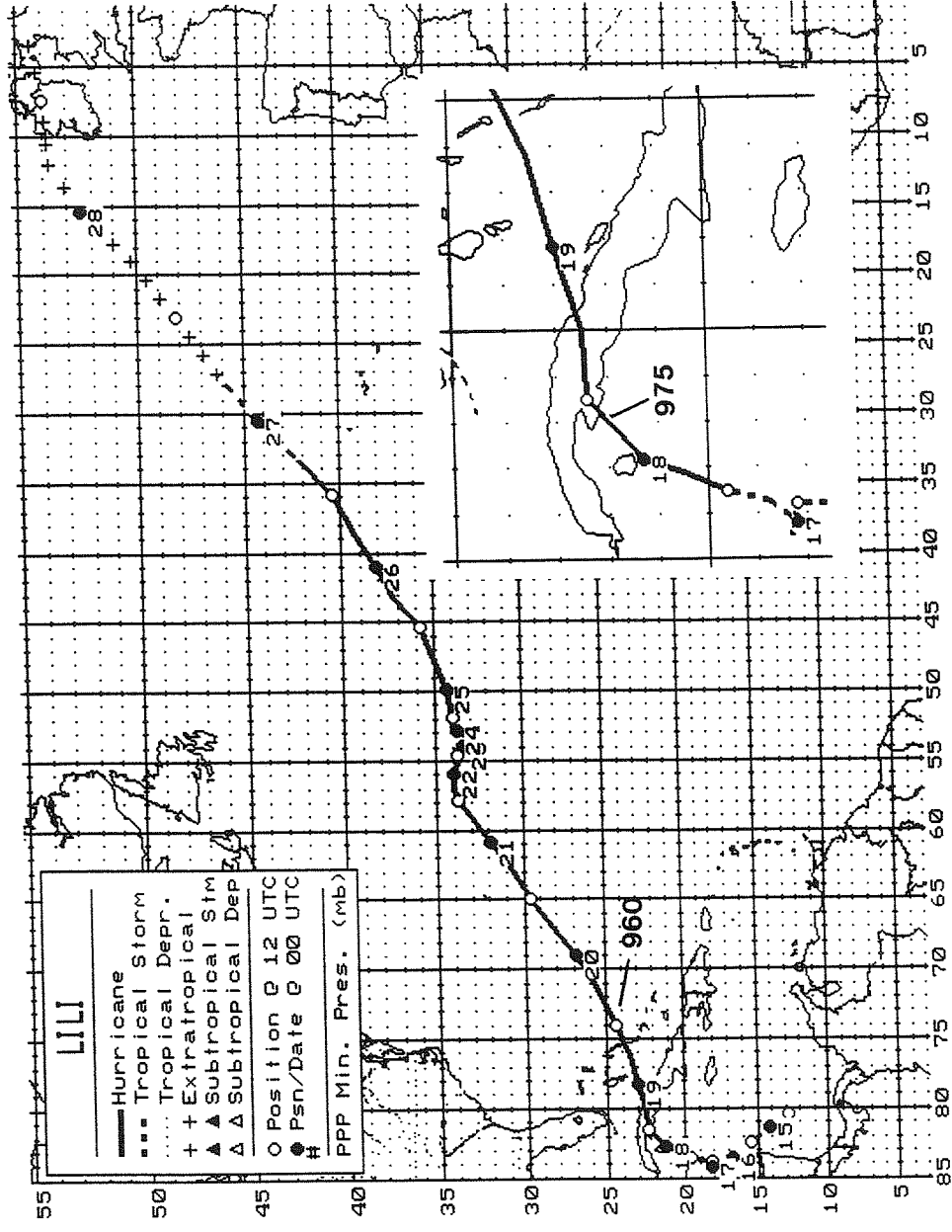


Fig. 1. Track of Hurricane Lili, 14 - 27 October 1996

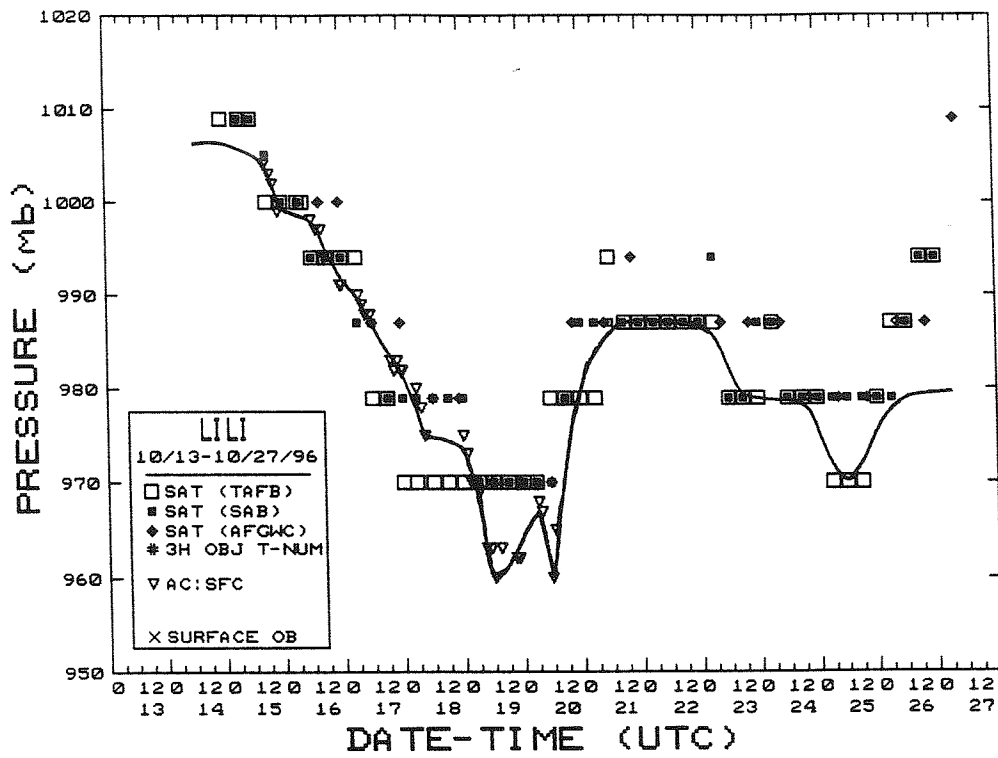


Fig. 2. Curve of minimum central sea-level pressure versus time for Hurricane Lili

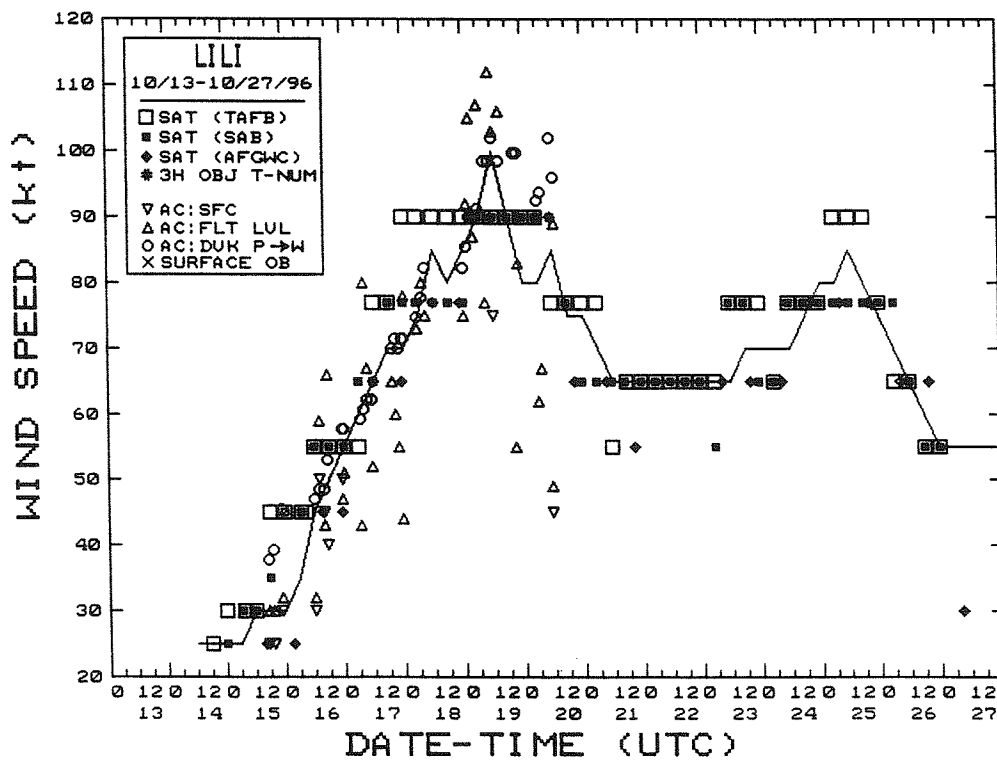


Fig. 3. Curve of maximum one-minute wind speed versus time for Hurricane Lili

Table 1. Best track, Hurricane Lili, 14 - 27 October 1996

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
14/1200	12.8	80.4	1006	25	tropical depression
1800	13.4	80.9	1005	25	“
15/0000	14.1	81.4	1005	25	“
0600	14.8	81.9	1005	25	“
1200	15.4	82.5	1004	30	“
1800	16.1	83.1	1003	30	“
16/0000	16.8	83.5	999	30	“
0600	17.5	83.8	998	35	tropical storm
1200	18.2	83.8	998	45	“
1800	18.3	84.5	996	50	“
17/0000	18.2	84.2	992	55	“
0600	18.8	83.7	990	60	“
1200	19.6	83.5	987	65	hurricane
1800	20.5	83.1	984	70	“
18/0000	21.3	82.8	982	70	“
0600	21.8	82.2	980	75	“
1200	22.4	81.5	975	85	“
1800	22.5	80.0	975	80	“
19/0000	23.0	78.2	975	85	“
0600	23.5	76.2	970	90	“
1200	24.4	74.0	960	100	“
1800	25.5	71.5	962	90	“
20/0000	26.9	69.0	964	80	“
0600	28.3	67.0	968	80	“
1200	29.6	65.0	960	85	“
1800	30.7	62.9	970	75	“
21/0000	31.9	60.8	980	75	“
0600	33.0	59.1	985	70	“
1200	33.7	57.9	986	65	“
1800	34.0	57.0	987	65	“
22/0000	34.0	55.9	987	65	“
0600	33.8	55.2	987	65	“
1200	33.7	54.6	987	65	“
1800	33.5	54.0	987	65	“
23/0000	33.4	53.9	987	65	“
0600	33.2	53.8	985	65	“
1200	33.1	53.7	981	65	“
1800	33.3	53.2	979	70	“
24/0000	33.7	52.8	979	70	“
0600	34.0	52.5	979	70	“
1200	34.0	51.9	979	70	“

Table 1 (continued). Best track, Hurricane Lili, 14 - 27 October 1996

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
1800	34.1	51.2	979	75	hurricane
25/0000	34.3	49.9	977	80	“
0600	35.0	47.8	973	80	“
1200	35.8	45.4	970	85	“
1800	37.2	43.3	971	80	“
26/0000	38.1	41.0	975	75	“
0600	39.2	38.8	978	70	“
1200	40.5	35.8	979	65	“
1800	42.3	33.2	980	60	tropical storm
27/0000	44.3	30.5	978	55	“
0600	46.3	27.2	980	55	extratropical
1200	48.2	23.1	978	55	“
1800	50.3	19.0	973	55	“
28/0000	52.5	15.5	973	55	“
0600	53.8	12.0	973	55	“
1200	54.0	7.5	970	55	“
1800	54.5	3.5	970	55	“
29/0000	54.0	1.0 (°E)	976	55	“
19/1200	24.4	74.0	960	100	minimum pressure
20/1200	29.6	65.0	960	85	minimum pressure
landfall on the Zapata Peninsula in Matanzas Province, Cuba					
18/0930	22.3	82.0	975	85	hurricane

The center also passed over the eastern tip of the Isle of Youth, Cuba at 18/0100 UTC. In the Bahamas, on the 19th, between 0600-1200 UTC, the center passed over Great Exuma and San Salvador and very near Long Island, Rum Cay, and Cat Island.

Table 2. Hurricane Lili selected surface observations, October 1996

Location	Press. (mb)	Date/time (UTC)	Sustained wind(kt) ^a	Peak gust	Date/time (UTC) ^b	Storm surge(ft) ^c	Storm tide(ft) ^d	total rain(in.)
Cuba								
Abreus, Guillermo Moncada								23.49
Agramonte, Union de Reyes Limonar								12.85
Cayo Largo del Sur	986.1	18/1050	80(10 min)	104	18/1050			
Jucaro			40(10 min)	50	18/1945			9.06
Cienfuegos				95	18/1550			
Guines								8.84
Havana			30(10 min)	42	18/1050			
La Moza								26.04
Nueva Gerona, Isle of Youth			60(10 min)	70	18/0448			
Punta del Este, Isle of Youth	977	18/0200						
Santo Domingo				97	18/1855			
Trinidad								21.20
Virgen del Camino								6.97
Florida								
Dry Tortugas DRYF1	1005.4	18/2000	22(2 min)	26	18/1800			
Key West	1003.5	18/2053	18	22	18/1904			1.61
Molasses Reef MLRF1	1003.1	18/2200	22(2 min)	26	18/1500			
Sand Key SANF1	1003.5	18/2000	26(2 min)	33	18/1100			
Sobrero Key SMKFI	1003.4	18/2000	27(2 min)	33	18/1400			
Bahamas								
Lee Stocking Island airport ^e			35(60 min)	53				
Lee Stocking Island hill ^e			41(60 min)	61				
San Salvador	963.5	19/1000	80(10 min)		19/1000			
Warderick Wells ^e			39(60 min)	45				

^a Averaging period is 1 min. unless otherwise indicated.

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

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

^d Storm tide is water height above National Geodetic Vertical Datum.

^e Courtesy of the Caribbean Marine Research Center.

Table 3. Selected Ship reports of 34 knots or higher wind speed, associated with Hurricane Lili, October 1996.

date/time (UTC)	ship name	latitude (°N)	longitude (°W)	wind dir/speed (knots)	pressure (mb)
17/1200	KLHZ	19.8	83.0	130/50	999.0
17/1500	KLHZ	19.6	82.9	180/38	1002.8
19/0600	P3TP6	19.5	80.0	330/60	1008.0
19/1200	ZCBC3	24.2	74.2	270/99	967.7

Table 4. Watch and warning summary, Hurricane Lili, October 1996.

Date/time (UTC)	Action	Location
15/2100	hurricane watch	Cuba: provinces of Pinar del Rio and Havana and Isle of Youth
16/0300	tropical storm warning	Mexico: Yucatan Peninsula from Isla Mujeres to Bahia de Chetumal
16/0600	tropical storm warning	Mexico: Yucatan Peninsula from cabo Catoche to Bahia de Chetumal
16/1200	tropical storm warning	Cayman Islands
16/1500	hurricane watch and tropical storm warning	Cuba: provinces of Pinar del Rio, Havana, Matanzas, Villa Clara, and Cienfuegos and Isle of Youth
17/0300	hurricane warning	Cuba: provinces of Pinar del Rio, Havana, Matanzas, Villa Clara, and Cienfuegos and Isle of Youth
17/0900	tropical storm warning discontinued	Mexico: Yucatan Peninsula from cabo Catoche to Bahia de Chetumal
17/1045	hurricane watch and tropical storm warning	Cayman Islands
17/1500	hurricane warning	Cuba: provinces of Camaguey, Ciego de Avila, and Sancti Spiritus
17/2100	tropical storm warning	Florida Keys from Key Largo to Dry Tortugas including Florida Bay
17/2100	hurricane watch	Northwest Bahamas
17/2100	watch and warning discontinued	Cayman Islands
18/0900	hurricane warning	northwest Bahamas
18/0900	hurricane watch	central Bahamas
18/1500	hurricane warning	central Bahamas
18/1500	hurricane warning discontinued	Cuba: Isle of Youth
18/1800	hurricane warning discontinued	Cuba: from Havana westward
18/1800	tropical storm warning discontinued	Florida Keys and Florida Bay
19/0300	hurricane warning discontinued	northwest Bahama Islands of Grand Bahama, Abaco, and Bimini
19/0500	tropical storm warning	southeast Bahamas and Turks and Caicos Islands
19/0600	hurricane warning discontinued	All of Cuba
19/1200	hurricane warning discontinued	northwest Bahamas
19/1800	all warnings discontinued	all of Bahamas