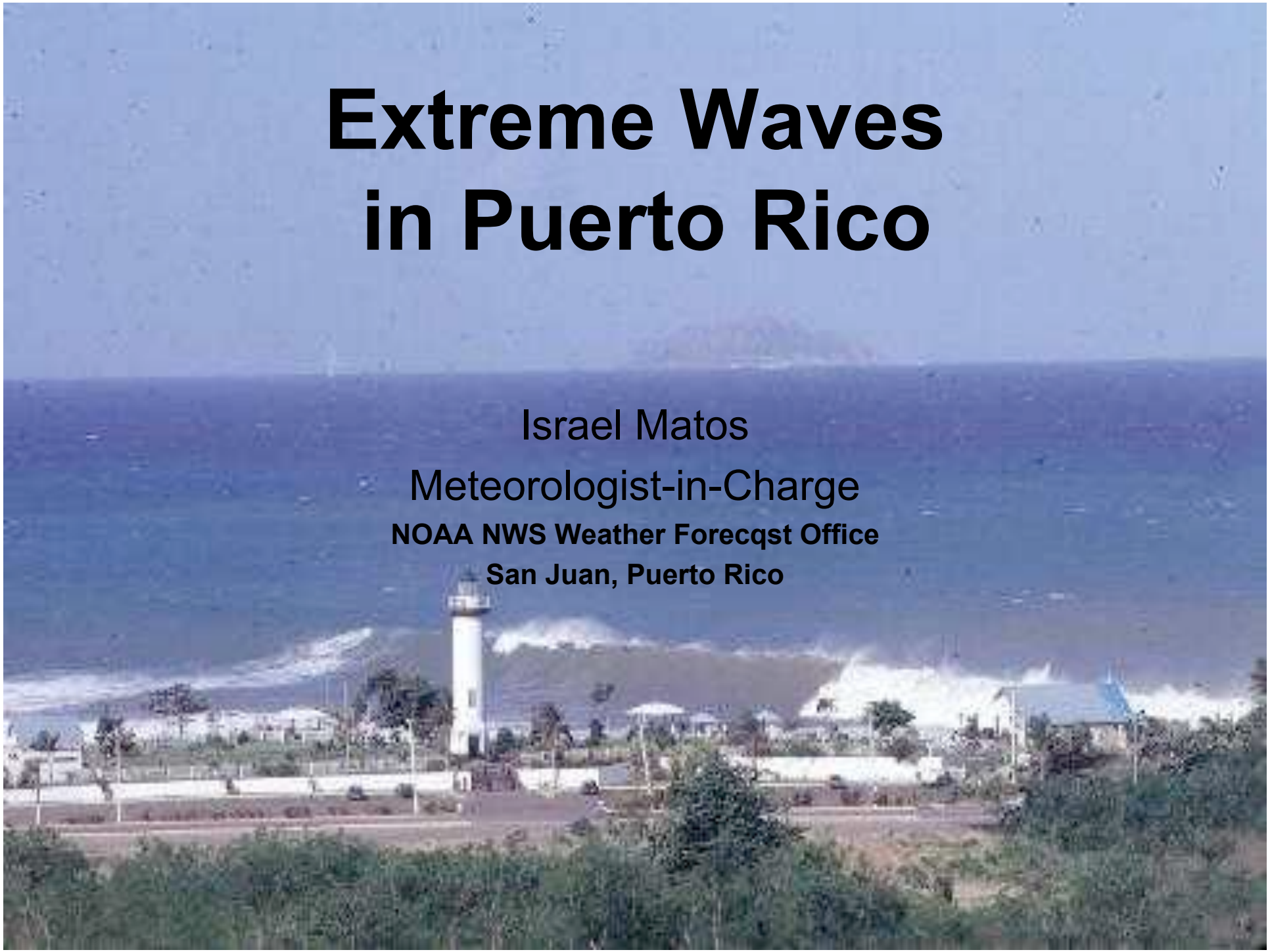
# Extreme Waves in Puerto Rico




Israel Matos

Meteorologist-in-Charge

**NOAA NWS Weather Forecqst Office**

**San Juan, Puerto Rico**

# Puerto Rico Extreme Wave Climatology

Tend to occur from two main sources:

- Hurricanes – frequent breaking waves 20+ ft
- Intense winter lows yielding large, very long period swell – frequent breaking waves 20-30 ft

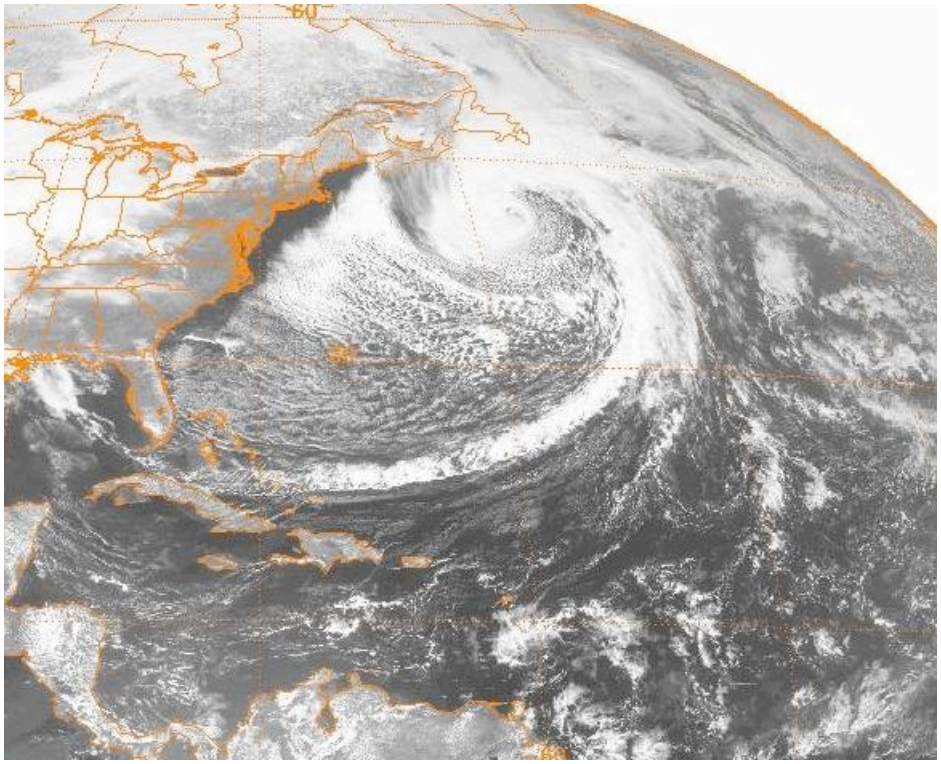
Feb 3, 1999

# Deep Baroclinic Lows

Recent regional events:

- Oct 30 – Nov 1, 1991
- Nov 18 – 20, 1996 *
- Feb 3 – 4, 1999
- Oct 16 - 17, 2005 *
- March 19 - 21, 2008

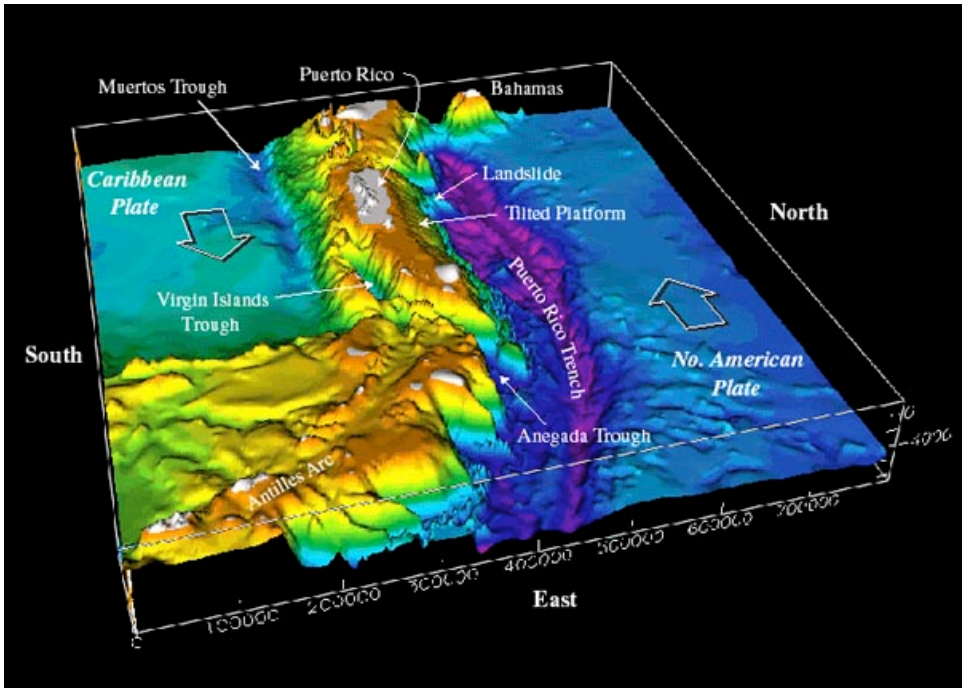
Due to local bathymetry, swell energy at 4 m or greater and 16 sec or greater capable of producing breaking waves of 30+ ft across Atlantic outer reefs, and widespread coastal inundation



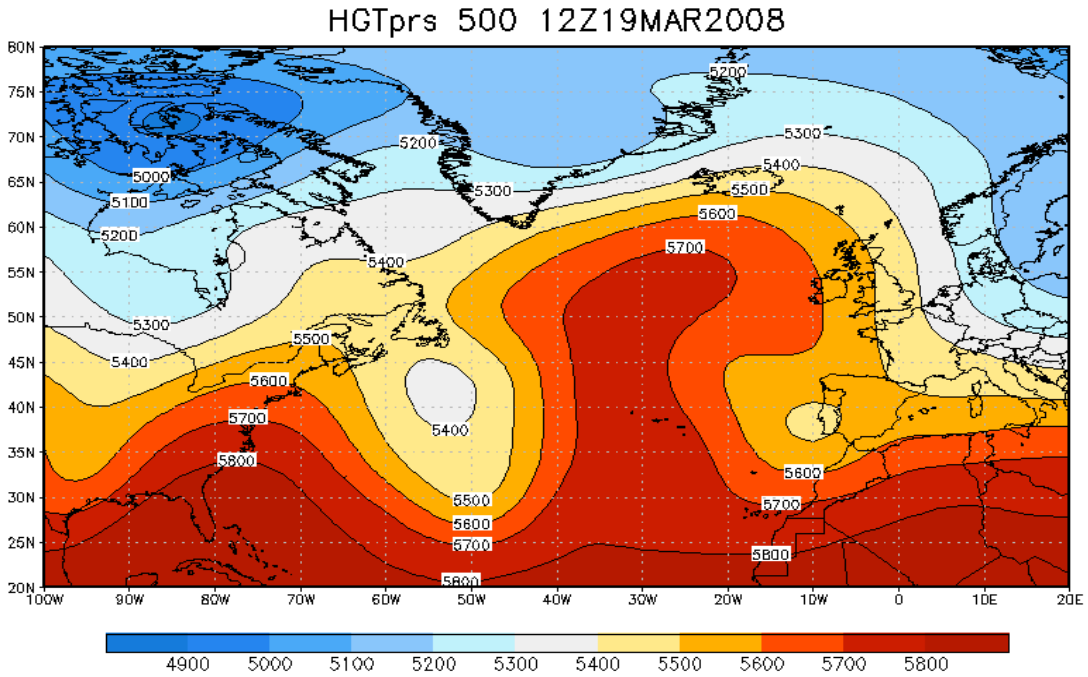
March 16, 2008

# Caribbean Bathymetry

Proximity of Puerto Rico trench allows Atlantic deep water swell energy to reach Atlantic coasts with minimal shallow water wave attenuation

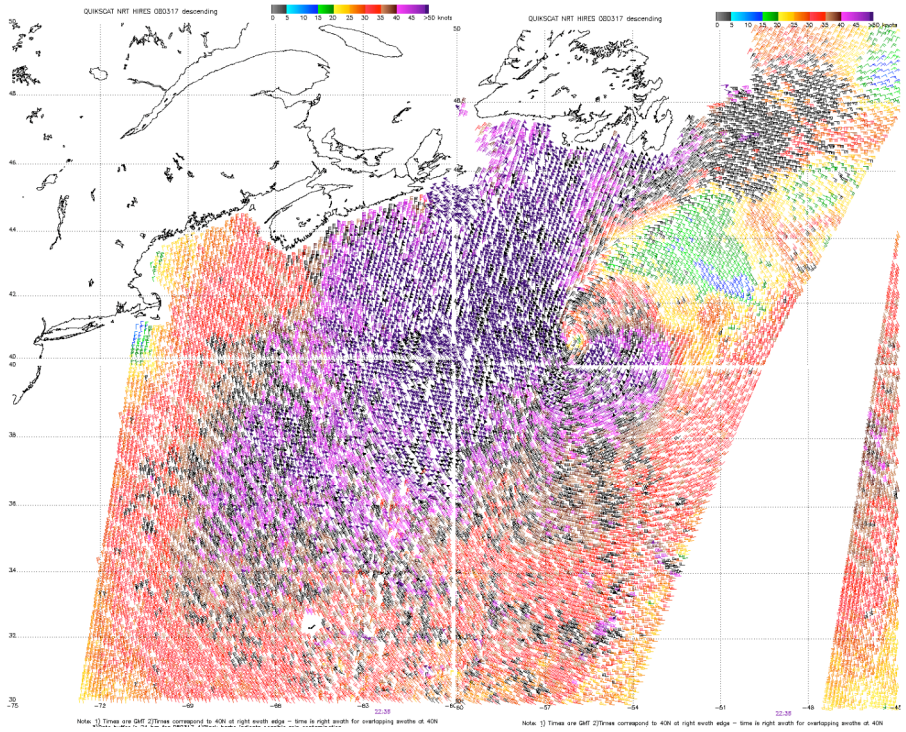


# Deep Baroclinic Lows



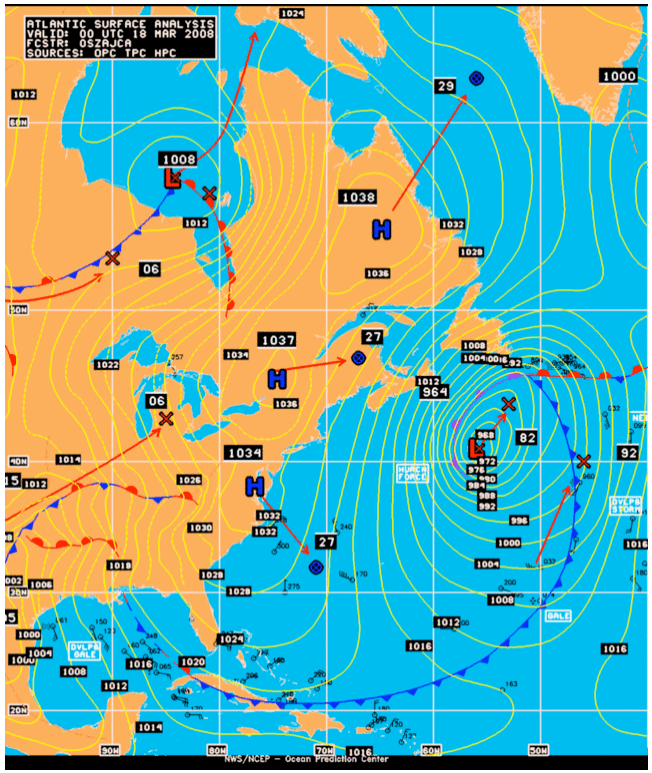

Blocking upper patterns yield scenario where associated surface low can oscillate very slowly within cutoff upper trough to produce a dynamic, or even trapped fetch. Best wave growth occurs when dynamic fetch moves in general motion **towards** NE Caribbean.

# Deep Baroclinic Lows



In the March 2008 event, a 964 mb low shifted very slowly northeastward within cutoff trough, while very cold air spilling into backside of low produced a dynamic fetch that shifted SSE 6 – 8 degrees over a 36 hr period

# Deep Baroclinic Lows

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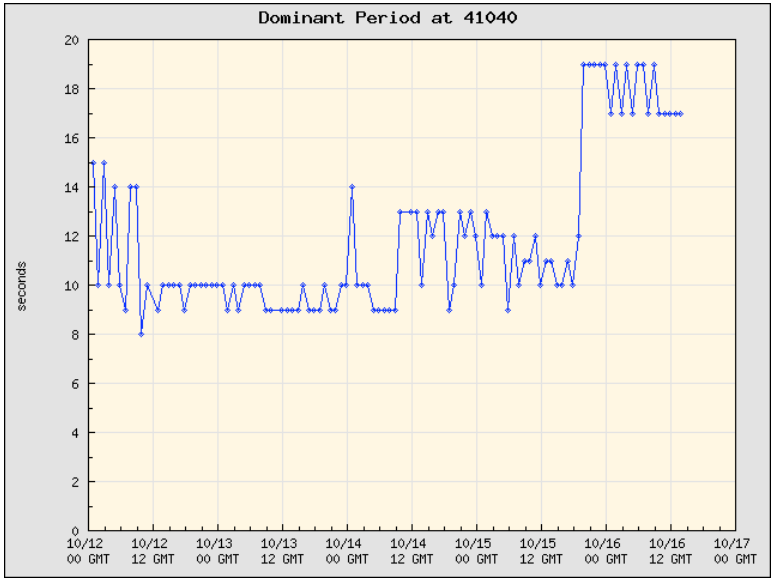
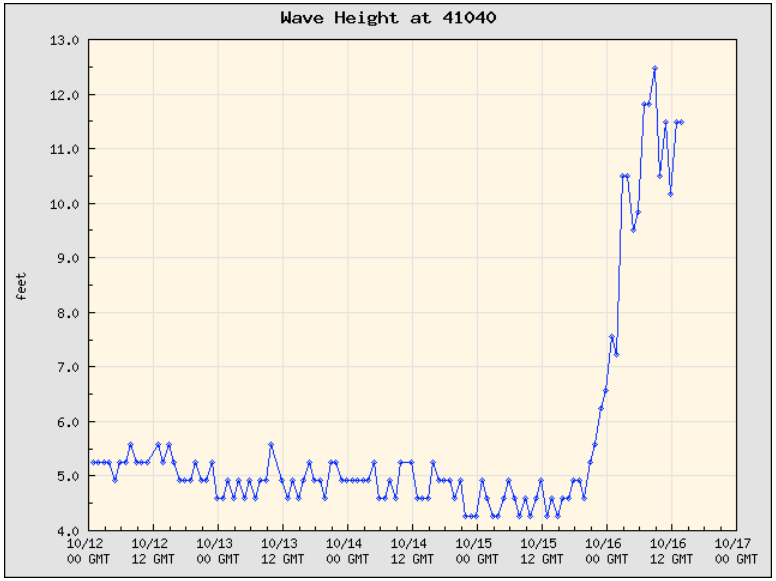
# Deep Baroclinic Lows

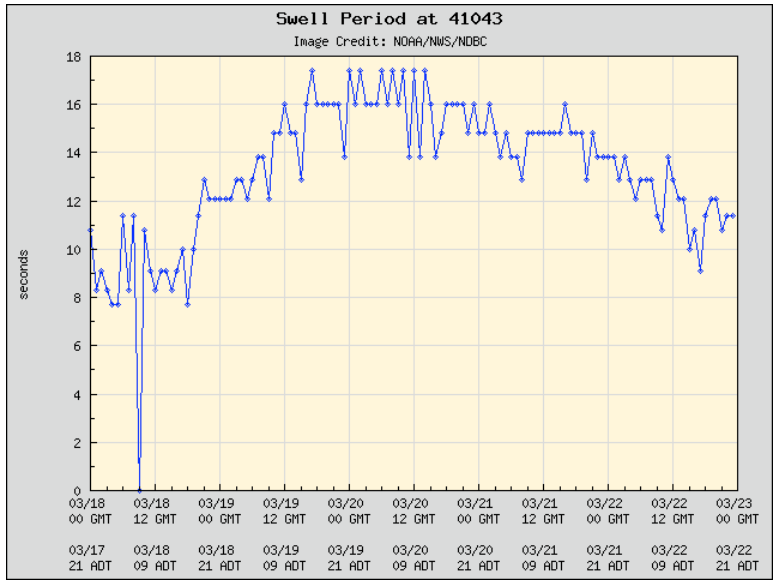


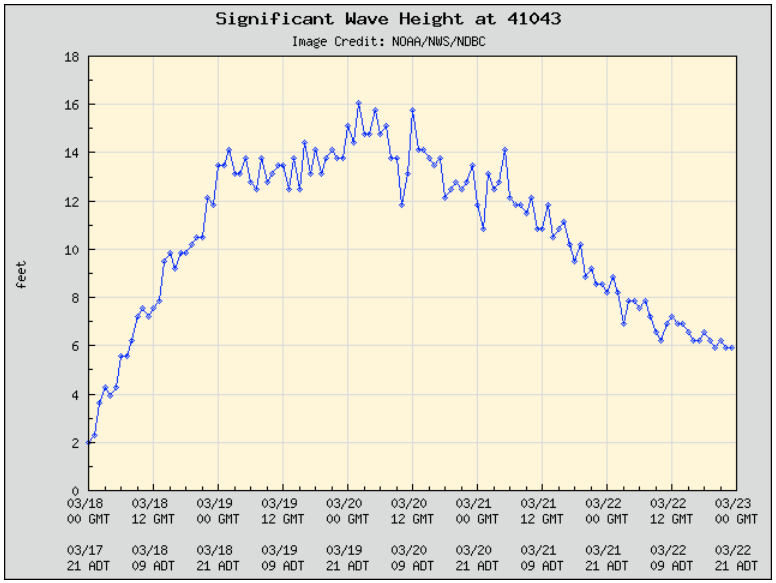




Oct 2005 swell event

- SWH and P at Buoy 41040 @ 14.48N 53.04W
- Affected Northeast and entire Eastern Caribbean
- Peak energy passed well east of Lesser Antilles

# Deep Baroclinic Lows

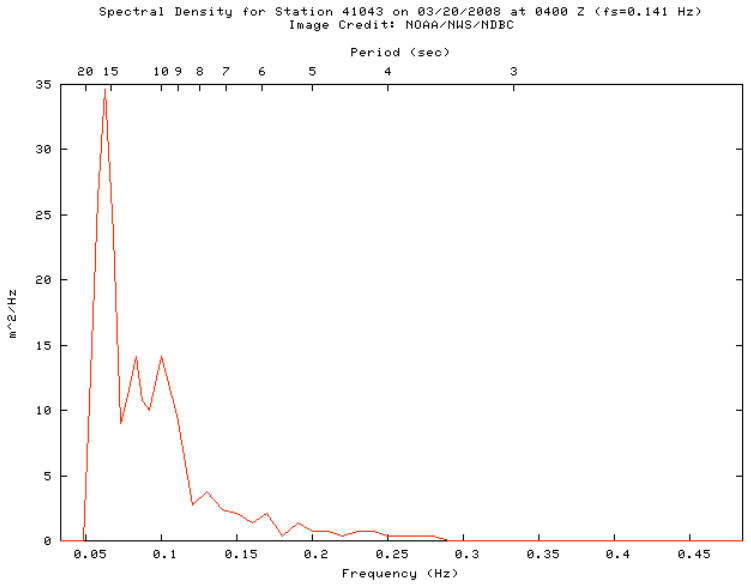


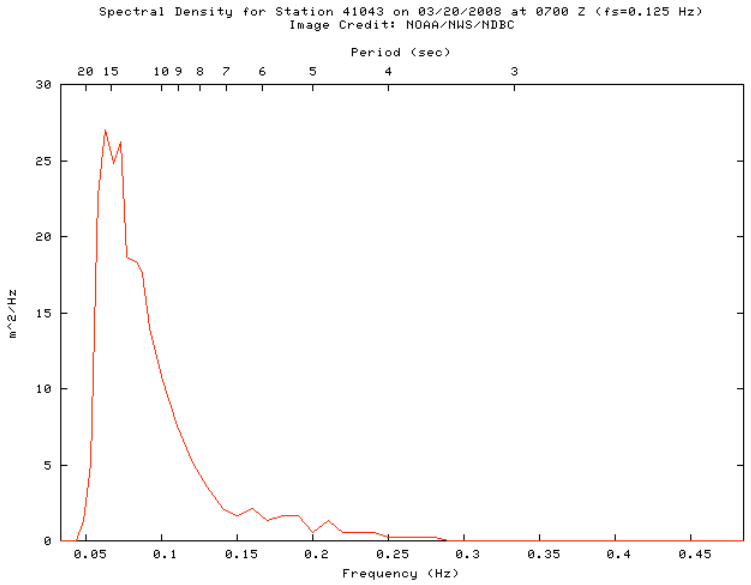




March 2008 swell event

- SWH and P at Buoy 41043 @ 20.99N 65.01W
- Affected entire North and Eastern Caribbean
- Peak energy passed just east of Lesser Antilles

# Deep Baroclinic Lows



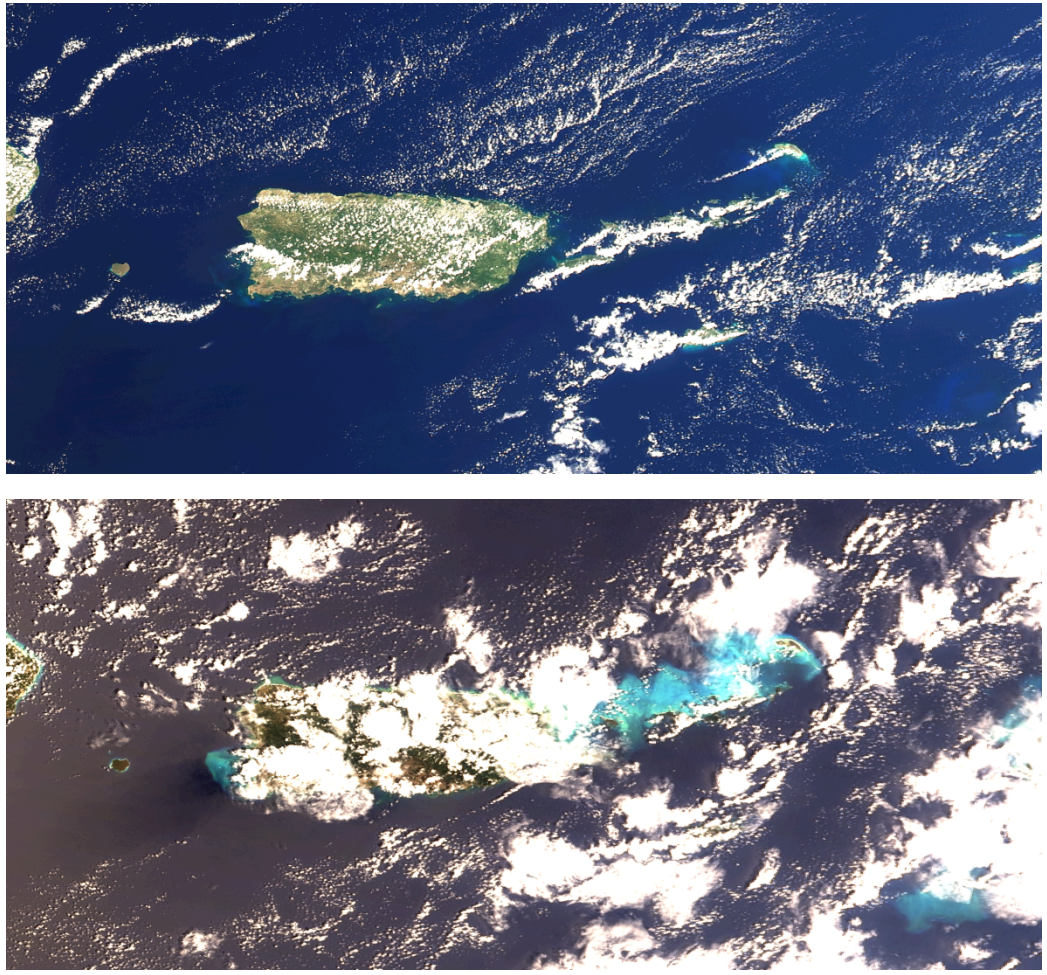

March 2008 swell event

- Spectral Density at Buoy 41043 @ 20.99N 65.01W
- Plots depict E near peak of event
- Peak energy centered at Period >= 15 sec

# Extreme Waves


30 + ft breakers at “Tres Palmas”,
Rincon, Puerto Rico
March 19, 2008

# Resultant Turbidity

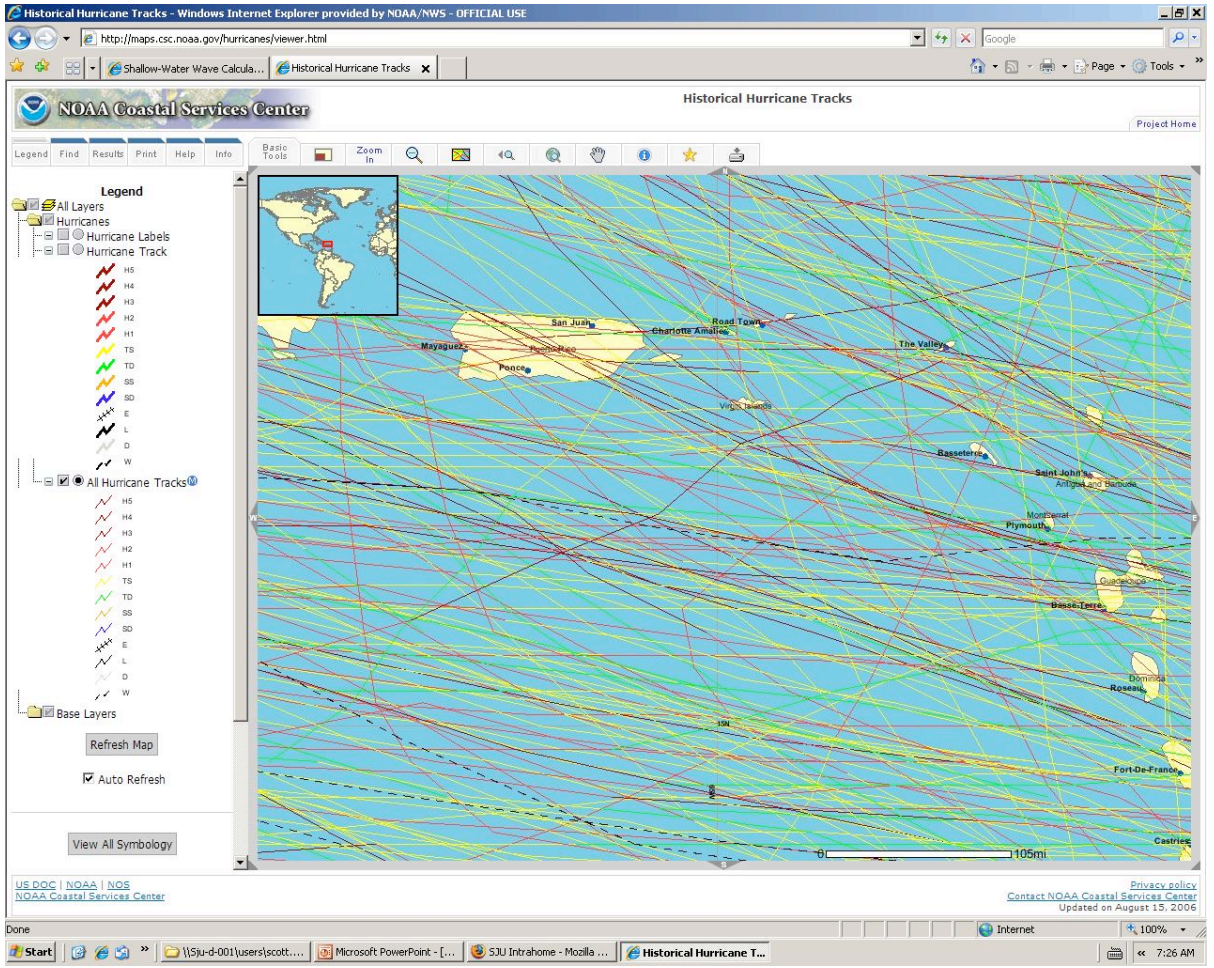


MODIS Imagery

Before: March 17

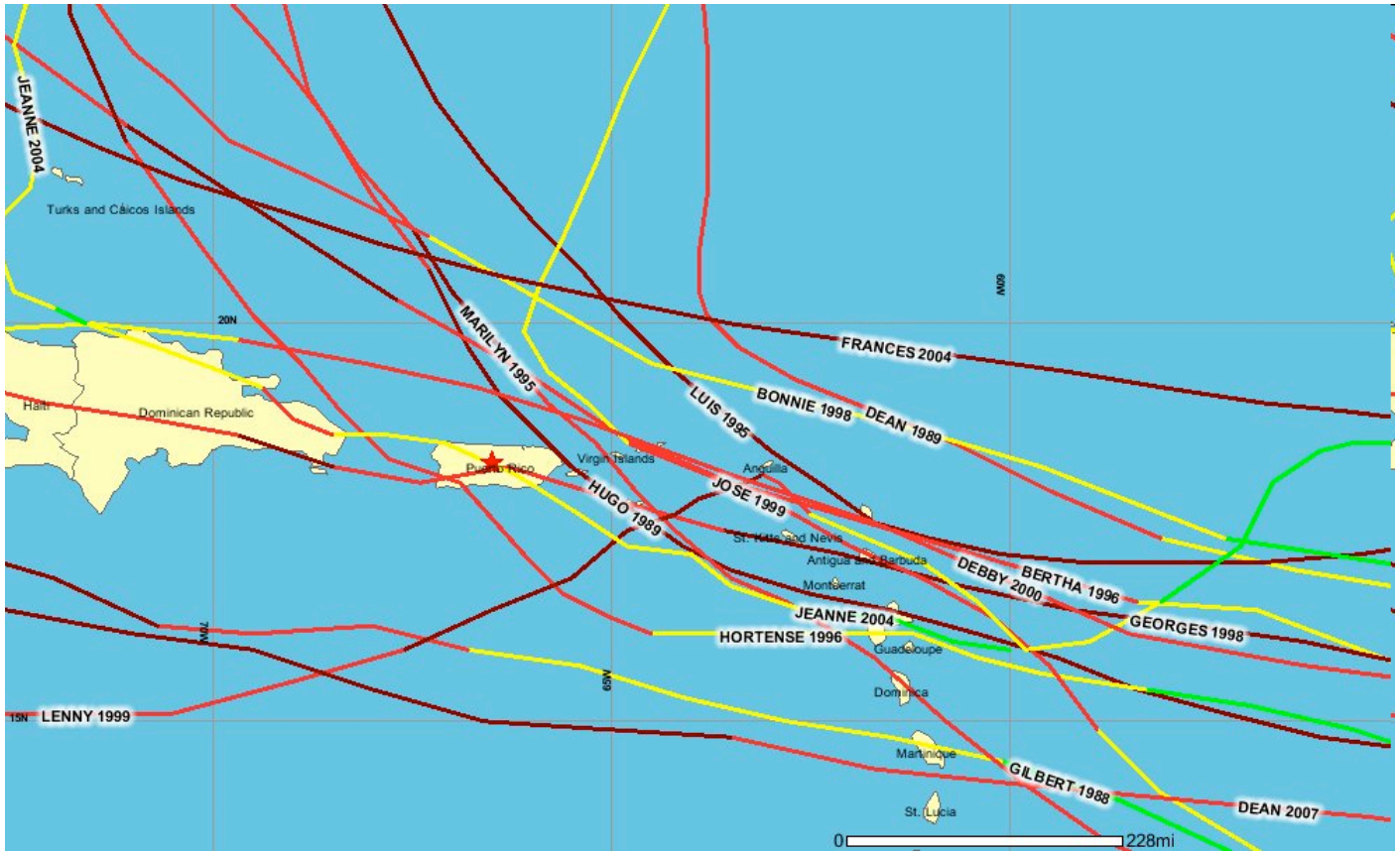
After: March 20

# Hurricane Wave Events



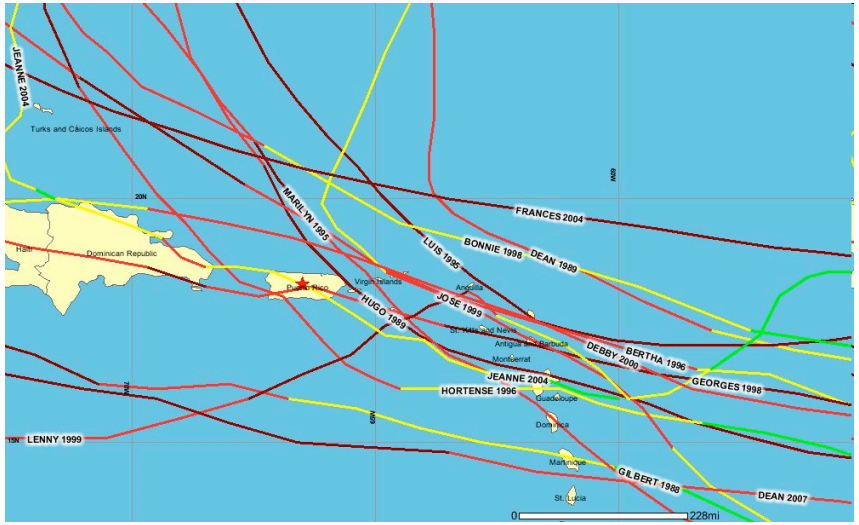

- Over the past 100 years, 30 hurricanes have passed within 200 miles of Puerto Rico, giving a return time of approximately 3-4 years

# Hurricane Wave Events




- **Hurricanes passing near Puerto Rico 1980 to 2007**
- **10 Hurricanes have had sufficient size, strength and trajectory to produce extreme waves in Puerto Rico and Virgin Islands**

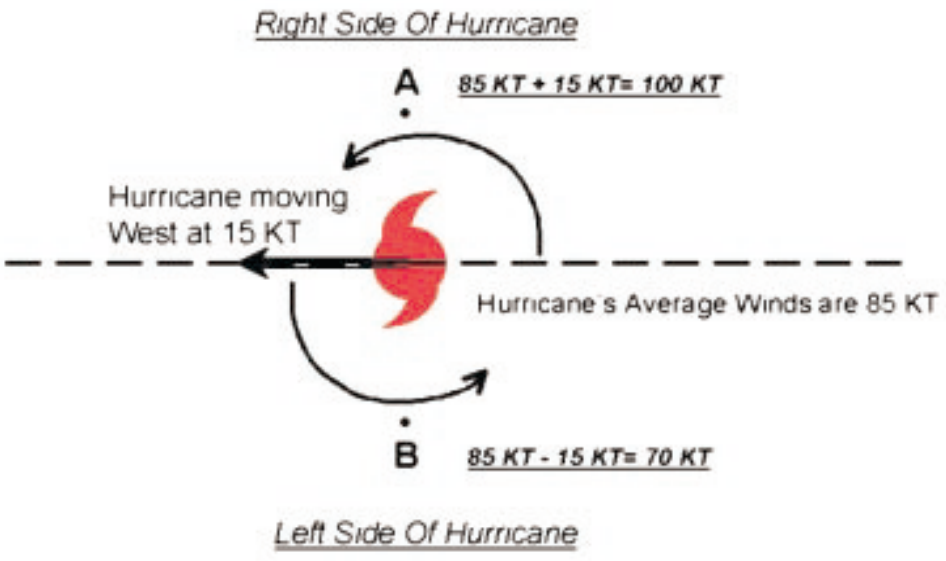
# Hurricane Wave Events




Past 20 years

- **Sep 1988 - Gilbert**
- **Sep 1989 - Hugo**
- **Sep 1995 - Luis**
- **Sep 1995 - Marilyn**
- **Jul 1996 - Bertha**
- **Sep 1996 - Hortense**
- **Sep 1998 - Georges**
- **Oct 1999 - Jose**
- **Nov 1999 - Lenny**
- **Aug 2007 - Dean**

# Wave Growth Considerations for Atlantic Tropical Cyclones




**Most efficient wave growth in TC's occurs from right semicircle of system (storm motion relative)**

- **Stronger winds typically on right side**
- **Fetch duration is extended in time vs left side**
- **Peak wave energy propagates with and to the right of storm motion**

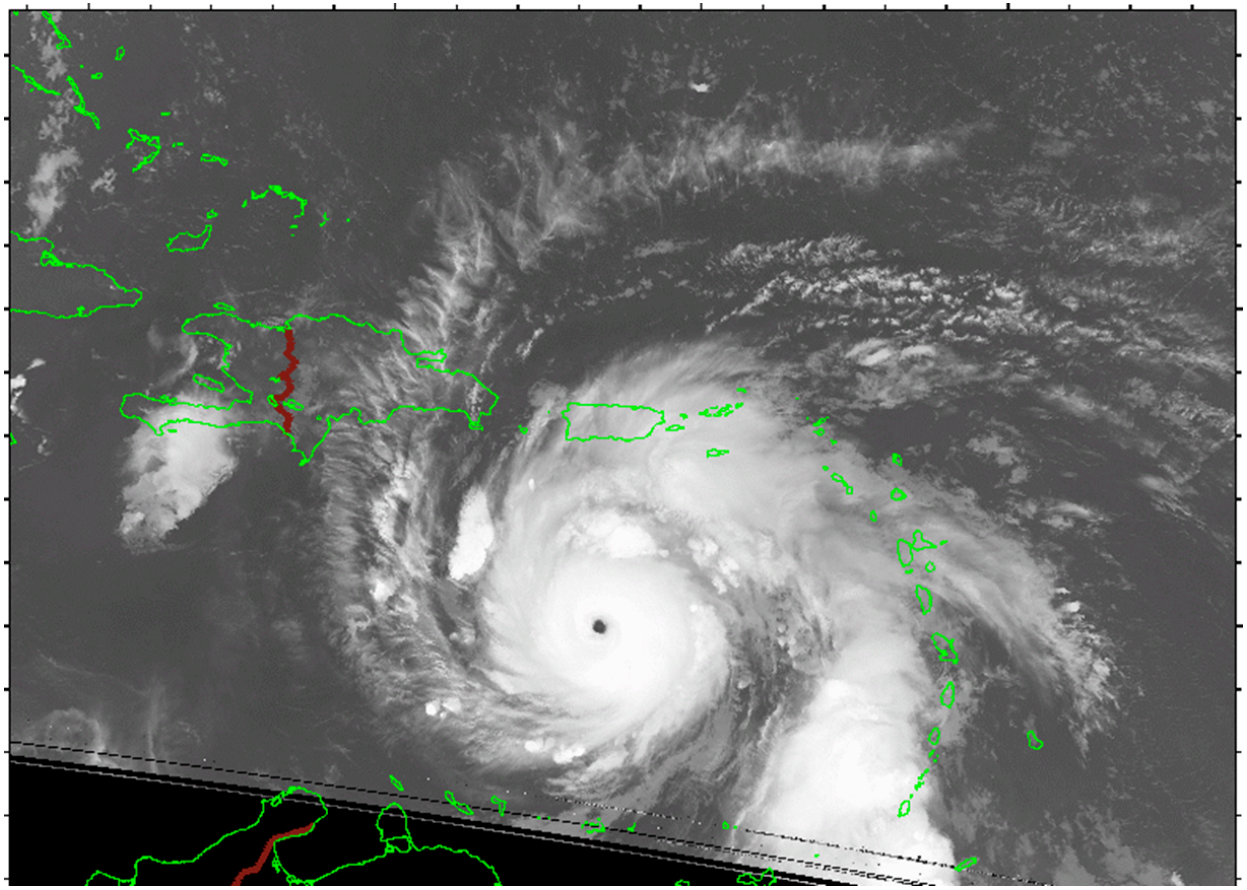
# Hurricane Wave Events

- Extreme Hurricane generated waves (20 ft or higher breakers) typically occur from systems passing across or very near the local islands
- Exception – extratropical transitions as with the “Perfect Storm” Oct 1991

Due to proximity of generated wave field:

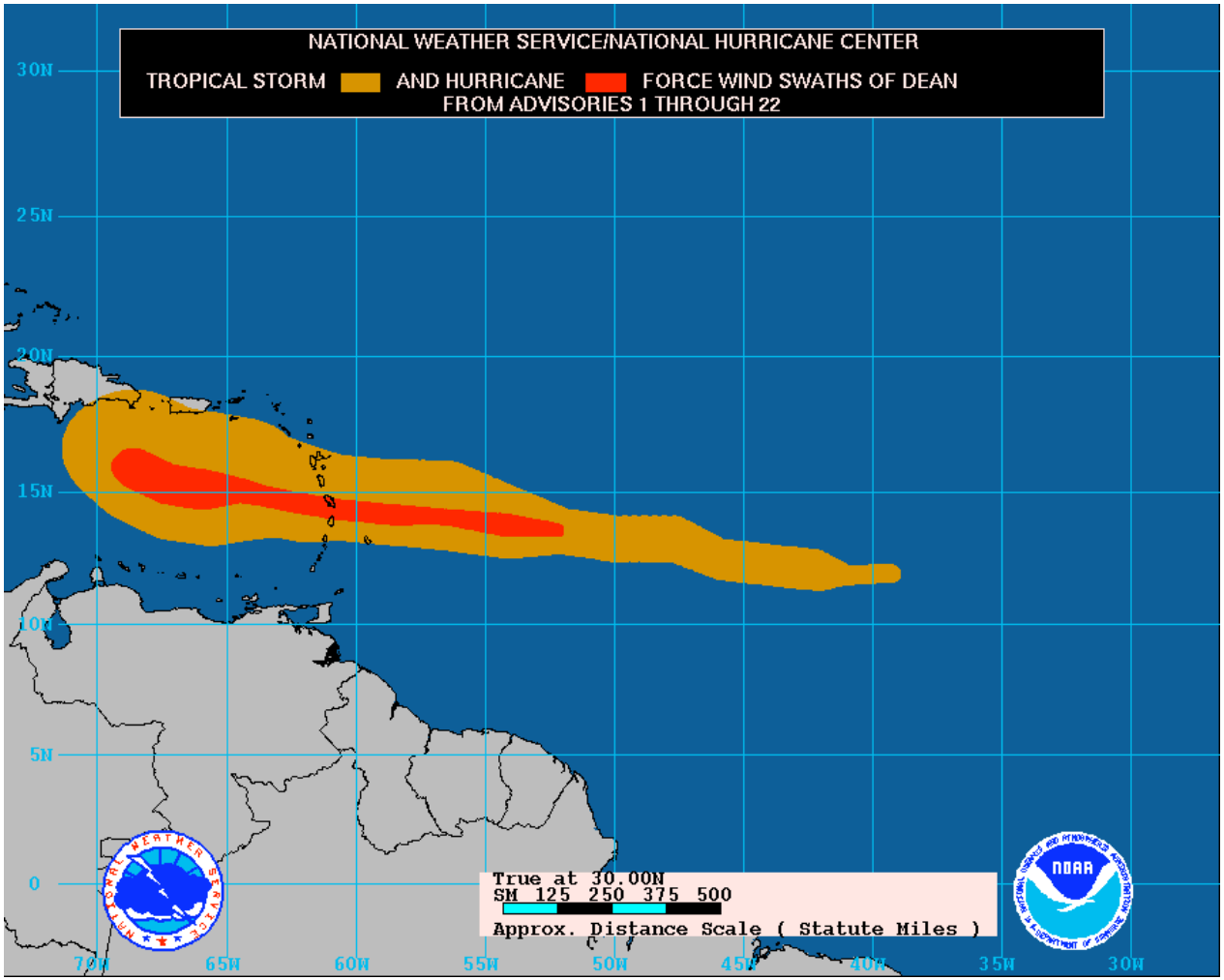
- Little to modest dissipation of wave heights occur before arrival to coast
- Wave lengths (L) tend to be lower than from distant baroclinic lows
- Extreme waves may affect only portions of coastlines depending on storm trajectory, size

# Hurricane Dean 2007



- Tropical Storm force wind field affected south coast of Puerto Rico
- 12 to 15 foot seas reported inside Port of Ponce

# Dean Wind Field (NHC)




**The core of Dean passed south of Puerto Rico, but it's relatively large wind and wave field impacted the local Caribbean waters**

# AOML Analysis Aug 17 1930Z

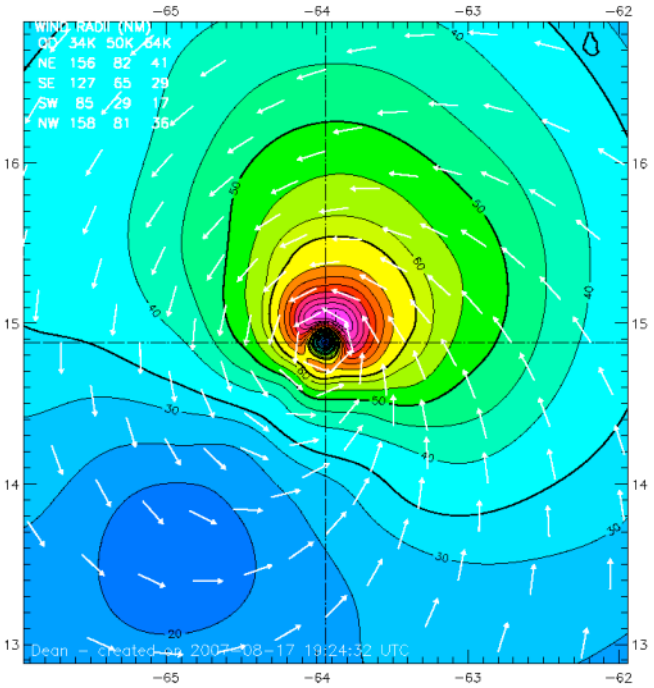
Hurricane Dean 1930 UTC 17 AUG 2007

Max 1-min sustained surface winds (kt)

Valid for marine exposure over water, open terrain exposure over land

Analysis based on GOES from 1302 - 1602 z; SFMR_AFREC from 1236 - 1753 z; METAR from 1400 - 1900 z; SHIP from 1239 - 1900 z;

1930 z position extrapolated from 1717 z Vortex wind center using 280 deg @ 18 kts; mslp = 966.0 mb




Integrated Kinetic Energy > TS: 39 TJ > Hurricane: 6 TJ

Destructive Potential Rating(0-6) Wind: 0.8 Surge/Waves: 3.4

Observed Max. Surface Wind: 106 kts, 10 nm NE of center based on 1714 z SFMR_AFREC

Analyzed Max. Wind: 105 kts, 10 nm NE of center

Experimental research product of NOAA / AOML / Hurricane Research Division

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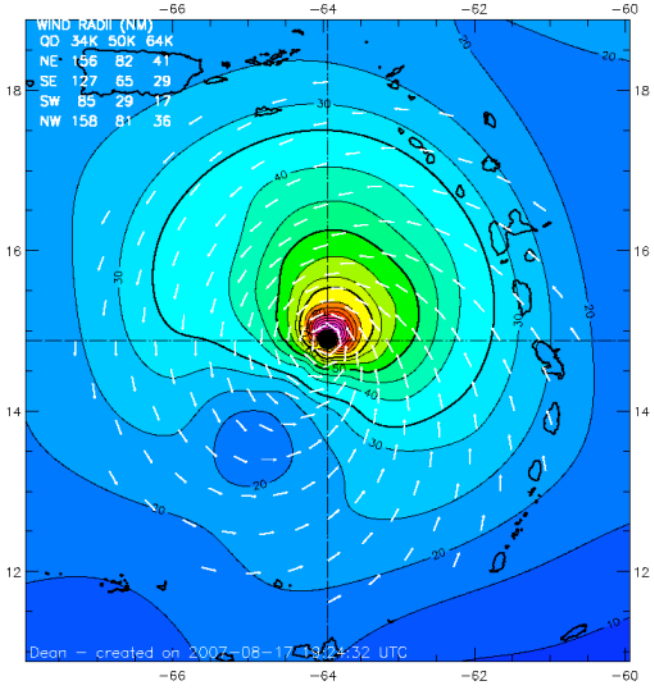


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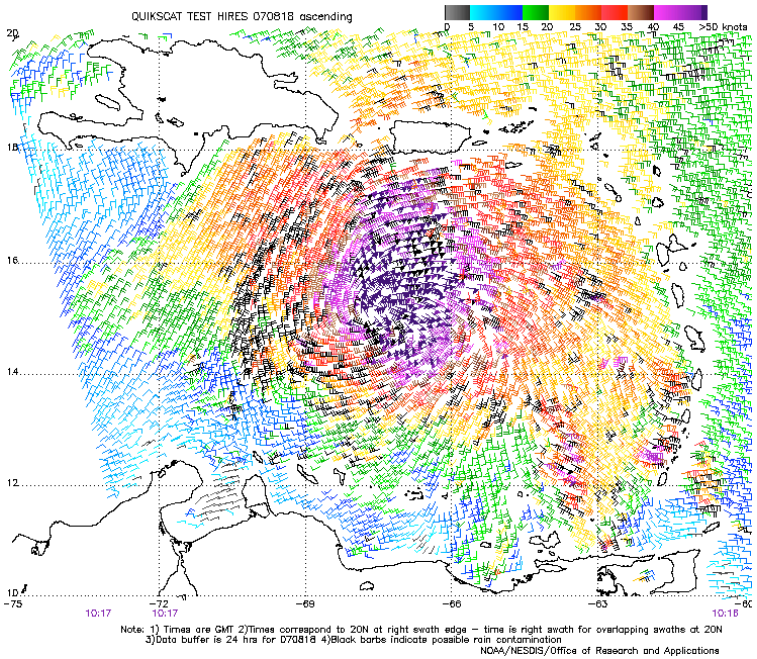
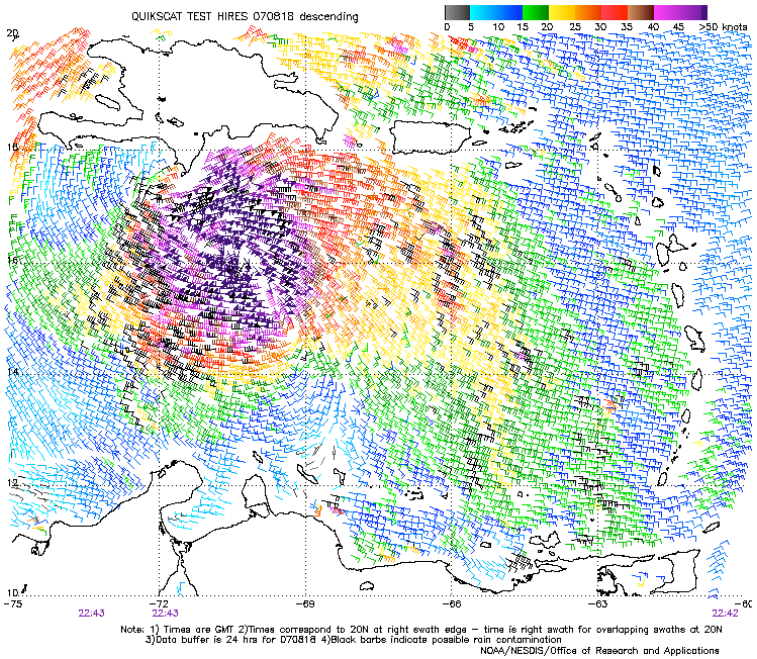
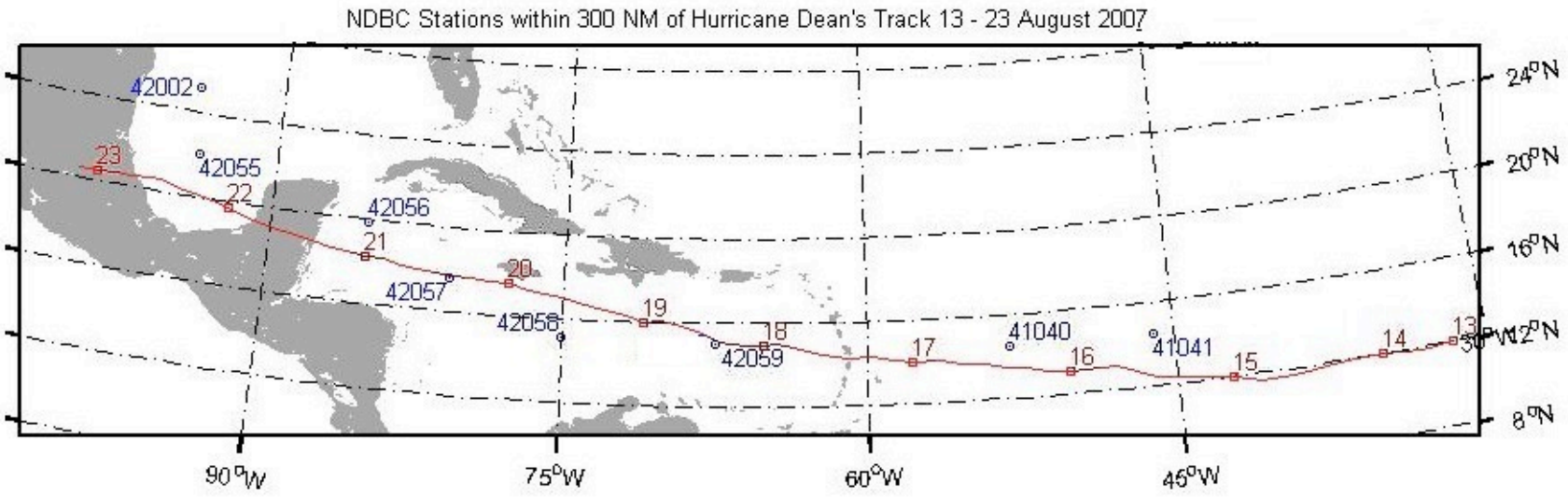
# QuikScat passes Aug 18



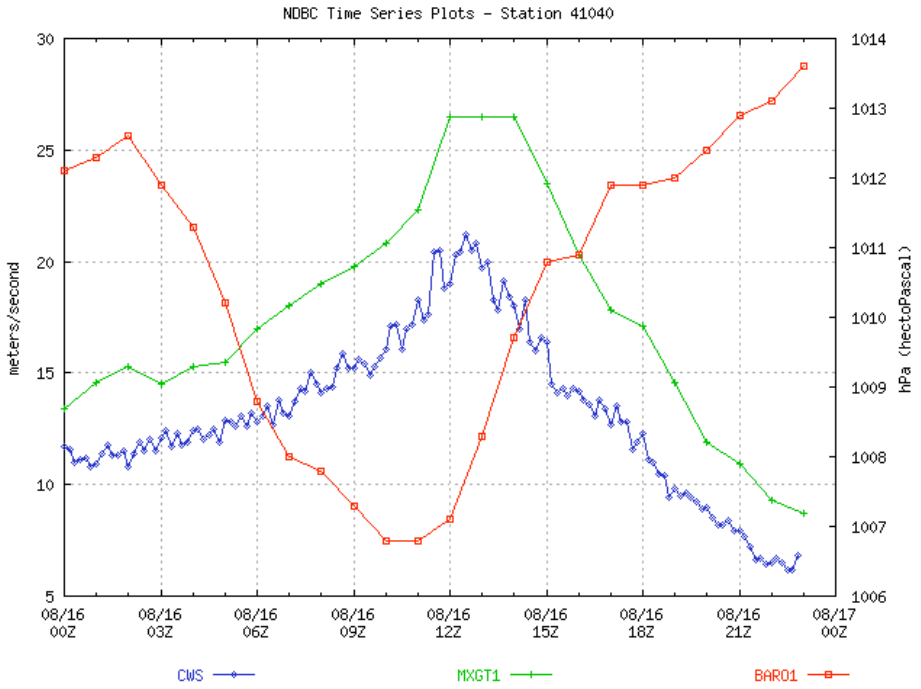

- Morning Quikscat pass (~1030Z) on left
- Evening Quikscat pass (~2300Z) on right

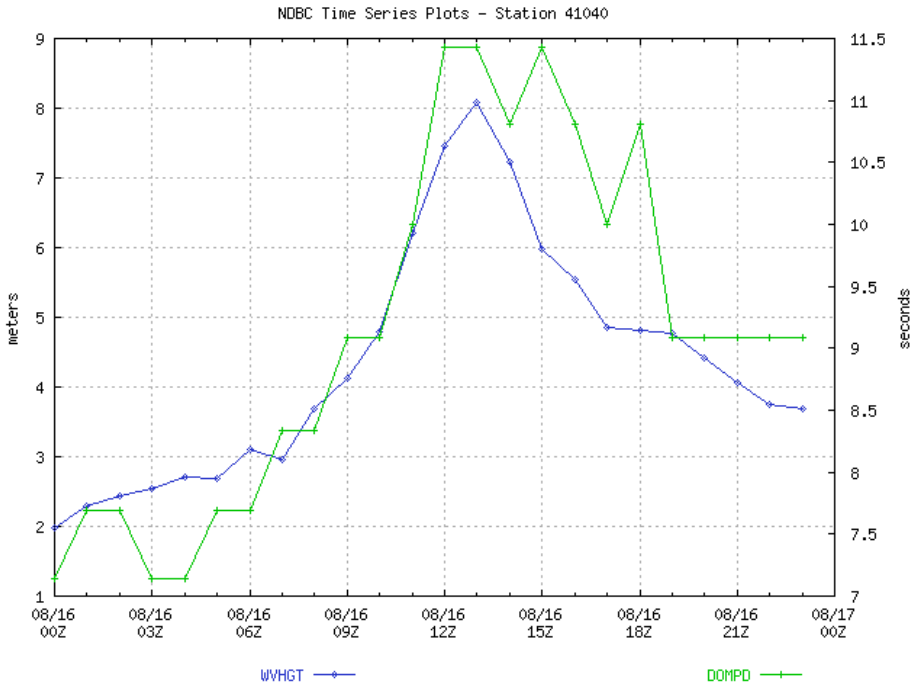
# NDBC Buoy Observations along Trajectory of Dean




- The straight running and low latitude trajectory of Dean took it along a path close to several NDBC buoys
- Of interest are buoys **41040 and 42059**

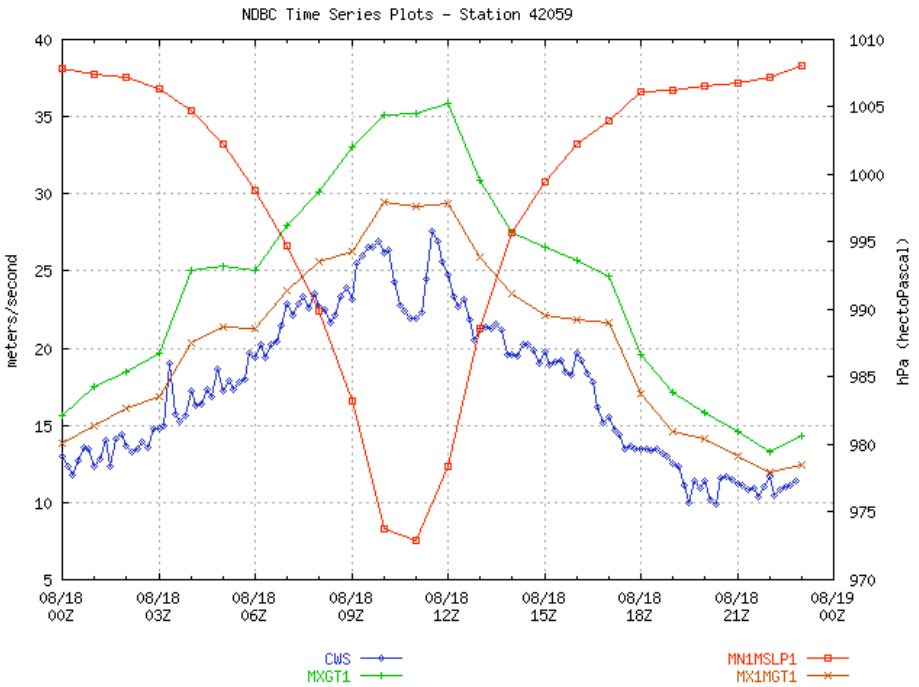
# Dean Passage by 41040

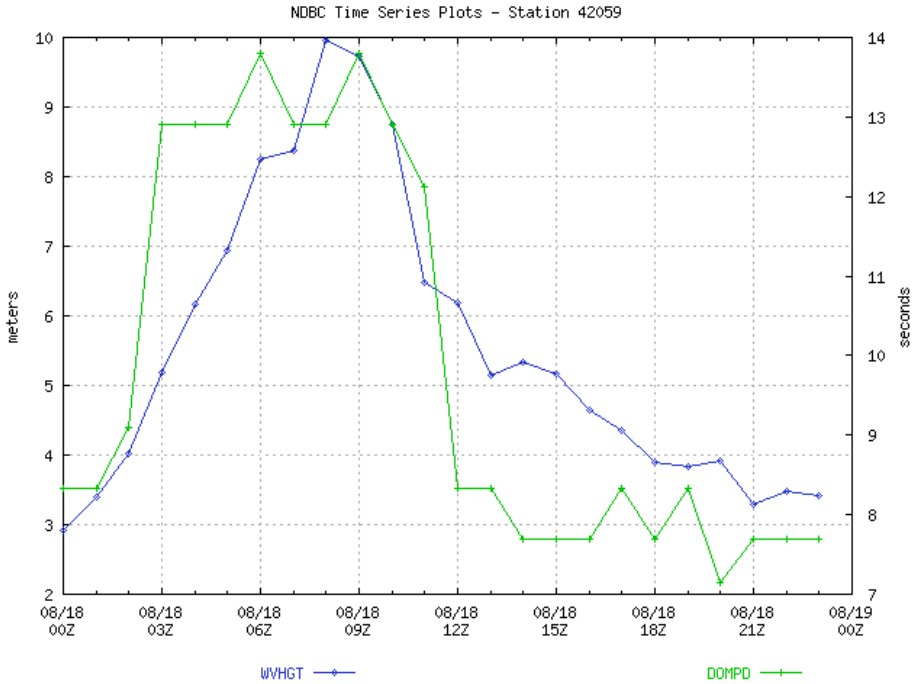



- Dean passed ~ 62.1 nm to the south at 08/16 1100Z
- MAX SUSTAINED WINDS 80 KT WITH GUSTS TO 95 KT per 15Z NHC bulletin
- Dominant P was 11.4 sec while Peak P was 16 sec
- SWH max occurs shortly after passage of Dean

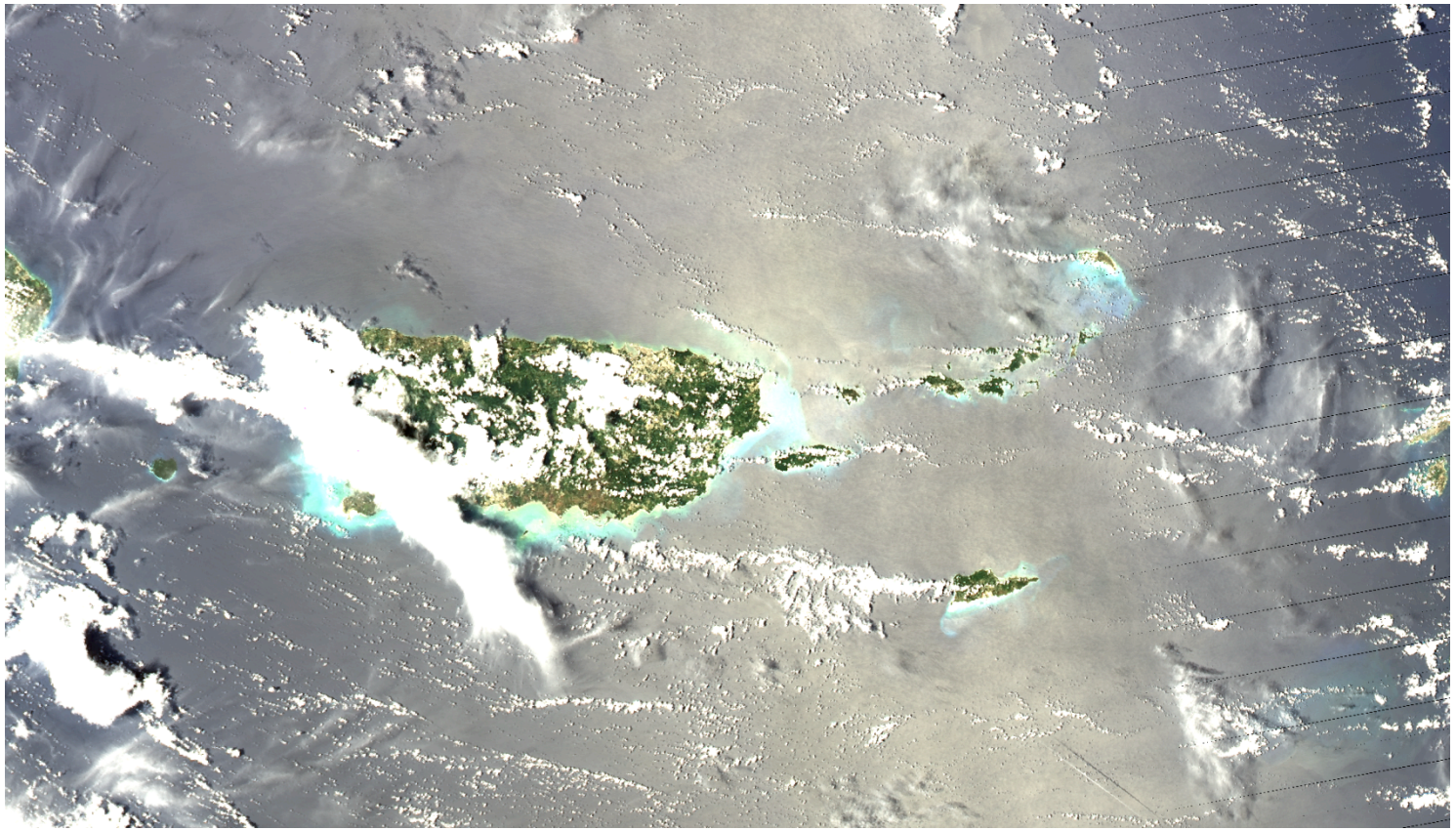
# Dean Passage by 42059




- Dean passed ~11.4 nm to the north at 08/18 1000Z
- Cat 4 moving WNW @ 15 kt
- Dominant P was near 14 sec while Peak P was 17 sec
- Notice SWH max occurs ahead of Dean's arrival in E swells

# Hurricane Dean 2007



- Buoy observations along trajectory of Dean reveal breaking wave potential for similar storms
- Dean passed ~170 nm south of Puerto Rico
- Closer trajectory typically yields extreme and more focused wave energy

# Extreme Wave Climatology

**Tend to occur from two main sources:**

**Hurricanes:**

- **Higher frequency of occurrence**
- **Shorter duration, typically more focused events**
- **Wave generation source is usually close leading to broader wave spectrum and shorter wave lengths as compared to winter swells**
- **Wave runup and setup contribute to coastal inundation**

**Deep Baroclinic Lows:**

- **Lower frequency of occurrence**
- **Tend to produce multiday events**
- **Blocking upper pattern contributes to slow moving surface lows at higher latitudes**
- **Produced by dynamic or trapped fetch scenarios**
- **Very long wave lengths (for Atlantic) of 16 seconds and greater**
- **Widespread coastal inundation across exposed coastlines**

"Caballos"

Carolina, Puerto Rico

Oct 16, 2005