



PUERTO RICO'S WAVE CLIMATE: HURRICANES, WINTER SWELLS AND CORAL REEFS

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Puerto Rico
Science, Technology
& Research Trust



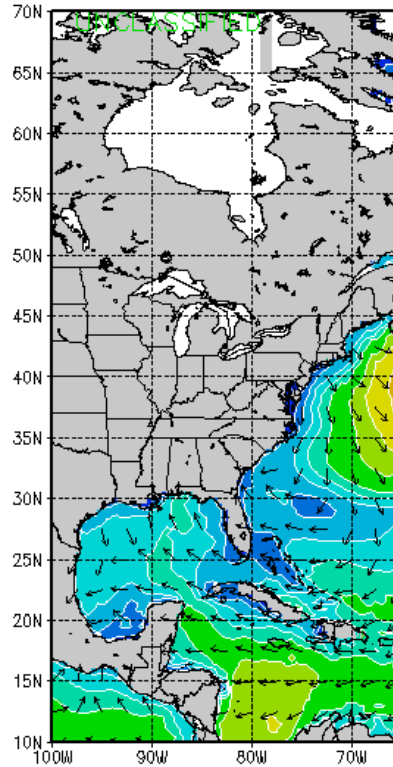
OVERVIEW

- Puerto Rico's wave climate: general characteristics
- The PRCZMP / CARICOOS Wave Climate Atlas
 - Rationale
 - Methods
- PRELIMINARY results
 - Case study: Ocean Park's 2019 erosion event
 - Preliminary maps
- Recommendations and concluding remarks

What is coastal erosion?

- **Erosion = Sediment deficit somewhere at some time scale**
 - Could be due to natural process of shoreline regression
 - Could simply be seasonal response of shoreline
 - Poorly designed coastal structures, interruption of sediment supply, and human intervention
 - Changing hydrodynamics:
 - Sea level rise
 - Changes / variability in wave climate

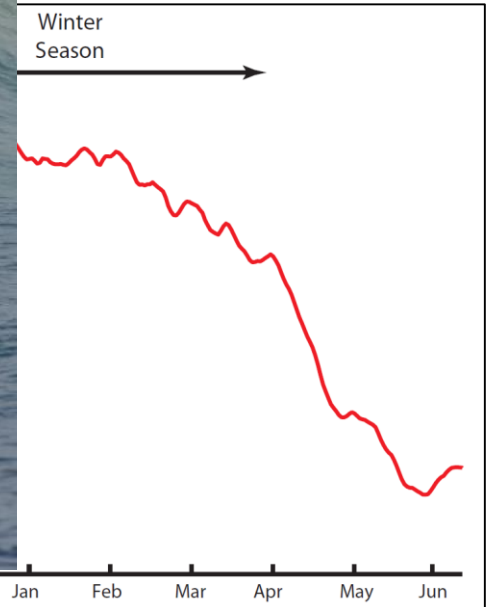
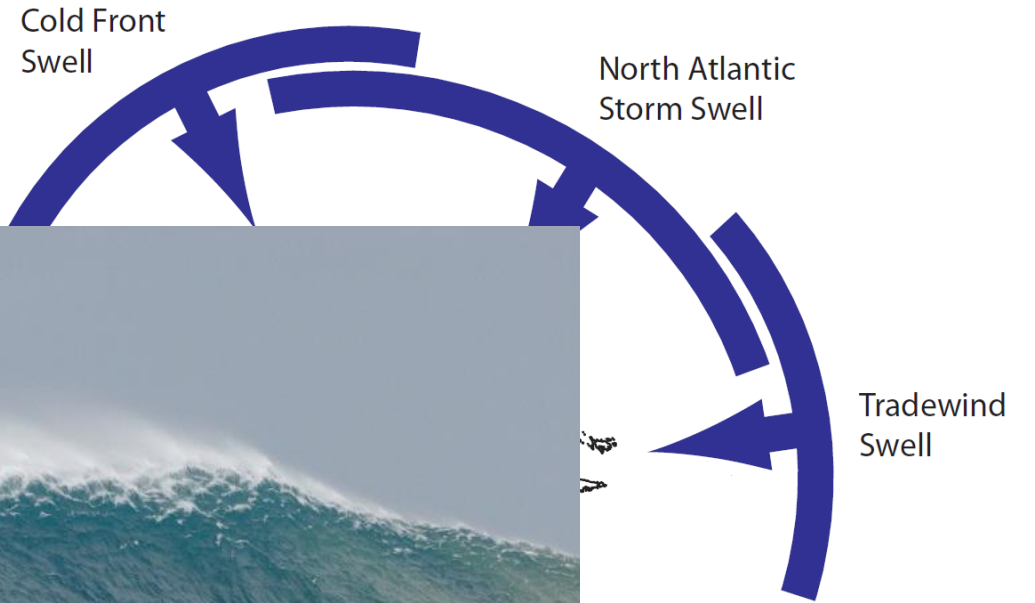
Puerto Rico's wave climate



VT: Sat 12Z 30 JAN 10
FNMOC NOGAPS (U): Swell Wave Height []
Run: 2010012812Z Tau: 48



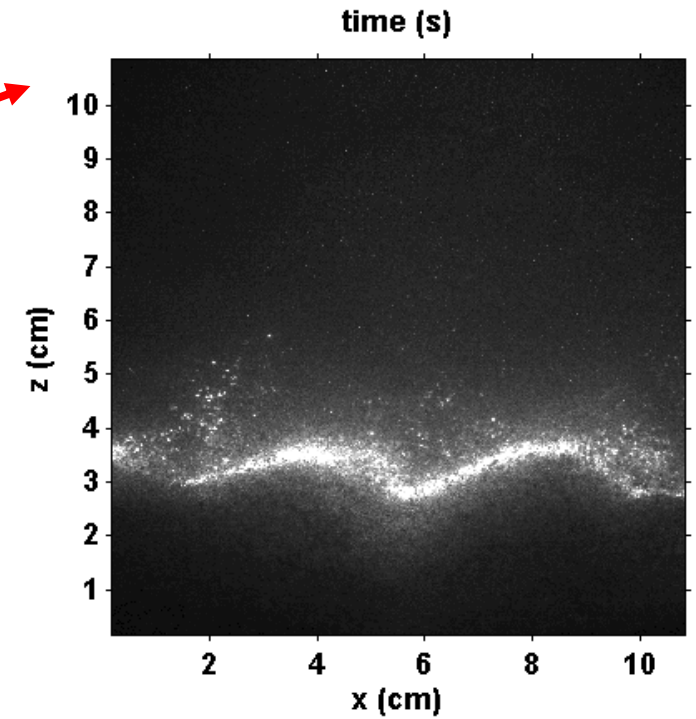
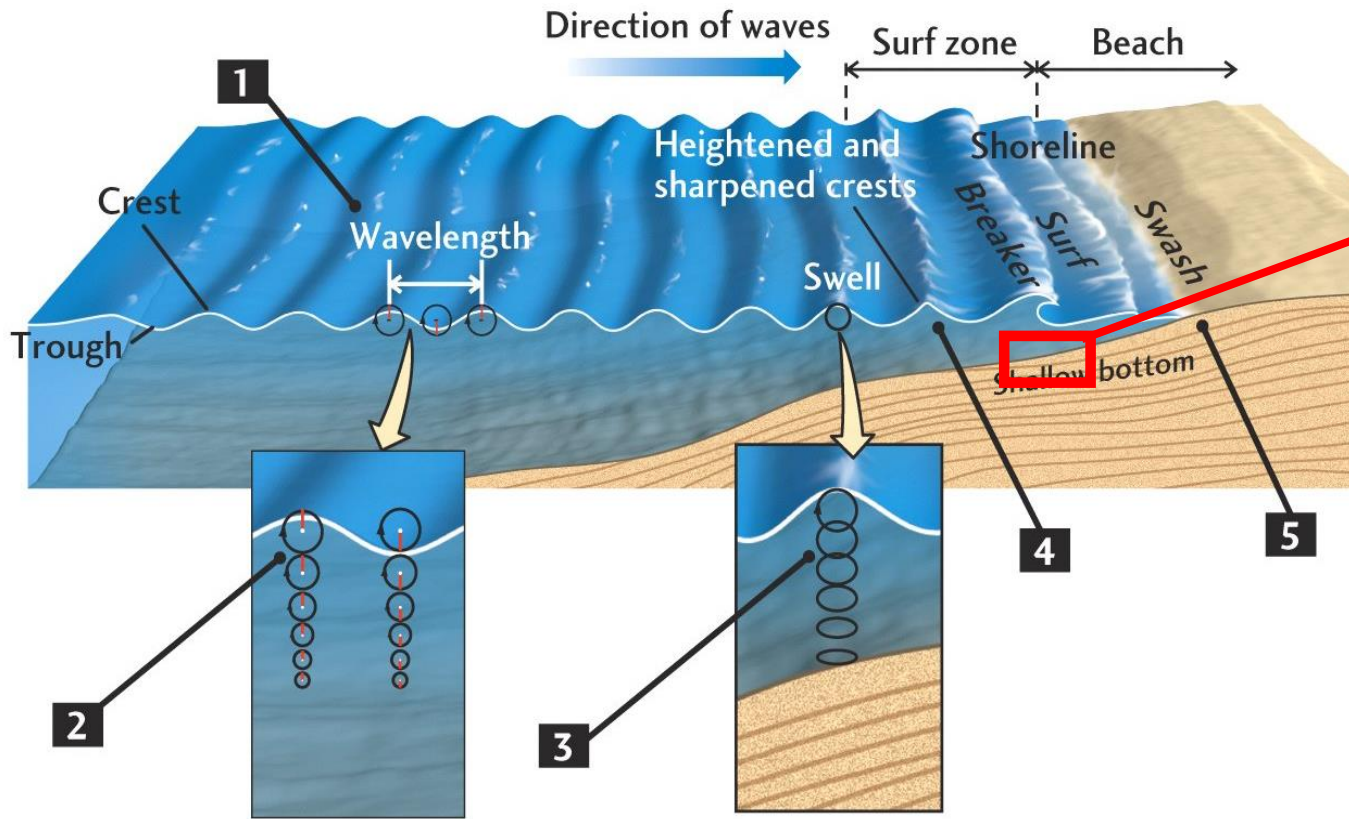
Angelo Cordero:PHOTOGRAPHY.



4 Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun

Q: What sets the dynamics and equilibrium profiles of beaches?

A: the annual wave cycle, NOT the direct hits by hurricanes



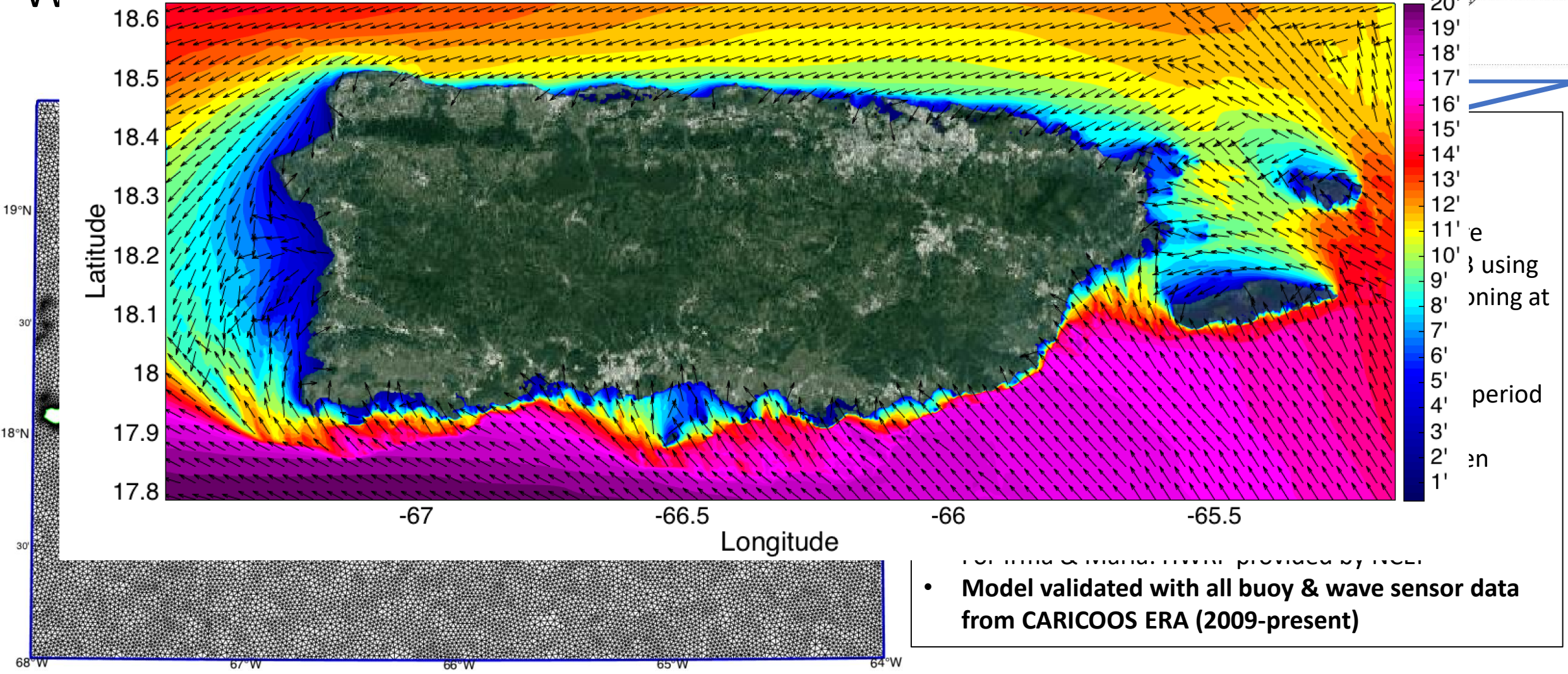
Rodriguez-Abudo (2012)

Image Source:
<http://bc.outcrop.org>

The PRCZMP/CARICOOS 40-year (1979-2019) High-Res

W

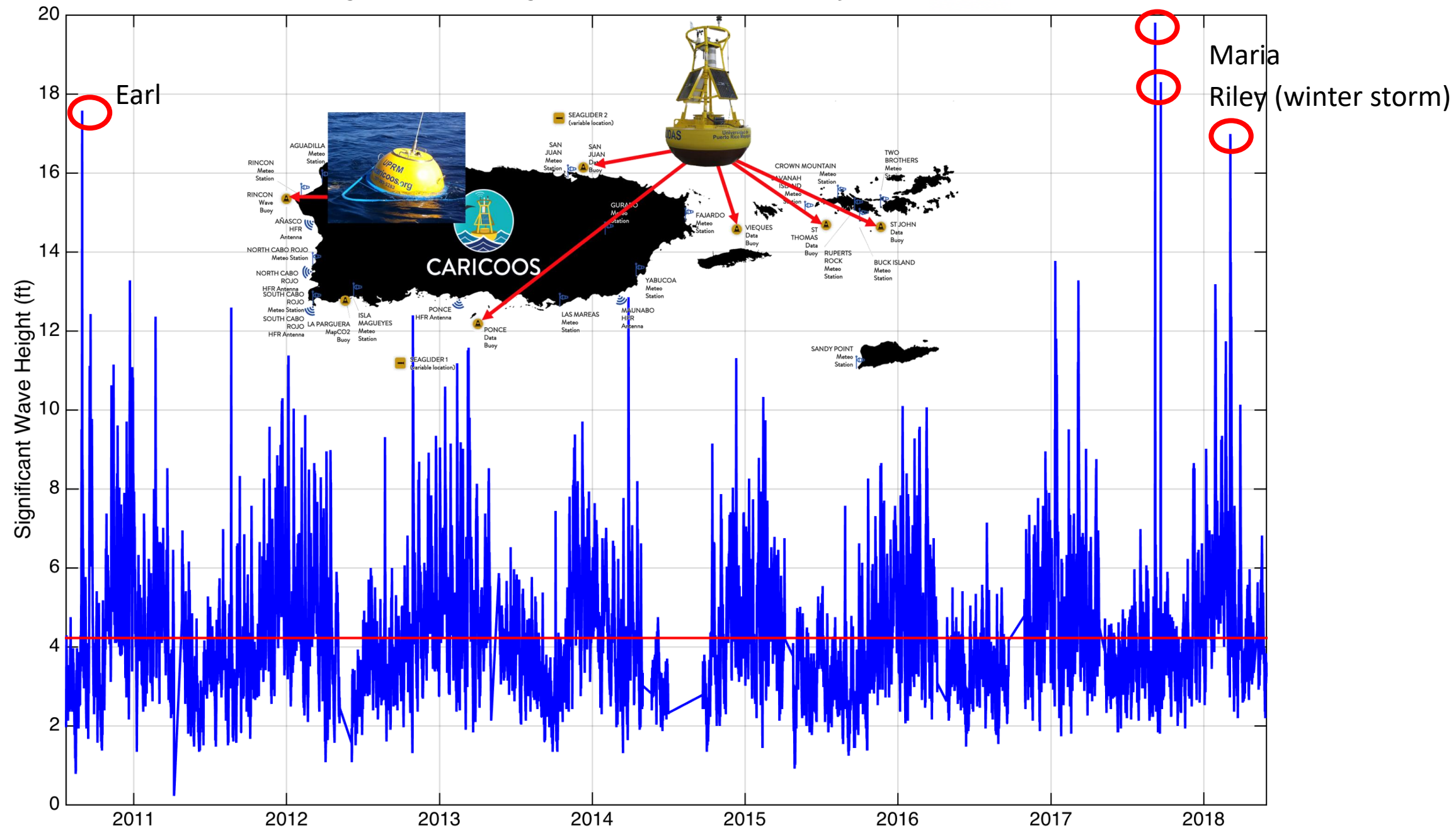
HURRICANE DAVID AUGUST 31 1979



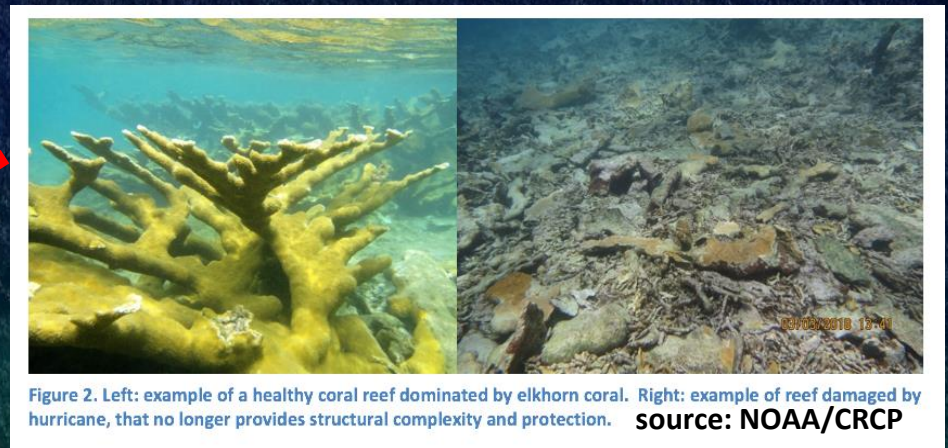
- Model validated with all buoy & wave sensor data from CARICOOS ERA (2009-present)

Significant Wave Height at CARICOOS San Juan Buoy

Irma

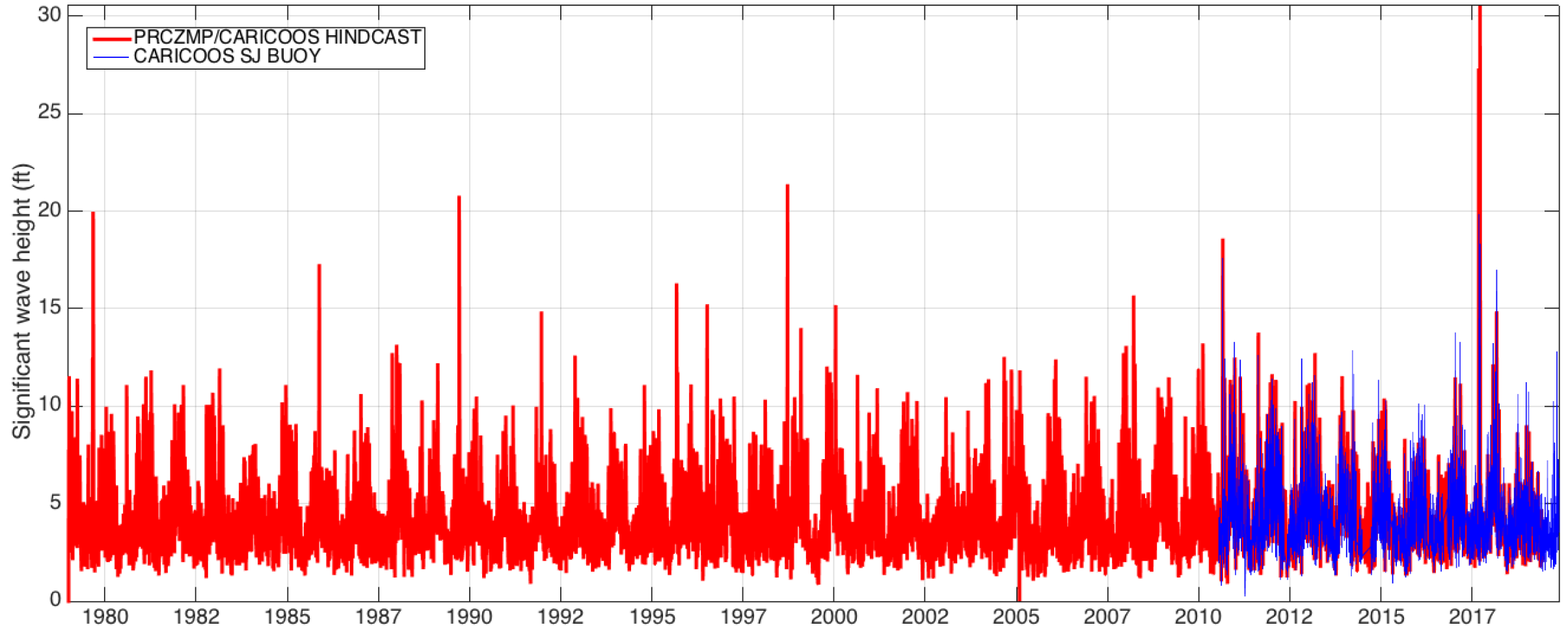


CASE STUDY: 2019 OCEAN PARK EROSION EVENT



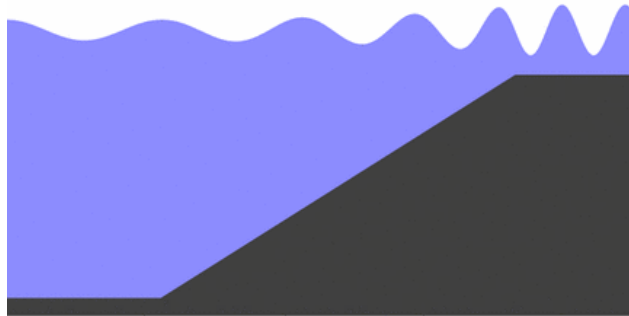
40 YEAR WAVE HISTORY OFF OCEAN PARK, OUTSIDE OF OUTER REEFS

PRCZMP/CARICOOS HINDCAST MODEL VALIDATION



WAVE POWER

- The energy and power of waves depends on the wave height, wave period and water depth
- 3 ft waves at 5 seconds = 2kW / m



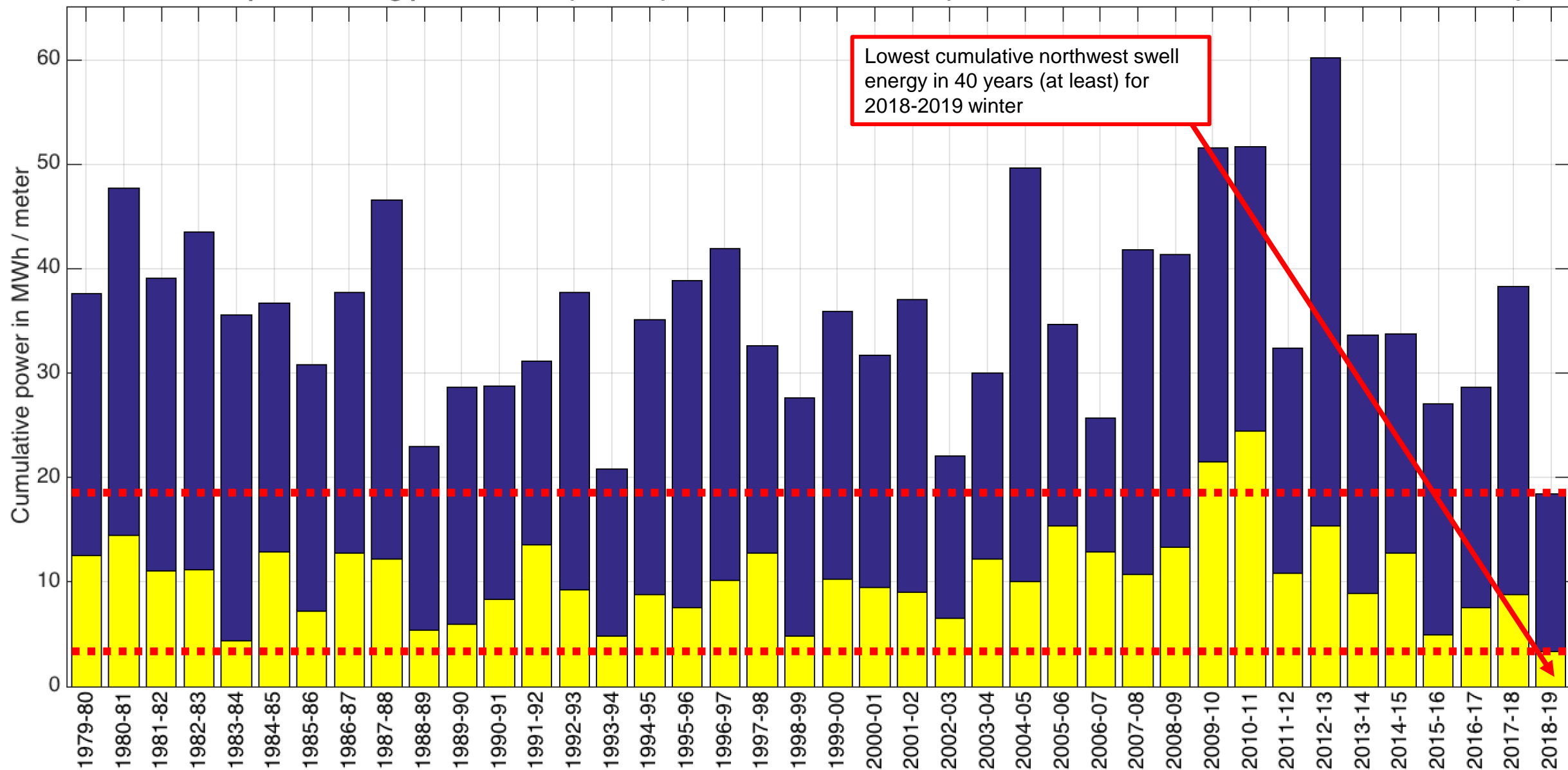
- If these waves hit the coast for 24 hours then:

$$2 \text{ kw/m} \times 24 \text{ h} = 48 \text{ kWh/m}$$



Morell's idea

Cumulative power of long period waves (T > 10 s) offshore of Ocean Park (All swell directions = BLUE, NW swells = YELLOW)

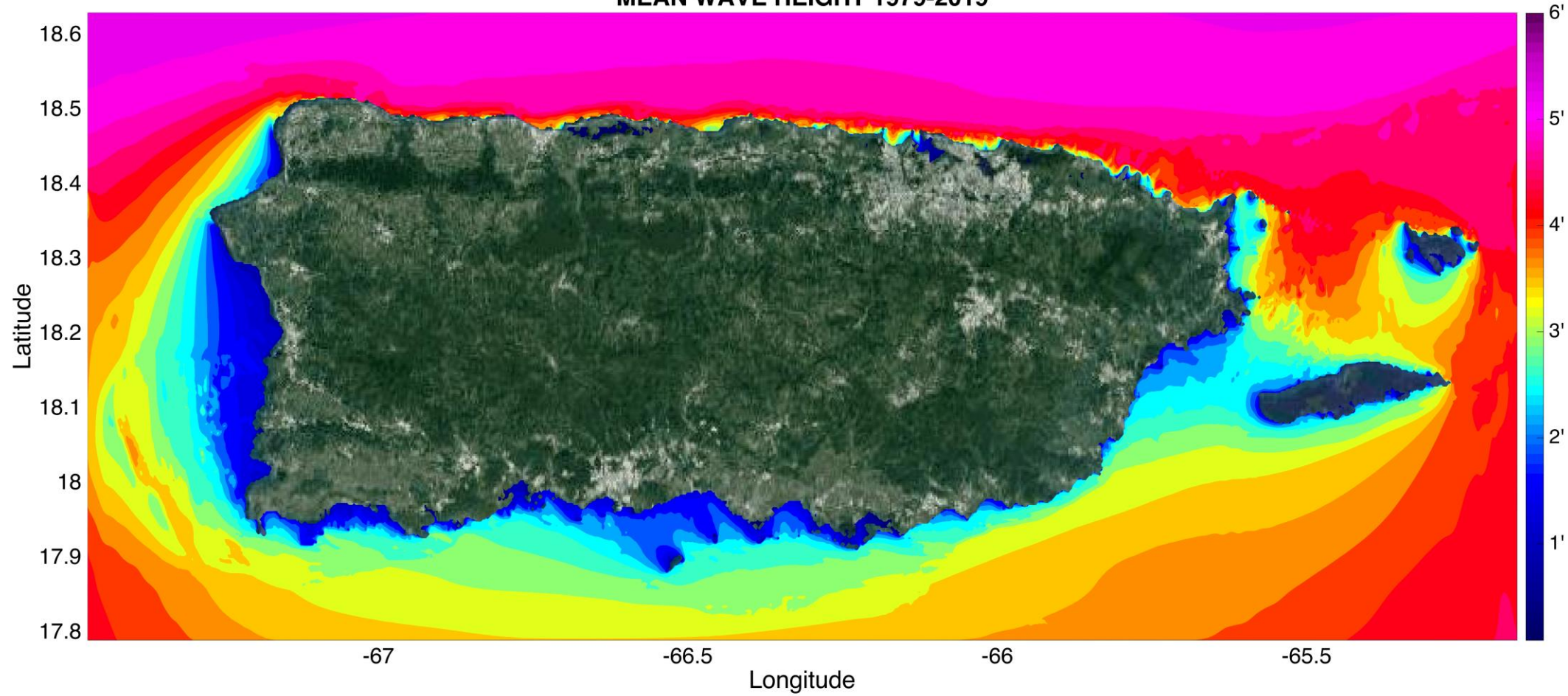


SWASH Water Level (m), Ocean Park, PR:

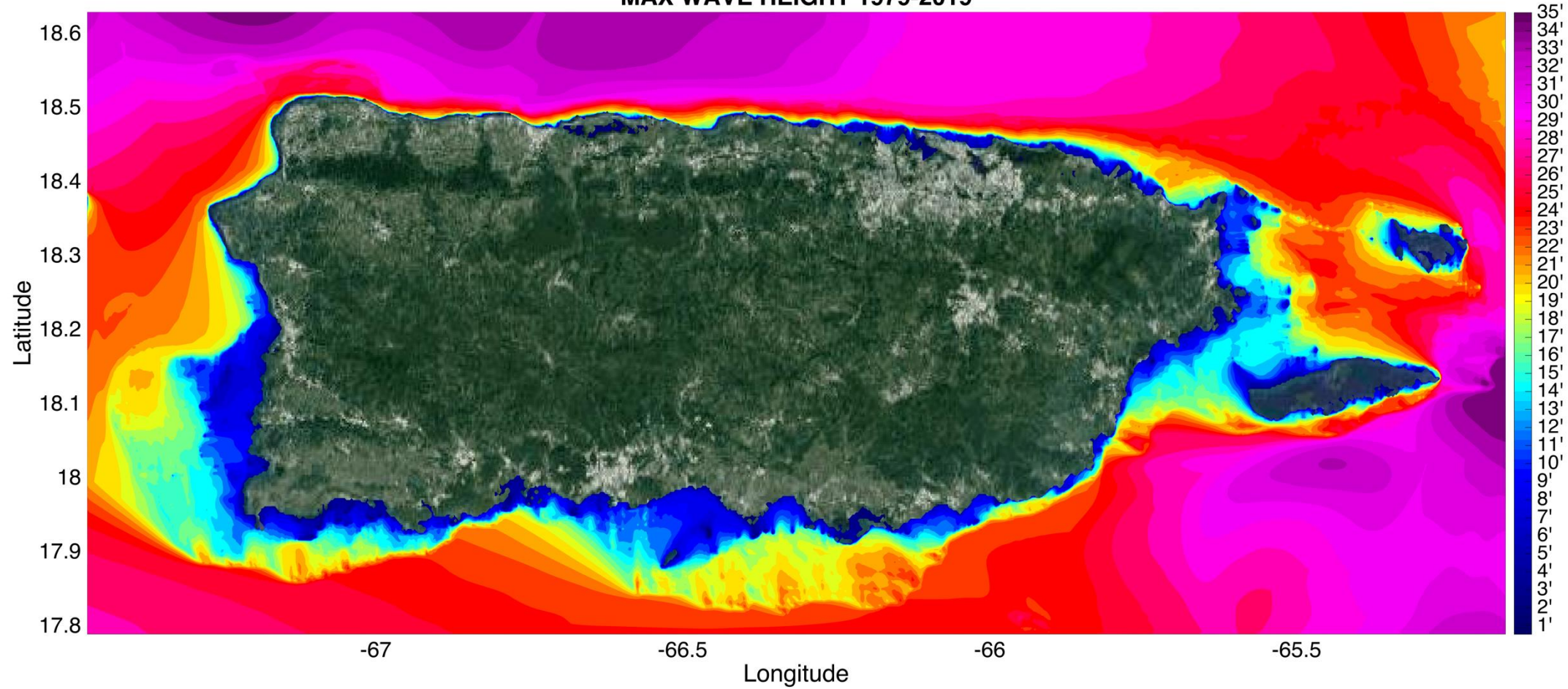


THREE RECEIVING TIDE MODELS by Dr. Patricia Charon, Scott Evans & Luis Perez as part of USGS project "A wave modeling testbed for Puerto Rico"

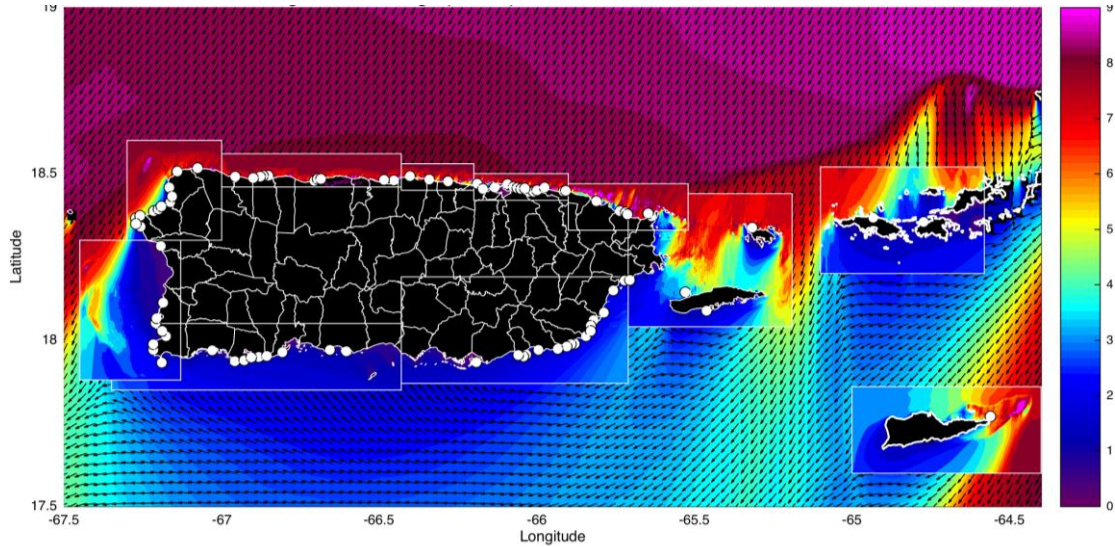
MEAN WAVE HEIGHT 1979-2019



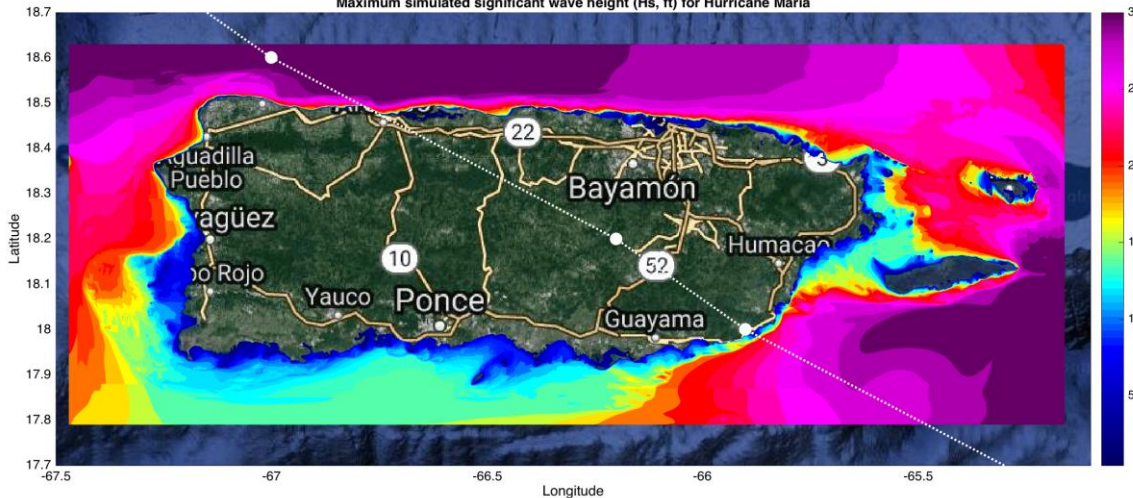
MAX WAVE HEIGHT 1979-2019



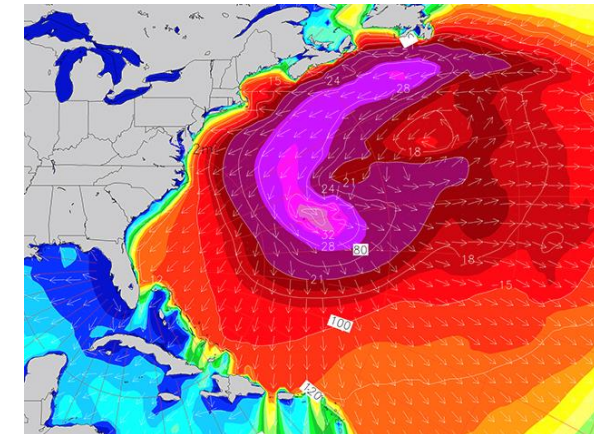
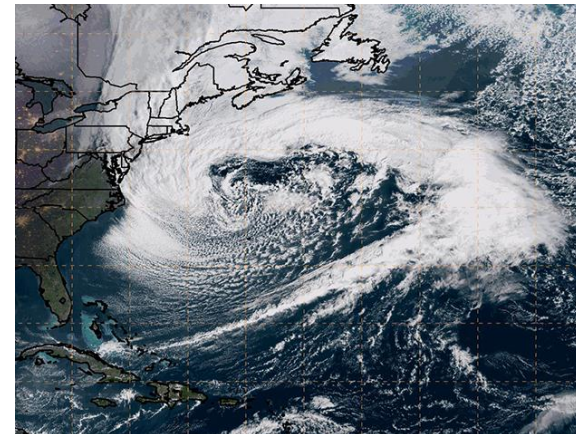
MARIA & RILEY



Maximum simulated significant wave height (Hs, ft) for Hurricane Maria

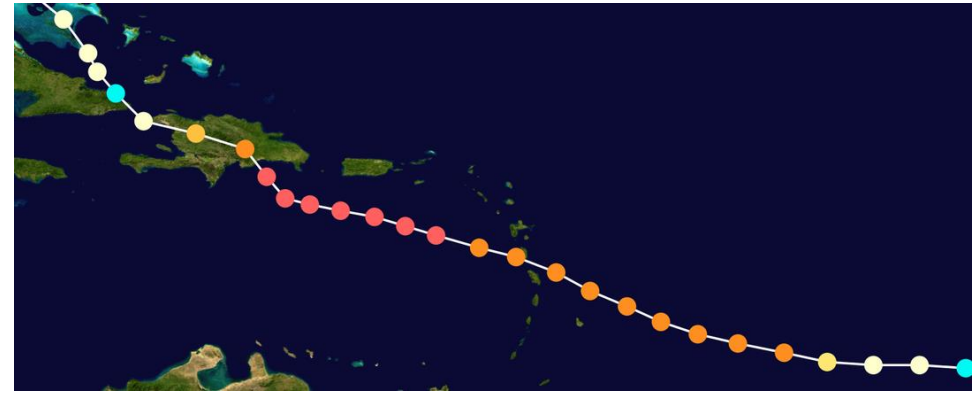
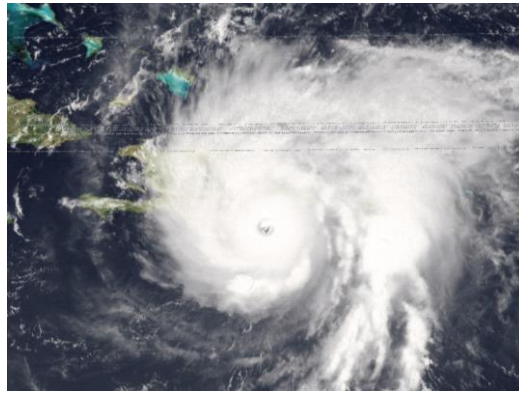


HURRICANE MARIA

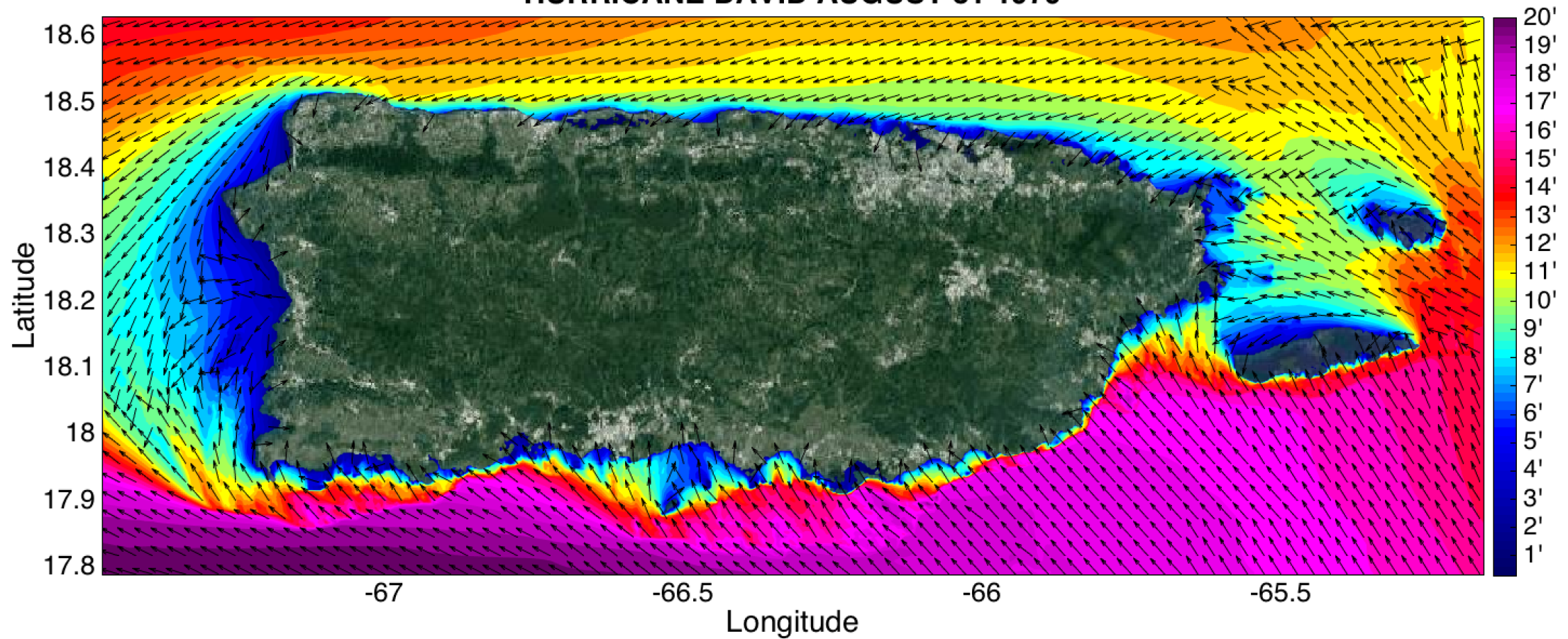


WINTER STORM RILEY

HURACAN DAVID: Agosto 1979

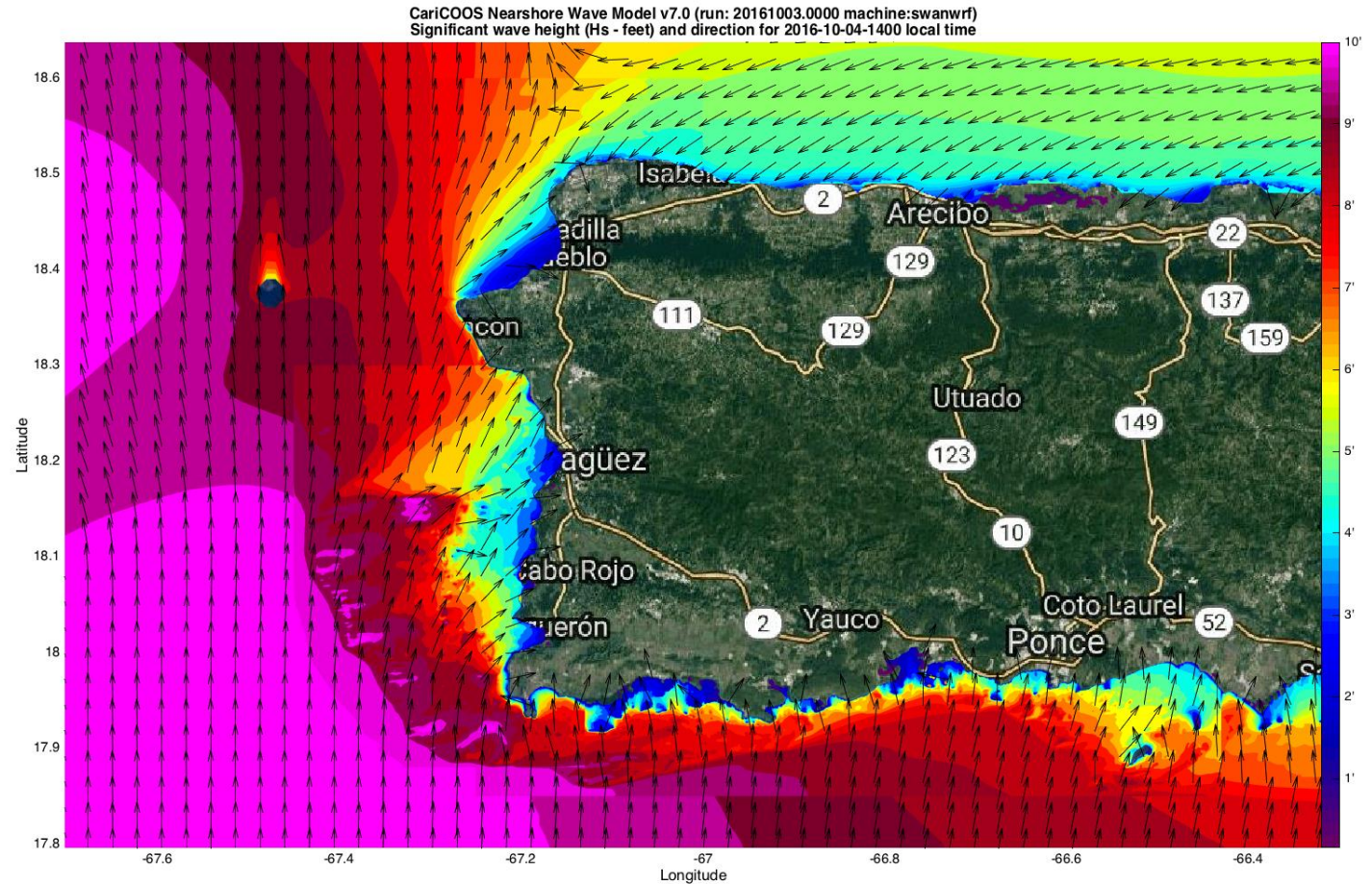
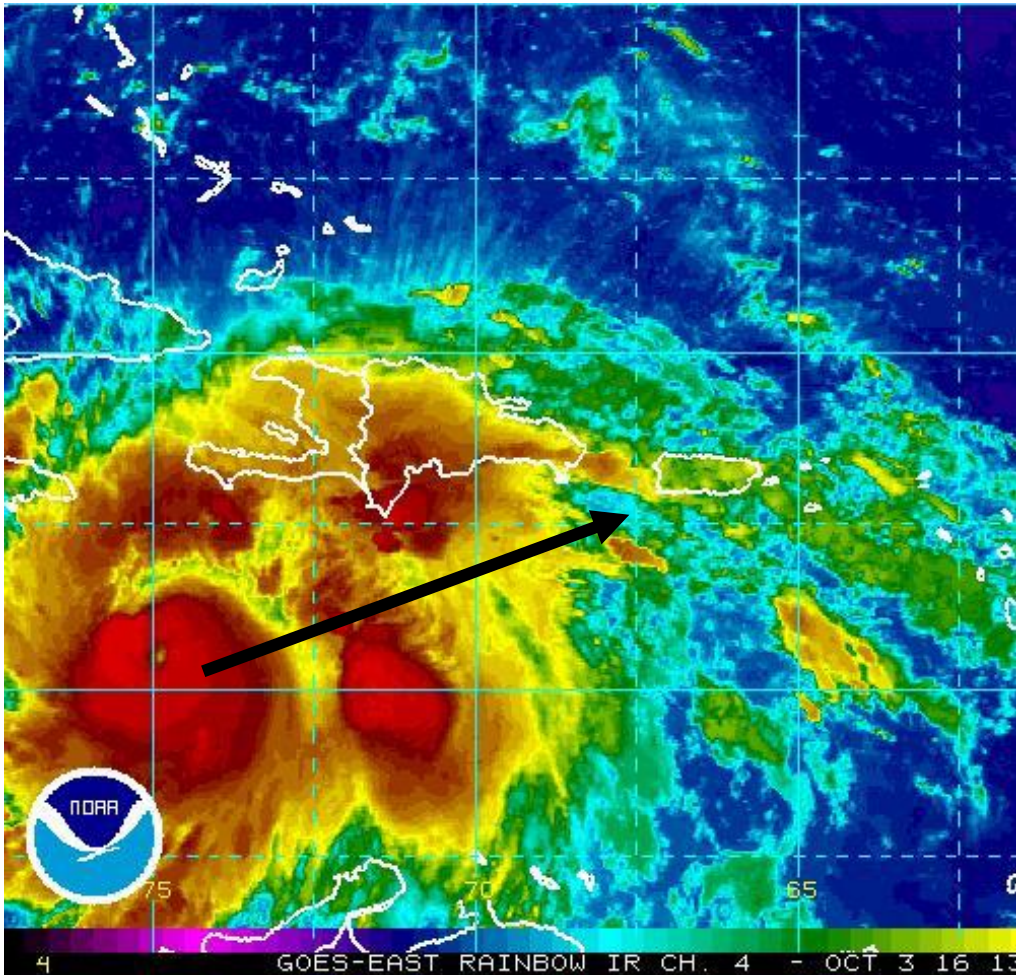


HURRICANE DAVID AUGUST 31 1979



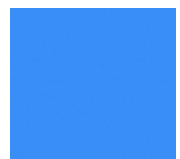
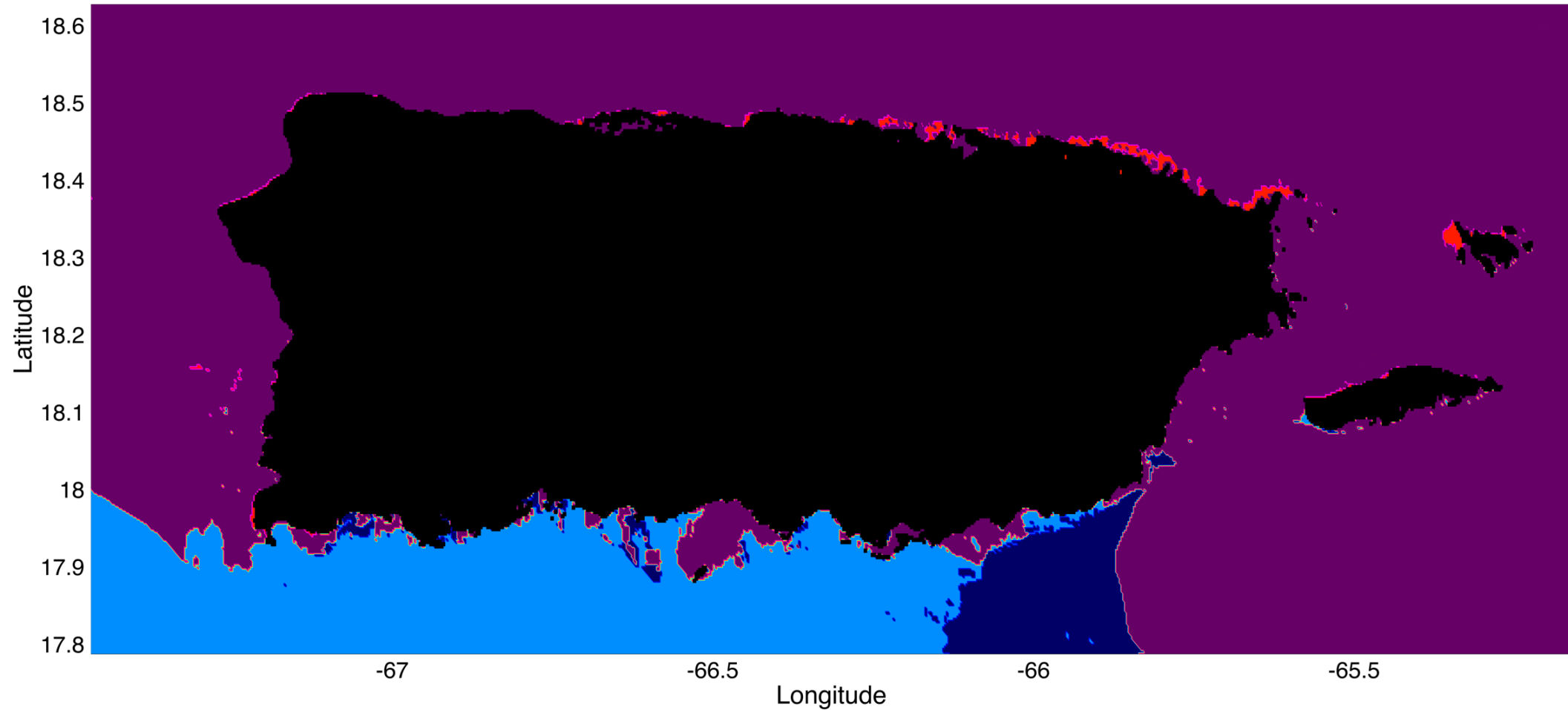
Hurricane Matthew west-southwest swell

Tuesday Oct 4 2016



WHICH EVENTS HAVE CAUSED THE LARGEST WAVE HEIGHTS IN PUERTO RICO?

HMAX EVENT ID 1979-2019



HURR. DAVID (1979)



HURR. ALLEN (1980)

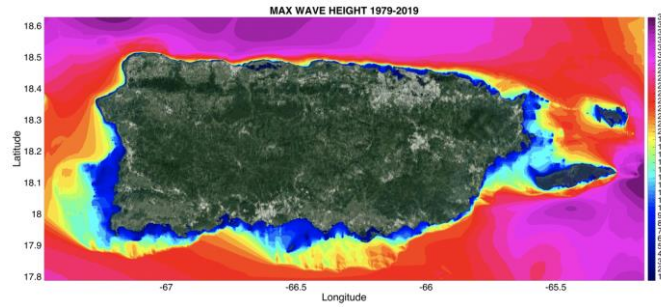


HURR. IRMA/MARIA (2017)

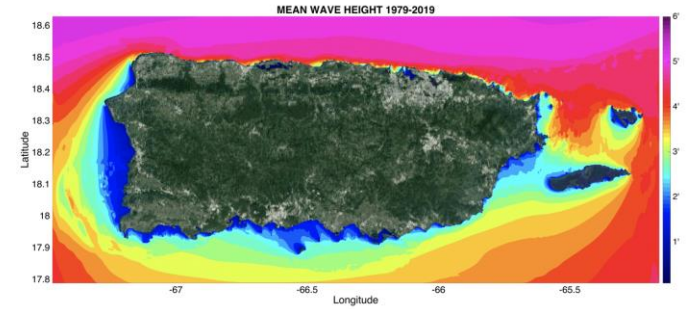


RILEY(2018)

$$RR = \frac{Hs_{max} (40yr)}{Hs (mean)} =$$

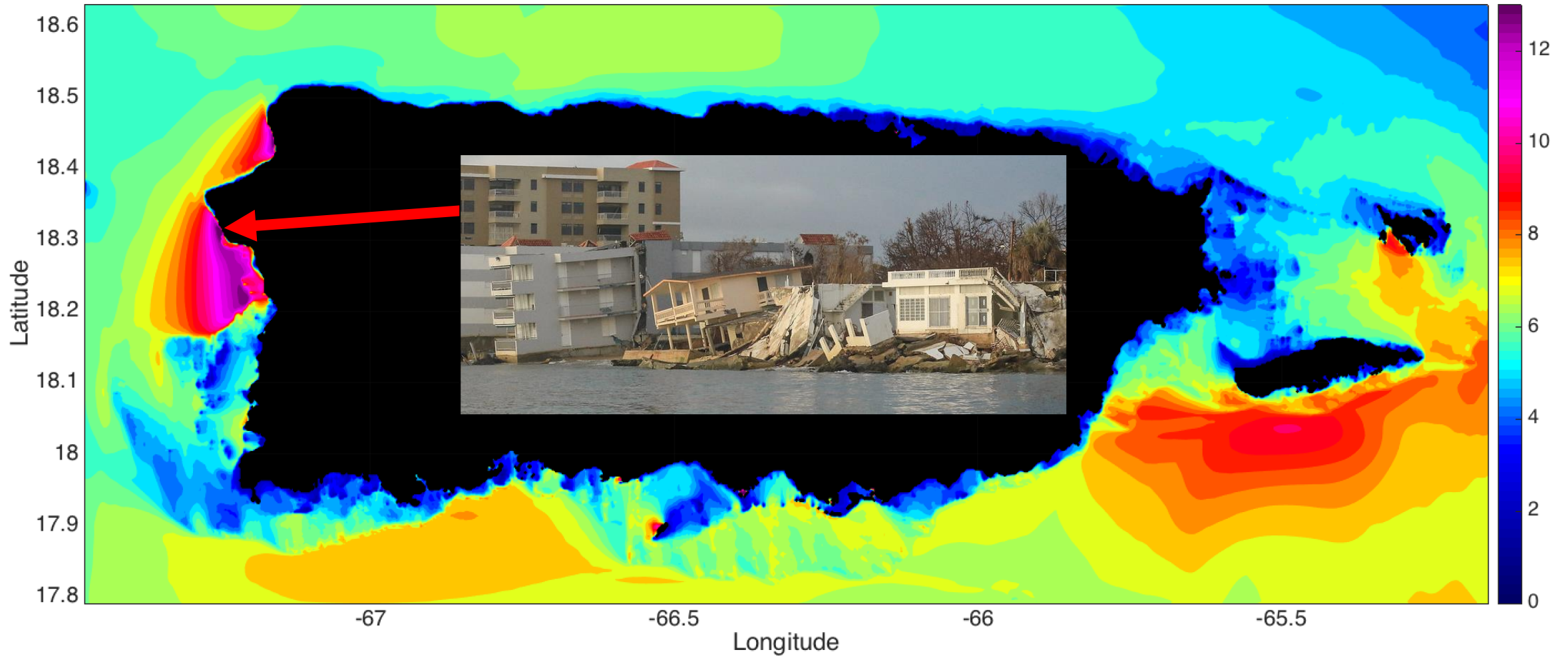


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RISK RATIO 1979-2019

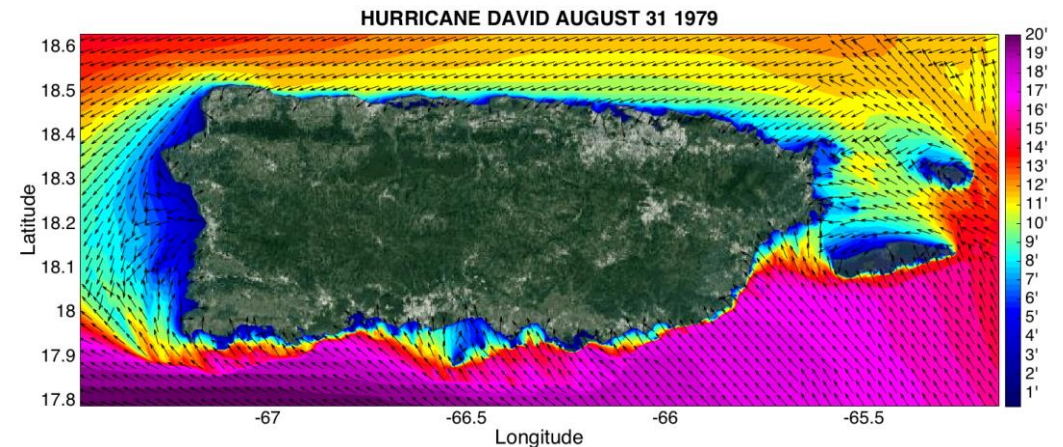


Ongoing work: Wave climate atlas web interface

- Online interface by summer 2020 at www.caricoos.org/waveatlas will provide:
 - Very high-resolution maps of wave heights with return periods of 1,5,10,20,50 and 100 years
 - Point output at locations requested by PR-CZMP and stakeholders with a 40-year hourly time series of wave parameters: significant wave height (H_s), peak wave period (T_p), mean wave period (T_m), mean wave direction (D_m), peak wave direction (D_p)
 - Wave hindcast maps at 6-hour intervals from Jan 1 1979 to present



Recurrence Interval T_r (y)	Design Wave Height H_s (ft)	95% Confidence Level Design H_s (ft)
100	35.2	37.2
75	33.3	35.2
50	30.5	32.3
20	24.7	26.4
10	20.7	22.3
2	13.1	14.6



Preguntas clave: Recomendaciones finales

- ¿Qué alternativas de intervención con elementos naturales (dunas, bermas, humedales, etc.) o híbridas pudieran sustituir o emplearse en combinación con las medidas estructurales para proteger vida y propiedad?
- Ante nuevos eventos extremos tales como huracanes, marejadas, inundaciones, ¿Qué estrategias de adaptación entiende importante considerar en la toma de decisiones para nuevos diseños?

An aerial photograph of a coastal city, likely Miami, showing a dense skyline of buildings along the shore. The ocean is a deep blue-green, with white-capped waves breaking in a line parallel to the coast. The sky is a pale blue with scattered, light clouds. The word "GRACIAS" is centered in the image in a large, black, sans-serif font.

GRACIAS