



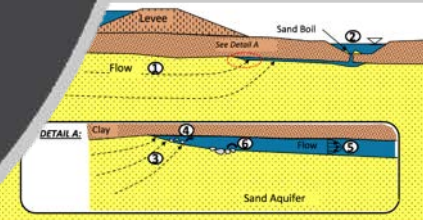
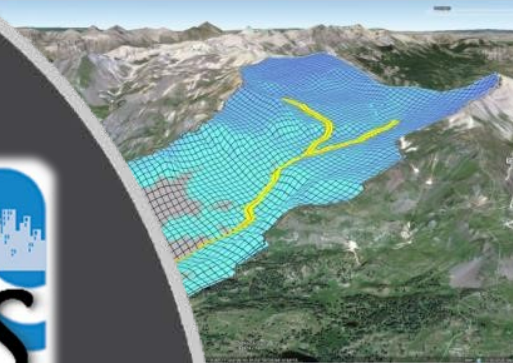
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South Atlantic Coastal Study: Coastal Hazards System



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*5th Annual Probabilistic Flood Hazard Assessment Workshop
U.S. Nuclear Regulatory Commission; Feb 19-21, 2020*



US Army Corps
of Engineers



Outline



- **Overview**
 - **South Atlantic Coastal Study (SACS)**
 - **Coastal Hazards System (CHS)**
- **Methodology**
 - **Probabilistic Coastal Hazard Analysis (PCHA)**
 - ▶ **Gaussian Process Metamodel (GPM)**
 - ▶ **Metal-Gaussian Copula (MGC)**
 - **Hydrodynamic Modeling (CSTORM)**
- **Results**
 - **Phase I: Puerto Rico & U.S. Virgin Islands**



Congressionally mandated regional study

Water Resources Development Act of 2016 (WRDA 2016)

Section 1204: South Atlantic Coastal Study (SACS)

Authorizes Secretary of the Army to conduct a comprehensive coastal study within the geographic boundaries of the South Atlantic Division (SAD) to

- 1. identify risks and vulnerabilities due to increased hurricane and storm damage as a result of sea level rise;**
- 2. recommend measures to address the vulnerabilities; and**
- 3. develop a long-term strategy**
 - address increased storm damages from rising sea levels**
 - identify opportunities to enhance resiliency and increase sustainability in high-risk areas**

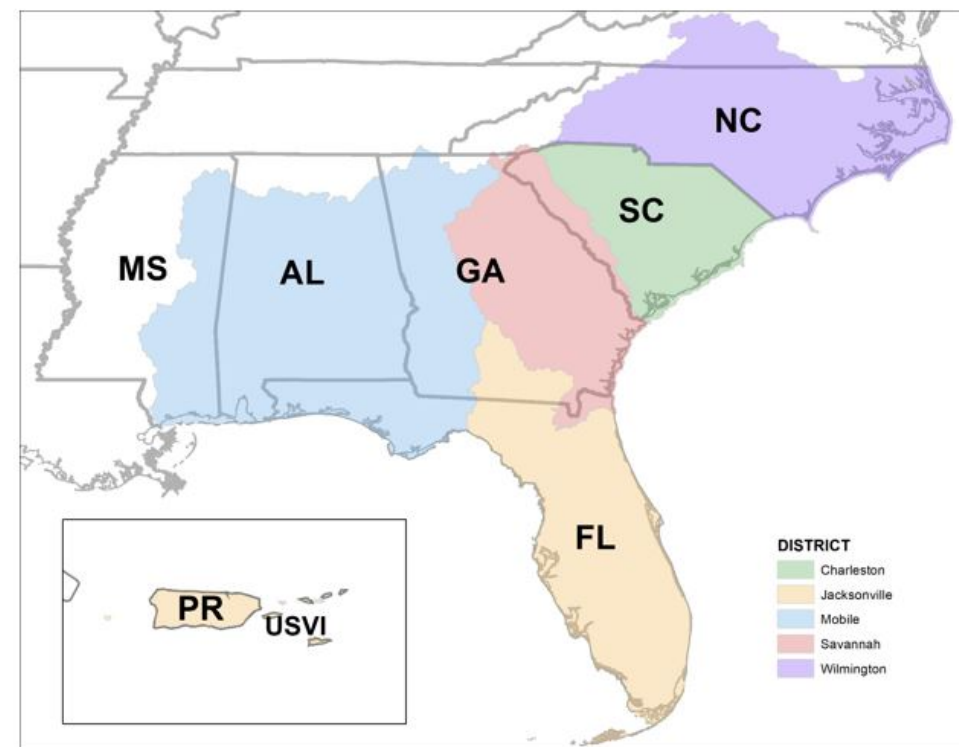


South Atlantic Coastal Study (SACS)

The geographic extent shall include the three distinct coastal regions within SAD's Area of Responsibility (AOR):

- Atlantic Coast
 - North Carolina to South Florida
- Gulf Coast
 - South Florida to Mississippi
- Caribbean
 - Puerto Rico and U.S. Virgin Islands

Coastal AOR: from the coast to the extent of the tidal influence.



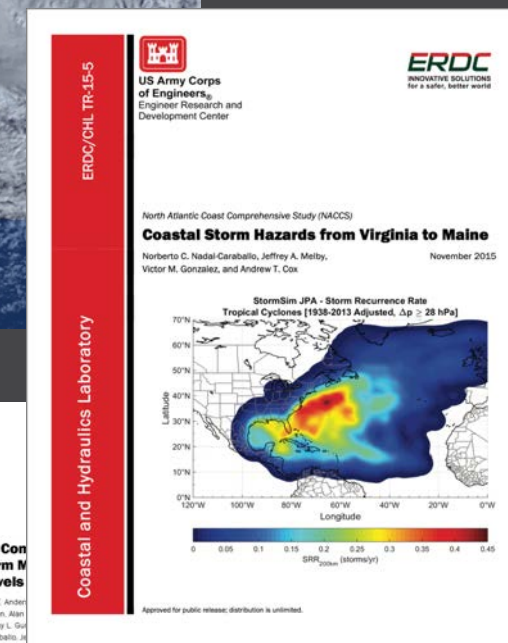
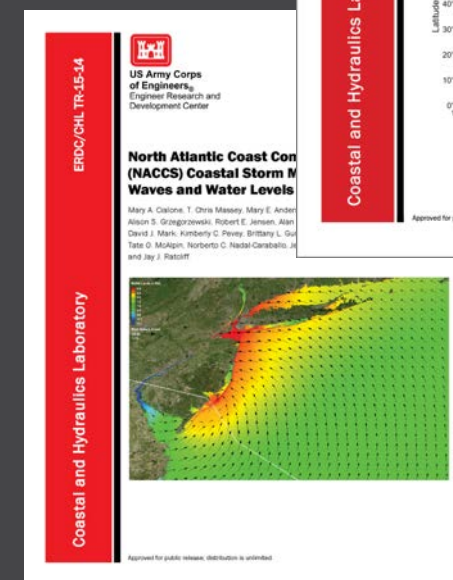
South Atlantic Coastal Study (SACS) Map
(Study extends from the coast inland to the extent of tidal influence)



South Atlantic Coastal Study (SACS)

This comprehensive study shall be modeled after the **North Atlantic Coast Comprehensive Study (NACCS)**

- Leverage tools and processes where practicable and with applicable lessons learned applied.
- Data shall be evaluated consistent with the NACCS to the maximum extent practicable so that consistent standards can be applied between NAD and SAD.
- **Coastal Hazards System (CHS)**



South Atlantic Coastal Study (SACS)

Coastal Hazards System (CHS)

A national program with the primary goal of quantifying coastal hazards due to tropical, extratropical cyclones, and extreme storms. The CHS includes a database, web-based data mining, and visualization of PCHA results: storm surge, wave climate, currents, wind, and rainfall

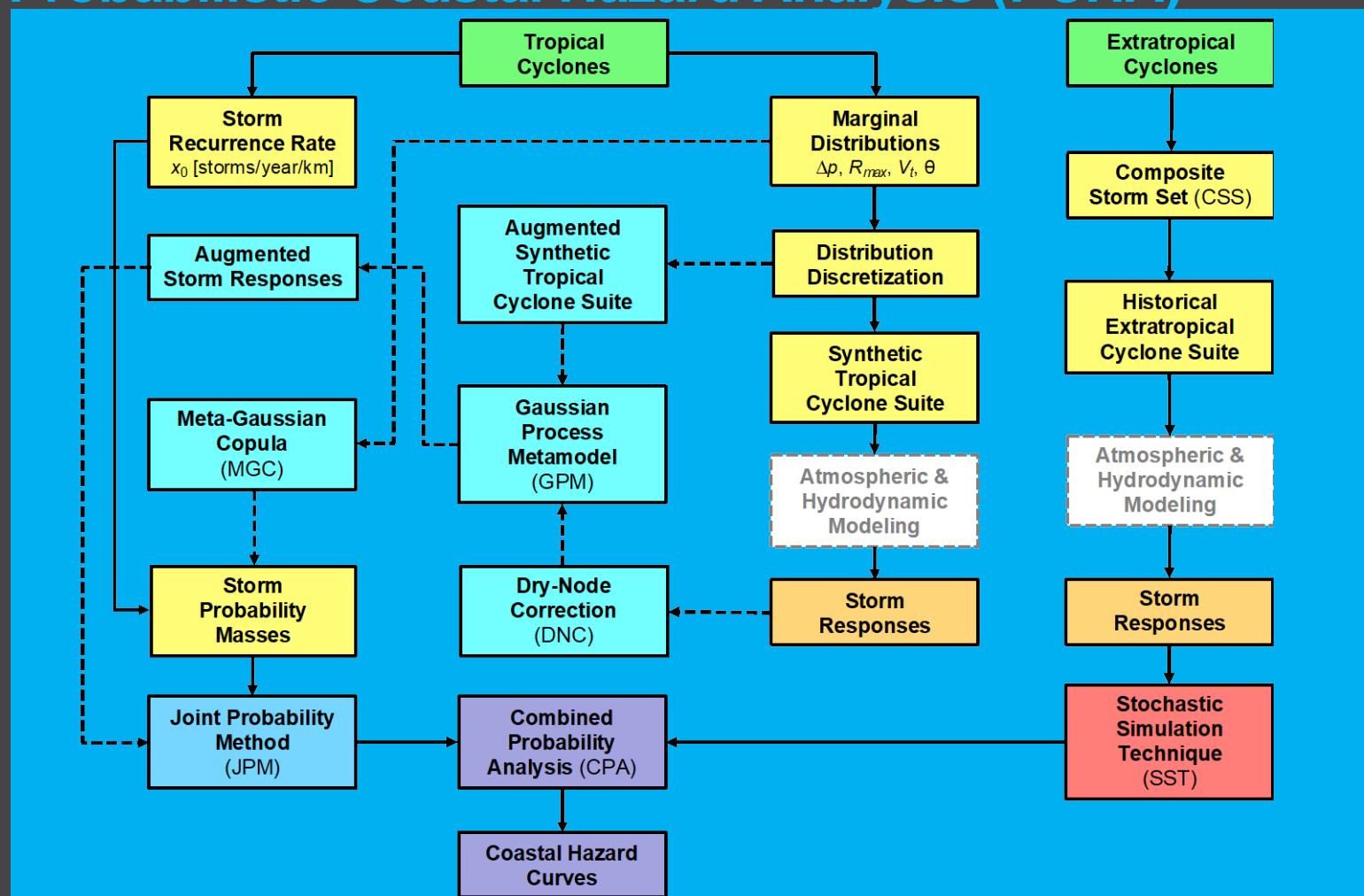
Probabilistic Coastal Hazard Analysis (PCHA)

An innovative statistical and probabilistic framework for the comprehensive characterization of storm climatology, high-resolution numerical modeling, and advanced joint probability analysis of atmospheric forcing and primary storm responses, including associated aleatory and epistemic uncertainties.



Coastal Hazards System (CHS)

Probabilistic Coastal Hazard Analysis (PCHA)



PCHA Advancements

Filling historical TC data gaps

- Central pressure
- Radius of maximum winds

Gaussian Process Metamodel

- Dry-node correction
- Augmented TC suites

Meta-Gaussian Copula

- Correlation matrix
- Higher resolution in parameter & probability spaces



Coastal Hazards System (CHS)

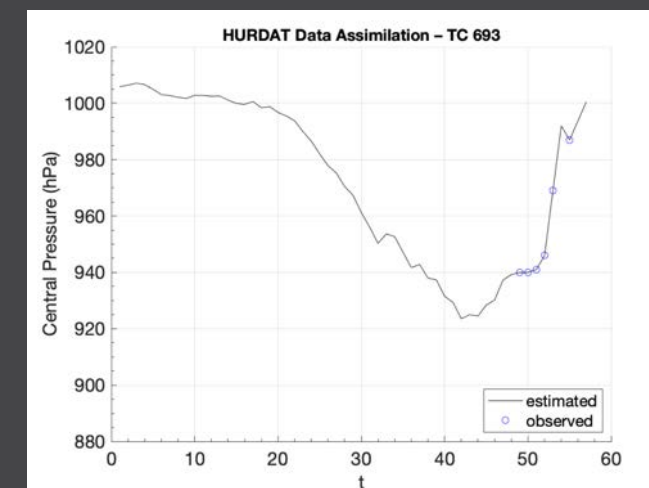
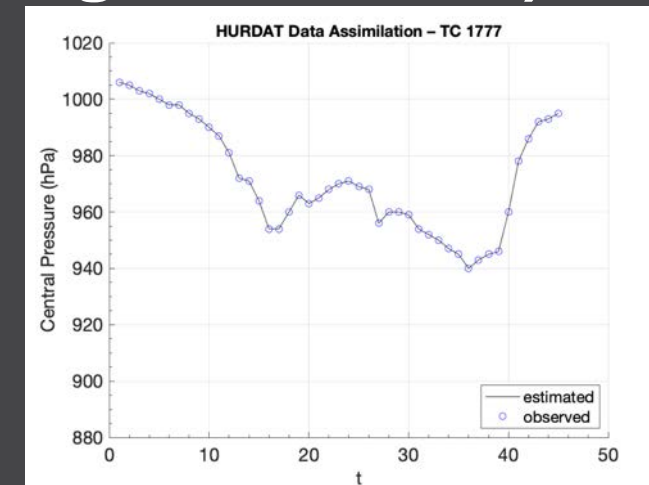
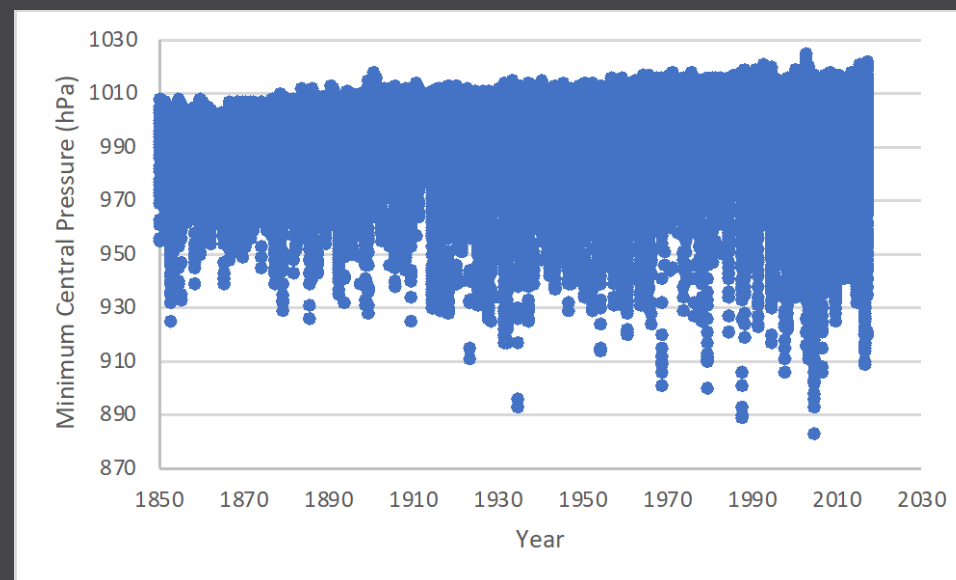
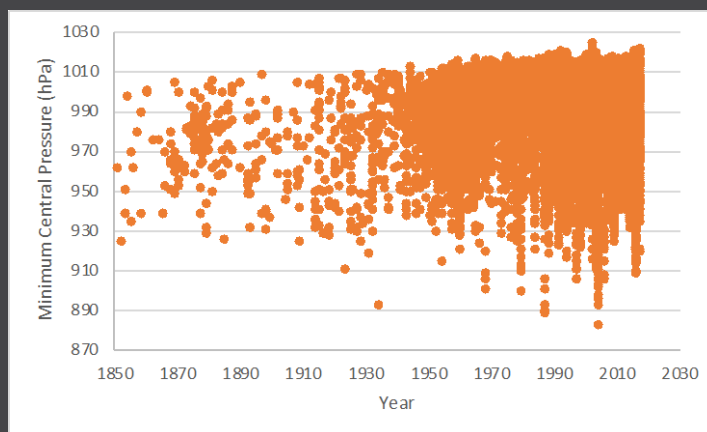
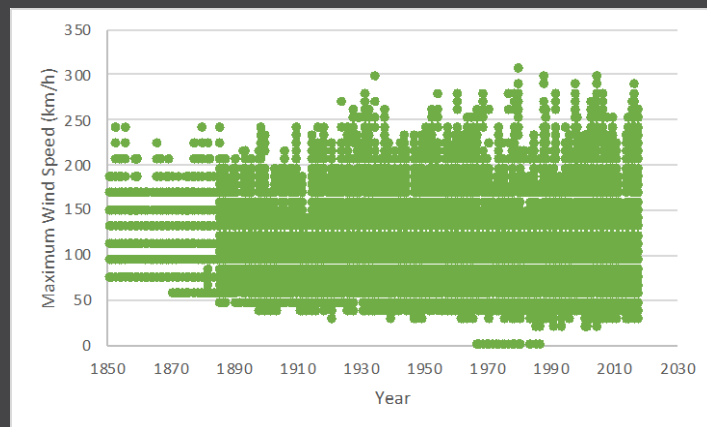
PCHA – Filling in the gaps

1. NHC HURricane DATA 2nd generation (HURDAT2)
 - TC parameters: max wind speed, central pressure, lat, lon
2. Automated Tropical Cyclone Forecast (ATCF)
 - Best track data: 2019
3. Colorado State (CSU) Extended Best Track (EBTRK)
 - R_{\max} (1988 – 2018)
4. Gaussian Process Metamodel (GPM)
 - Fills in gaps in **central pressure** and estimates R_{\max}
 - Period: 1851 – 2019



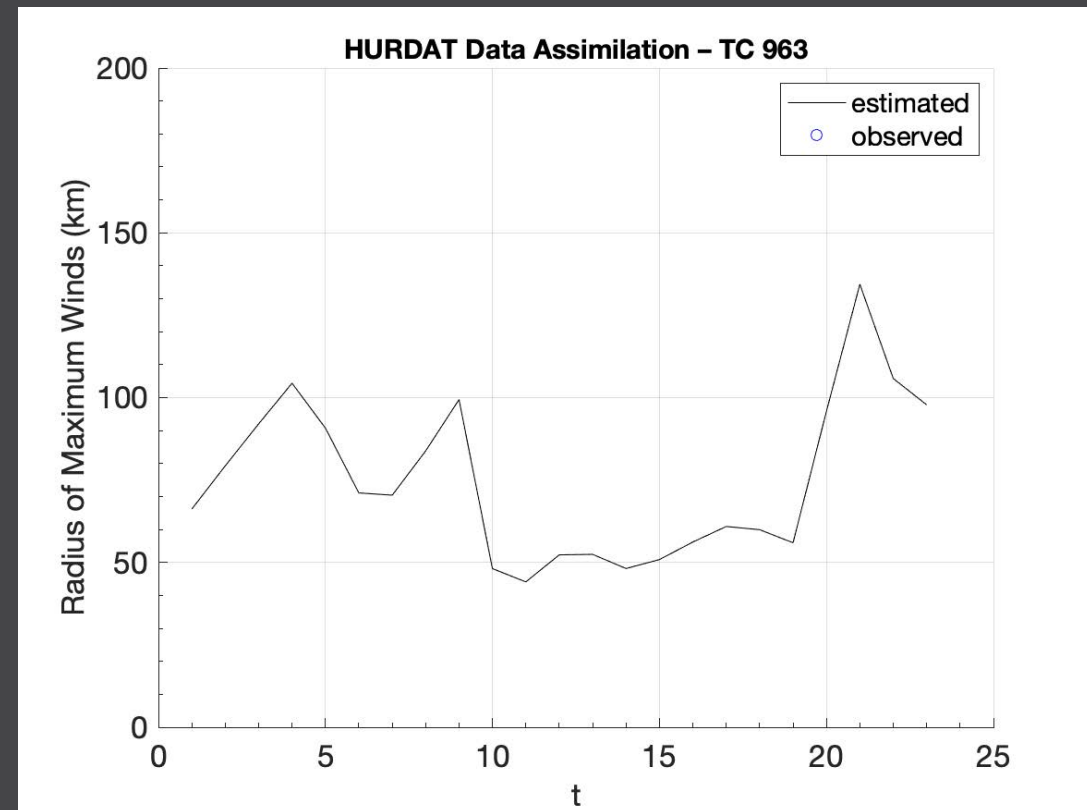
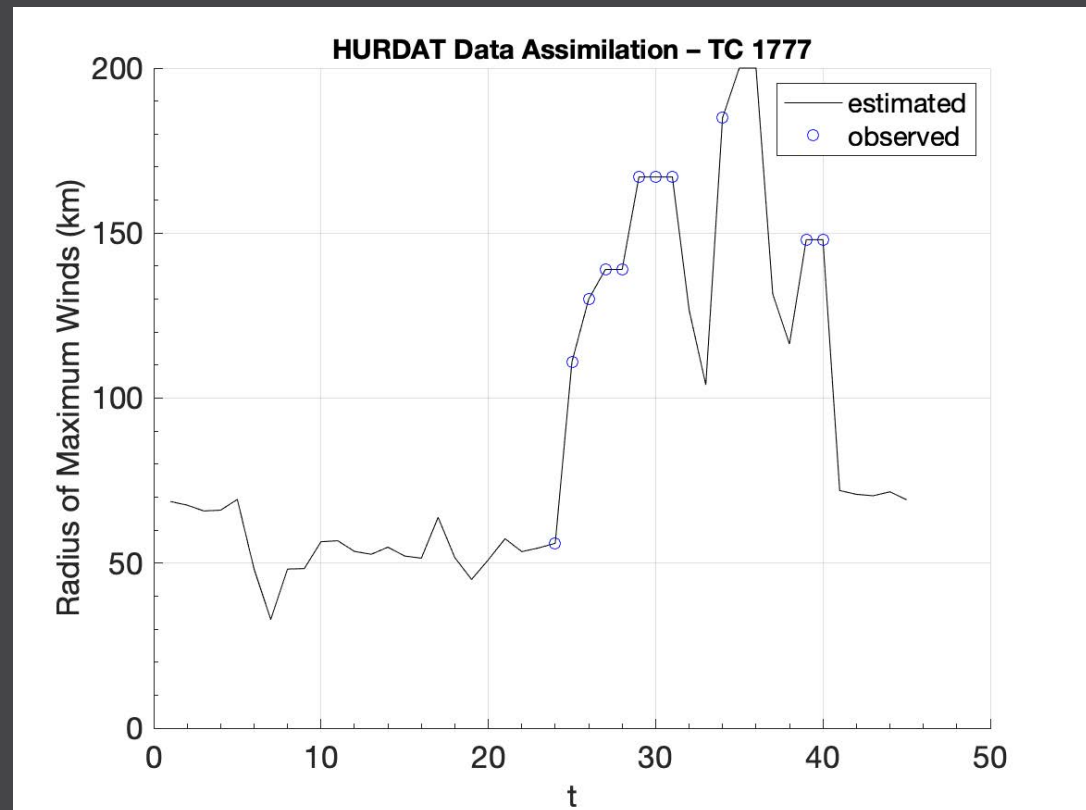
Filling in the gaps: Gaussian Process Metamodel (GPM)

- Central pressure $\rightarrow f(\text{lat, lon, wind speed, heading, translation})$



Filling in the gaps: Gaussian Process Metamodel (GPM)

- $R_{\max} \rightarrow f(\text{lat, lon, wind speed, central pres, heading, translation})$



SACS-CHS

• Phase I: Puerto Rico & USVI

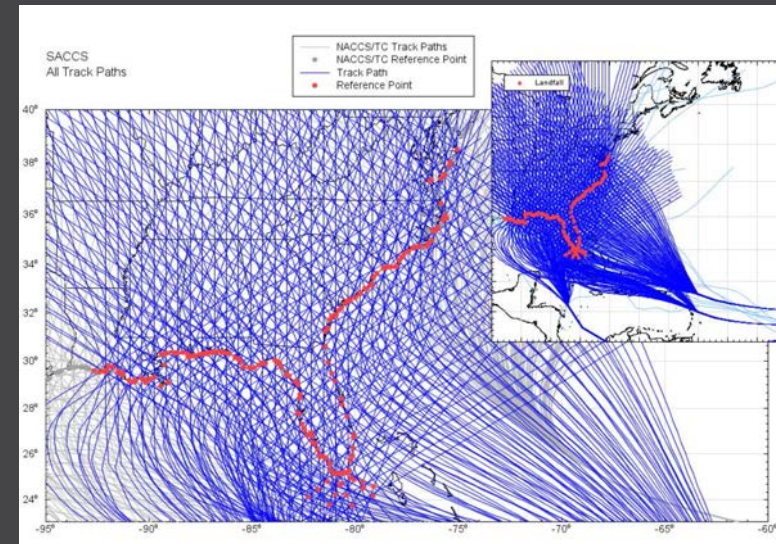
- TC suite: 300
- Virtual gages: 14,891

• Phase II: Atlantic Coast

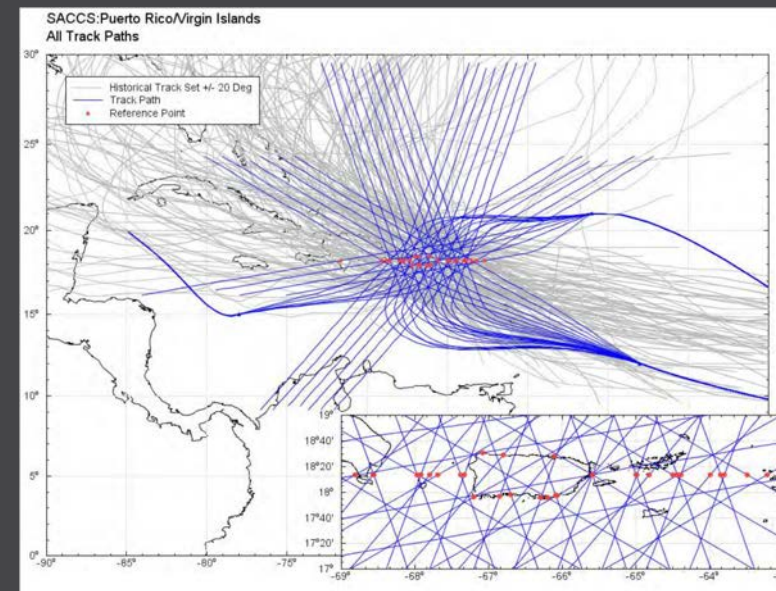
- TC suite: 1,060
- Virtual gages: 30,830

• Phase III: Gulf of Mexico

- TC suite: 1,085
- Virtual gages: 21,705



CONUS
1,700 TCs
70 XCs



OCONUS
300 TCs



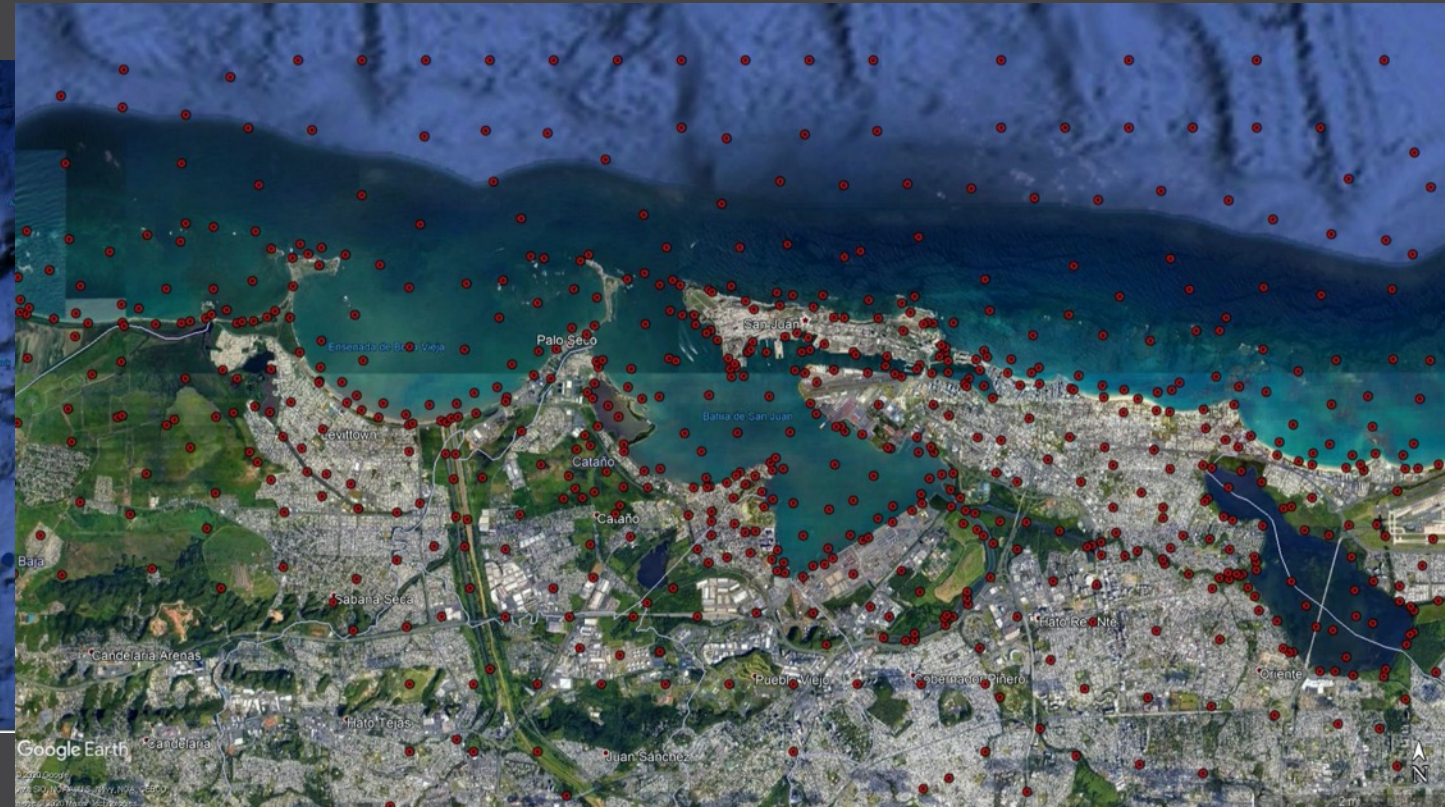
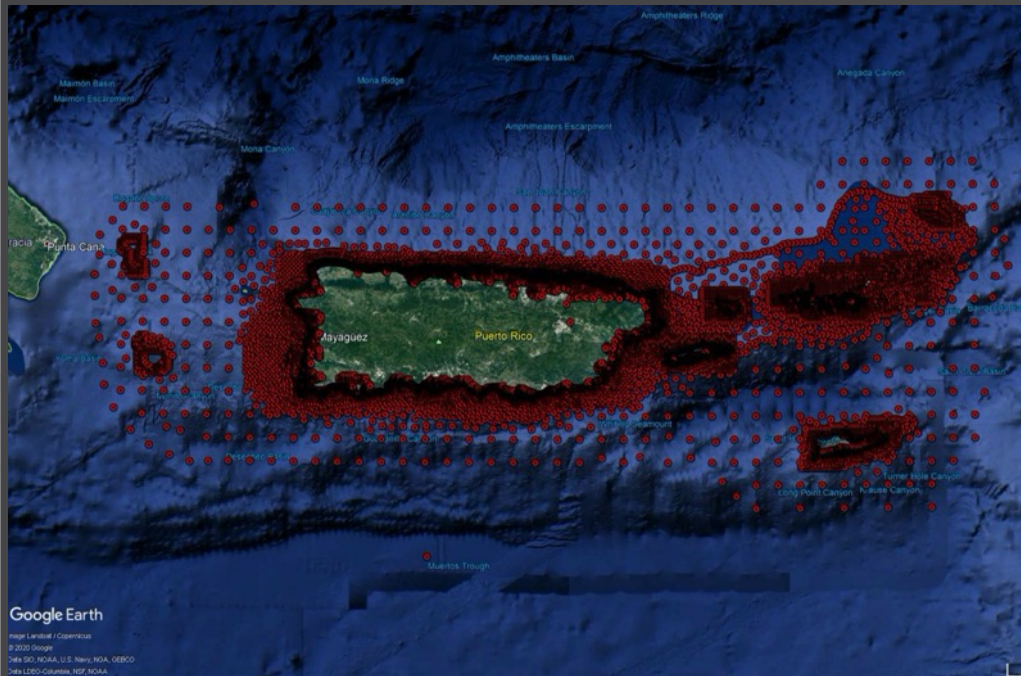
SACS-CHS Phase I

Puerto Rico and U.S. Virgin Islands



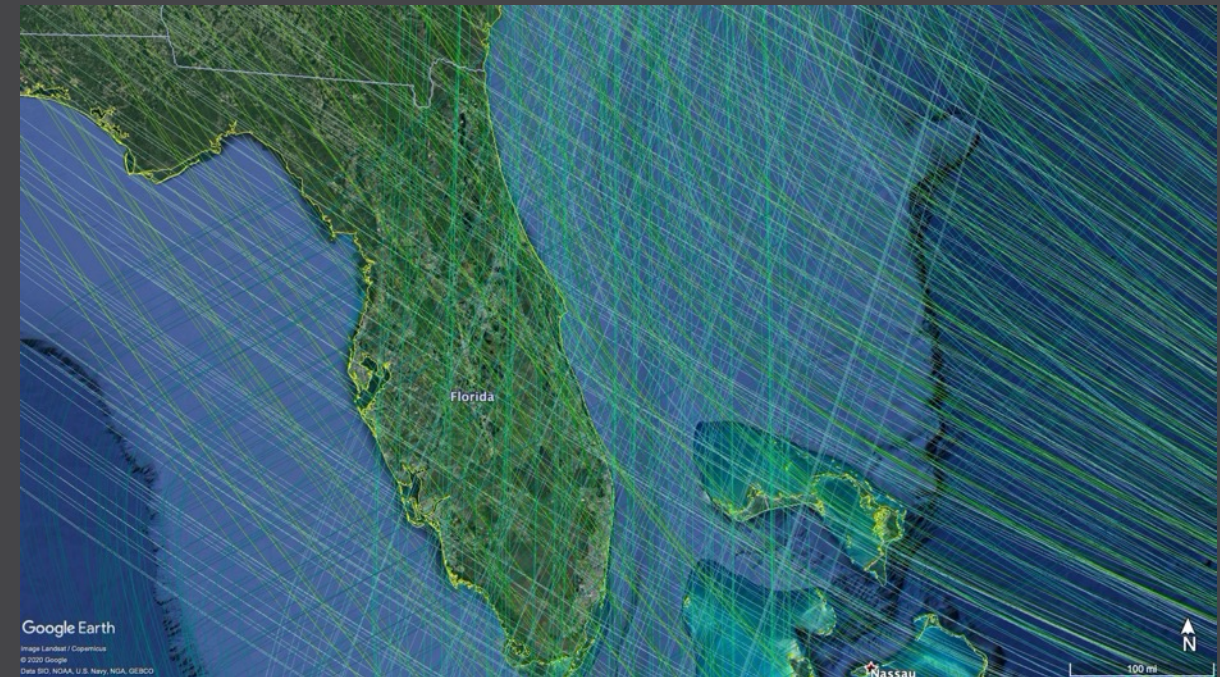
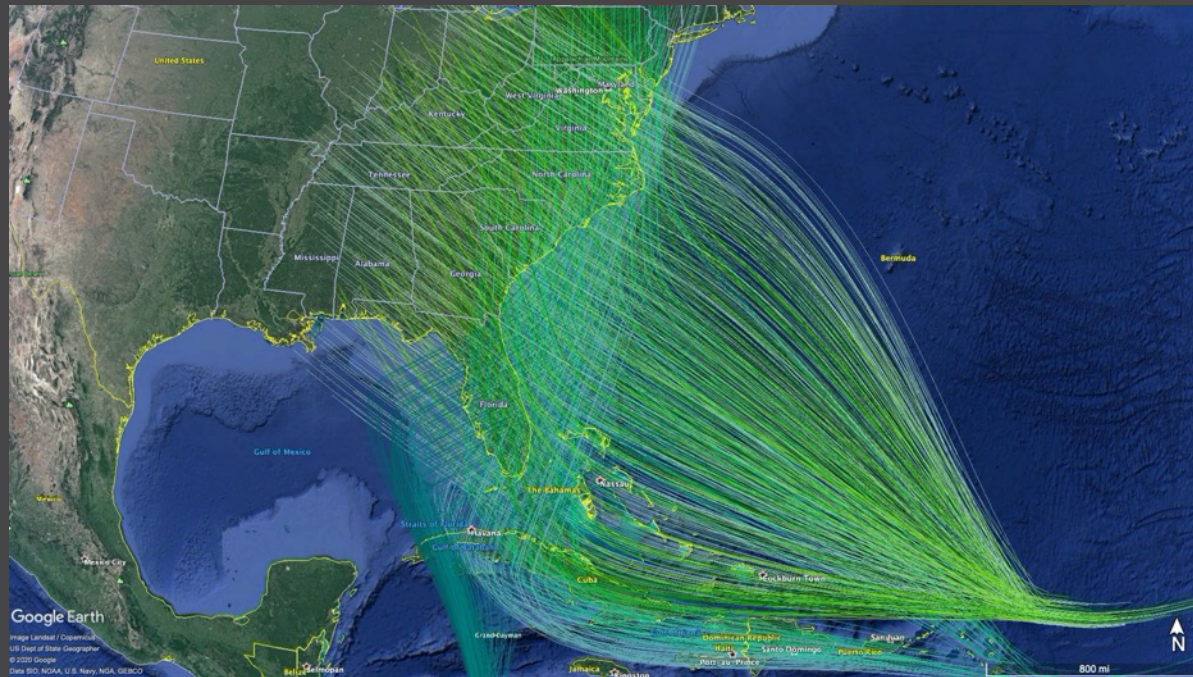
SACS-CHS Phase I

Puerto Rico and U.S. Virgin Islands



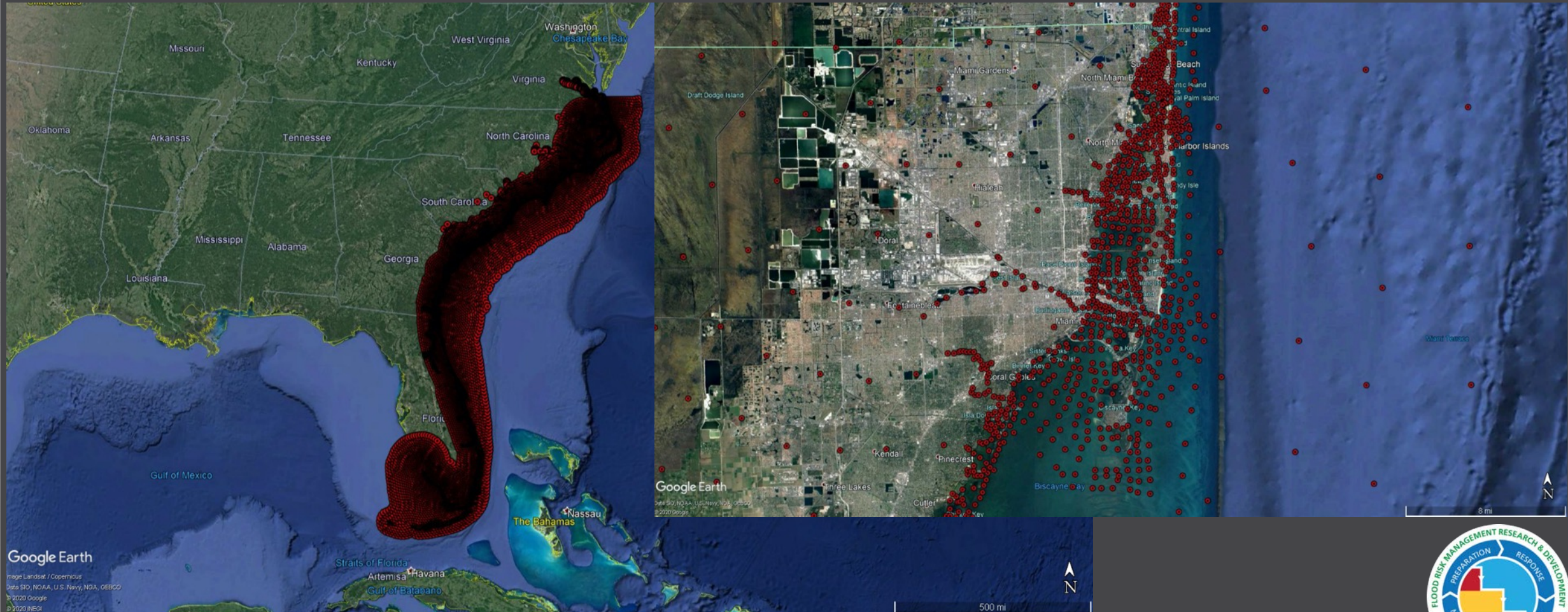
SACS-CHS Phase II

North Carolina to South Florida



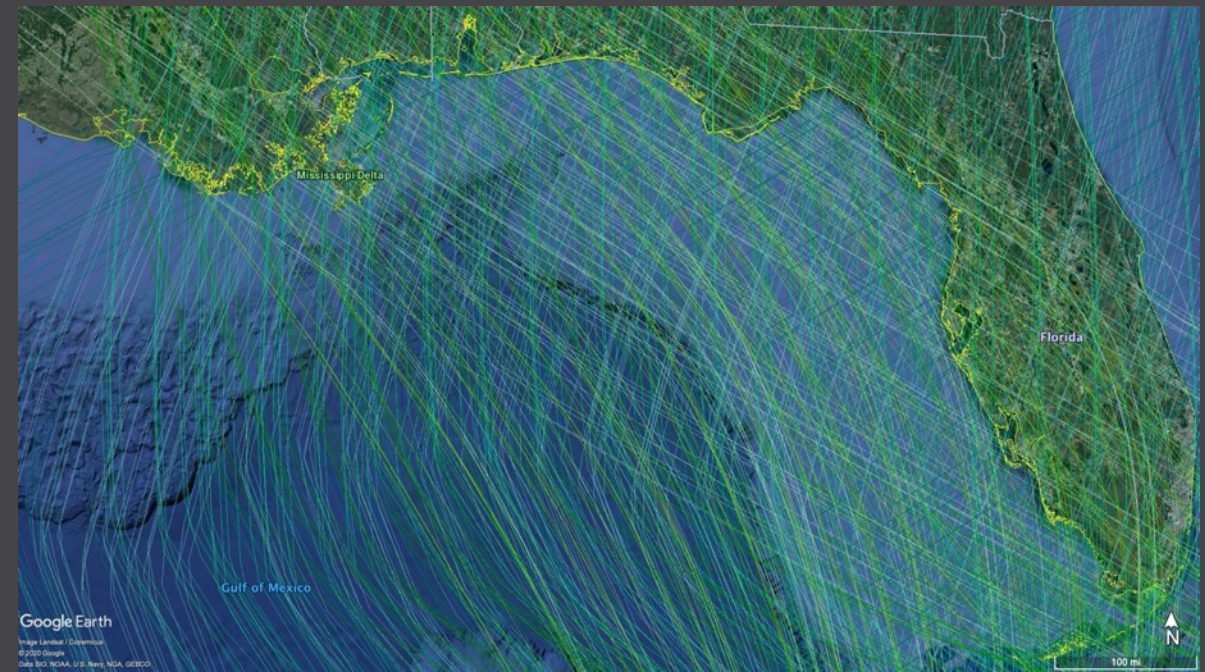
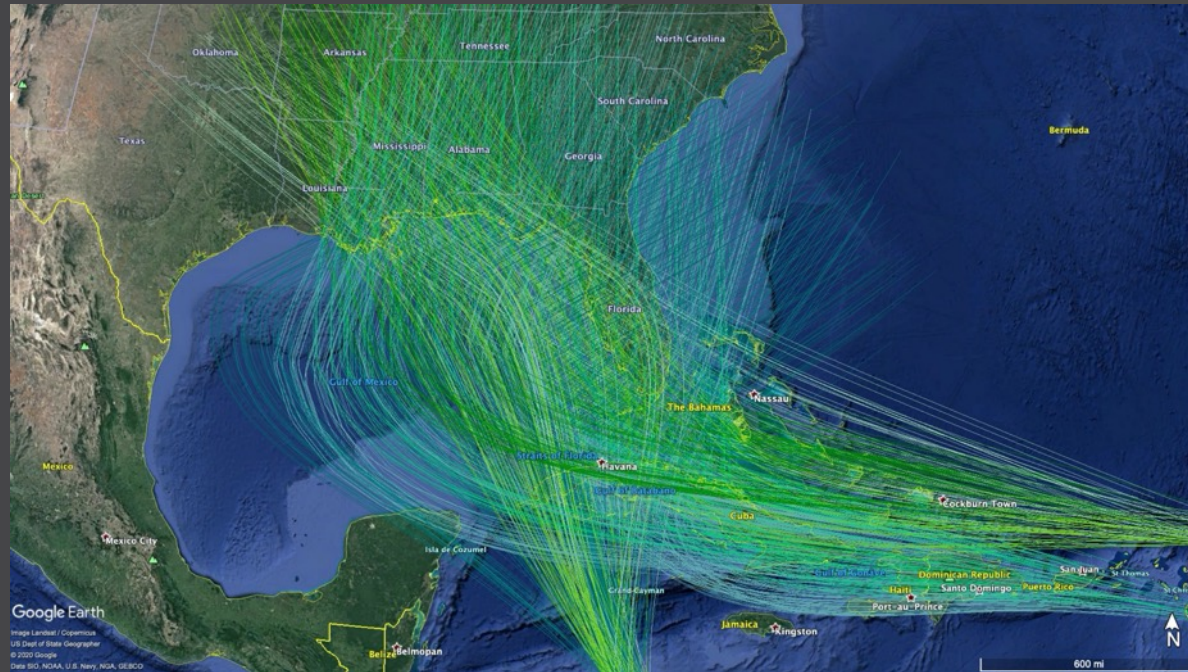
SACS-CHS Phase II

North Carolina to South Florida



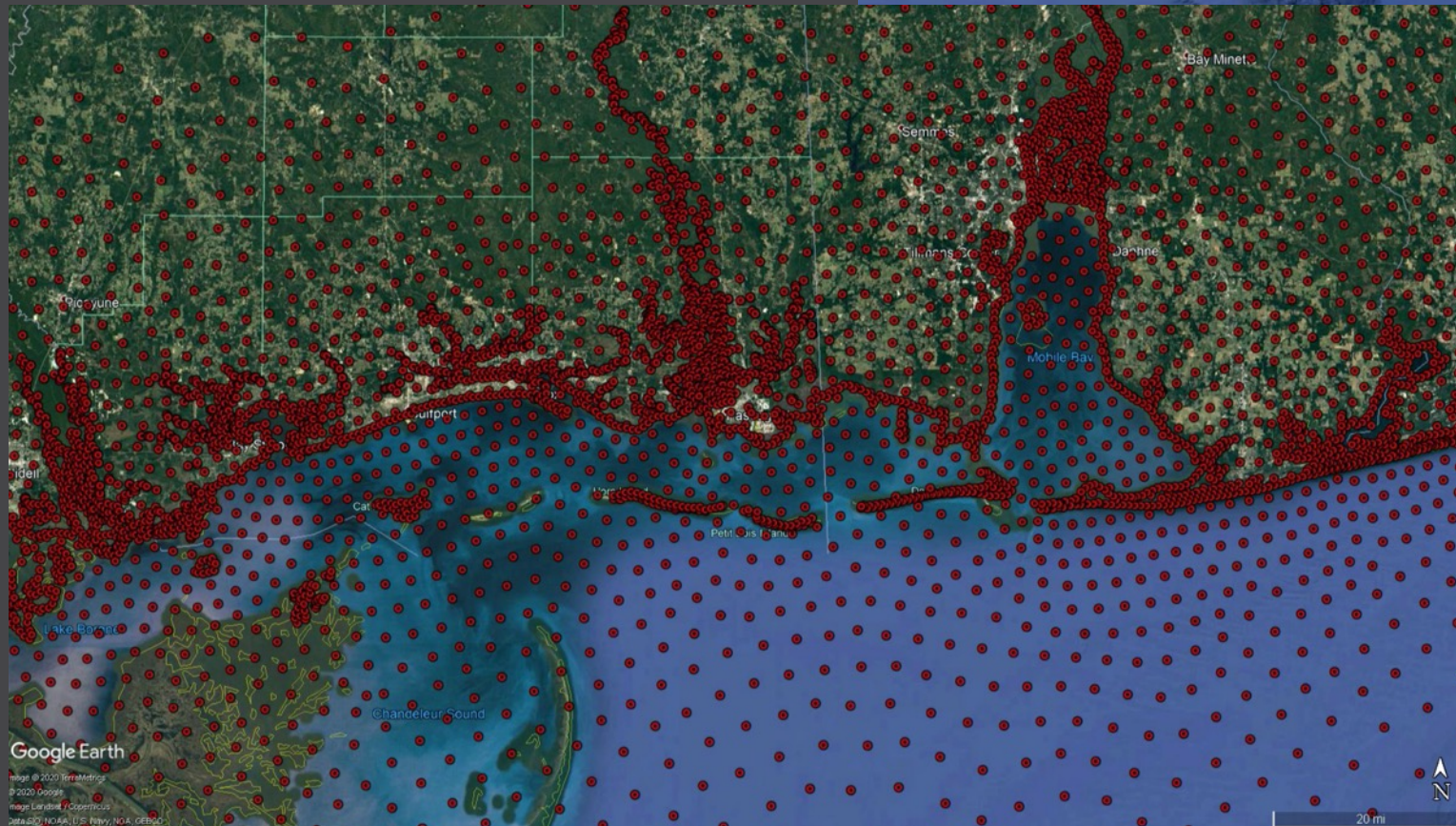
SACS-CHS Phase III

South Florida to Mississippi



SACS-CHS Phase III

South Florida to Mississippi



SACS-CHS Phase I: Hydrodynamic Modeling



ADCIRC

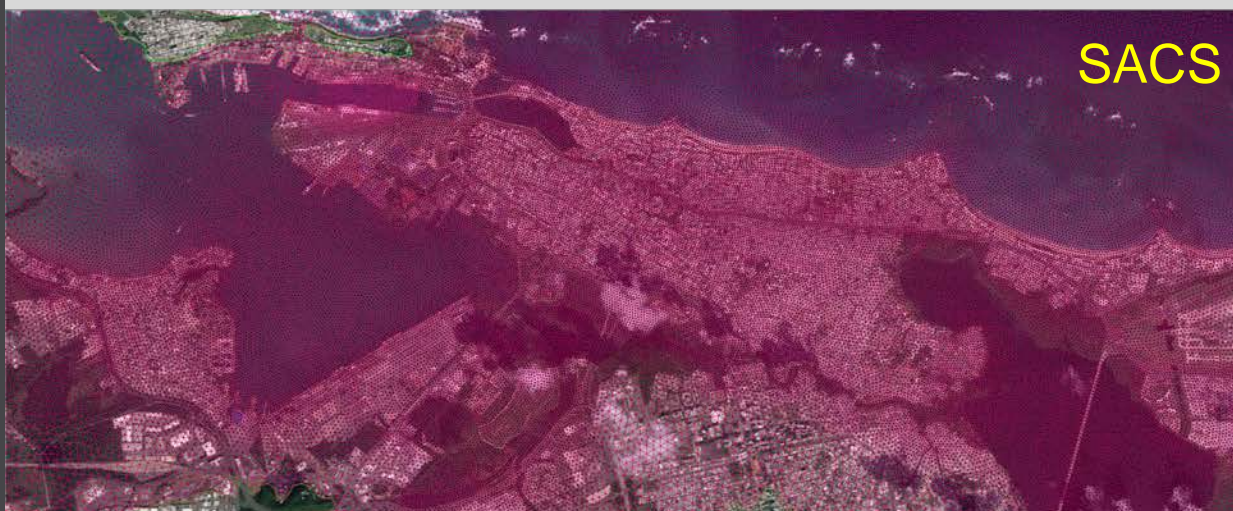


Base

San Juan



Resolution Before: 70-100 m



SACS

Resolution After: 30-85 m

Notes:

- The largest city in Puerto Rico, contains significant amount of critical infrastructure

Base ADCIRC Mesh – Courtesy of Dr. Juan Gonzalez-Lopez

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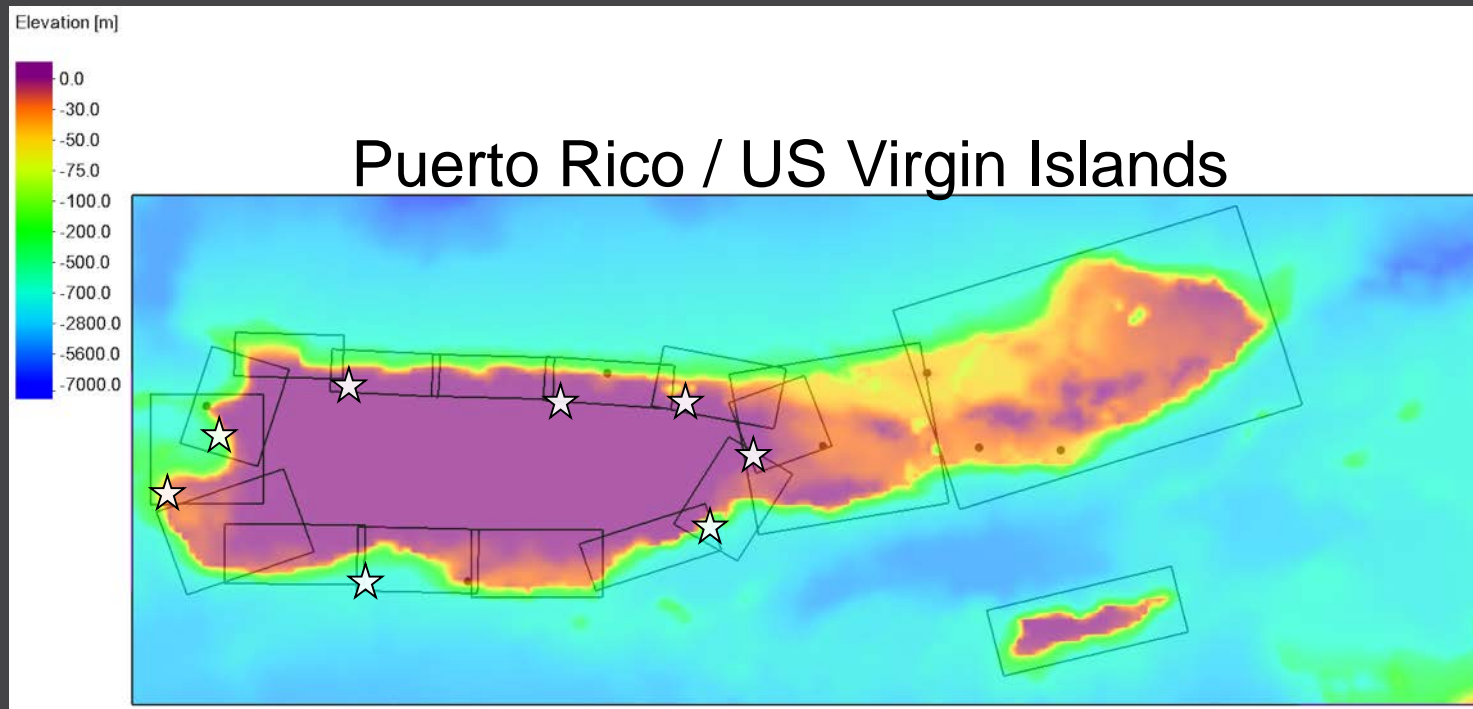


SACS-CHS Phase I: Hydrodynamic Modeling



Waves

- Nearshore spectral wave model
- 17 STWAVE domains
 - starred domains are 150-m resolution, focused on PR population centers
 - others, including Vieques, Culebra, St. Croix, and the Virgin Islands, are 200-m
 - extended into deep water where possible for wave transformation over reefs/shallow water to be estimated by STWAVE model
- Black dots indicate location of buoys for validation



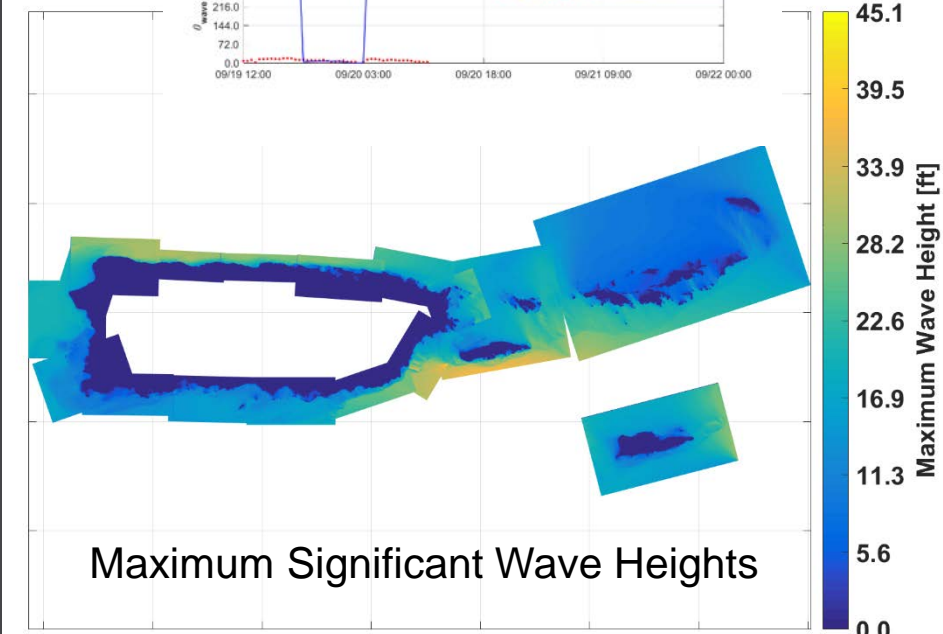
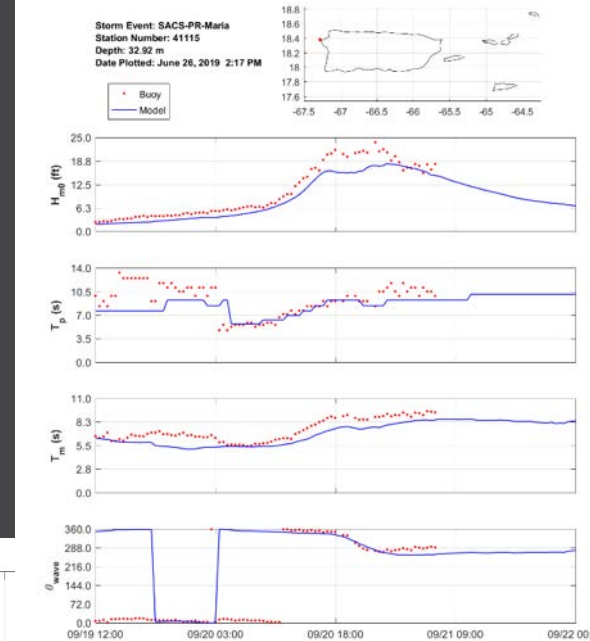
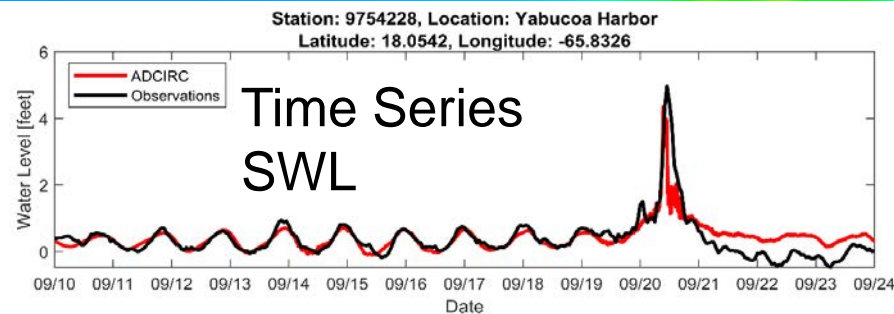
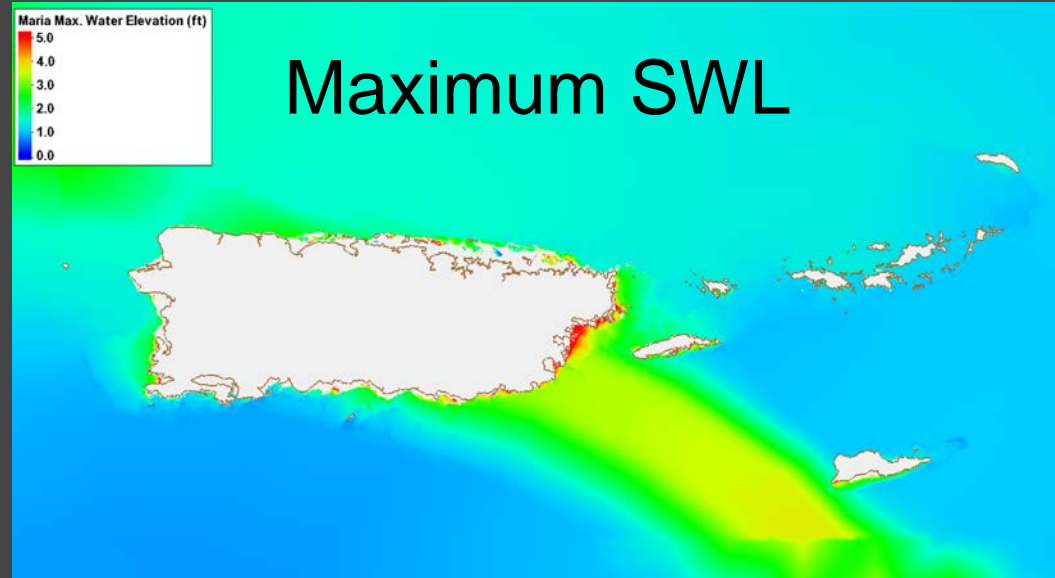
STWAVE domains overlaid on Level WAVEWATCH III domain.

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SACS-CHS Phase I: Validation

Hurricane Maria

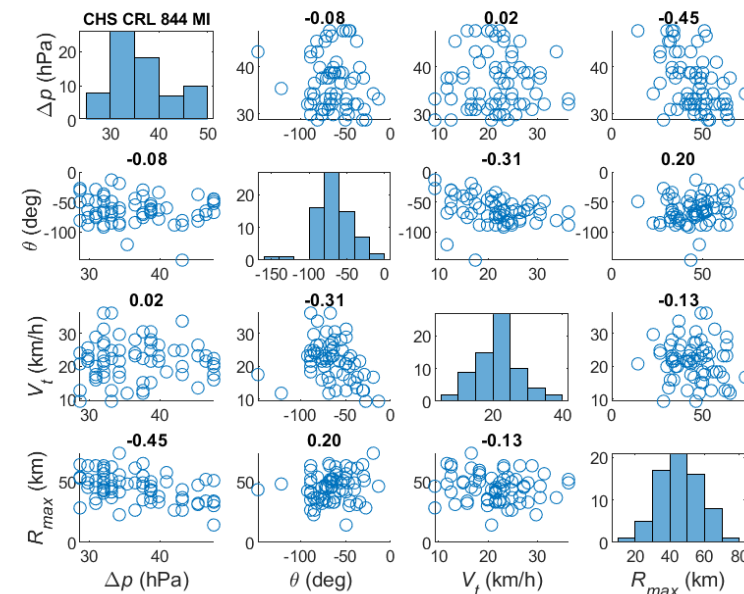
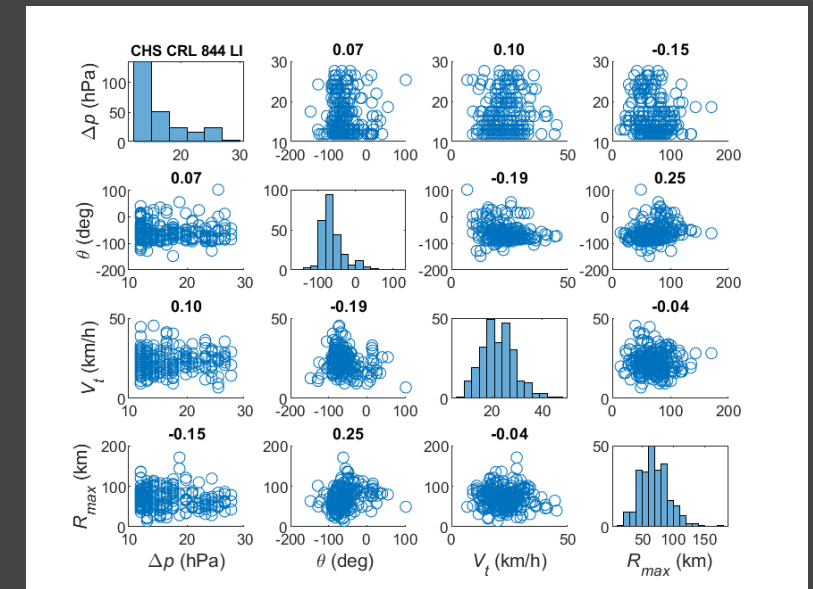
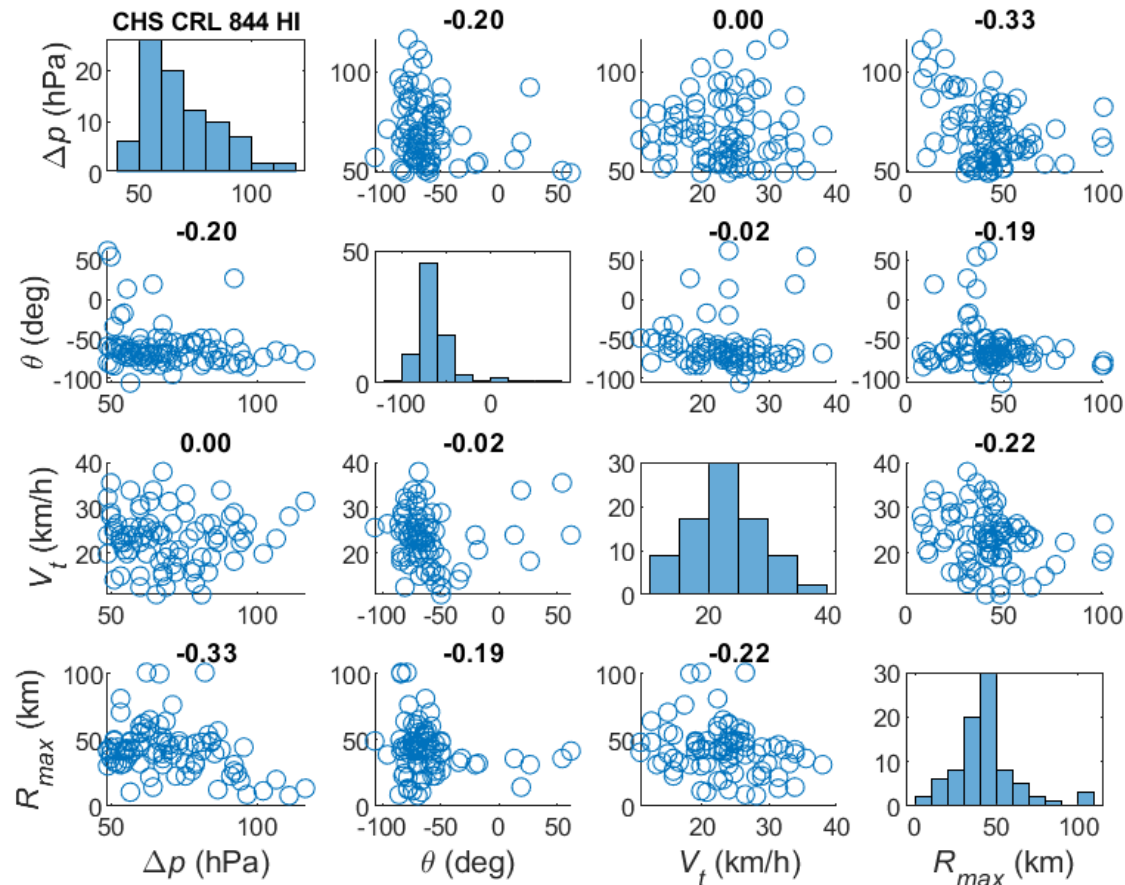


Time Series Waves



SACS-CHS Phase I: PCHA

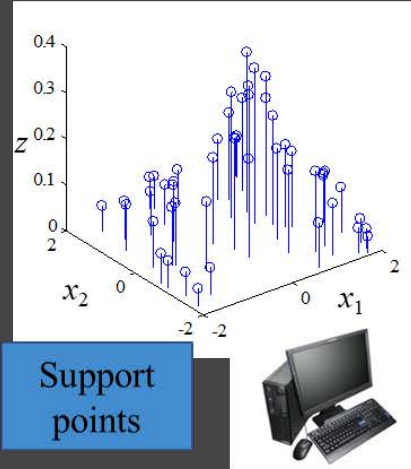
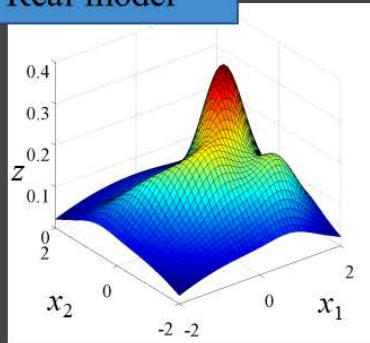
Meta-Gaussian Copula: Correlation Matrix



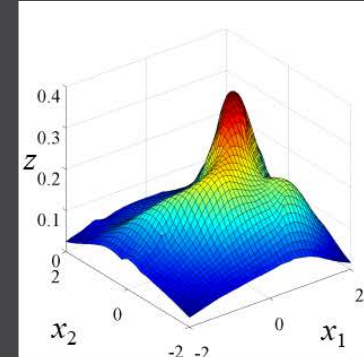
SACS-CHS Phase I: PCHA

Gaussian Process Metamodel (GPM)

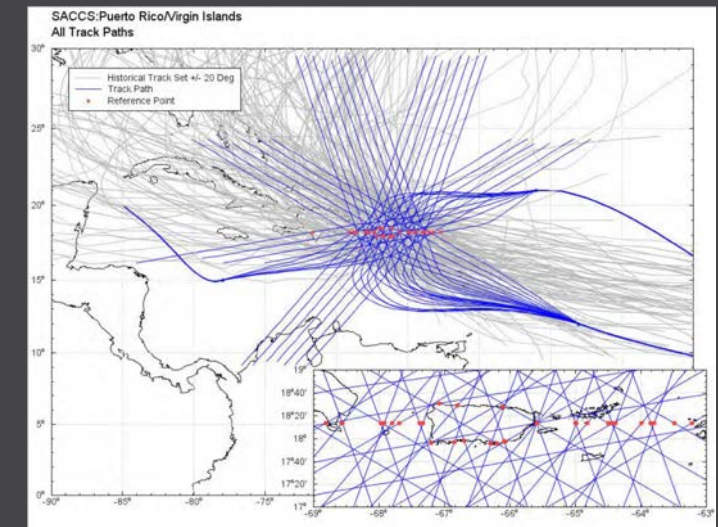
Real model



Support points



GPM approximation (global)
+ correction (local)



TC Parameter	Full Suite 300 TCs	Augmented Suite 348,000 TCs
θ (deg)	-60:20:60	-60:20:60
Δp (hPa)	8:10:148; 18:10:138	8:5:148
R_{max} (km)	8 to 143.6	10:5:155
V_f (km/h)	8 to 40	5:5:50



SACS-CHS Phase I: Results

Virtual gages 106 (red) and 102 (orange)

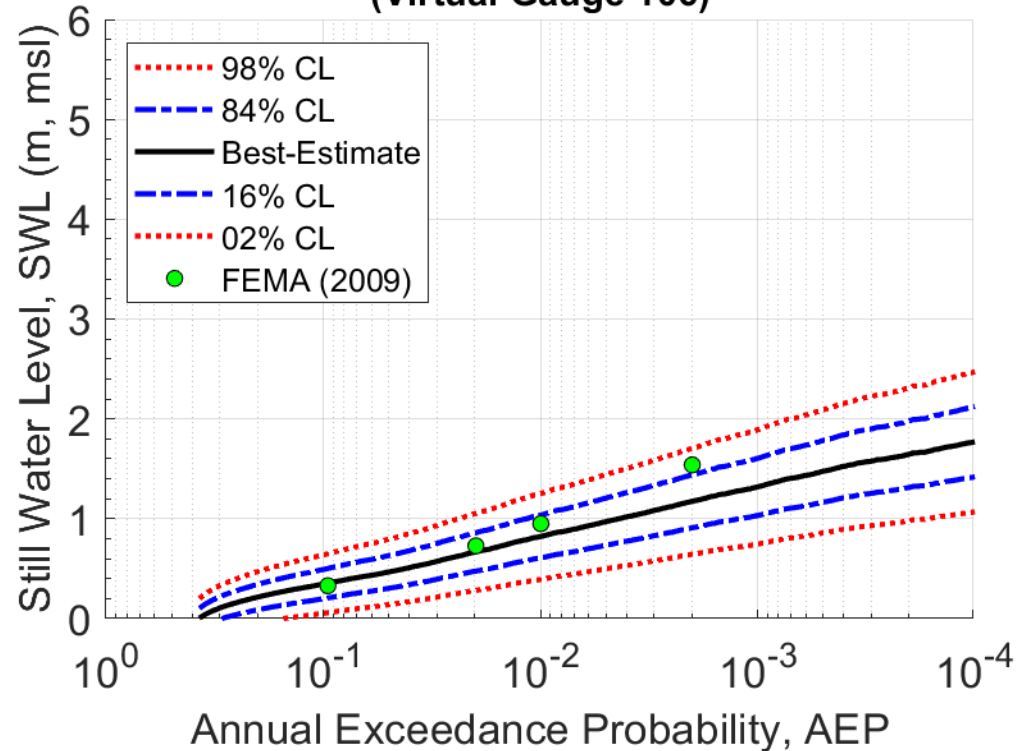


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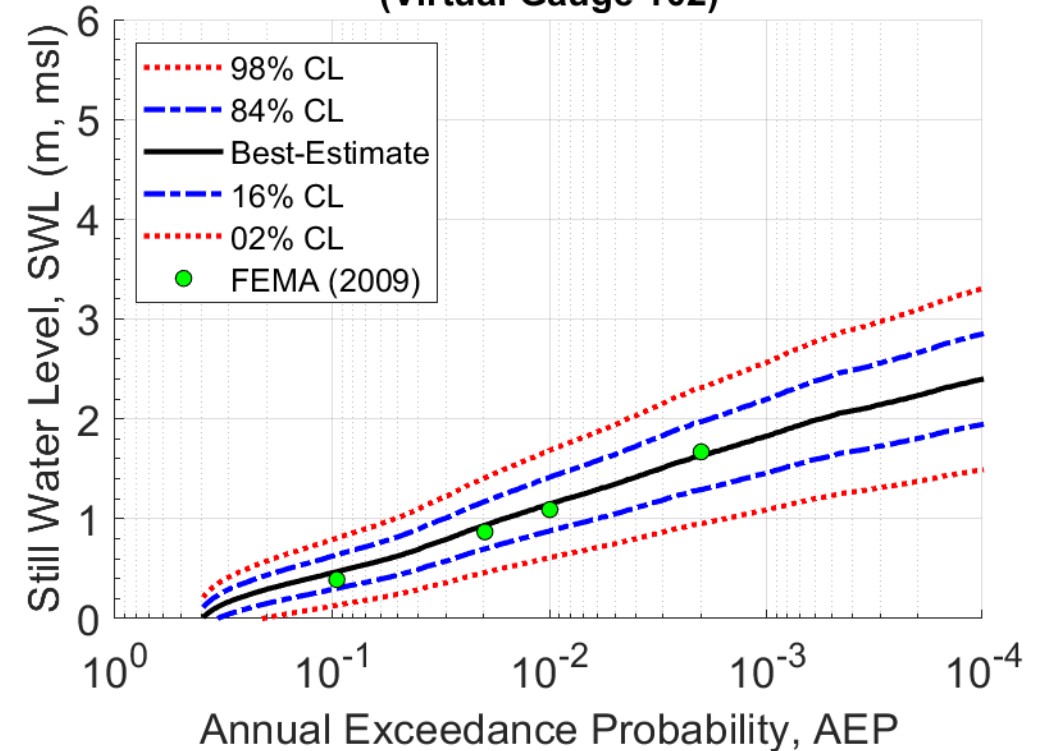


SACS-CHS Phase I: SWL

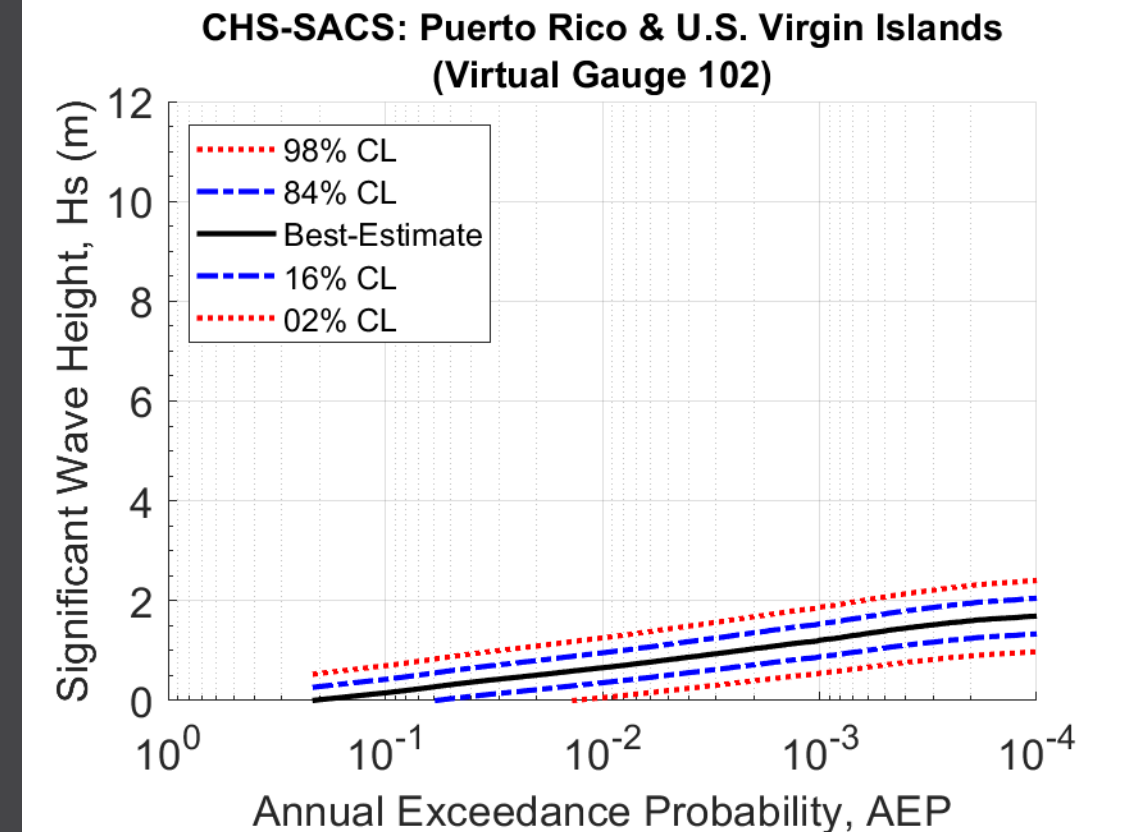
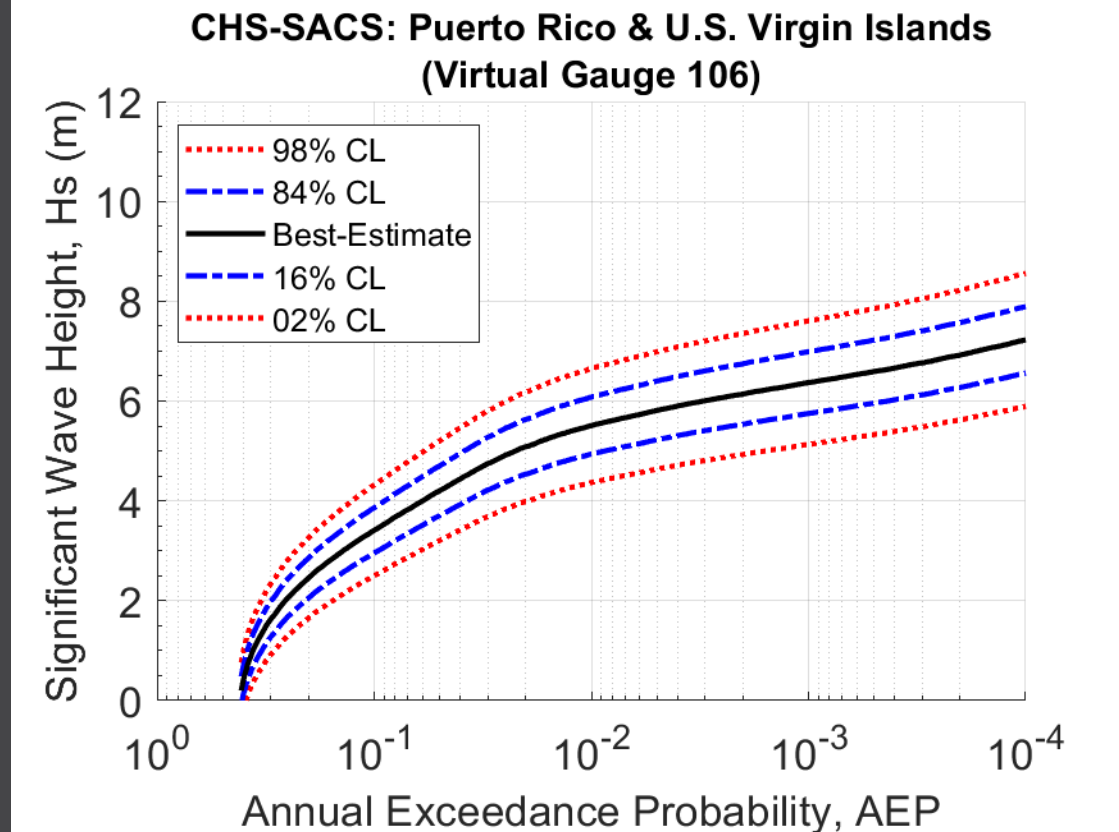
CHS-SACS: Puerto Rico & U.S. Virgin Islands
(Virtual Gauge 106)



CHS-SACS: Puerto Rico & U.S. Virgin Islands
(Virtual Gauge 102)

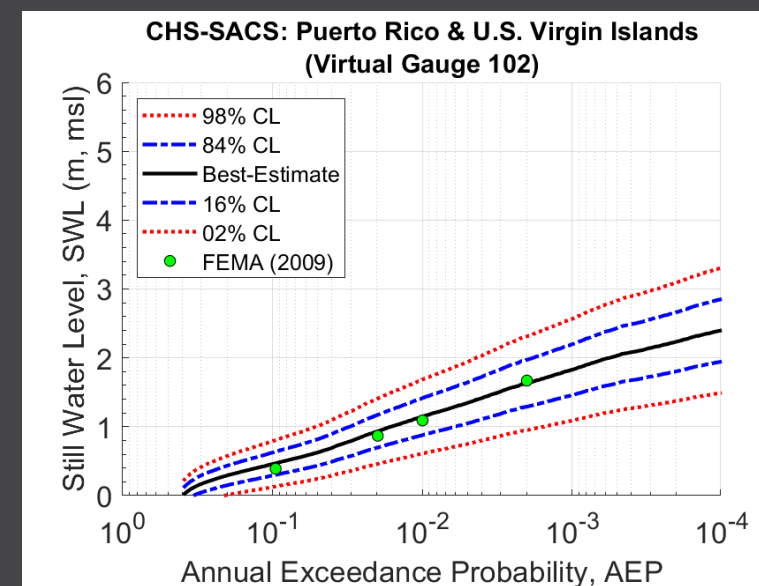
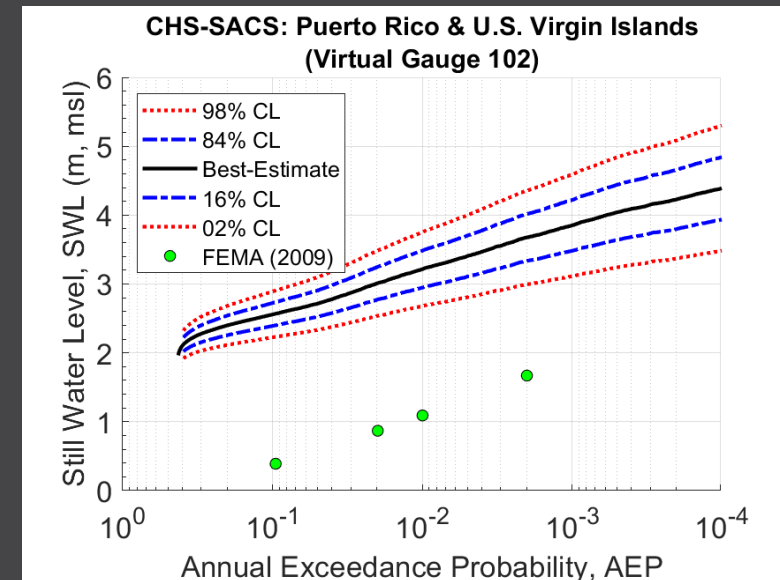


SACS-CHS Phase I: Waves

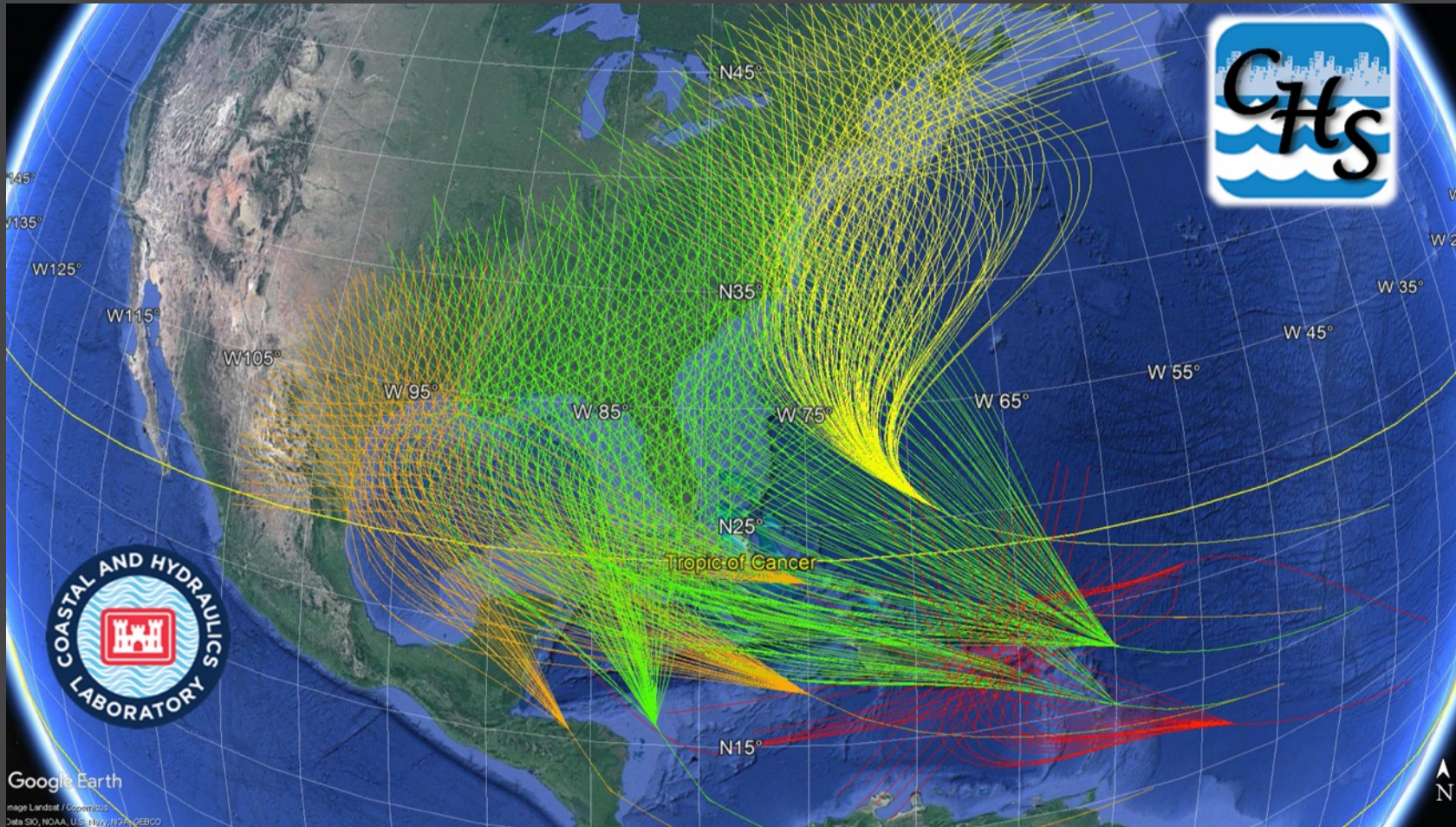


SACS-CHS Phase I: Sea Level Change

AEP	Base (m)	Base+2.12 m (m)	Difference (m)
10^{-1}	0.46	2.56	2.11
10^{-2}	1.15	3.21	2.07
10^{-3}	1.83	3.85	2.02
10^{-4}	2.40	4.39	1.99
10^{-5}	2.91	4.87	1.96
10^{-6}	3.35	5.27	1.92



CHS Synthetic Tropical Cyclone Suite: 4,356 TCs



- North Atlantic Coast Comprehensive Study (NACCS)
– 1,050 TCs (**yellow tracks**)
- Coastal Texas Protection and Restoration Feasibility Study (CTXS)
– 660 TCs (**orange tracks**)
- South Atlantic Coastal Study (SACS): Puerto Rico & USVI
– 300 TCs (**red tracks**)
- South Atlantic Coastal Study (SACS): OCONUS
– 1,700 TCs (**green tracks**)
- Louisiana Coastal Protection and Restoration (LACPR)
– 646 TCs (not shown)



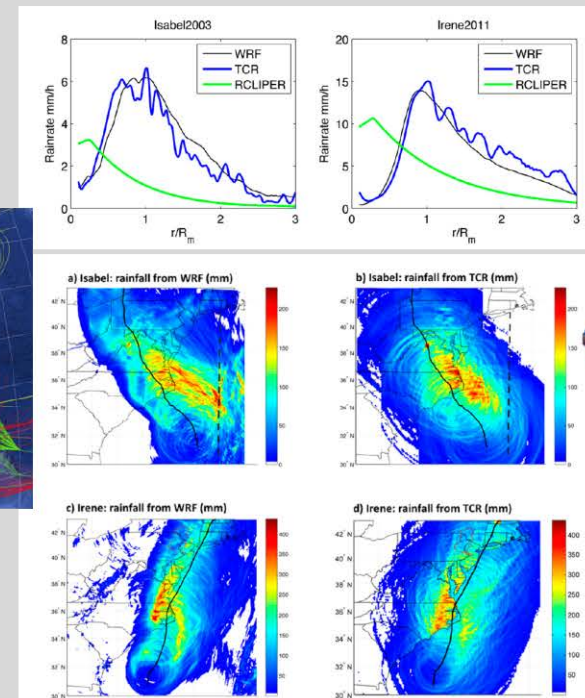
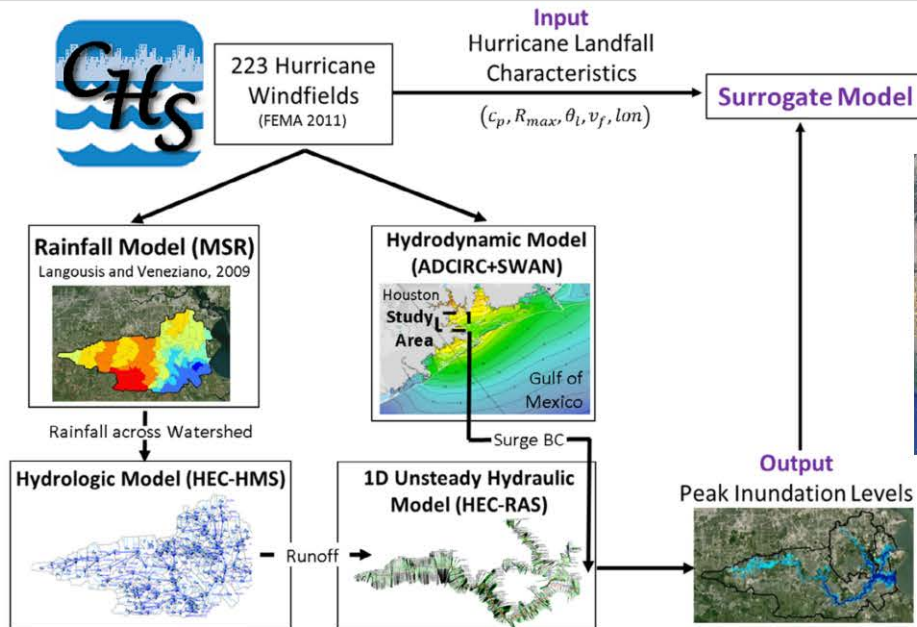
Compound Coastal & Inland Hazards

PCHA + Physics-based Parametric TC Rainfall Model

Lu et al. (2018)

Bass and Bedient (2018)

CHS
3,700+
Synthetic TCs

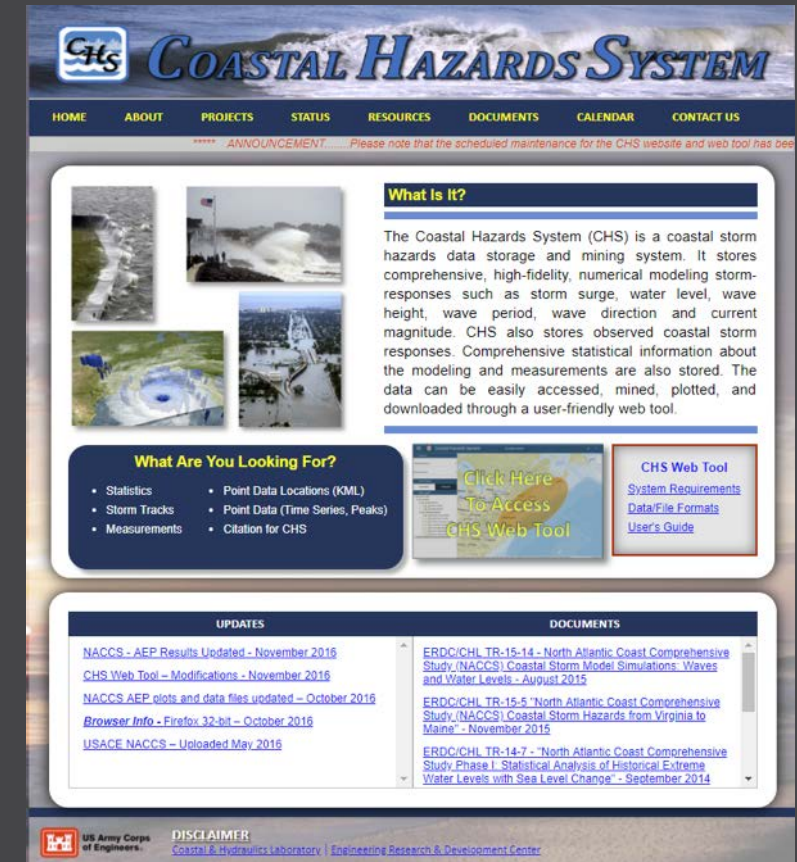


Conclusions

Coastal Hazards System (CHS)

The **SACS-CHS** will provide oceanographic and storm information to engineers, planners and managers across the South Atlantic and Northern Gulf of Mexico

- understand the likelihood and extent of present and future storm surge and storm waves
- design more reliable engineering projects and effective coastal storm damage solutions to **reduce wave attack**, **provide flood protection**, and **create robust environments** that can provide a buffer to coastal flooding
- allow communities to prepare for the future





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Questions?

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