STORMSIM RUBBLE MOUND HINDCASTING FRAMEWORK

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CHL COASTAL & HYDRAULICS LABORATORY

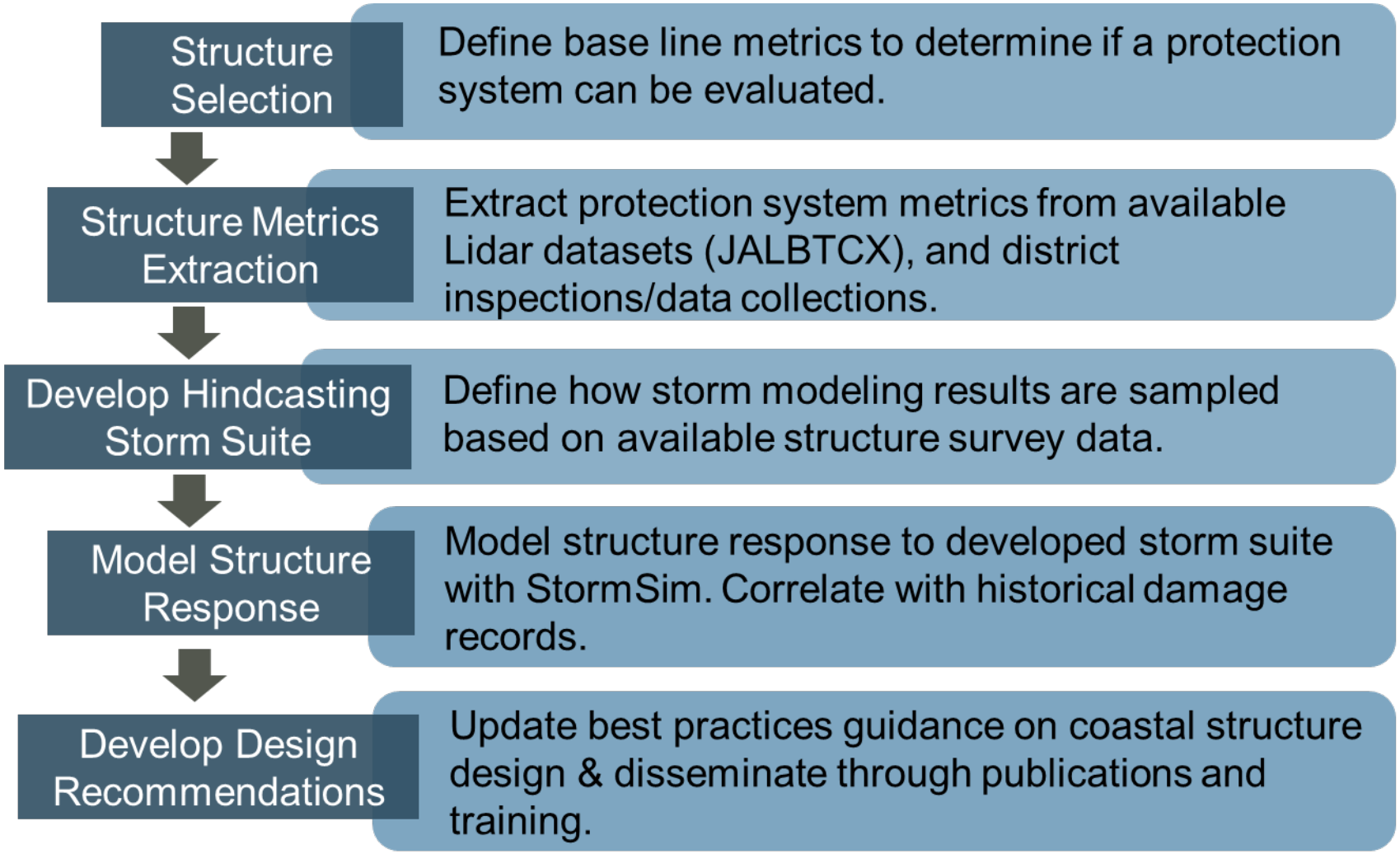
AGENDA

- Introduction
- Hindcasting Framework
  - Protection system geometry (transects)
  - Project Forcing
  - Project Responses & Structure Assessment
- Path Forward
- Questions

INTRODUCTION

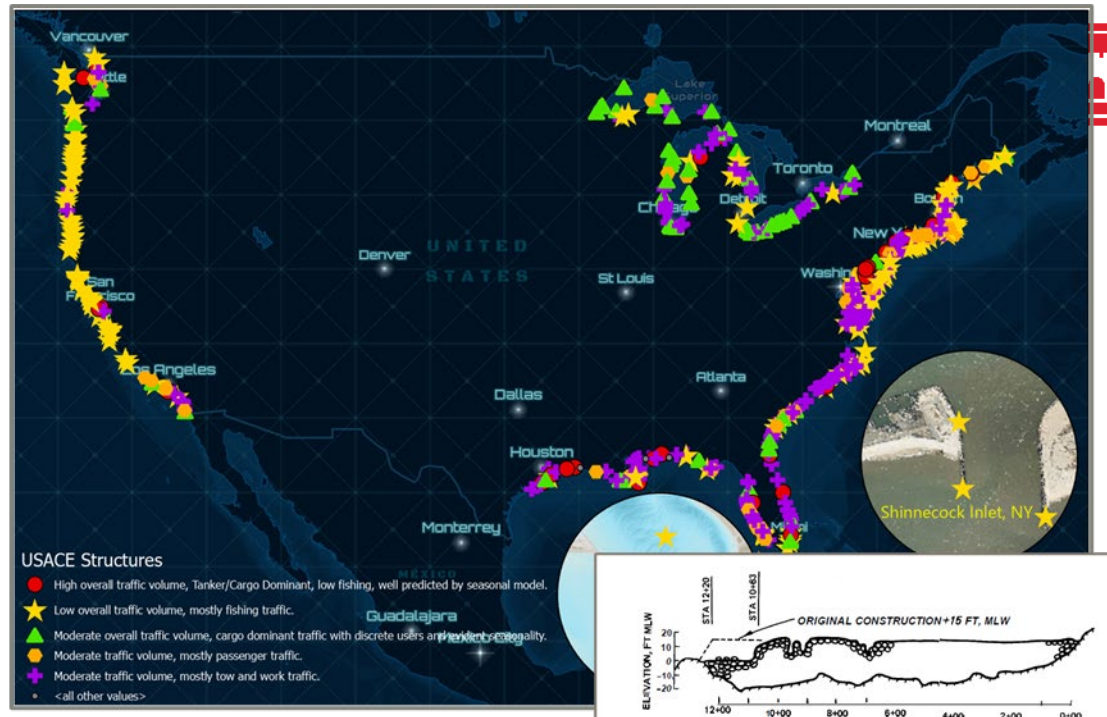
- Present empirical coastal rubble mound damage predictions have not been validated with in-place designs over extensive wave and water level forcing conditions.
- This effort seeks to sort out and provide guidance on coastal rubble mound design and performance metrics (i.e., Annual Exceedance Probabilities (AEPs), level of confidence, and limit states) within the developed probabilistic framework.
- There is great potential for collaboration with field SME's/partners:
  - Hindcasting framework considerations
  - Any knowledge of high accuracy and/or frequency of damage quantification.
  - District projects that can serve as candidates to test the proposed framework (Data request)

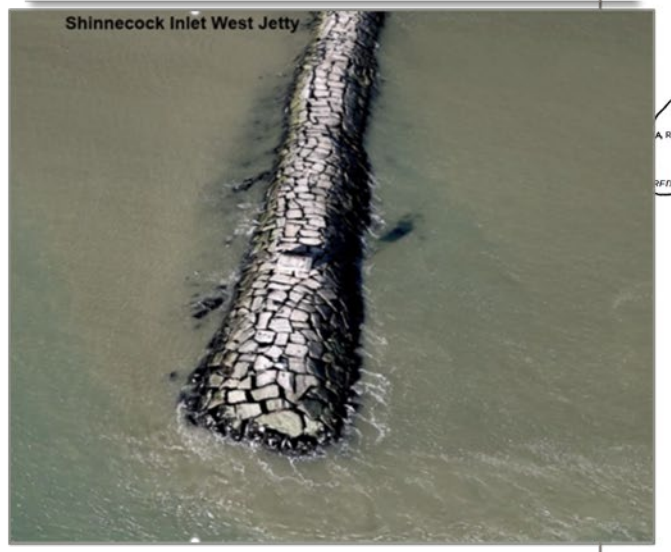
RUBBLE MOUND HINDCASTING FRAMEWORK

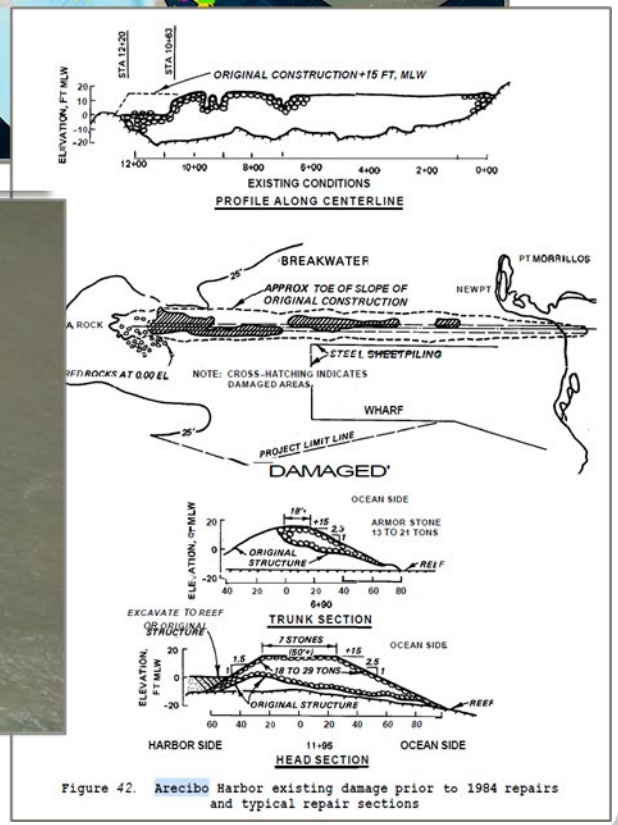


1.STRUCTURE SELECTION

- USACE manages over +1000 rubble mound structures (breakwaters/Jetty).
- Structures will be selected based on the available data in the following context:
  - **Lidar Surveys**
  - Field inspections
  - Published Reports (i.e., REMR Reports)
- Analysis ability hinges upon frequency of damage information and quantification of damaged area.







REMR-Repair, Evaluation, Maintenance And Rehabilitation

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2.STRUCTURE METRICS

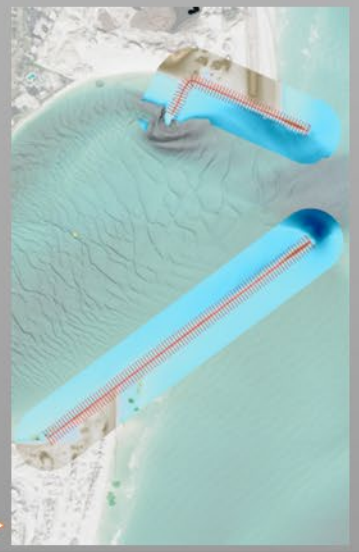
DEM Processing

Extract QC

Void Fill (if needed)

Transect Generation

@ 10-m spacing along structure centerline



Point Generation

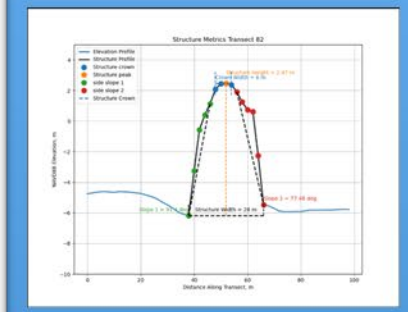
@ 1-m spacing along structure transects

Structure Classification

Structure Crown

Side Slope 1

Side Slope 2



Metrics Computations

Elevation

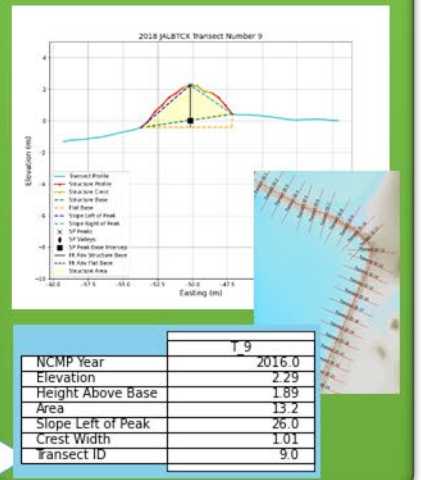
Height

Slope

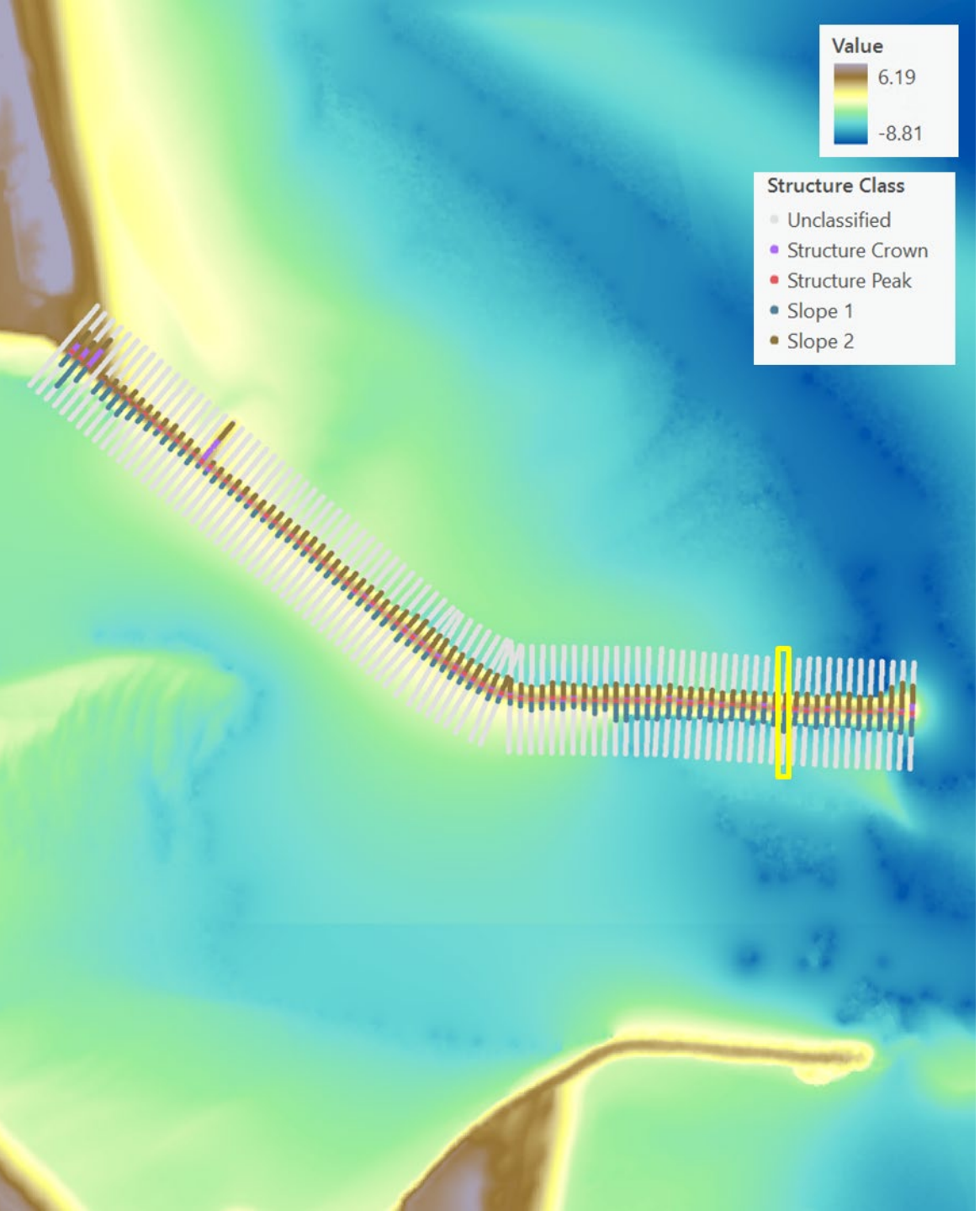
Width

Volume

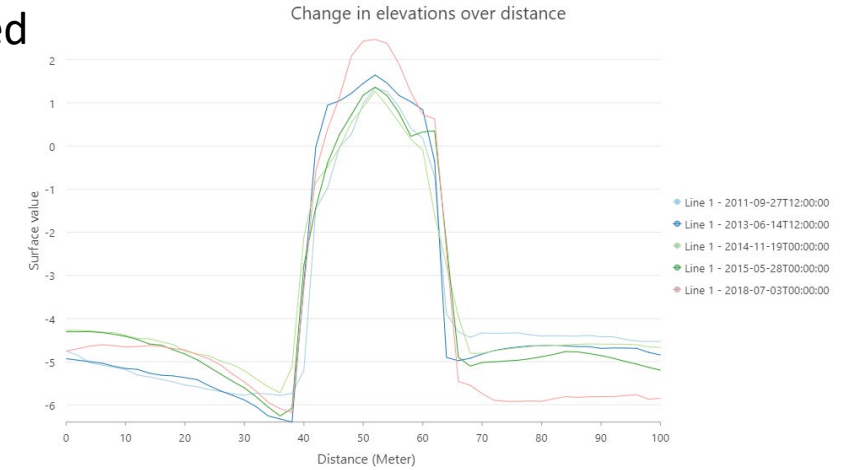
Difference

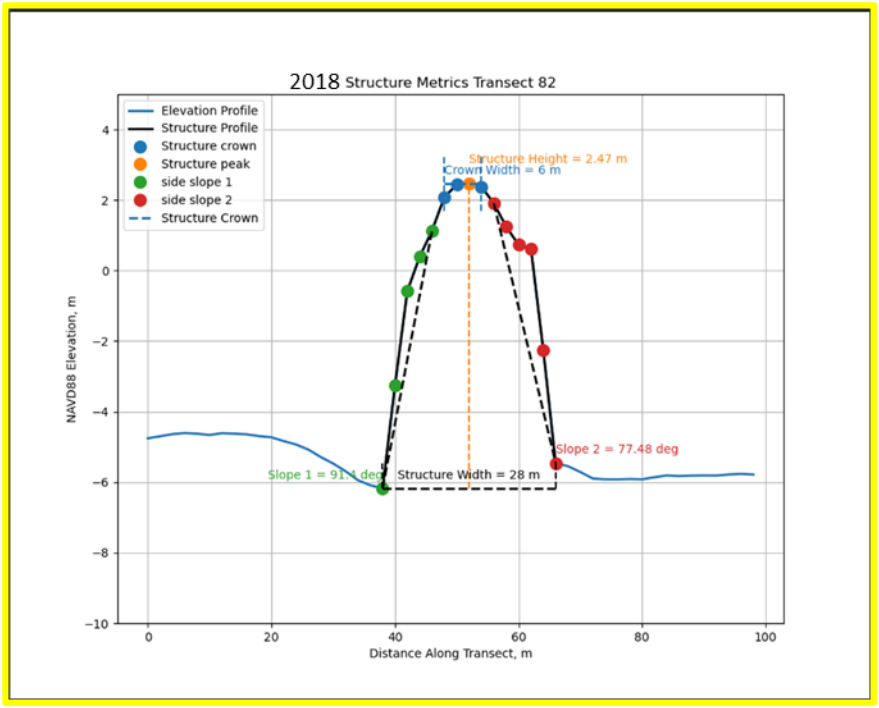


	T 9
NCMP Year	2016.0
Elevation	2.29
Height Above Base	1.89
Area	13.2
Slope Left of Peak	26.0
Crest Width	1.01
Transect ID	9.0

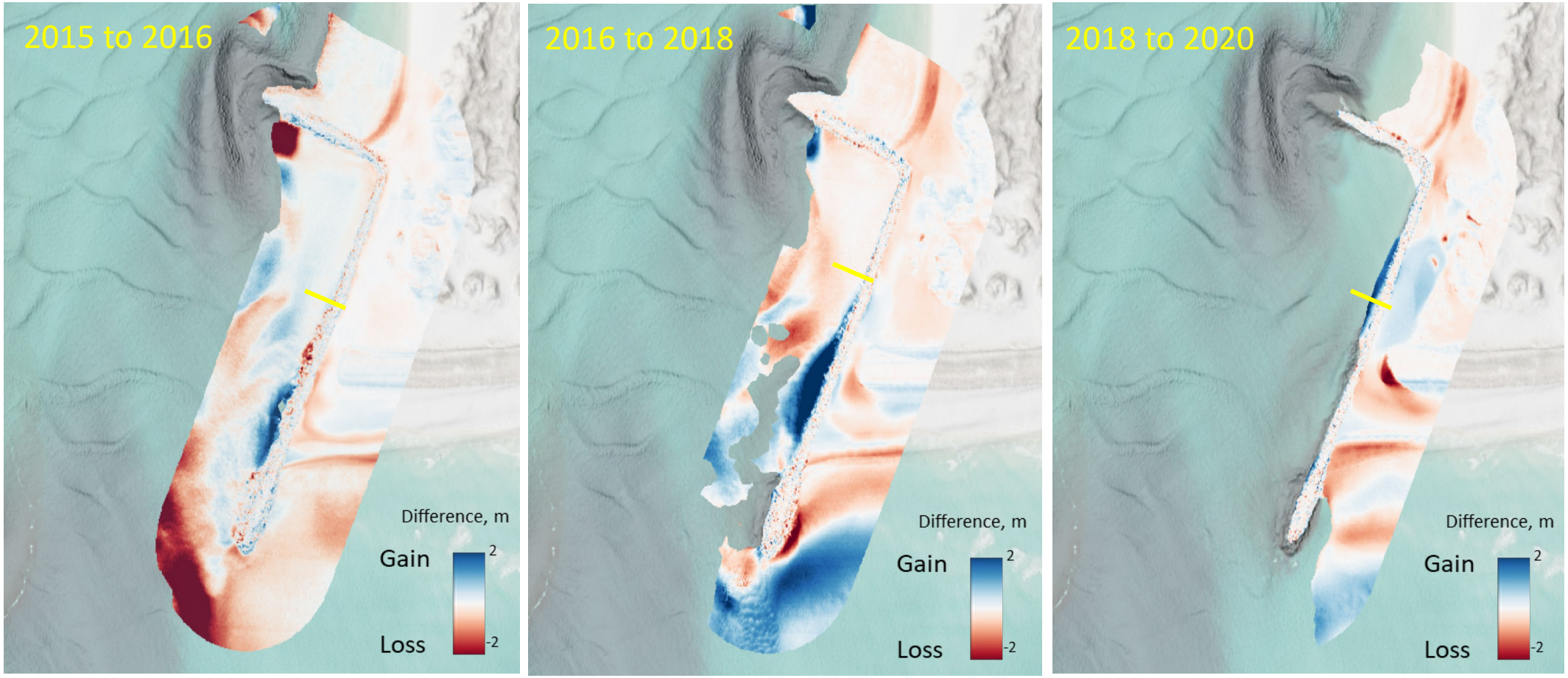


Merrimack River North Jetty
Lidar: 2018 NCMP (void-filled)
Centerline: hand-digitized
Transects: 10-m spacing





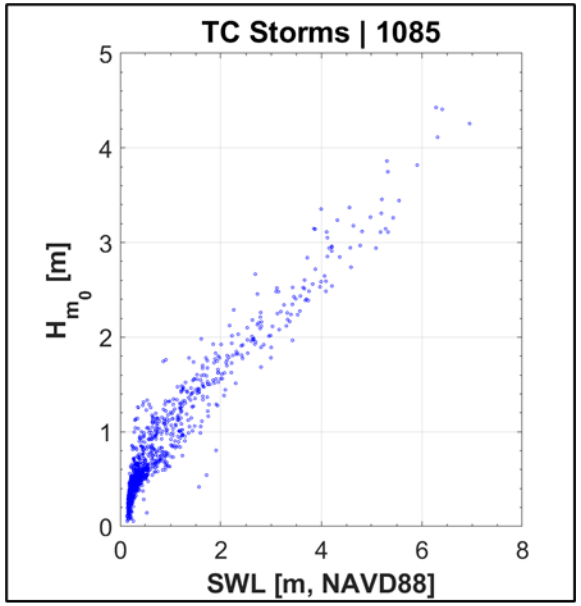
East Pass (FL) East Jetty Elevation Difference

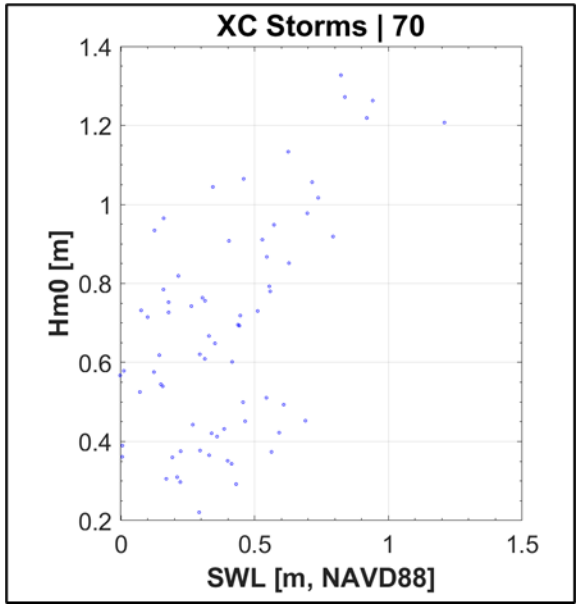


3.HINDCAST STORM SUITE

- Hindcasting analysis will leverage the following data sources to characterize the forces acting upon the structures:
  - Wave Information Study (WIS)
  - National Oceanic and Atmospheric Administration (NOAA)
  - Coastal Hazard System (CHS) -> surrogate models

- Hindcasting storm suite is built according to the surveying data found for the system.
  - Before/after extreme event
    - Data limited to specific extreme event. (historical)
  - Routine inspections
    - Surveys cover a range of years of operation.
    - Storm suite must be synthesized from mentioned sources.





Coastal Hazards System (CHS)

What is the CHS?

A national-scale, multi-agency initiative for accurate, efficient, and consistent quantification of coastal storm hazards along U.S. coastlines and other strategic locations critical to our national security.

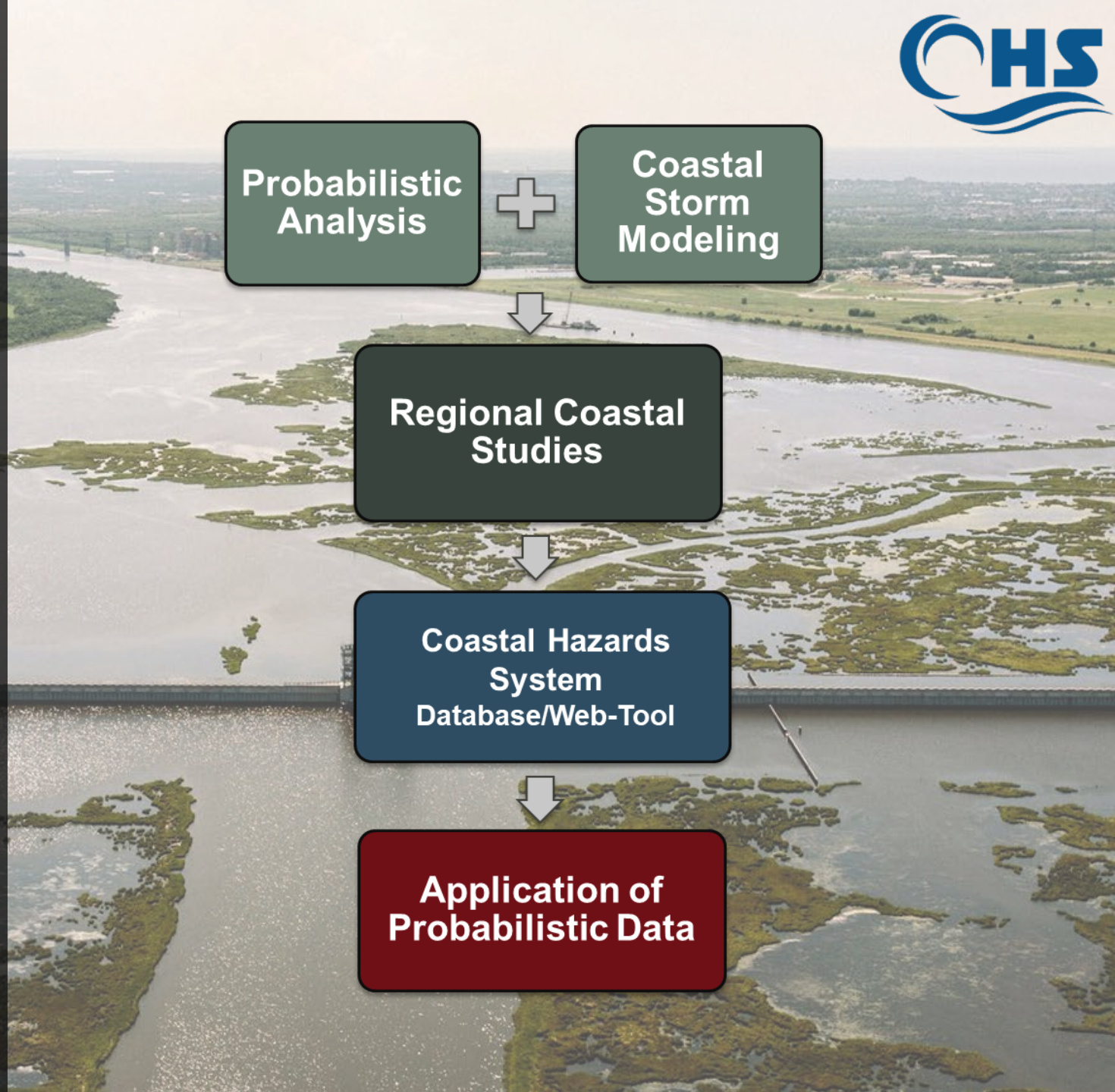
Goal:

Provide high-fidelity, high-resolution state-of-the-art hydrodynamic and probabilistic modeling and companion tools in a multivariate statistical context for coastal planning, engineering, and operations and maintenance.

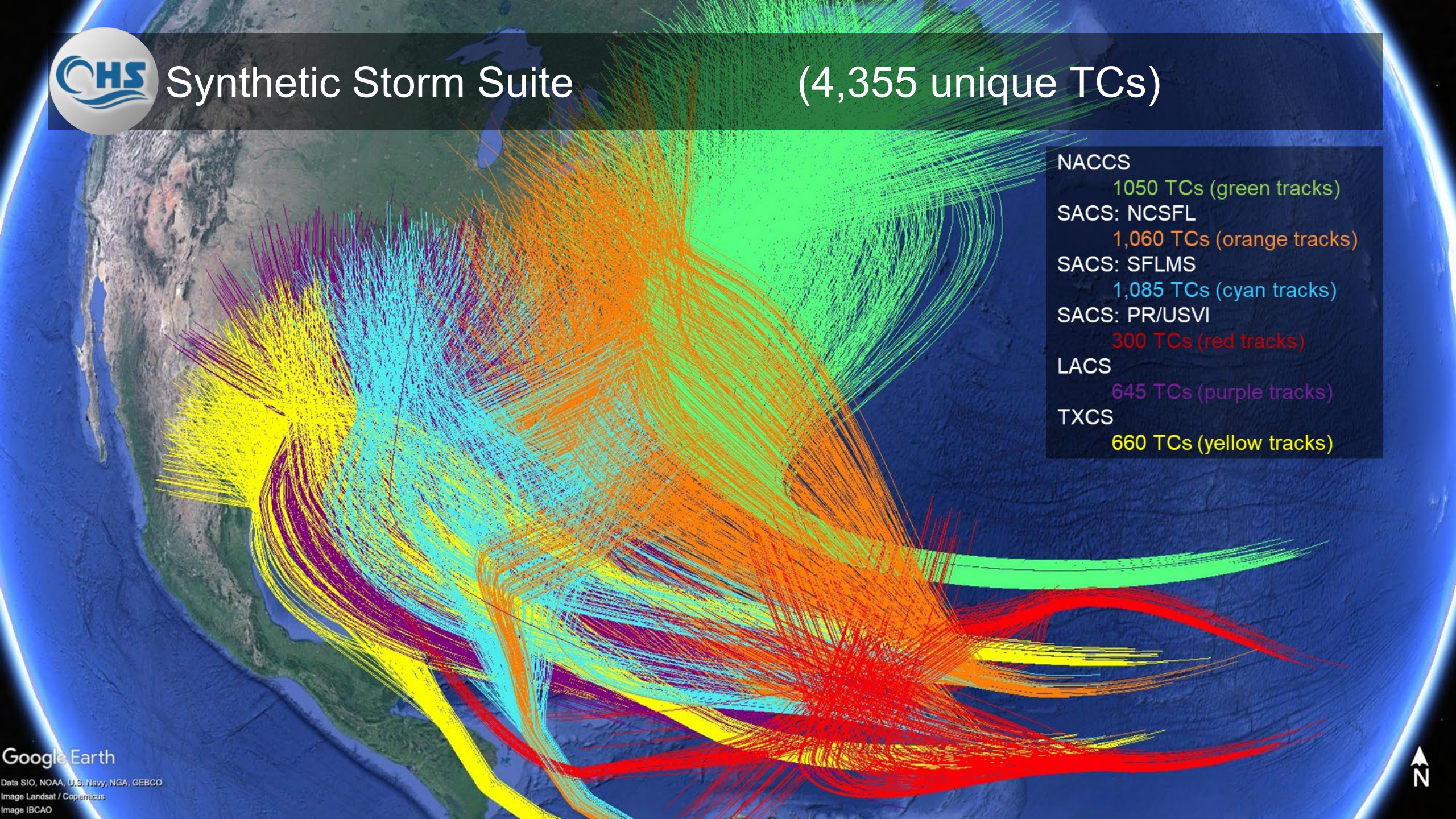
Impact to the Nation:

Methods, data, and tools within the CHS serve as the basis for coastal engineering by providing high-fidelity, probabilistic coastal hazards on a national scale.

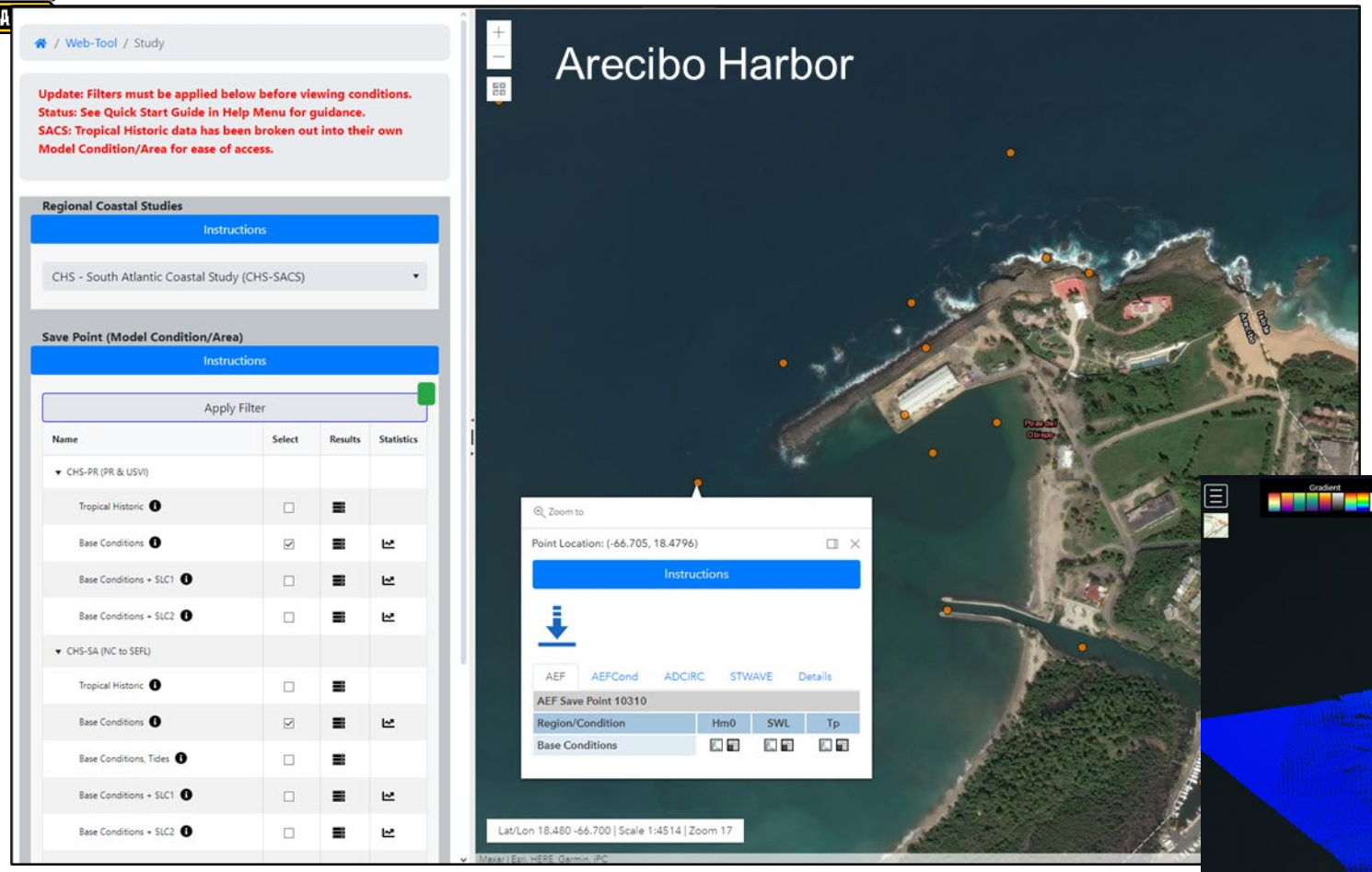
https://chs.erdc.dren.mil



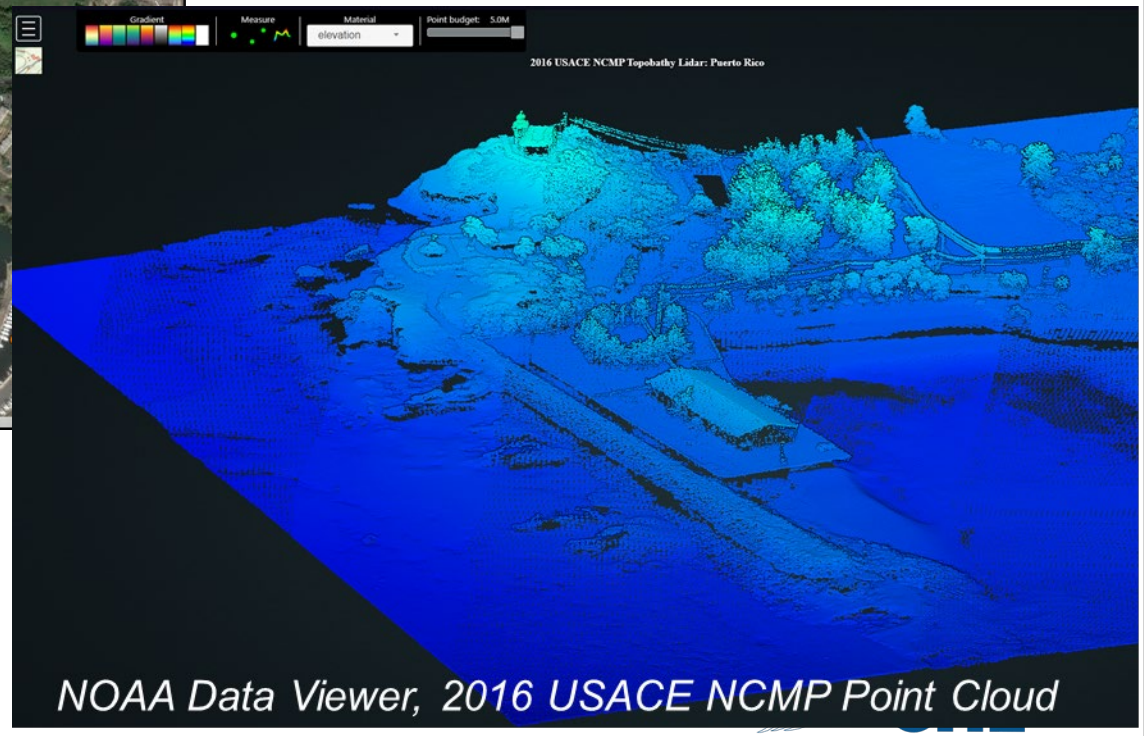
Synthetic Storm Suite (4,355 unique TCs)



CHS INTERFACE



- ADCIRC/STWAVE **Peaks**
- ADCIRC/STWAVE **Timeseries**
- **Associated probability and statistics files**
- Details regarding regional CSTORM modeling can be found on the CHS library.



Using CHS data takes care of multi variate problem (correlation of storm surge + waves.) and aleatory uncertainty.

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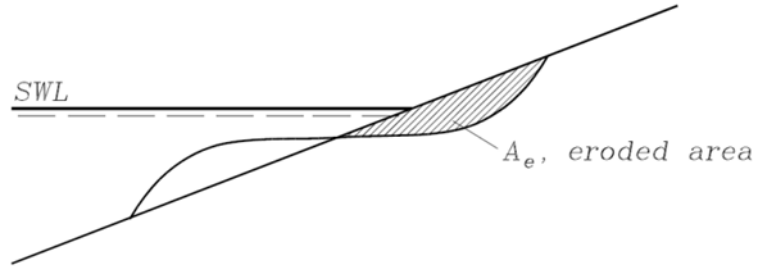
4.MODEL STRUCTURE RESPONSE

- Initial protection system evaluation will be done with the Stochastic Storm Simulation (StormSim) library.
- The StormSim: Life Cycle Simulation module will be used to estimate the following responses:
  - Run-up (R2%)
  - Overtopping Discharge Rate (q)
  - Armor Stone Damage Progression (S)
- Additional modeling external to StormSim will be considered if needed on a structure-to-structure basis.

CEM pg VI-5-57



$$D = \frac{\text{number of displaced units}}{\text{total number of units in area}}$$

$$N_{od} = \frac{\text{number of units displaced}}{(\text{width of tested section})/D_n}$$

$$D = \frac{\text{average eroded area from profile}}{\text{area of average original profile}} \times 100\%$$

$$S = \frac{A_e}{D_{n50}^2}$$

WHAT IS STORMSIM?

- Universal, modular and data agnostic MATLAB functions library that provides users with tools that help in:
  - Probabilistic Coastal Structure Responses and Life Cycle Performance
  - CSRM Feasibility Studies and Engineering Design
  - Flood Risk Management
  - Data Visualization
  - Technology Integration
- Developed as part of regional studies (NACCS, CTXS, SACS) and reimbursable projects.
- Native support for CHS response and statistical data

STORMSIM: COMPUTATIONAL KERNELS & INTEGRATED WORKFLOWS

Response Base Kernel (For Peaks &/or Timeseries)

1. StormSim: Probabilistic Response Of Structures (PROS)
2. StormSim: Life Cycle Simulation (LCS)
3. StormSim: LCS-Coastal Structure Reliability (LCS-CSR)
4. StormSim: LCS-CSR: Damage Progression Analysis (DPA)

Frequency Base Kernel

1. StormSim: PROS-Frequency Base (PROS-FB)
2. CSRM Spreadsheet

*Everything is executed from a centralized master script

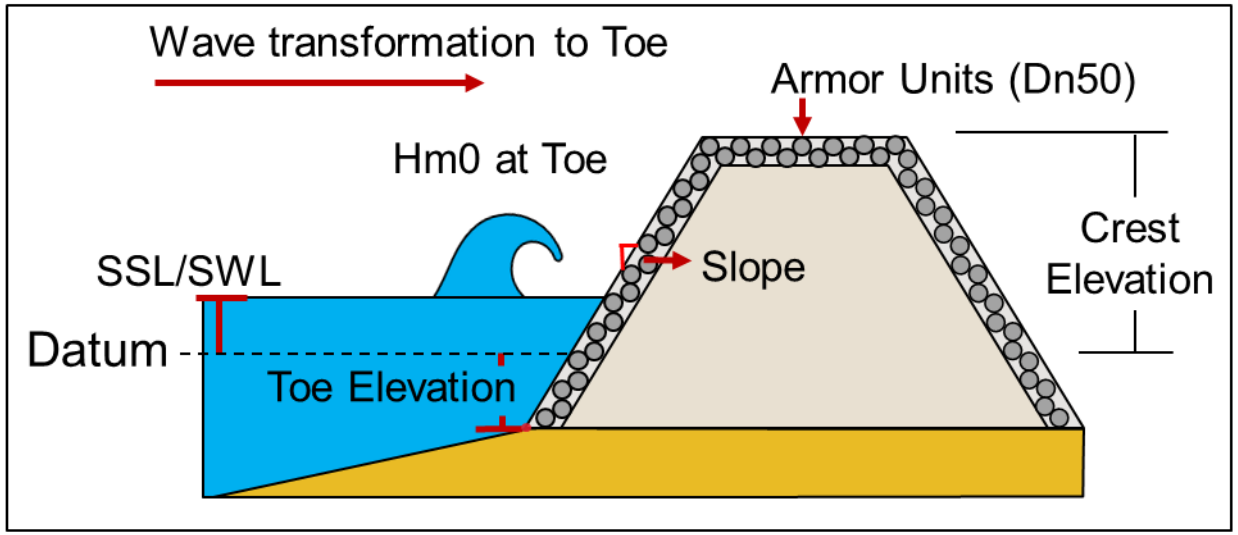
StormSim: PROS Responses
Run-up [m]
Combined Overtopping Discharge Rate [m^3/s per m] (q_wave_ot + q_overflow)
Overtopping Discharge Rate [m^3/s per m] by wave overtopping
Overtopping Discharge Volume [m^3 per m]
Median Seaside Stone Size [m]
Median Leeside Stone Size [m]
Low Crested Median Seaside Stone Size [m]
Goda Wall Pressures [Pa]
Overtopping Nappe Responses

StormSim: LCS Responses
Seaside Armor Damage
Leeside Armor Damage
Low Crested Armor Damage
StormSim: PROS supported response in a LC context

STORMSIM: PROJECT CONCEPTUALIZATION

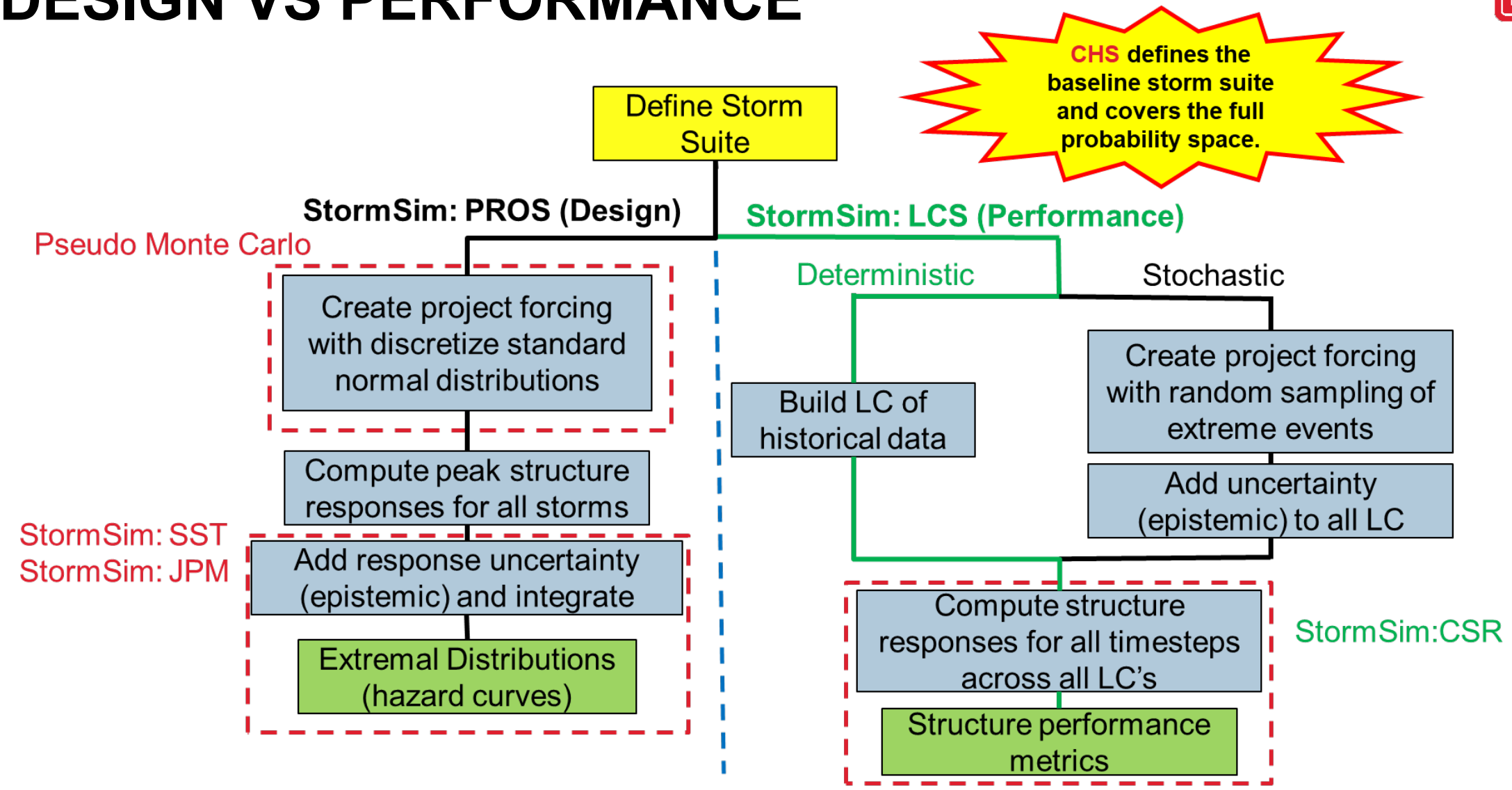
1. **Forcing:**
   - Extratropical (XC) & Tropical Cyclones (TC)
   - Storms/Events (Peaks/Timeseries)
   - Steric SWL
   - Tides
   - RSLC
2. **Protective System Element (PSE's):**
   - Levee, Rubble Mound, Floodwall
3. **Uncertainty:**
   - Aleatory (e.g. annual, intra-annual storm variability)
   - Epistemic (i.e., Model Error)
4. **Configuration File:**
   - Project/Module set-up

What does StormSim "see" in a simulation?



**SSL -> Storm Surge Level*
**SWL -> Storm Water Level (SSL + Tides + SLR + other)*

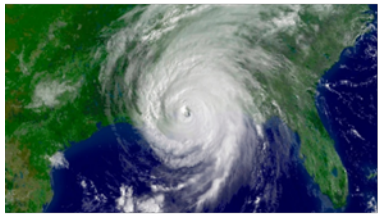
DESIGN VS PERFORMANCE



STORMSIM: MASTER SCRIPT FLOWCHART

Inputs

Configuration File



Uncertainty

Initialize Project Environment
- Create Project
- Parse Configuration

CHS Storms Suite QA/QC
- Storm Screening
- Storm Data Pairing

Create Project Forcing
- StormSim: PROS
- StormSim: LCS

Create PSE
- Geometry
- Properties

Project Forcing Adjustments
- Uncertainty
- SLR, Rand Tides, DL

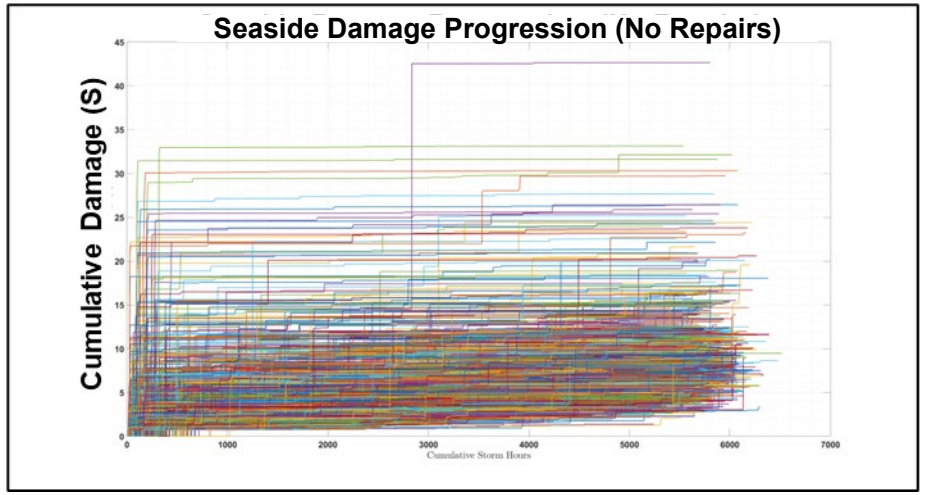
Compute Project Responses
- R2%, q, S, Dn50, Goda Wall Pressures,…

Outputs (Matlab Output Structures)

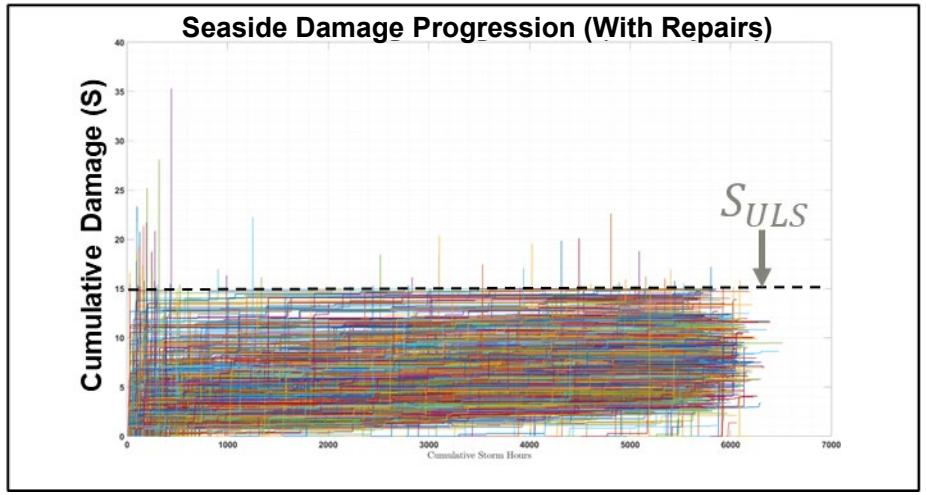
- Config
- Storm
- Prob_mass
- Project_forcing
- Structure
- Resp

STORMSIM RESPONSES EXAMPLE OUTPUTS

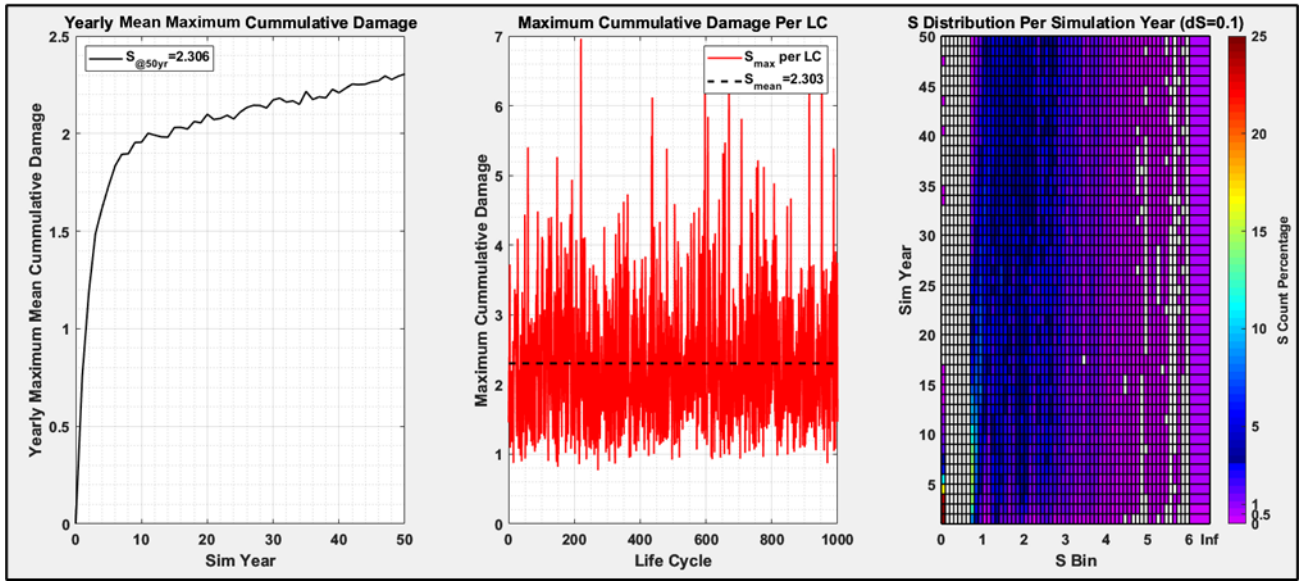
Damage Accumulation No repairs



Damage Accumulation With repairs



Yearly Mean Maximum Cumulative Damage

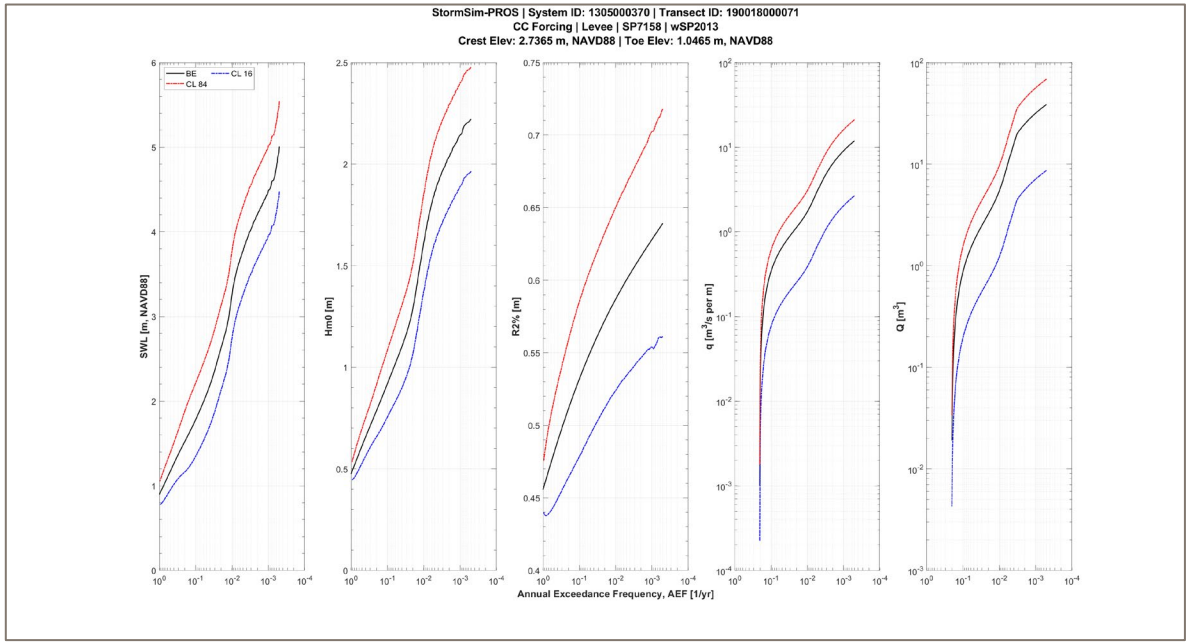


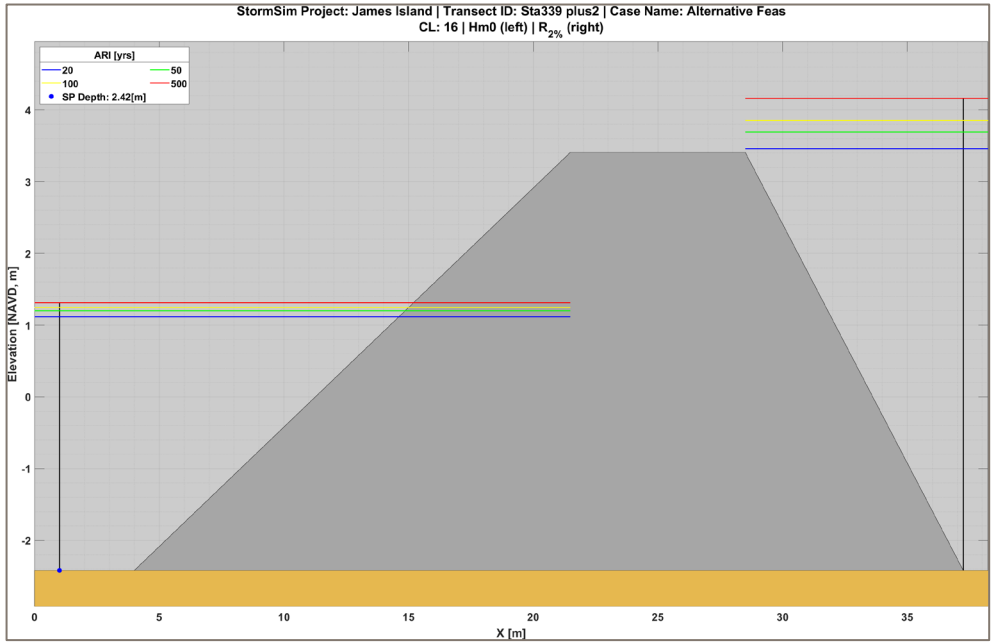
How are yearly values computed?

1. Bin all storms damage vectors across all LC by simulation year.
2. Find the maximum cumulative damage (S) for all storm damage vectors across all bins.
3. Average out the maximum values to get a singular value for year N (Mean-maximum)

STORMSIM RESPONSES EXAMPLE OUTPUTS, CONT.

Storms & Structure Responses Hazard Curves





StormSim: PROS leverages the use of:

- StormSim: Joint Probability Method (JPM)
- StormSim: Stochastic Simulation Technique (SST)

CURRENT STATUS

- StormSim Library is near beta stage.
- StormSim documentation is in process.
- Hindcasting is currently in the structure selection stage. Aiming to pick 5 protection systems to evaluate through framework.
- Structure analysis will serve as a reference to guide district partners in the evaluation of new systems or repairs.

STORMSIM INTEREST?

Levels of engagement:

- Rubble mound Hindcasting
  - Provide candidate structure corresponding surveying data.

- Beta testing
  - Testing of StormSim library and review of guidance draft documents.

- Tool improvements:
  - Provide feedback on missing metrics for project deliverable.

- Python conversion:
  - Interest on helping the migration of StormSim to Python.

QUESTIONS

STORMSIM CONTACT INFO

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