Sustainability of Barrier Island Protection Policies under Changing Climates

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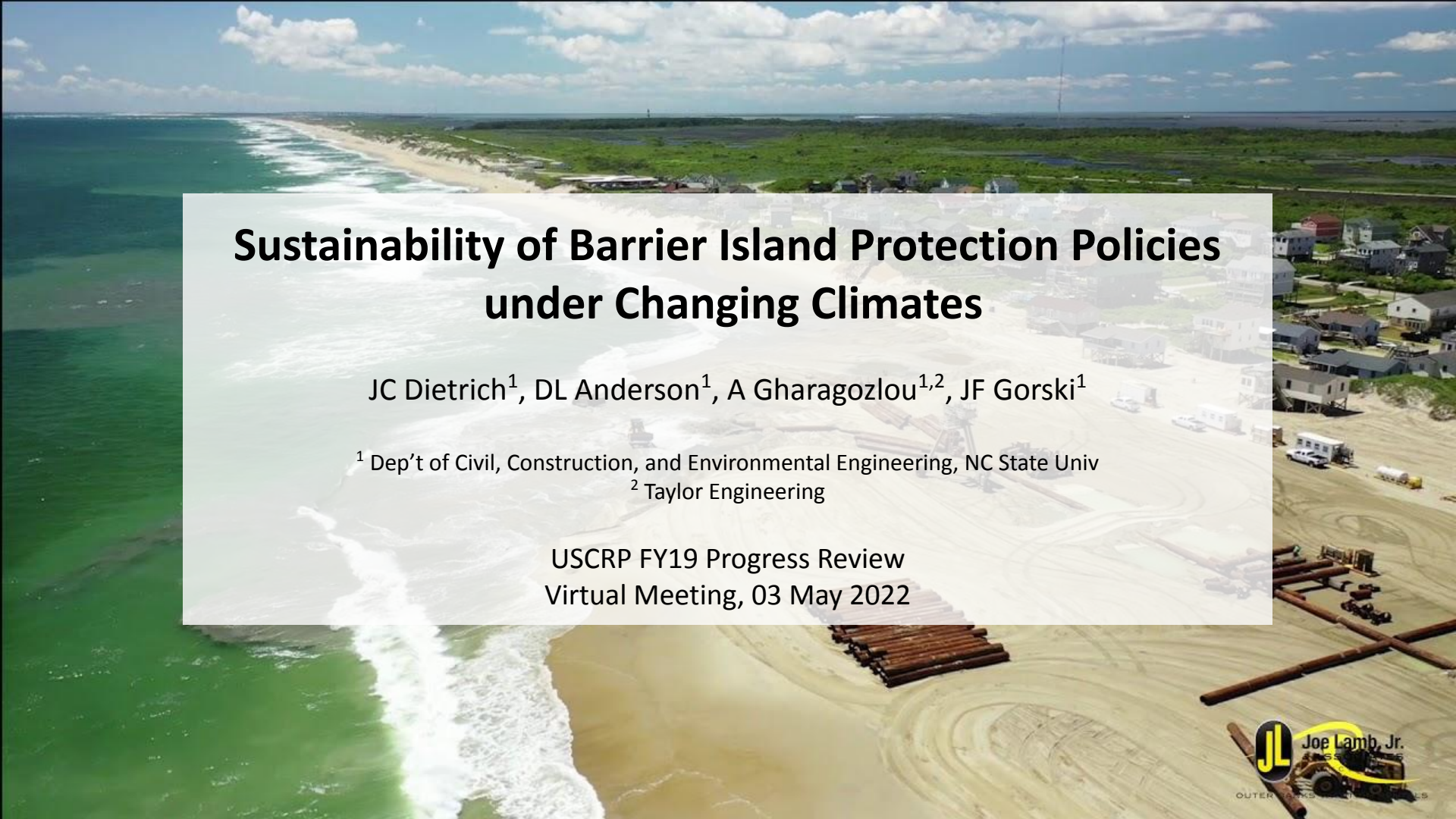
USCRP FY19 Progress Review
Virtual Meeting, 03 May 2022



1. Objectives

USCRP Priorities and Objectives

This project aligns with FY19 USCRP Research Topic 11: Coastal Adaptation Pathways for Barrier Island Communities

1. Summarize the state-of-knowledge for adaptation method of coastal communities
2. Develop conceptual models for determining alternative adaptation strategies
3. Test, revise, and validate approaches using open-source numerical models

We proposed to develop a framework that can assess the sustainability barrier island protect policies (e.g. when will an alternate adaptation pathway need to be adopted?)

- Motivated by widespread use of beach nourishments on barrier islands (Elko *et al* 2021)
- Working with the Town of Nags Head, NC (**David Ryan**, town engineer)

1. Objectives

Two Recent Beach Nourishments in Nags Head NC

2011 nourishment ($32m)

Hit by Hurricane Matthew in 2016

2019 nourishment ($32m)

Hit by Hurricane Dorian in 2019

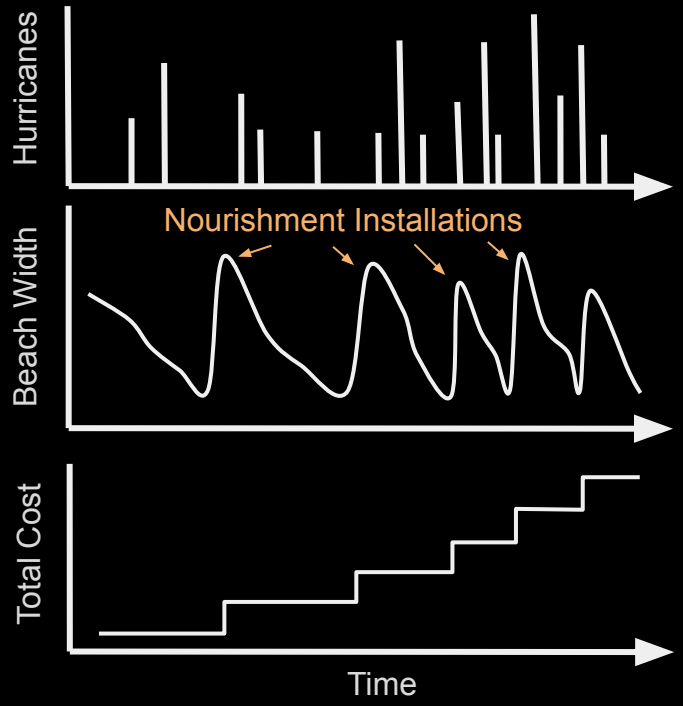
Requiring 2022 repairs ($14m)

1. Objectives

Accounting for Future Weather Patterns

Our predominant form of coastal protection is dependent on the randomness of storm events…

– But we have only seen one roll of the weather dice…



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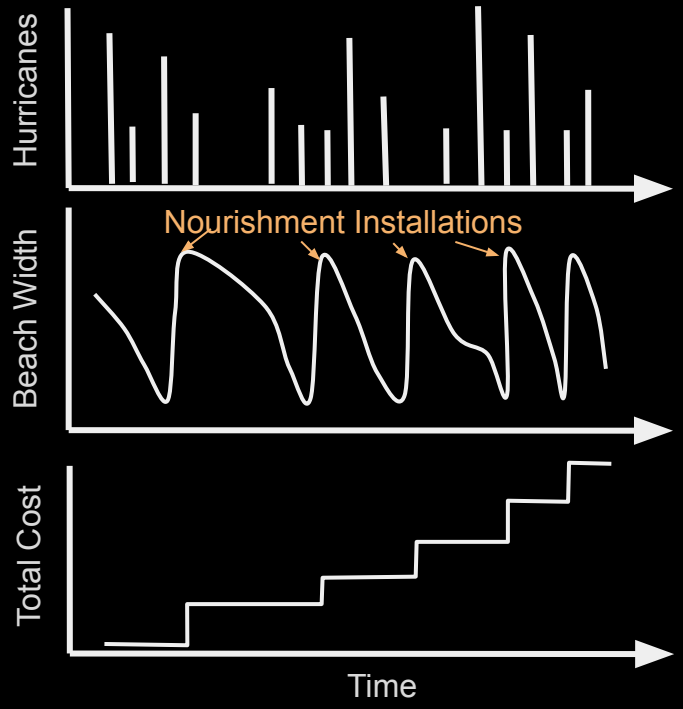


1. Objectives

Supporting Coastal Communities

Whitehead, J. and White, H. B. (2017). “Adaptation planning in the Town of Nags Head: Vulnerability, Consequences, Adaptation, Planning Scenarios (VCAPS) Report.”

- *[T]he most important and immediate next step, prior to engaging in any long range planning efforts and studies identified in the overall priority actions, will be to develop a suite of SLR scenario/probability distributions.*
- *The scenarios would not predict future changes, but describe future potential conditions in a manner that supports decision-making under conditions of uncertainty allowing thetown to analyze vulnerabilities and impacts ....*
- *[T]hey could be utilized for long range planning such as development of an estuarine shoreline management plan, development of a long term shoreline management plan, and ... progressively improving the town’s stormwater drainage infrastructure.*

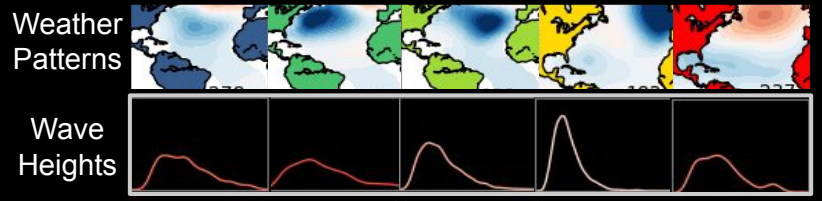
2. Approach

Stochastic Weather Generator

Synthetic daily weather predicted by ALR:

f(AMO, MJO, seasonality, daily markov chain)

(Anderson et al. 2019, Time-varying Emulator.. JGRO)



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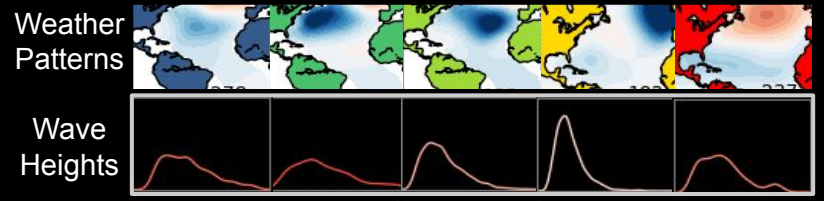
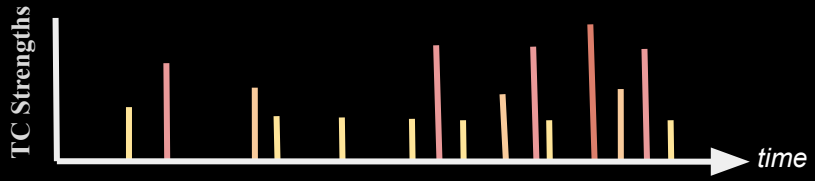
Downscaled Coastal Conditions

Synthetic hourly time series of wave and water levels conditions





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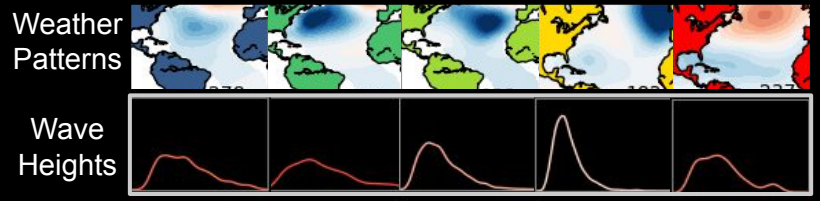

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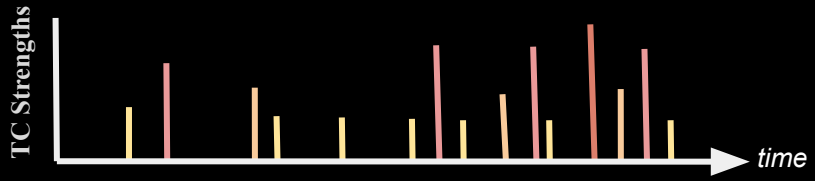
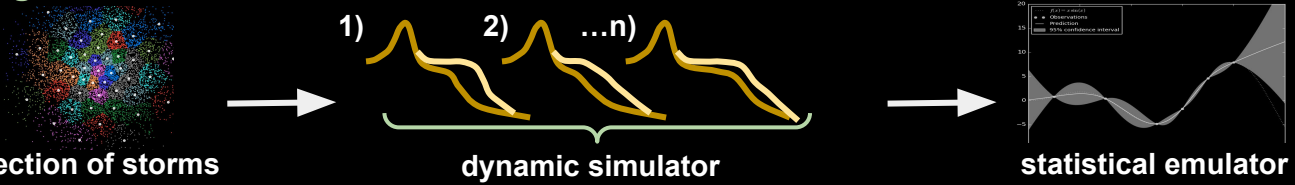


Surrogate Model of Nourishment Erosion



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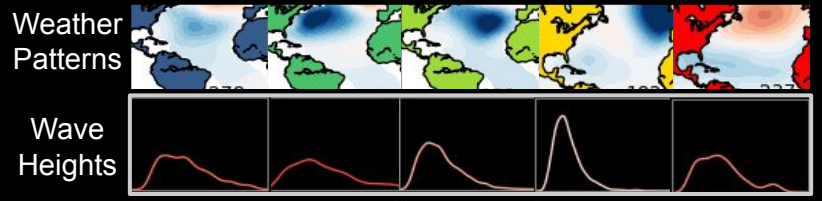

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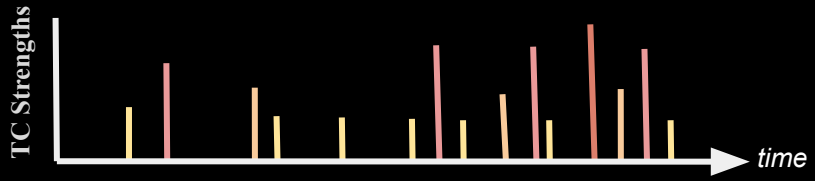

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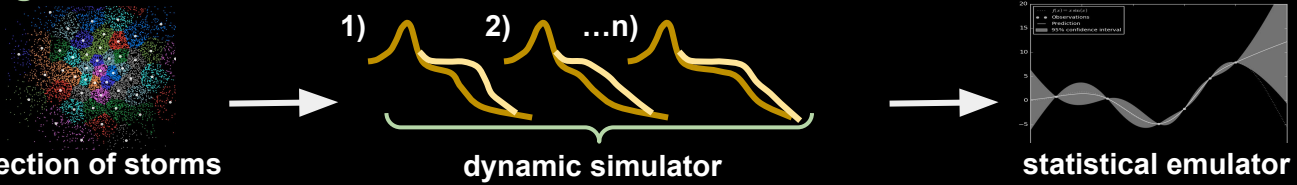
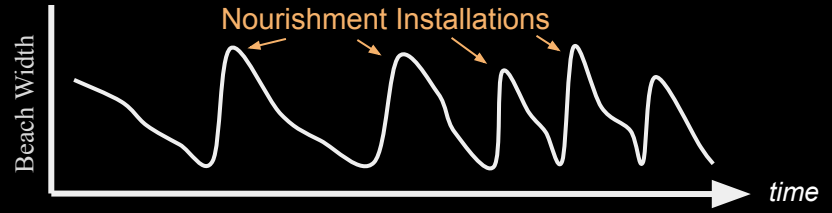


Monte Carlo of Nourishment Evolution

- Erosion during storms, recovery during calm
- Initiate nourishments when beach becomes too narrow



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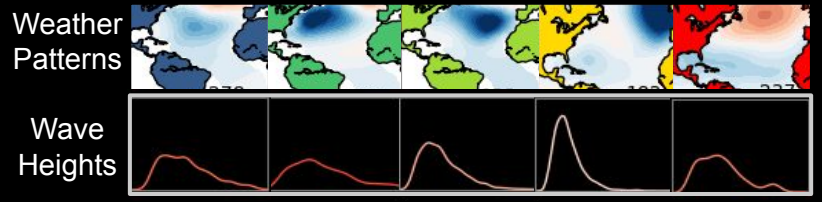

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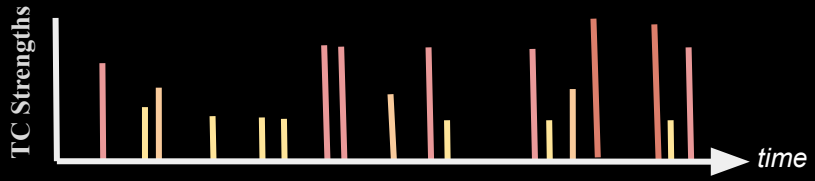

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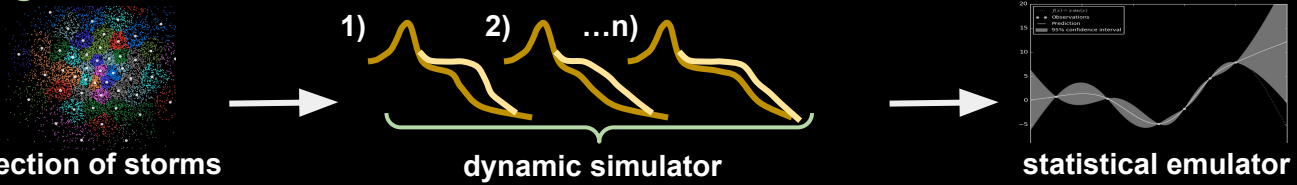

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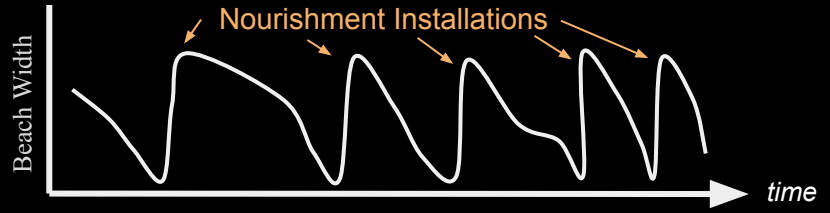


3. Execution Challenges

We had two challenges related to our relationship with the Town of Nags Head

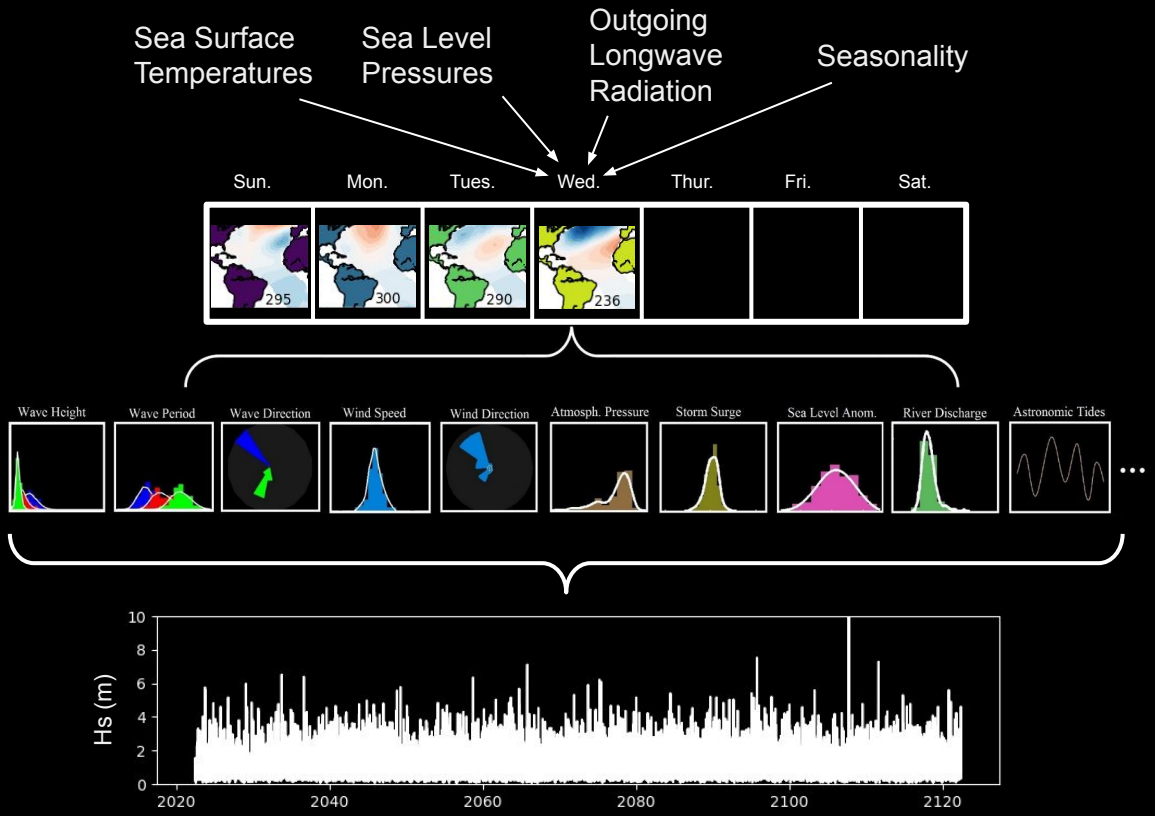
1. Our collaborator Jess Whitehead took a new position
   - Formerly the coastal communities hazards adaptation specialist for NC Sea Grant
   - Worked previously with Nags Head, participated in USCARP pre-proposal, planned to facilitate connections to the town
   - Took position as Director of ODU's Institute for Coastal Adaptation and Resilience
2. Nags Head hired a new coastal engineering firm
   - Now working with Moffat and Nichol
   - Sharing of surveys with the town was delayed until Aug 2020

Both challenges were overcome

- Connected with **David Ryan**, town engineer
- Developed relationships with **Sarah Spiegler** and **Cayla Cothron** at NC Sea Grant

4. Results

Synthetic Future Climates with Potential Coastal Conditions



- Related large-scale climate drivers to local oceanic & meteorological forcing
- Monte Carlo simulations of hypothetical weather sequences
- Downscaled to hypothetical wave and water level time series

Anderson *et al* (in prep) Extreme Coastal Storm Sequences

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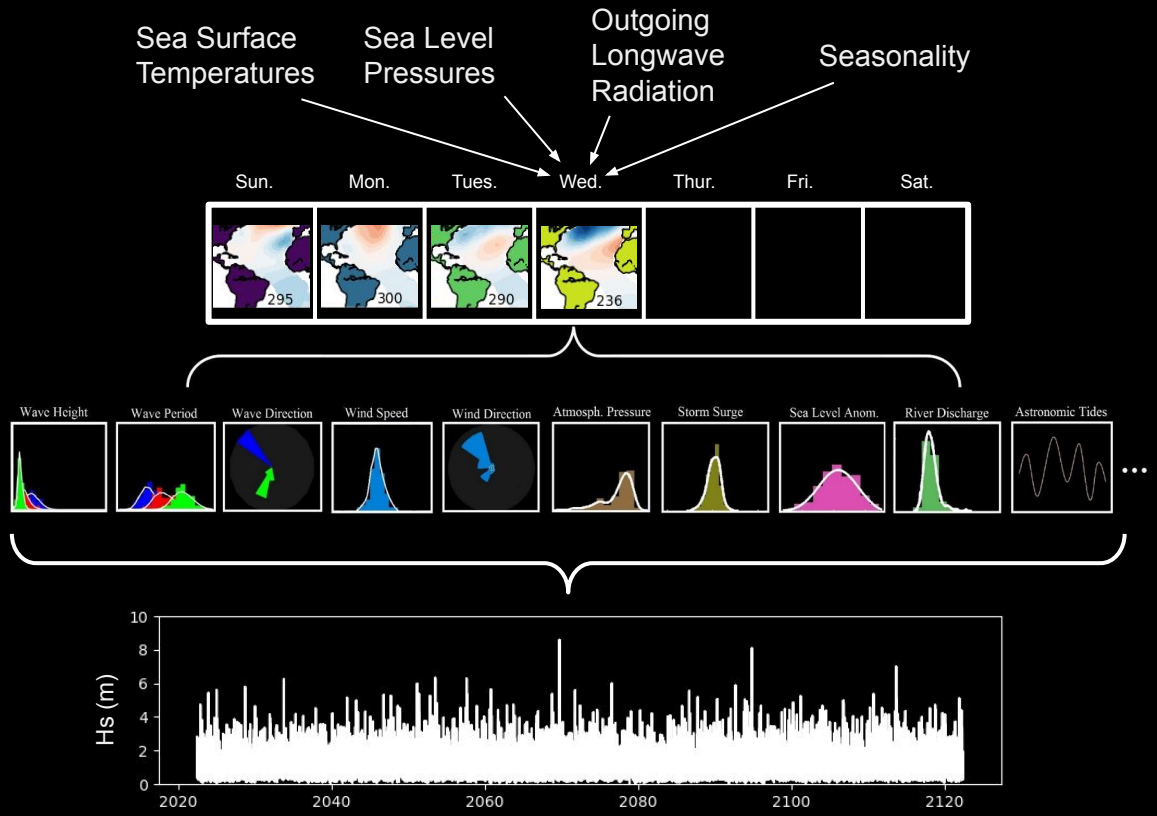

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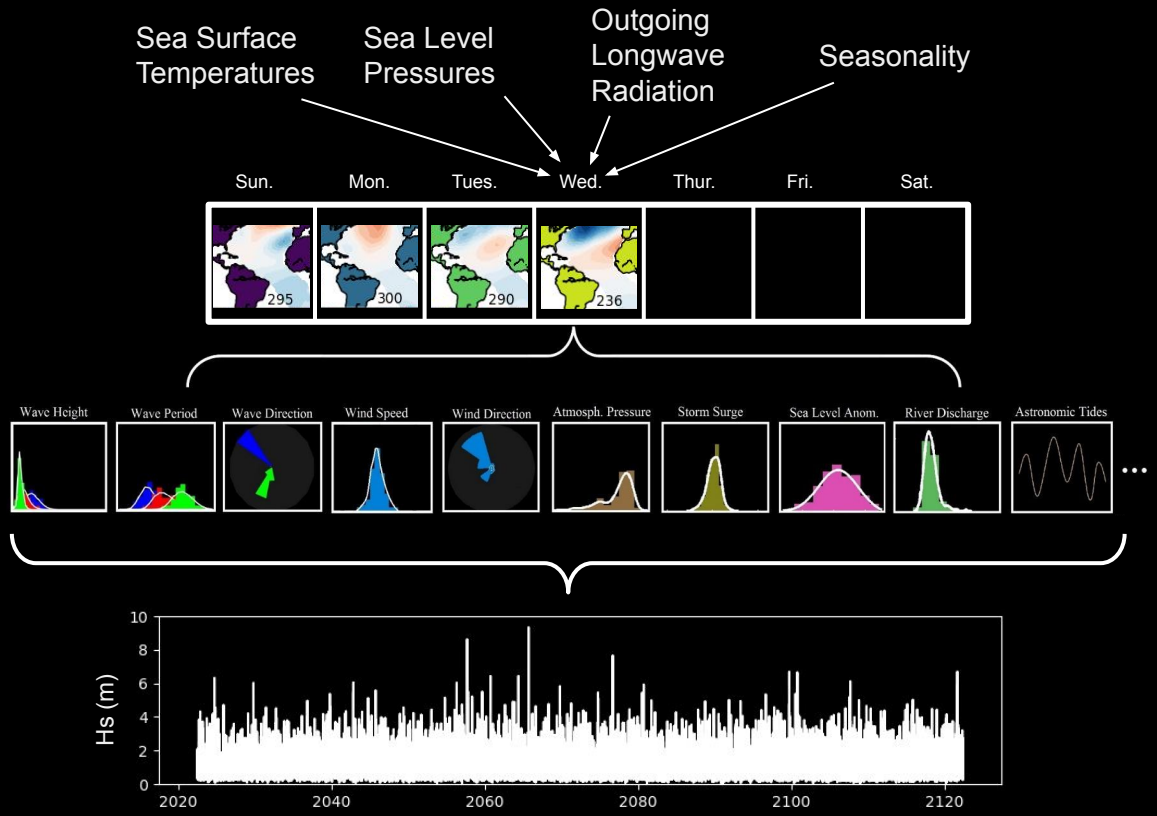

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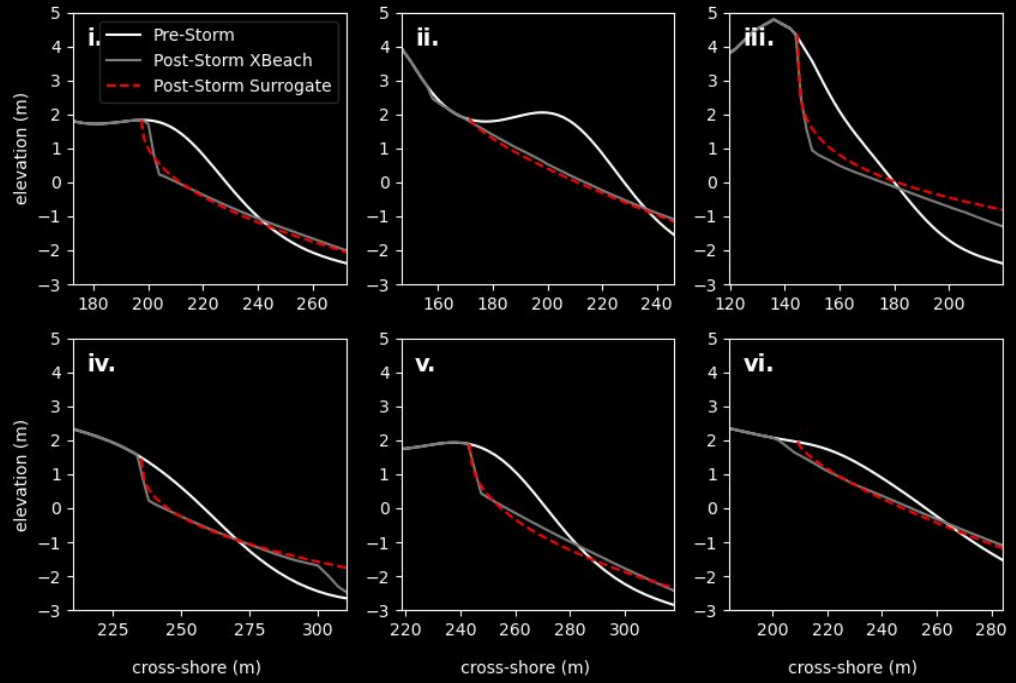
Efficient Prediction of Erosion from a Hypothetical Storm

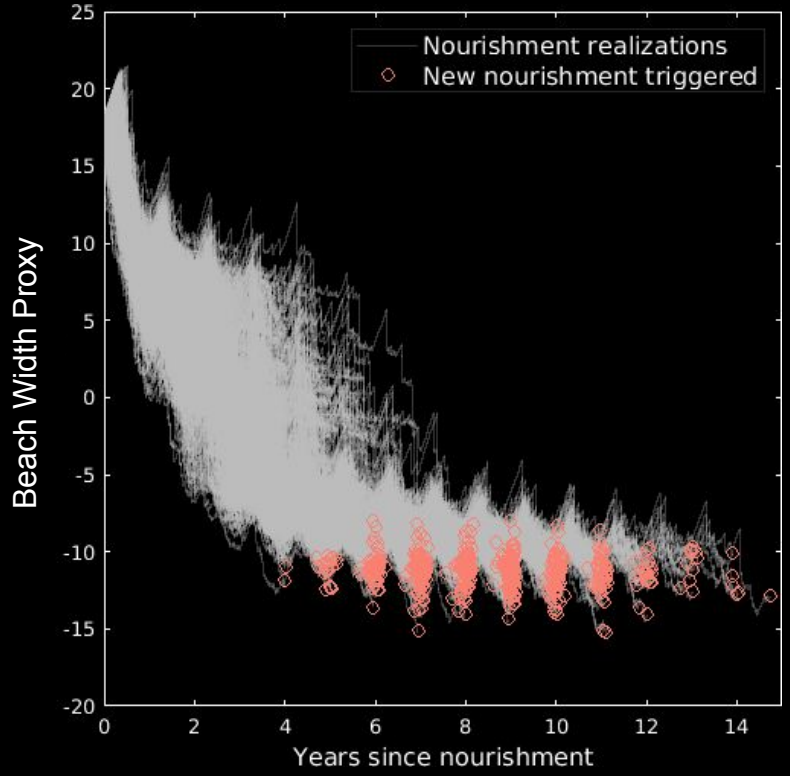


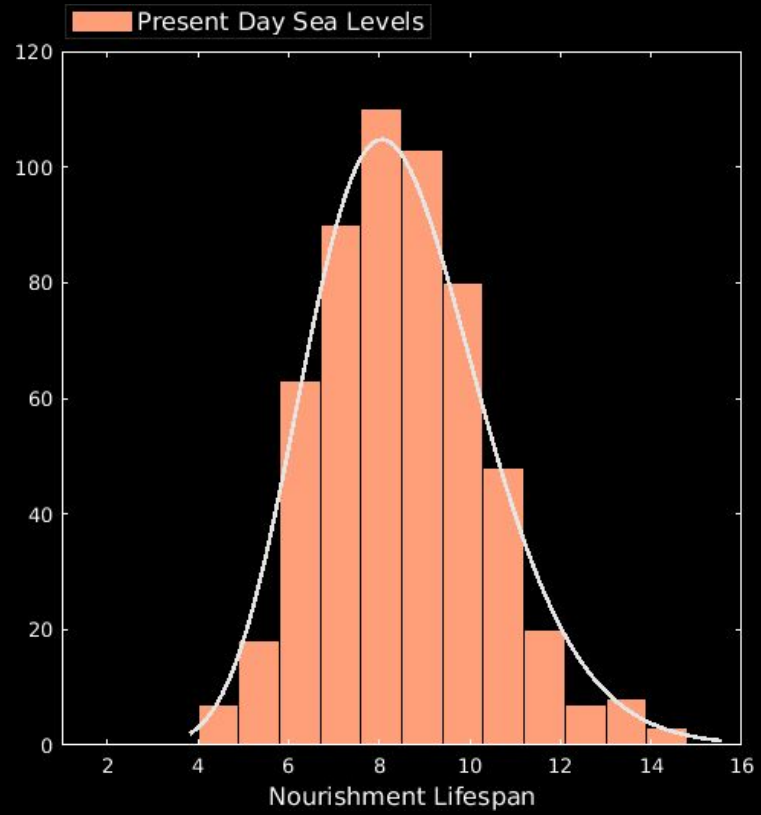
- Created 1250 synthetic storms using Wahl *et al* (2016)
- Reduced dimensionality of the beach profile using EOF magnitudes
- Predicted the scarp feature as defined by an exponential curve

Gharagozlou *et al* (in revision) Emulator for Post-Storm Beach and Dune Erosion

4. Results

Quantify a Range of Nourishment Life Spans





5. Status of Project Deliverables

1. Summarize the state-of-knowledge for adaptation method of coastal communities
   - Published a review article in *Shore & Beach*: “Adaptation pathways for climate change resilience on barrier islands”
2. Develop conceptual models for determining alternative adaptation strategies
   - Framework development with emphasis on future conditions and ability to probabilistically assess adaptation pathways
3. Test, revise, and validate approaches using open-source numerical models
   - Created a surrogate model for subaerial beach and dune erosion
     - Used 1250 XBeach scenarios to train a Gaussian Process Regression model
   - Created a climate emulator for the North Carolina Outer Banks to generate future coastal wave and water level time conditions
     - Developed codes completely in Python for transferability to other locations
   - Currently assessing scenarios of long term nourishment erosion

6. “So What”

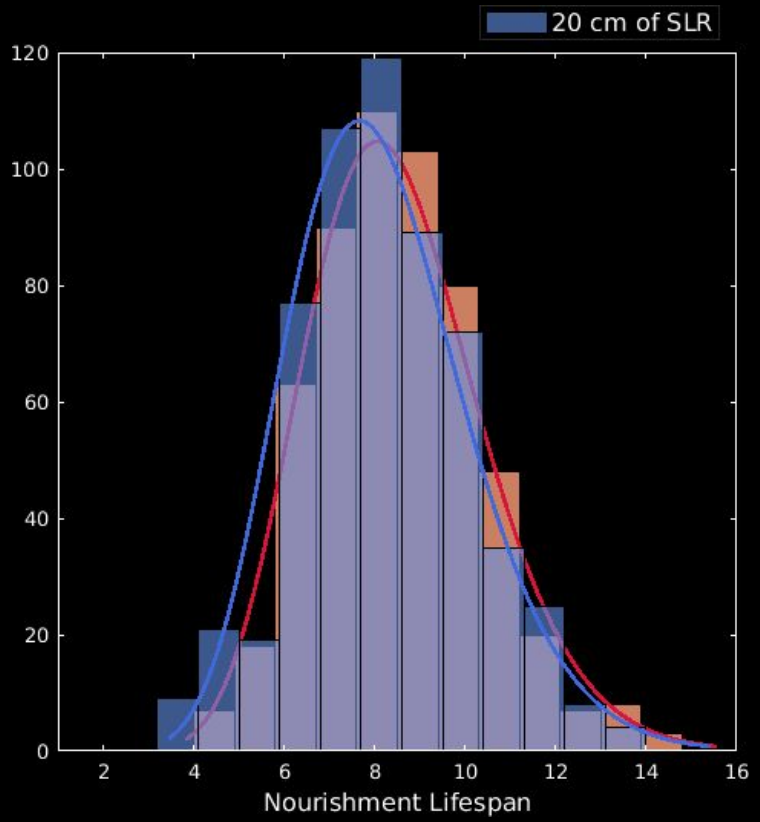
Analysis of Future Scenarios

Surrogate model is fast

- Allows us to understand the effect of slightly higher sea levels, or changes in any environmental variable

Example: sea level rise

- Simulated the exact same storm waves but with 20 cm of SLR
- Randomness of storm variability will remain the dominant determinant of nourishment lifespans during the next ~20 cm of SLR



7. Stakeholder Engagement

1. **David Ryan**, town engineer for Town of Nags Head
   - Slow to connect due to COVID
   - Extremely helpful with sharing surveys of nourishment performance
   - Need to cycle back to him
2. Developed collaborators in new positions at NC Sea Grant
   - Two folks in new positions:
     - **Sarah Spiegler**, coastal resilience specialist
     - **Cayla Cothron**, climate resilience extension associate
   - Excited about our technology, but limited currently in how they can engage
3. Well-positioned to expand
   - Other communities
   - Other weather patterns
   - Other beach/dune responses

8. Summary Metrics

This project supported the training of:

- Dr. **Dylan Anderson** - beginning at USACE May 9
- Dr. **Alireza Gharagozlou** - supported last 2 years of degree, now at Taylor Engineering
- **Jessica Gorski** - supported as an undergraduate and stayed for graduate school


This project supported 2 conference presentations:

- Gharagozlou, *et al*, ASBPA *National Coastal Conference*, October 2020
- Anderson, *et al*, AGU *Ocean Sciences Conference*, February 2022

This project supported 2 publications:

- Anderson, *et al* (2022) *Shore & Beach*
- Gharagozlou, *et al* (in revision) *JGR Earth Surface*

9. Future Plans

Our future plans will focus in key aspects of results and communication

- Push forward the technology
  - Currently preparing a manuscript specific to the wave and water level generator
  - Refining framework for predictions of long-term erosion
    - Calibrating non-storm processes (recovery, alongshore diffusion)
    - Evaluating nourishment scenarios for a manuscript tying the project together
- Push forward the engagement
  - Follow up with **David Ryan**, town engineer for Nags Head
  - Have been in discussions with NC Sea Grant (**Sarah Spiegler** and **Cayla Cothron**) for engagement with other towns and stakeholder interest in dune management

10. USCRP and You

How can the USCRP help you to advance and/or communicate your research findings?

- Need to better plug into expertise at USCRP member agencies
  - Other datasets to consider?
  - Other models/tools to try?
- Need feedback
  - Thanks for your attention!