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Spatial controls & efficiency gains within a coupled spectral wave & circulation model

2025 ADCIRC Users Group Meeting

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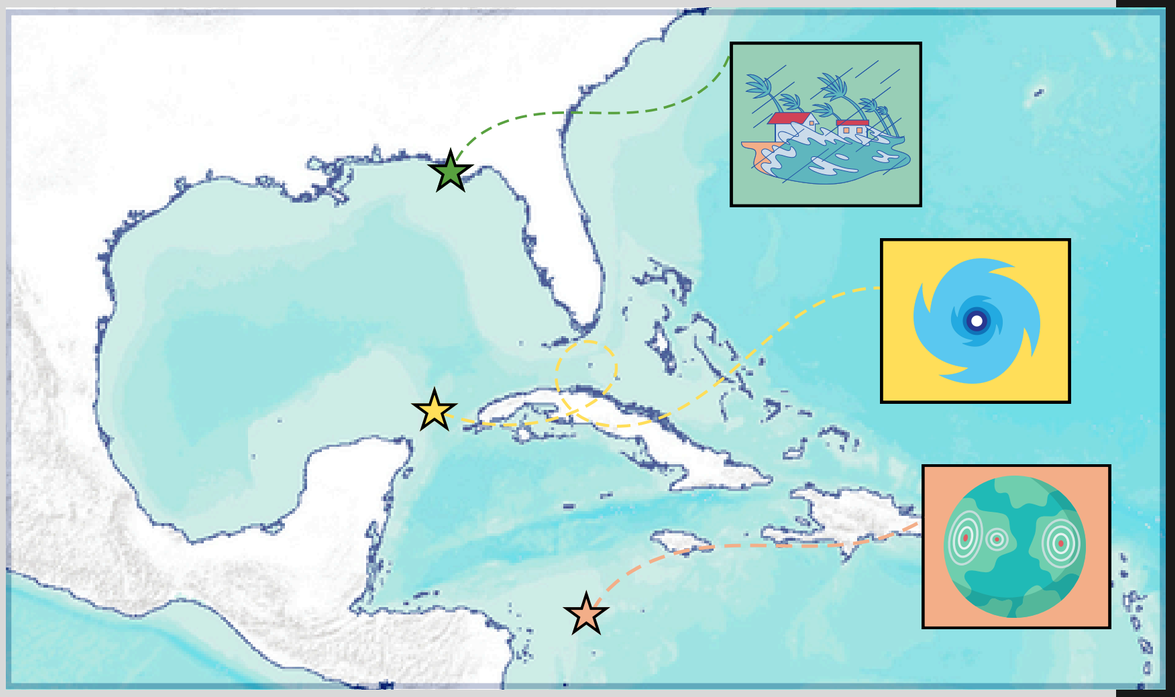
INTRODUCTION

Introduction

Motivation: need for accurate and timely predictions of waves at the coast

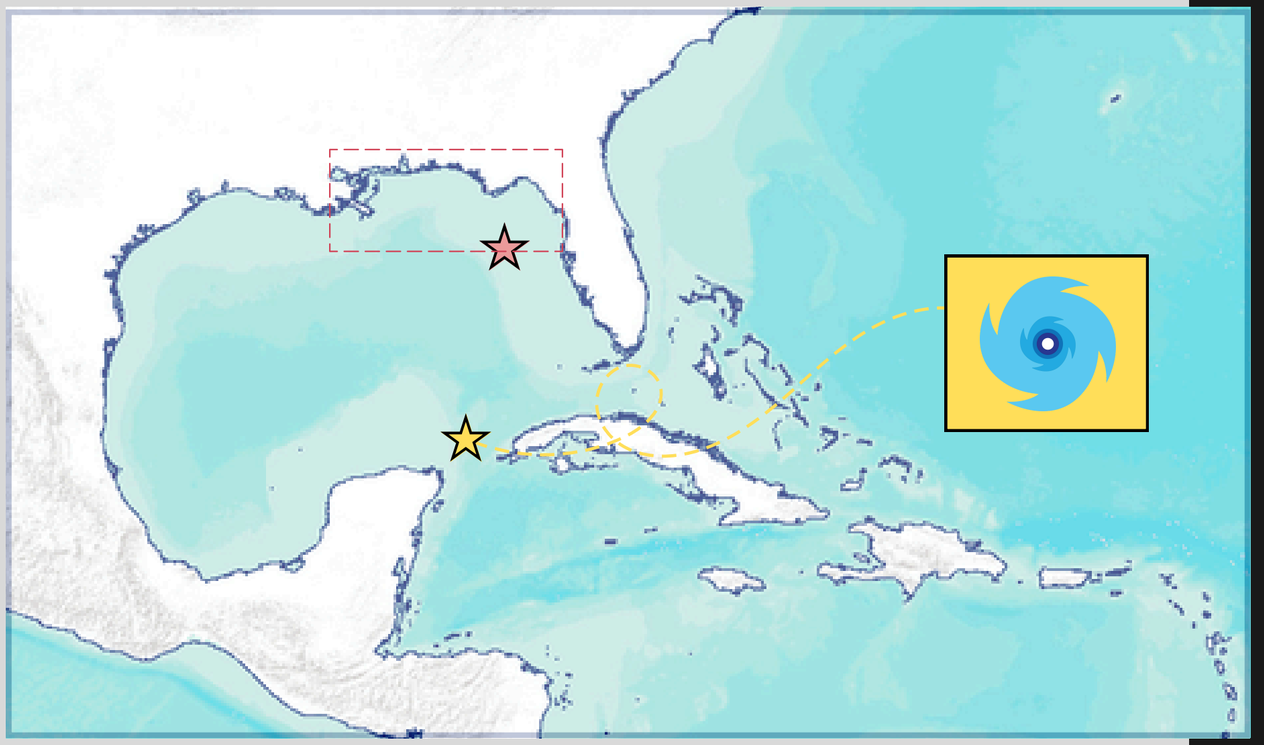
- Coupled spectral wave (SWM) and hydrodynamic circulation models predict wave parameters and spectra, water levels, and storm surge
- Circulation simulated over a large domain
- Nearshore waves modeled over a smaller domain
  - Wave modeling – computationally expensive and time consuming



Introduction

Nearshore wave models require spectral boundary conditions from another source

- To capture the spectral energy generated offshore
- Spectral boundary condition source options:
  - Another model (deep–water or global)
  - Wave buoy
  - Previous simulation of same model

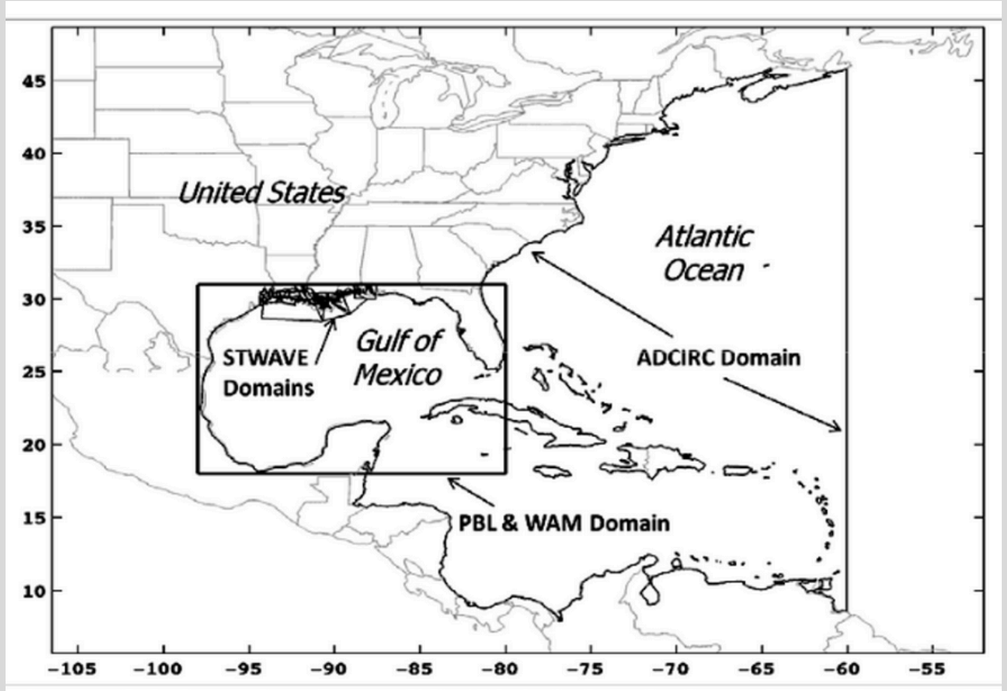


Coupling Configurations

Most coupled models use different domain sizes but this requires heavy spatial interpolation

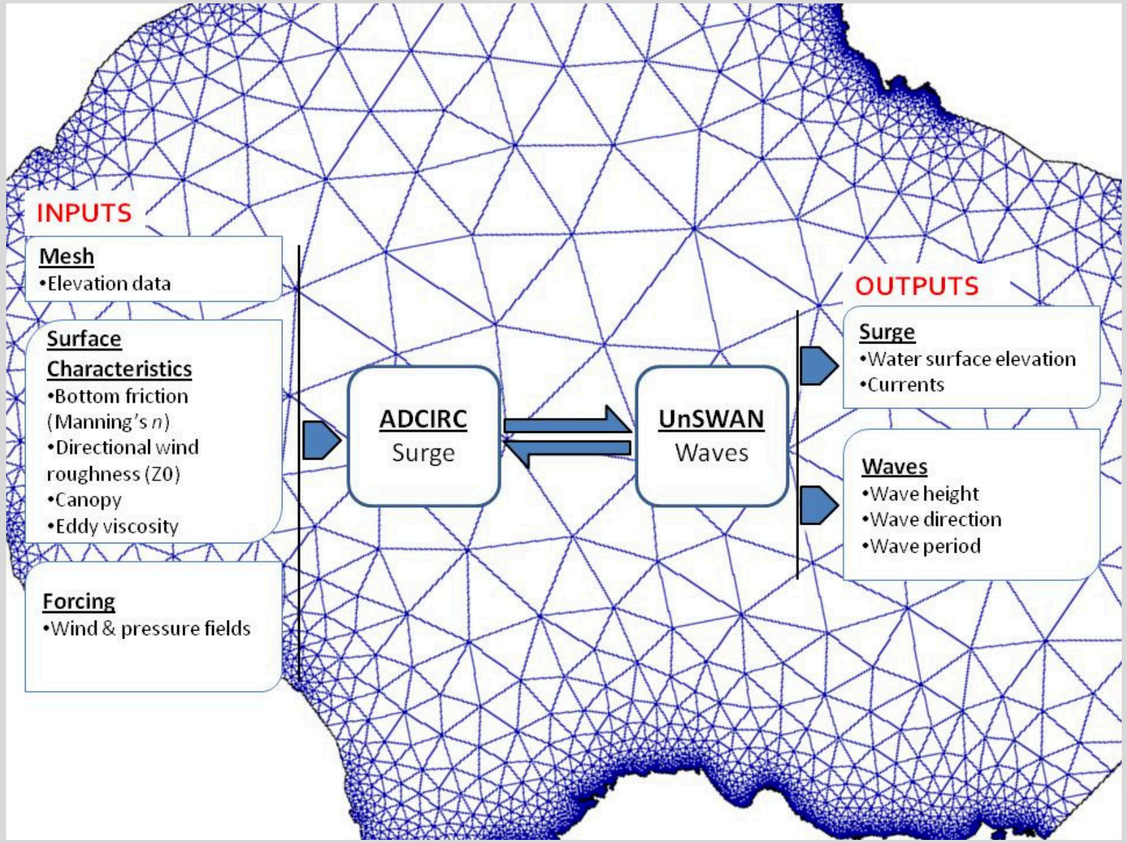
CSTORM–MS (Massey et al., 2011)

- USACE's Coastal Storm Modeling System
  - Uses different spatial coordinate systems
  - Different temporal scales
  - Different cores
- Uses the ESMF framework to couple the ADCIRC and STWAVE models
  - Manages when and how each model runs and interpolates information between the models
  - Manages which model runs on which CPU's



Massey et al., 2011

Coupling Configurations



www.adcirc.org

SWAN+ADCIRC (Dietrich et al., 2010)

- Tightly coupled inside the ADCIRC source code
- SWAN+ADCIRC uses:
  - Identical spatial mesh domain
  - Same inputs
  - Same duration
- Same spatial domain eliminates the spatial interpolation, but results in waves computed in a larger domain than the primary area of interest

Coupling Configurations

	Framework (CSTORM)	Source Code (SWAN+ADCIRC)
Domain Size	Different	Identical
Coupler High Level (Simulation)	Controlling when models start and stop, assigning models to CPU's	None
Low Level (Per Time Step)	Handling interpolation and communication between models	No interpolation, local communication

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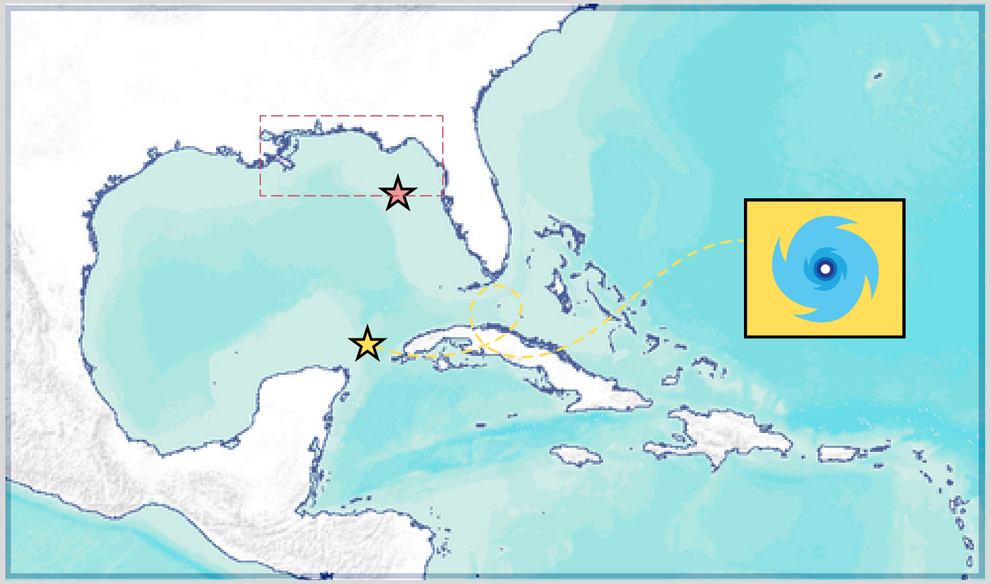
RESEARCH OBJECTIVE

Objective

Model waves over a smaller area still using *identical mesh*

- **Increase speed and efficiency of SWAN+ADCIRC, while preserving accuracy**

- Alter spatial controls
- Remain on an identical mesh domain
  - Deactivate SWAN outside of new smaller domain

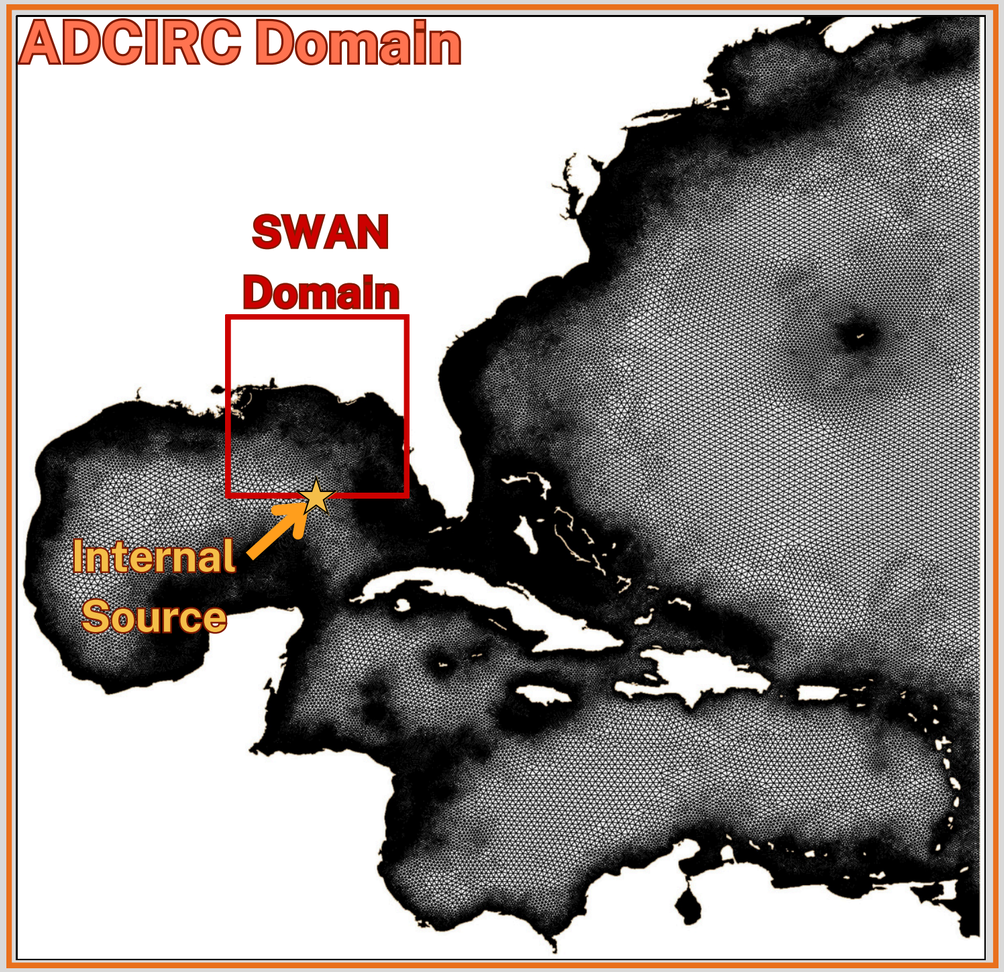


Objective

Run SWAN+ADCIRC using limited SWAN domain and internal sources

1 – Activate SWAN for a specific desired domain

2 – Input spectral boundary conditions (internal sources) for the partial domain (wave parameters, spectra from buoy or previous simulation)



Coupling Configurations

	Framework (CSTORM)	Source Code (SWAN+ADCIRC)	New Modifications (SWAN+ADCIRC)
Domain Size	Different	Identical	Identical, SWAN only active in partial domain
Coupler High Level (Simulation)	Controlling when models start and stop, assigning models to CPU's	None	None
Low Level (Per Time Step)	Handling interpolation and communication between models	No interpolation, local communication	No interpolation, local communication

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USER WORKFLOW

Nodal Attribute

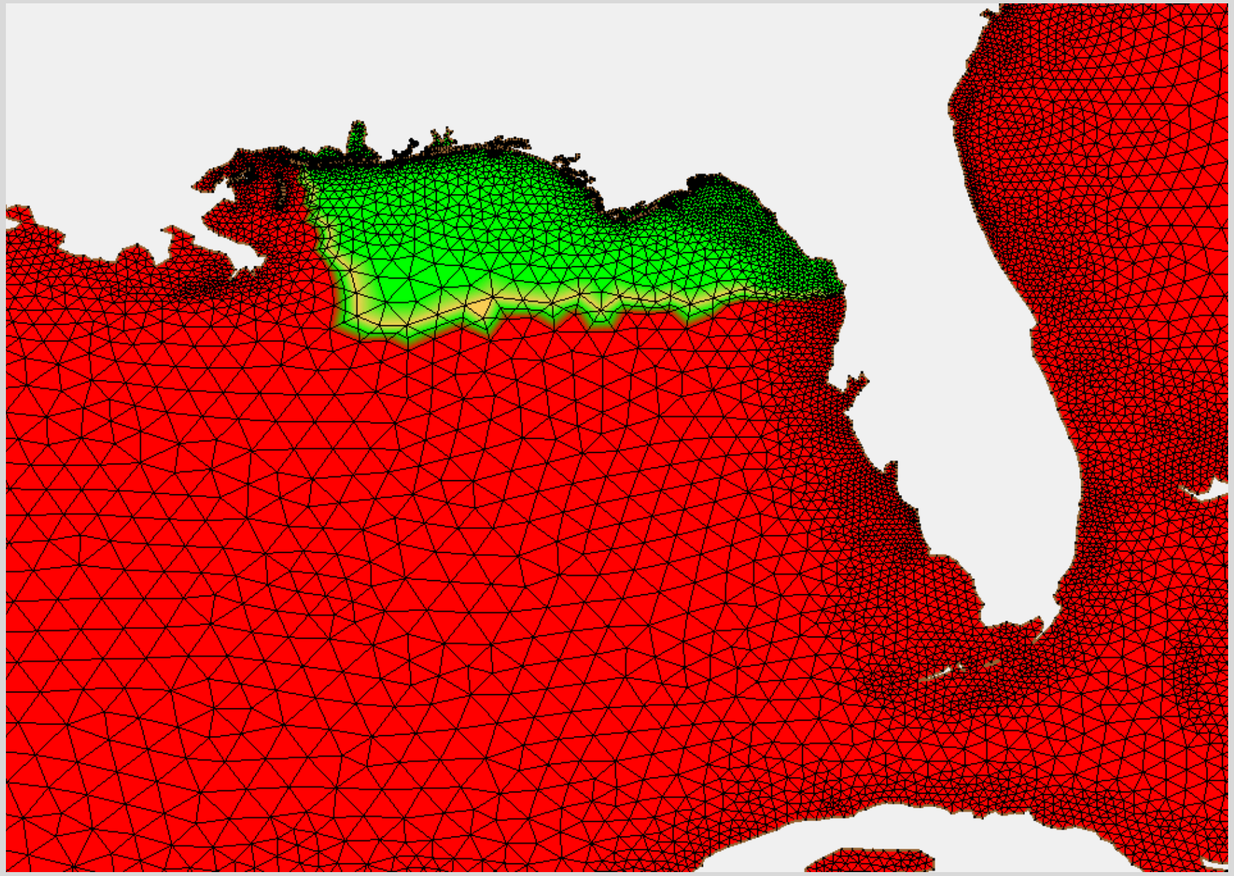
Swan Local Control –

- Two values
  1. Is SWAN active at this node?
     - 1 = on (default value)
     - 0 = off
  2. Is this node an ‘internal source’?
     - 0 = not an internal source (default value)
     - Positive integer = internal source

```
Spatial attributes description
swan_local_control
 1                          units
 2                          number of values
 1  0                       default values
```

```
swan_local_control
 28910
 1  0  0          Node #, SWAN on, internal
 2  0  0          source (side number)
 3  0  0
 4  0  0
 5  0  0
 6  0  0
 7  0  0
 8  0  0
 9  0  0
 10  1  101
```

Nodal Attribute



```
Default value 1 0
```

SWAN on Internal source

```
swan_local_control
 28910
 1  0  0
 2  0  0
 3  0  0
 4  0  0
 5  0  0
 6  0  0
 7  0  0
 8  0  0
 9  0  0
 10  1  101
```

User Workflow – Steps

Step 1

Pre-processing Python code with user inputs

User Input

Input mesh domain (fort.14), nodal attributes file (fort.13), polygon outline of desired SWAN domain (list of lon/lat points)

Input internal sources (lon, lat, .spc file name)

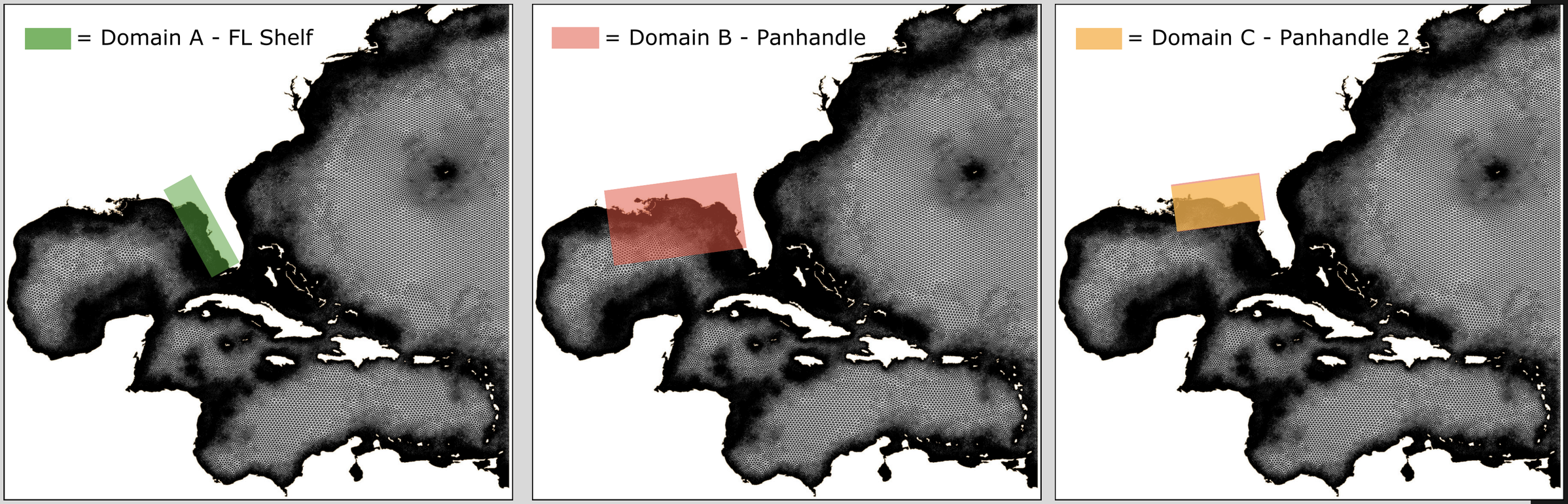
Python Code

Checks every node in mesh to find nodes within the polygon and sets to active in the nodal attribute file

Finds nodes closest to given sources and sets to a positive integer in nodal attribute file. Then prepares SWAN input file (fort.26) with commands to apply spectral BCs here

User Workflow – Steps

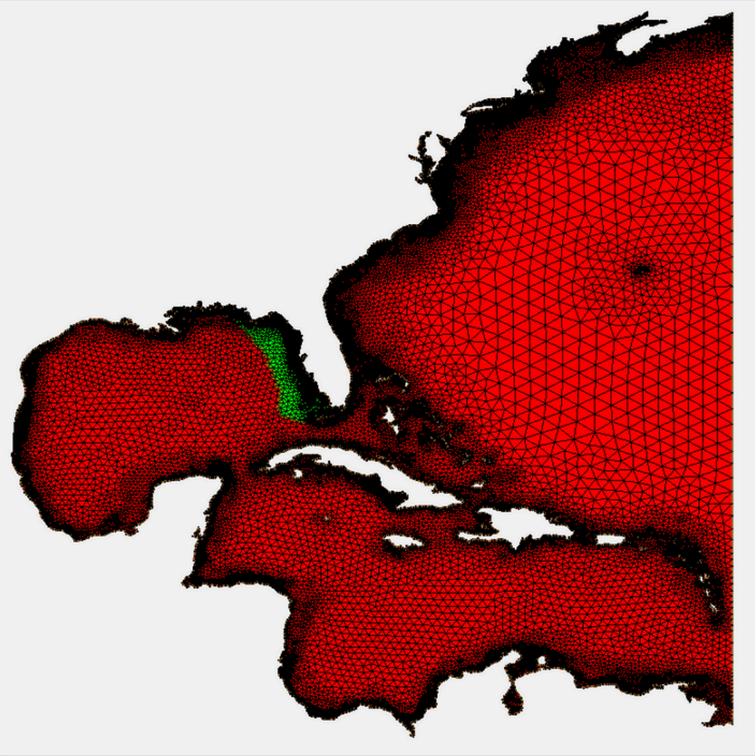
Varying spatial SWAN domains – Polygon Inputs



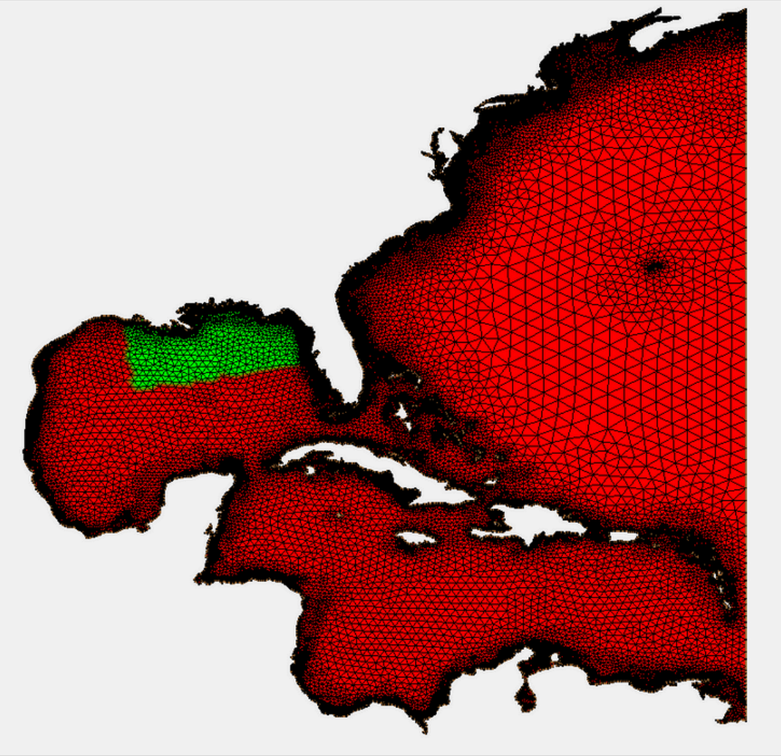
EC–95 Mesh Domain

User Workflow – Steps

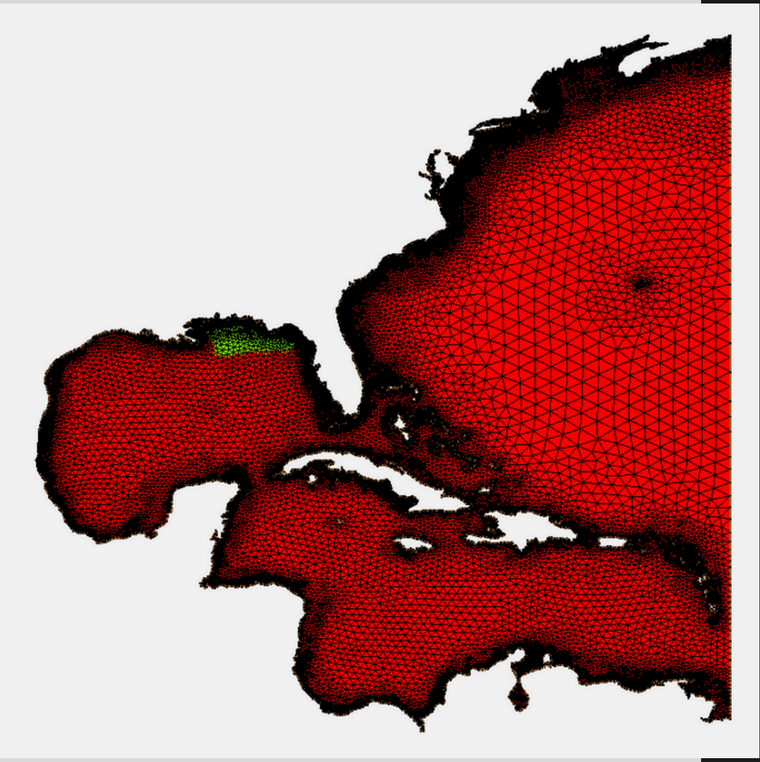
Varying spatial SWAN domains – Active Regions



Domain A - FL Shelf



Domain B - Panhandle



Domain C - Panhandle 2

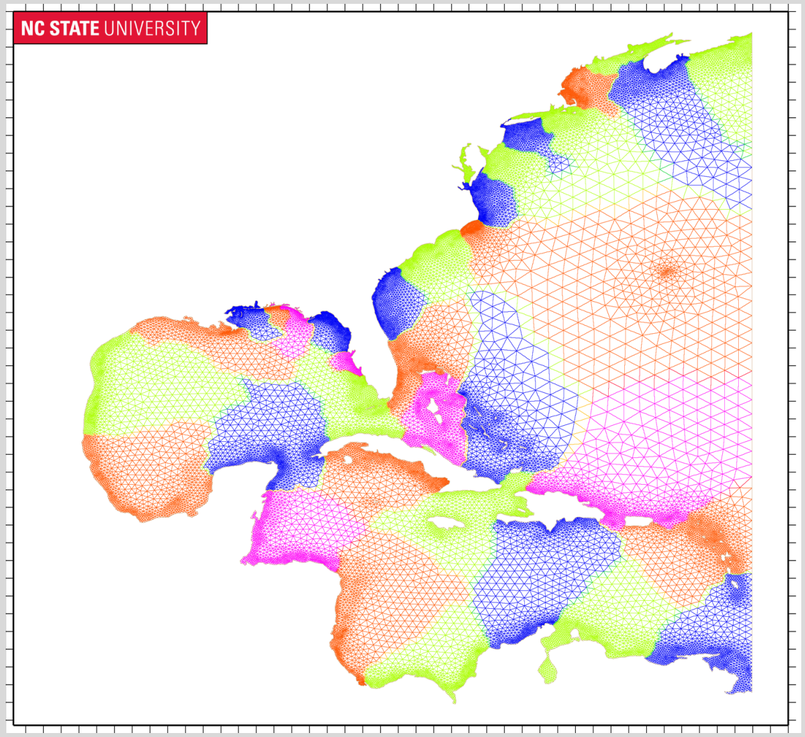
User Workflow – Steps

Step 2

Run ADCPREP using new nodal attribute file and SWAN input file

Parallel SWAN+ADCIRC

ADCPREP decomposes and splits domain into PE subfolders (ex. 32 cores)

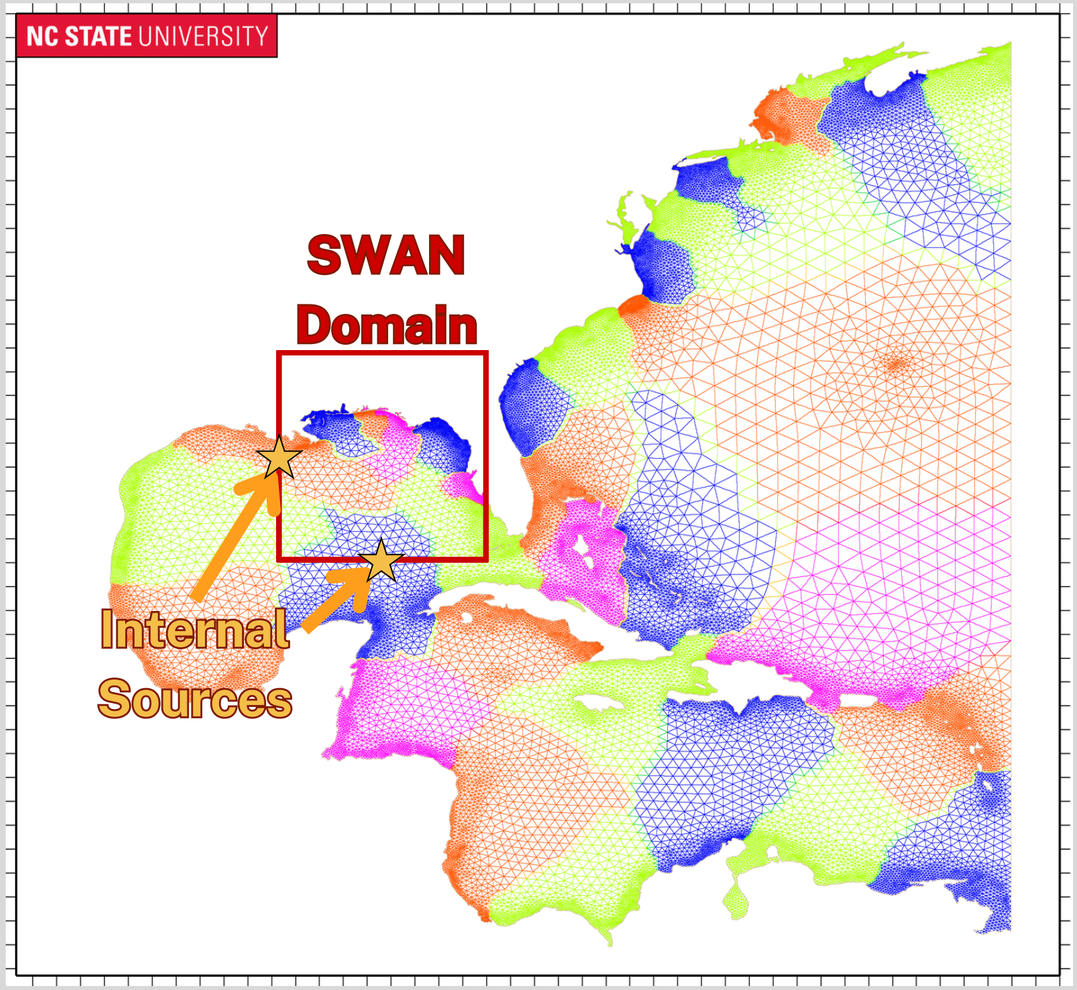


User Workflow – Steps

Step 3

Source Prep Python code

- Identifies which internal source nodes are in which PE folder
- Adds lines to local SWAN input files (fort.26) to apply spectral BCs



User Workflow – Steps

Step 4

Run PADCSWAN

SWAN+ADCIRC

ADCIRC identifies nodal attribute. SWAN activates only nodes within polygon

SWAN adds internal sources to boundary data. Applies energy density from input and prohibits spectral energy computations here.

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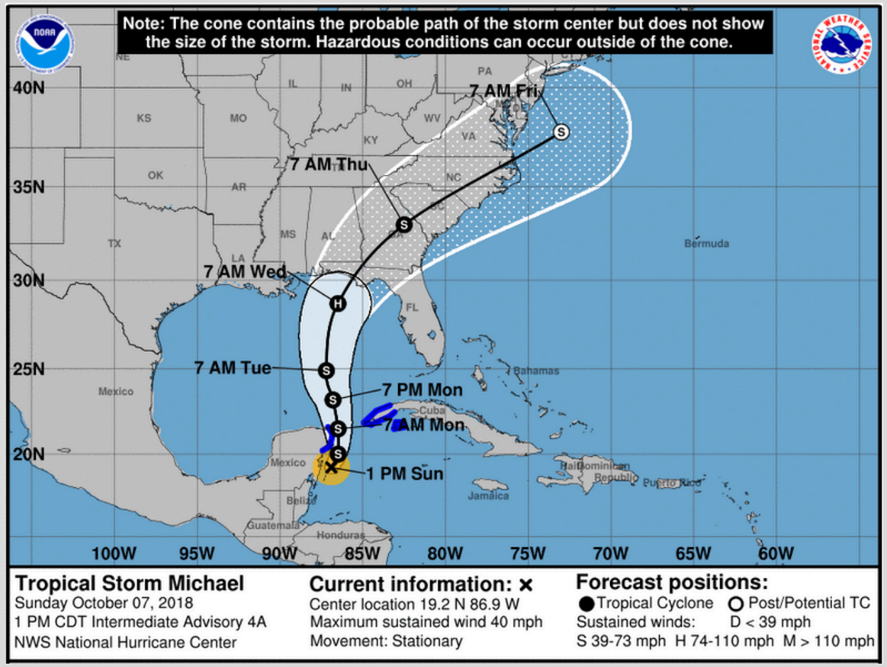
TEST CASE

Model Validation

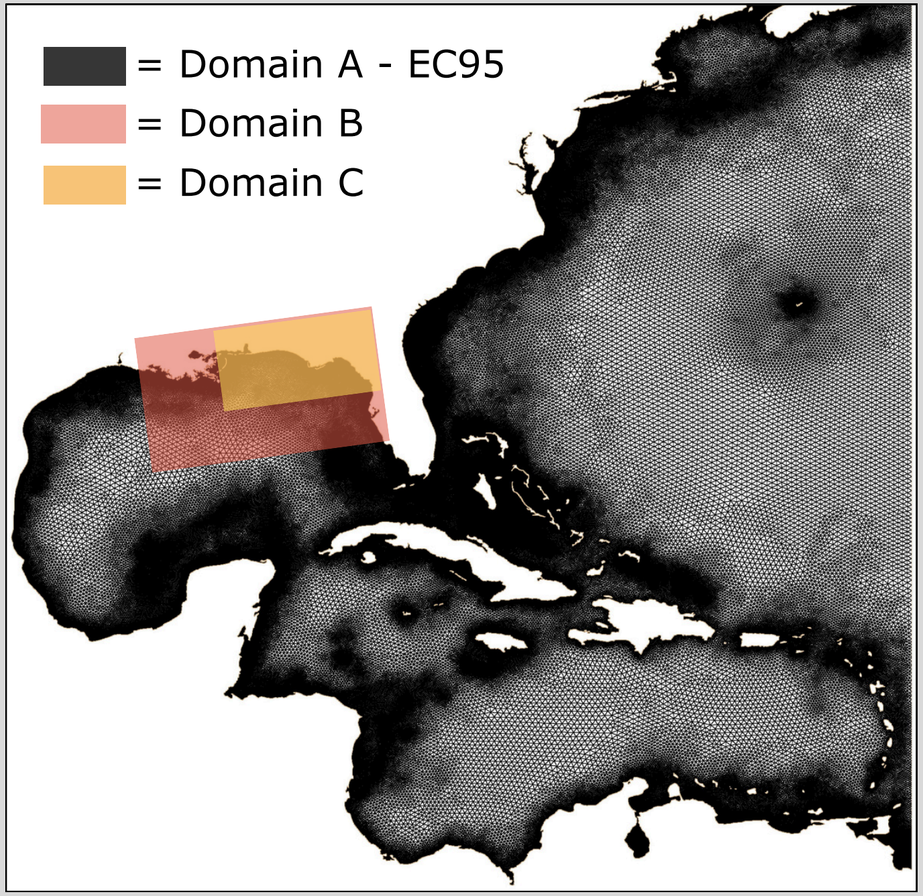
Storm and Data:

- Hurricane Michael, 2018
  - EC–95 mesh domain



nhc.noaa.gov

Varying spatial SWAN domains

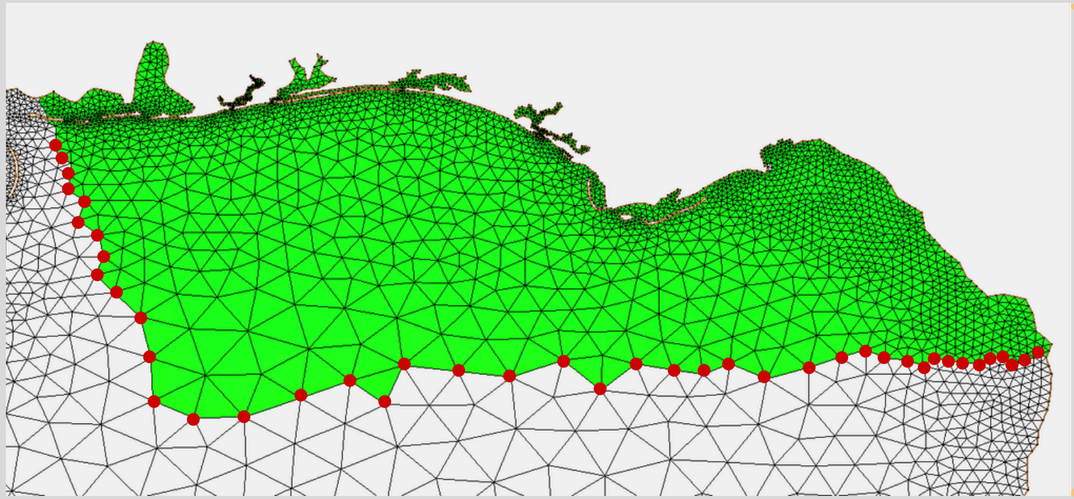


EC-95 Mesh Domain

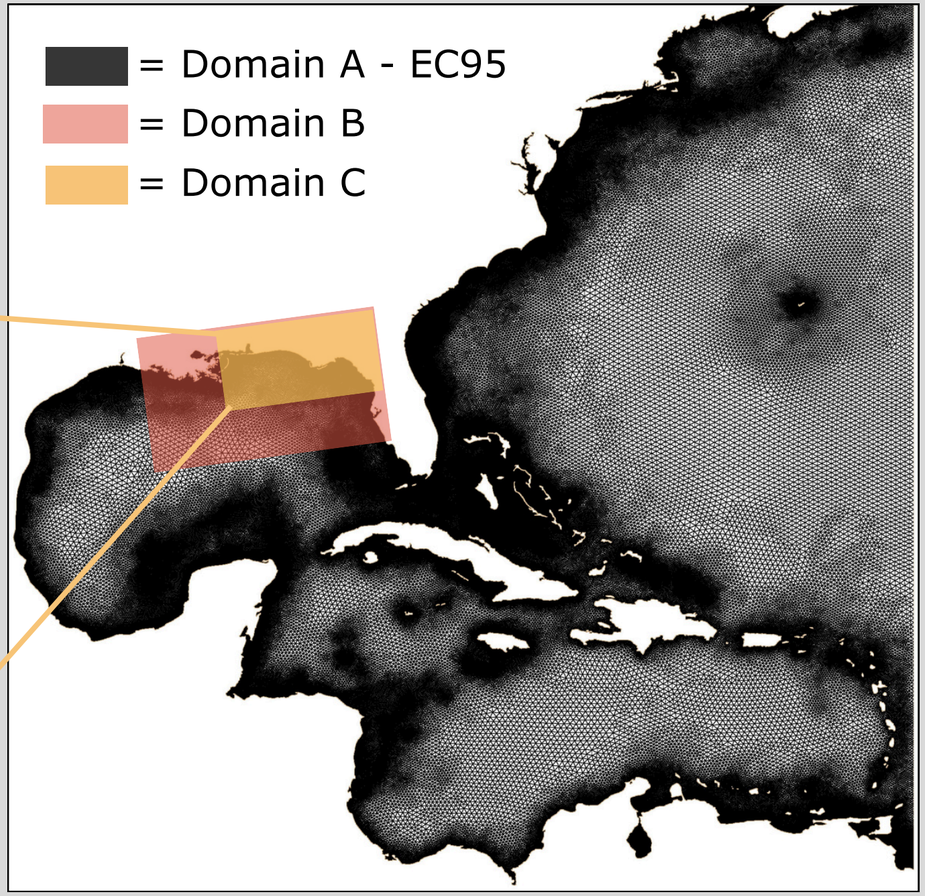
Model Validation

Spectral Internal Sources:

- 2D wave spectra exported from Domain A
  - At every node along SWAN domain



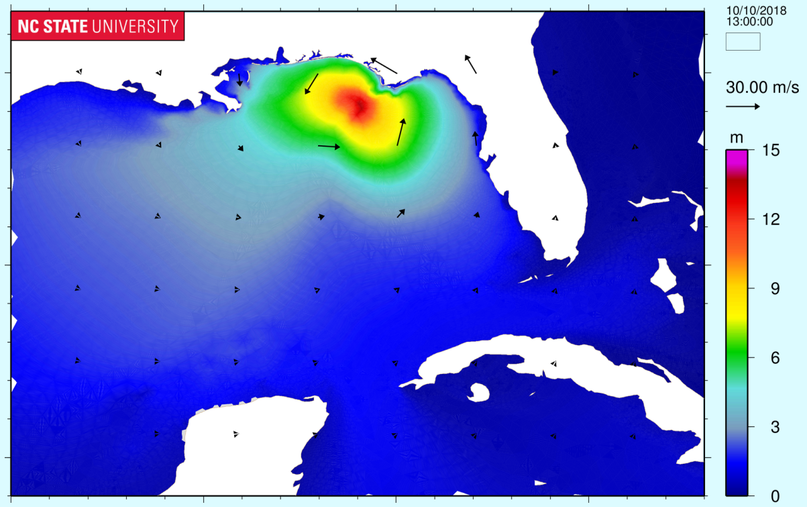
Varying spatial SWAN domains



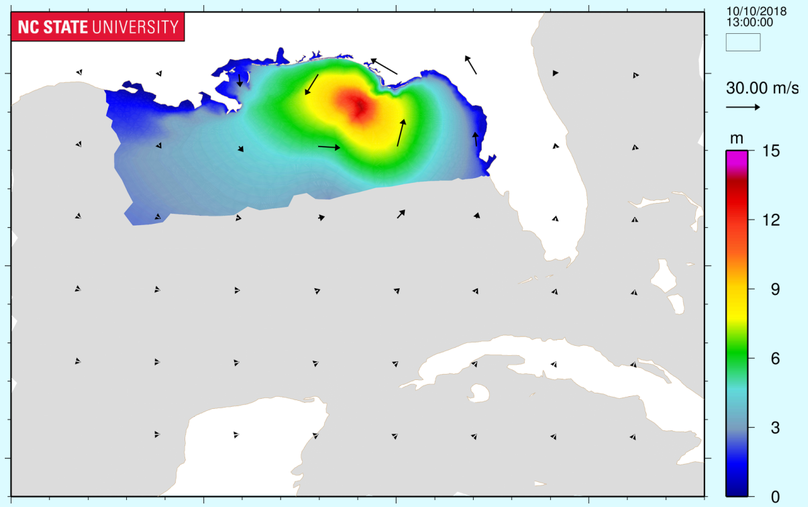
EC-95 Mesh Domain

Successful Domain Comparisons

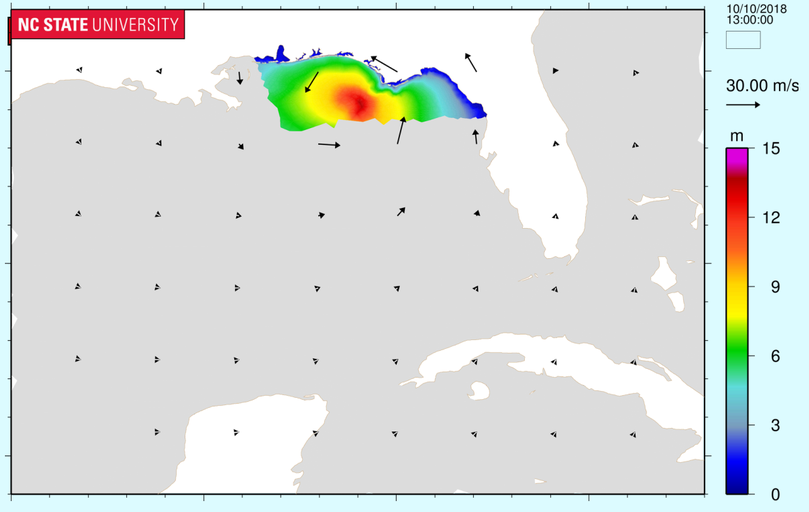
Hurricane Michael (2018) Significant Wave Heights (m) for varying spatial SWAN domains



Domain A



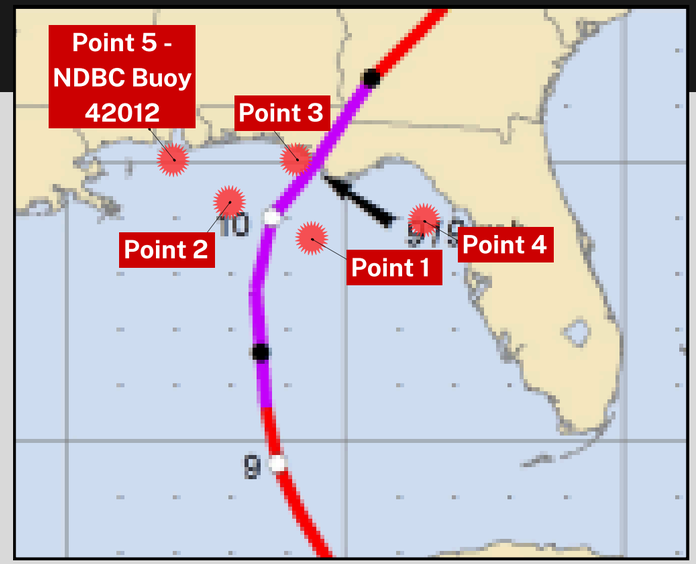
Domain B



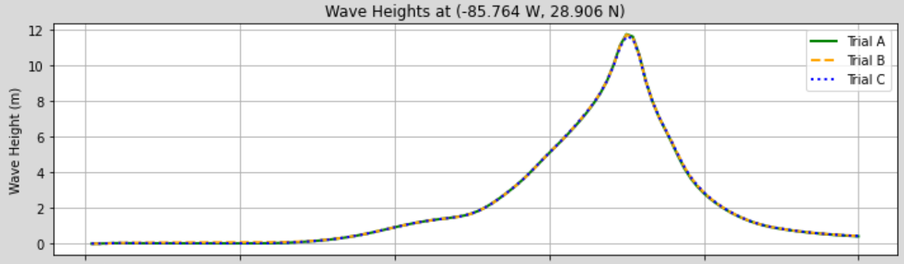
Domain C

Successful Domain Comparisons

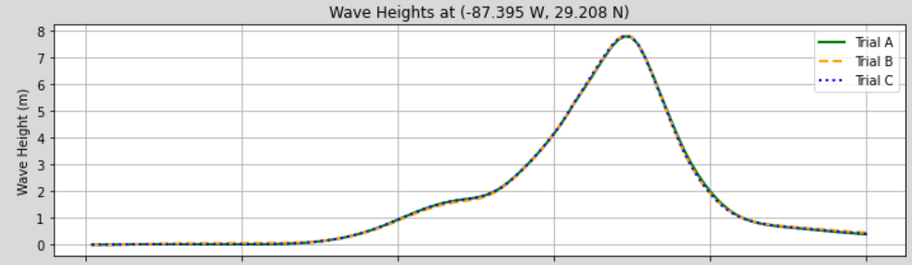
Significant Wave Height Time Series



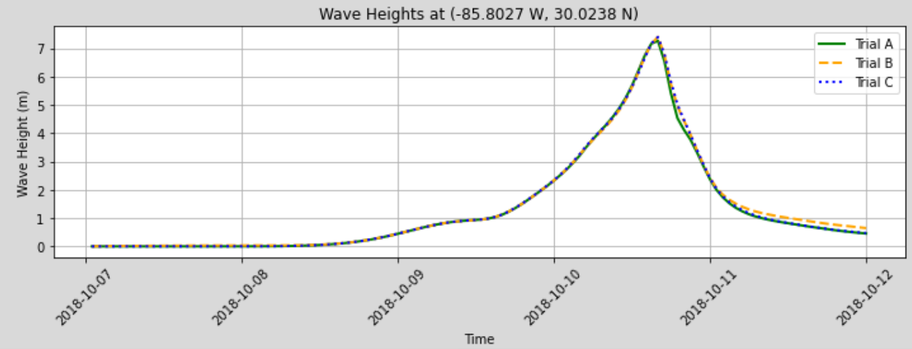
Point 1



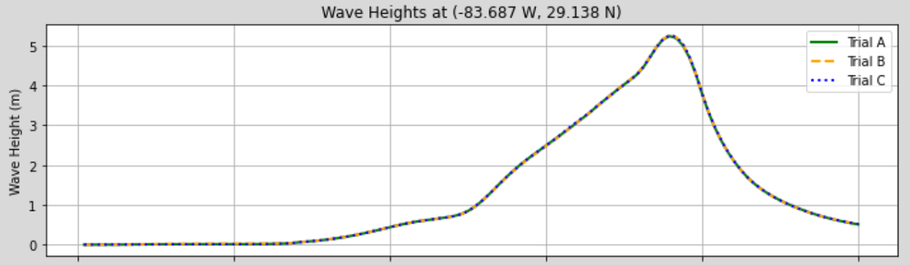
Point 2



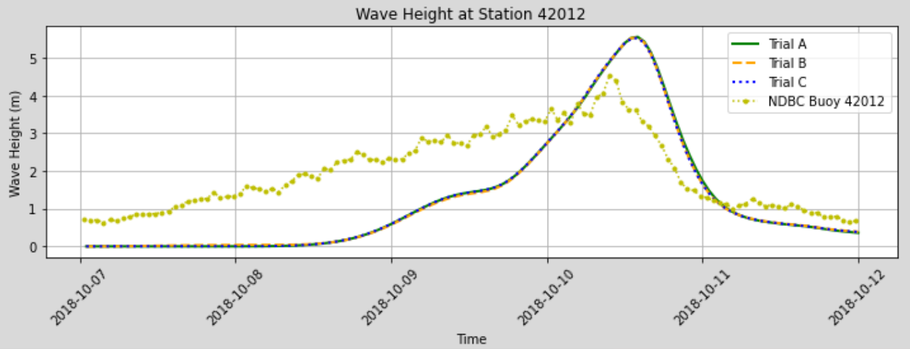
Point 3



Point 4



Point 5 - NDBC Buoy 42012



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CONCLUSION

Next Steps & Conclusion

Conclusion:

- We can use any spatial extent for wave computations
  - *If* we have *sufficient* spectral energy inputs
  - Must adequately represent the wave energy generated from offshore

Initial Timing Tests:

- Show a 27.48% speedup in simulation time
  - Comparing modifications with limited domain versus full domain
  - Likely will improve when computational load balancing is implemented

- Very preliminary findings – will need to test more
  - Account for different domain cuts, meshes, cores

Next Steps & Conclusion

Next Steps:

- Finalize implementation for all use cases
  - Including varying sources of spectral inputs
- Quantify efficiencies gained with model performance
  - Timing tests
- Test varying domains and examine the impact of domain extents in wave interactions

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We appreciate your interest and engagement today

Thank You for Your Attention!

Presented by:
Nicole Arrigo

QUESTIONS?

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