Forecasts of Waves, Storm Surge, Flooding and Damage due to Hurricane Ian (2022)

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Casey Dietrich, Jessica Gorski - North Carolina State

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3rd International Workshop on Waves, Storm Surges, and Coastal Hazards

10/5/2023

National Oceanographic Partnership Program

COASTAL RESILIENCE CENTER
A U.S. Department of Homeland Security Center of Excellence

NOPP - Hurricane Coastal Impacts Program

10 NOPP teams

- Meteorological forcing
- DEMs and land cover
- Wave buoy obs
- Shore based obs
- Remote sensing
- 3 modeling teams

Goal: End to end prediction from tropical cyclone meteorological forecasts to impact**s** on land

- Improved understanding and predictability of hurricanes and their impacts on land
  - Flooding
  - Coastal Breaching
  - Erosion
  - Property Damage
  - Infrastructure Damage
- Pre-landfalling forecasts of up to 3 hurricanes per year in 2022-24
- Ian was our 2022 event
- Idalia, Lee in 2023, so far….

Components

1. Meteorology
    - Typically use - NHC Best Track & forecasts → parametric TC model
    - NOPP project – Navy COAMPS-TC, 4 km dynamic gridded model
2. Tide + Surge + Wave model
    - ADCIRC + SWAN
    - ADCIRC + WWIII (NOAA)
3. Dune Overtopping & Morphology change models
    - 1D Xbeach – Jessica Gorski
4. Damage model
    - HAZUS – Flood Hazard Import Tool – FEMA
    - Considerable ongoing work to catalogue damage and build ML damage models

1. Meteorology – COAMPS-TC

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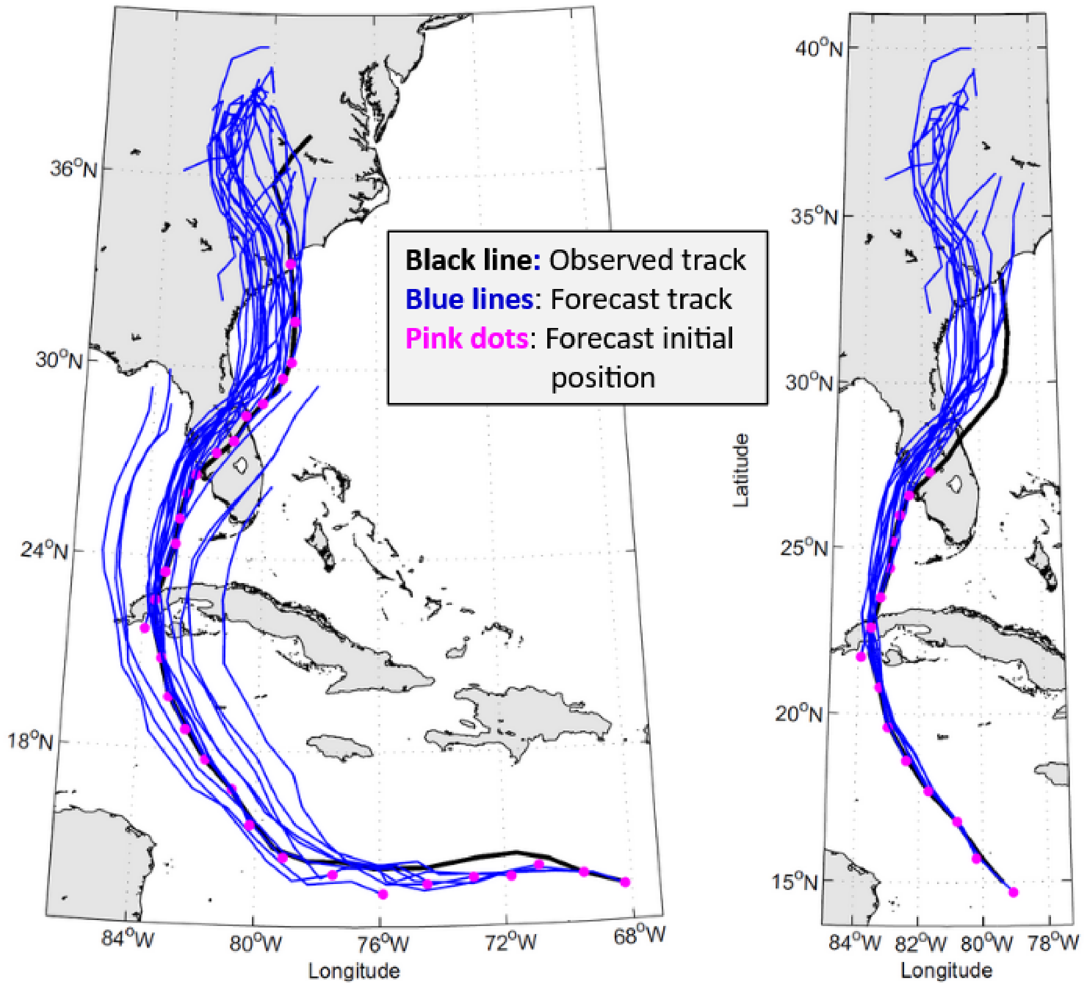
Track Validation

- **Some early CTCX forecasts took the storm over the Florida Keys or towards the Big Bend region on the Florida Gulf coast, but starting with the 25/12z initial time CTCX locked on to a landfall position between Fort Myers and Tampa**
- All CTCX track forecasts issued with five days of the South Carolina landfall correctly indicated that Hurricane Ian would emerge off the Florida east coast and make a second U.S. landfall in SC

CTCX: All forecasts | **CTCX: 25/12z – 29/00z initial times**



W. Komaromi, J. Doyle, J. Moskaitis, H. Jin
US Naval Research Laboratory

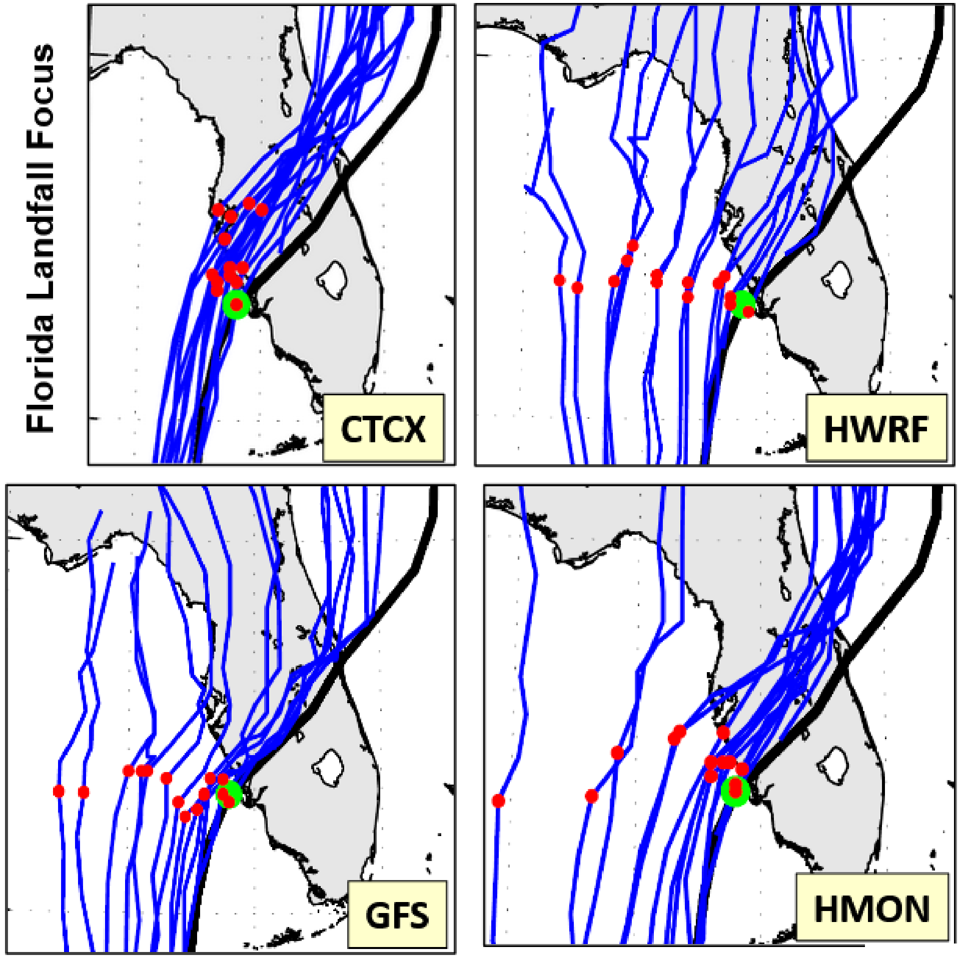
1. Meteorology – COAMPS-TC

Track Validation

- Within three days of Florida landfall, COAMPS-TC forecasts did exceptionally well to predict the timing of landfall on the Florida west coast, but erred a bit north on position

- GFS, HWRF, and HMON tended to track the storm too far west, with landfall too late and too far north/west along the west coast of Florida

25/12z – 28/18z initial times



Black line: Observed track
Green dot: Observed TC position at time of landfall

Blue lines: Forecast tracks
Red dots: Forecast TC positions at time of landfall

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1. Meteorology – COAMPS-TC

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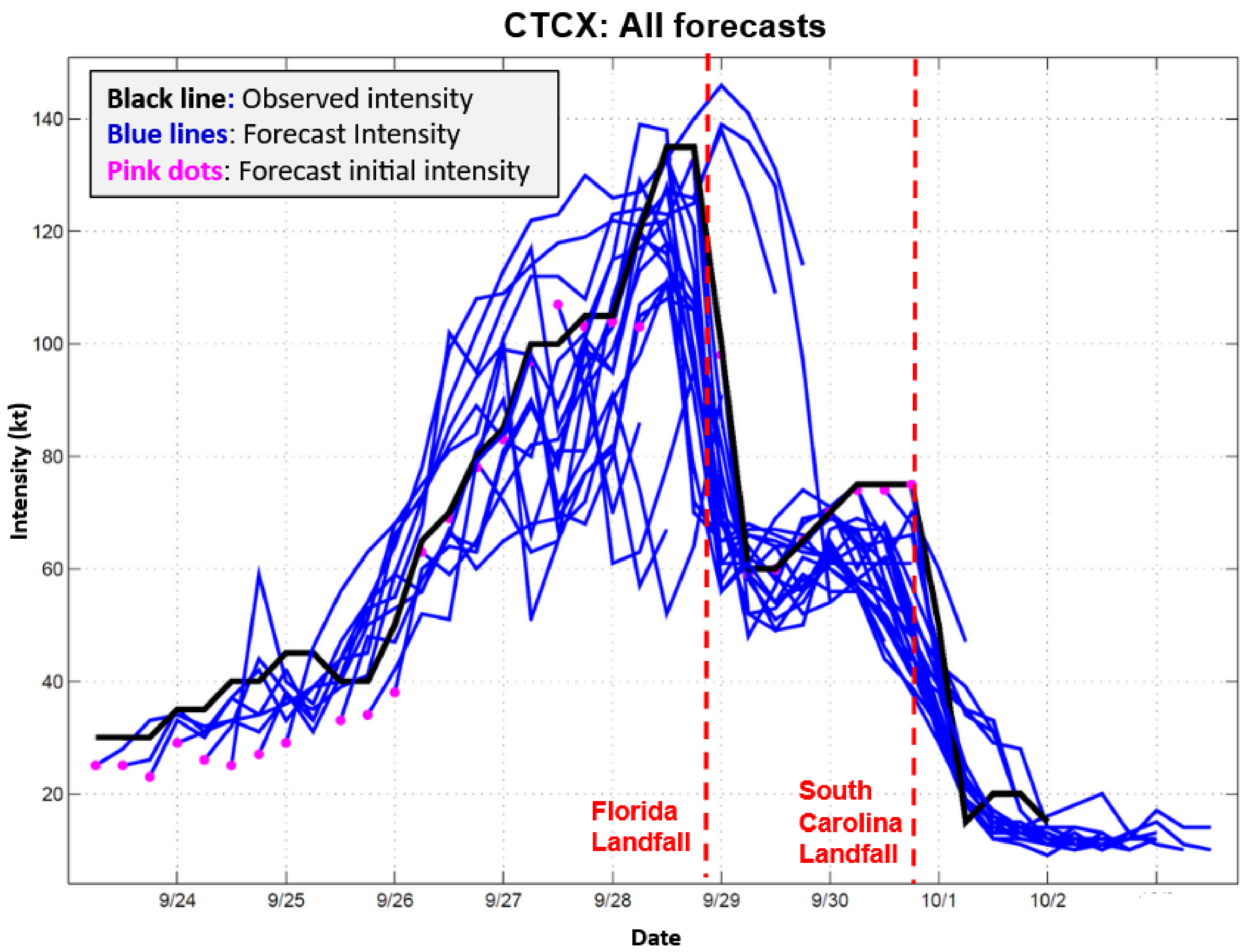
Intensity Validation

- Even in early forecasts 4 to 5 days in advance, when Ian was a weak tropical storm, CTCX predicted Ian to be a major hurricane in the Gulf of Mexico

- CTCX tended to somewhat underestimate the intensity at landfall, both for Florida and South Carolina



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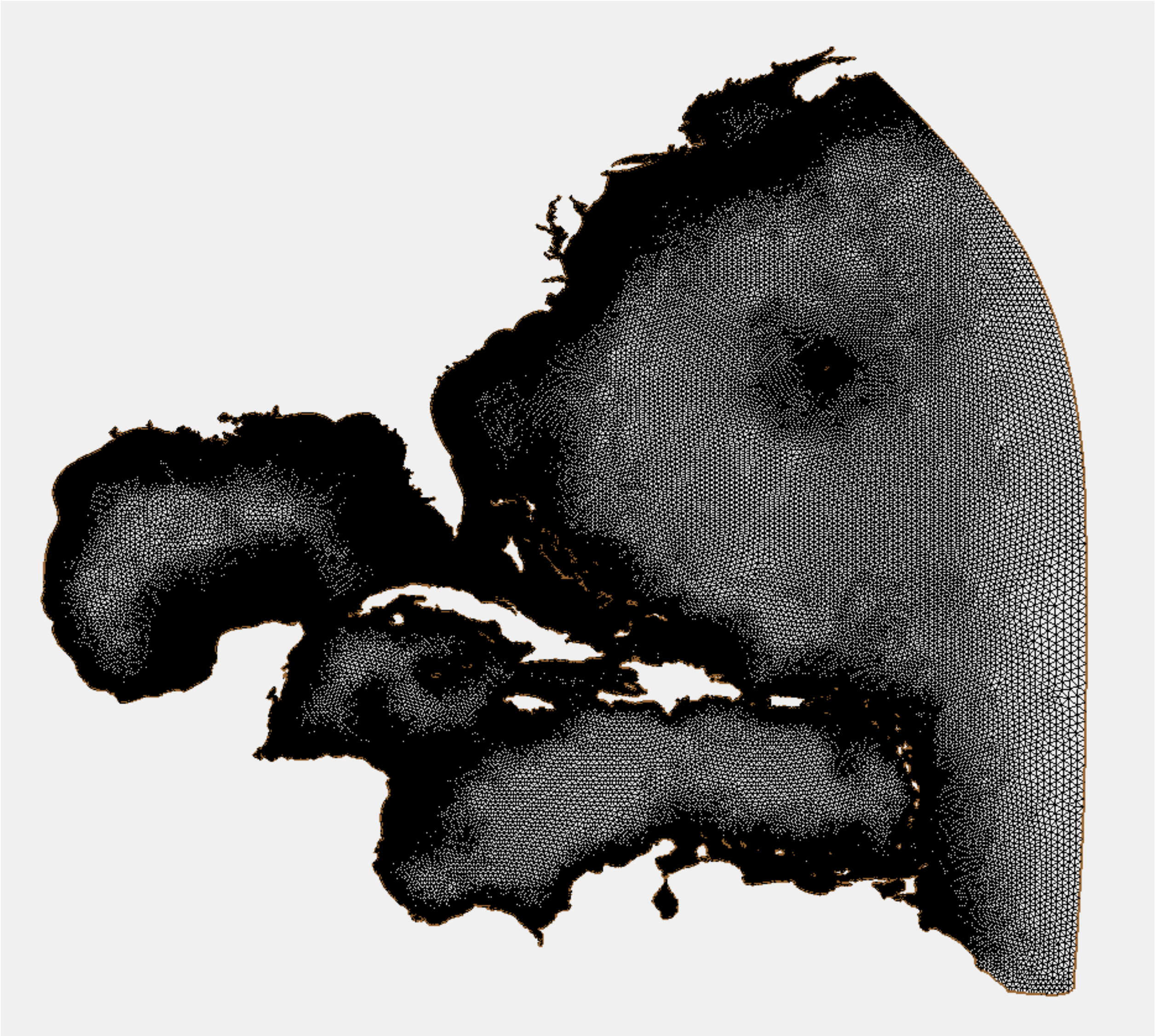
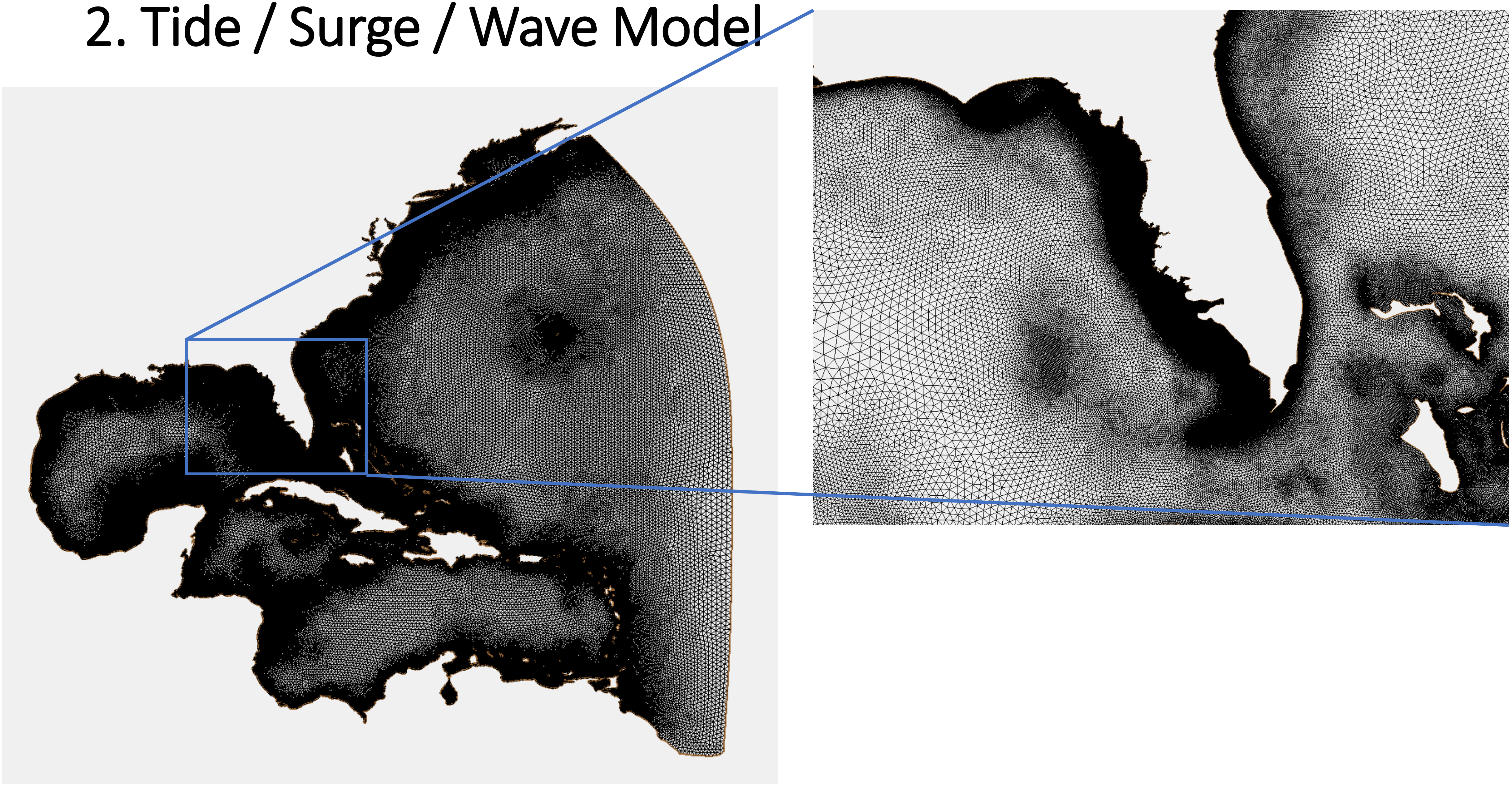
2. Tide / Surge / Wave Model



EGOM-RT_v20b Mesh

- 2.2M nodes
- ADCIRC+SWAN ~1hr / 5 day
- 1024 processors at Pittsburg Super-Computer Center

2. Tide / Surge / Wave Model



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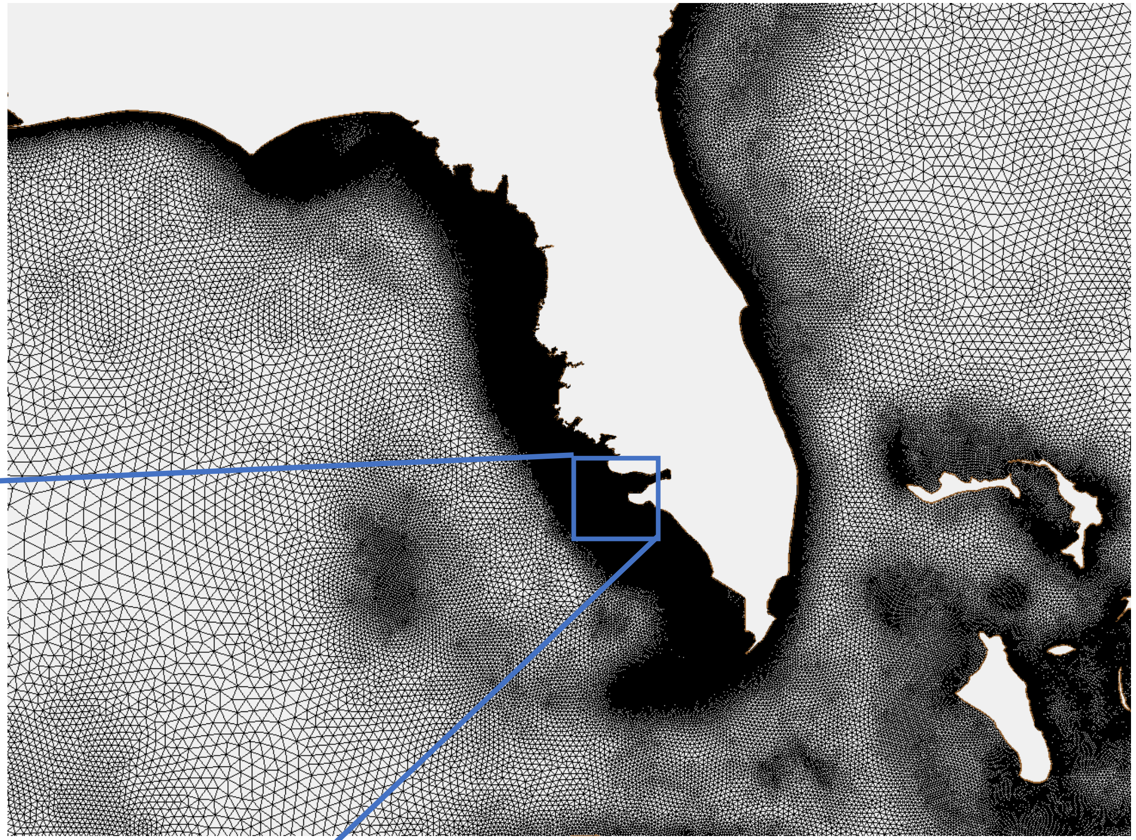

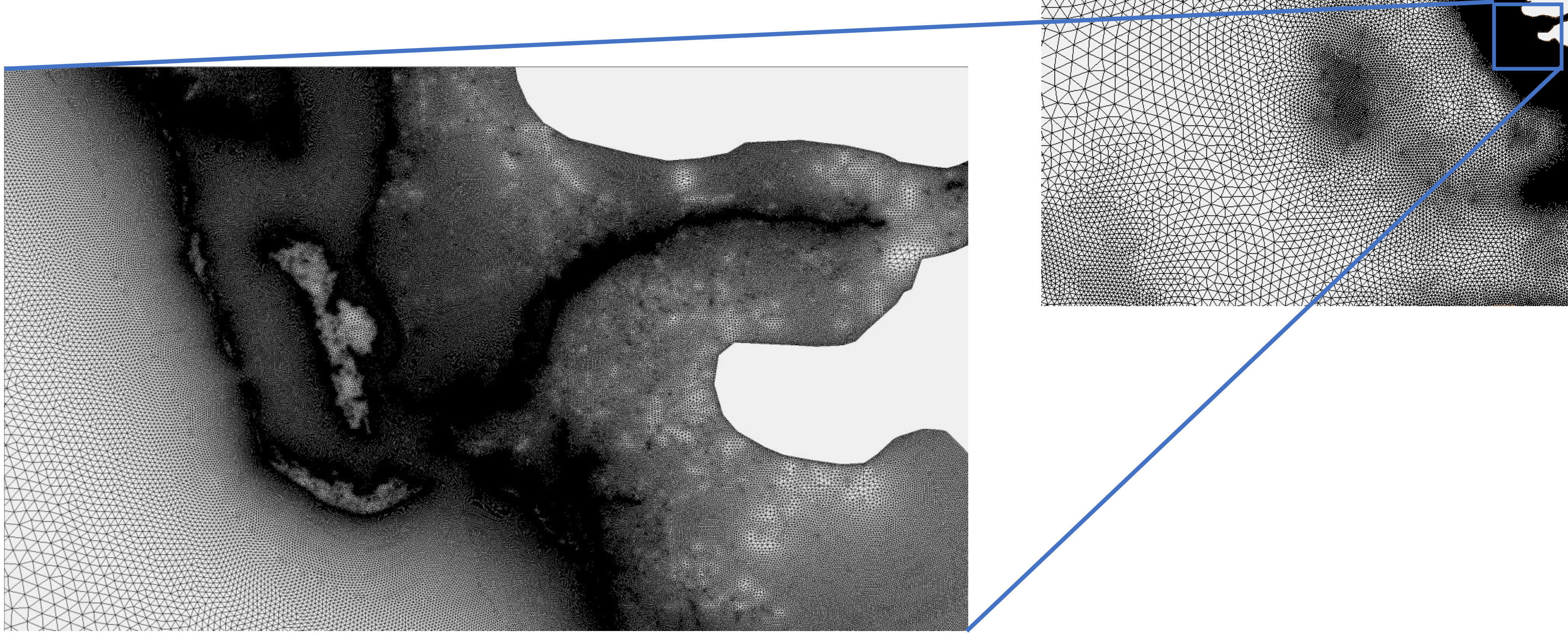

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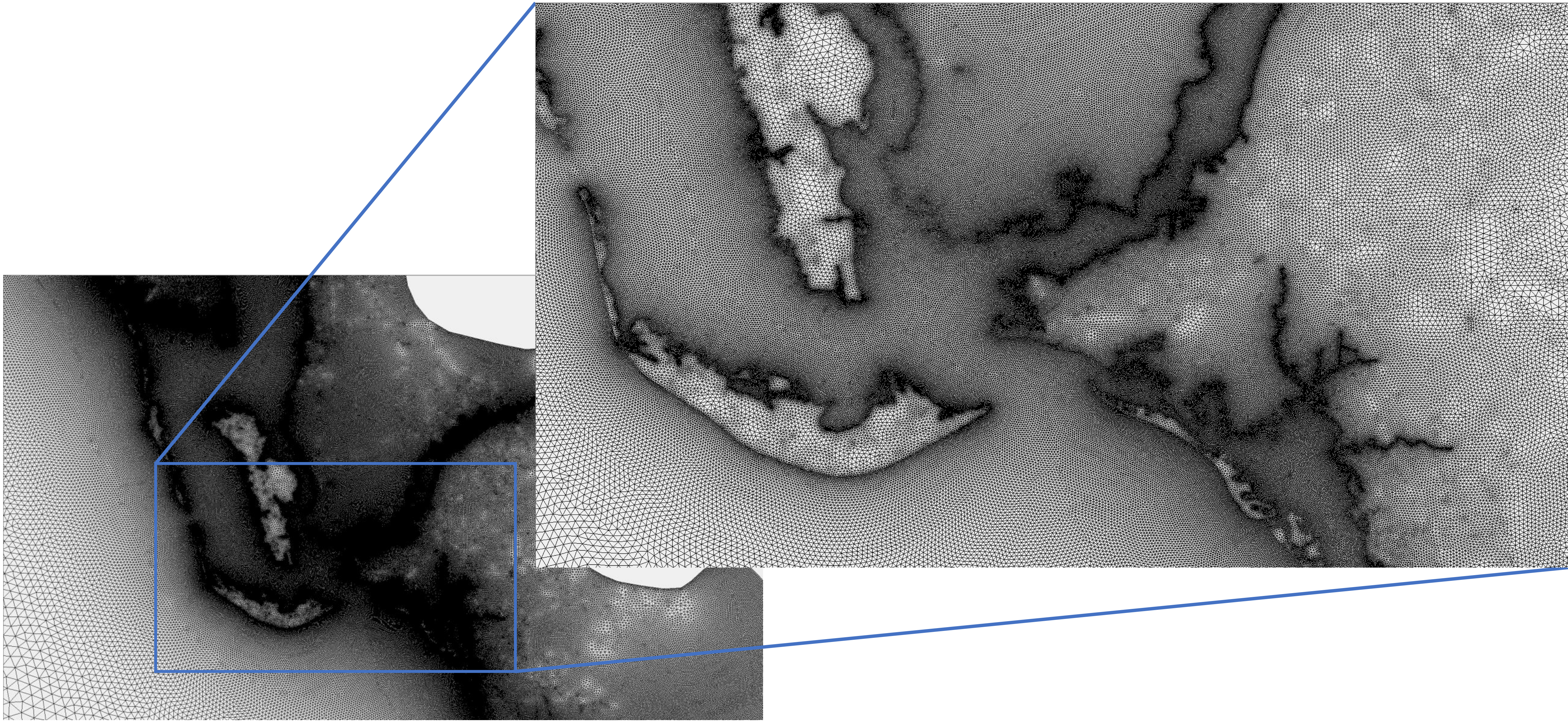

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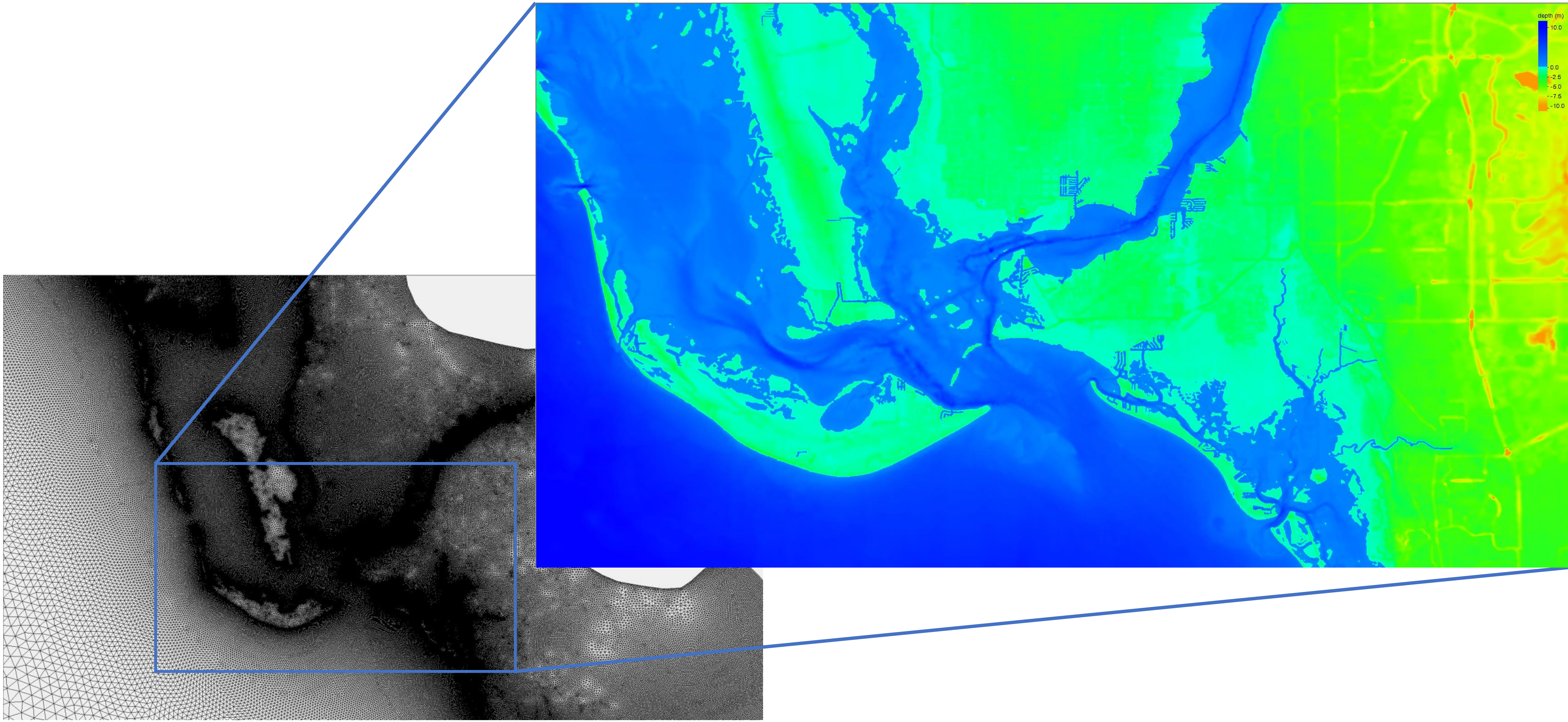
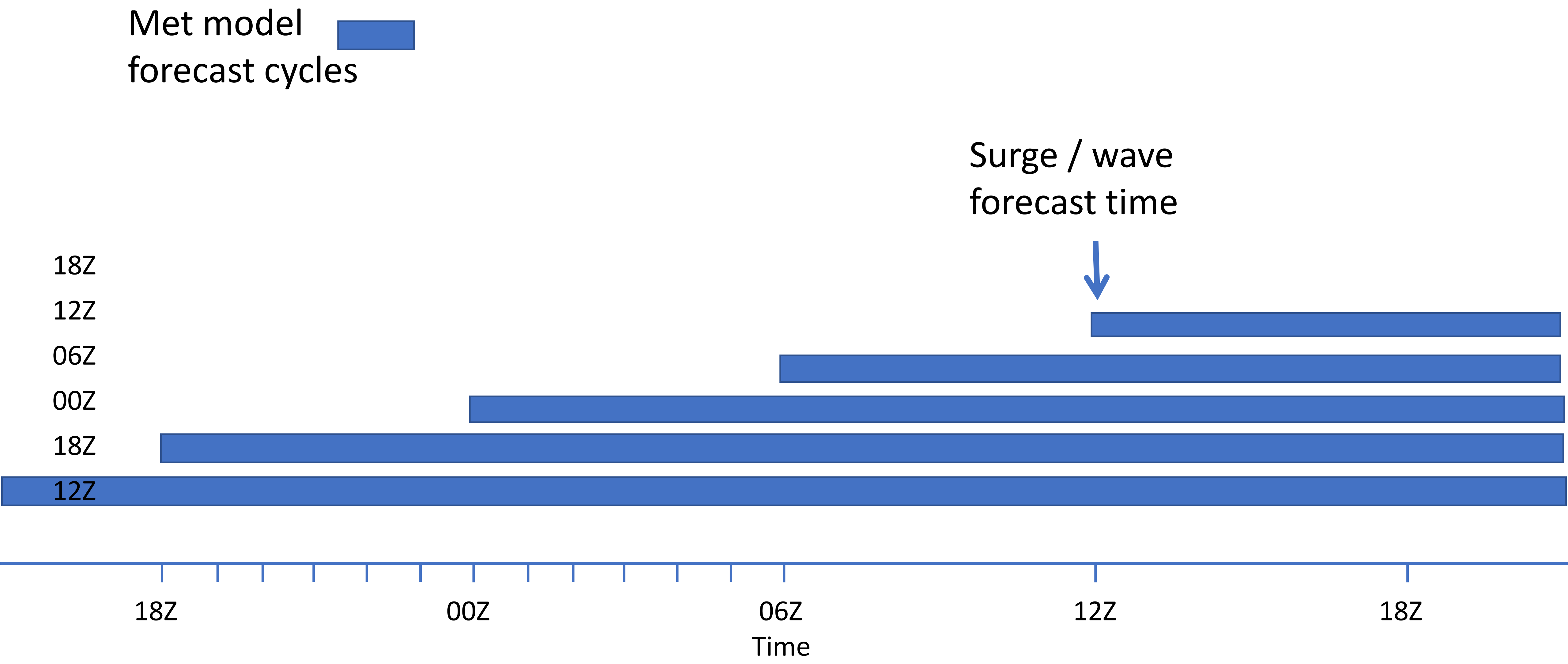


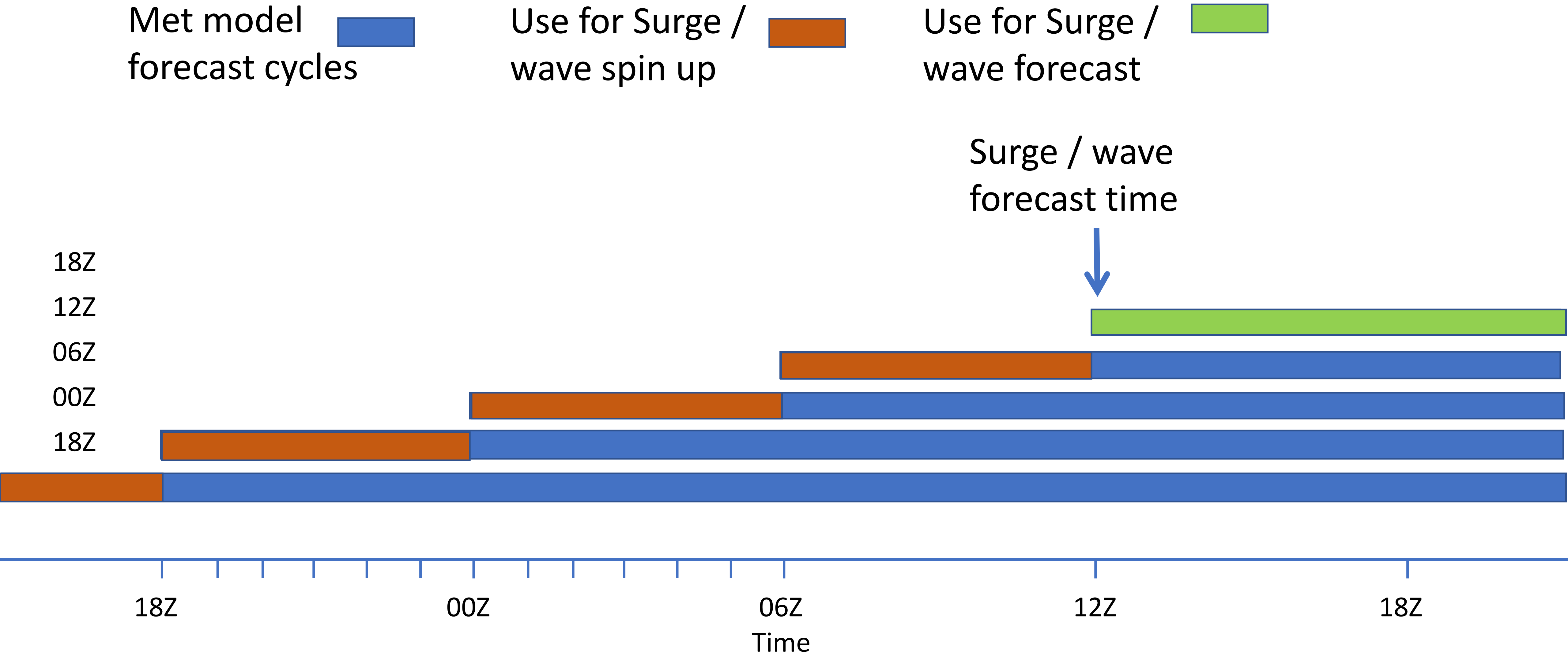
Initial Conditions – needed every forecast cycle (6 hrs)

1. Dynamic TC meteorology model (e.g., COAMPS-TC) – from MetGet
    - Estimate initial conditions, plug into model and allow model to adjust dynamically over initial time period
2. Surge / Wave model (e.g., ADCIRC+SWAN)
    - requires spin up (tides, meteorological, fluvial forcing) to create initial condition
    - extra-tropical applications – string together initial 6 hrs of several previous meteorological model forecast cycles
    - TC applications – do the same?

Meteorological Forcing for Surge + Wave Model

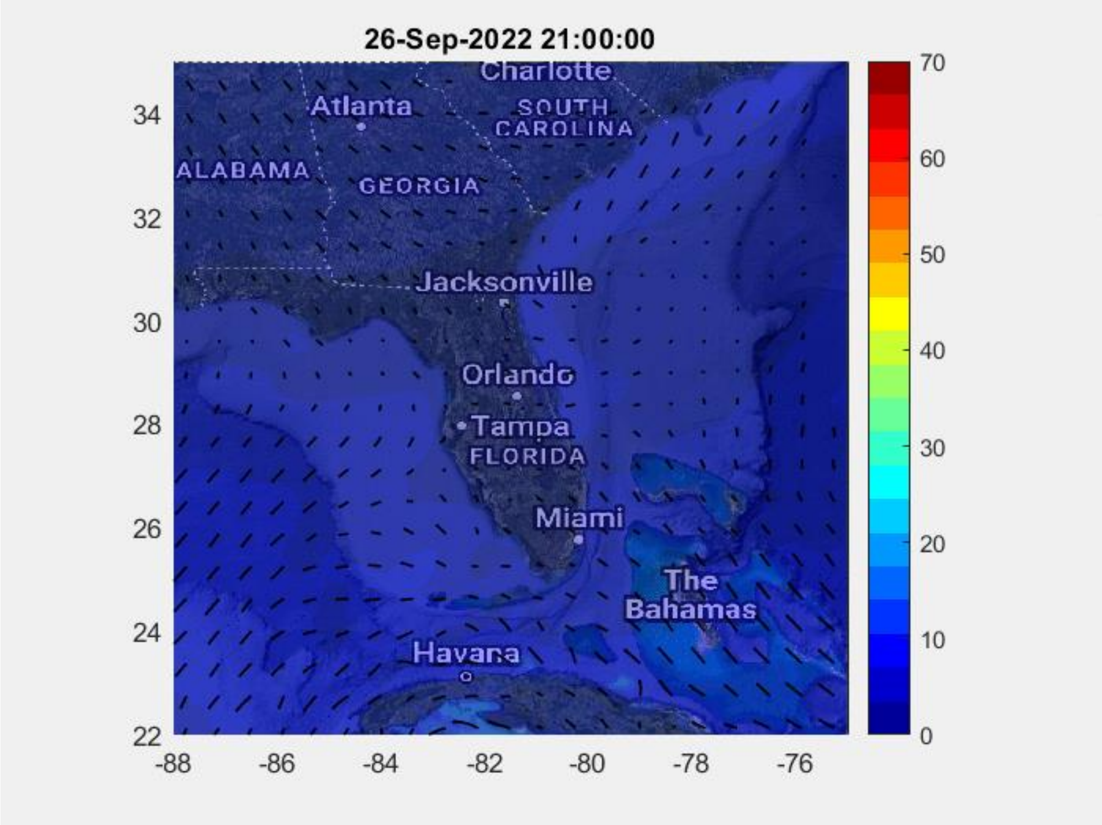


Meteorological Forcing for Surge + Wave Model



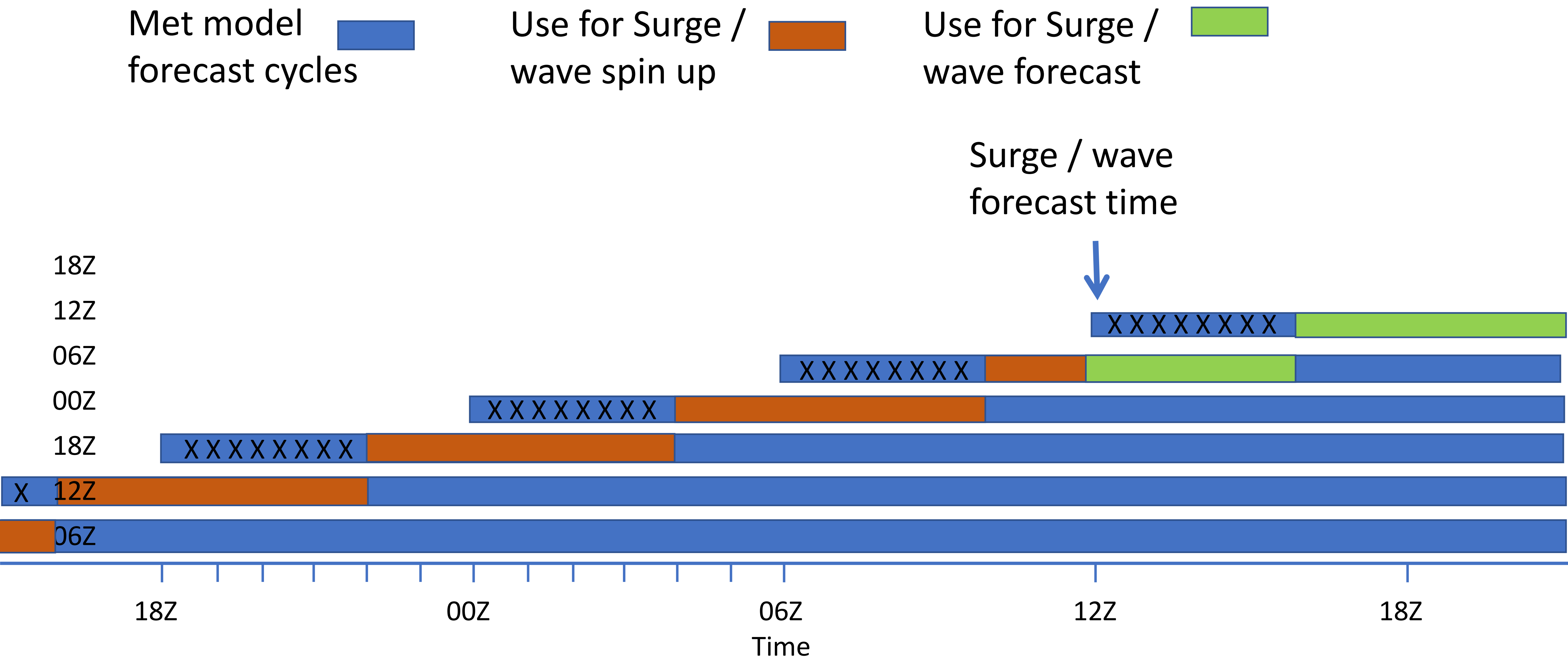
Initial Conditions – needed every forecast cycle (6 hrs)

first 6 hrs of each COAMPS-TC forecast cycle



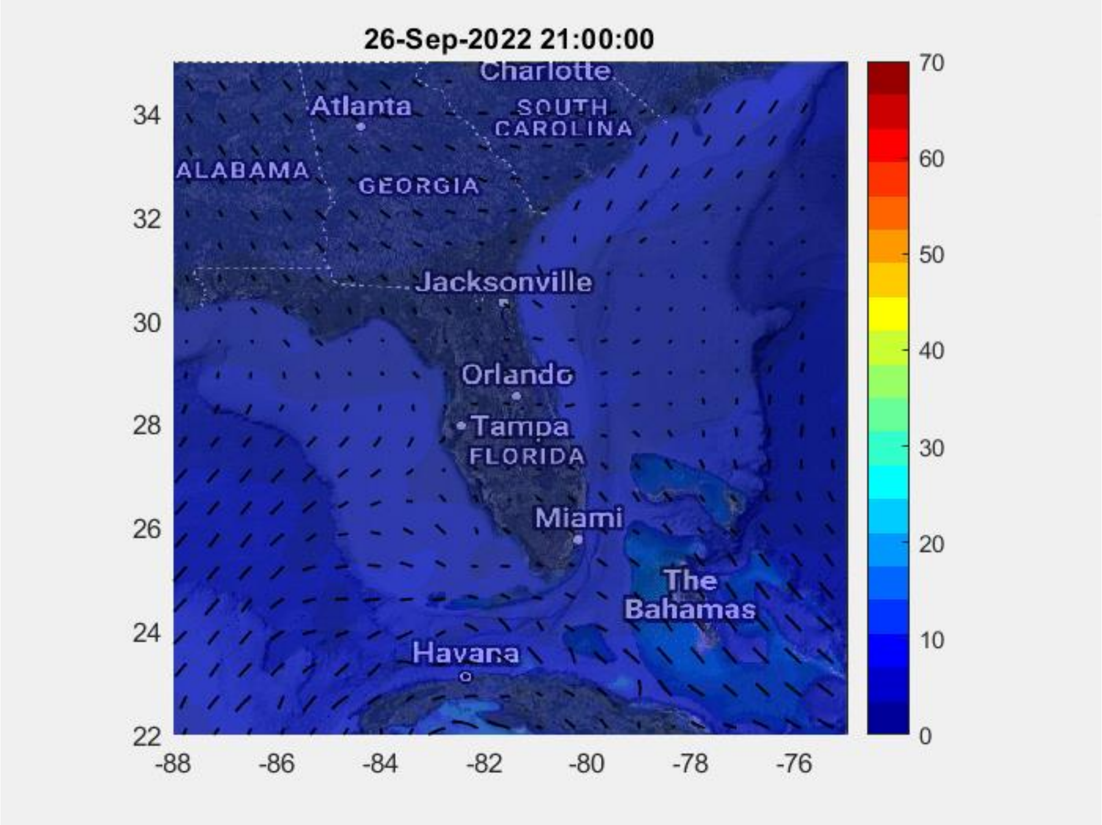
Meteorological Forcing for Surge + Wave Model

skip X hrs in met forecast cycles

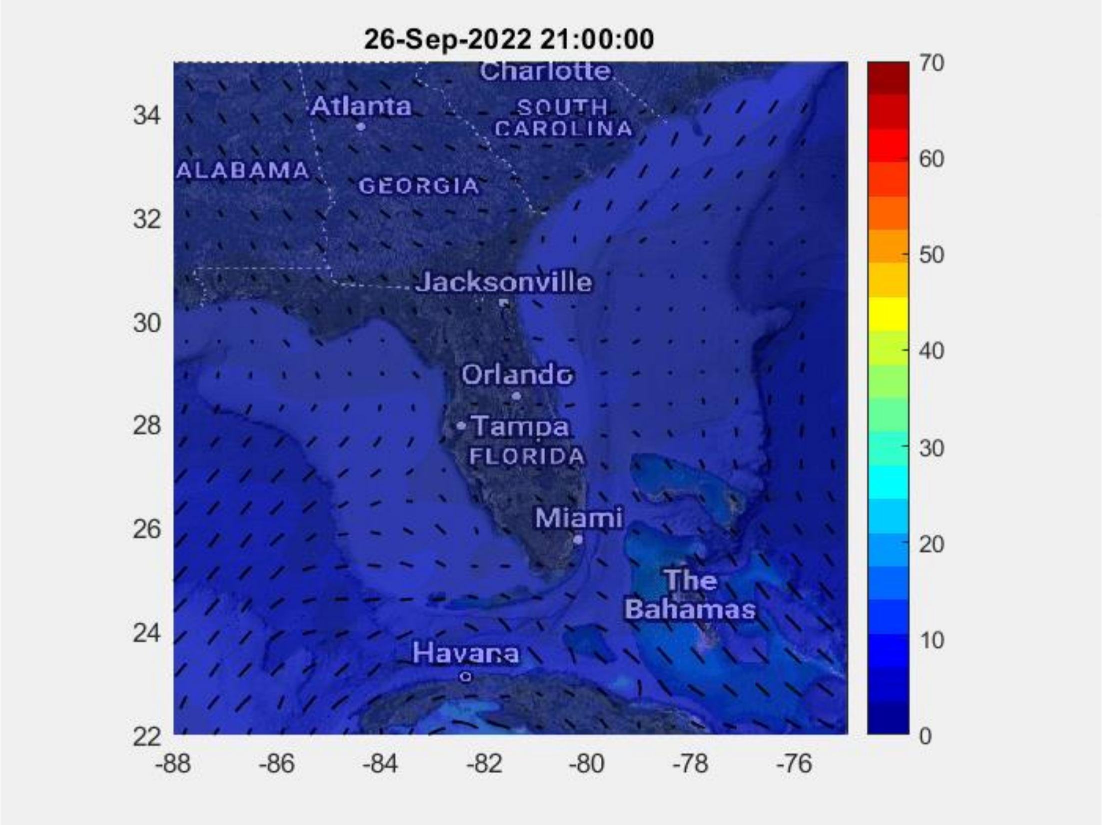


Initial Conditions – needed every forecast cycle (6 hrs)

first 6 hrs of each COAMPS-TC forecast cycle



skip initial ?? hrs of each COAMPS-TC forecast cycle

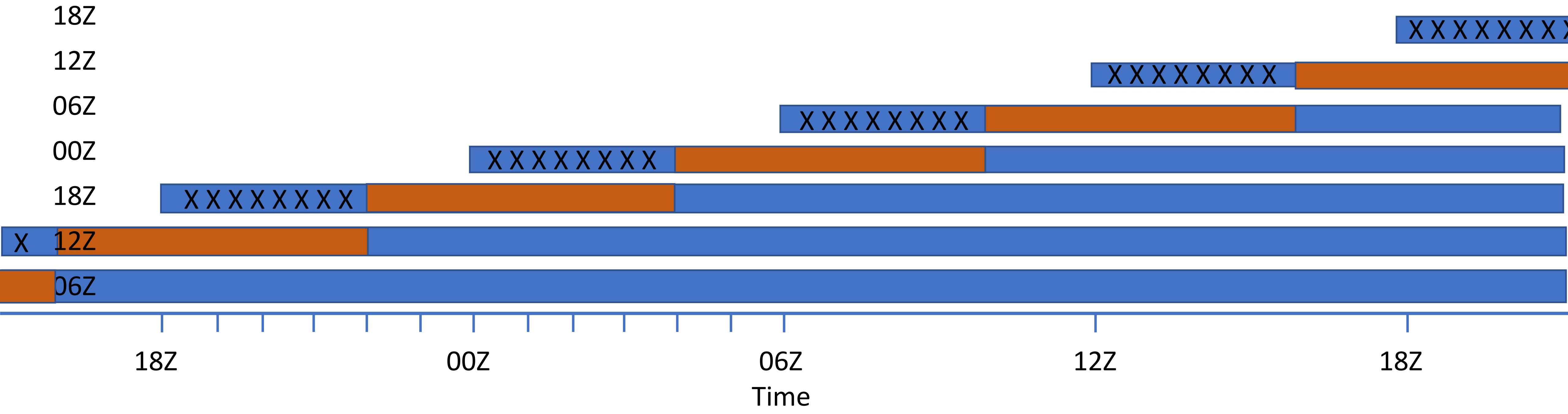


Meteorological Forcing for Surge + Wave Model

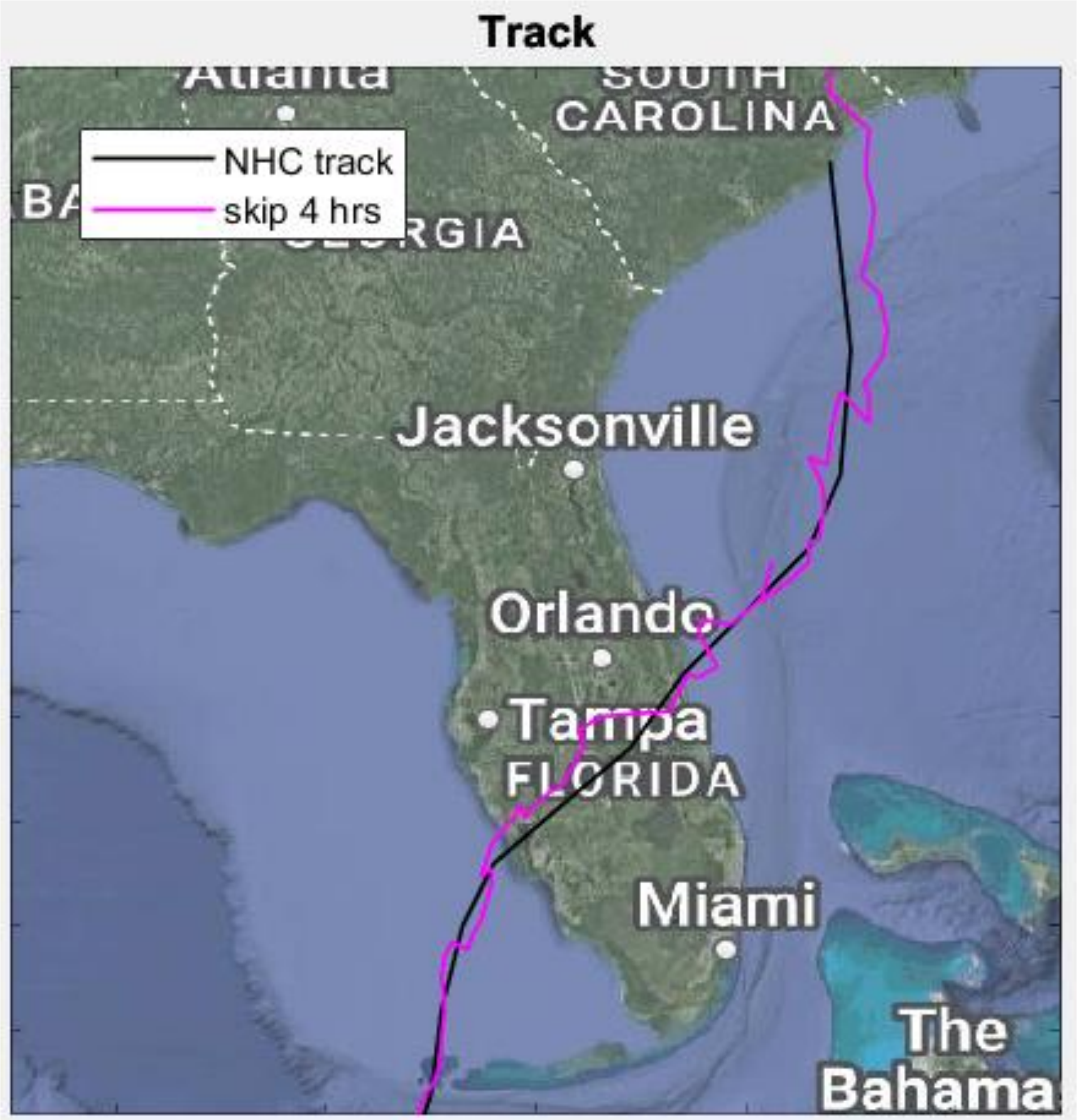
skip 4 hrs in met forecast cycles seemed optimal for H. Ian (also worked well in 2023)

Met model forecast cycles

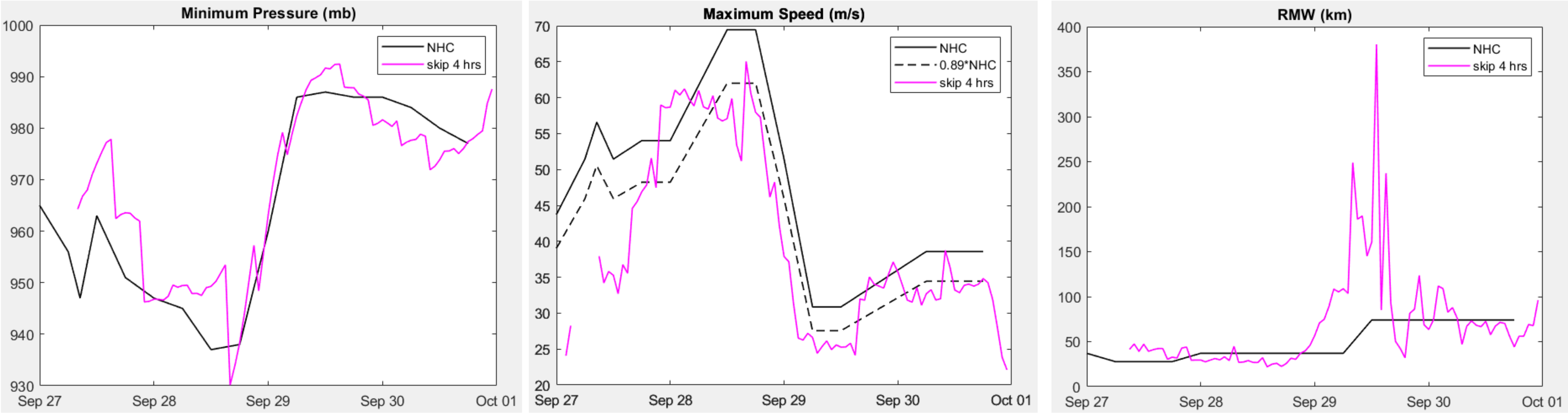
Use for Surge / wave hindcast / validation



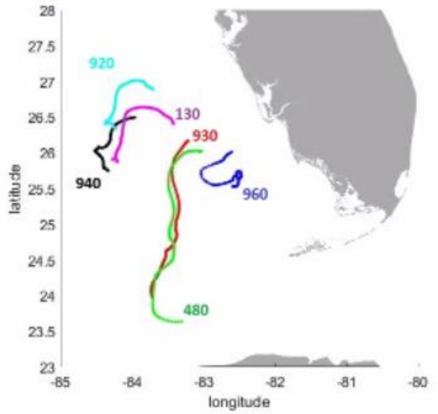
Initial Conditions – skip first 4 hrs of each COAMPS-TC cycle



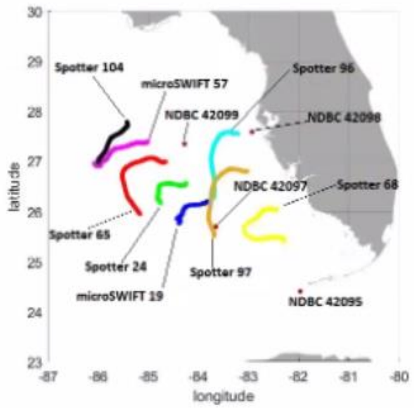
Initial Conditions – skip first 4 hrs of each COAMPS-TC cycle



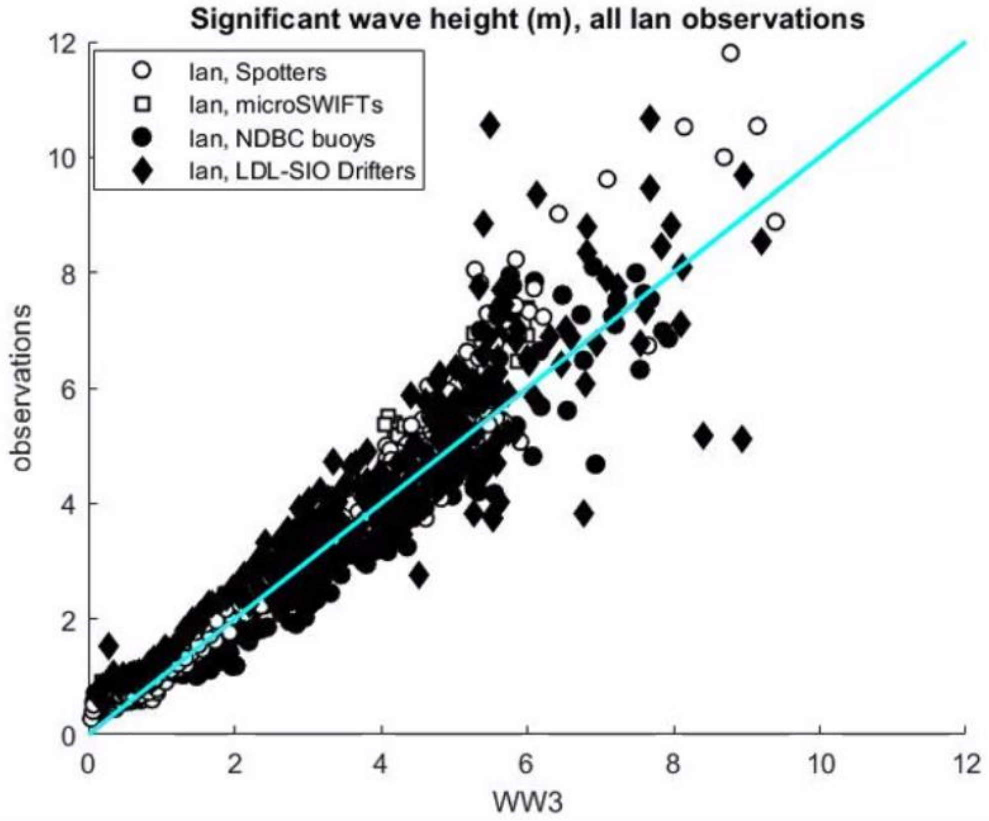
Wave Results - ADCIRC+SWAN vs ADCIRC+WaveWatch3



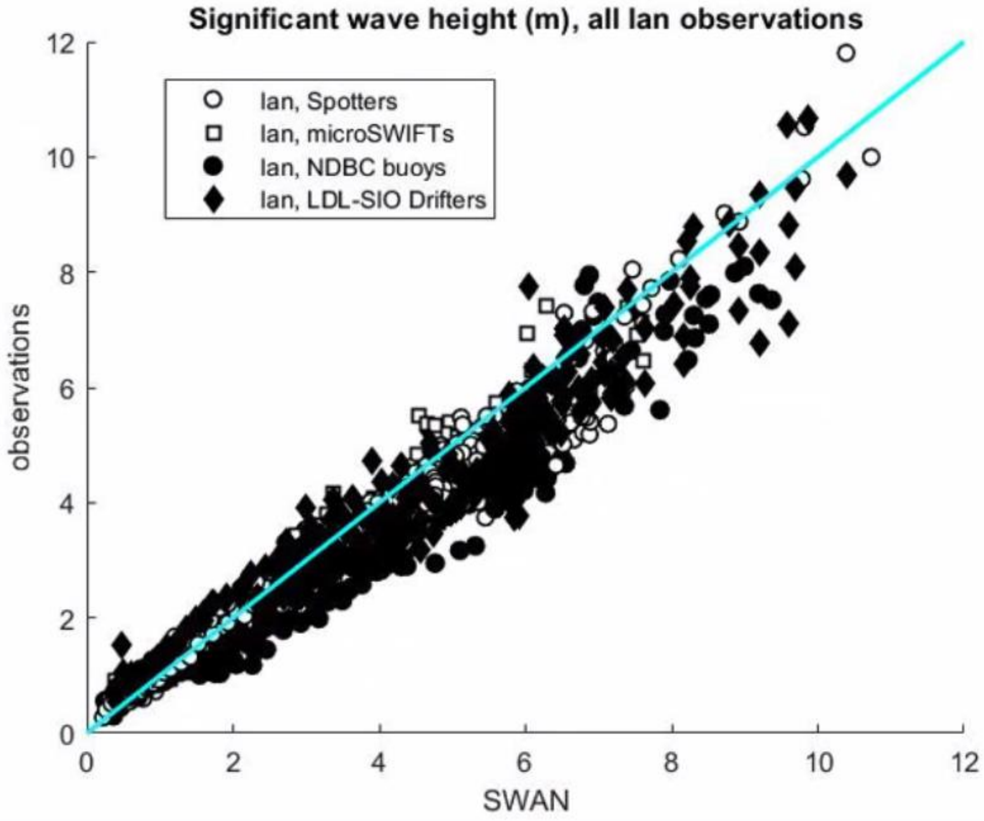
Ian, all observations



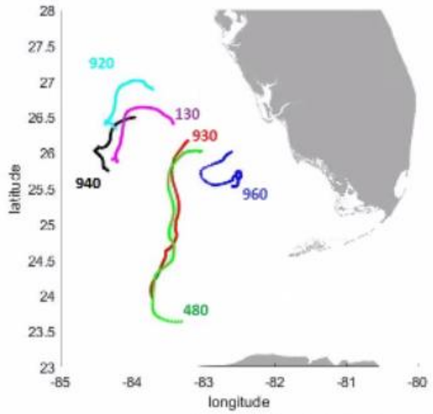
ADCIRC + WW3



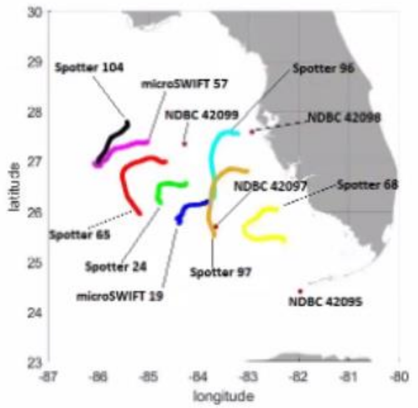
ADCIRC + SWAN



Wave Results - ADCIRC+SWAN vs ADCIRC+WaveWatch3

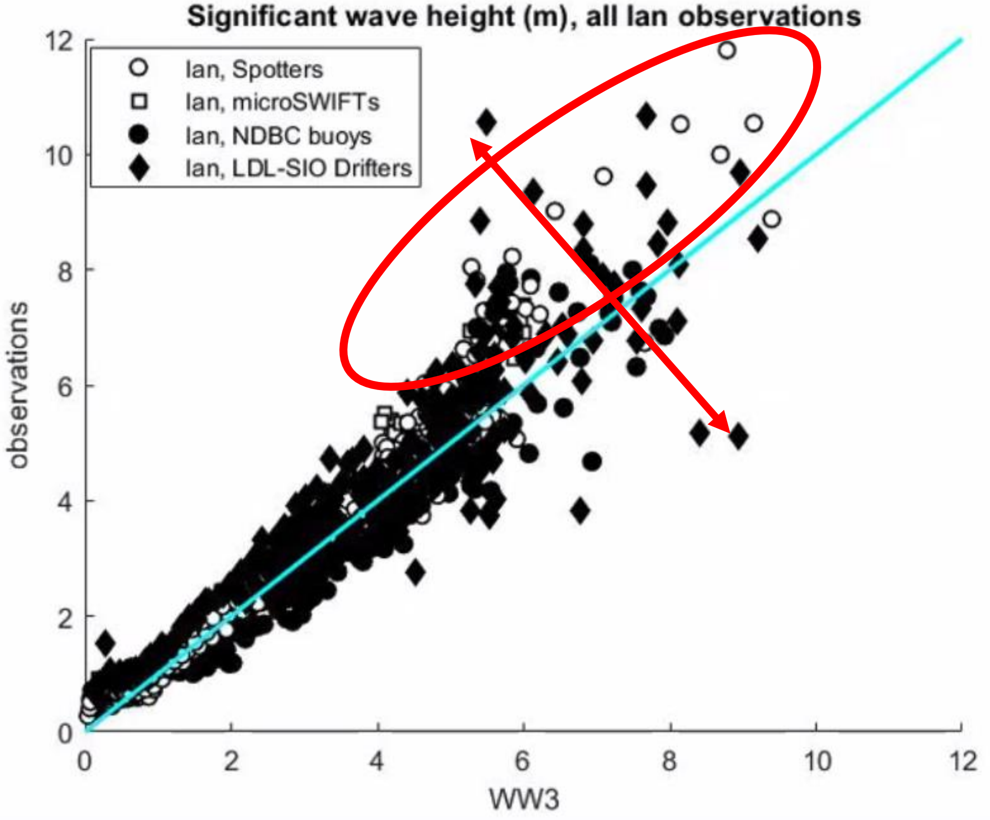


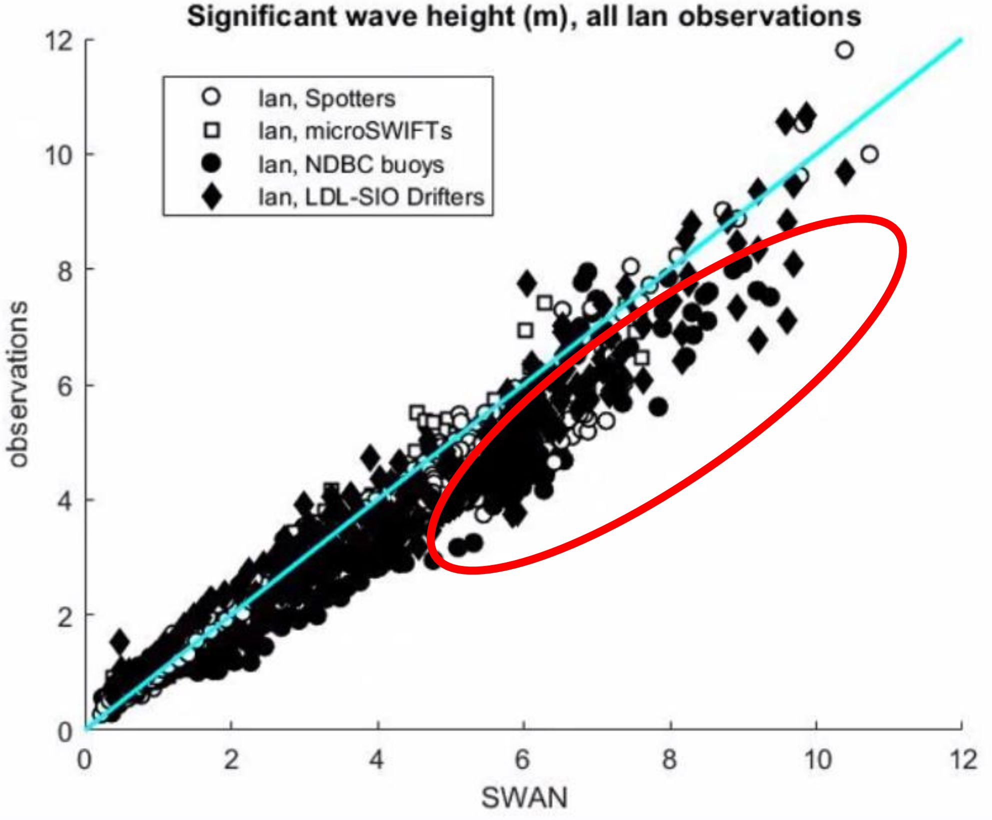
Ian, all observations



ADCIRC + WW3

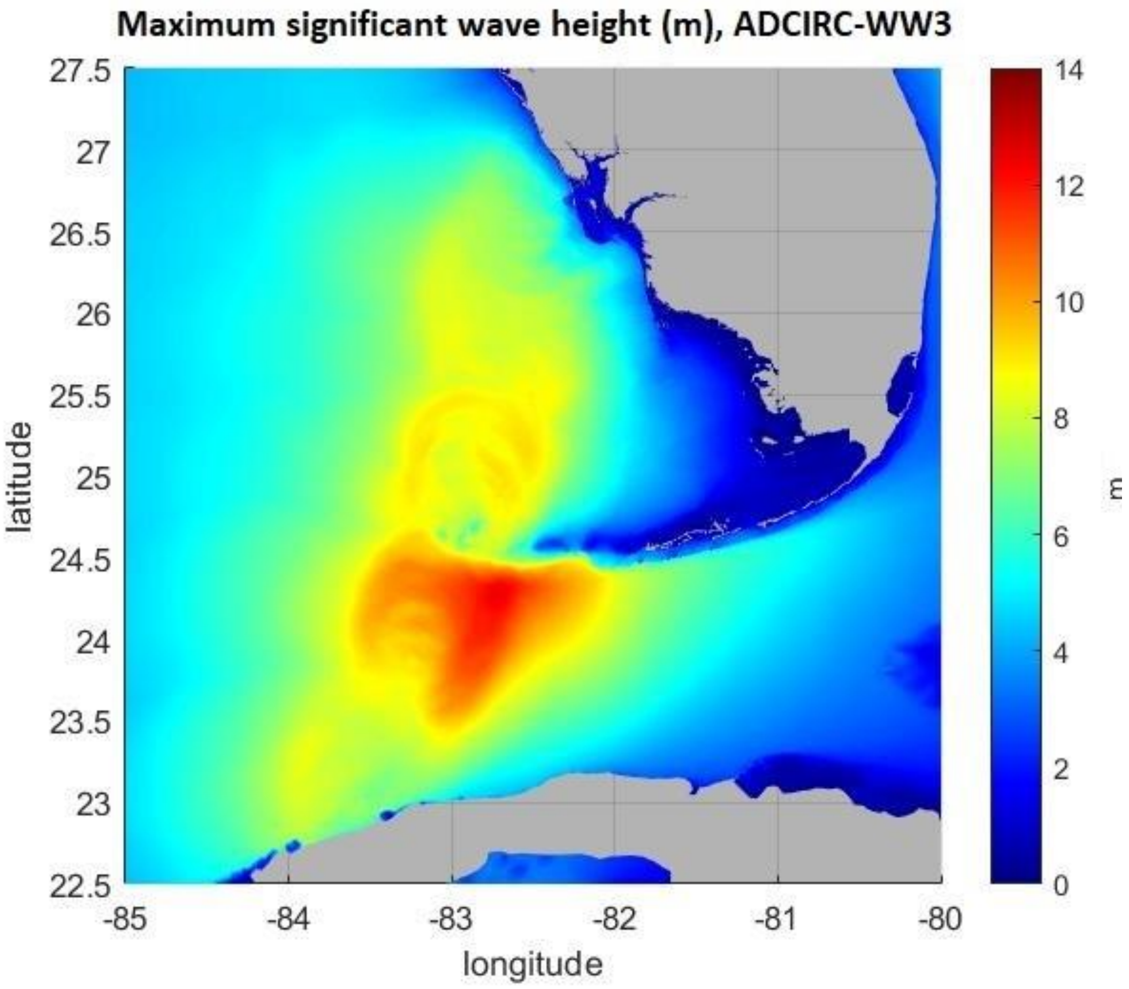
ADCIRC + SWAN



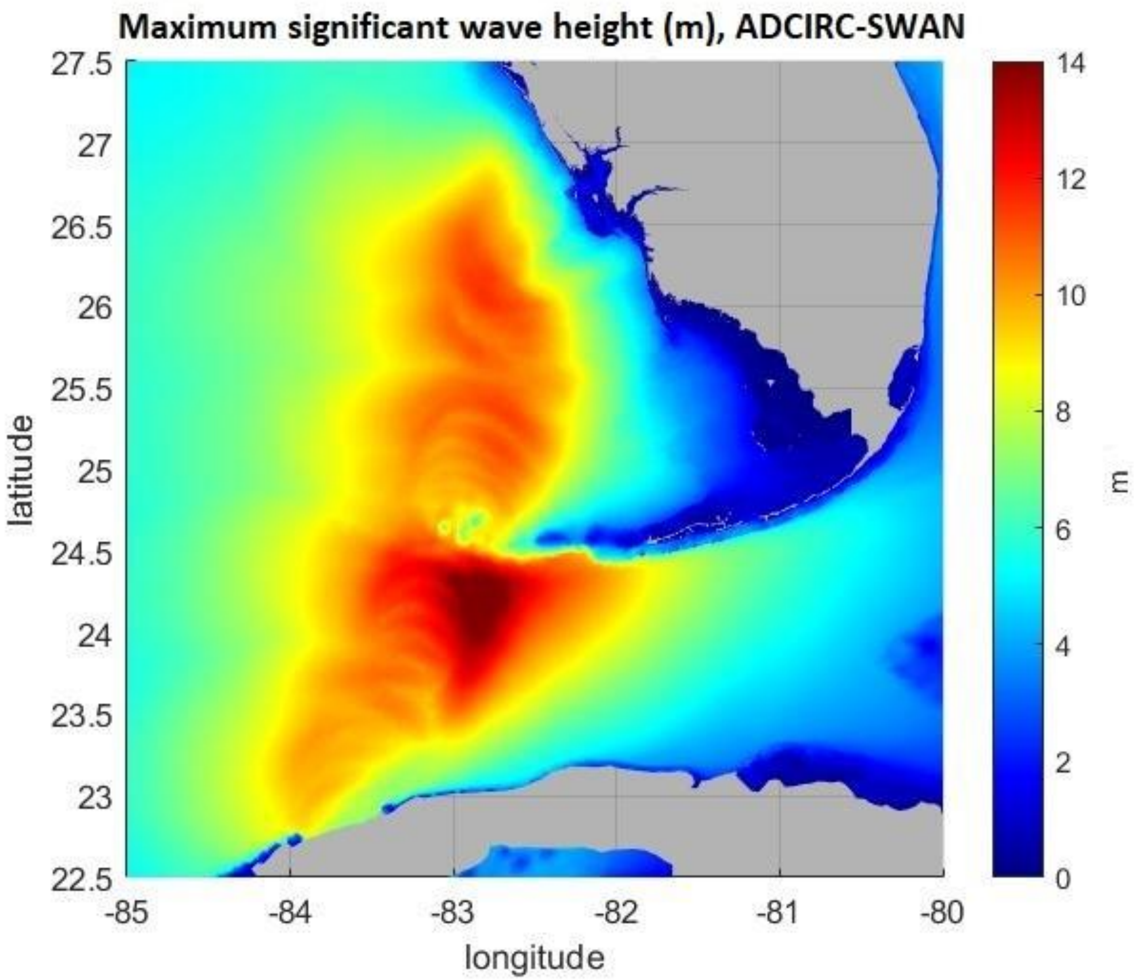


Wave Results - ADCIRC+SWAN vs ADCIRC+WaveWatch3

ADCIRC + WW3



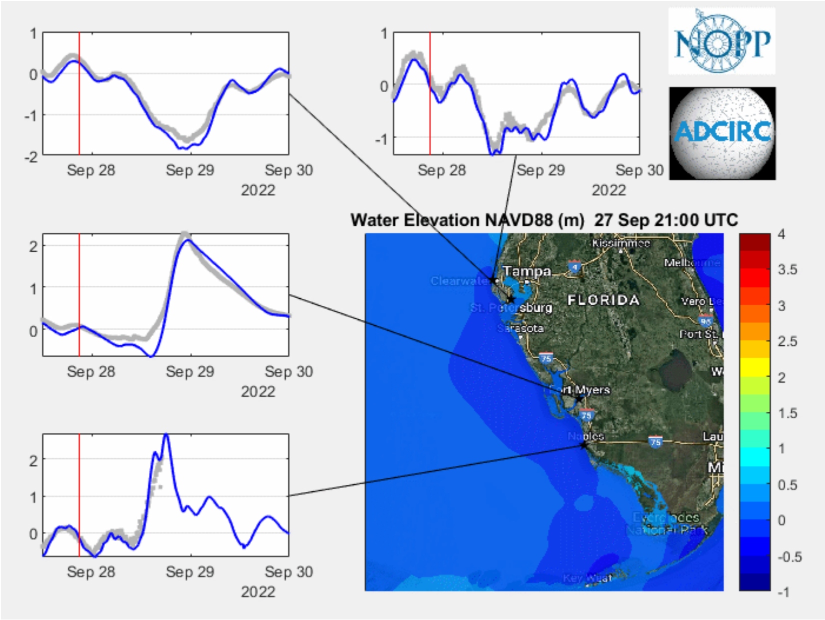
ADCIRC + SWAN

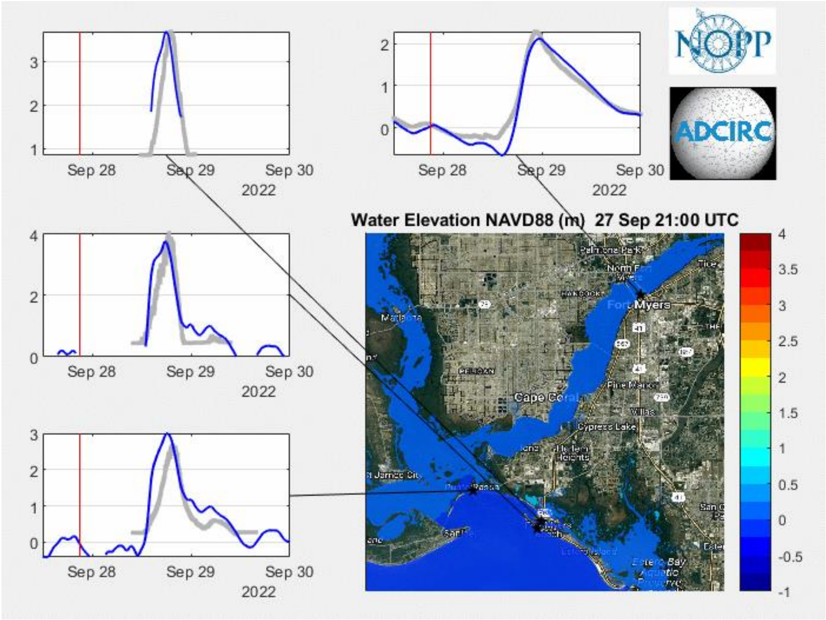


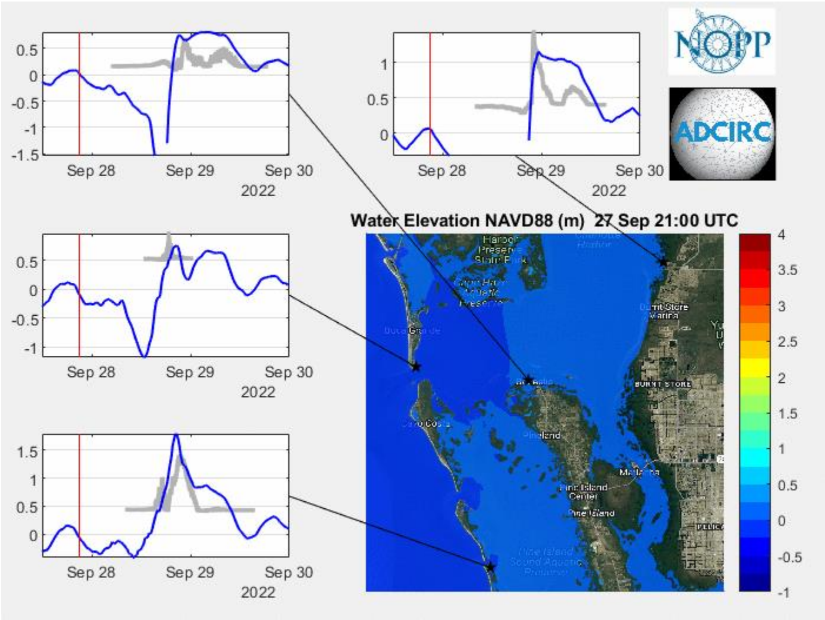
Simulated & Observed Water Levels, Hurricane Ian
September 27 – September 29, 2022

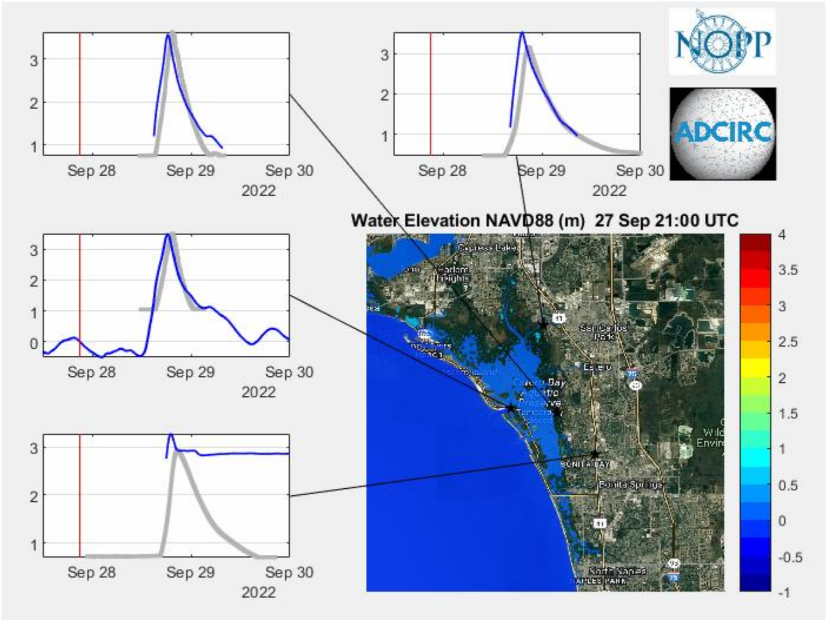
White line: COAMPS-TC storm track

Grey line: NHC storm track

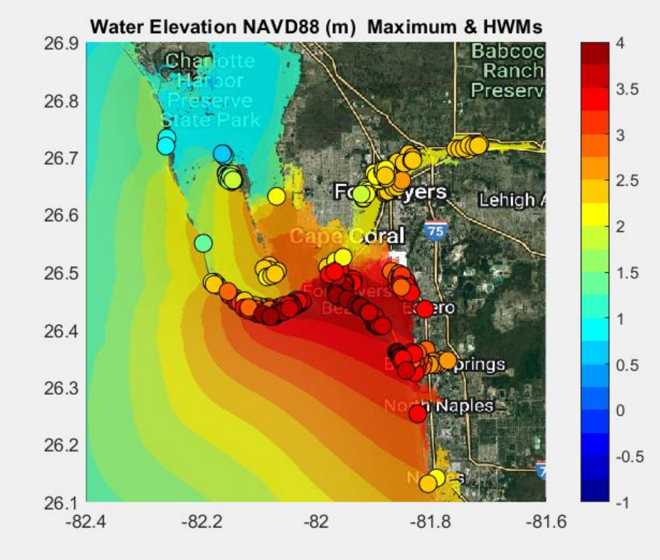


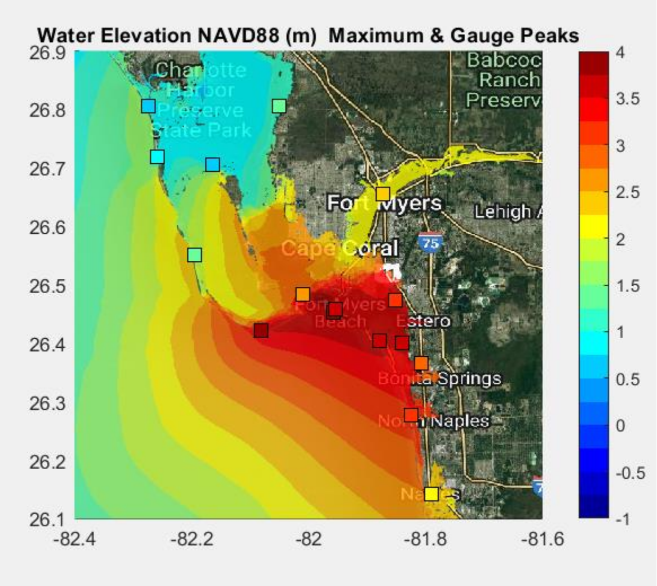


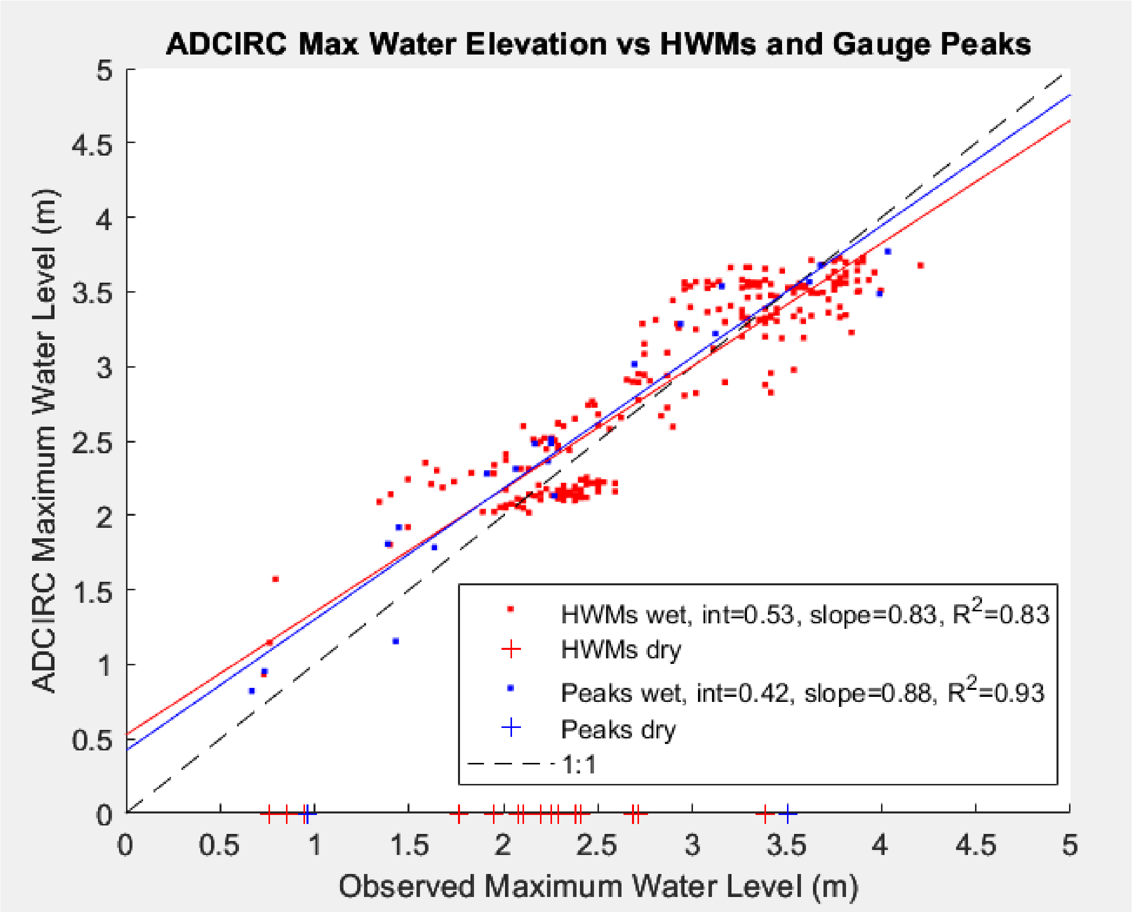




ADCIRC Maximum Water Levels vs Observed High Water Marks & Gauge Peaks







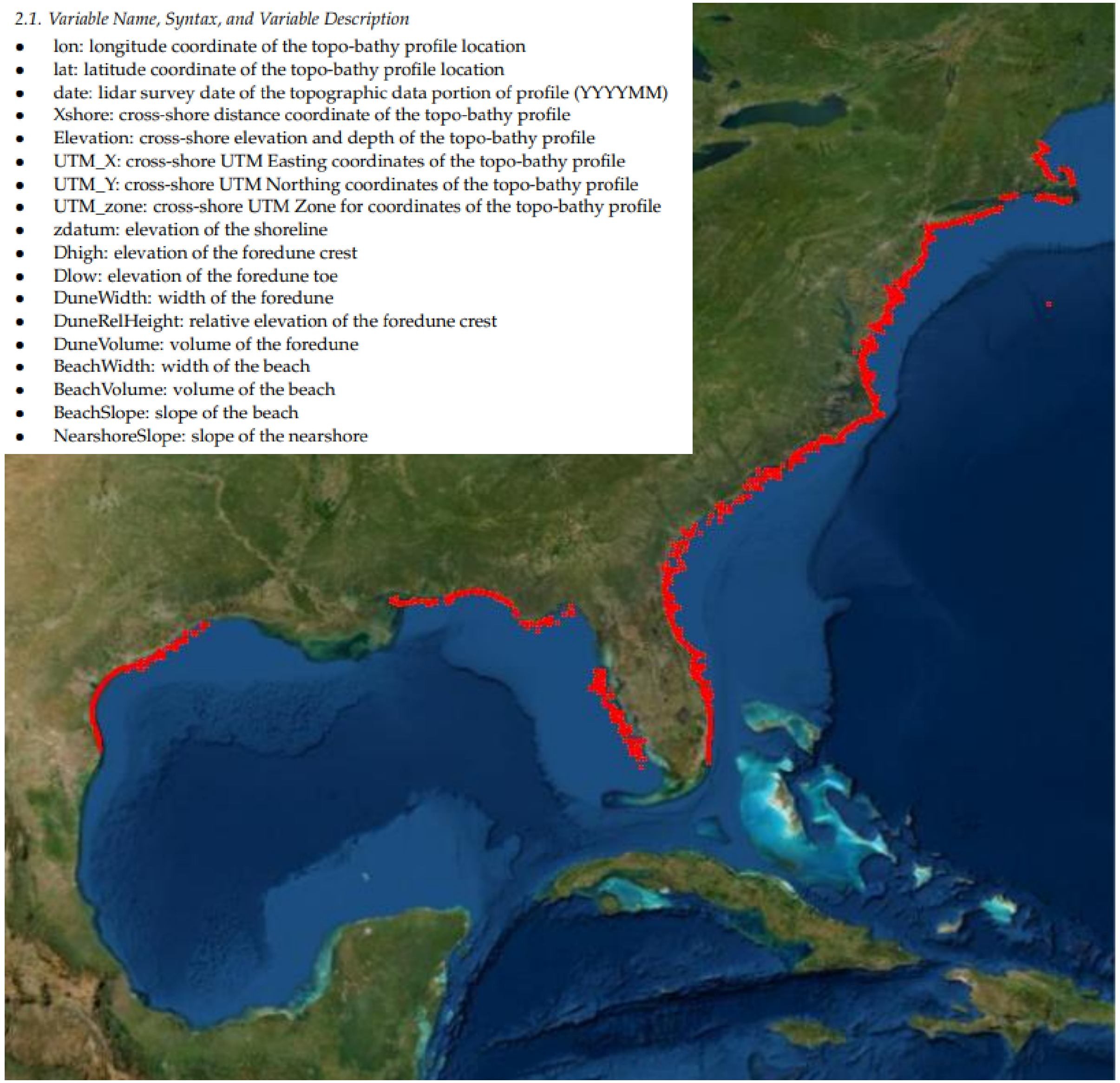
3. Dune Overtopping & Morphology – 1D XBeach

1D Transects (4023)

Jessica Gorsky, talk after next

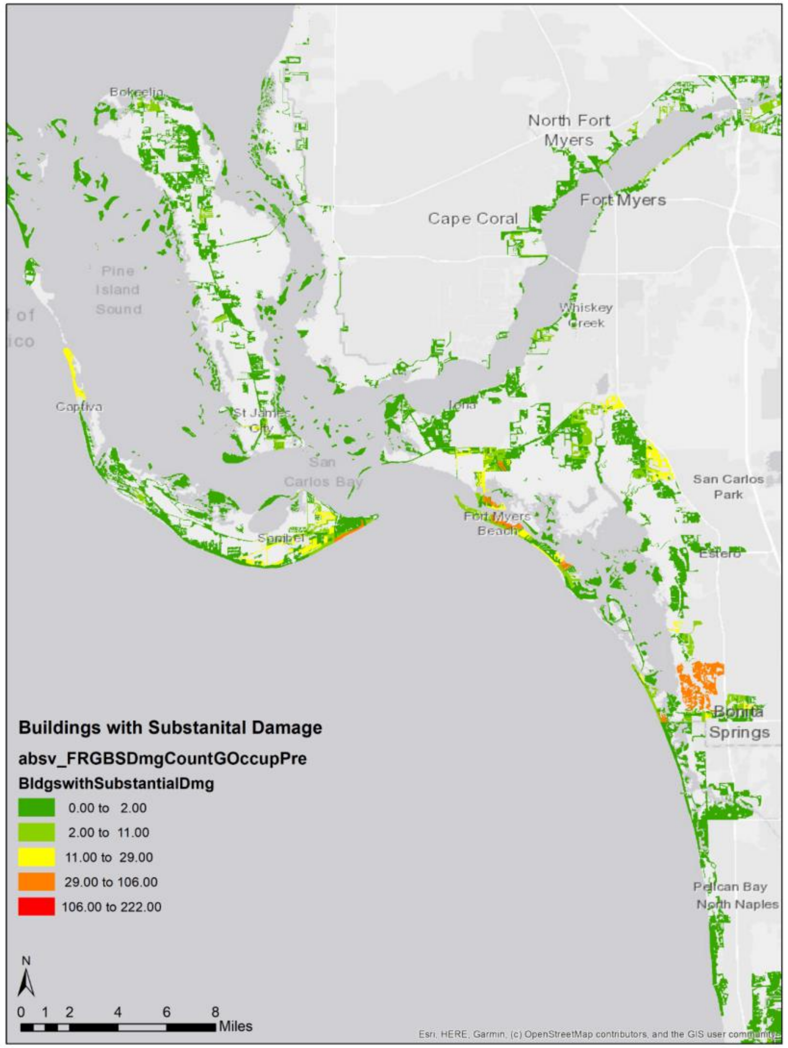
2.1. Variable Name, Syntax, and Variable Description

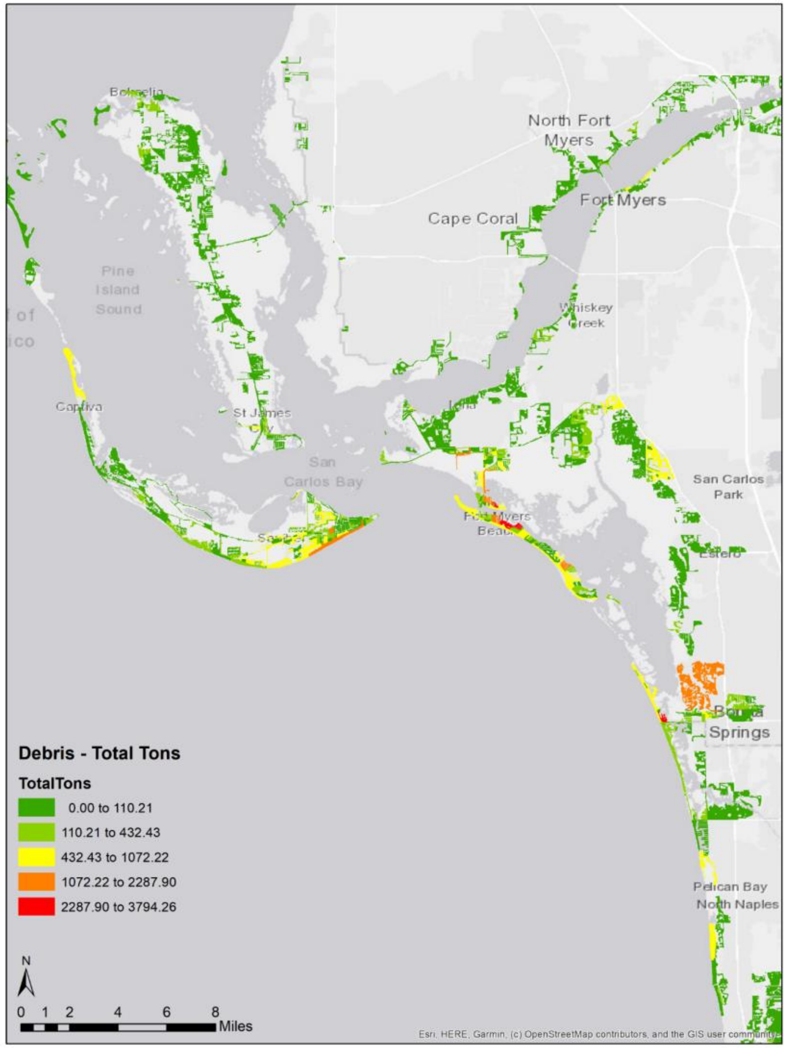
- lon: longitude coordinate of the topo-bathy profile location
- lat: latitude coordinate of the topo-bathy profile location
- date: lidar survey date of the topographic data portion of profile (YYYYMM)
- Xshore: cross-shore distance coordinate of the topo-bathy profile
- Elevation: cross-shore elevation and depth of the topo-bathy profile
- UTM_X: cross-shore UTM Easting coordinates of the topo-bathy profile
- UTM_Y: cross-shore UTM Northing coordinates of the topo-bathy profile
- UTM_zone: cross-shore UTM Zone for coordinates of the topo-bathy profile
- zdatum: elevation of the shoreline
- Dhigh: elevation of the foredune crest
- Dlow: elevation of the foredune toe
- DuneWidth: width of the foredune
- DuneRelHeight: relative elevation of the foredune crest
- DuneVolume: volume of the foredune
- BeachWidth: width of the beach
- BeachVolume: volume of the beach
- BeachSlope: slope of the beach
- NearshoreSlope: slope of the nearshore

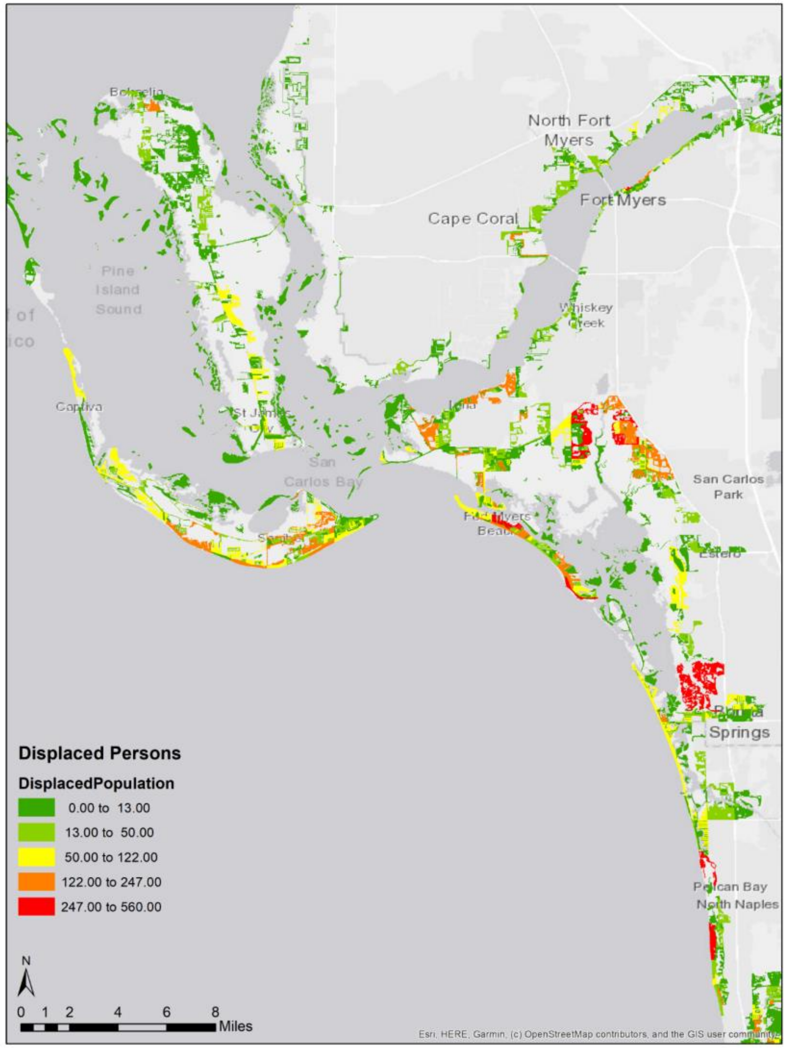


3. Damage Model

HAZUS level 1 Damage Assessment - 0928 12Z forecast







Hurricane Ian

HAZUS level 1 Damage Assessment - 0928 12Z forecast

HAZUS EARTHQUAKE · WIND · FLOOD · TSUNAMI

FEMA

Quick Assessment Report

RiskMAP
Increasing Resilience Together

September 28, 2022

Study Region :	Ian928_Expanded
Scenario :	Ian928
Return Period:	Mix0
Analysis Option:	0

Regional Statistics

Area (Square Miles)	7,288
Number of Census Blocks	101,668
Number of Buildings	
Residential	1,580,011
Total	1,723,096
Number of People in the Region (x 1000)	4,021
Building Exposure ($ Millions)	
Residential	391,818
Total	495,809

Scenario Results

Shelter Requirements

Displaced Population (# Households)	16,340
Short Term Shelter (# People)	15,852

Economic Loss

Residential Property (Capital Stock) Losses ($ Millions)	2,362
Total Property (Capital Stock) Losses ($ Millions)	2,909
Business Interruption (Income) Losses ($ Millions)	2,246

Disclaimer:

Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific flood. These results can be improved by using enhanced inventory data and flood hazard information.

Conclusions

- COAMPS-TC performed well for H. Ian compared to other dynamic TC models
- Use of dynamic TC models to force hydrodynamic response requires care, particularly related to initial conditions. Skipping 4 hrs in each COAMPS-TC cycle provided a reasonable representation of the storm for surge and wave modeling. Not clear how general this is – (seemed to work for H. Idalia in 2023).
- Rich wave observational data set, wave model predictions of bulk parameters were encouraging. Systematic differences between Hs in WWIII and SWAN wave models.
- Water levels were reasonably well predicted, both for drawdowns and surge / inundation
- Damage estimates from HAZUS are quite low versus values reported in the media. These do not include waves. Further work ongoing w HAZUS & other damage estimation procedures.
- Exploring COAMPS-TC 21-member ensemble for probabilistic results – see poster by Nashid Mumtaz – COAMPS-TC Ensemble Driven Storm Surge Simulations for H. Ian

THE UNIVERSITY OF RHODE ISLAND GRADUATE SCHOOL OF OCEANOGRAPHY | Oregon State University | NC STATE UNIVERSITY | THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL | renci RESEARCH ENGAGEMENT INNOVATION | COASTAL RESILIENCE CENTER | THE WATER INSTITUTE OF THE GULF | UNIVERSITY OF GEORGIA Coastal Ocean Analysis and Simulation Team