Hydrodynamic and Coastal Response to Large Swell Events in Reef-Fronted Embayment: Observations and Numerical Modeling

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Image Credit: Kevian Pérez, University of Puerto Rico

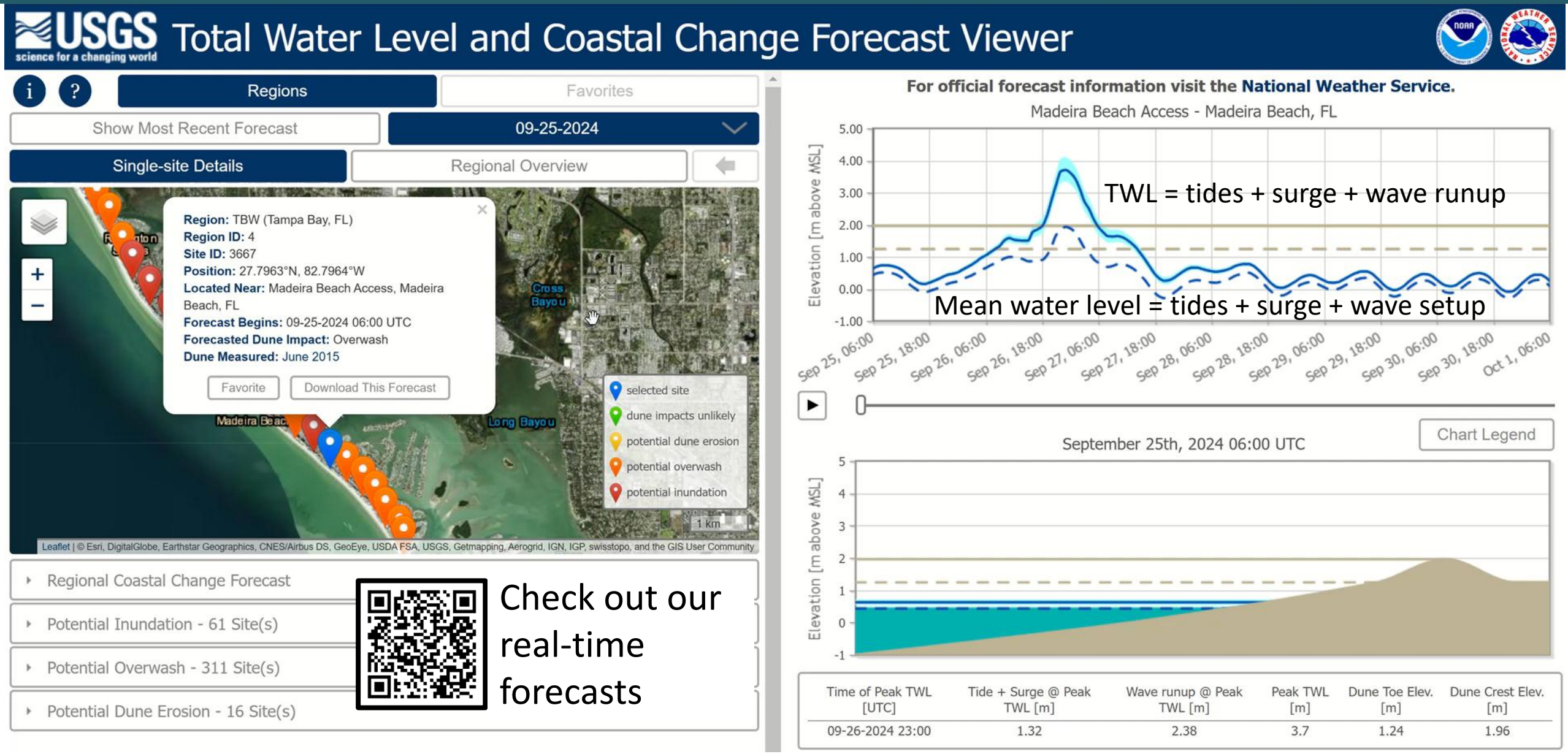

North Atlantic Ocean
~110 miles
~35 miles
Isabela
Camuy
Arecibo
Dorado
Vega Baja
San Juan
Trujillo Alto
Fajardo
Culebra
Roosevelt Roads
Humacao
Caguas
Cidra
Aibonito
Cayey
Coamo
Guayama
Ponce
Yauco
Guánica
Pole Ojea
Boquerón
Cabo Rojo
San Germán
Mayagüez
Aguada
Aguadilla
Rincón
San Sebastián
Lares
Utuado
Barinquen
Isla de Mona
Vieques

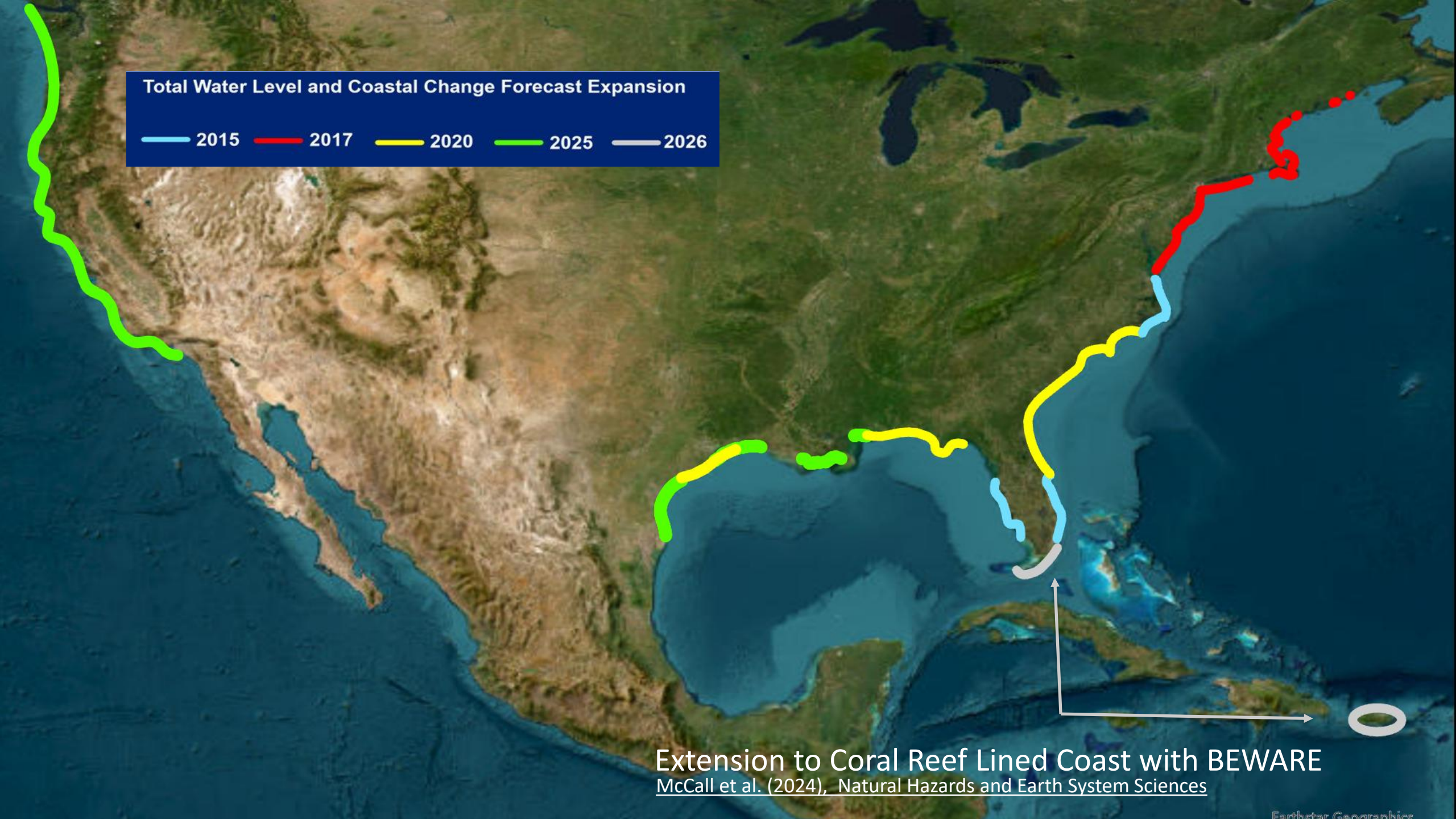
Puerto Rico is prone to coastal hazards

Hurricane-induced erosion at Rincón by Hurricane María in 2017

Still in August 2021…

Motivation


USGS science for a changing world
Total Water Level and Coastal Change Forecast Viewer
Regions
Favorites
Show Most Recent Forecast
09-25-2024
Single-site Details
Regional Overview
Region: TBW (Tampa Bay, FL)
Region ID: 4
Site ID: 3667
Position: 27.7963°N, 82.7964°W
Located Near: Madeira Beach Access, Madeira Beach, FL
Forecast Begins: 09-25-2024 06:00 UTC
Forecasted Dune Impact: Overwash
Dune Measured: June 2015
Favorite
Download This Forecast
selected site
dune impacts unlikely
potential dune erosion
potential overwash
potential inundation
Cross Bayou
Long Bayou
Madeira Beac
1 km
Leaflet | © Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Regional Coastal Change Forecast
Potential Inundation - 61 Site(s)
Potential Overwash - 311 Site(s)
Potential Dune Erosion - 16 Site(s)
Check out our real-time forecasts
For official forecast information visit the National Weather Service.
Madeira Beach Access - Madeira Beach, FL
Elevation [m above MSL]
TWL = tides + surge + wave runup
Mean water level = tides + surge + wave setup
Sep 25, 06:00
Sep 25, 18:00
Sep 26, 06:00
Sep 26, 18:00
Sep 27, 06:00
Sep 27, 18:00
Sep 28, 06:00
Sep 28, 18:00
Sep 29, 06:00
Sep 29, 18:00
Sep 30, 06:00
Sep 30, 18:00
Oct 1, 06:00
Chart Legend
September 25th, 2024 06:00 UTC
Time of Peak TWL [UTC]
Tide + Surge @ Peak TWL [m]
Wave runup @ Peak TWL [m]
Peak TWL [m]
Dune Toe Elev. [m]
Dune Crest Elev. [m]
09-26-2024 23:00
1.32
2.38
3.7
1.24
1.96

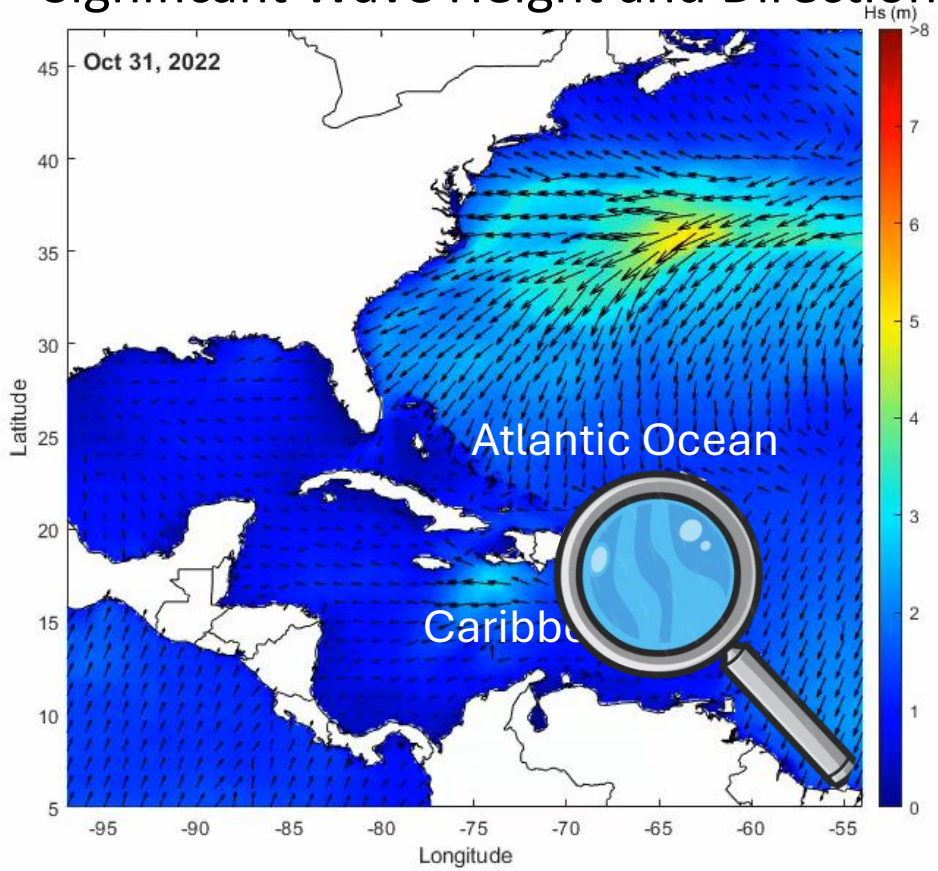


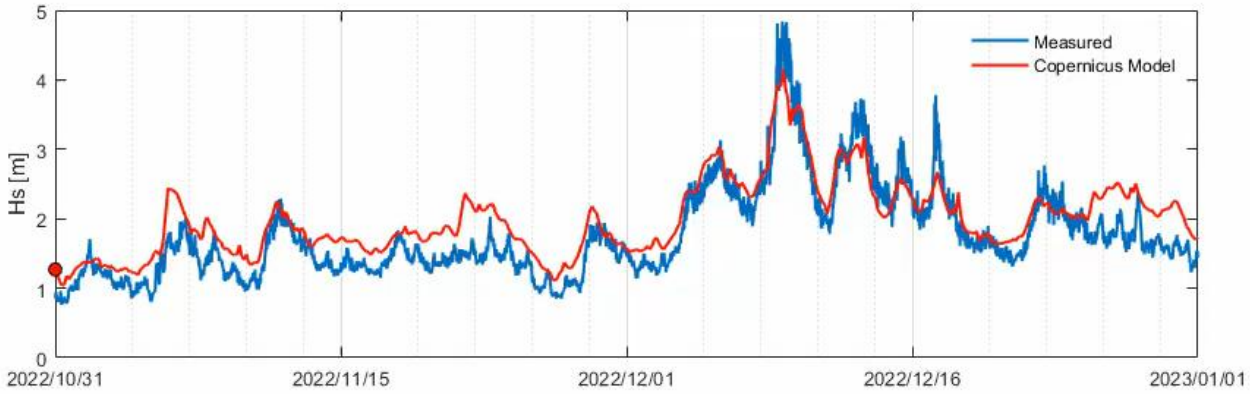
Extension to Coral Reef Lined Coast with BEWARE

McCall et al. (2024), Natural Hazards and Earth System Sciences

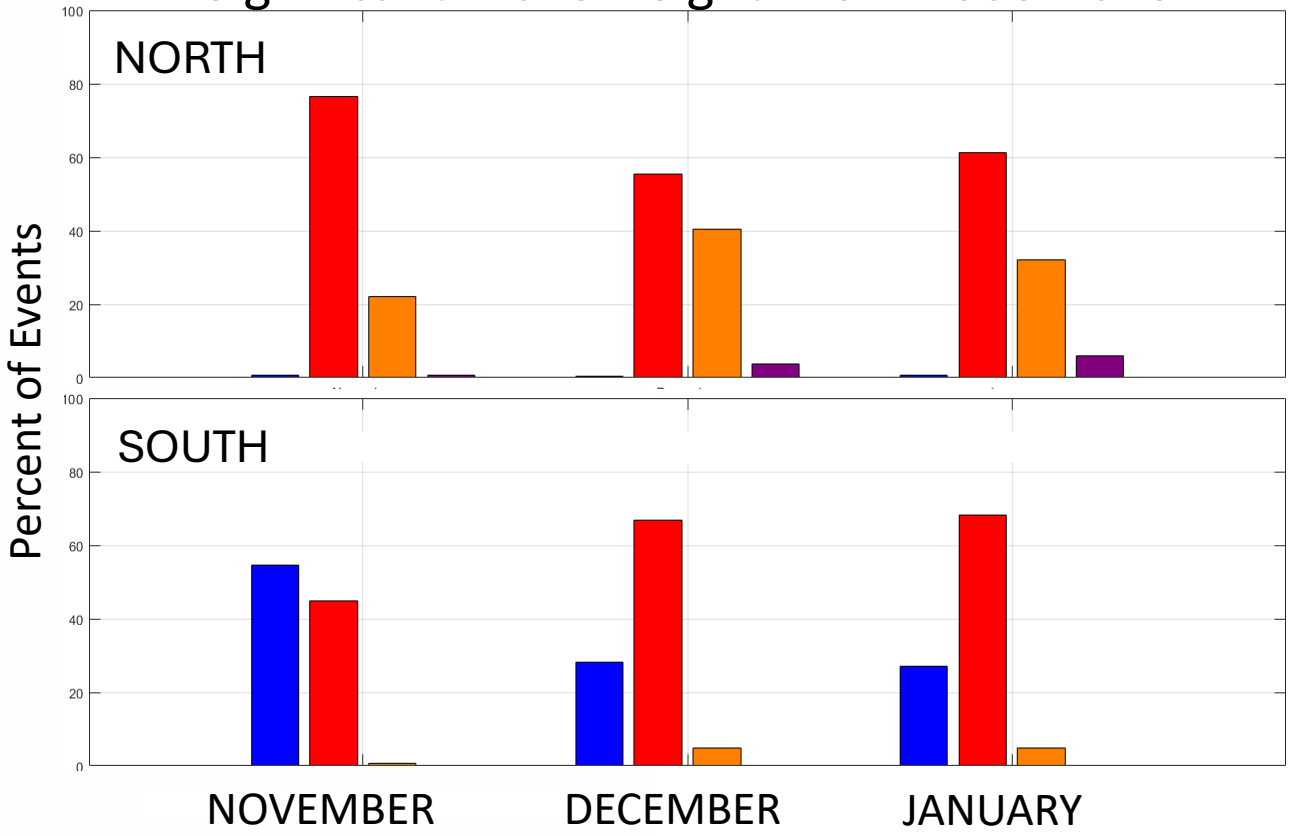
Which error sources in 1-D TWL forecasts are attributable to neglected 3-D processes, and how much does site-specific 3-D modeling reduce them?

Significant Wave Height and Direction



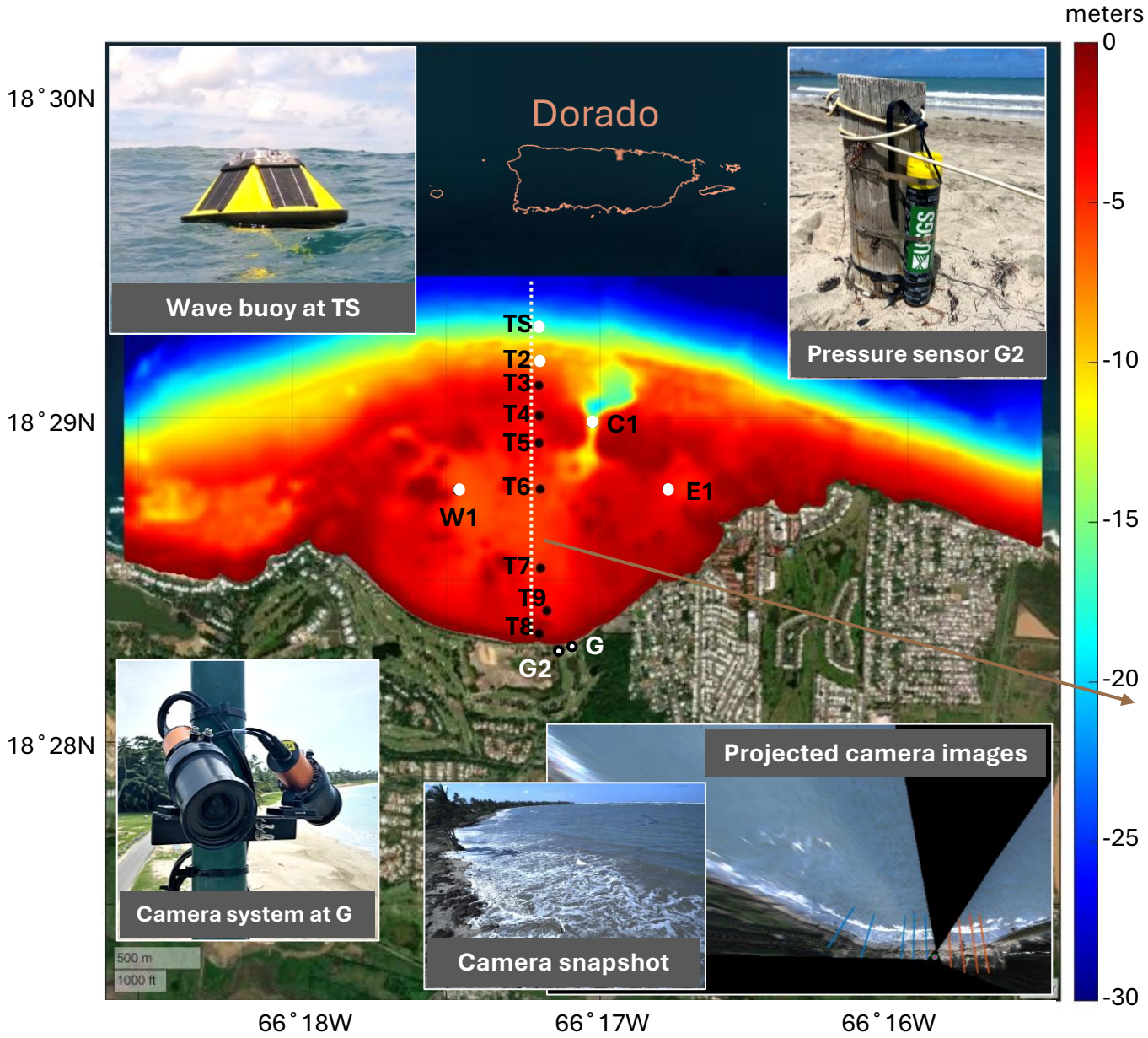


Significant Wave Height from 2006-2023



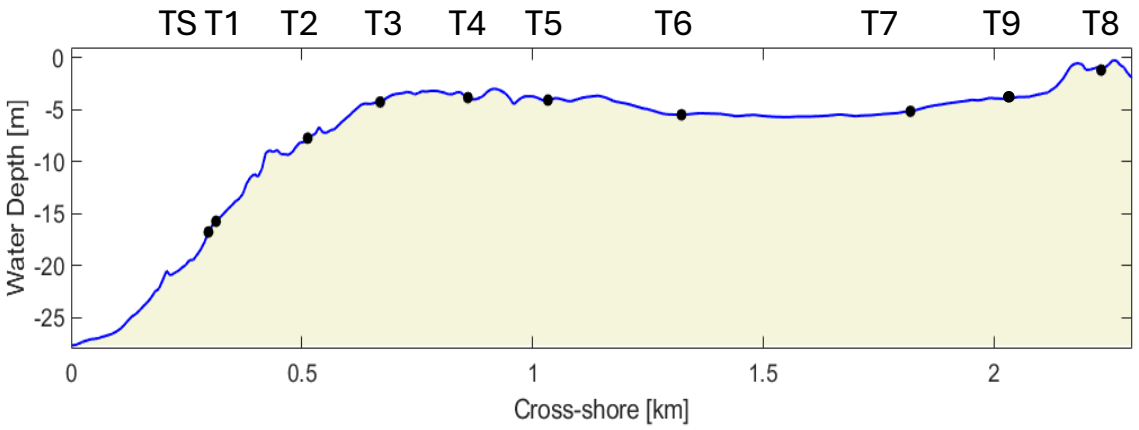
Source: ERA5

Study Site: Dorado, Puerto Rico



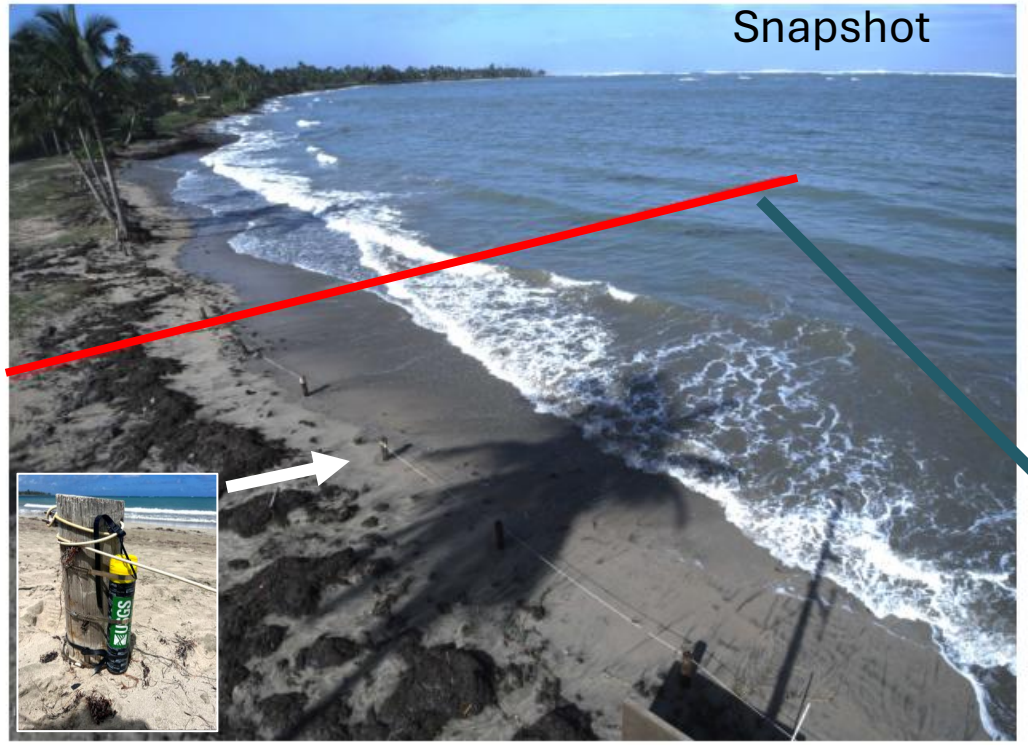
Deployment from October 2022 to February 2023

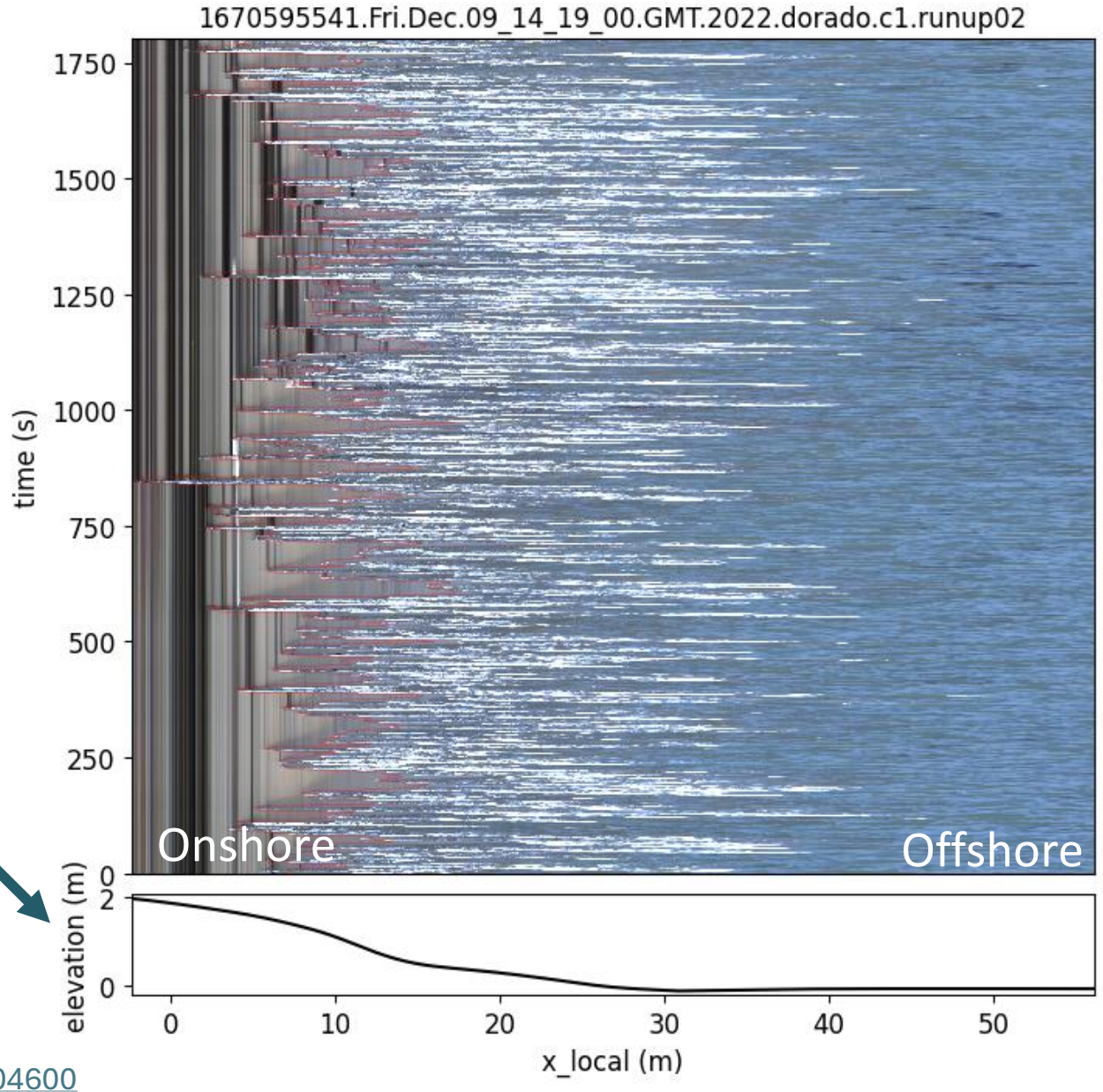
- 11 RBR pressure sensors
- 1 wave buoy (TS)
- 4 ADCP •
- 1 Camera System



In-situ Observations: Camera

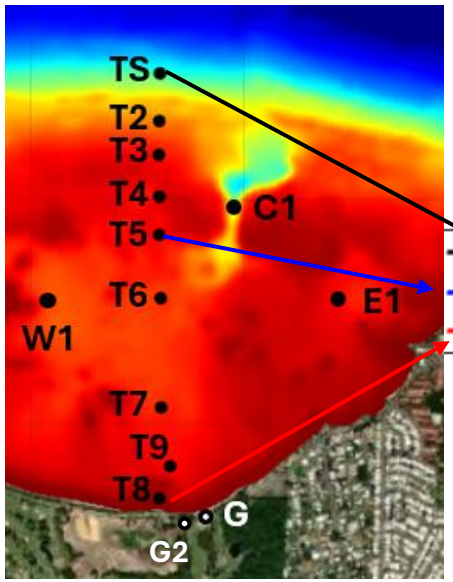
- Composite pixel over 10 minutes
- Measure through time

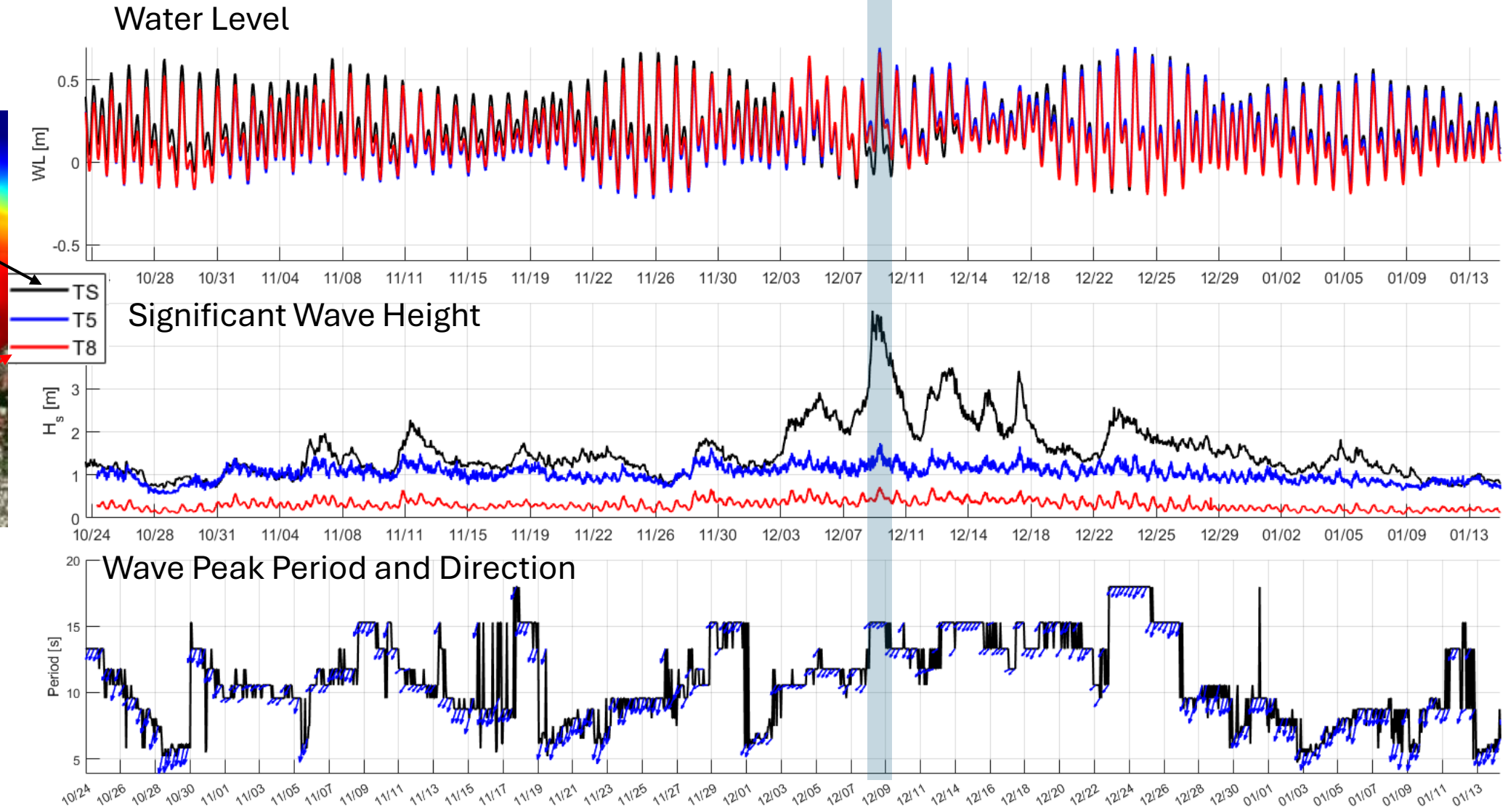




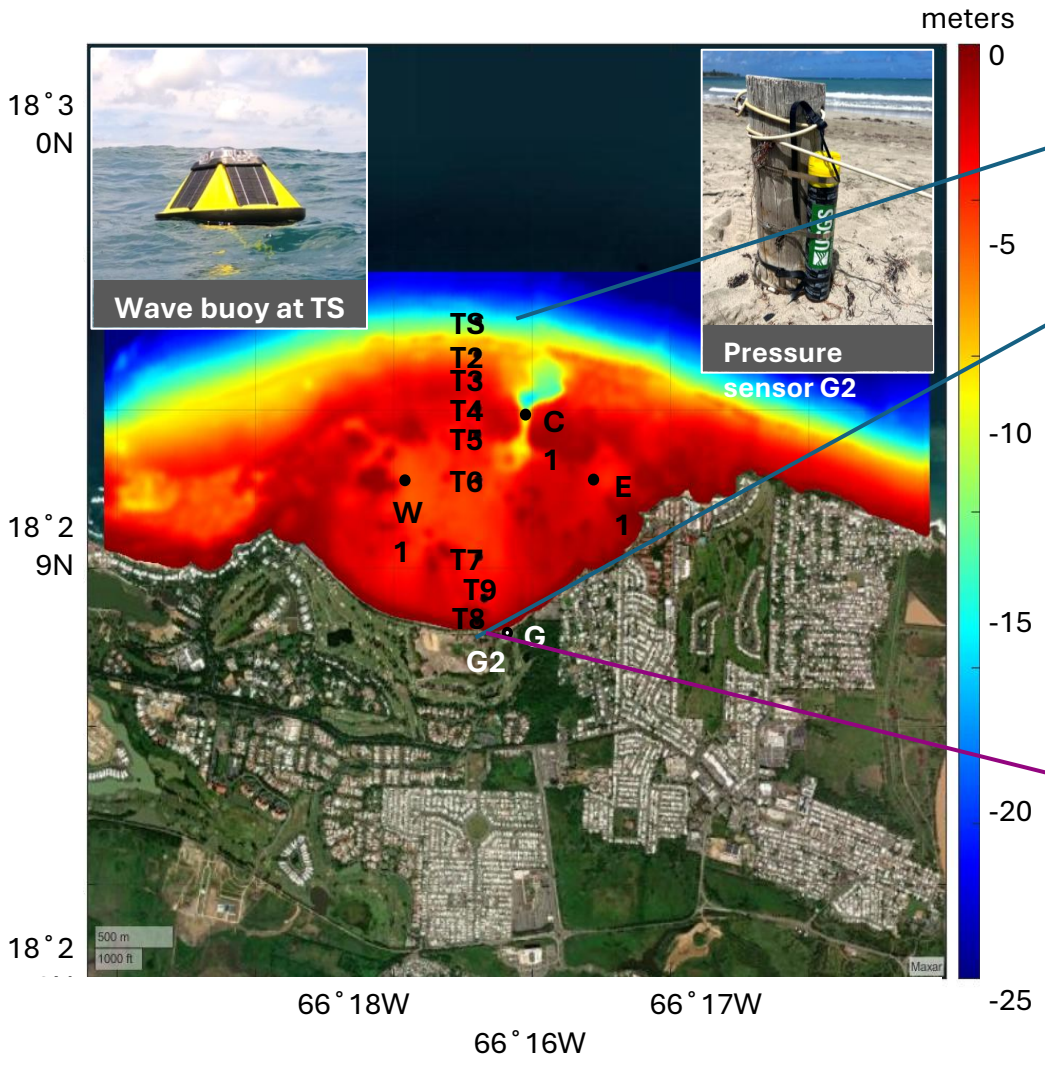
Buckley et al. (2024), Coastal Engineering 10.1016/j.coastaleng.2024.104600

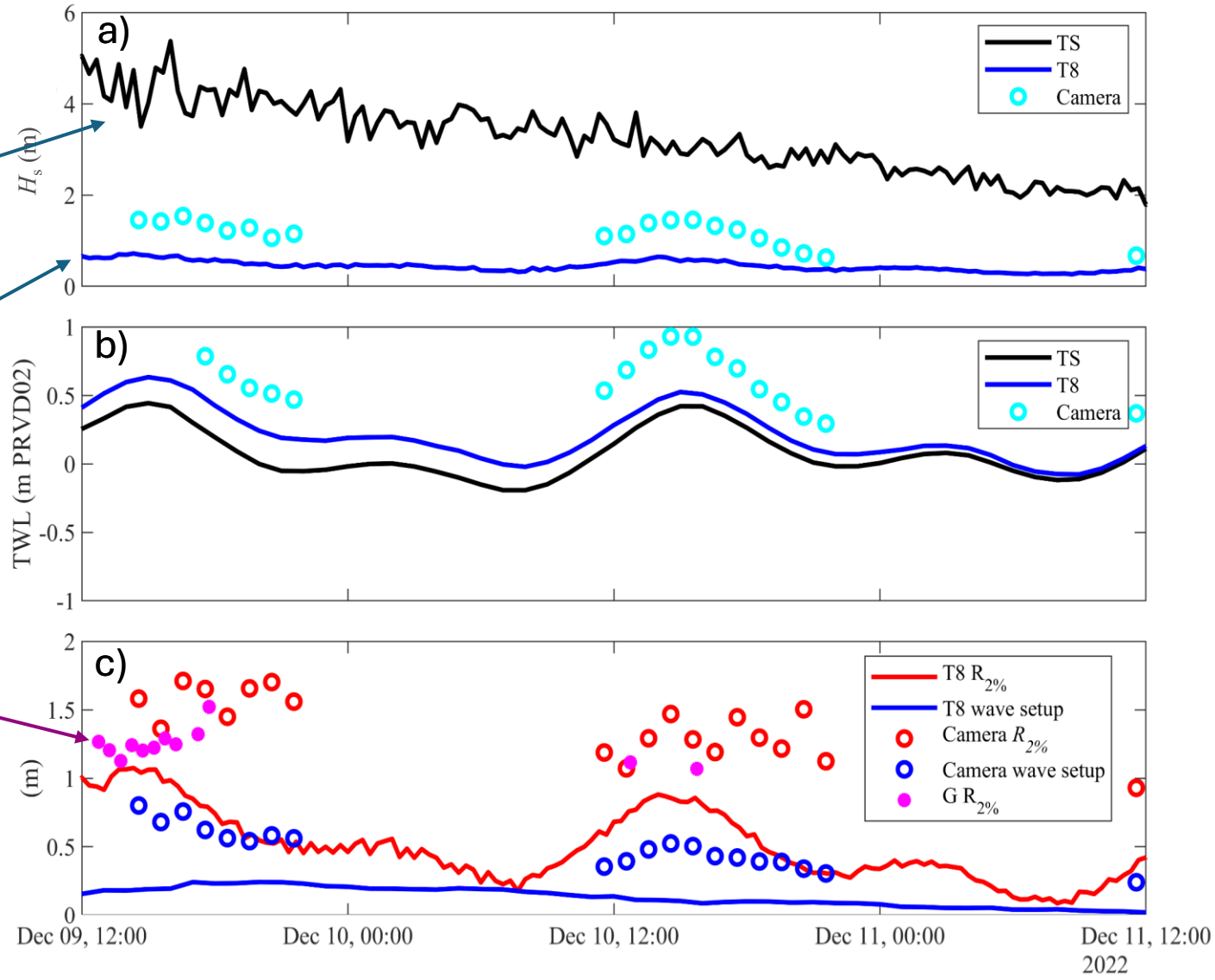
In-situ Observations: Time Series



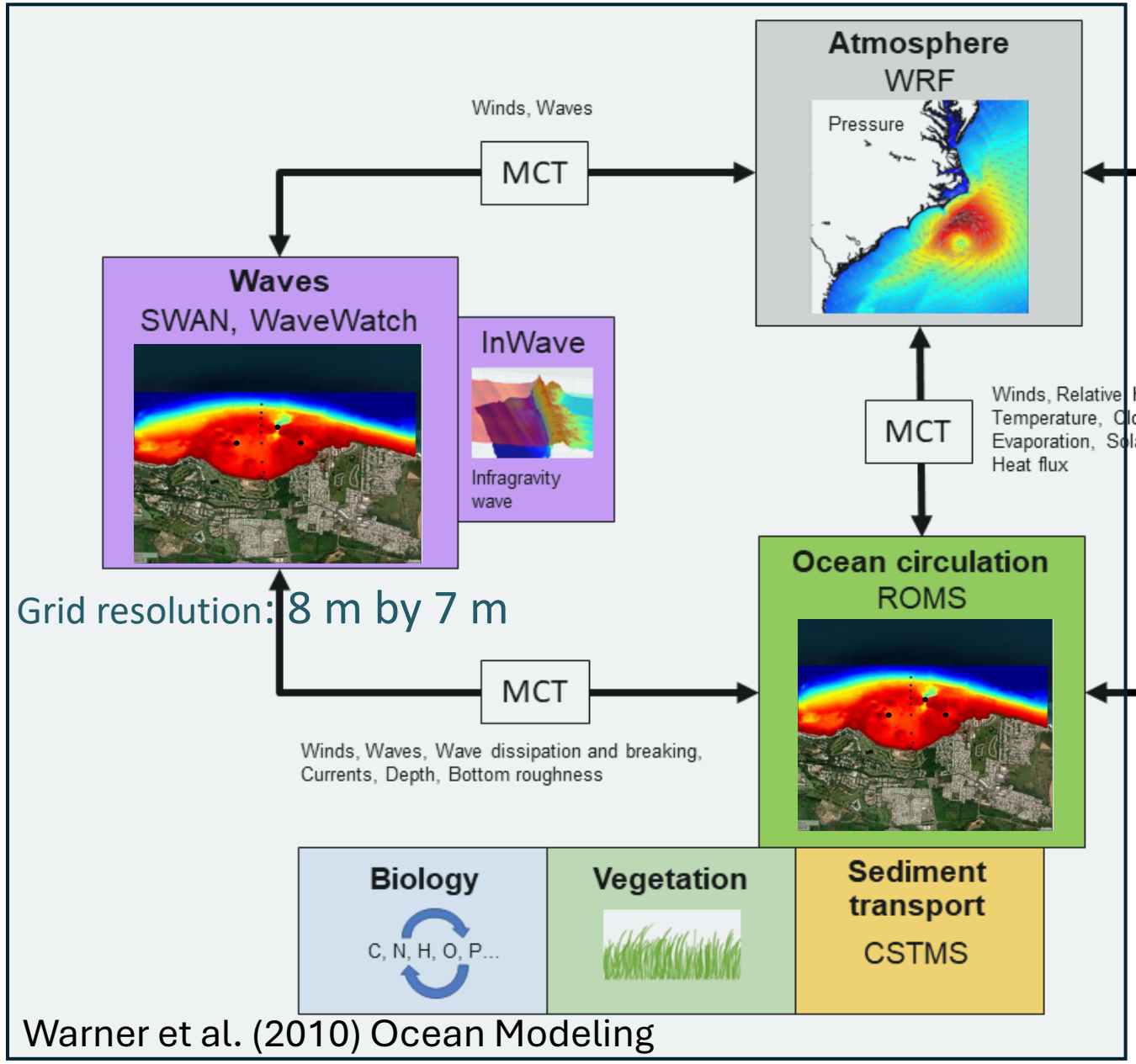


In-situ Observations: Time Series





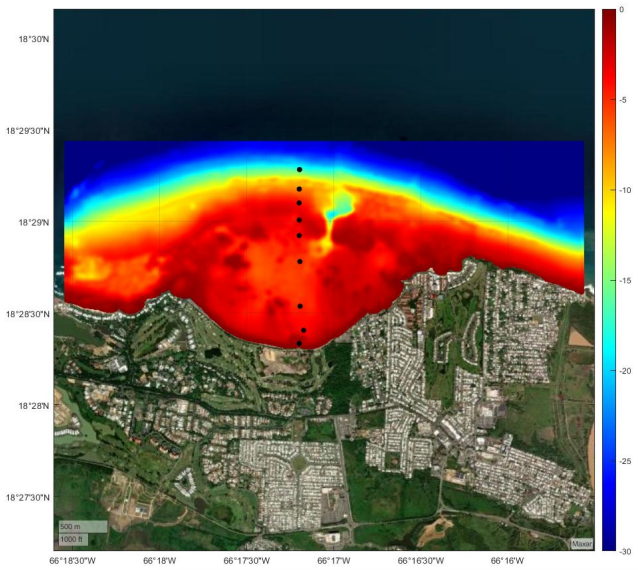
COAWST: A Coupled-Ocean-Atmosphere-Wave-Sediment Transport Modeling System

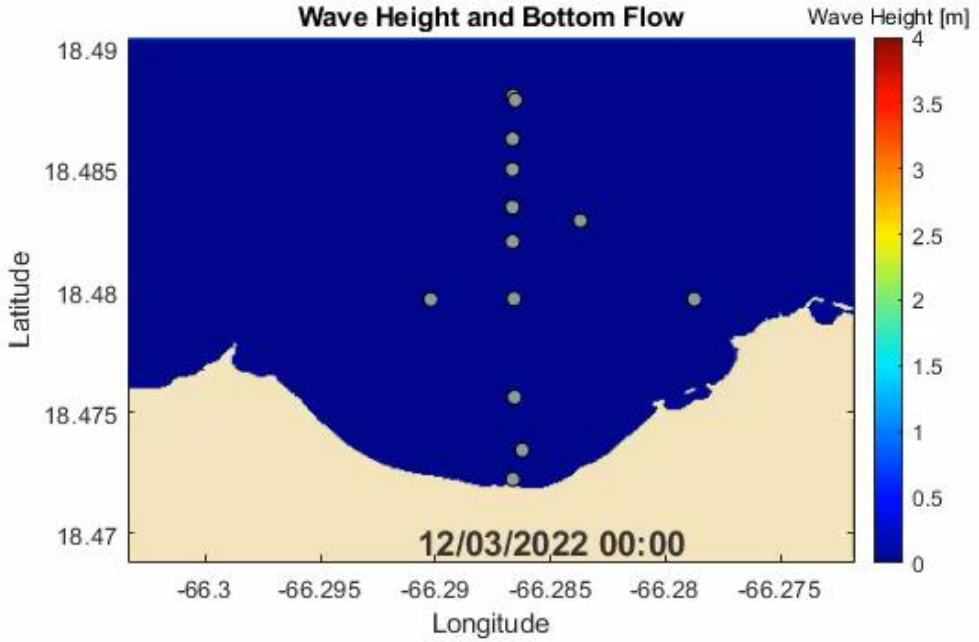


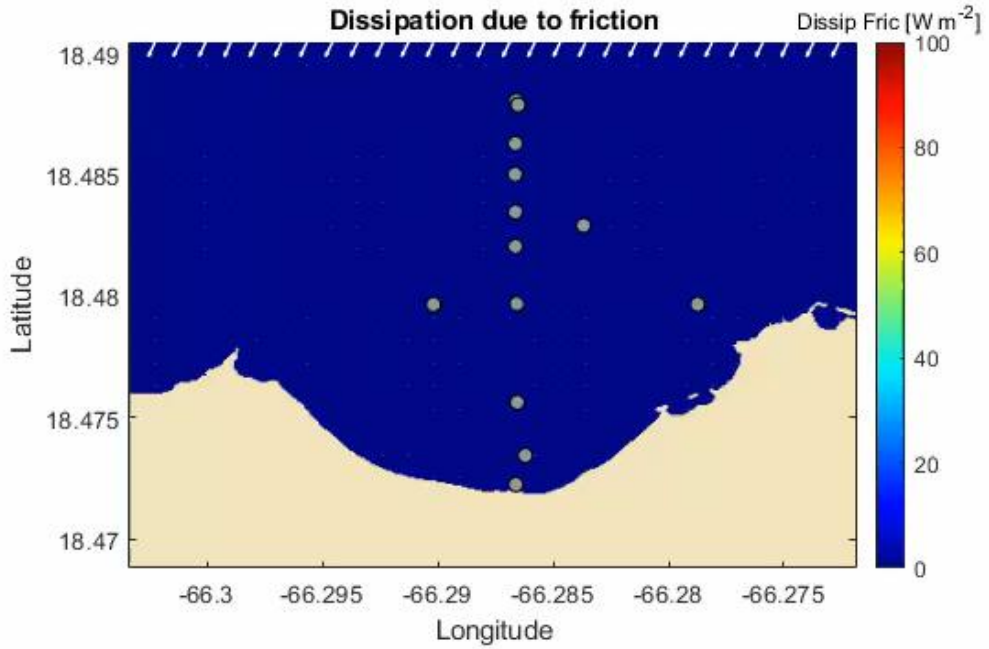
Warner et al. (2010) Ocean Modeling

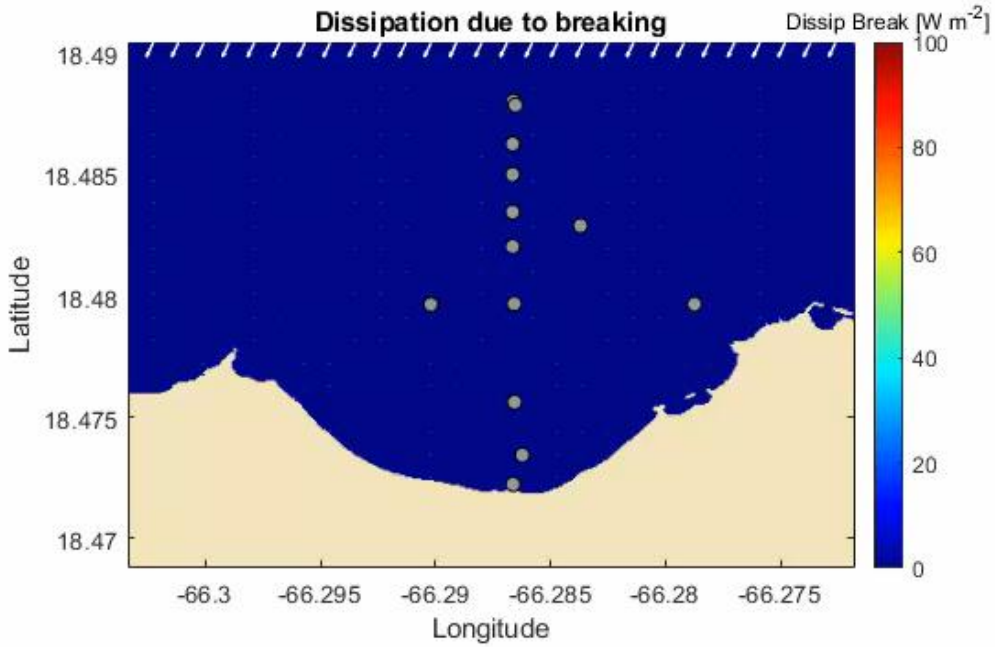
- Coupled SWAN and ROMS
- Wave forcings with wave buoy at TS
- Water levels with RBR pressure logger at TS
- Wind forced with WRF output from CARICOOS

Model Result: Dissipation over the Embayment



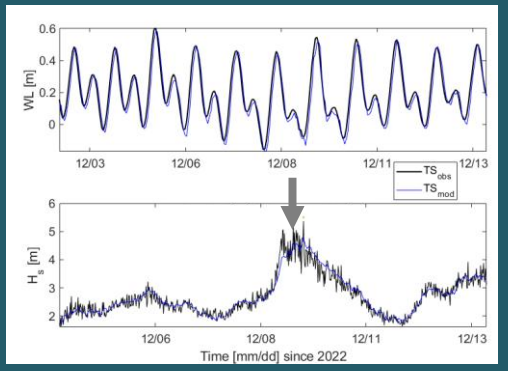




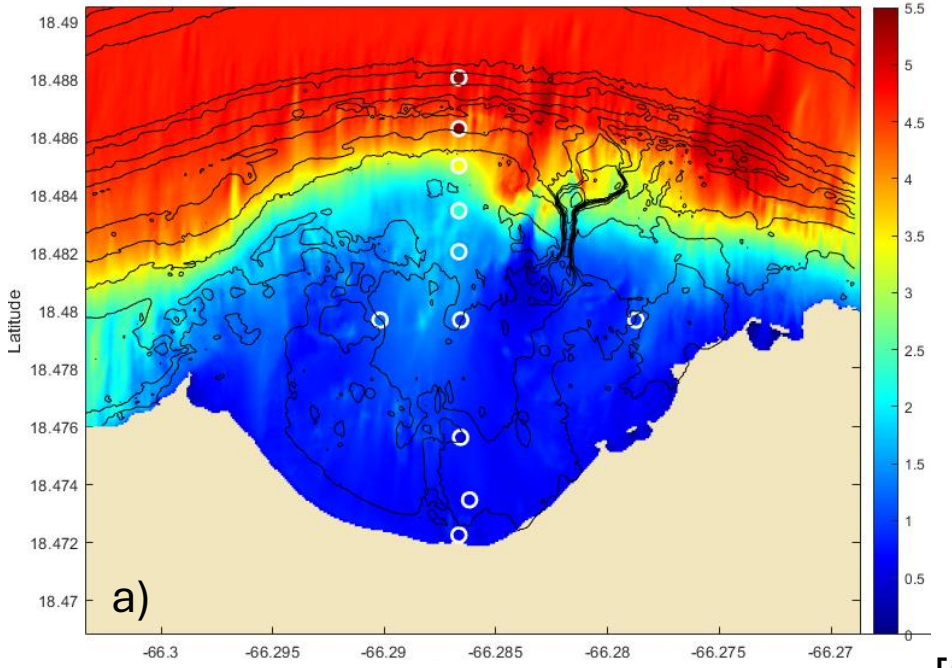


Dec 9,2022
~5 m Event

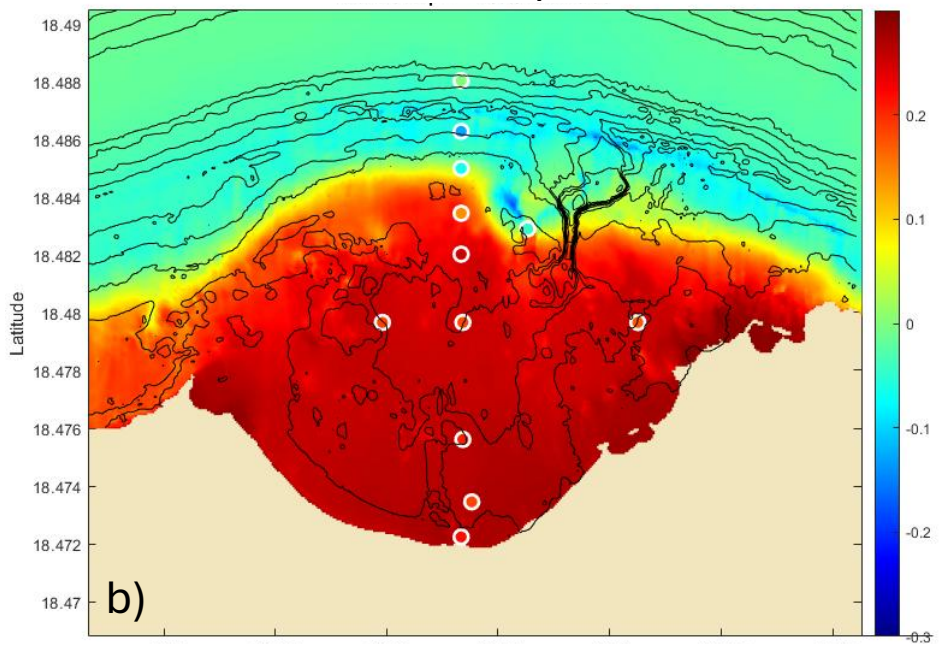
Depth-averaged cross-shore



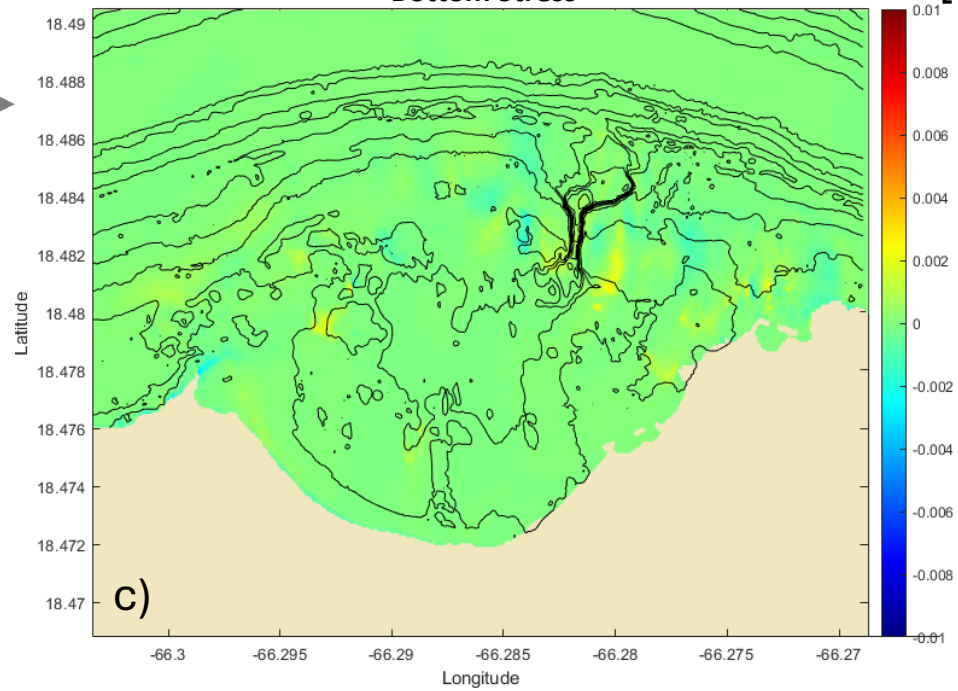
Significant Wave Height [m]



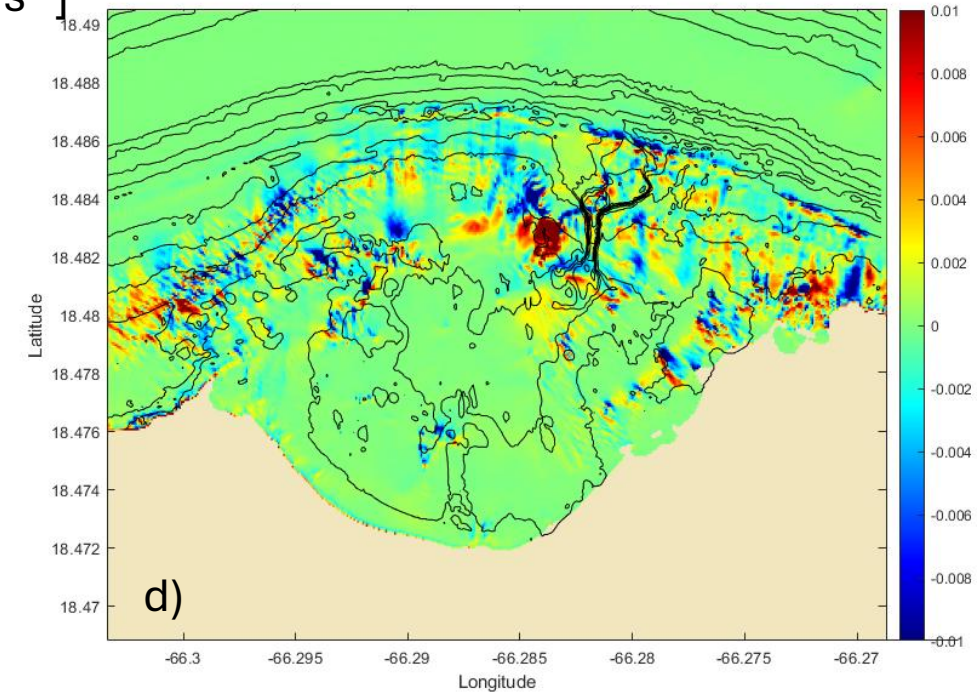
Wave Setup



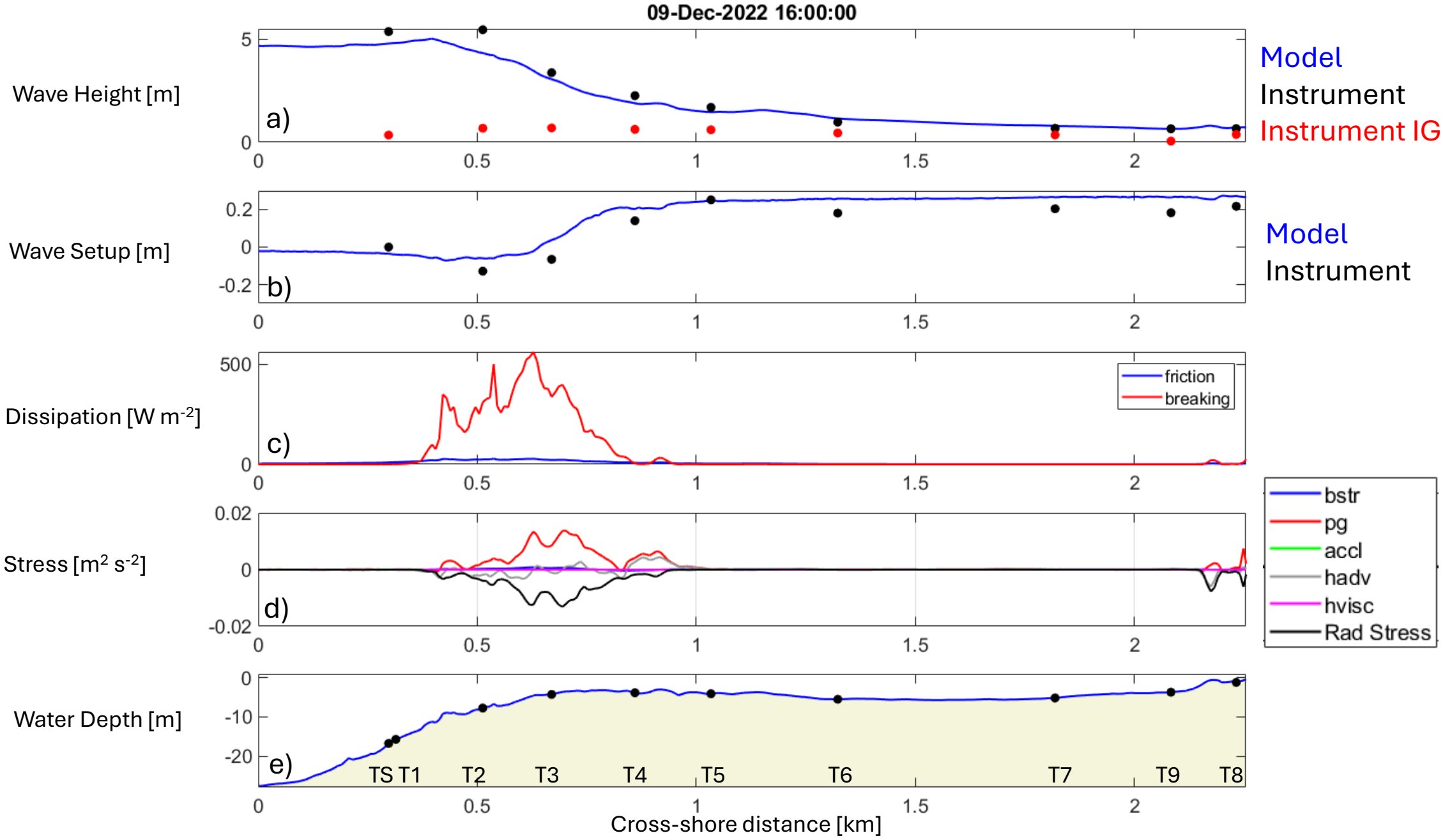
Bottom Stress [$m^2 s^{-2}$]



Horizontal Advection

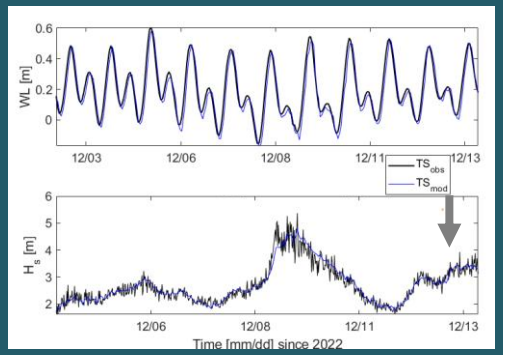


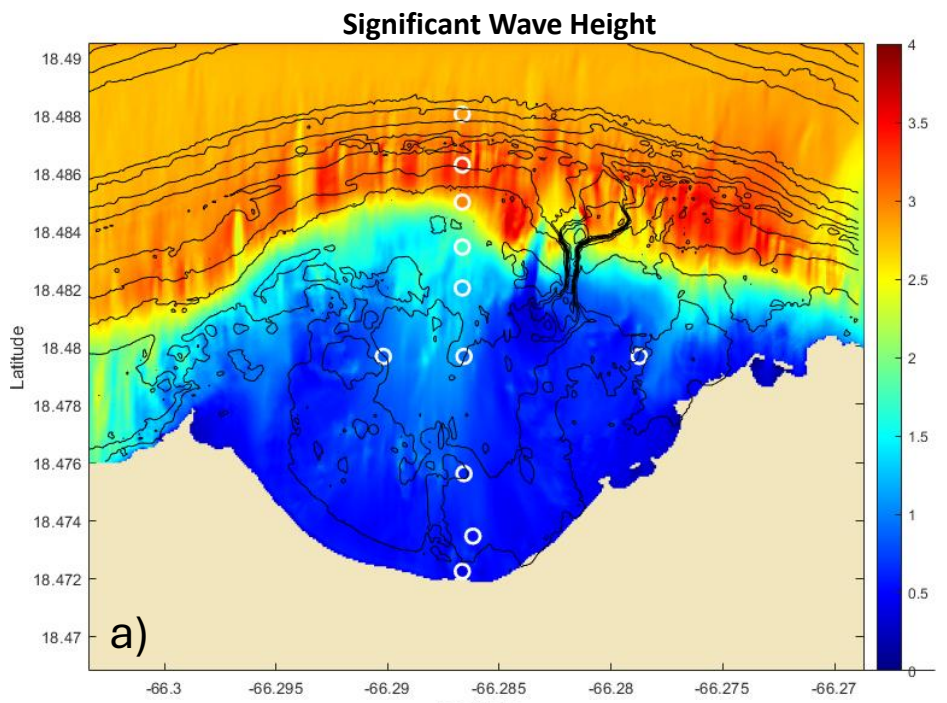
Cross-Shore Reef at ~5 m Event



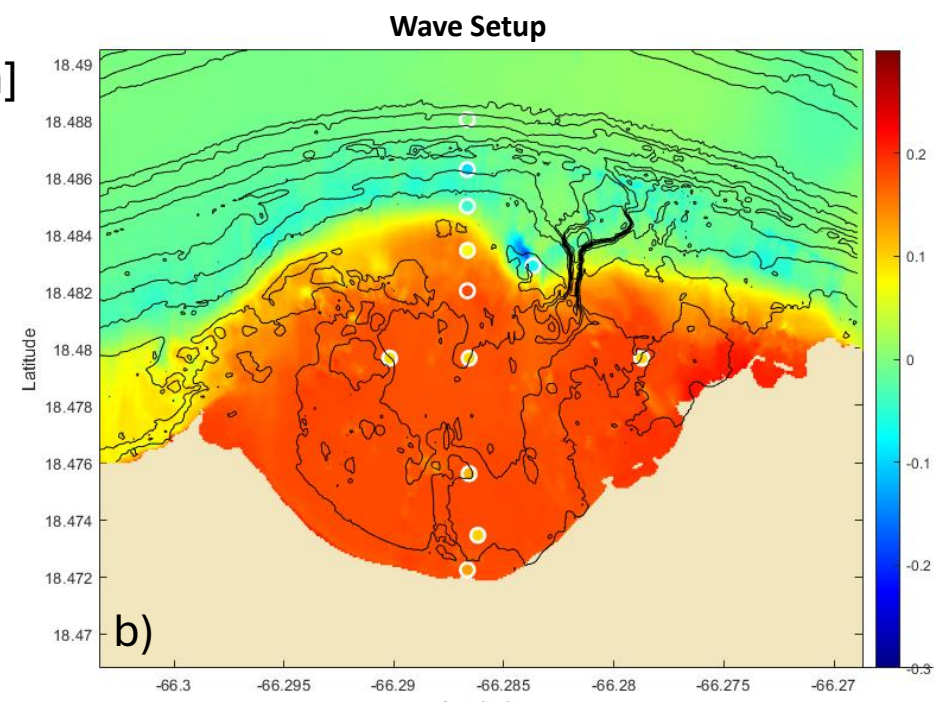
Dec 13, 2022
3 m Event

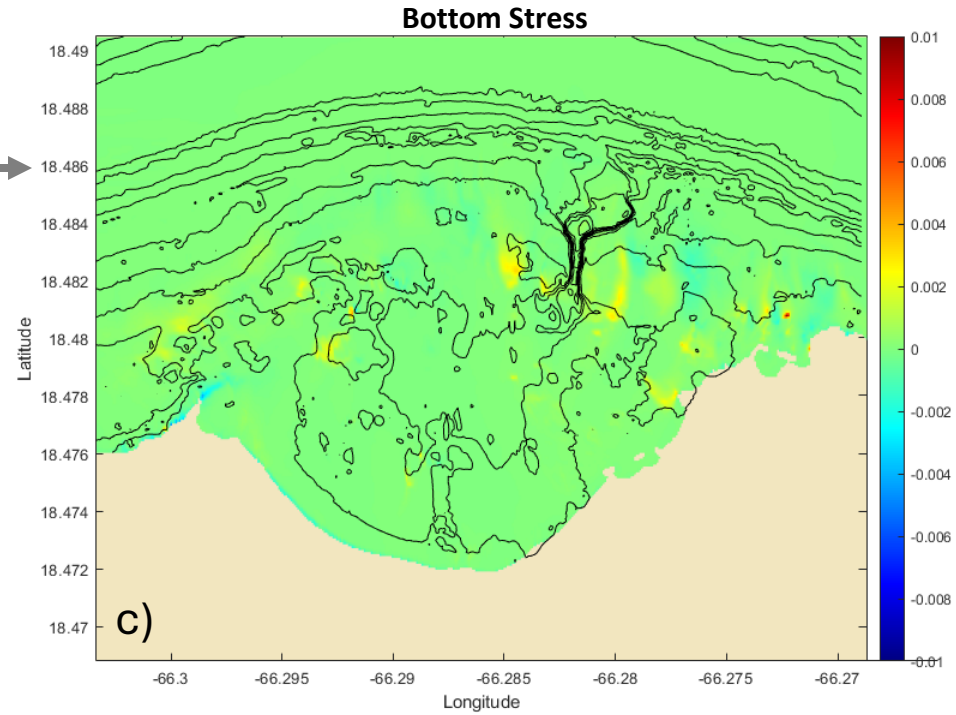
Depth-averaged cross-shore



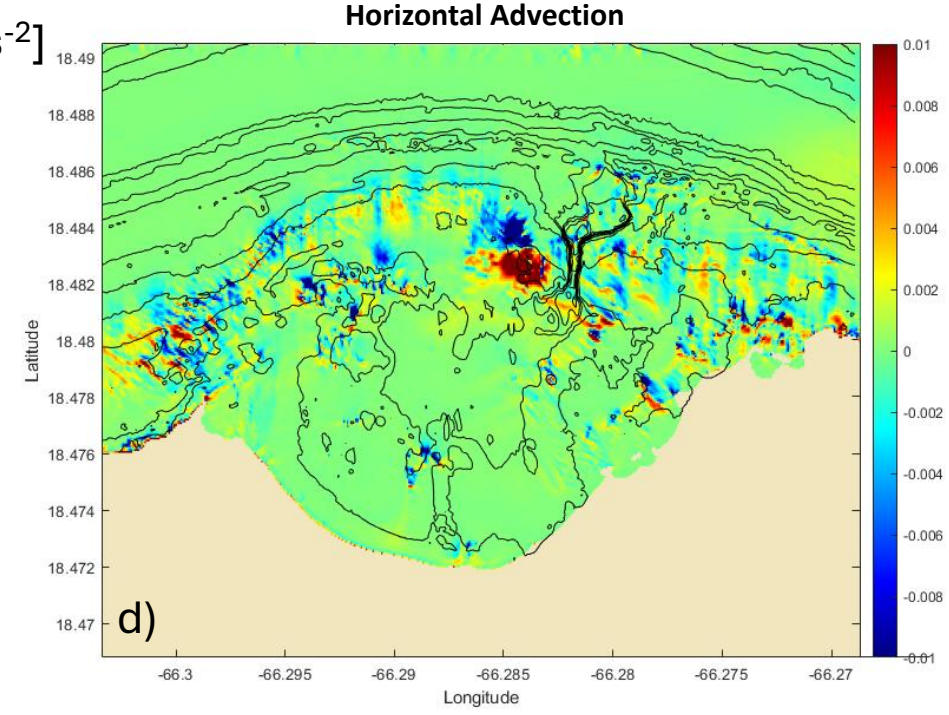


[m]

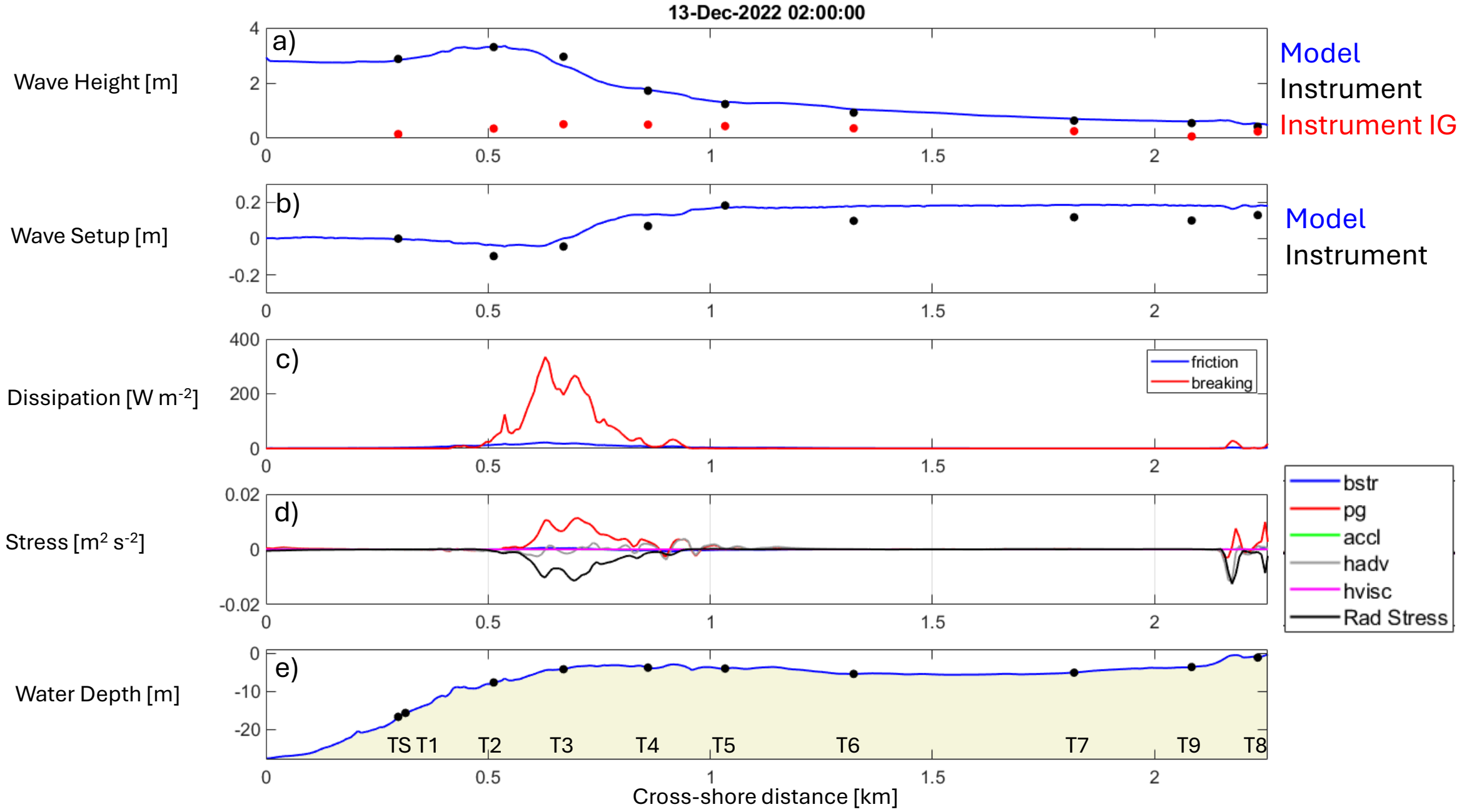




[m^2 s^{-2}]



Cross-Shore Reef at 3 m Event



On Going Work and Conclusions

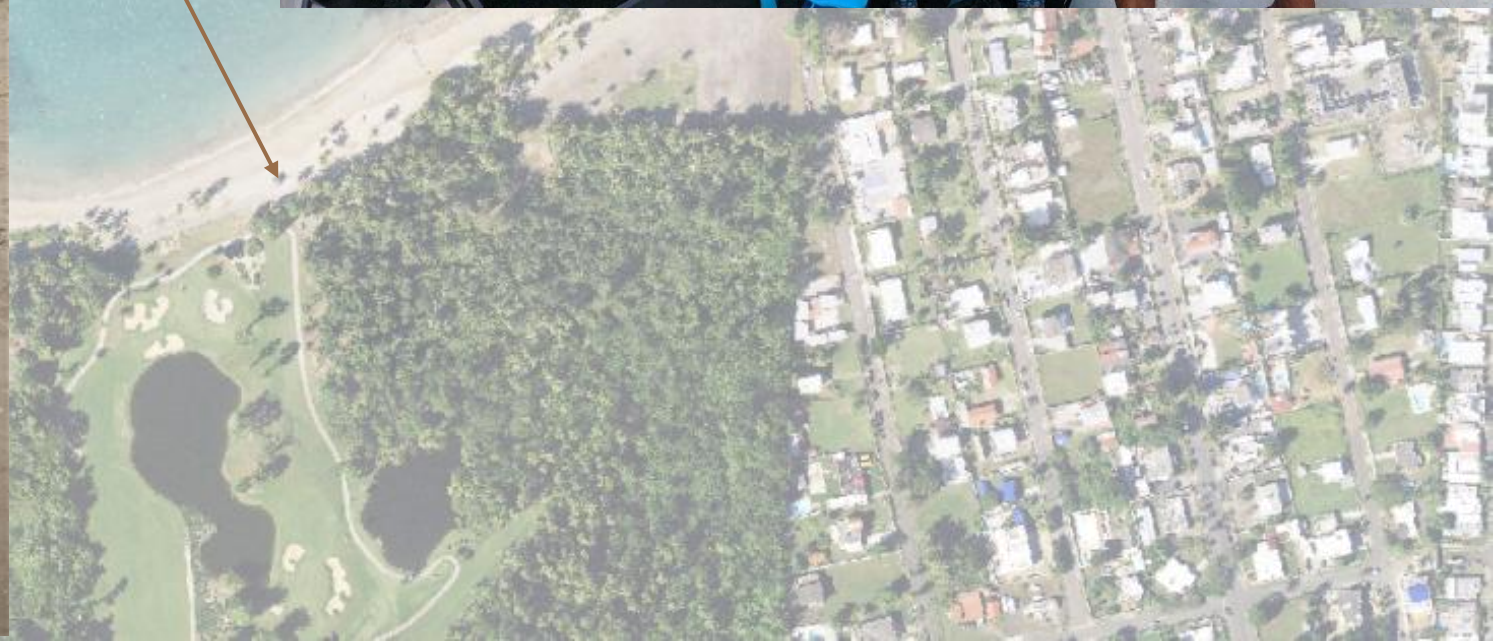
SUMMARY:

- Wave dissipation across the embayment was primarily due to wave breaking at the reef crest.
- Wave setup accounted for ~50% of $R_{2\%}$ during the largest observed wave conditions.
- The COAWST model is being used to better understand the full system dynamics and to identify sources of uncertainty.

ON GOING WORK:

- Coupling In-wave in COAWST modeling
- Model Validation
- Data Comparison
- Inter-model comparison (e.g., Xbeach)

¡Muchas gracias!



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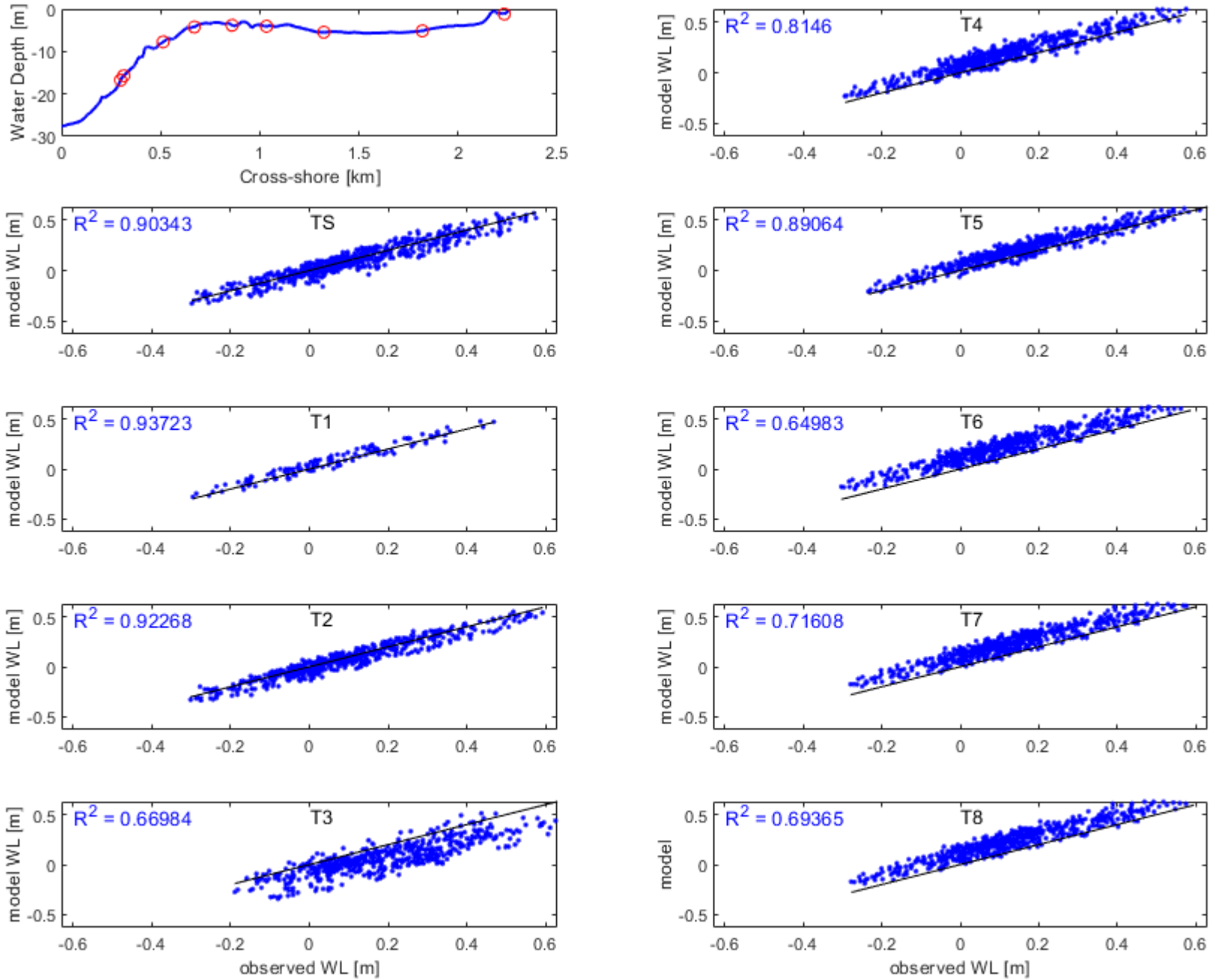
Water Depth [m]
Cross-shore [km]
R2 = 0.8146
T4
R2 = 0.90343
TS
R2 = 0.89064
T5
R2 = 0.93723
T1
R2 = 0.64983
T6
R2 = 0.92268
T2
R2 = 0.71608
T7
R2 = 0.66984
T3
R2 = 0.69365
T8
model WL [m]
model
observed WL [m]