Deterministic, dynamic forecasts of storm-driven erosion during Ian (2022)

Jessica Gorski [1], Casey Dietrich [1],
Rick Luettich [2], Matthew Bilskie [3], Davina Passeri [4], RC Mickey [4]

Beach/Dune Erosion Impacts Infrastructure

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- More frequent, high-intensity storms
- Significant storm-driven erosion leaves coastal communities more vulnerable

[LUIS SANTANA | Tampa Bay Times]

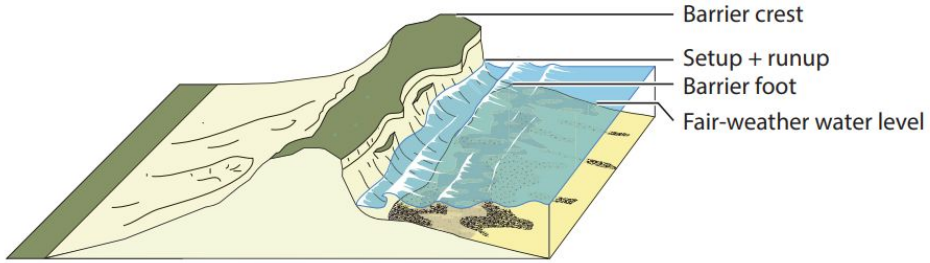
Bonita Beach, FL
Post Hurricane Ian

- Dune height: ~2m
- Max WL: ~1.4 m
- Max Hs: ~5.5 m

Sallenger (2000) Impact Regimes

Collision regime

$D_{low} < R_{high} \ll D_{high}$



Goslin & Clemmensen (2017)

Sallenger (2000) Impact Regimes

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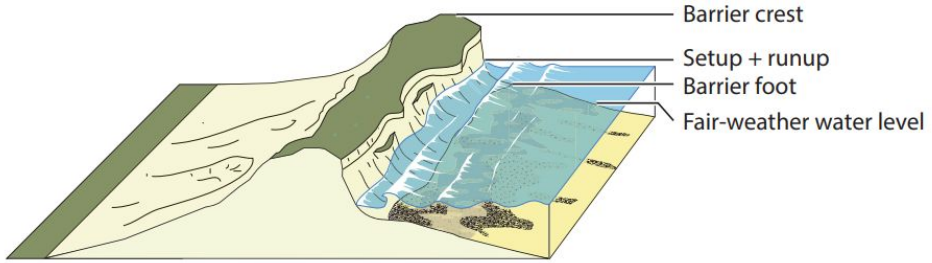
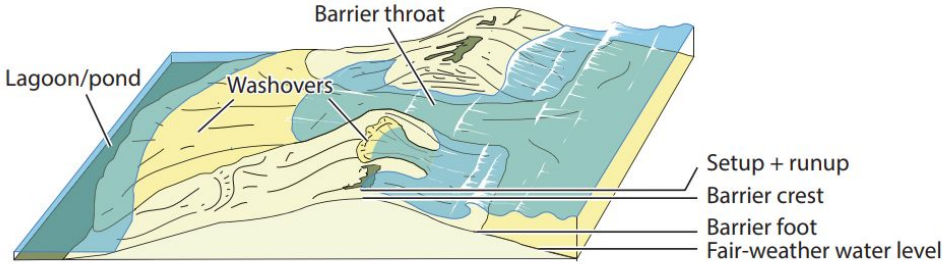


Overwash regime

$R_{high} > D_{high}$



Goslin & Clemmensen (2017)

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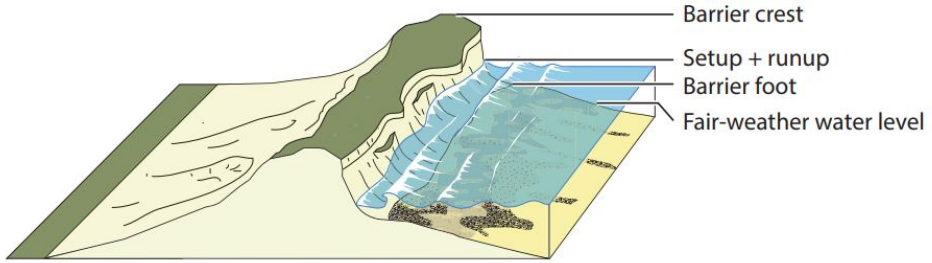

Overwash regime

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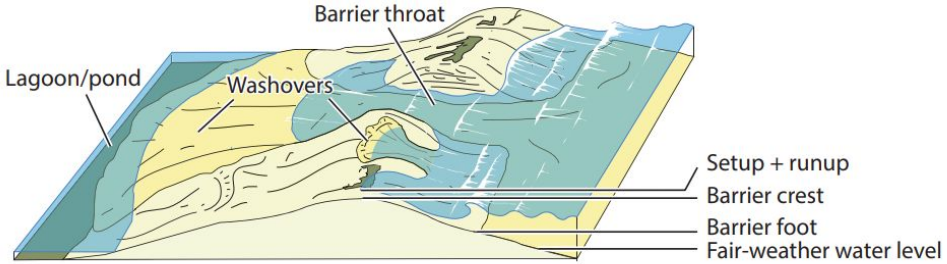
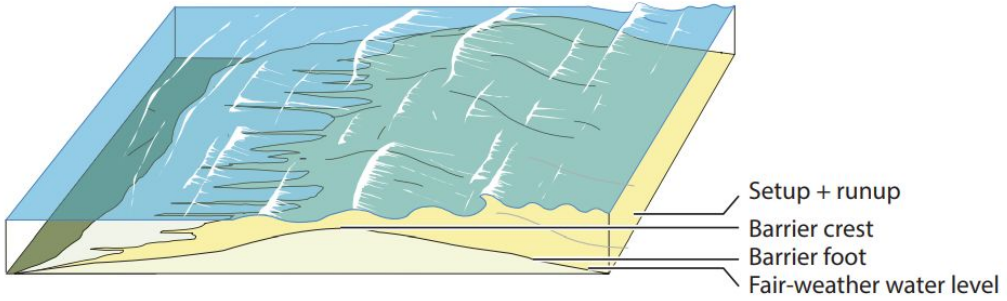


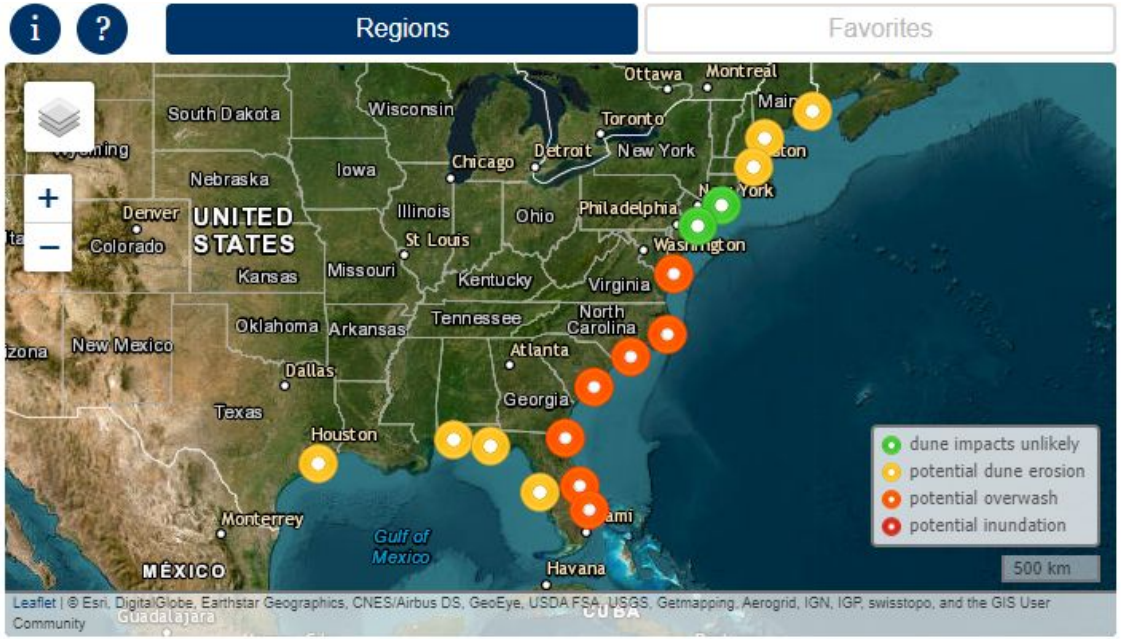
Inundation regime

$R_{low} > D_{high}$



Goslin & Clemmensen (2017)

Erosion Forecasts with Impact Regimes



USGS Total Water Level and Coastal Change Viewer

- Stockdon (2006) equations → Sallenger (2000) impact regimes
- Extratropical Surge and Tide Operations Forecast Systems (ESTOFS) and Nearshore Wave Prediction System
- Assumes **static**, simplified profile

https://coastal.er.usgs.gov/hurricanes/research/twlviewer/

Erosion Modeling with XBeach

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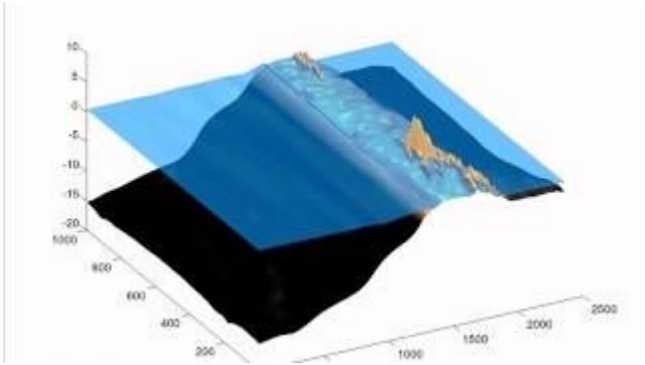
eXtreme Beach (XBeach)

- Morphological model for storm-driven erosion
- 1D or 2D options
- High resolution, dynamic results
- Typically used in hindcast scenarios
  - Data availability limitations
  - Computational expensive
  - Can take hours



XBeach-Deltares

Can **1D XBeach** be used in real time?

- Harley, M. et al (2011) did this with an 8 km stretch of coast in Northern Italy

We are attempting to represent **more than 4000 km** of the U.S. Atlantic and Gulf coasts

Goal and Research Questions

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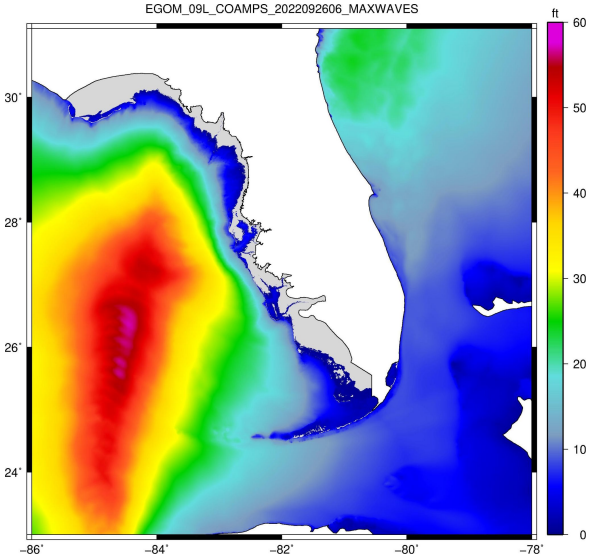
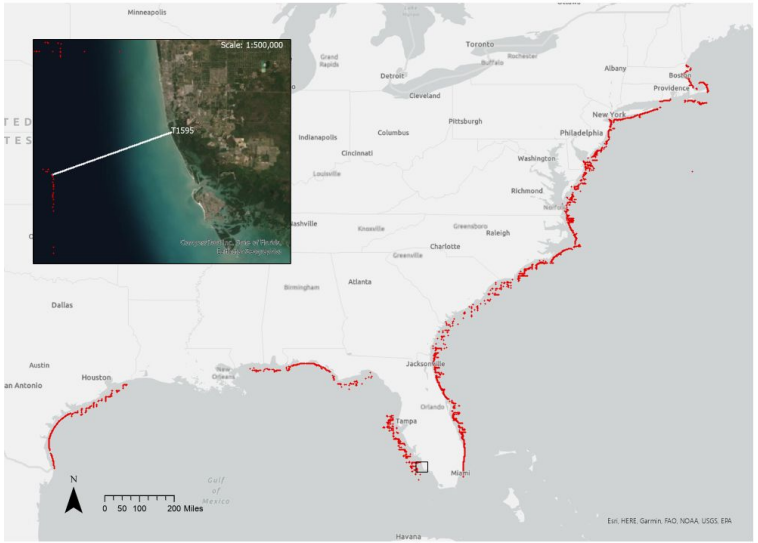
Use the morphological model XBeach to forecast storm-driven erosion along the U.S. East and Gulf Coast prior to landfall

1. How can we evaluate the predictive accuracy of the Ian forecasts?
2. Do our predictions improve with each forecast?
3. When during the storm is the dune impacted?

Forecasts with 1D XBeach



η, Hs, Tp, θ

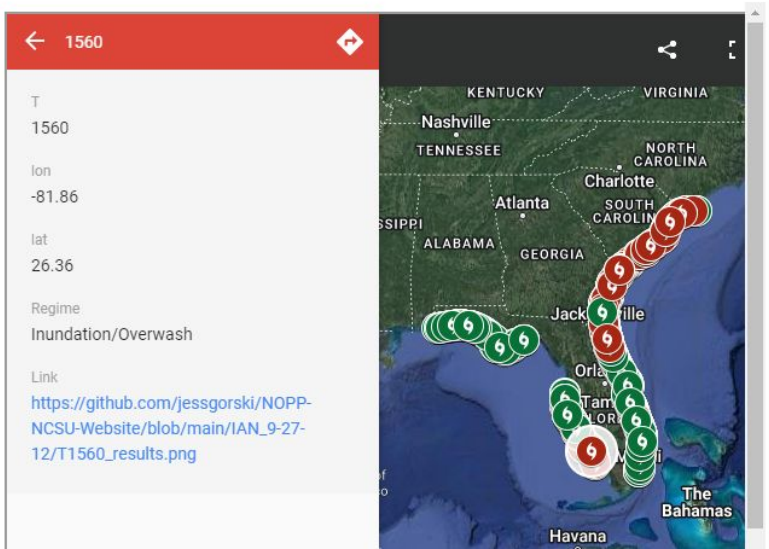


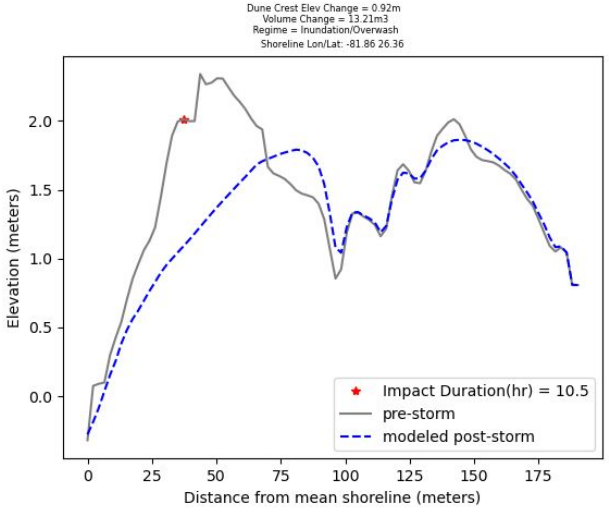
[Mickey & Passeri 2022]

1D XBeach simulations

- Calibrated with NOPP collaborators (van Dongeren and team)
- Hundreds of 1D simulations in less than an hour

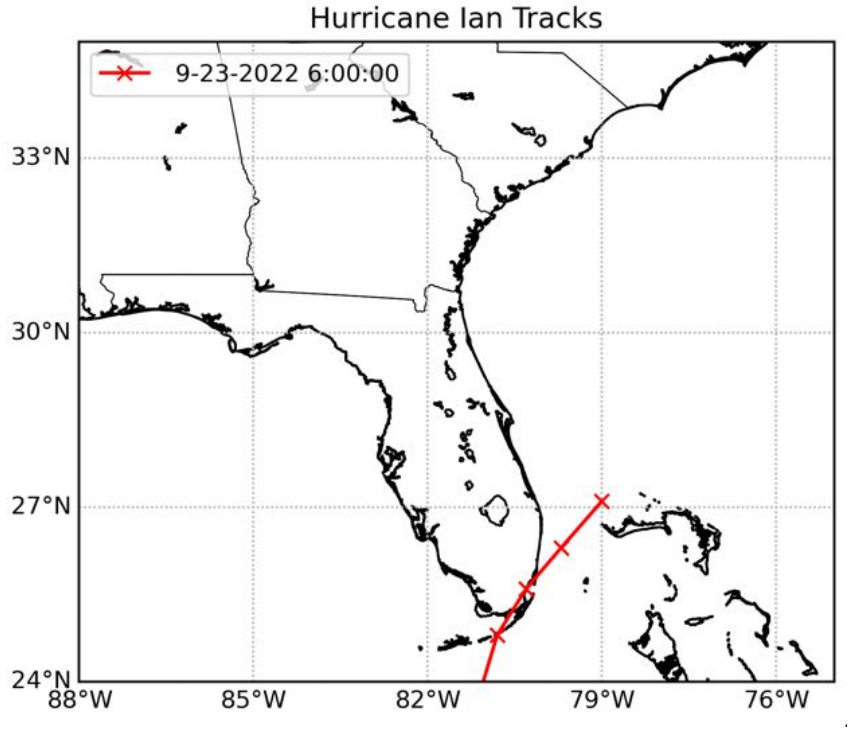
Examples of Forecast Guidance

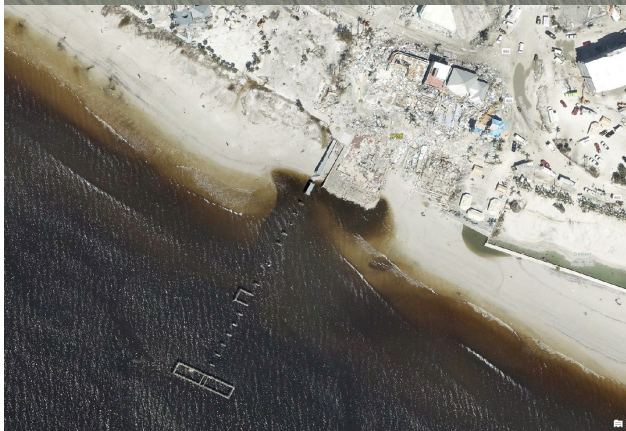




Hurricane Ian

- **3rd costliest storm on record**: $112.9 Billion
- Track originally estimated to make landfall in Tampa
  - Shifted south, made landfall in Fort Myers, moved into Atlantic, made another landfall north of Charleston
  - Adv 15 (~3 days before landfall) vs Adv 23 (~1 days before landfall)





Advisory Progression

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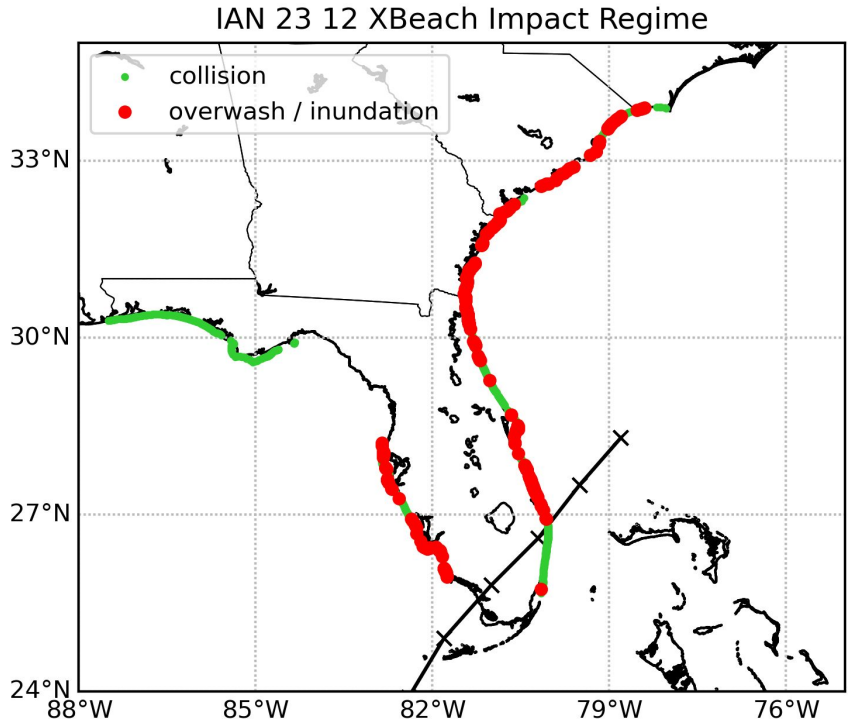

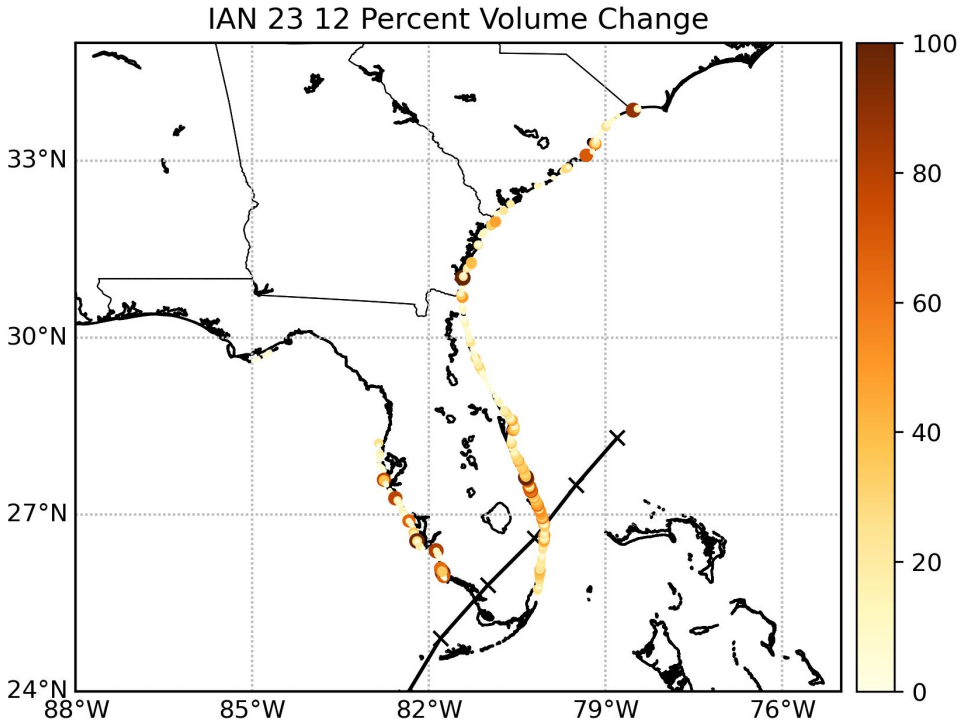

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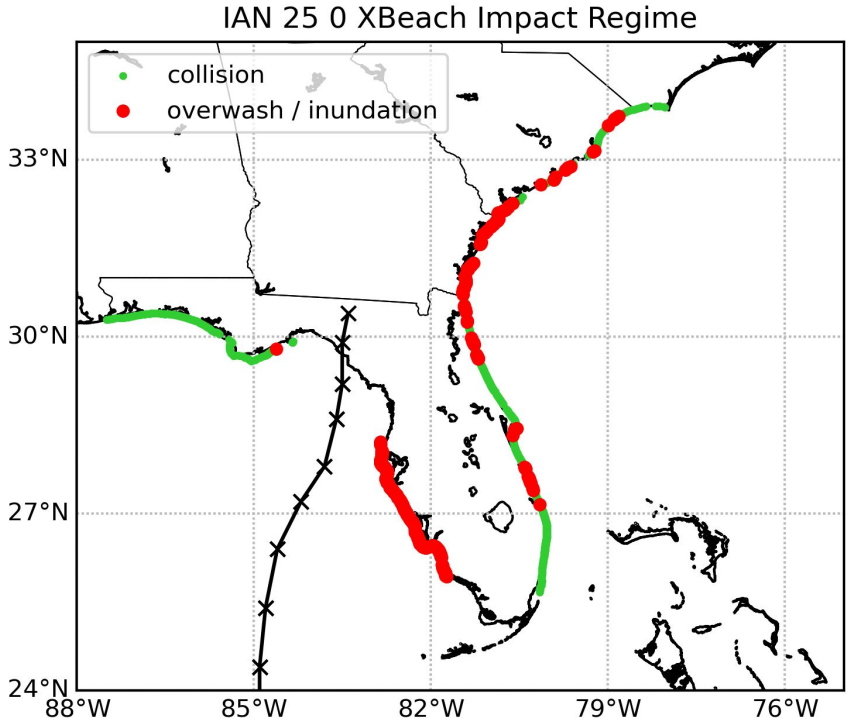

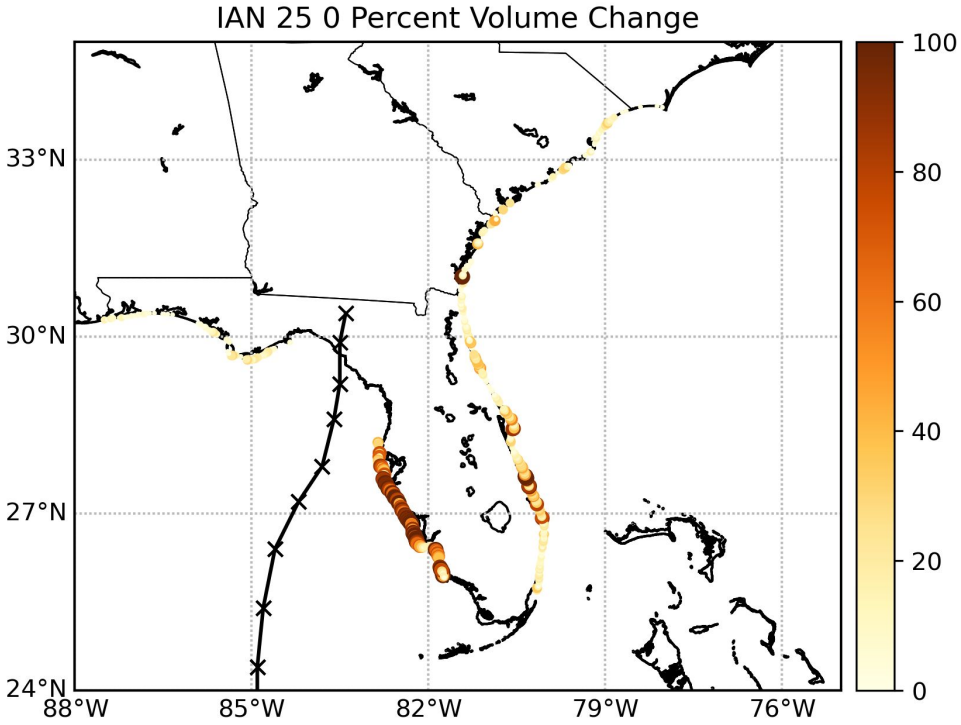

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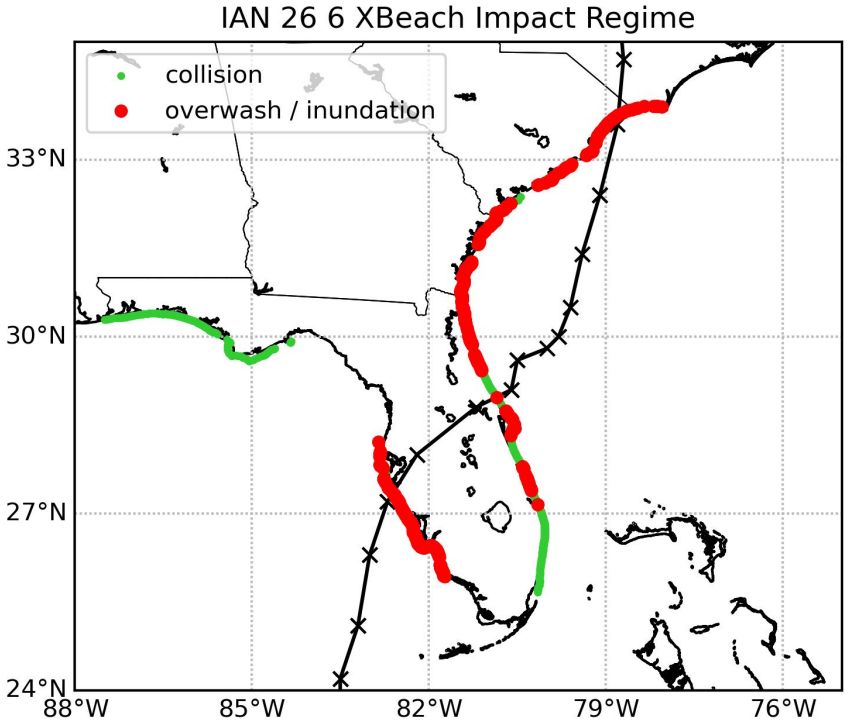

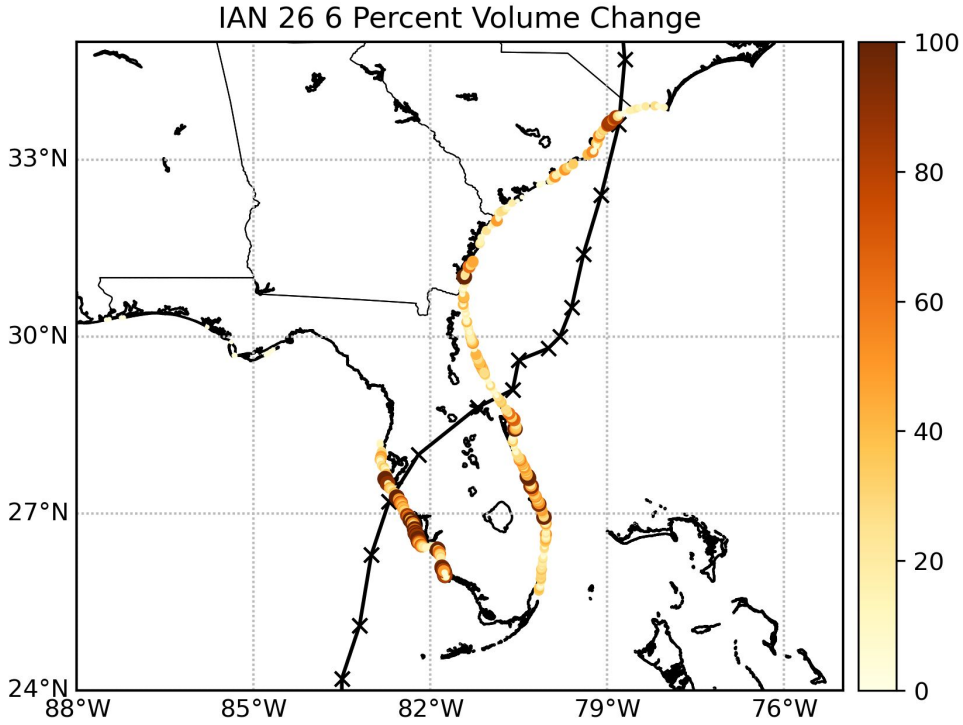

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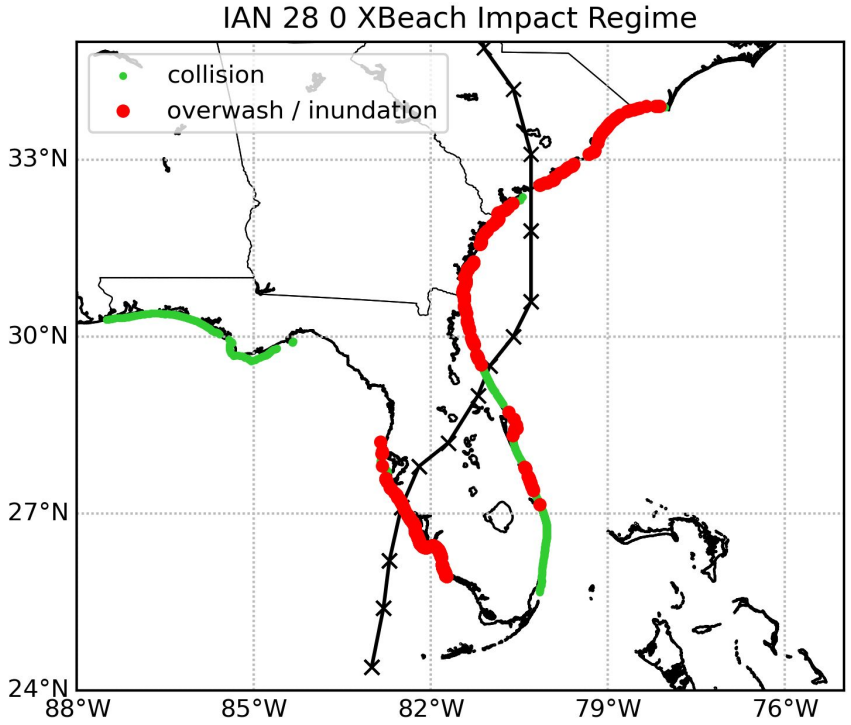

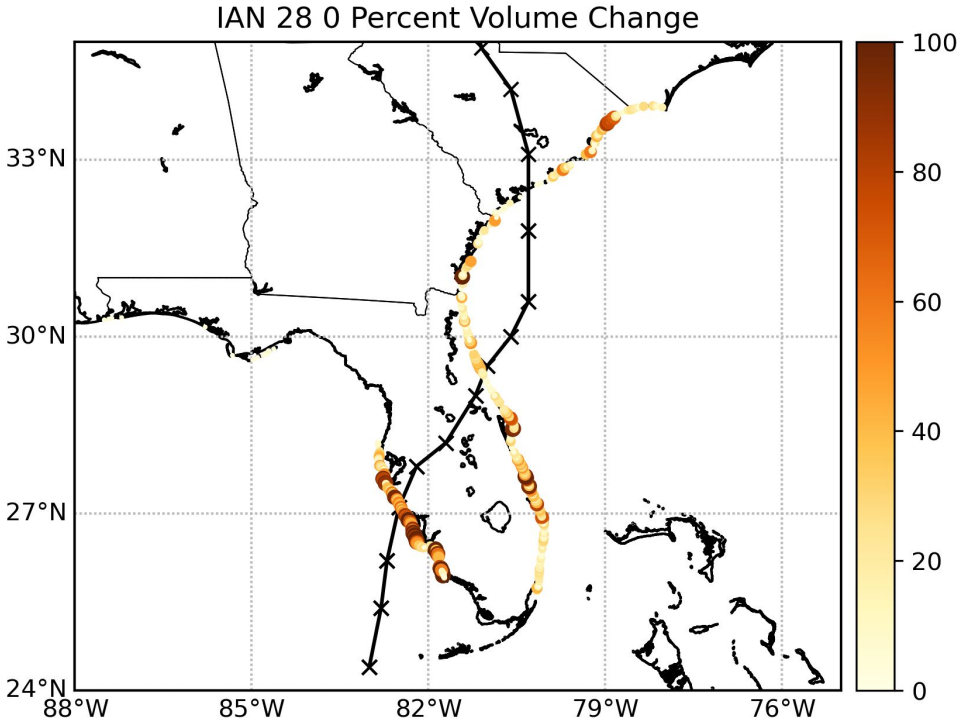

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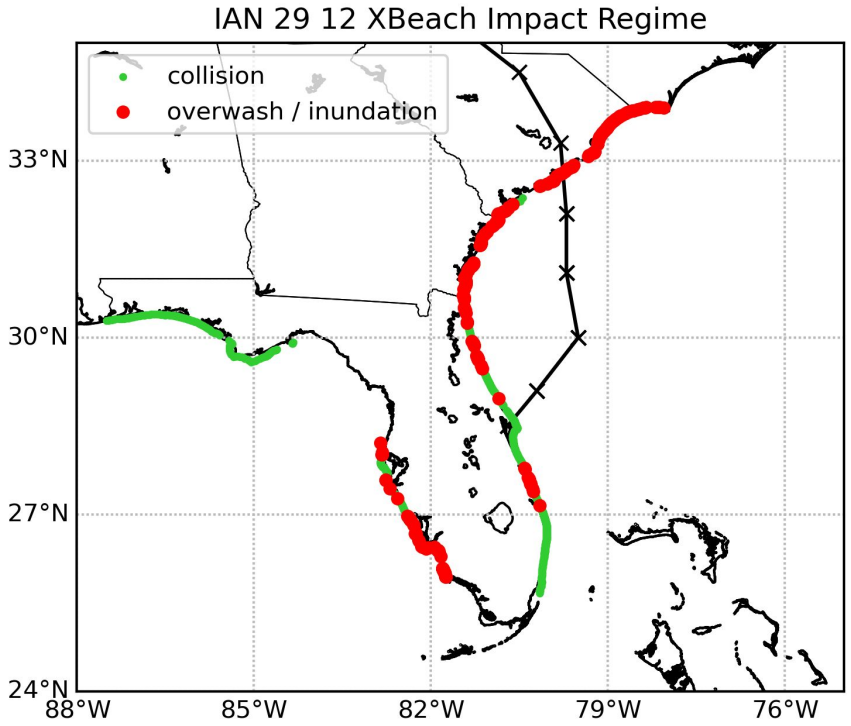

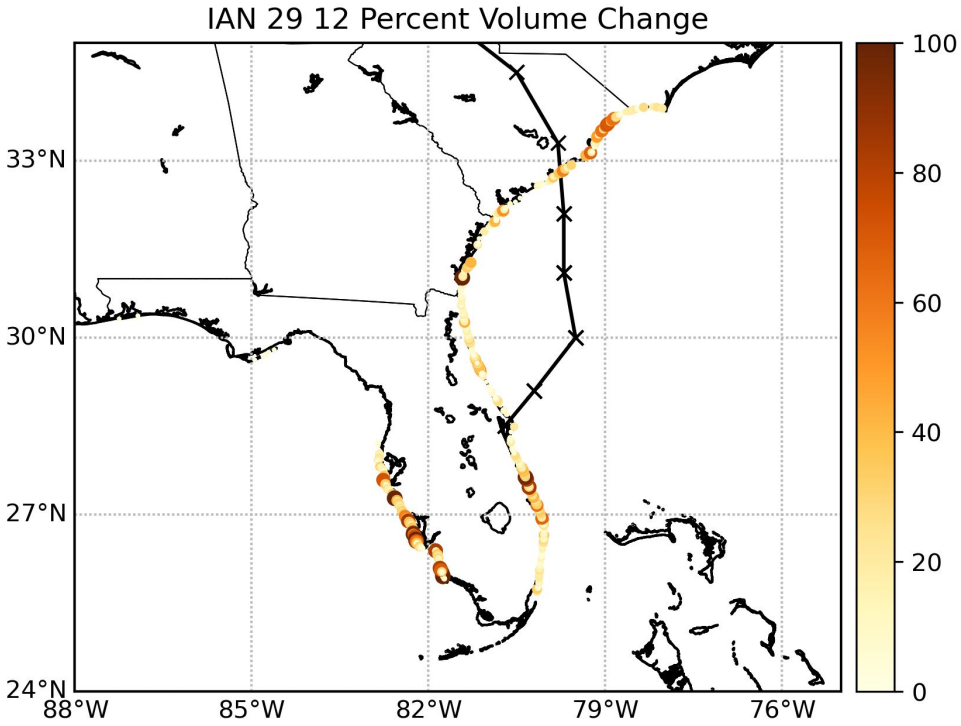

Regions Affected: SW Florida, SE Florida, South Carolina

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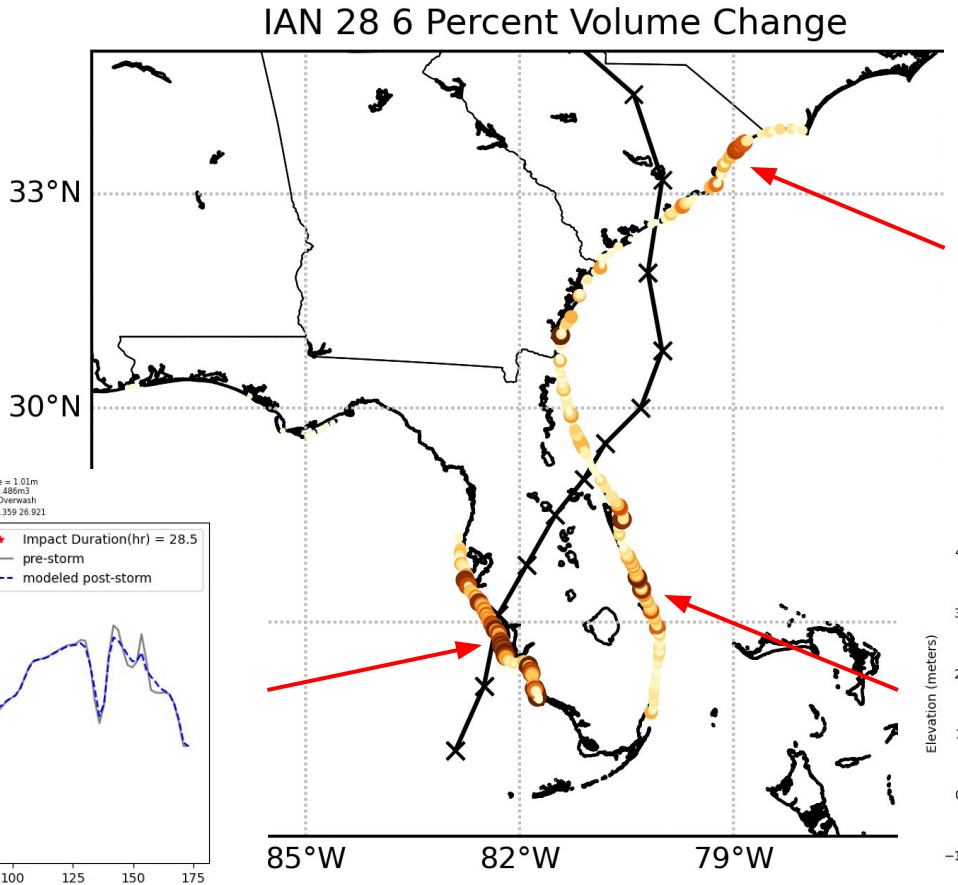

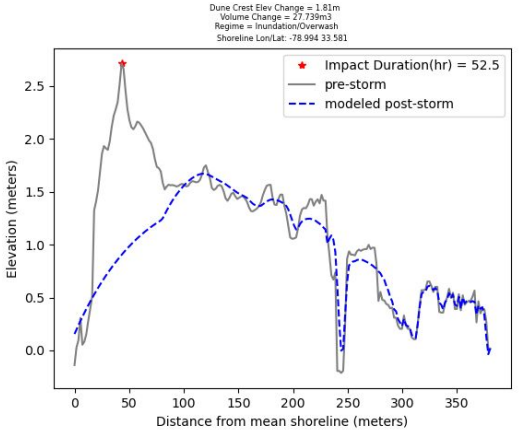

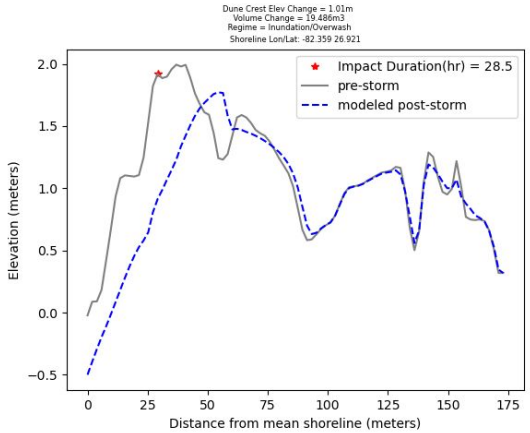

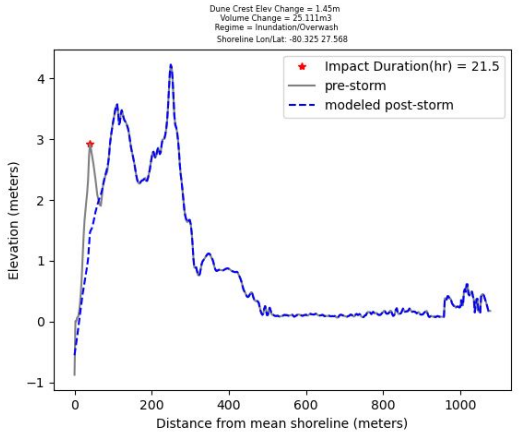

Southwest Florida: T3940

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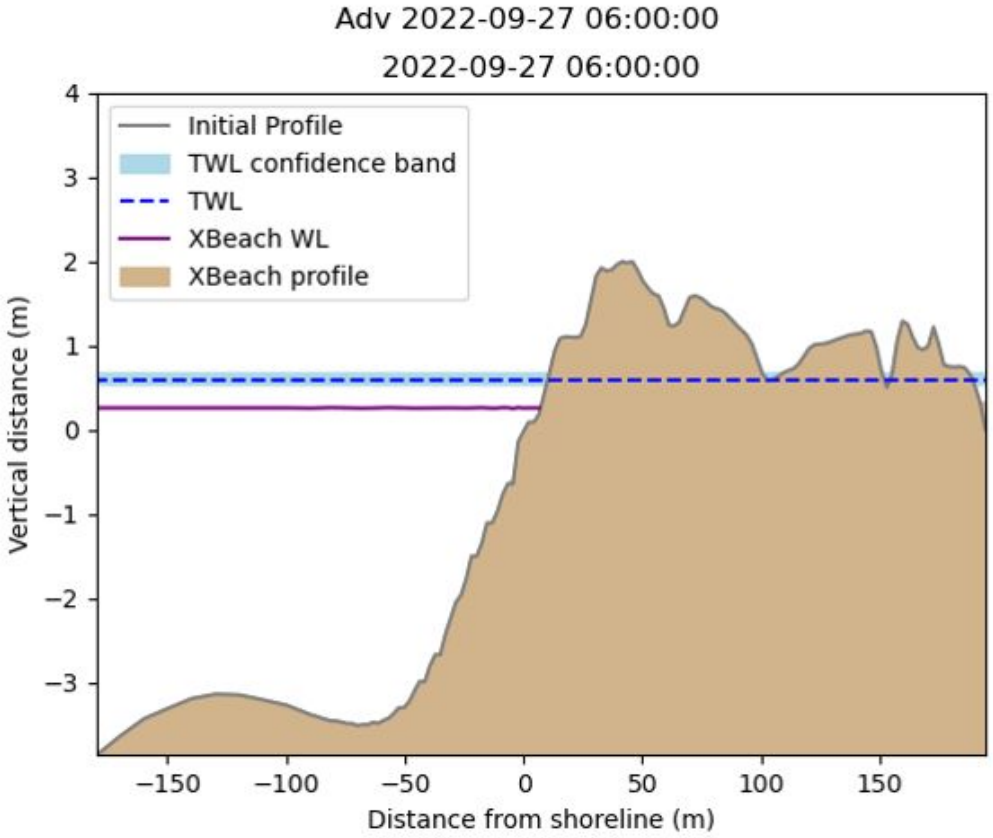
Location: Englewood Beach, Manasota Key, FL
TWL closest profile: 3838
TWL dune crest: 2.56 m

XB reaches the dune **7 hours** before TWL viewer



Southeast Florida: T2656

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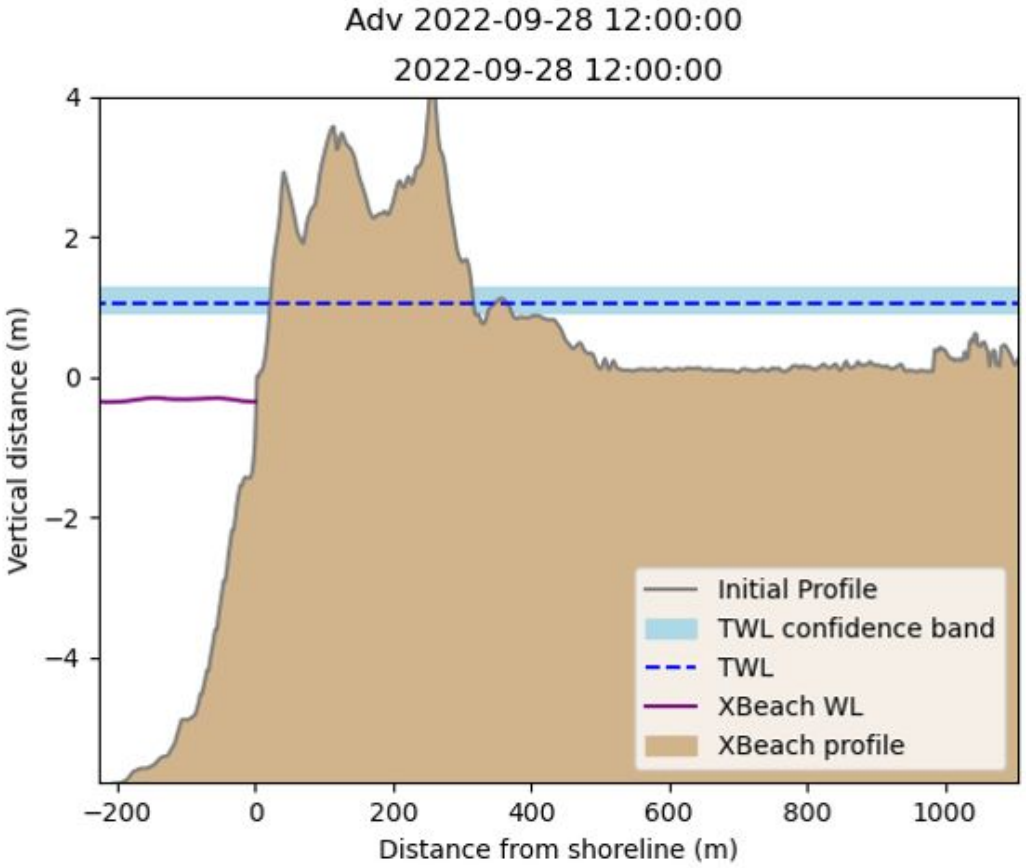
Location: Round Island, South Beach, FL
TWL closest profile: 4485
TWL dune crest: 3.98 m

TWL → collision
XBeach → overwash



South Carolina: T1144

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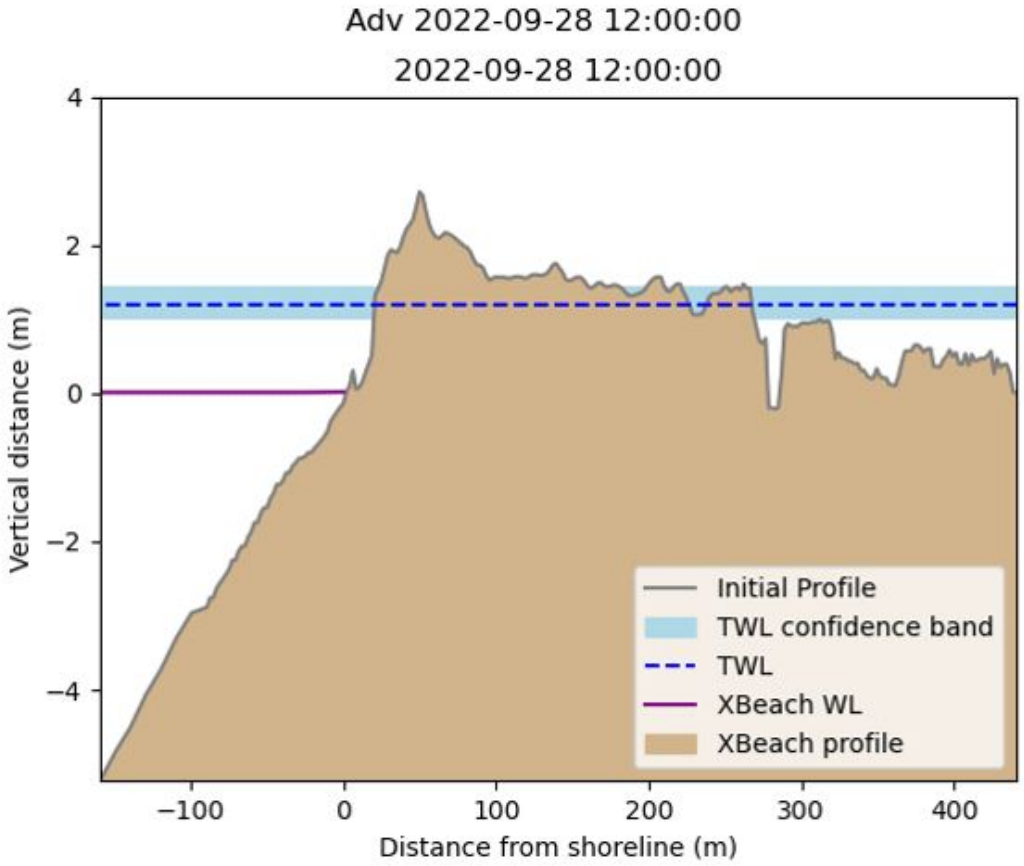
Location: Long Bay,
Garden City, SC
TWL closest profile: 6131
TWL dune crest: 3.18 m

XB predicts impact
~1.5 days before
TWL viewer



Conclusions

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1. How can we evaluate the predictive accuracy of the Ian forecasts?
    a. Later forecasts match qualitative observations
    b. Strong comparisons to TWL and CC viewer
    c. Future work: compare to post-storm elevation data to validate
2. How do our predictions improve with each forecast?
    a. Forecasts improved with reduced track uncertainty
3. When during the storm is the dune impacted?
    a. Addition of morphology affects time of predicted dune impact

Citations

Slide 2:

https://www.tampabay.com/hurricane/2022/09/30/friday-live-updates-florida-recovers-hurricane-ian-targets-carolinas/

Slide 3: Goslin J, Clemmensen LB. 2017. Proxy records of Holocene storm events in coastal barrier systems: stormwave induced markers. Quat. Sci. Rev. 174

Slide 4: https://coastal.er.usgs.gov/hurricanes/research/twlviewer/

Slide 5: https://www.deltares.nl/en/software/xbeach/

Harley, M., Armaroli, C. and Ciavola, P., 2011. Evaluation of XBeach predictions for a real-time warning system in Emilia-Romagna, Northern Italy. Journal of Coastal Research, SI 64 (Proceedings of the 11th International Coastal Symposium), – . Szczecin, Poland, ISSN 0749-0208

Slide 8: NOPP slides made by Rick Luettich and Matt Bilskie