Geomorphological Classification of Beaches Based on Bathymetric Lidar and Wave Climate

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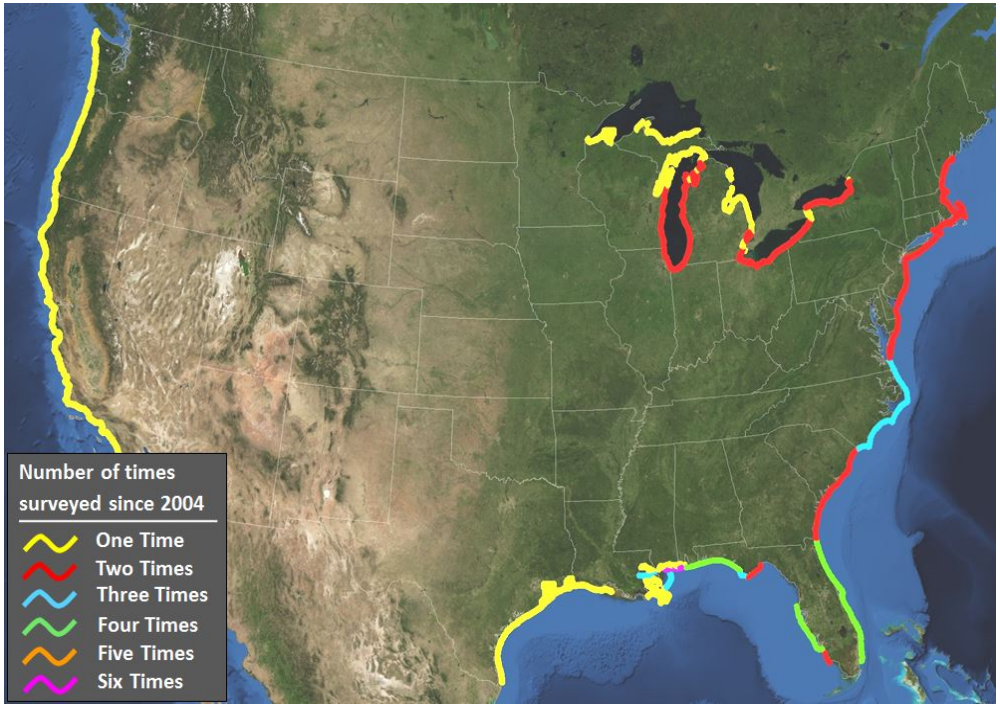
LIDAR Datasets

- Since 2004, the National Coastal Mapping Program has collected large scale bathymetric LIDAR data for sandy coasts
  - More data and at higher resolution than any other nearshore dataset in history (currently using 57)
  - With repeated surveys at some locations



Research Objective

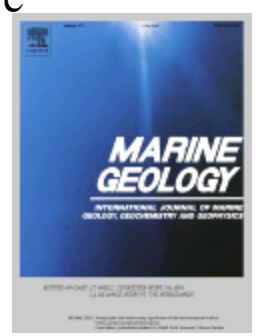
- **To take the full JALBTCX dataset on open, sandy, shorelines** (*or as much as we can handle*) and **relate the morphology** (*slope, bar locations, alongshore structures, beach state classification*) **to the local wave climate** (obtainable from WIS data), the recent wave history (obtainable from NOAA WWIII hindcasts), and sediment characteristics (from various sources).
- To **examine a very large number of sites with quite different wave and sediment conditions**, and to try to piece together an **overall picture of how sandy shorelines exist and develop, and at what length and time scales**.

Morphological Analysis

Many topics have been addressed:

1. Sandbar Location
2. Feature Identification
3. Depth of Closure
   - Hartman, Michael, and Andrew B. Kennedy. "Depth of closure over large regions using airborne bathymetric lidar." *Marine Geology* 379 (2016): 52-63.

NOW AVAILABLE
ONLINE



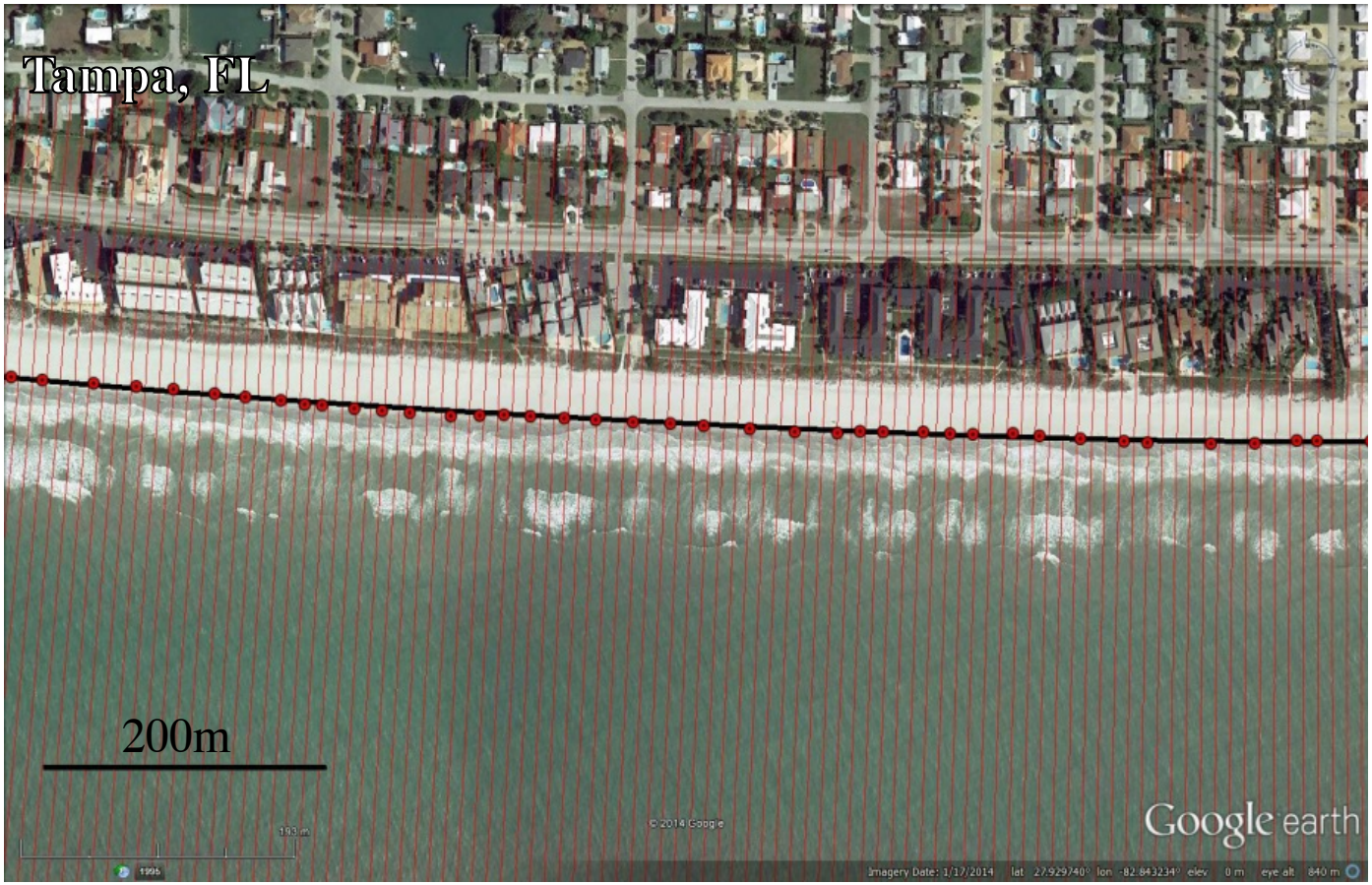
Recent Work

Since the last JALBTCX workshop:

- Sandbar characteristics
  - Moving beyond sandbar position
- Beach state classification
  - Quantitatively
  - Qualitatively

But first, a quick reminder of how we pre-process the lidar data.

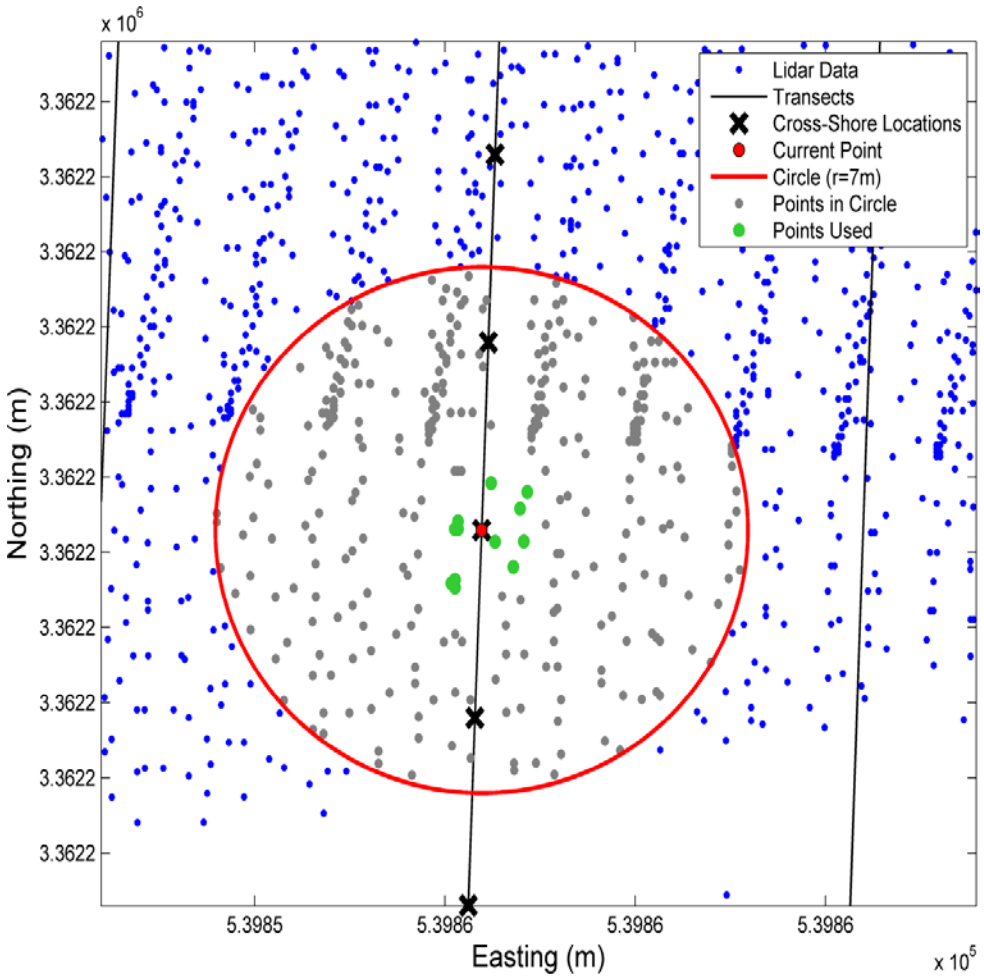
Creation of Shoreline-Following Grid



- From 200m onshore to 1000m offshore
- 5m cross-shore spacing, 10m alongshore

Interpolation from Point Cloud to Grid

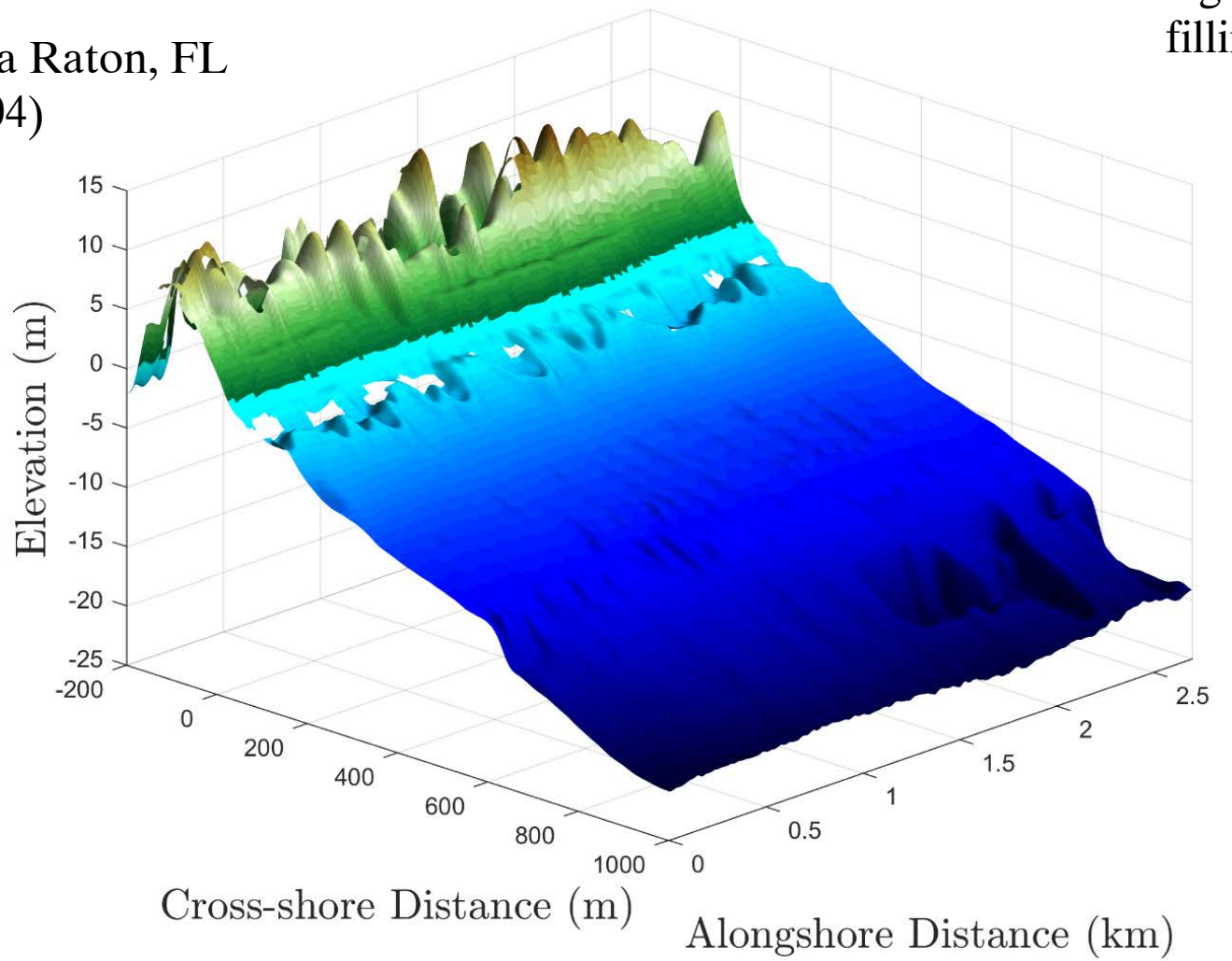
- Consider points within 7m radius of grid point
- Select closest 12 points
- Make sure grid point is in convex hull (interpolation, not extrapolation)
- Least-squares interpolation of 2D polynomial to grid location



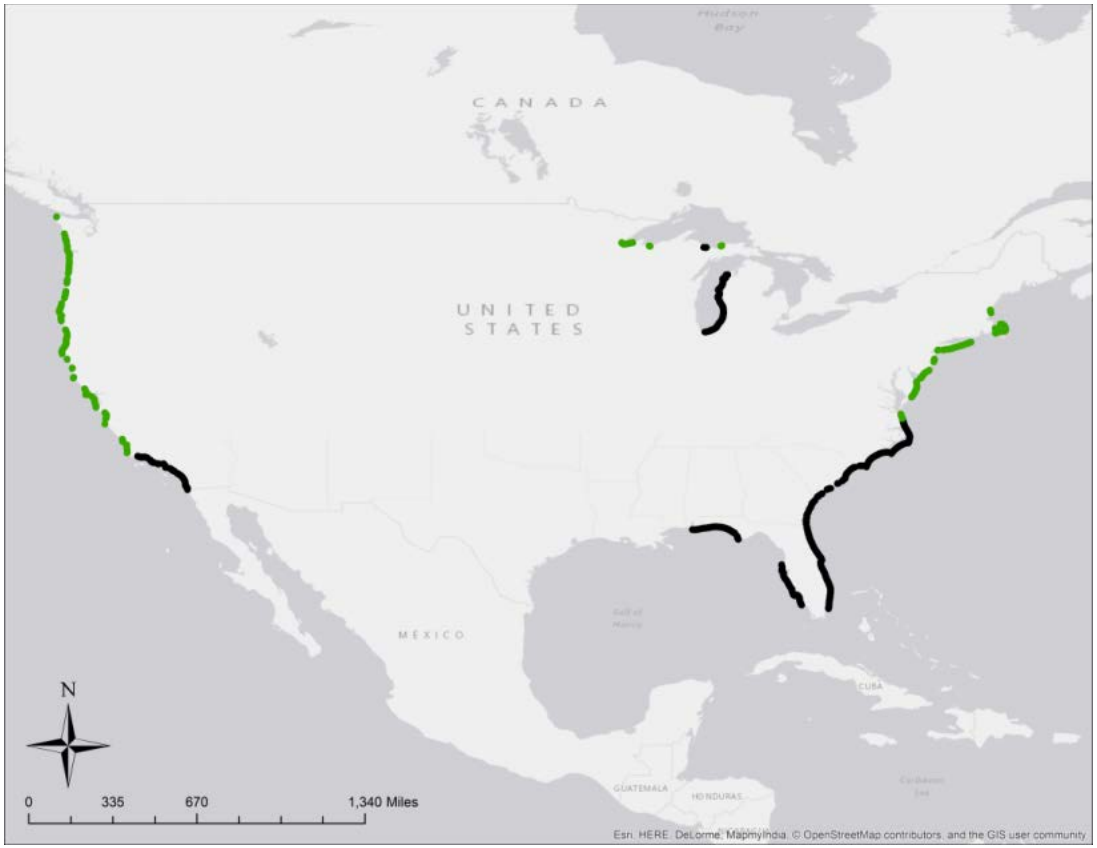
Shoreline-Following Grid

After smoothing transects and filling small gaps

Boca Raton, FL (2004)



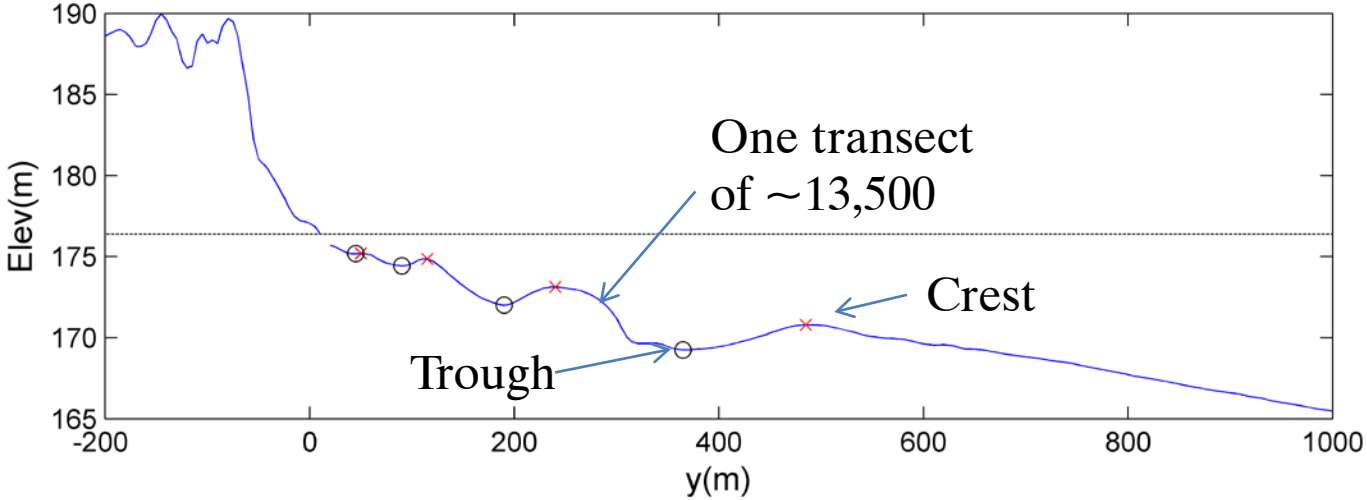
Study Area

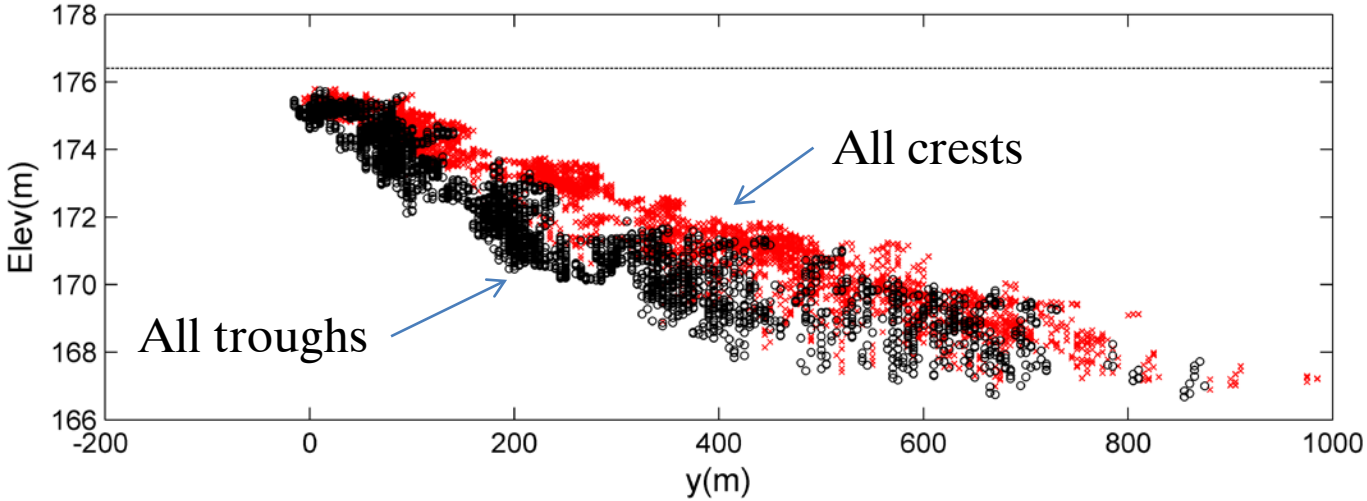


Past (black) and current (green) shoreline coverage.

IMPROVED SANDBAR CHARACTERISTICS

Crest/Trough Locations





Crest/Trough Locations

Pre-Ivan 2004

Post-Ivan 2004

Grouping points process

- Initially assigned sandbar crests to the same group if they were directly adjacent (just a simple D8 search)
- Sandbars that appeared to be continuous were being separated into many, small segments.

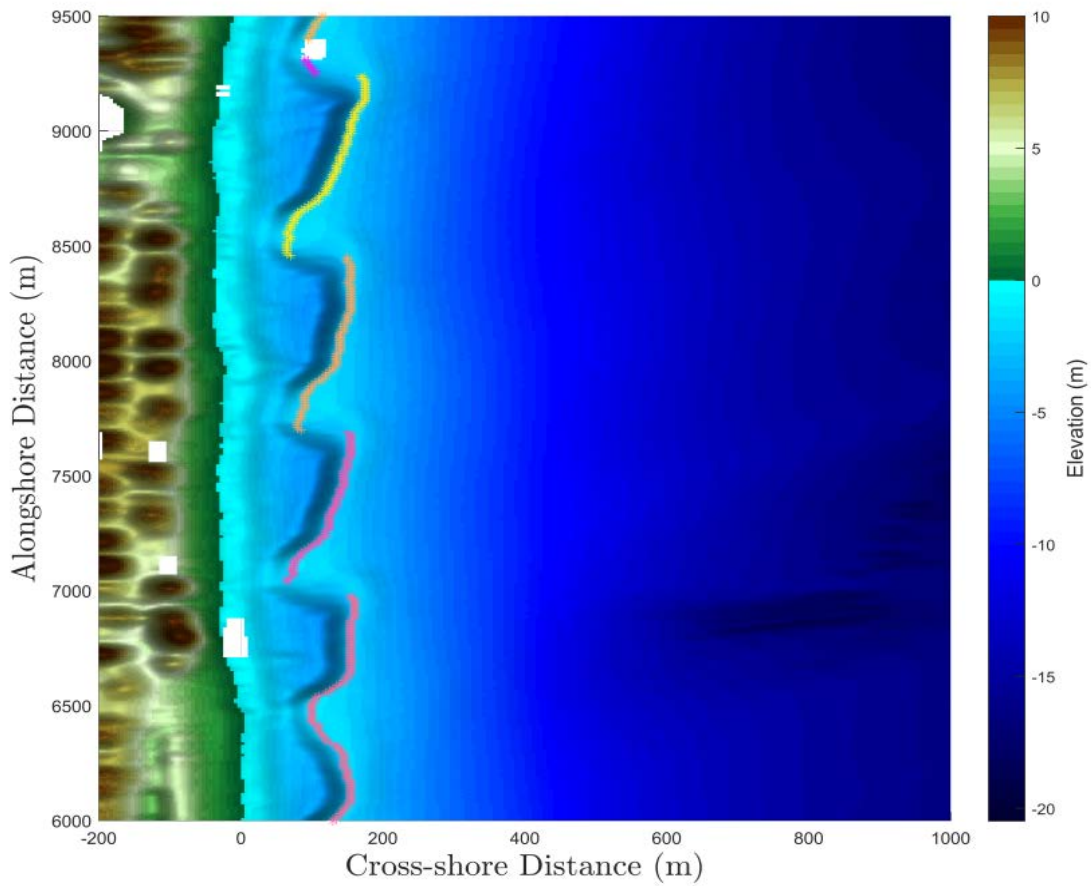
x								
	x	x	x		x			
						x	x	x

Grouping points process

- Initially assigned sandbar crests to the same group if they were directly adjacent (just a simple D8 search)
- Sandbars that appeared to be continuous were being separated into many, small segments.
- From a GIS standpoint, a buffer could be applied and then just group crests with overlapping buffers.
  - Computationally expensive
- Treated as binary image and used MATLAB's built-in morphological dilation/erosion functions

x								
	x	x	x		x			
						x	x	x

Sandbar Object Characteristics



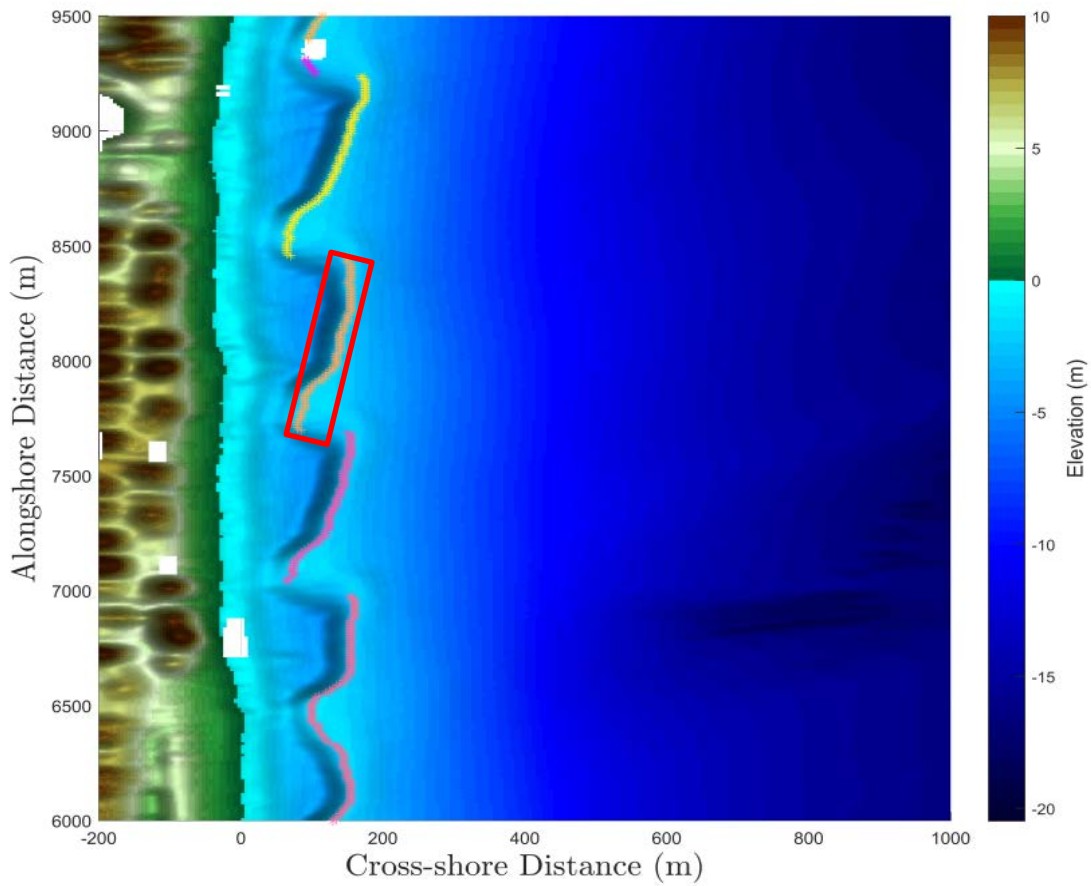
Object statistics (Min/Max/Mean/St. Dev/Range) for cross-shore and alongshore positions + depth

Fitting a minimum bounding rectangle to each sandbar enables even more descriptive capabilities

Eccentricity = major/minor
Sinuosity = total distance along crests/linear length

The automated process still is not perfect, but much improved

Sandbar Object Characteristics



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BEACH STATE CLASSIFICATION

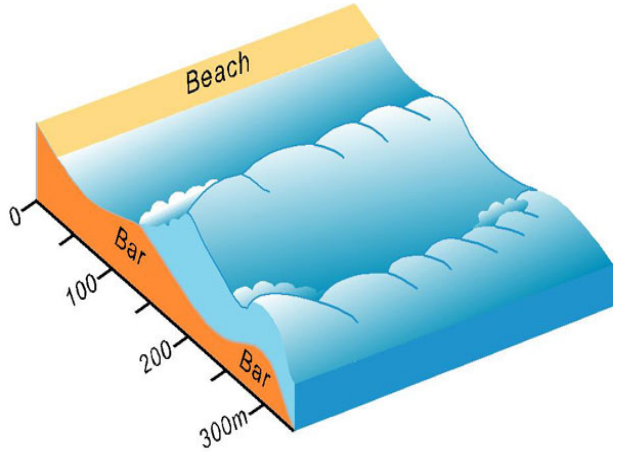
Beach State

- Beach morphologies of sandy shorelines are dependent on many factors:
  - Waves
  - Tides
  - Sediments
  - Geographic setting (e.g. headlands, shoreline orientation, etc.)
- These factors can be temporally or spatially variable

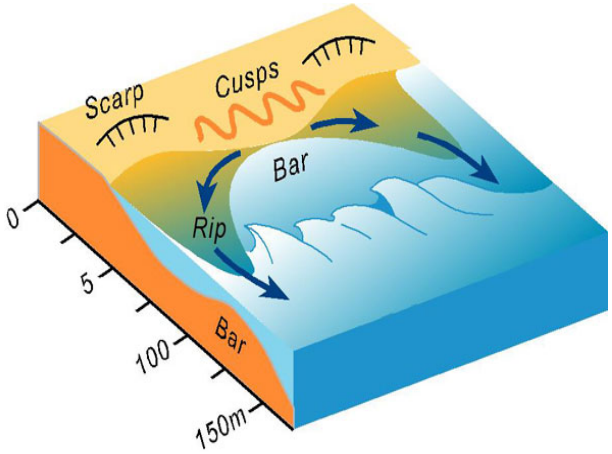
3. Beach State Classification

- Many studies have tried to relate distinct beach morphologies (or beach states) to environmental parameters
- The most commonly used classification system is the Australian beach model

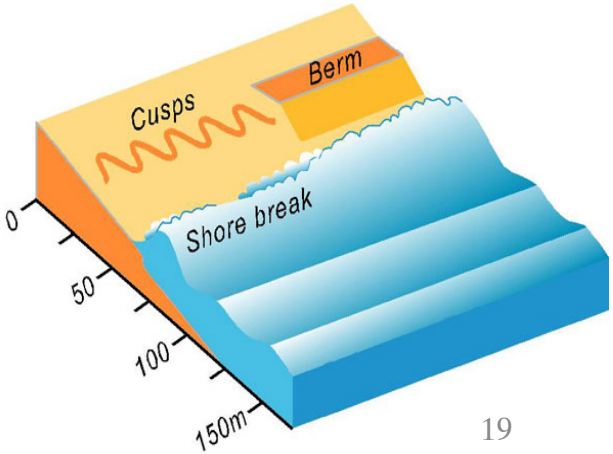
Dissipative



Transverse bar and rip



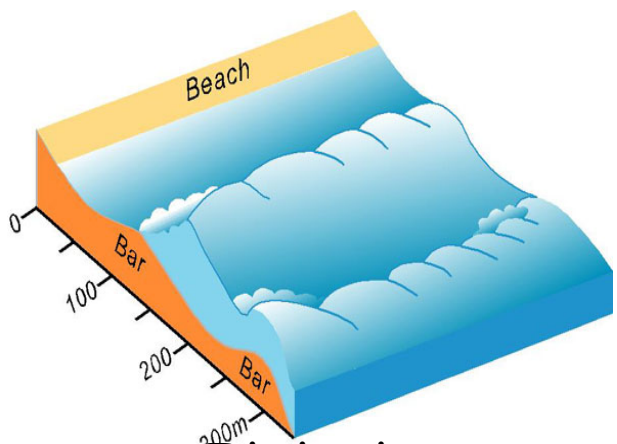
Reflective



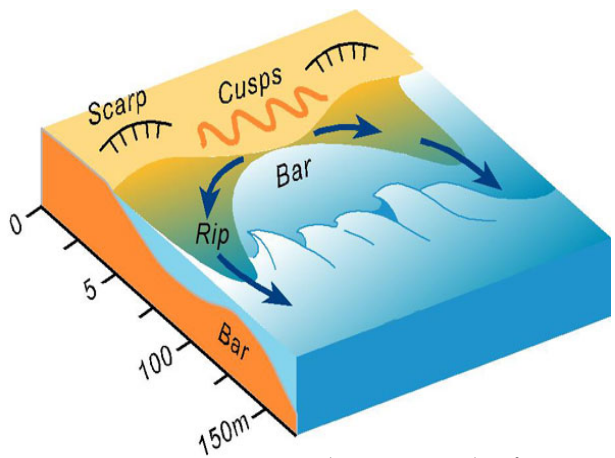
3. Beach State Classification

- Wright and Short (1984) classifications:
  - Dissipative
  - Longshore bar-trough
  - Rhythmic bar and beach
  - Transverse bar and rip
  - Ridge-runnel/Low tide terrace
  - Reflective

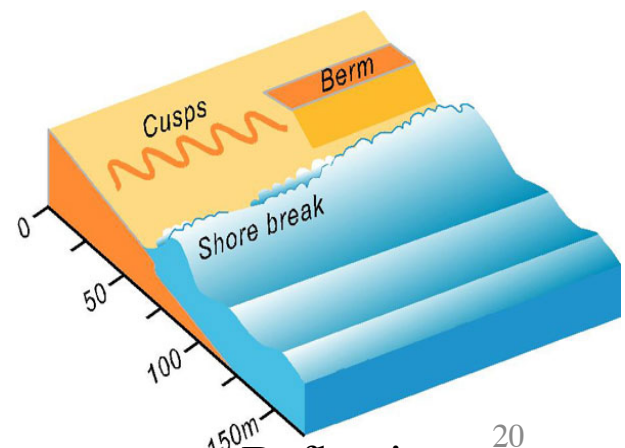
Intermediate



Dissipative



Transverse bar and rip



Reflective

Quantifying Beach State

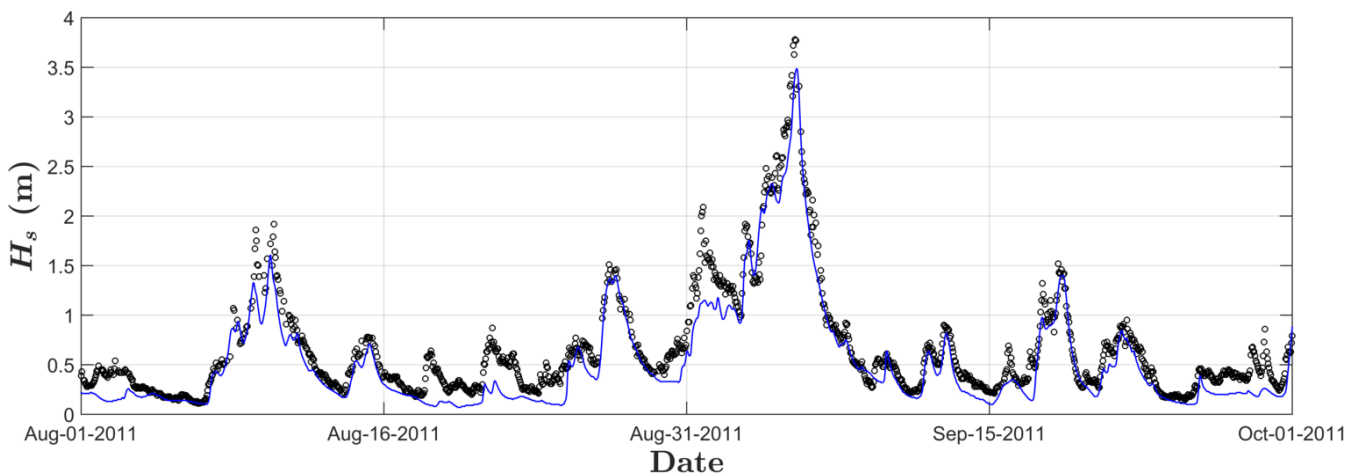
Previous studies have related beach states to dimensionless parameters: (Wright and Short, 1984; Lippmann and Hollman 1989; Masselink and Short, 1993)

$$\Omega = \frac{H_b}{w_s T} \qquad RTR = TR / H_b \qquad \xi = \frac{\tan \beta_f}{\sqrt{H_b / L_b}}$$

H_b, L_b, and T are breaking wave height, wavelength, and period, respectively
w_s is sediment fall velocity
TR is mean annual spring tide range
β_f is local beach slope

Wave Data

- Wave information already available from depth of closure study
- Not nearly enough in situ measurements, must use models
- Use USACE Wave Information Study (WIS) hindcasts
  - Many virtual stations near to bathymetry measurements
- Since stations are in different depths, standardize significant wave heights by shoaling to breaking, accounting for wave refraction

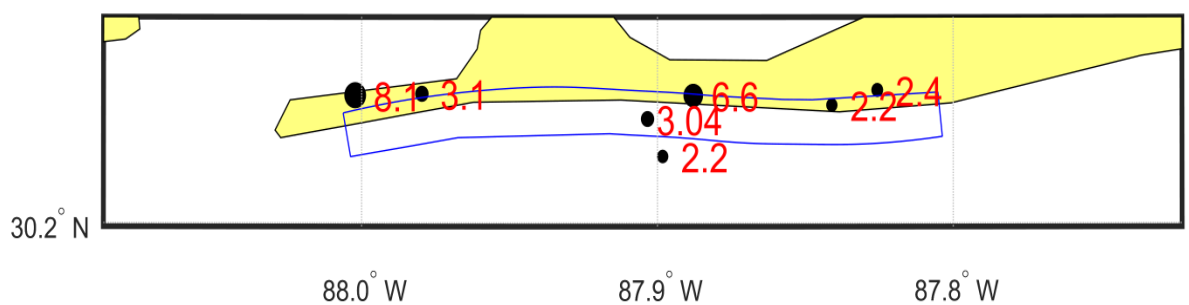


Comparison between buoy data (dots) and WIS simulations (lines)

Sediment Properties

- Sediment databases
  - usSeabed – whole US
  - Regional Offshore Sand Search Inventory (ROSSI) – FL
  - USGS East Coast Sediment Texture Database (2014)
  - NOAA National Centers for Environmental Information (formerly National Geophysical Data Center) – whole US
- Not ideal, but can make it work
  - Find samples in study area, use mean or coarsest
  - Default values if nothing close

Fort Morgan, AL



d_{50} in phi units

Tidal Data

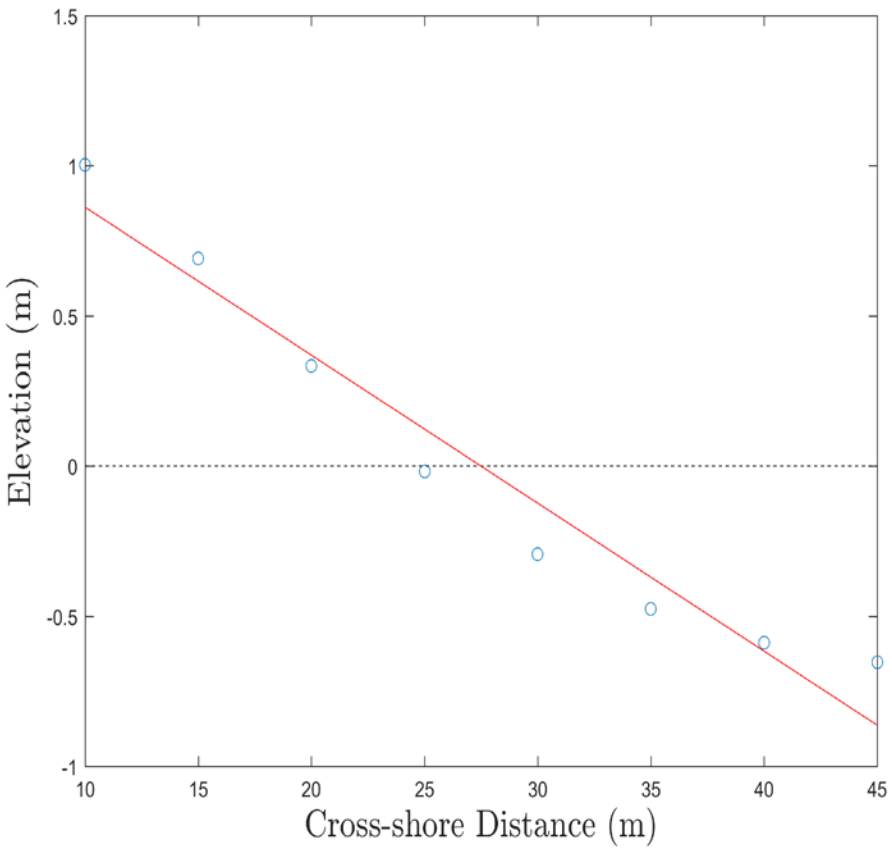
- Used mean annual spring tide range (as defined by Masselink and Short, 1993)
- NOAA provides a wide range of tidal products (e.g. water levels, harmonic constituents, tidal datums)
  - But not this one
- Calculated from water level time series
  - Use Oregon State Tide Predictions

Beach Slope

1. Beach slope definition can vary based on application
2. Beach slope varies alongshore

We used a method similar to Doran et al. (2014)

- For each transect, fit a least-squares line to points +1m and -1m, and record the slope
- Calculated the mean slope for each 2km segment



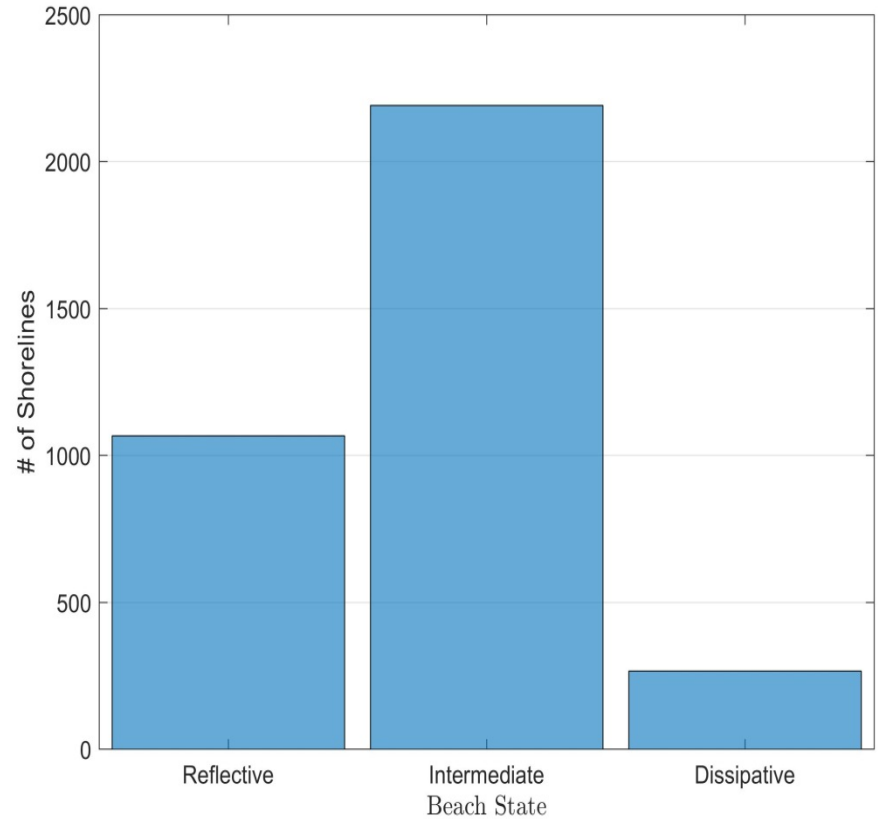
Quantifying Beach State

<u>Current Progress</u>

Have completed calculating dimensionless parameters for all shorelines.

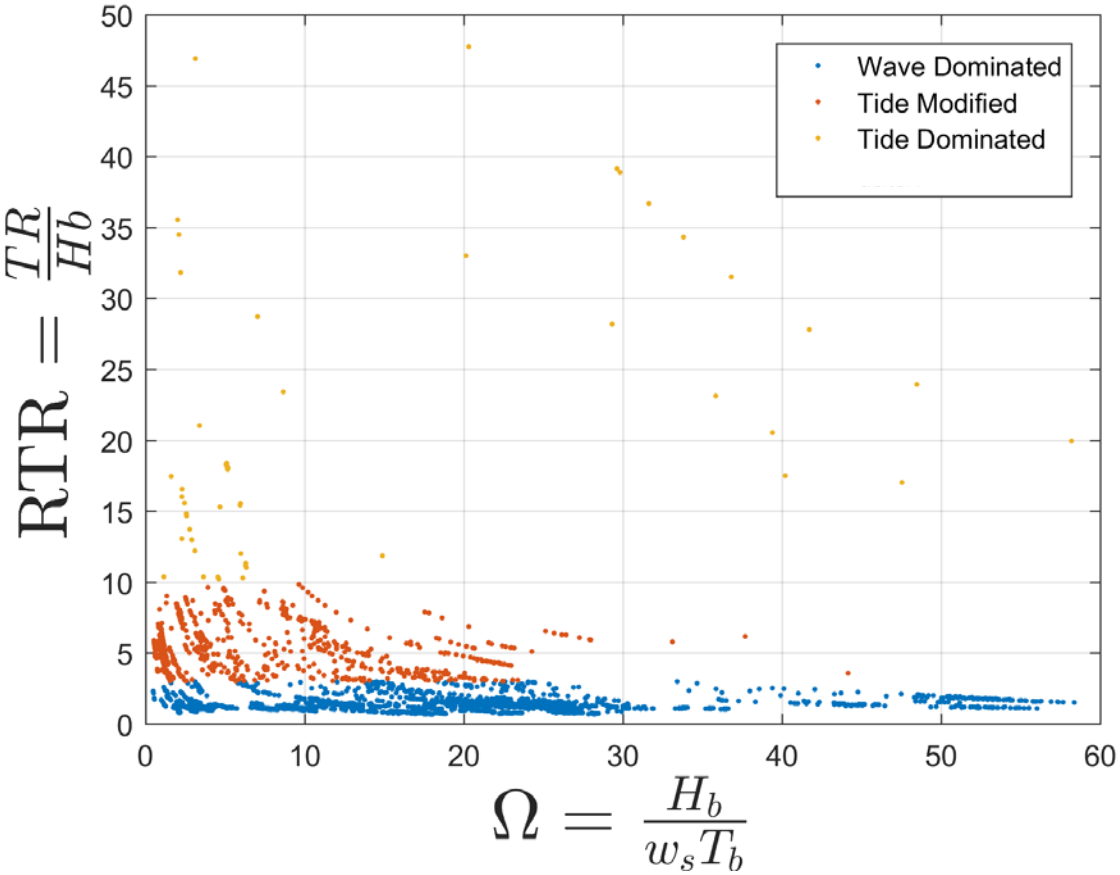
$$\Omega = \frac{H_b}{w_s T} \qquad RTR = TR / H_b$$

$$\xi = \frac{\tan \beta_f}{\sqrt{H_b / L_b}}$$



Going forward, how do these classifications relate to H_s, P_0, H_b/L_b, and H_s/T?

Quantifying Beach State



Results seem reasonable when compared to previous studies, but in order to validate our results, we need to compare to qualitatively determined beach state.

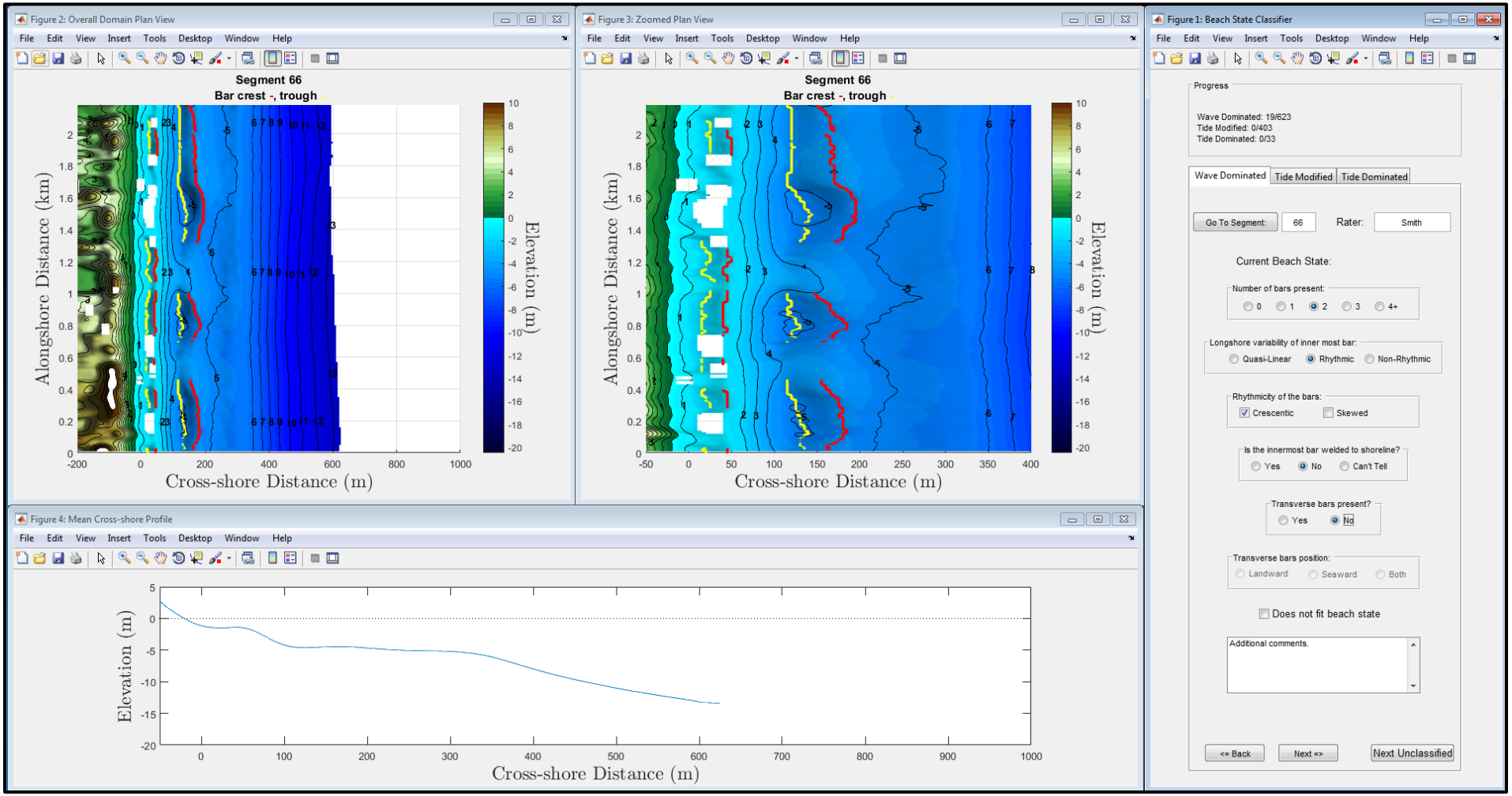
Qualitative Beach State

Qualitative assessment is highly subjective

- Increase the number of expert classifiers
- Lippmann and Holman established a hierarchical decision tree for classification
  - Example: Are bars present? Are the bars rhythmic? Continuous?

A MATLAB GUI could help in sharing our data with experts and making the classification process as painless for everyone.

Beach Classification App



Still in beta, but looking for anyone willing to participate.

Conclusions

- Further development of earlier sandbar analysis to extract additional metrics
- Quantitatively determined beach state using previously established
- Developed an app that will assist experts to make qualitative beach state classifications

Acknowledgements

- Jennifer Wozencraft, JALBTCX
- Northrop Grumman
- Bob Jensen, WIS

Questions?