

## **COASTAL MONITORING WITH SATELLITE IMAGERY**

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### CIRP TD 7/12/22

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# Outline

- Background
- Methodology
- Test site selection
- Accuracy summary
- Tidal correction, slope and runup influences
- Management applications
- ArcTool development
- Discussion and feedback



## Satellite Background

- Traditional surveys costly, infrequent
- Recent satellite developments with multi-spectral, bathymetric inversions, 3D structure from motion, etc. (e.g., Luijendijk et al., 2018; Turner et al., 2021)
- Satellite shoreline data free yet requires validation
- Could act as supplement and/or inform survey timing
  - Hazardous areas









\*CoastSat Global Viewer http://coastsat.wrl.unsw.edu4au/

## What is a "shoreline"?

- CoastSat extracts instantaneous shoreline at sand/water boundary

  Influenced by tide, setup and runup
  Visual interface must be converted to elevation-based
  datum; requires slope
- Multiple factors potentially contribute to error
  - Slope, tide, image rectification, ML algorithm

### **CoastSat Application** -Wrightsville Beach, NC Nourishment





\* Shannon Brown (UNCW) 2021 Thesis

### Wrightsville Beach, NC Nourishments

- Long-term nourishment cycles + exponential decay rate
- Helps for project planning and optimization



\* Shannon Brown (UNCW) 2021 Thesis

7

- Evaluate open-source satellite shoreline extraction algorithm accuracy at a range of test sites (CoastSat – UNSW; Vos et al., 2019)
  - Identify areas of improvement
- Assess how imagery can be used for management applications
- Create user-friendly ArcTool for USACE District use





Gulf of Mexico

#### **Absolute Shoreline Position Accuracy Summary** 35 Orig. Landsat 30 m/pixel Pan-Sharp/Down-Sample 25 Offset (m) 20 Landsat 15 m/pixel Sentinel 2 10 m/pixel 5 Sthan avaleaching for interesting the strain avaleaching for interesting the strain of 0 Harvey Ce Ce dars 3 HarveyCedarP Cand and and and and and and a dealed the dress of a particular of the and a dress of a particular of the and a pression of the appression of the appressi

## **Historical Trends**

- Trends show good agreement across sites
- Useful decadal context
- Could be problematic if combining other survey types



 Histogram of all slope comparisons appear to be narrowly centered around zero



Estimated Trend Distance from Reference Trend (m/day)

## Coastal Trends Comparison – Impact of Time Span

- Δt has large impact on the trend comparison results
- Differences in shoreline change rates decrease after two years of observations
- Missing medium-term surveys separated by ~2-6 years



## **Tidal Adjustments**

- Careful gauge selection, some distant
- Benson Beach, WA (2.8 m tidal range, shallow slope)
- Does not account for wave processes



## CoastSat Slope vs. User Slope

- Vos et al., 2022: Gentle and steep beaches have best predicted slopes; intermediate beaches worst
- Benson Beach, WA
  - CoastSat slope = 0.08
  - User-defined slope = 0.025
- Galveston, TX
  - CoastSat slope = 0.035
  - User-defined slope = 0.04
- Lake Michigan
  - CoastSat slope = 0.25
  - User-defined slope = 0.25







Duck, NC

## Benson Beach, WA

- 16.2 m offset
- Tidal station issue 80 km away
- Combination of waves, meso/macrotidal (2.8m), slope (~0.025?)
- Try only high tide? Potential low tide artifacts



## **Runup Assessment**



- Wave Height (m)
- At Duck, if only incorporate runup for wave events > 1.5 m, the offset is reduced from 9.6 m to 9.1 m

#### Runup at 6 Sites



Cardiff

### Image Coregistration: AROSICS and ArcPy



AROSIES



- Offsets among missions (color clusters)
- Perhaps related to regional differences in accuracy (e.g., South Padre Island, TX ranges from 4 m to 21 m accuracy at 3 km long sites)
- Currently can only coregister single missions
- Investigating mask capability (remove shoreline and water tie points)

#### Proposed Integrated Workflow

n [3]: 🕨 metadata = SDS\_download.retrieve\_images(inputs)

Retrieve satellite images from GEE

Downloading images: L5: 787 images 100% L7: 722 images 100% L8: 142 images 100% S2: 288 images 100% 135 pairs of overlapping Sentinel-2 images were merged

#### Batch shoreline detection

Extracts the 2D shorelines from the images in the spatial reference system specified by the user in 'output\_epsg'. The mapped shorelines are saved into output.pk1 (under ./data/sitename) and output.geojson to use in GIS softwares.

#### ]: M %matplotlib qt

output	Ŧ	SDS_	_shoreline.	extract_	shorelin	es(metadata,	settings
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Mappir	g shorelines
L5:	100%
L7:	100%
L8:	100%
c	100%

### 2010 Nourishment at Avalon Beach, NJ





• Longshore dispersion to south

#### Management Applications - New Smyrna, FL



B. Bruder et al., 2019

Onnink, 2020 TU Delft Thesis

#### Management Applications - New Smyrna, FL



#### Satellite Timestack



#### Harvey Cedars, NJ – Nearshore Berm Placement



- Volume: ~60k cu yd.
- Drops: ~210
- Berm Length: 1,400 ft
- Time: 42 days

- Collaboration with McFall/Krafft/Harris/Bain /McGill (ERDC)
  - Hydrodynamics

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- Beneficial Re-Use
- Volume: ~60k cu yd.
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- Collaboration with McFall/Krafft/Harris/Bain /McGill (ERDC)
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#### Lake Ontario – Detroit District Collaboration

Great Lakes Coastal Resiliency Study

Bluff\_1

Lincoln, ON

- Ultimately predict drivers of shoreline change along Great Lakes shorelines, many of which have been experiencing severe erosion
- Opportunity to evaluate tool scalability and potential ML workflow improvements

Bluff\_2

Image NOAA Image Landsat / Copernicus









## ArcTool Development

- What time and length scales are you generally interested in?
- Do you have access to robust wave and water level data?
- Analysis products?
  - Historic shoreline shapefiles
  - Time stacks
  - Shoreline change rates
  - Trend plots

# Conclusions

- CoastSat algorithm errors ranged from 4.2 m to 31.7 m at 37 test locations.
- CoastSat algorithm robustly identifies land/water boundary from satellite imagery. Challenges arise when translating the land/water interface to datum-based shoreline for analysis.
- Satellite shoreline position trends generally align well with ground- truth data and provide decadal context.
- Satellite-derived shorelines useful for tracking a variety of coastal engineering projects - potential to improve project timing and design.
- Runup and coregistration complex to account for. Work ongoing.
- Beta ArcTool created need feedback!



# Thank you!

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