Bathymetry-Derived Stratigraphic Mapping of Bogue Inlet, NC

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1. Introduction

Tidal inlets and ebb-tidal deltas are **highly dynamic** features of sandy barrier coasts, giving rise to **coastal management concerns** like navigational safety and controlling **erosion** of adjacent shorelines.

Bogue Inlet, North Carolina is a **microtidal** (mean tidal range ≈ 1 m), **wave-dominated** (mean H_{s0} ≈1.7 m) inlet on the Atlantic coast of the United States which is **regularly exposed to hurricanes** (e.g., Hurricane Florence in 2018). A new channel was dredged in 2005 to maintain navigability, but has since migrated several hundred metres to the east.

In order to better understand the inlet system and manage it more effectively, we need to **quantify recent geomorphological changes**.

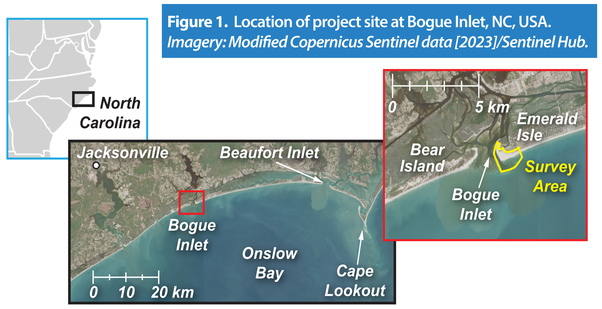

Figure 1. Location of project site at Bogue Inlet, NC, USA. *Imagery: Modified Copernicus Sentinel data [2023]/Sentinel Hub.*

2. Bathymetric Data

High resolution semi-annual to annual bathymetric surveys between 2005-2022 of Bogue Inlet's east side permit a detailed examination of its morphodynamics. Data were resampled to a common 20 m resolution grid for all surveys using MATLAB, and clipped to the maximum shared survey extent to ensure consistent temporal coverage in the stratigraphic model. A survey from 2008 was removed because its smaller extents greatly limited coverage of the outer ebb-tidal delta.

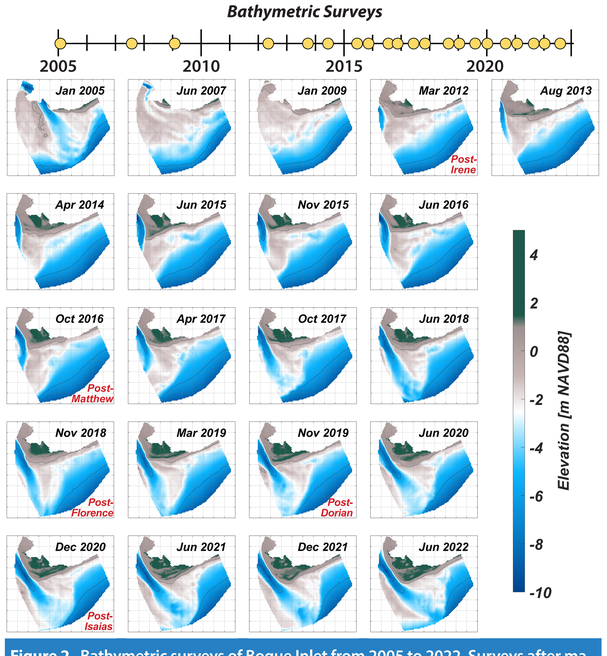

Figure 2. Bathymetric surveys of Bogue Inlet from 2005 to 2022. Surveys after major hurricanes are indicated in red.

4. Results

Here we present four stratigraphic cross-sections representative of Bogue Inlet's channel and ebb-tidal delta morphodynamics.

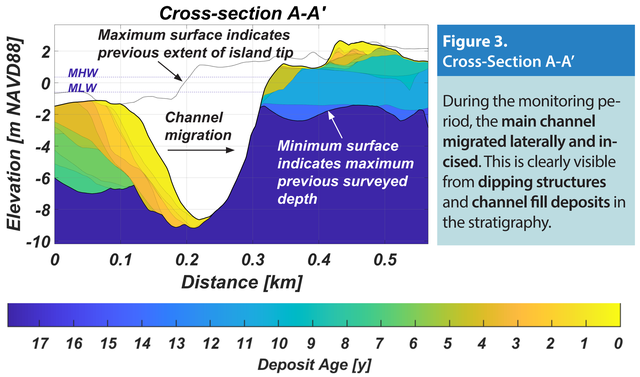

Figure 3. Cross-Section A-A'

During the monitoring period, the **main channel migrated laterally and incised.** This is clearly visible from **dipping structures** and **channel fill deposits** in the stratigraphy.

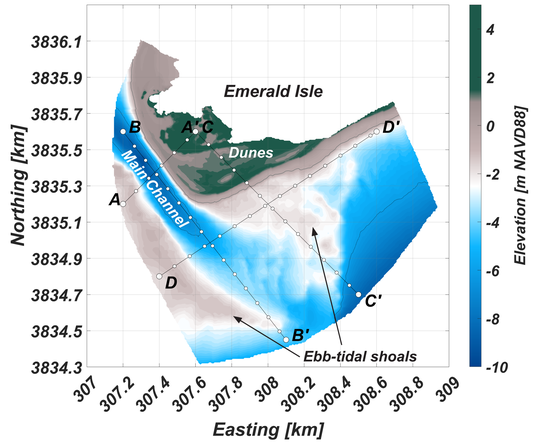

Figure 4. Cross-section locations at Bogue Inlet (circa 2022). Depth contours indicate Mean Low Water (-0.59 m) and -6 m depth.

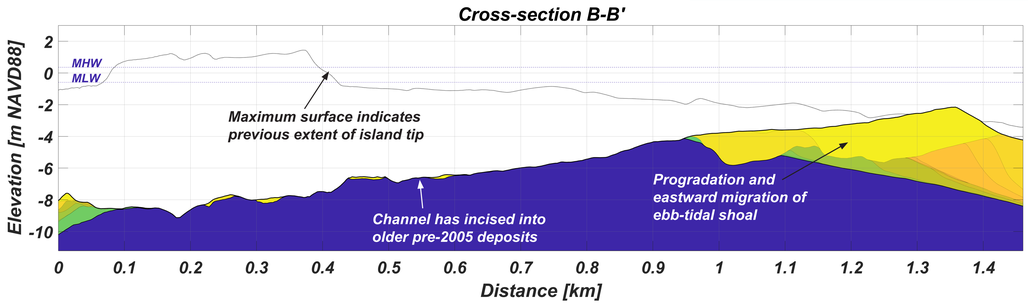

Figure 5. Cross-Section B-B'

The **channel incision** seen in Cross-Section A-A' is more clearly visible in this section along the channel thalweg, and is contrasted by the **expansion of the ebb-tidal shoal**.

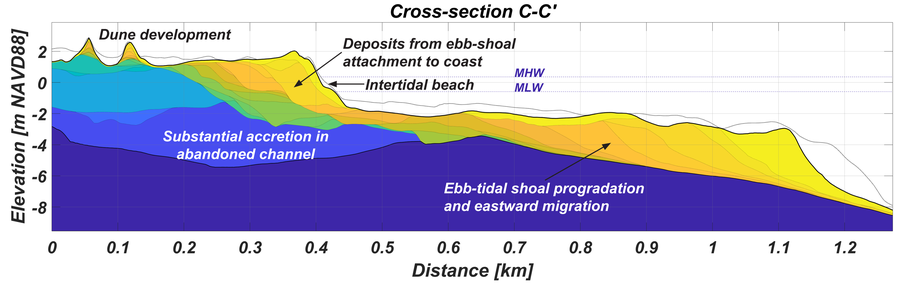

Figure 6. Cross-Section C-C'

The **seaward progradation** and **eastward migration** of the ebb-tidal delta can be observed subtidally. In the intertidal and supratidal zone, **ebb-tidal delta shoals attach** to the adjacent coast, leading to **beach progradation**. Substantial accretion is seen in the former channel after a new channel was dredged to the west in 2005.

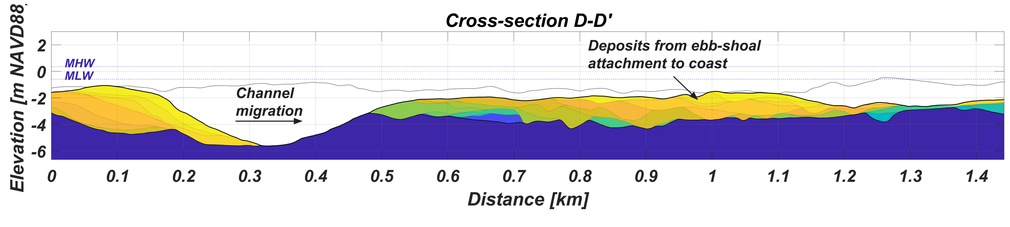

Figure 7. Cross-Section D-D'

As with Cross-Section A-A', the eastward migration and incision of the channel can be seen. The **attachment of ebb-tidal shoals** to the shoreline visible in Cross-Section C-C' is also apparent here.

3. Stratigraphic Mapping Approach

Using the approach of Pearson et al. [*2022*], we develop a stratigraphic model of Bogue Inlet derived from the bathymetric data. By taking the **difference between subsequent surveys in MATLAB**, we can estimate the erosion and deposition to create stratigraphic cross-sections.

For example, at t_1 (**Figure 3b**), the channel migrates to the right and fills in slightly. The left side of the shoal accretes, but the right side erodes slightly below the t_0 elevation, z_0. Sediment deposited at t_1 is coloured teal.

At t_2 (**Figure 3c**), the channel continues infilling and migrating to the right as it erodes into t_0 and t_1 deposits. Sediment also deposits on top of the shoal, as shown by yellow shading.

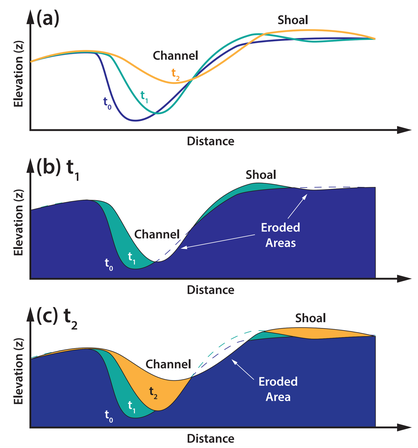

Figure 8. Schematic diagram demonstrating how the stratigraphy is computed from bathymetry at three sequential timesteps (t_0, t_1, t_2) [*Pearson et al., 2022*].

This calculation repeats for each grid cells in the bathymetry at every surveyed timestep. Note: eroded and deposited volumes are not necessarily conserved along the transect because it represents a 2D vertical slice of 3D stratigraphy.

5. Discussion

The usefulness of this approach spans several timescales:

- **Sub-annual**, as we can relate the observed patterns to **major storms** and **hurricanes** or eventful storm seasons;
- **Sub-decadal**, we can use the knowledge of persistent sediment deposits to **infer dredging impacts and needs**, track the **fate and preservation of sand nourishments** and identify the impact of **longer-term developments in the backbarrier basin** (e.g., changes to the tidal prism);
- **Decadal to Centennial**, as knowledge of decadal-scale morphodynamics will help us to better understand the implications for longer term **preservation of sediment** within barrier island systems, which is essential for managing **climate-robust barrier coasts** in the future;
- **Millennial and beyond**: by giving insight into contemporary inlet dynamics on the Outer Banks, we provide a valuable analogue for understanding ancient sedimentary deposits of the Atlantic Coastal Plain.

6. Next Steps

Validate the stratigraphic model using high-resolution **geophysical surveys** (CHIRP subbottom data), **hydrodynamic modeling**, and **sedimentological data** [*Brown et al., this session*]. Relate observed stratigraphy to hurricanes.

Acknowledgements

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References

Brown, C., Mallinson, D., Pearson, S.G., Mulligan, R. (2023). Testing a stratigraphic model of Bogue Inlet, NC, using geophysical, hydrodynamic, and sedimentological analyses. *GSA Joint 72nd Annual SE/58th Annual NE Section Meeting - 2023*.

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