Common Era Sea-Level, Chesapeake Bay, U.S. Atlantic Coast

Sea Level Research Rutgers University

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1. Background

The application of salt-marsh sediments and microfossils (e.g. foraminifera and diatoms) contained within to reconstruct late Holocene relative sea-level (RSL) has shown strong potential in extending our knowledge of sea-level change beyond the limits of direct observations (i.e. tide-gauges). They have proven useful in providing supplementary evidence to assess the timing of recent accelerations in sea-level (Gehrels and Woodworth, 2013) and can be regarded as natural archives comparable to tide-gauge records (e.g. Barlow et al., 2013). Their use as sea-level indicators stems from an established quantifiable relationship within the tidal frame where characteristic species occur in abundance (Scott and Medioli, 1978). When applied to fossil counterparts observed in sediment cores, improvements in chronological controls and numerical models (i.e. transfer functions) have enabled decadal to decimeter precision in quantifying the timing and magnitude of sea-level trends. Along the US Atlantic coast, reconstructions of sea-level from sites in New Jersey and North Carolina show four phases of sea-level with modern rates exceeding anything observed over the Common Era (CE) (Kemp et al., 2011; 2013). However the rates and timing of CE sea-level changes are not synchronous between sites (**Fig. 1**). Here we present the preliminary results towards a new RSL reconstruction focusing on sites in the Chesapeake Bay region that may provide answers to this conundrum. Global eustatic sea-level rise superimposed on top of regional sea-level changes caused by non-climatic factors such as GIA, sediment compaction, and groundwater extraction contribute to some of the fastest rates of RSL rise along the US Atlantic coast (~3-5mm/yr).

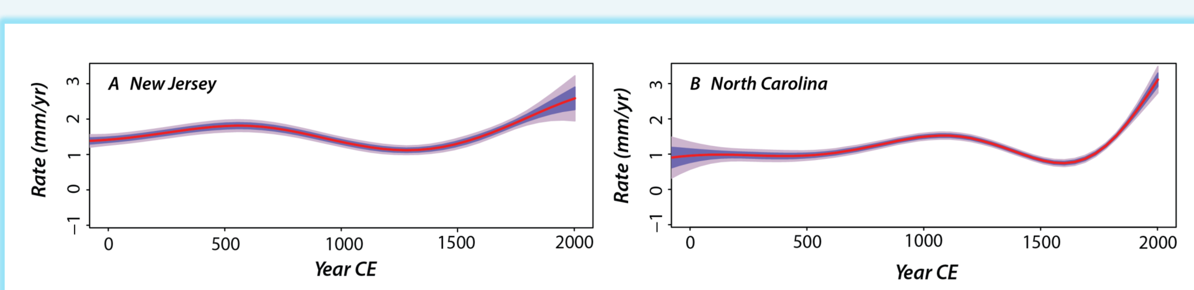

Figure 1. Rates of Common Era sea-level change derived from proxy based reconstructions in (a) New Jersey and (b) North Carolina.

2. Reconstructing Sea-Level

Q. How do we reconstruct RSL trends using salt-marsh foraminifera?

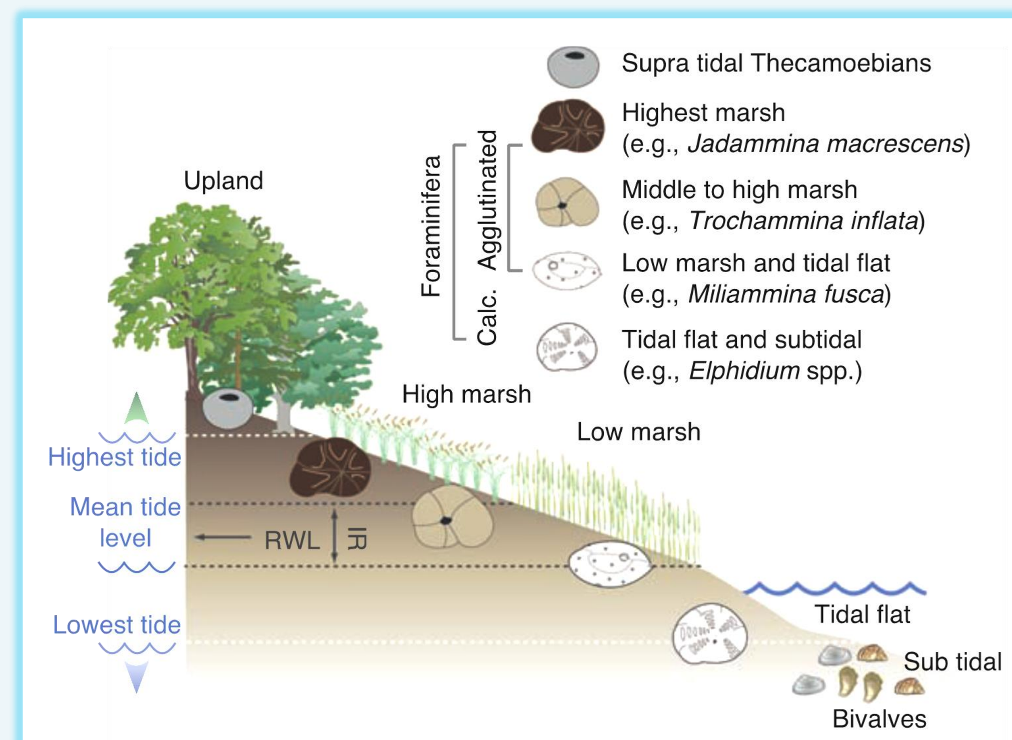

Figure 2. Modern distribution of foraminiferal assemblages in the intertidal environment and their relationship with tidal level.

- Compile modern training set of foraminifera from the salt-mash environment.
- Quantify the assemblage relationships with tidal level (**Fig. 2**).
- Analyze the biostratigraphy of sediment core for fossil analogues.
- Develop chronology (e.g. ^{14}C) to determine changes in sedimentation rate.
- Calibrate fossil analogues to provide estimates of paleo marsh elevation (PME).
- **RSL (m) = Altitude (m) – PME (m).**

3. Study Area

Our area of investigation is focused in the upper reaches of the Chesapeake Bay system (**Fig. 3**). Tidal ranges decrease from ~0.9m at the Bay entrance to a minimum of ~0.4m at Annapolis, MD before rising to ~0.7m at the head of the bay. This region offers an ideal base for a study of this type, thanks to the small tidal ranges, which increases the vertical precision of the proxy based reconstruction, and also due to the high-quality long-term tide gauges (e.g. Baltimore) in close proximity to the sample sites which offer an independent assessment to the record. The studied salt-marsh environments are located at the Smithsonian Environmental Research Centre, Edgewater, approximately 7 miles south of Annapolis. The area is characterized by numerous pockets of salt-marsh environment boarded by woodlands. Here we established multiple stratigraphic and modern surface transects and surveyed relative to national geodetic datum (NAVD88).

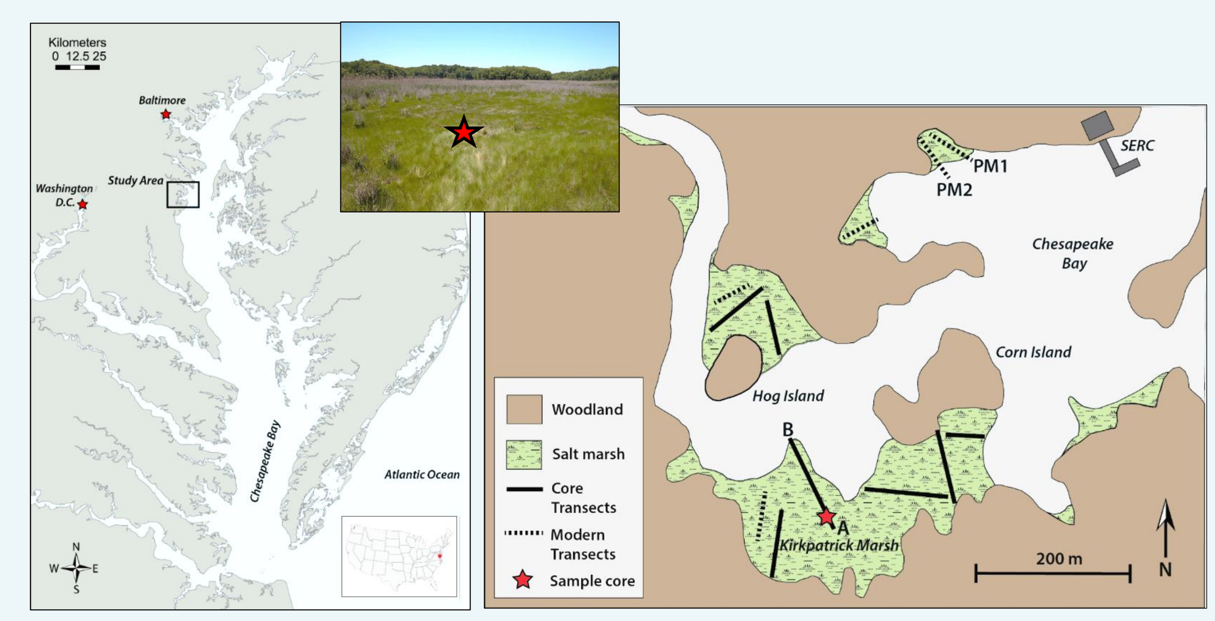

Figure 3. Location of study area in the Chesapeake Bay and overview of environments located at the Smithsonian Environmental Research Centre. Location of stratigraphic and modern transects and sample core are shown. Photo of sample site also shown.

4. Results

Modern

An initial modern training set comprising 60 surface samples was collected across multiple transects and incorporated all sub-environments from the high-marsh zone to the low-marsh sea interface. Analysis of foraminiferal distributions conforms to the theory of intertidal zonation where characteristic species occur in abundance in relation to tidal level. Surface data from transect PM2 show the assemblages dominated solely by agglutinated taxa (**Fig. 4a**). Unconstrained cluster analysis identifies two faunal zones at this site with faunal zone PM2-A characterized by high abundances of *Jadammina macrescens* (**Fig. 4b**). Faunal zone PM2-B shows a decrease in the relative abundance of *J. macresscens* and increases in *Tiphotrocha comprimata, Ammoastuta inepta* and *Arenoparrella mexicana* (amongst others). Boxplots of these faunal zones plotted by elevation (m NAVD88) shows a *J. macresscens* dominated assemblage occupying a narrow indicative range around mean higher high water (MHHW) (**Fig. 4c**).

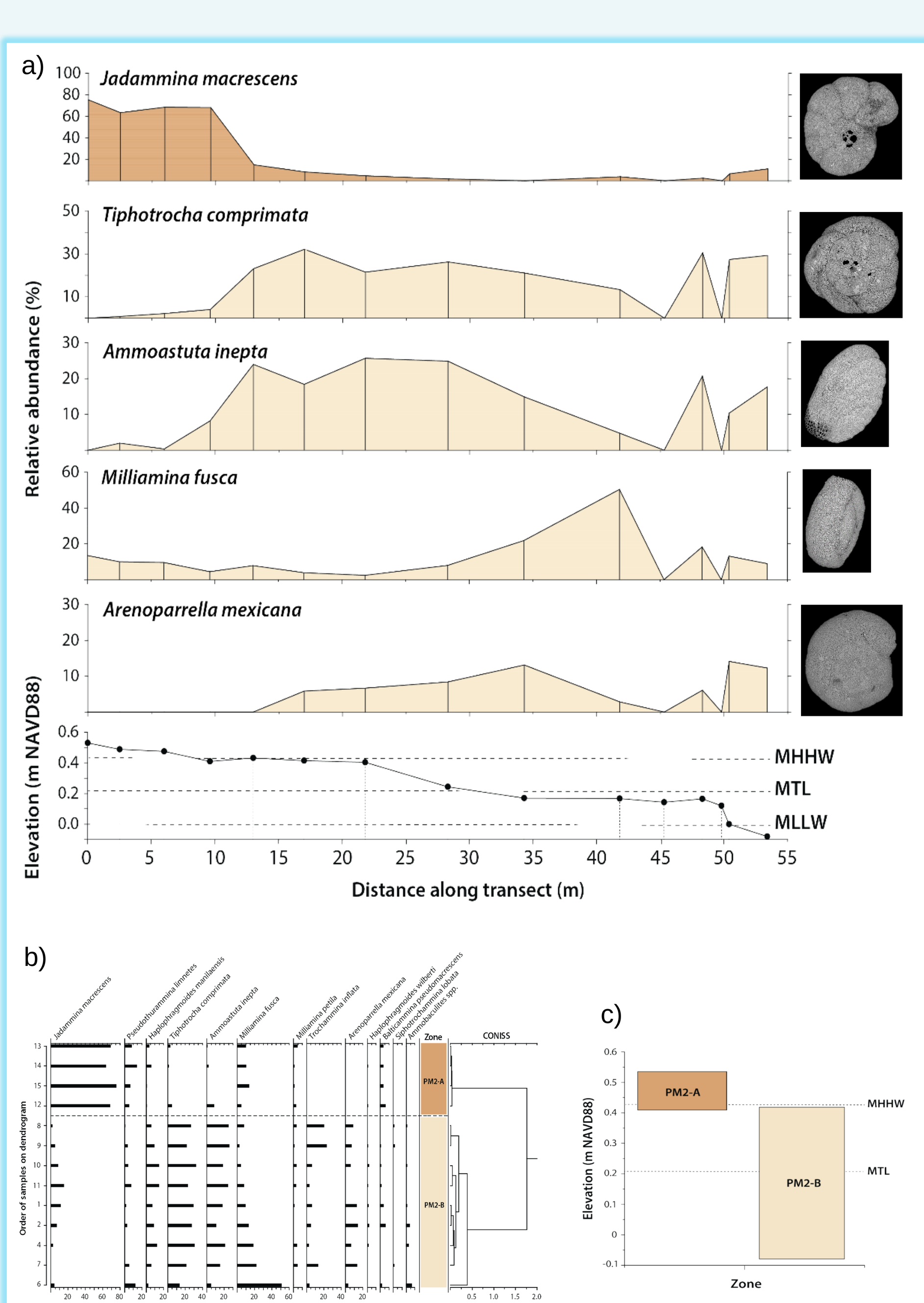

Figure 4. Surface distributions of foraminifera from PM2 (a), unconstrained cluster analysis identifying assemblage zones (b) and elevation of assemblage zones plotted by elevation (NAVD88) with tidal levels superimposed (c).

Fossil

Sediment boreholes were drilled to understand the depositional history of the site and to identify sequences of high-marsh peat ideally suited for RSL reconstructions. **Fig. 5a** shows stratigraphic transect *A-B* from Kirkpatrick Marsh (**Fig. 3**) where core depth generally decreases with distance towards open water. Dense minerogenic basal grey sands and silts are overlain by increasingly organic silts and clays and extensive sequences of marsh peat. Preservation of foraminifera extends to ~3.5 m of the sample core and shows fossil assemblages to mirror those observed in the modern environment (**Fig. 5c**) The accumulation history has so far been established using a suite of ^{14}C dates (n=15) coupled with short-lived radionuclide data (^{210}Pb and ^{137}Cs) providing a RSL record spanning the past ~2000 years (**Fig. 5b**). Geochemical analyses are currently being sought to provide additional age-markers to accurately constrain sedimentation rates during the anthropogenic era, together with pollen chronohorizons associated with historical land use change. The modern training set was used to develop a preliminary transfer function modelling the relationship between surface distributions of foraminifera and tidal level. Fossil samples were then calibrated to provide estimates of PME before being subtracted from surveyed altitude to provide RSL trends.

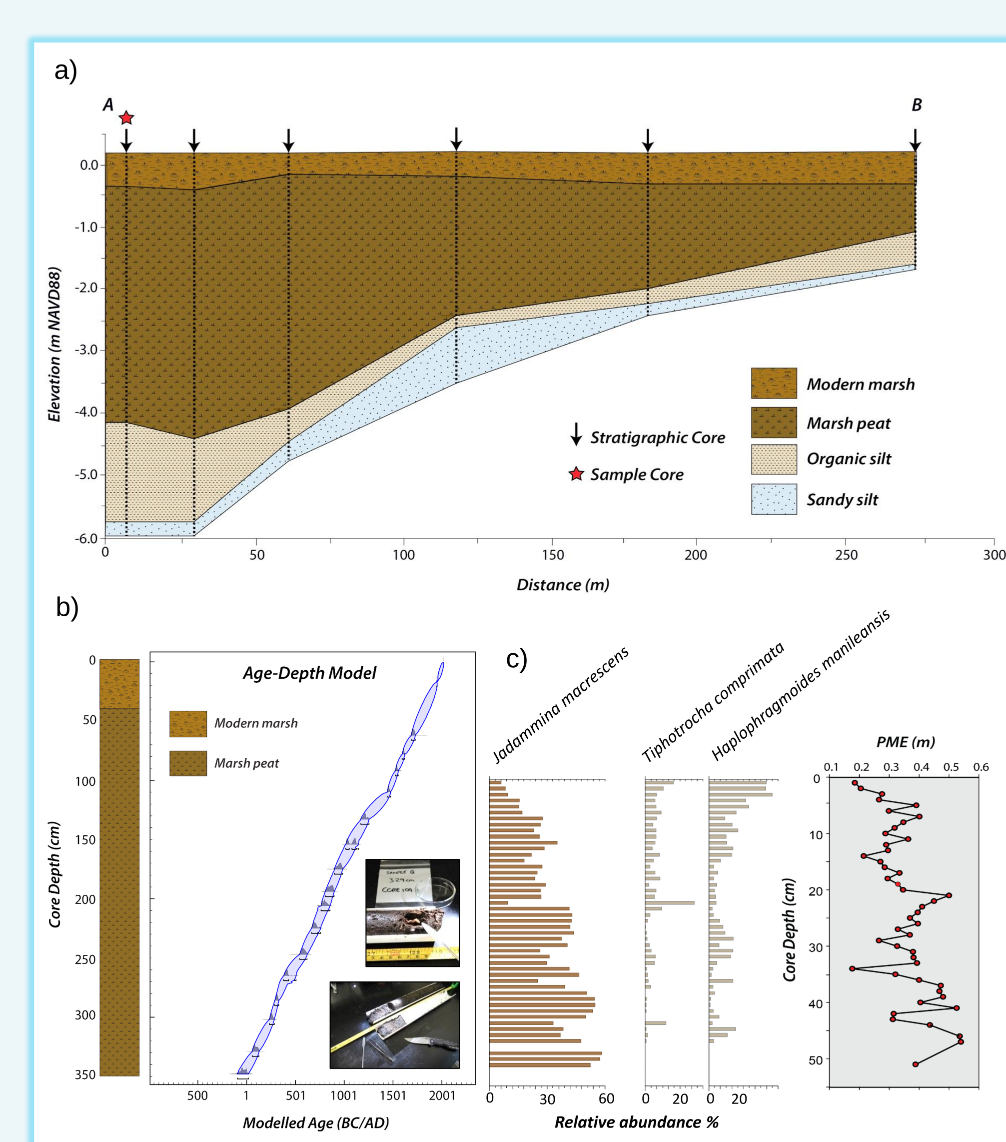

Figure 5. Stratigraphy of transect *A-B* from Kirkpatrick Marsh showing location of analysed core (a), age-depth model including photos of dated material (b) and PME predictions derived from fossil foraminifera (c).

Sea-Level Reconstruction

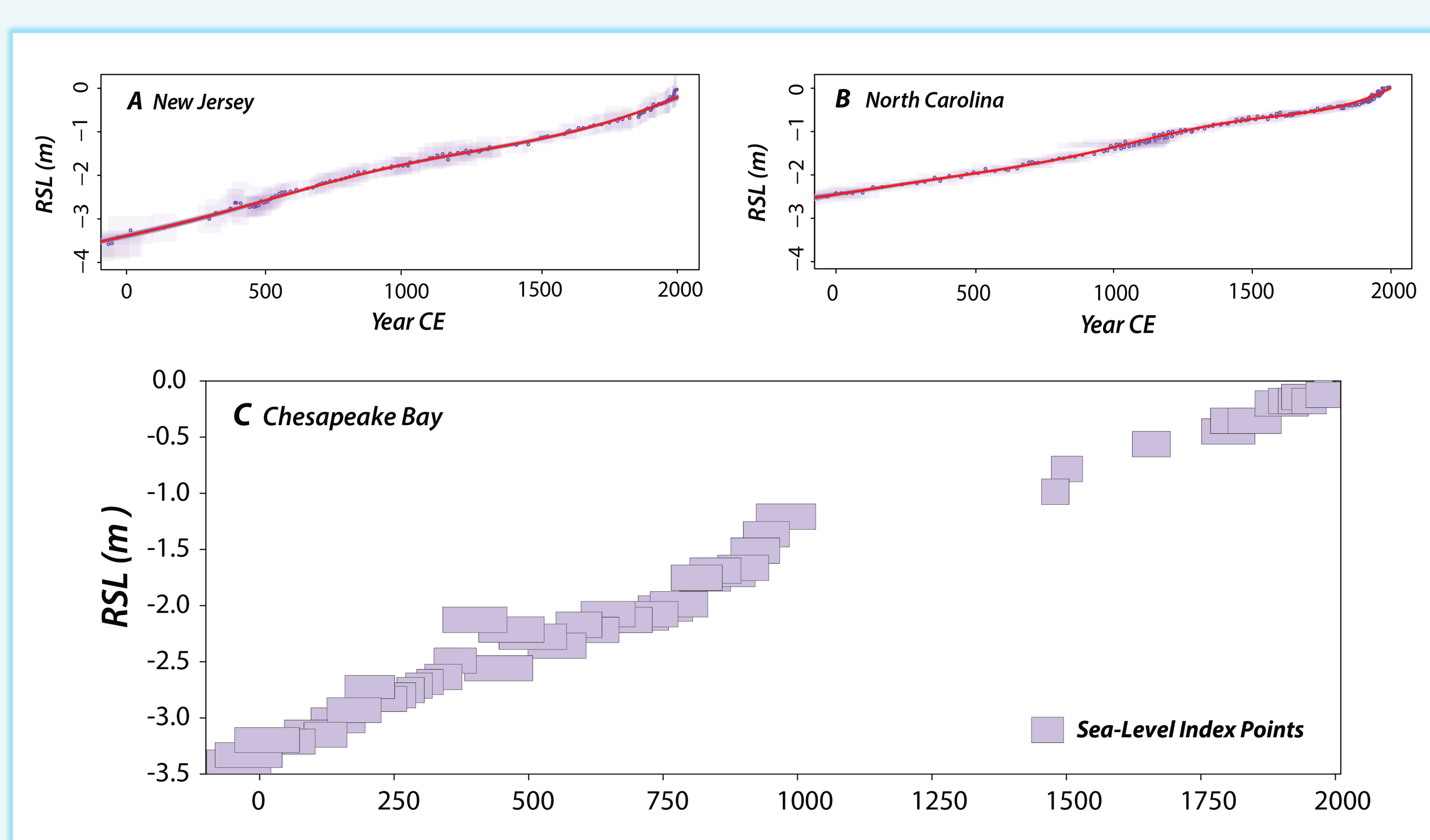

Figure 6. Proxy based reconstructions of RSL over the Common Era for (a) New Jersey, (b) North Carolina and this study, Chesapeake Bay (c).

The foundations of a new reconstruction shows strong potential in extending sea-level histories for the Chesapeake Bay region back ~2000 years comparable to previous records in New Jersey (**Fig. 6a**) and North Carolina (**Fig. 6b**). The new reconstruction currently provides 87 new sea-level index points (SLIPs) for this region (**Fig. 6c**). The SLIPs incorporate a 2σ horizontal error from age-depth model results and vertical errors from transfer function predictions, sampling and surveying (± 0.11m). The preliminary RSL curve shows an overall increases in SL over the Common Era of ~3.5m at an average rate of ~1.6 mm/yr. We anticipate rates of change during the modern era to be similar to that observed in the instrumental data (i.e. double the background rate) where a more detailed chronology for this period will soon be acquired. Newly developed statistical techniques (e.g. Cahill et al., 2015) will also be employed to accurately delimit changes in RSL for this region to provide answers to the spatial and temporal variability of late Holocene sea-level changes along the mid-US Atlantic Coast.

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