Using X-Ray Computed Tomography and Grain-size Analysis of Oxbow Lake Sediments to Reveal a Centennial-Scale Paleoflood History of the Pee Dee River, SC

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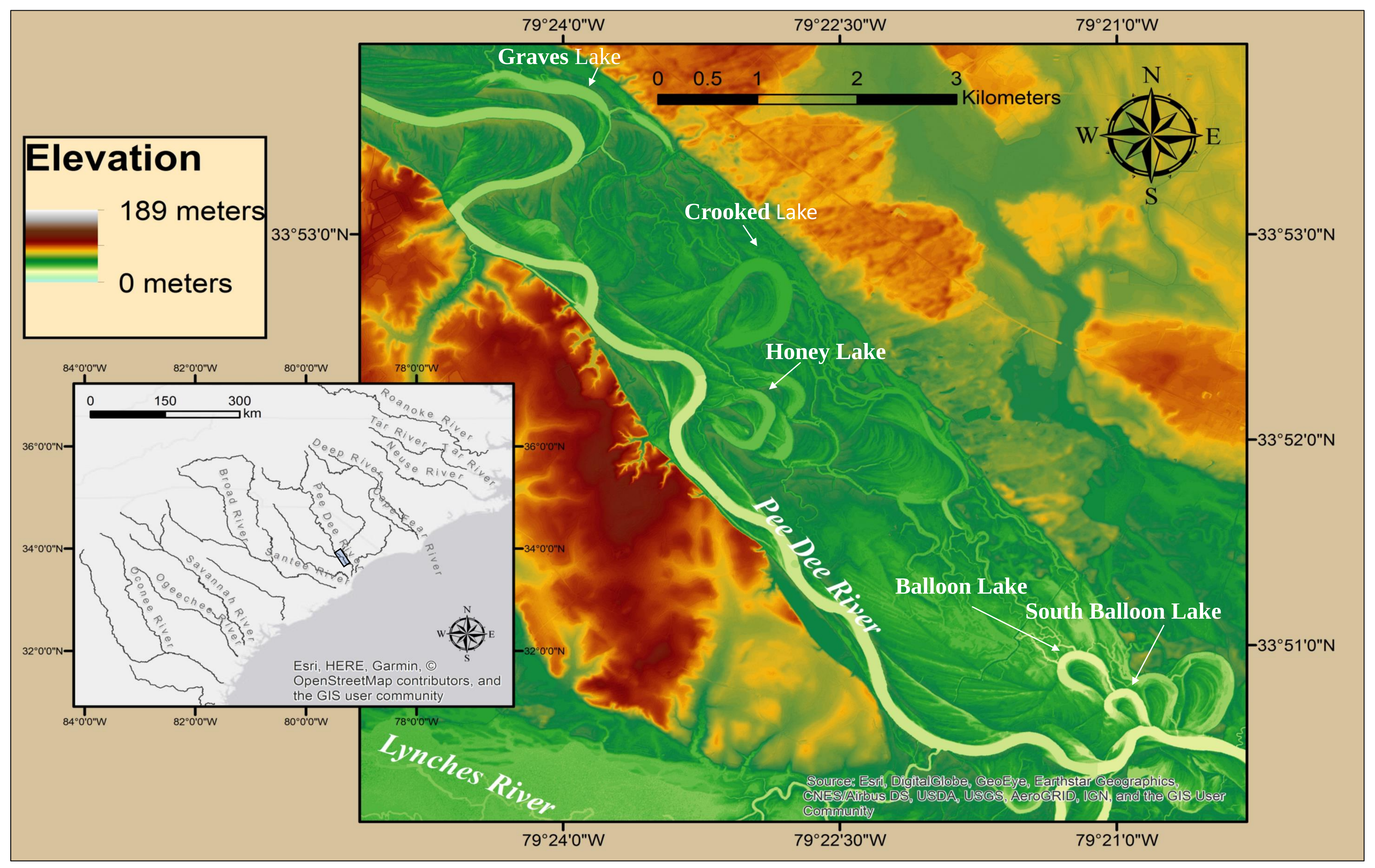
Introduction

Prediction that **anthropogenic warming may increase northern hemisphere precipitation by 30% creates concerns about future flood frequency and intensity** (Dankers at al., 2014; Paasche & Støren, 2014). Recent research by Muñoz et al. (2018) concludes that the interaction of artificial channelization of the Mississippi River, with natural climate variability, has **greatly amplified flood magnitudes** over the last century. **May similar changes be occurring in the Pee Dee River (PDR) basin in South Carolina (SC)? Do upstream dams, anthropogenic climate change, or natural climate modes have an effect on the frequency and magnitude of PDR floods?** Unfortunately, answering these questions is hampered by a lack of long-term hydrological data for this region, and **before advancing our understanding of flood controls, research must generate a long-term paleoflood history that extends beyond current historical records.**

Study Area

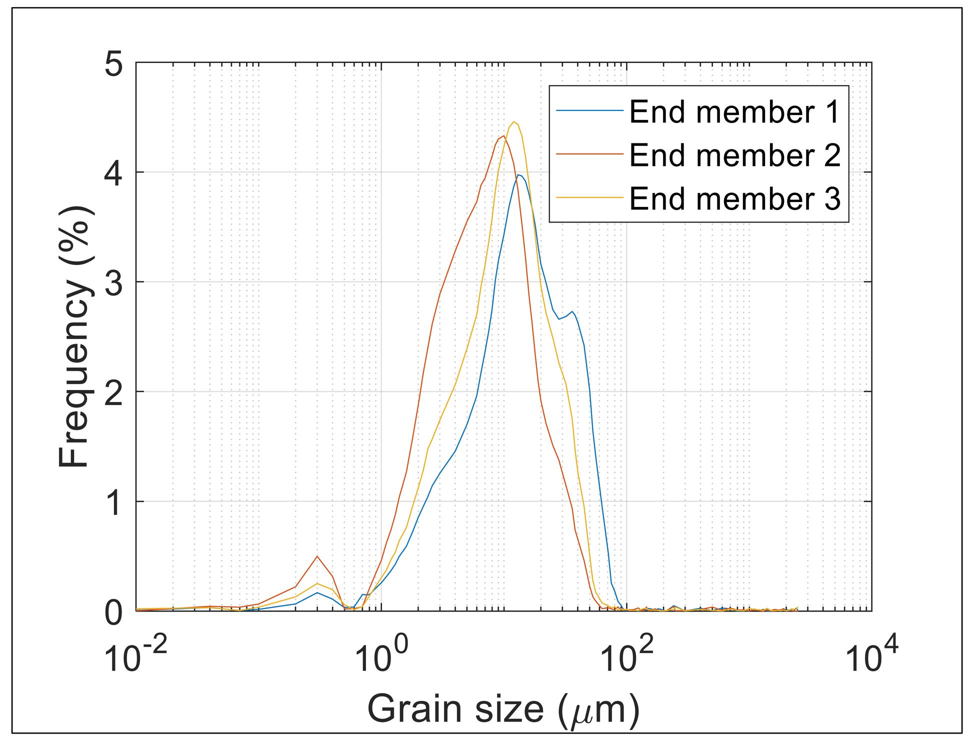


Oxbow lakes form when a meandering river cuts off at the neck of a meander loop, usually during floods (Toonen et al., 2012). The resulting oxbow lake is hydrologically disconnected from the main river channel and the coarse sediments it transports. During major floods oxbow lakes along the PDR may act as sediment traps capturing coarse bed-load transported by overbank river flows.

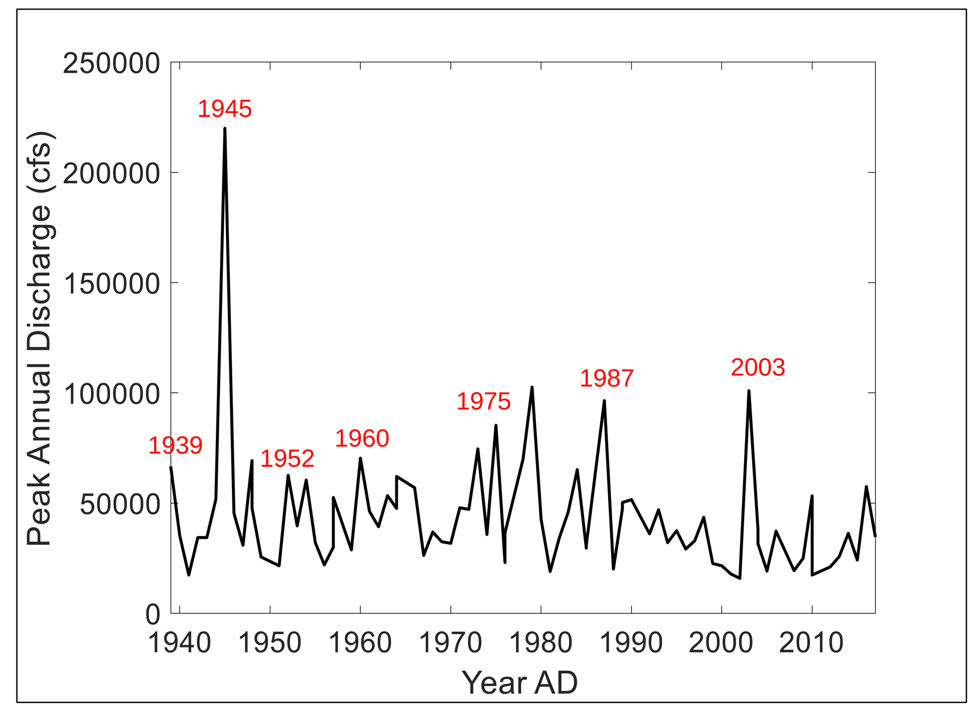
Methods

- Piston Core (SBL2) was collected in South Balloon Lake from a small aluminum boat.
- X-ray computed tomography (CT) scans were performed at 0.625 mm down-core resolution using a GE Optima CT scanner at Conway Medical Center. CT data were extracted and processed using MATLAB to obtain the 90% cumulative frequency (CT D90) for each CT-scan slice. CT data were detrended by a 101 point moving minimum of the 90 percentile (CT D90). Flood events are identified where CT D90 exceeds a 71 point moving mean by a one standard deviation threshold of CT D90.
- Laser diffraction grain-size (GS) analysis was performed at 0.5 cm down-core resolution using a Cilas 1190 particle-size analyzer. End-member (EM) modelling analysis (Yu et al., 2016) was used to unmix GS distributions. A model with three EM's was established to characterize the measured grain-size distributions**.** The coarsest EM's, EM1+EM3, were used to trace paleofloods. EM1+EM3 score was linearly detrended between section breaks following change point analysis (CPA; Taylor, 2000) and z-scored to unify sections. Linear regression between EM1+EM2 z-score and instrumental peak annual discharge of PDR was performed to reconstruct historical flood magnitudes.
- We created an age-depth model using Bacon v.2.2 (Blauuw & Christen, 2011), a Bayesian age-depth modelling program informed by multiple dating techniques including: ^{210}Pb and ^{137}Cs activity (CRS-model used), radiocarbon (^{14}C) dating of a terrestrial plant macrofossil (performed at NOSAMS), and core-tops taken as the date of collection (December, 2017).

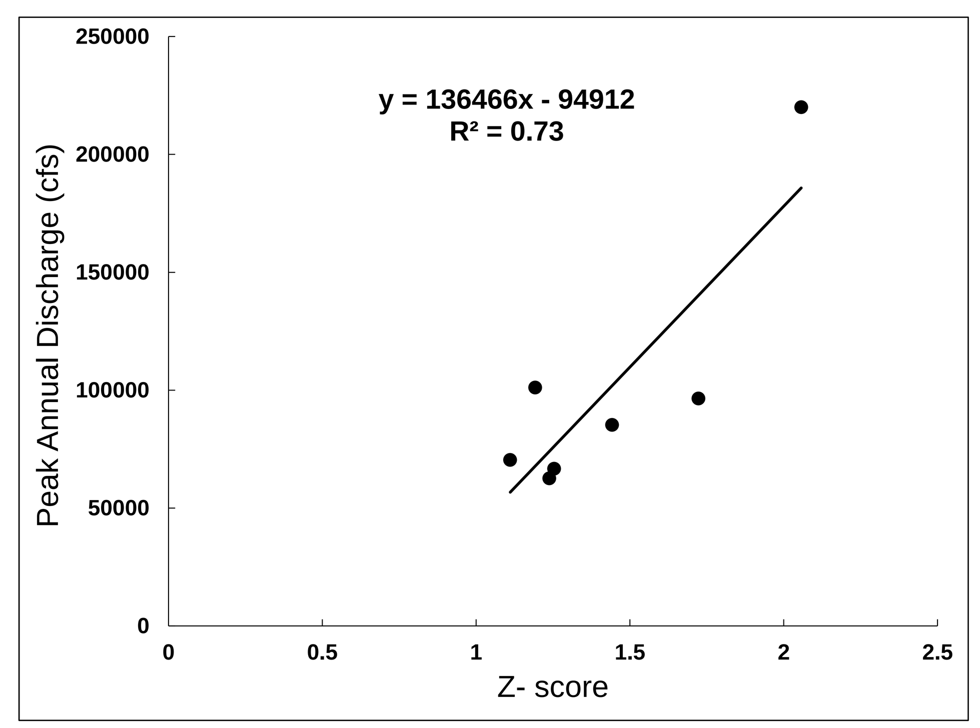
Results



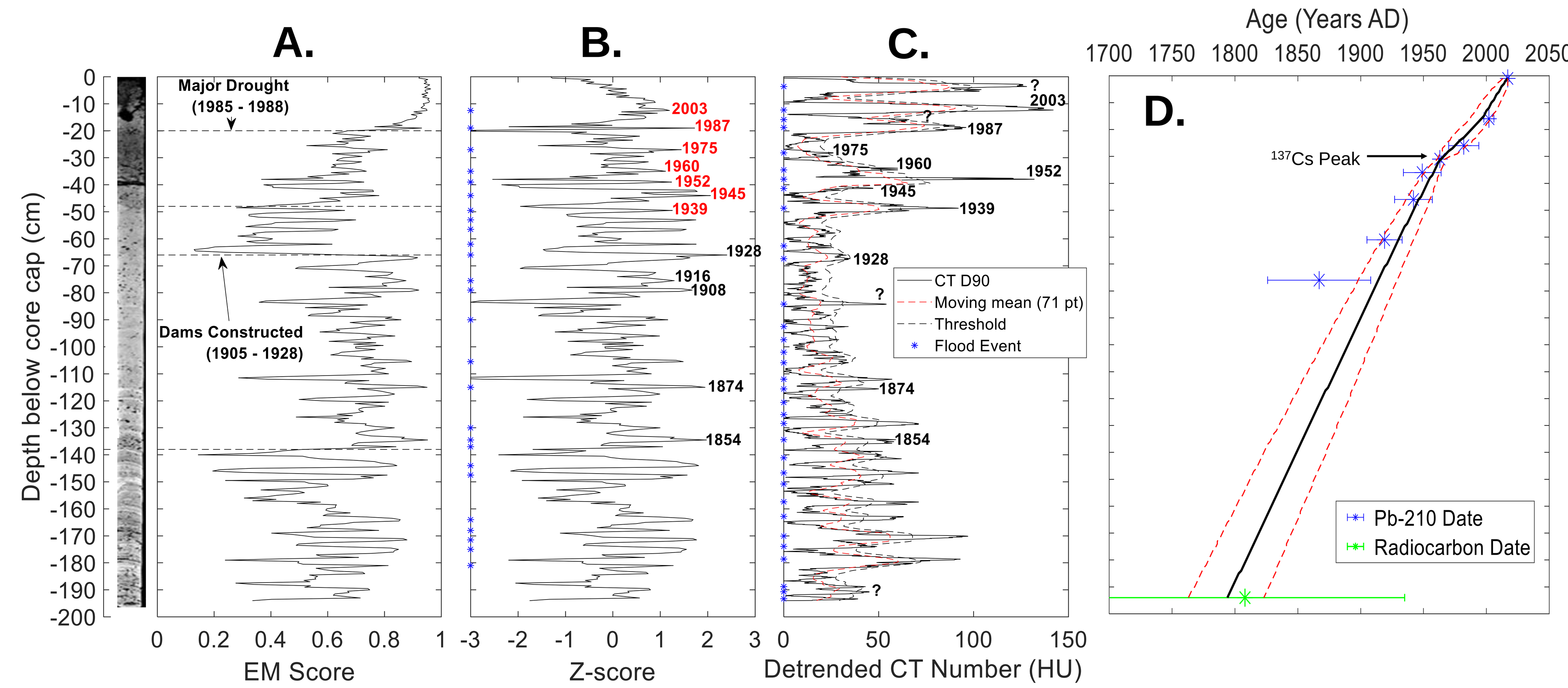
Sum of EM1+EM3 is used to trace paleofloods of the PDR, EM3 may prove to be a useful tracer for drought periods.



Daily discharge measurements (October, 1938 – December, 2017) of PDR at Pee Dee, SC (USGS, gage 02131000). Dates in red show discharges that fed the linear regression below.



Linear regression between PDR peak annual discharge and EM1+EM2 z-score.



CT-scan image, EM1+EM3 score, and CT number for SBL2 reveal coarse mineral-rich layers and are used as tracers of extreme paleofloods. A. Sum of the two coarsest EM's (EM1+EM3) has change points (gray dotted lines) at 20 cm and 66 cm that may correspond to drought and completion of dam construction, respectively. **B**. Following the age-depth model, identified flood peaks have been tied to years (in red) that have extreme (moderate to major flood stage) peak annual discharges. **C.** CT data confirm flood events identified in z-scored EM1+EM3 data, however some events are overcounted (see question marks). **D.** The age-depth model shows the median age probability (black line) and 1 σ confidence intervals (red dotted lines), with 1 σ confidence intervals on individual ^{210}Pb dates, and 2 σ confidence interval on the radiocarbon date.

Discussion

- Our estimates show that the historical flood caused by Hurricane #4 in 1928 (2nd deadliest hurricane to hit the U.S.) may have produced a discharge of 233,016 cfs. This flood would be the greatest discharge of the PDR according to our proxy record.
- The final dam constructed on the PDR in 1962 for flood control may have been effective, as extreme flood magnitudes appear to decrease through time.
- Z-scored EM1+EM3 seems to be more reliable than CT number for reconstructing paleoflood frequency and magnitude.
- A major shift in sedimentation to finer sediments occurs at 66 cm, indicating that upstream damming completed in 1928 has effected the natural behavior of the PDR.
- The change point identified at 20 cm may correspond to the drought of 1985 – 1988. Dry conditions in the floodplain and decreased vegetation cover most likely provided excellent coarse sediment transport potential for the 1987 spring flood event. Creating an extreme contrast in sediment grain-size from ~19 – 20 cm.

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