Title

Recent Acceleration of Coastal Wetland Accretion Along the U.S. East Coast

Authors

Nathaniel B. Weston[1*], Elise Rodriguez[1], Brian Donnelly[1], Elena Solohin[2], Kristen Jezycki[1], Sandra Demberger[1], Lori Sutter[3], James T. Morris[4], Scott Neubauer[5], and Christopher B. Craft[2]

[1]Department of Geography and the Environment, Villanova University, Villanova, PA 19085, USA;
[2]O'Neill School of Public and Environmental Affairs, Indiana University, Bloomington, IN 47405, USA;
[3]Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602, USA;
[4]Department of Biological Sciences, University of South Carolina, Columbia, SC 29208, USA;
[5]Department of Biology, Virginia Commonwealth University, Richmond, VA, 23284, USA;
[*]Corresponding Author: nathaniel.weston@villanova.edu

Keywords
Accretion, Carbon sequestration, Mineral, Organic, Sea level rise, Salt marsh

Funding Sources
This work was funded by National Science Foundation grants DEB 1457442 to NBW, 1457513 to CC, 1457435 to SN, 1457622 to JM, and the NSF-funded Plum Island Ecosystem Long Term Ecological Research (PIE-LTER) grant OCE 1637630 and Georgia Coastal Ecosystem (GCE-LTER) grant OCE 9982133.

Abstract

The long-term stability of coastal wetlands is determined by interactions among sea level, plant primary production, sediment supply, and wetland vertical accretion. Here, we examine rates of vertical accretion and carbon sequestration in nine tidal wetland systems along the U.S. East Coast from Maine to Georgia. We show that rates of vertical accretion have accelerated over the past century by between 0.010 and 0.083 mm yr^{-2}, at roughly the same pace as the acceleration of global SLR. Wetland accretion has accelerated more rapidly in coastal systems with greater relative RSLR, higher watershed sediment availability, and lower temperatures. These findings suggest that the biogeomorphic feedback processes that control accretion in these tidal wetlands have responded to accelerating RSLR, and that changes to RSLR, watershed sediment supply, and temperature interact to determine wetland vulnerability across broad geographic scales. Acceleration in coastal wetland accretion provides further evidence of widespread response in Earth's biological systems to human-induced climate change.

Methods

This study was conducted in nine tidal marsh and watershed systems along the East Coast of the United States from Maine to Georgia. The systems included the Kennebec (KEN), Plum Island Sound (PIE), Connecticut (CON), Delaware (DEL), York (YRK), James (JMS), Cape Fear (CPF), Edisto (EDS), and Altamaha (ALT) Rivers. These sites were chosen as they ranged in flow-weighted average riverine suspended sediment concentration (SSC), with lowest SSC in the KEN and the highest in the DEL. An analysis of changes in SSC over time in these systems indicated that over half have experienced declines in sediment (PIE, CON, DEL, JMS, CPF) while two systems have experienced increases in SSC (EDS and ALT) over recent decades. Rates of relative sea-level rise (RSLR) and the mean tide range (MTR) were determined for the closest National Oceanographic and Atmospheric Administration (NOAA) tide gauge and retrieved from the NOAA Tides and Currents website (https://tidesandcurrents.noaa.gov/sltrends/sltrends.html). Rates of RSLR were determined from a common date (1950) to remove bias in rates due to differences in the length of the record.

Accretion rates in each of the tidal marsh systems was determined using radiodating techniques on marsh soil cores. Soil cores were taken on the marsh platform at several (n = 3 to 4) locations in each wetland system (31 cores total). The plant community was predominantly *Spartina patens* with some *Distichlis spicata* in the northeast KEN, PIE, and CON sites, and *S. alterniflora* in the remaining sites. Cores (10.2 cm i.d. at all sites except DEL where smaller 6.4 cm i.d. cores were used) were taken to a depth of between 40 cm and 120 cm. Coring locations and elevation were recorded with a high accuracy real-time kinematic global positioning system (Trimble 5800 RTK GPS). Cores were returned to the laboratory and sectioned in 1 cm (from 0 to 50 cm) or 2 cm (beyond 50 cm) increments. The soil compaction during coring in the field and sectioning in the laboratory was measured, and soil depths were corrected for these compaction factors. Soil dry bulk density (ρ; g cm^{-3}) was determined by the change in weight upon drying a known volume, and soil organic and mineral content was determined for a subsample of soil by the loss of weight on ignition (LOI; 500 °C). Soil ^{137}Cs and ^{210}Pb activities were determined by gamma spectrometer (Canberra Instruments broad energy germanium detector) on a homogenized portion of the dry soil section. The excess ^{210}Pb was determined from the background ^{210}Pb activity at depth, which was confirmed by ^{214}Pb and ^{214}Bi activities for a subset of soils at secular equilibrium. The constant rate of supply (CRS) model of ^{210}Pb was used to determine age-dependent rates of soil accretion where the age (t; years) of each soil section was calculated as:

$$t = \frac{1}{\lambda} ln \frac{Q_0}{Q_x}$$

where Q_0 is the total inventory of excess ^{210}Pb, Q_x is the inventory of excess ^{210}Pb below depth x, and λ is the ^{210}Pb decay constant (0.03101 yr^{-1}; Appleby and Oldfield 1992; Kolker 2009). The age-specific accretion rate (ω; cm yr^{-1}) was then calculated by the change in age (t) with depth (in cm). The portion of accretion attributable to mineral accretion (ω_M; cm yr^{-1}) at each depth was determined as (Kolker 2009):

$$\omega_M = \frac{\omega\rho(1 - LOI)}{k_2}$$

where k_2 is the self-packing density of marsh soil mineral matter (1.99 g cm^{-3}; Morris et al. 2016) and ρ and LOI are the depth-specific soil bulk density and loss on ignition, respectively. The organic accretion (ω_O; cm yr^{-1}) was calculated as the difference between total accretion and mineral accretion, and the accretion deficit (ω_D) was determined by the difference between the rate of local RSLR and ω.

Additional, complementary methods of estimating soil accretion rates were employed for comparison, though neither of these methods provide age-specific rates of accretion. The maximum ^{137}Cs activity from gamma counting of soils was assumed to correspond to the soil at the marsh surface in 1964, and the depth of that section was used to calculate an accretion rate (Pennington et al. 1973). ^{210}Pb activities were also used to calculate a whole-core accretion rate using the constant initial concentration model (ω_{CIC}), in which:

$$\omega_{CIC} = \frac{-\lambda}{r}$$

where r is the slope of the regression of natural log of the excess ^{210}Pb against depth (Appleby and Oldfield 1992). Comparison of accretion rates across the three methods (CRS, CIC, and ^{137}Cs) indicated strong agreement.

References Cited

Appleby, P. G. & Oldfield, F. in *Uranium-Series Disequilibrium: Applications to Earth, Marine, and Environmental Sciences. 2nd ed.* (eds. Ivanovich, M & Harmon R. S.) 731-783 (Clarendon, 1992).

Kolker, A. S., Goodbred, S. L., Hameed, S. & Cochran, J. K. High-resolution records of the response of coastal wetland systems to long-term and short-term sea-level variability. *Estuarine Coastal and Shelf Science* **84**, 493-508, doi:10.1016/j.ecss.2009.06.030 (2009).

Morris, J. T., Barber D. C., Callaway J. C., Chambers R., Hagen S. C., Hopkinson C. S., Johnson B. J., Megonigal P., Neubauer S. C., Troxler T., Wigand C. Contributions of organic and inorganic matter to sediment volume and accretion in tidal wetlands at steady state. *Earths Future* **4**, 110-121, doi:10.1002/2015ef000334 (2016).

Pennington, W., Cambray, R. S. & Fisher, E. M. Observations on lake sediments using fallout Cs-137 as a tracer. *Nature* **242**, 324-326, doi:10.1038/242324a0 (1973).