Supporting Information

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SI Text

A. Shear Strength Measurement. The field-vane shear strength measurement often overestimates soil strength (1). Shear measurements are influenced by strain rate and anisotropy within the soil. The strain rate is controlled by the rotation rate and the diameter of the vane. Lower strain rates allow more time for the soil to slide, deform, and creep, resulting in lower values of peak strength, while more rapid strain rates result in a higher apparent strength. Clays often display anisotropy and are stronger in the vertical plane than the horizontal plane due to incremental sedimentation and the existence of laminations (2). During the field test, 80% of the shear occurs in the vertical plane. A correction factor has been proposed by Bjerrum to reduce the field-vane strength estimates based on the plasticity index of the soil (1); however, it was not possible to apply this correction to our data. An additional consideration should be the effect of friction between the instrument rod and soil, which adds to the apparent strength of soil and is difficult to consistently quantify and thus correct for. No adjustments were made to the field-vane data, since it was felt that this would increase the uncertainties. The field-vane values should therefore be considered conservative and are likely overestimates of strength.

To further quantify the low shear strength layer observed in the low salinity wetland, laboratory vane measurements were made on the undisturbed half cores that were collected in the field. In this test the shearing occurs in both the horizontal plane and vertical planes, such that an average strength is obtained. It also eliminates the effect of rod friction. The lab vane is smaller in diameter (12.7 mm × 12.7 mm) and is less likely to contact rooting, and thus isolates the strength of the soil matrix itself. One limitation of the test is that the soils have to be removed from the field, which decreases the effective stress and can result in a slight rearrangement of soil particles, reducing soil strength.

B. Wave Shear Stress Calculations. The presence of vegetation within a flow field decreases near bed velocity. Within the canopy, the obstruction by the plant stems and leaves increases turbulence, dramatically decreasing the average flow speeds, damping wave motion and thus reducing the potential for erosion by the resuspension of particles (3–7). This sudden reduction in velocity can also force the settling of suspended particles and actually increase sedimentation (8, 9). Deceleration is correlated to vegetation density (4, 9). The movement of rooting at a marsh platform edge has been seen to dislodge grains in small waves (10); however, herein we consider a broader scale.

When vegetation is fully submerged (as occurred during the storm surge associated with Katrina), while flow through the canopy is reduced, an accelerated skimming flow develops above the canopy. The skimming flow displays a logarithmic velocity profile, beneath which the vegetation may be considered as a form of macro-roughness (6). For a review of the impact of vegetation on flow the reader is referred to Neumeier (2007).

Several studies have assessed the impact of vegetation in terms of the roughness length (Z_0) that they impart onto the flow (5–7). These studies consider *Spartina maritima* and *Spartina anglica* (Table S2), and although no estimates of Z_0 for *Spartina alterniflora* have been published, Leonard and Croft (2006) publish measurements of turbulent kinetic energy (TKE) within flows over a submerged stand of *Sp. alterniflora* 30 cm in height. This vegetation had been artificially shortened to a height lower than the depth of the water column in order to examine their impact on supernatant flow. These data have been used herein to estimate a Z_0 for *Sp. alterniflora*, using relationships between TKE and near bed shear stress τ (Eq. **S1**) (11–13), and then rearranging the von Karman-Prandtl relationship (Eq. **S2**) to provide an estimate of roughness length from this τ (Eqs. **S1** and **S2**):

$$\tau = \rho u_*^2 \qquad \textbf{[S1]}$$

$$u = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_0}\right) \qquad \textbf{[S2]}$$

These results are shown in Table S2. The roughness length (Z_0) of the vegetation depends only on the vegetation characteristics (stem diameter, vegetation density and height), and is not sensitive to the current velocity or the water depth (5).

Klopstra et al (1997) used an analytical modeling approach to derive a Z_0 for varying vegatation characteristics, finding values of between 22 and 46 cm for submerged vegetation of between 0.5 and 2 m height in water depths of 5 m (14). Given that no data exist for *Spartina patens*, which is generally shorter (~30–50 cm) but denser than *Sp alterniflora*, we will use estimates for the *Sp alterniflora* to represent this vegetation at our lowest limit of roughness ($Z_0 = 17$ cm; this is a conservative estimate as a higher roughness is expected with increased vegetation density). As the both the Sp patens and Sp alterniflora will likely have been at their tallest late in summer higher roughness ($Z_0 = 30$ cm) was also considered obtained by averaging the modeling results for the taller plants (14).

The wave friction factor (f_w) can be related empirically to the ratio of the amplitude of the orbital excursion to the bed roughness (11). Z_0 has been shown to be equivalent for both current and wave conditions (15), thus the estimates of Z_0 discussed above can be used within Eq. **S4** to provide f_w. This friction factor can then be used to relate shear stress (τ_w) to the maximum near bed orbital velocity of the wave during a wave period ($u_{w,m}$; Eq. **S3** and **S4**).

$$\tau_w = \frac{1}{2}\rho f_w u_{w,m}^2 \qquad \textbf{[S3]}$$

where

$$f_w = 1.39\left(\frac{A}{z_0}\right)^{-0.52} \qquad \textbf{[S4]}$$

where A is the near bed orbital amplitude of the wave (11). Calculations were made using the estimates of wave height, period and water depth extracted from the STWAVE-ADCIRC modeling of Hurricane Katrina.

In order to consider the most extreme conditions both the significant and maximum wave heights ($1.868H_s$) were used in calculations of A and thus shear stresses for each of these conditions, for $Z_0 = 17$ cm and $Z_0 = 30$ cm were determined at each of the 7 sites for which model data were extracted (Fig. S1).

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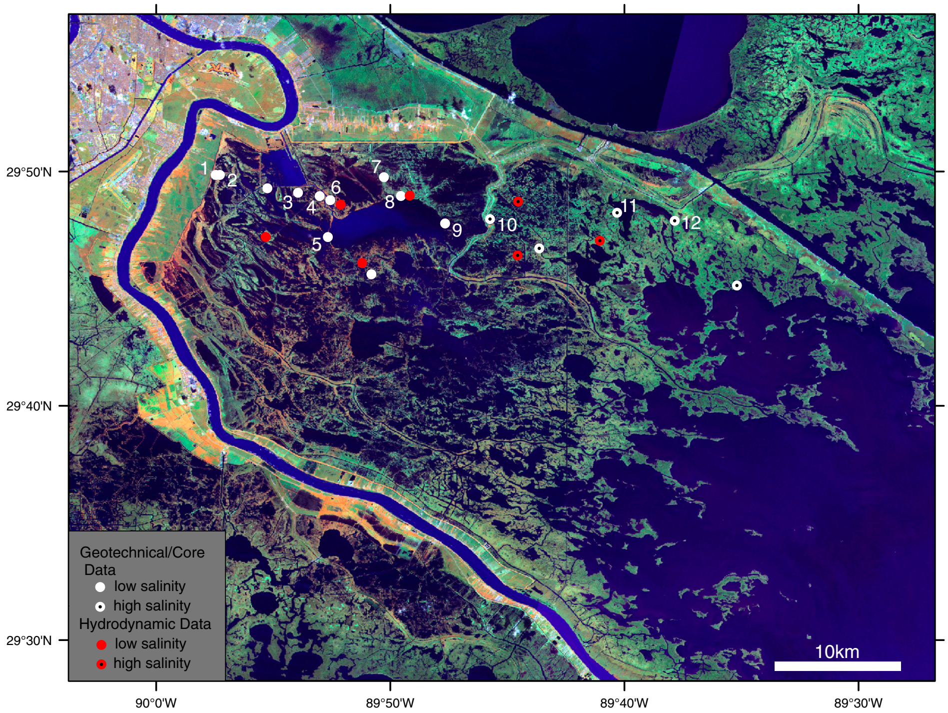

Fig. S1. Showing the positions at which model data were extracted and wave shear stress calculations were undertaken (red circles). Also showing sites of geotechnical measurements in the field (all white circles) and coring sites for geotechnical measurements in the laboratory (numbered white circles). Low and high salinity sites are differentiated using a black dot.

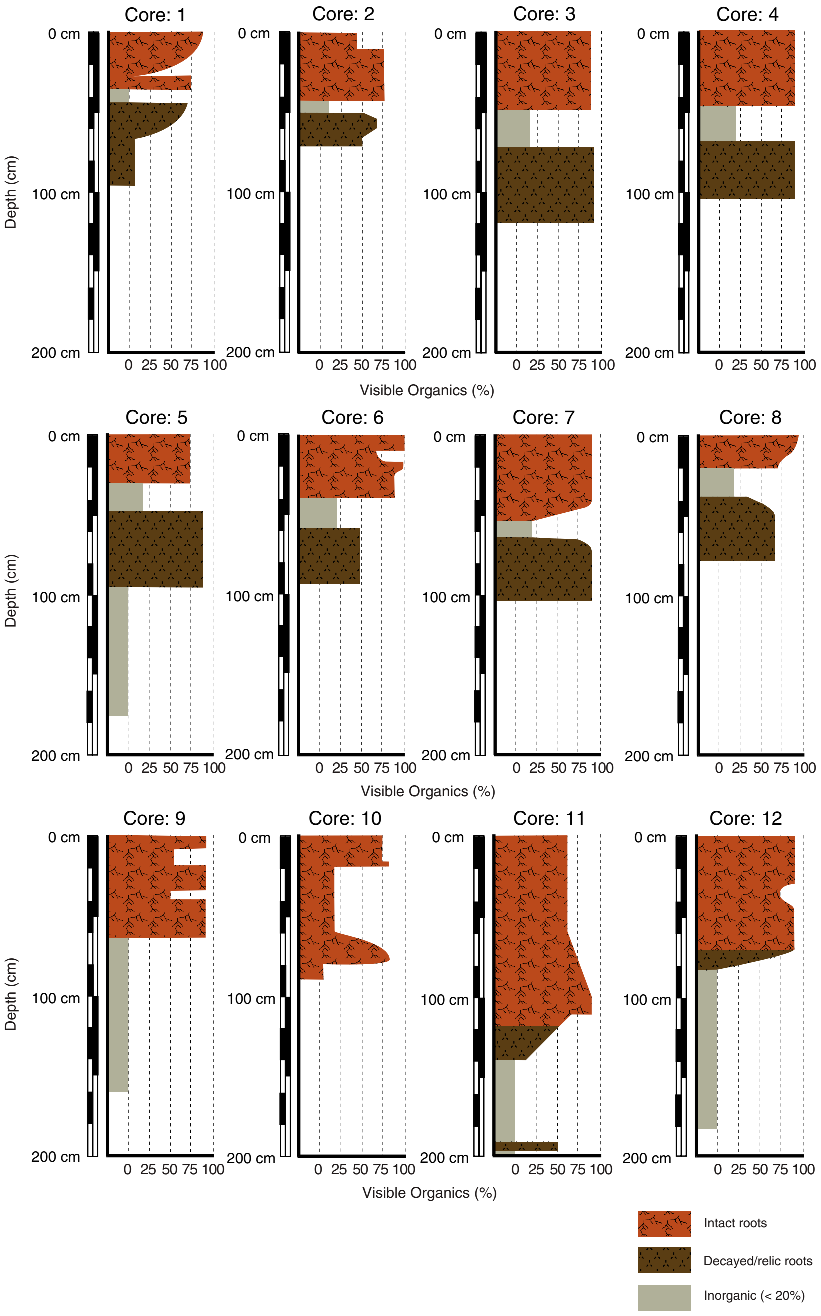

Fig. S2. Stratigraphy of the short cores. Cores 1–9 were taken in the low salinity wetland, while cores 10–12 were taken in high salinity wetlands. Intact rooting in the low salinity cores extends to average depth of 42 cm (range 31–67), below which an inorganic layer separates the live rooting from an older decomposing root horizon. In the high salinity region, roots extend to an average depth of 92 cm (range 74–112) and intact rooting is seen within relatively inorganic layers.

Table S1. Environmental characteristics of the wetland categories

	Fresh	Intermediate	Brackish	Saline
Vegetation	***Sagittaria sp., Panicum hemitomon****, Hydrocotyle sp., Pontederia cordata, Althernantera philoceroides.*	***Sagittaria sp., Spartina patens,****Vigna luteola, Scirpus californicus, Echinochloa walteri, , Cladium jamaicense, Phragmites australis.*	***Spartina patens, Spartina alterniflora****, Scirpus americanus, Scirpus robustus and Eleocharis parvula.*	***Spartina alterniflora,*** *Juncus roemerianus, Batis maritima, Avincennia germinans, Distichlis spicata*
Mean salinity (ppt)	0	4	10	18
Salinity range (ppt)	0–3	2–8	4–18	8–29
Equivalent salinity classification	Limnetic (0–0.5 ppt)	Oligohaline (0.5–5 ppt)	Mesohaline (5–18 ppt)	Polyhaline (18–30 ppt)
Further description based on 2008–2009 observational data from monitored sites in each zone				
Sites (N)	2	8	4	1
Mean marsh elev. NAVD88 (m)	0.357	0.372	0.259	0.265
Average percentage of time inundated	41.7	25.2	36.7	42.02
Mean water elev. NAVD88 (m)	0.405	0.311	0.247	0.198
Average number of species observed	26	16	12	2

The first half of the table presents general conditions for the vegetation zones used in this study based upon observations by Visser et al. (1998) and Linscombe and Charbreck (2001). Dominant vegetation types in each zone are bolded. The second portion of the table presents average conditions determined from 1–2 years of in situ measurements collected at permanent monitoring stations within Breton Sound. Data were extracted for individual stations using http://www.lacoast.gov/crms_viewer/, and averaged in Excel.

Table S2. Values of Z_0 from field measurements

Study	Vegetation Type	Vegetation Height	Z_0
Neumeier & Ciavola (2004)	*Spartina maritima*	20–35 cm	13.2–18.1 cm
Neumeier & Amos (2006)	*Spartina maritima & anglica*	19–34 cm	11–23.9 cm
Leonard & Croft (2006)	*Spartina alterniflora*	30 cm *	20 cm †
Neumeier (2007)	*Spartina anglica*	15–24.5 cm	9.9–20.9

*Vegetation cut in order to produce a submerged condition.

†Z_0 not calculated by the study but estimated here using the given TKE data.