Analysis and selection of storm surge profiles

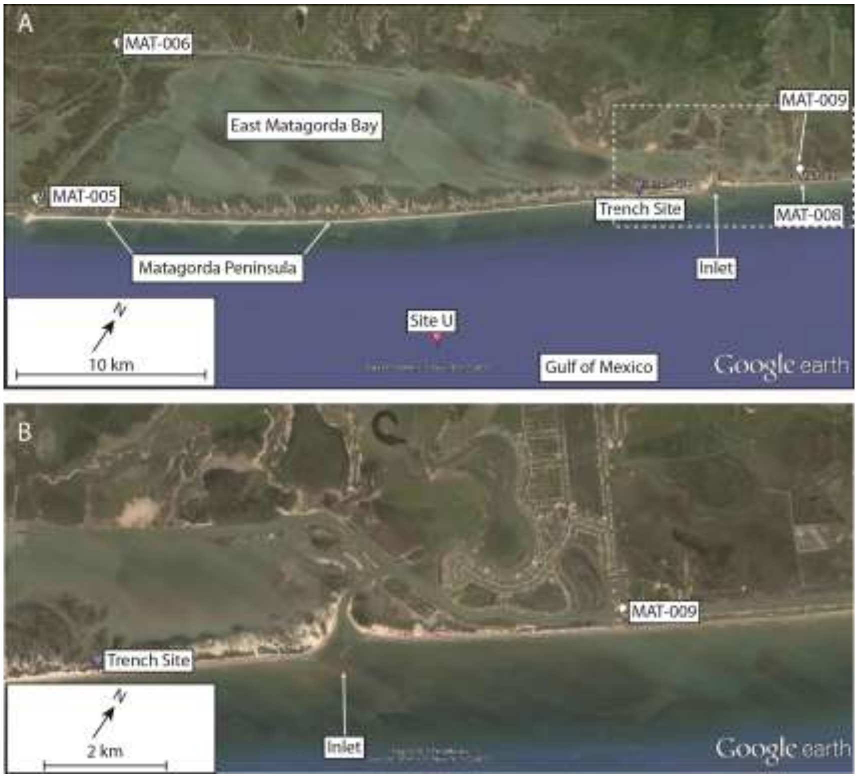

Figure S1: (A) Map of the Matagorda Peninsula near the observation trench. The location of the overwash trench, and storm surge records are shown. The records collected by East et al. (2008) are labeled as MAT-005, MAT-006, and MAT-009 while the record collected by Kennedy et al (2011) is labeled Site U. (B) Detailed map of the area between the trench site and MAT-009, outlined in a dashed white box in (A).

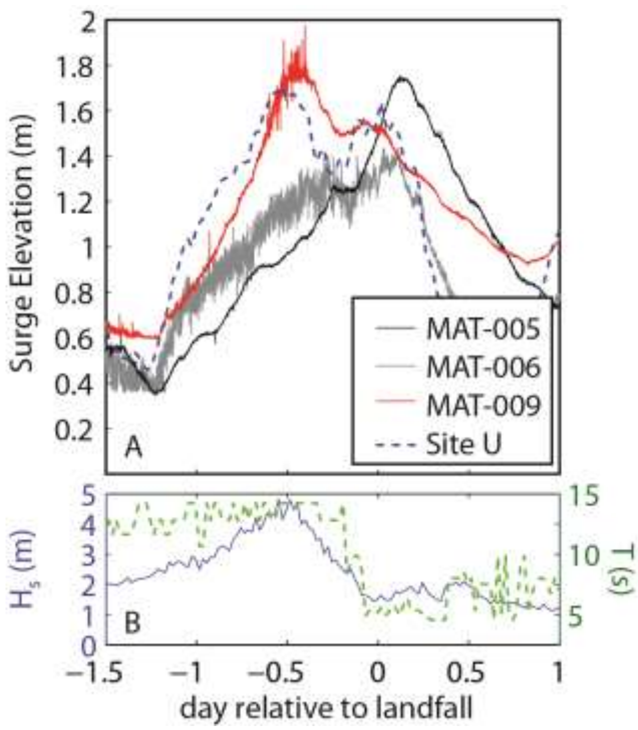

Figure S2: (A) Surge profiles relative to hurricane landfall that occurred at 2:10 AM (CDT) on 13 September, 2008 (see locations in Figure S1). MAT-005, MAT-006, and MAT-009 are from East et al. (2008) and are referenced to NAVD88. Site U is the relative change in water depth from Kennedy et al. (2011) and does not reflect an absolute elevation. (B) Significant Wave Height (blue) and wave period (dashed green) series measured at Site U.

Records of storm surge elevation are required to estimate the timing and environmental conditions during deposition from the trajectory of the topset-foreset break (TFB) in washover stratigraphy. Here we determine which storm surge records most accurately characterize the water surface elevations both seaward and landward of the trenched washover fan (Fig. S1). Our analysis shows that the proximity of the mainland behind the barrier island can influence the storm surge profile by hindering the spreading of flow. Accordingly, this analysis finds that the most accurate records of storm surge seaward and landward of the trenched site were MAT-005 and MAT-006 collected by the U.S. Geological Survey (East et al., 2008).

Two sites record storm surge on the seaward side of the Matagorda Penninsula. Water depth measurements were made at Site U 7 km from the coast in roughly 14 m of water (Kennedy, Gravois, and Zachry, 2011), and the relative changes in elevation are shown in Fig. S2A. The US Geological Survey (USGS; East et al., 2008) measured storm surge on the beach near the mouth of the Colorado river (MAT-005), with levels referenced to NAVD88. Two sites recorded storm surge landward of Matagorda Peninsula, MAT-006 was collected at the intersection between the Colorado River and the Intra-Coastal Waterway (hereafter ICW, Fig 1A, S1A), 15 km from the first major connection to East Matagorda Bay. MAT-009 is located to the northeast along the ICW, 9 km to the northeast of the first major connection to East Matagorda Bay. Coastal marsh and sparse housing developments are found directly landward of MAT-009 (Fig. S1B) due to proximity of the mainland behind the barrier island.

Storm surge time series (Fig. S2) trace different trajectories and have different peaks depending on their location. For the one day preceding landfall, Site U and MAT-009 rose rapidly (0.061 m hr^{-1}) compared to MAT-005 and MAT-006 (0.038 m hr^{-1}, Fig. S2A). Significant wave height at Site U also increased its growth rate from 0.073 m hr^{-1} to 0.165 m hr^{-1} one day before landfall (Fig. S2B). The storm surge peak also varied among sites: MAT-005 peaked 20 hours after the peak of MAT-009. This portion of the coast was subject to a large forerunner surge propagating to the southwest at 5-6 m s^{-1} (Kennedy, Gravois, Zachry, et al., 2011). This would have produced a delay of just 1.9 hours over the 35 km between measurement locations and therefore cannot explain the later and more gradual rise of MAT-006 and MAT-005.

Meteorological conditions near the trench site from a well-validated numerical model (Hope et al., 2013) show that winds were from the northwest in the day before landfall. They were also mild, not exceeding 20 m s^{-1} until landfall. For this reason, water surface slopes due to wind shear would have been minimal. Furthermore, because the trench was on the dry (southwest) side of the hurricane, it received very little precipitation, so changes in the volume of East Matagorda Bay were primarily the result of water flux from the Gulf of Mexico.

We argue that storm surge rise at MAT-005 and MAT-006 was slowed by the gradual filling of East Matagorda Bay, and this should be accounted for when assessing back barrier surge. The area of East Matagorda Bay is roughly 148 km^2, so the rates of storm surge rise measured at MAT-005 and MAT-009 would require a discharge into the bay of 1600-2500 $m^3 s^{-1}$. Although there is one small inlet to East Matagorda Bay, it is most likely that this discharge occurred through distributed wave overwash given the significant discharge, and because MAT-006 lagged MAT-005. H_s began to peak one day at about the same time (Fig. S2A), providing a mechanism for the distributed overwash flow.

Given a spatially distributed discharge into East Matagorda Bay from overwash flow, it is likely that the storm surge at MAT-009 was influenced by the constricted environment landward of the barrier island there. Spreading of flow at this site would have been hindered by heightened drag imposed by the coastal marsh (e.g. Nepf, 2012), as well as the housing developments which may have been able to partially contain the elevated surge levels. In contrast, overwash flow directly into East Matagorda Bay could easily redistribute itself to an even level within the bay which could be recorded at MAT-006 without bias from overwash discharge.

From this analysis, we conclude that MAT-005 and MAT-006 tracked the storm surge elevation seaward and landward of the trenched site during the day leading up to the landfall of Hurricane Ike. We use these records in our stratigraphic analysis.

References Cited

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