# Wax Lake Delta, Louisiana: Factors Controlling Hydrodynamics and Morphological Changes during Hurricane Rita (2005)

**Fei Xing[1], Albert Kettner[1], James Syvitski[1], Qinghua Ye[2]**

[1)] Community Surface Dynamics Modeling System (CSDMS), Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder CO, USA.
[2)] Deltares, Delft, 2600 MH Netherlands.
Fei.Xing@colorado.edu

## Objective

Explore the effects of wind, waves, and vegetation on deltaic hytrodynamics and morphological changes during extreme conditions; better understand the mechanisms by which vegetation protects coastal wetlands from floods and erosion.

## Introduction

Close to half a billion people live on deltas, many of which are threatened by flooding (Syvistsk and Saito, 2007) (Figure 1).
The main forces during storms are tides, wind, and wave surges. On the other hand, vegetation can significantly decrease erosion by reducing flow velocity, and increasing soil strength ( Temmerman, et al., 2005; Pollen-Bankhead and Simon, 2008). As a result, native vegetation has been used as an effective and economic way to diminish flood impact. However, vegetation can also intensify erosion under some circumstances, for example, when flood wave shear stress becomes larger than soil strength. In this case, the root may be pulled out of the ground, capturing soil and increasing erosion (Howes, et al., 2010). Thus, more study is needed to understand the role of vegetation during severe flood conditions.

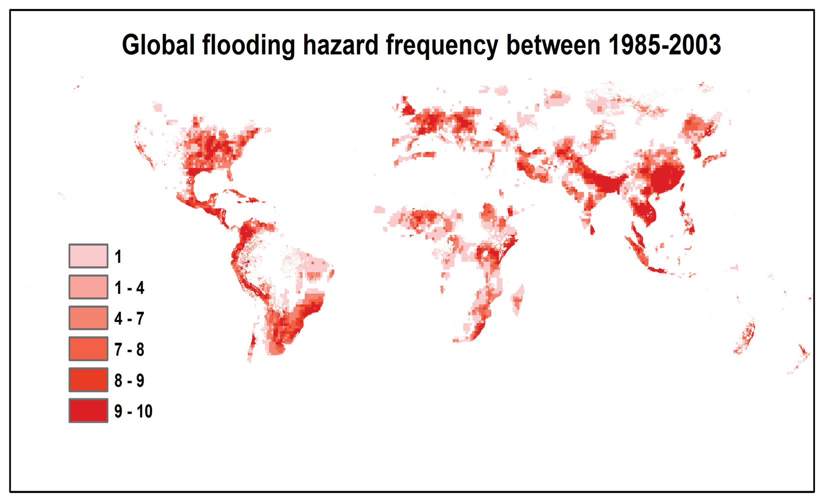



**Figure 1.** World Atlas of Large Flood Events (2.5*2.5 minutes grid )

## Study area

The Atchafalaya-Wax Lake Delta system is the new prograding lobe of the Mississippi River Delta system (Figure 2). It has been selected for this study for the following reasons: 1) the delta formed within the last 70 years, so modern data are abundant; 2) it is prograding very fast without significant elevation and is therfore vulnerable to coastal storms; 3) the delta is currently exposed to several patterns of flooding, due to e.g. tropical or winter storms, and the former can produce very high wave surges which significantly influence the delta morphology.

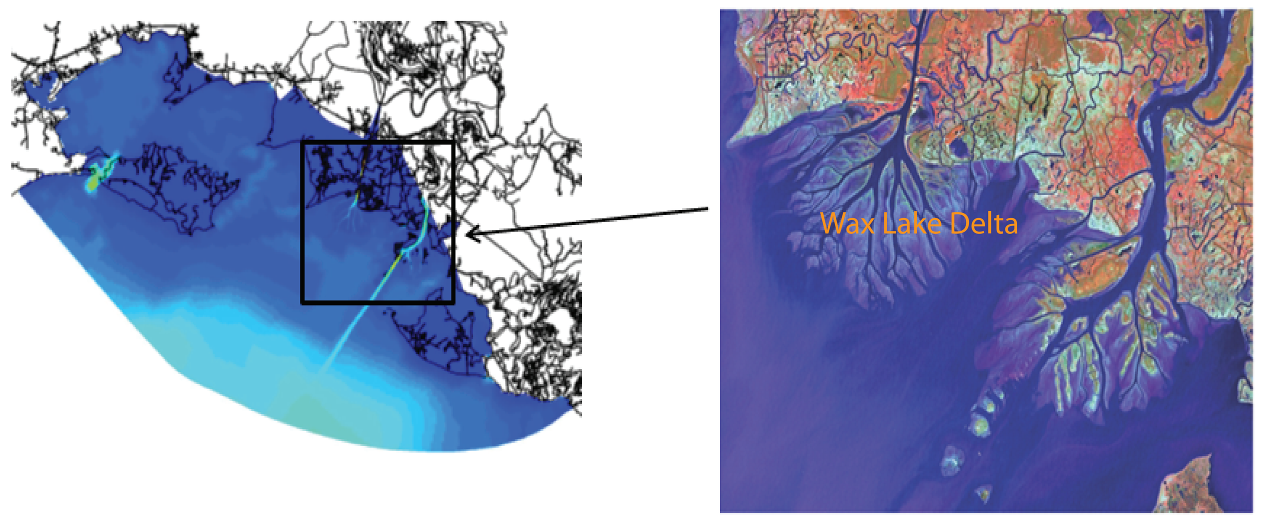
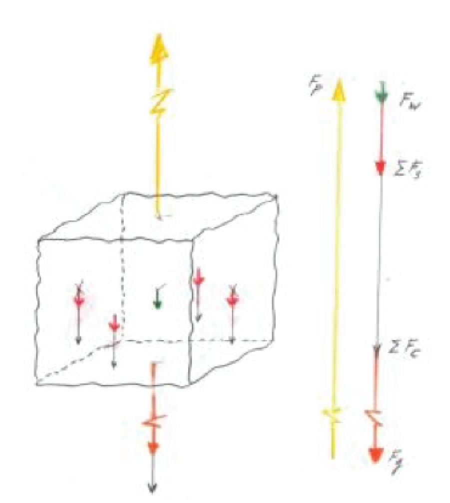



**Figure 2.** Overview (left) and detailed map (right) of Wax Lake Delta and Atchafalaya Delta.

## Methodology

For this study, Delft3D, a widely used hydrodynamic and sediment transport model (Lesser, et al., 2004), has been applied to the Wax Lake Delta in Lousiana to explore the impact of wind, waves, and vegetation during Hurricane Rita (2005). Vegetation is incorporated by increasing 2D bed roughenss, and root effects are included through adding a new root routine which will calculate the soil strength needed for root-soil aggregate to be eroded. The mechanism for the root routine is in Figure 3. In order to explore the impact of each of the different factors, five numerical experiments have been designed (see Table1).



$F_p$ = maximum lift force $\quad F_p = p_{\max} \cdot l_x l_y = p_{\max} \cdot d^2$

$F_w$ = weight due to gravity $\quad F_w = (1-n)(\rho_s - \rho_w) g \cdot l_x l_y l_z$

$F_s$ = shear force $\quad \Sigma F_s = f(\rho_s - \rho_w) g (l_x + l_y)(l_z)^2$

$F_c$ = cohesion force $\quad \Sigma F_c = (c_{grass,c} + c_{clay,c}) \cdot \{2(l_x + l_y) l_z\}$

$F_g$ = grass reinforcement $\quad F_g = c_{clay,c} + \sigma_{roots,c}(z = l) \cdot l_x l_y$

Where:

$p_{\max}$ = maximum under pressure at the surface

$n$ = porosity =0.4

$\rho_s$ = Density of the soil

$f$ = friction factor ( $\tan\varphi$ )

**Figure 3**. Forces on a soil cube (Hoffmans, et al., 2009)

| EX_name | EX1 | EX2 | EX3 | EX4 | EX5 |
|---|---|---|---|---|---|
| Settings | Tide | Tide, Wind | Tide, Wind, Waves | Tide, Wind, Waves, Veg | Tide, Wind, Waves, Veg, Roots |

**Table 1.** Numerical experiments settings

## Results

The simulation results are shown in Figures 4 and 5.

* Wind (EX2) can significantly influence water levels (up to ~2 m) and velocities (up to ~1 m/s) (Figures 4A and 4E) at coastal shallow water areas. However, winds have minor impact on sediment transport patterns (Figures 5B and 5G)

* Waves (EX3) have little effect on water levels and velocities (Figures 4B and 4F) but do cause significant sediment transport through increased bed shear stress (Figures 5C and 5H).

* Vegetation (EX4) reduces water levels, decreases flow velocities (Figures 4C and 4G) and substantially changes the sedimentation and erosion pattern in the areas surrounding the islands (Figures 5D and 5I). Wetlands receive high deposition while their adjacent channels become more eroded (Figure 5I).

* The simulation incorporating vegetation roots (EX5) shows a similar pattern to EX4 for both hydrodynamics and sedimentation/erosion (Figures 4D, 4H, 5E, 5J). Flow velocity on vegetated islands becomes less. The magnitude of deposition and erosion is more pronounced. Highly eroded areas occur in front of vegetated islands.

## Discussion

The numerical experiments for Wax Lake Delta indicate that deltaic hydrodynamics and morphological changes are determined by the interaction of several factors. Wind is critical in producing high water levels and velocities, while waves increase bed shear stress and activate sediment transport. Vegetation, modeled as 2D bed roughness, can reduce erosion on the weltands. At the same time, the surrounding channels erode more.

Roots help increase soil strength, which decreases erosion, while intensifing erosion in the surrounding channels. When the storm magnitude increases, aggregate and rootball erosion can occur, which results in more erosion on the wetlands. The role of vegetation during storms is complicated, and more studies are needed to determine the best applications of vegetation as protection against coastal erosion.

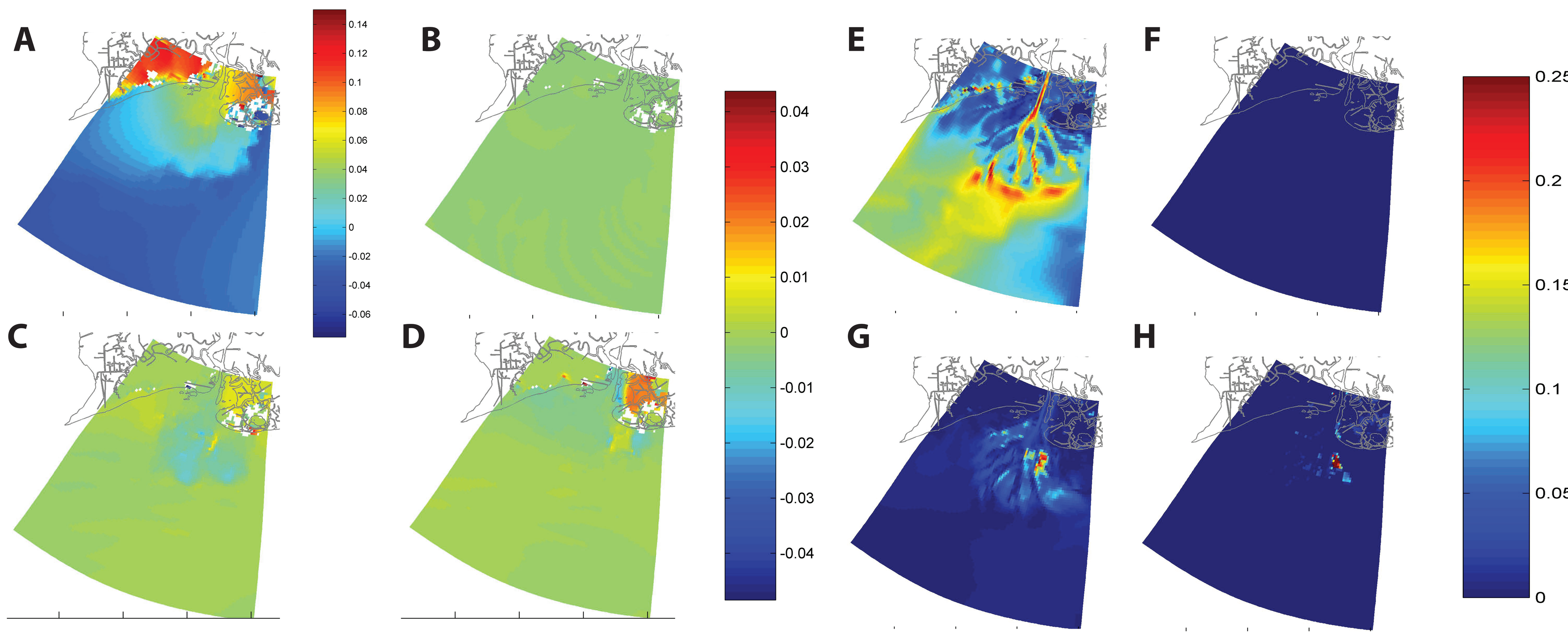



**Figure 4.** Impact of wind, waves, vegetation, and vegetation roots on water level (A~D) and flow velocity (E~H) in the deltaic area. (A),(E): (EX2-EX1); (B), (F): (EX3-EX2); (C), (G): (EX4-EX3); (D), (H) :(EX5-EX4) (unit: m/s)

## References

* Howes, N.C., FitzGerald, M.D., Hughes, Z.J., Georgiou, L.Y., Kulp, M.A., Miner, M.D., Smith, J.M., Barras, J.A., 2010. Hurricane-induced failure of low salinity wetlands. PNAS, 107(32): 14014~14019.
* Lesser, G.R., Roelvink, J.A., Van Kester, J.A.T.M., Stelling, G.S., 2004. Development and validation of a three-dimensional morphological model. Coastal Engeering, 51(8-9):883~915.
* Pollen-Bankhead, N., Simon, A., 2008. Enhanced application of root-reinforcement algorithms for bank-stability modeling. Earth Surface Processes and Landforms, 34: 471~480.
* Syvitski, J.P.M., Saito, Y., 2007. Morphodynamics of deltas under the influence of humans. Global and Planetary Change, 57:261~282.
* Temmerman, S., Bouma, T.J., Govers, G., Wang, Z.B., De Vries, M.B., Herman, P.M.J., 2005. Impact of vegetation on flow routing and sedimentation patterns: Three dimensional modeling for a tidal marsh, Journal of Geophysical Research, 110, F04019.

## Acknowledgements

Award #1135427

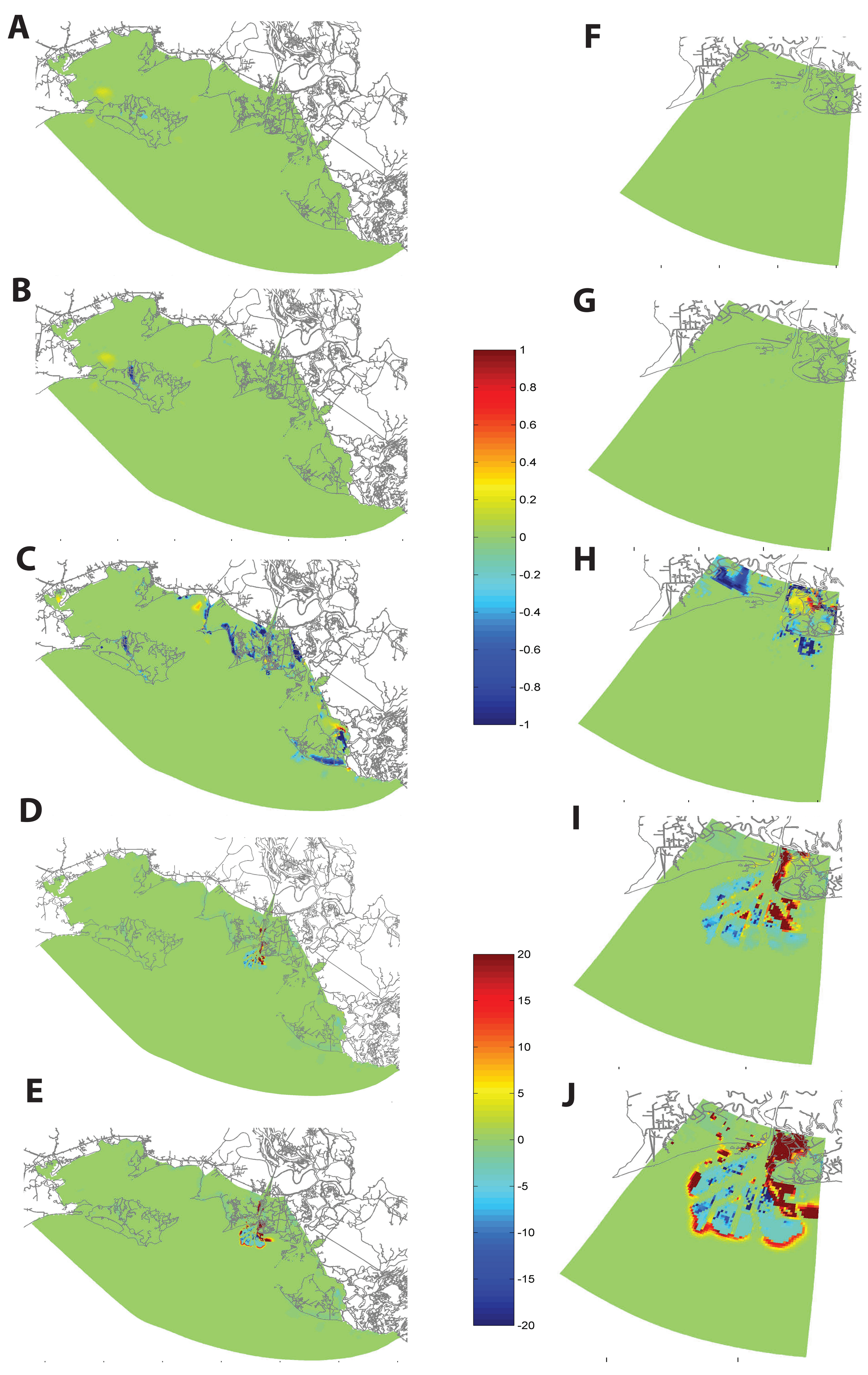



**Figure 5.** Impact of wind, waves, vegetation, and vegetation roots on sedimentation and erosion patterns for the simulated area (A, B, C, D, E) and detailed map for the deltaic area (F, G, H, I, J) (unit: mm). (A) & (F): EX1; (B) & (G): EX2; (C) & (H): EX3; (D) & (I): EX4; (E) & (J): EX5