



Hurricane Impacts on Mangrove Forests in Florida Coastal Everglades (FCE): The Importance of Sediment Deposition in the Biogeochemistry and Fertility of Mangrove Soils

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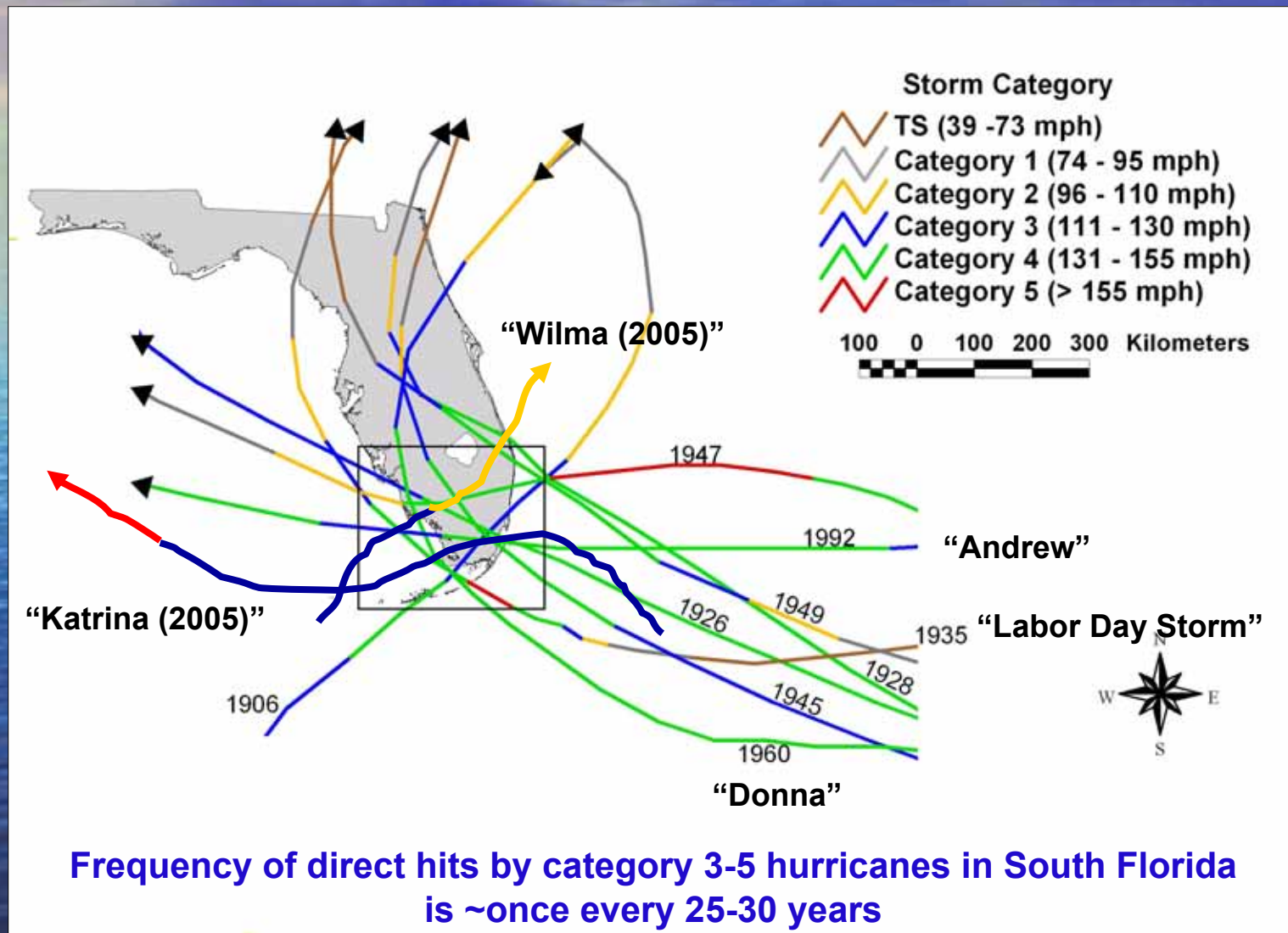
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Hurricane Impacts on Mangrove Forests

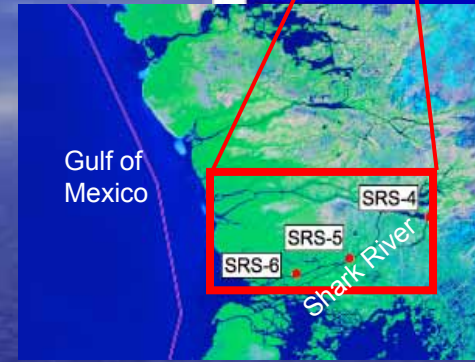
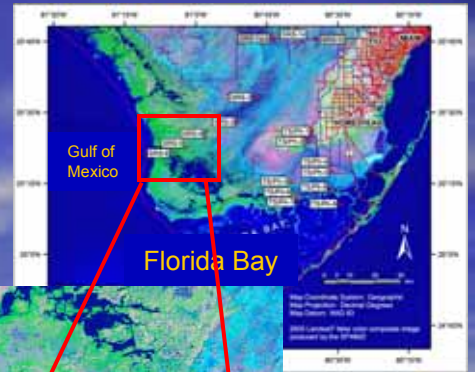
- Hurricanes are frequent large-scale pulsing events that shape community structure and ecosystem function of tropical and subtropical forest ecosystems.
- Mangrove forests are particularly susceptible to damage because of their position in the intertidal zone.
- Hurricane effects change:
 - Physical environment of the forest
 - Vegetation structure and species composition
 - Succession
 - Nutrient cycling
 - Soil accretion
 - Animal population dynamics
- Neotropical mangrove forests are highly resilient systems to natural disturbances.

High Recurrence of Tropical Storms and Hurricanes in South Florida

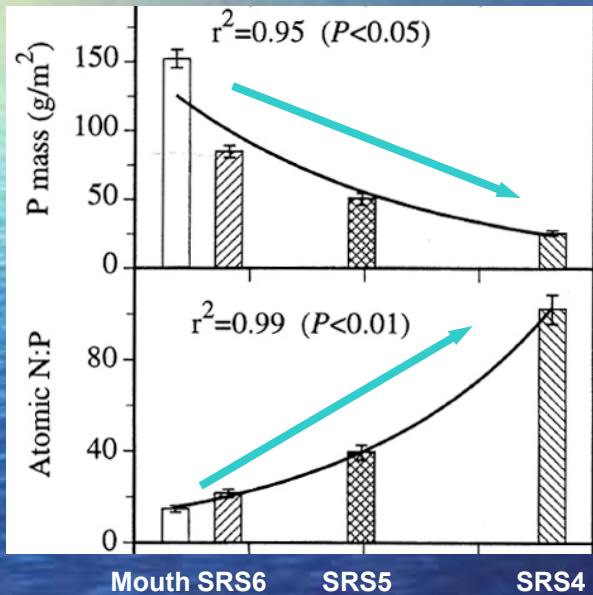


Shark River, southwestern FCE

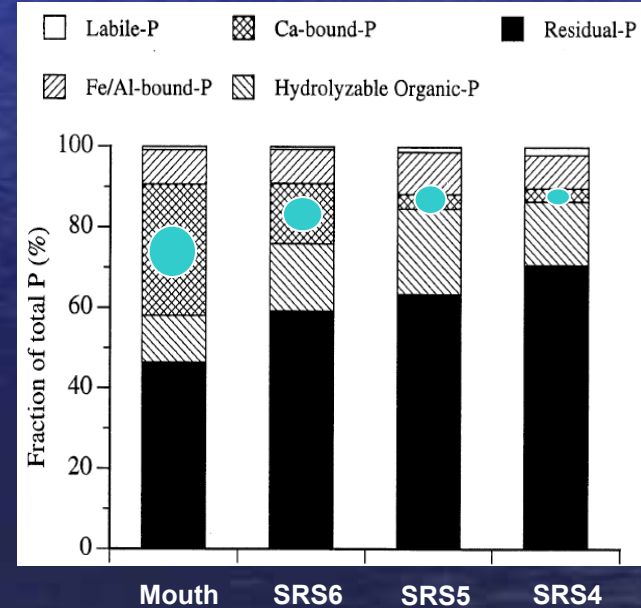
HYPOTHESIS: Marine inputs of P (Ca-bound) during storm events are a significant contribution for mangrove forest development along southwestern FCE.



Chen and Twilley (1999a)



Distance from mouth:
 SRS-4 = 18.2 km
 SRS-5 = 9.9 km
 SRS-6 = 4.1 km

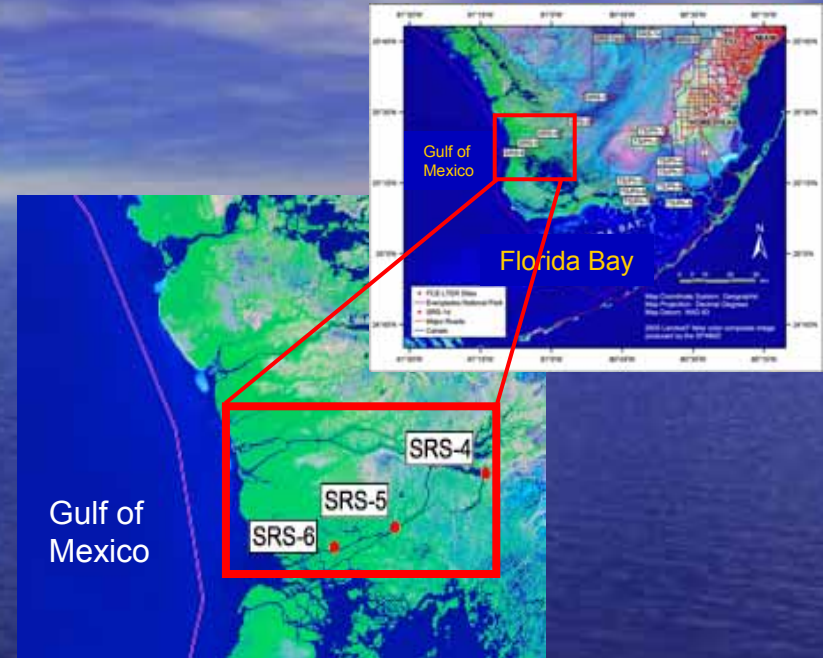
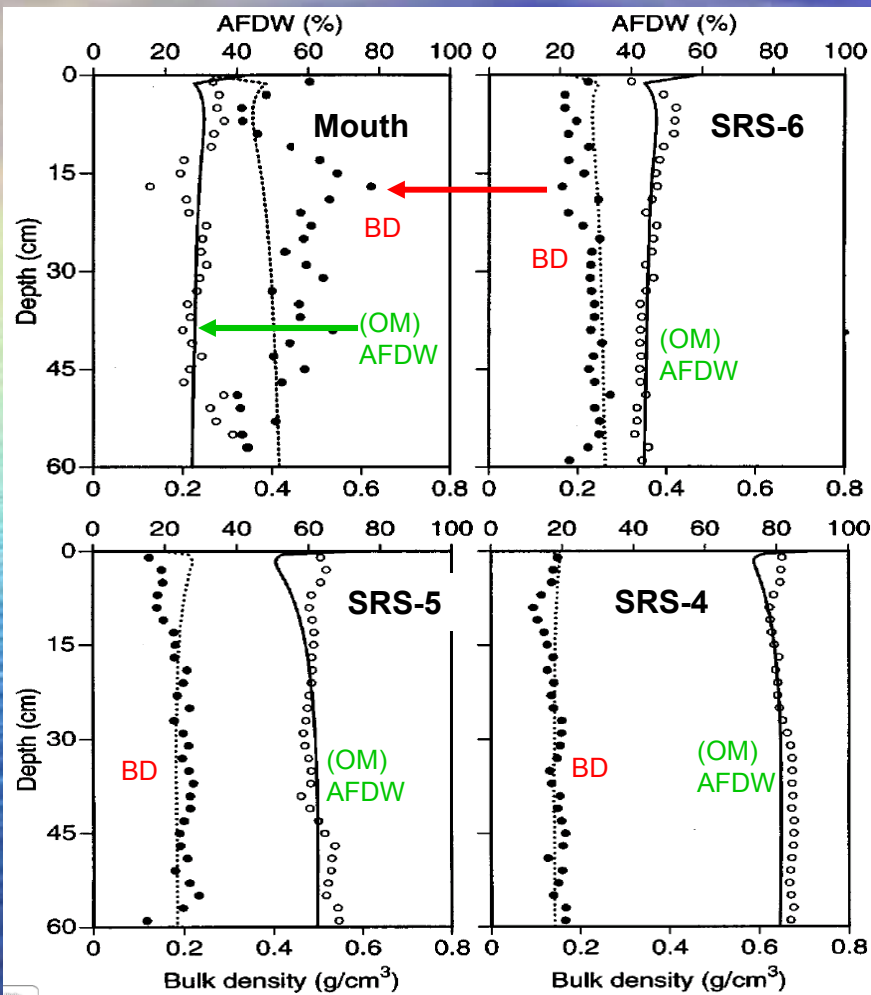


➤ P concentrations decrease with distance from the mouth of Shark River. SRS-4 is P limited - N:P > 80.

➤ Soil fertility gradient along Shark River.

➤ The Ca-bound P fraction was significantly higher in downstream sites (32%) and decrease with distance from the mouth of Shark River (SRS4: 2%).

Model Simulations Mangrove Nutrient Model (NUMAN) Shark River, Florida Coastal Everglades (FCE)



➤ Simulation profiles of bulk density (BD) and OM content significantly fit the observed results in the field.

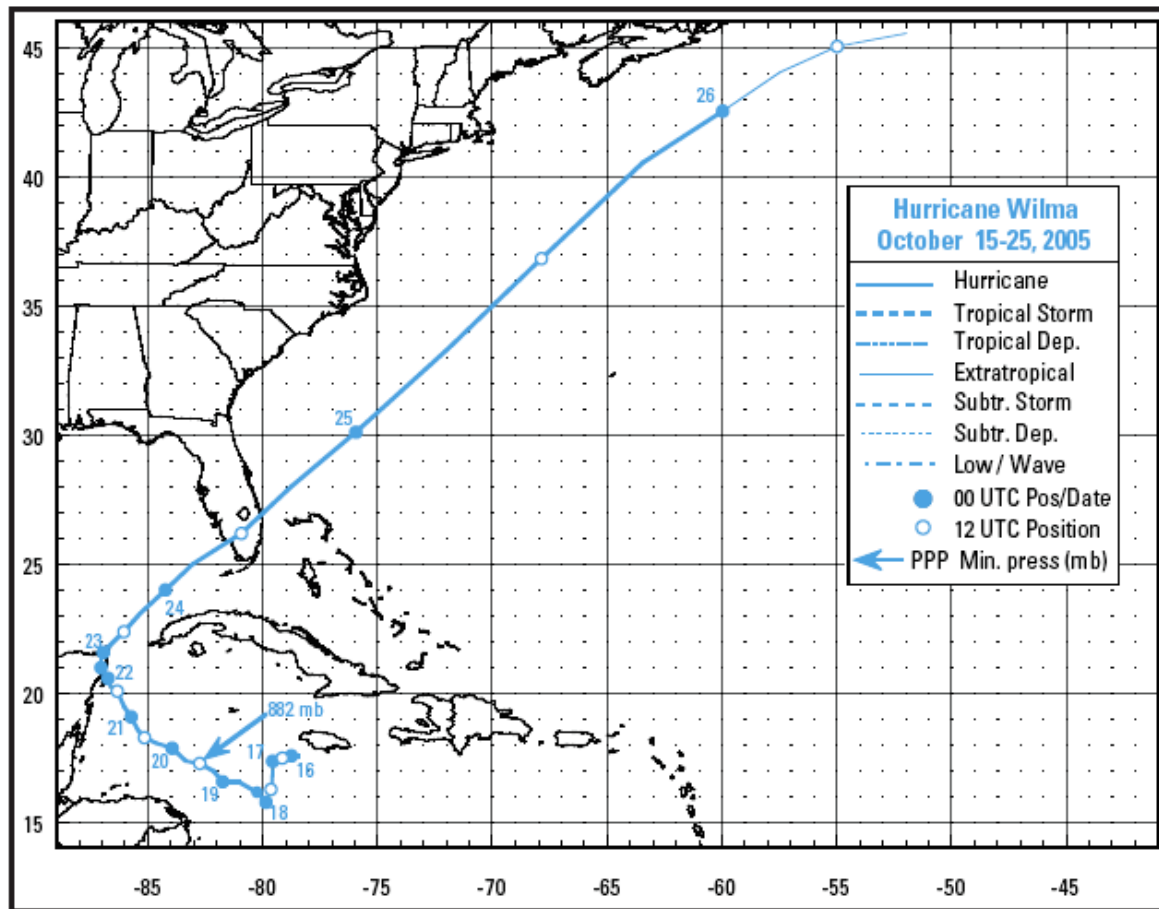
➤ Model simulations (Chen and Twilley 1999b) showed an increase in OM content and decrease in soil bulk density from downstream (mouth) to upstream (SRS-4) mangrove sites.

➤ These changes are controlled by variation in allochthonous inputs of mineral matter at the mouth of the estuary.



HYPOTHESIS TESTING

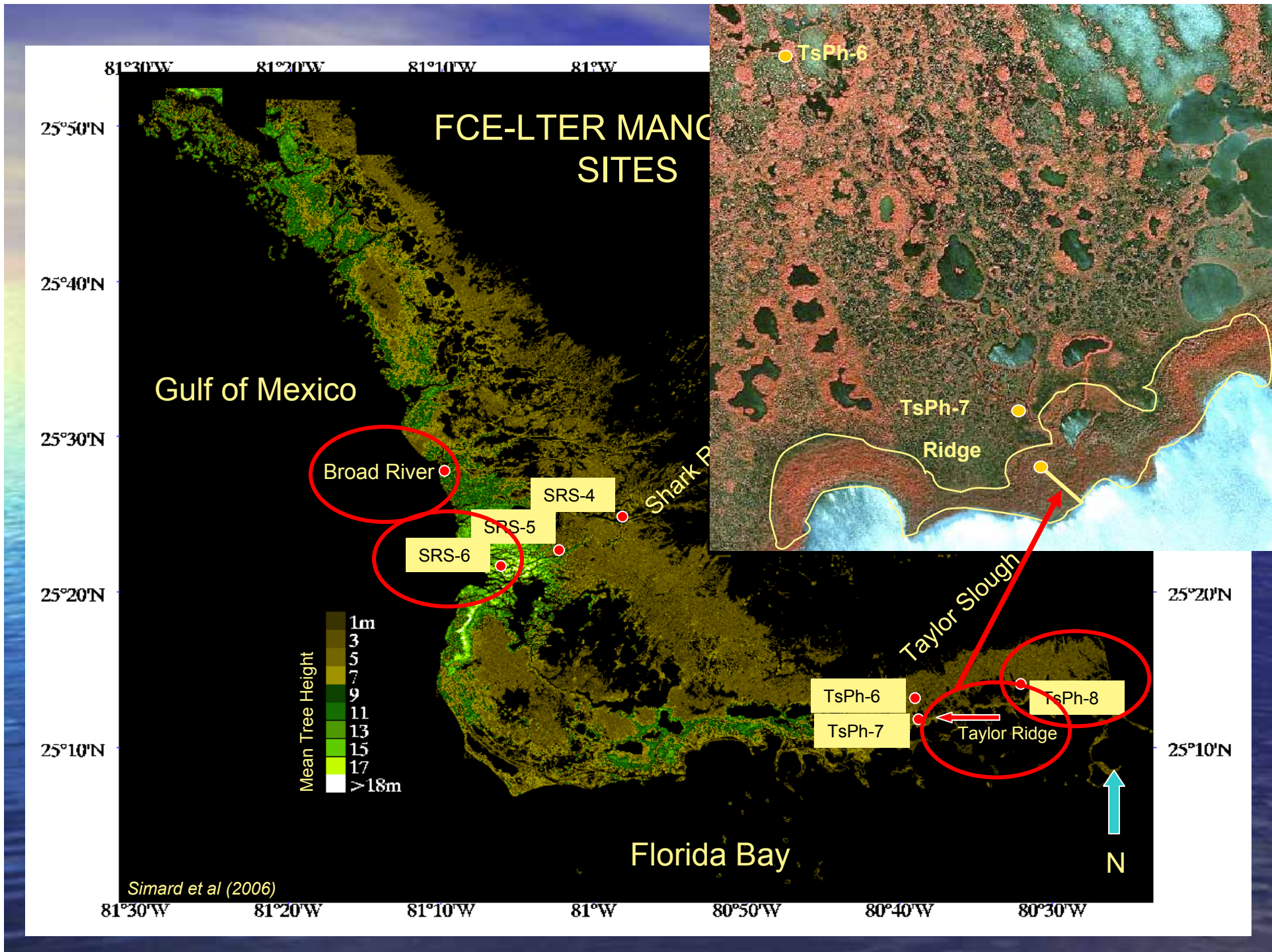
Track of Hurricane Wilma - October 2005



- Wilma became a tropical storm on October 17, 2005.
- Wilma made landfall in southwestern Florida on October 24, 2005 as a category 3.
- It was the strongest Atlantic tropical cyclone on record with a minimum pressure of 882 mb

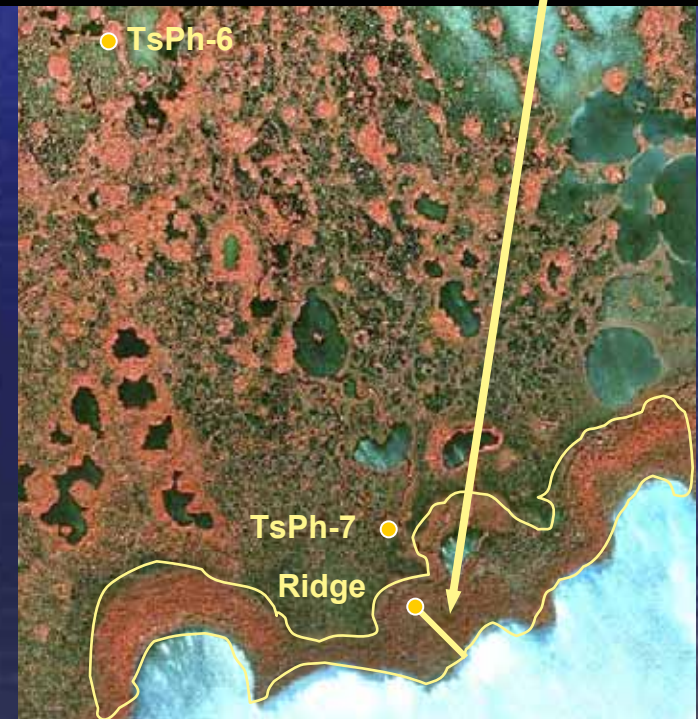
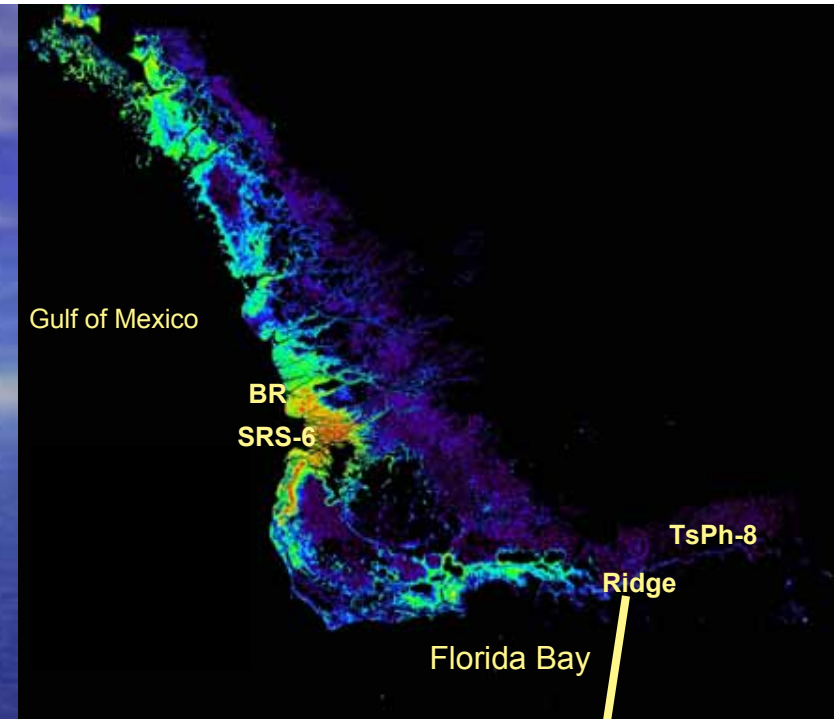
Research Questions

- What are the sediment characteristics, distribution and thickness of the sediment deposited by Hurricane Wilma in FCE mangrove forests?
- What are the nutrient inputs (total C, N, and P) from hurricane sediments to the nutrient pools in mangrove soils?
- What are the inorganic and organic pools of P in the storm deposits, and how these pools differ from mangrove soils?
- What is the role of hurricane sediment deposition in regulating soil fertility, nutrient burial, and vertical accretion in mangroves?



Methods

- Transects perpendicular to the edge of the water:
 - SRS-6 (700 m in length)
 - Broad River (BR - 700 m)
 - Taylor Buttonwood Ridge (150 m)
- Transects in SRS-6 and BR were previously established in May 2004 (Simard et al. 2006). Sampling was conducted on Dec 2005. The Ridge transect was established and sampled in October 2006.
- Plots:
 - TsPh8 (Joe Bay, Florida Bay): Two permanent vegetation plots (20 x 20 m) previously established in December 2000. Sampling carried out in Oct 2006.
- All three transects and TsPh-8 plots were sampled to assess hurricane impacts on forest structure and biogeochemistry of mangroves.
- Duplicate sediment cores were collected at different intervals along each transect and at TsPh8 plots.
- Sediment cores were collected with a piston corer (2.5 cm diameter x 15 cm length), sectioned into two layers, upper (hurricane deposit) and lower (soils - top 10 cm) layers.



High FCE Mangrove Forests

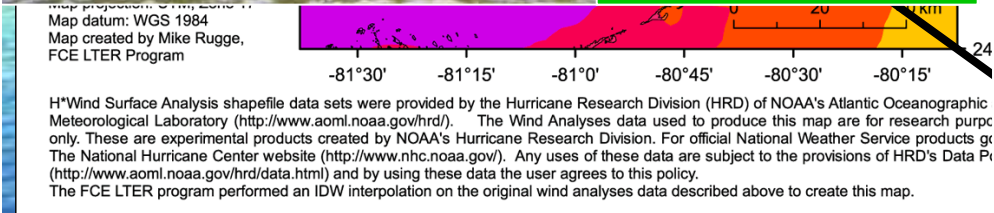


SRS-6 before Wilma



SRS5

Catastrophic damage to the forest canopy

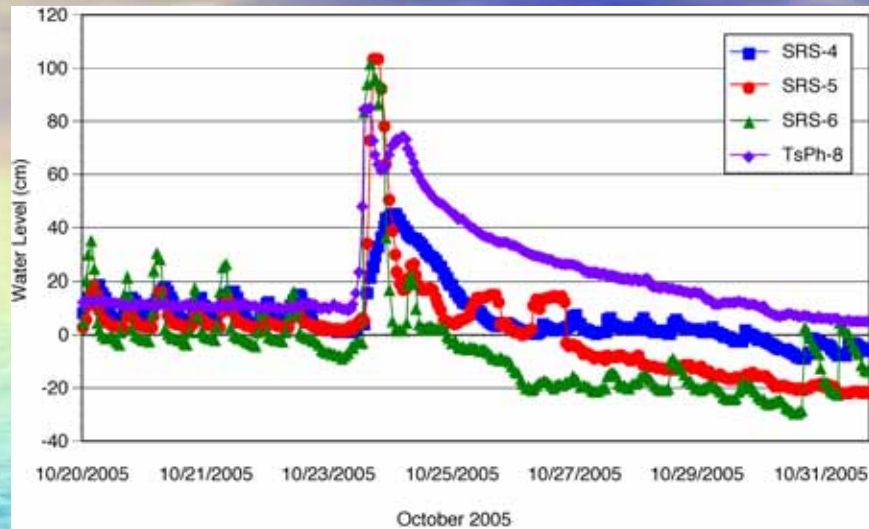


Mangrove Forest in SRS-6 before Wilma



SRS-6 after Wilma

Water Levels during Storm Surge in FCE Mangrove sites



- Water levels were higher downstream Shark River (SRS-6) and decreased upstream (SRS-4).
- Storm surge reached levels of 3-4 m above normal levels as indicated by deposition on CO₂ tower equipment.
- Storm surge deposited inorganic sediments as it moved inland.



Water level recorder in SRS-6 (50 m inland)

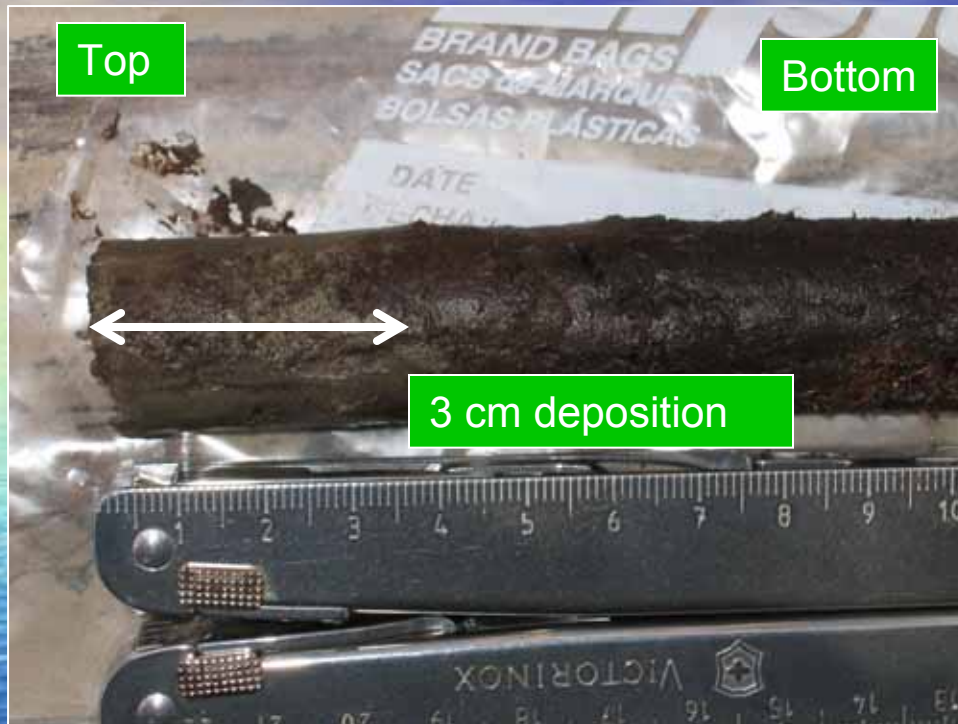


CO₂ tower in SRS-6 (100 m inland) **before** Wilma.



CO₂ tower in SRS-6 (100 m inland) **after** Wilma (see deposition).

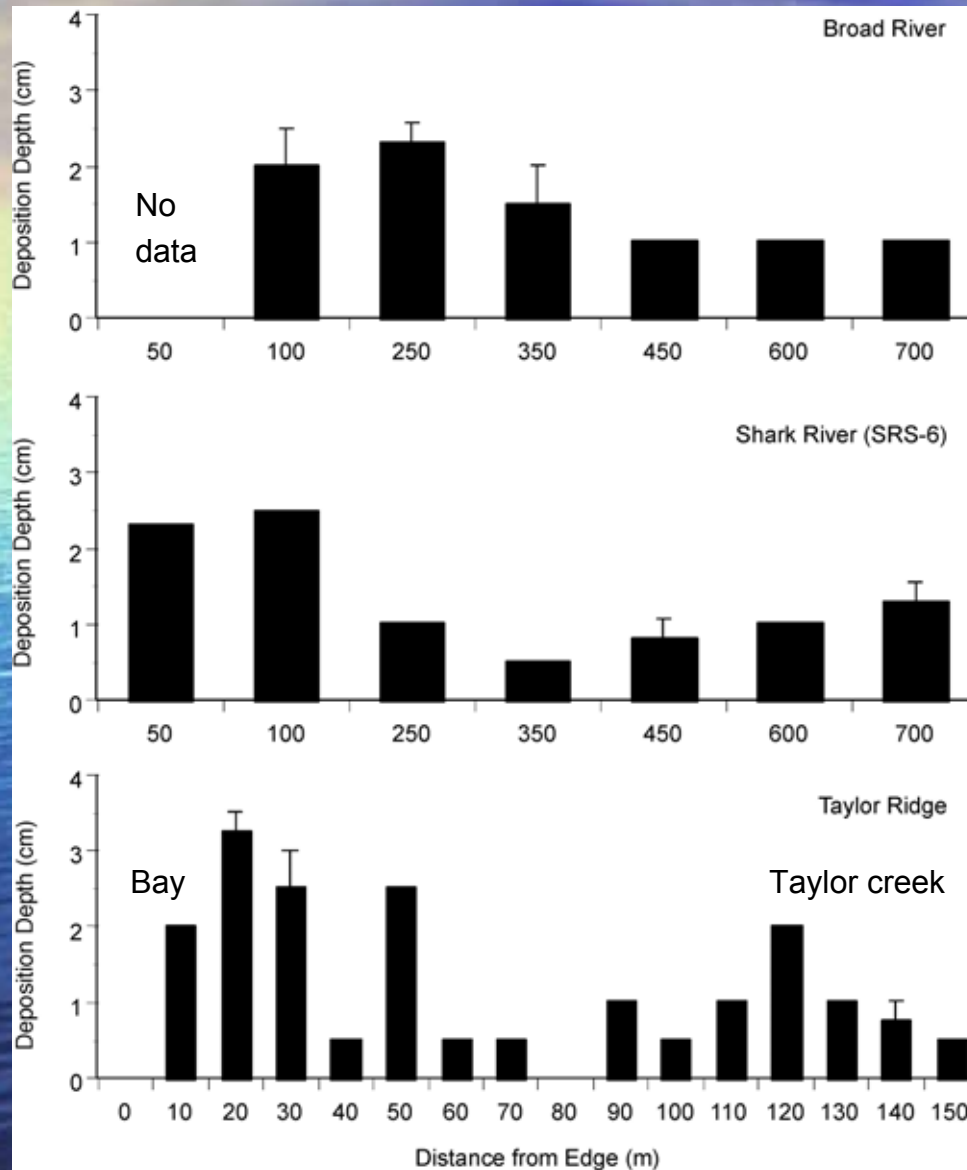
Hurricane Deposition on FCE Mangrove Forests



Large-scale sediment deposition (1-4 cm) in mangrove forests of FCE.

Along Shark River, deposition was maximal close to the GOM (mouth of Shark and SRS-6) and decrease upstream. No deposition was evident in SRS-4 (18.2 km from GOM).

Hurricane Deposition Depth (cm)



➤ Deposition was variable along each transect.

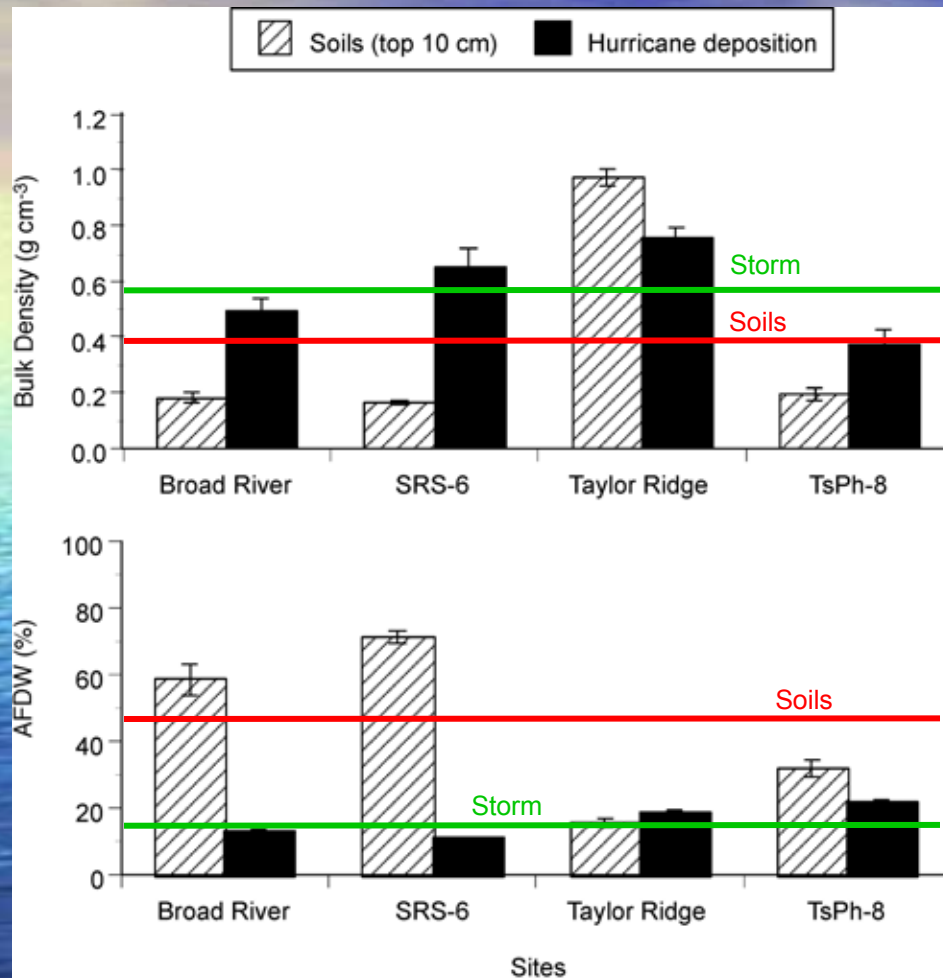
➤ The thickness of the sediment deposited decreased with distance along each transect.

➤ In BR and SRS-6, deposition was on average 2.5 cm in the first section of the transect and decreased to 1 cm at the end.

➤ In the Ridge, deposition was about 2.5 cm in the Bay side (first 50 m) of the transect and decreased to 1.0-1.5 cm at the end.

➤ Deposition on TsPh-8 was on average 4.5 cm.

Bulk Density and Organic Matter (AFDW%)



➤ Bulk density of hurricane deposits was consistently higher in all sites compared to soils (top 10 cm), except in the Ridge.

➤ The Ridge is a depositional berm that isolates scrub mangrove forests along Taylor River from the direct influence of Florida Bay and the Gulf of Mexico.

➤ Only during hurricane events, the Ridge is inundated and bay sediments are deposited in the Ridge (Davis et al. 2004).

➤ Mean BD:

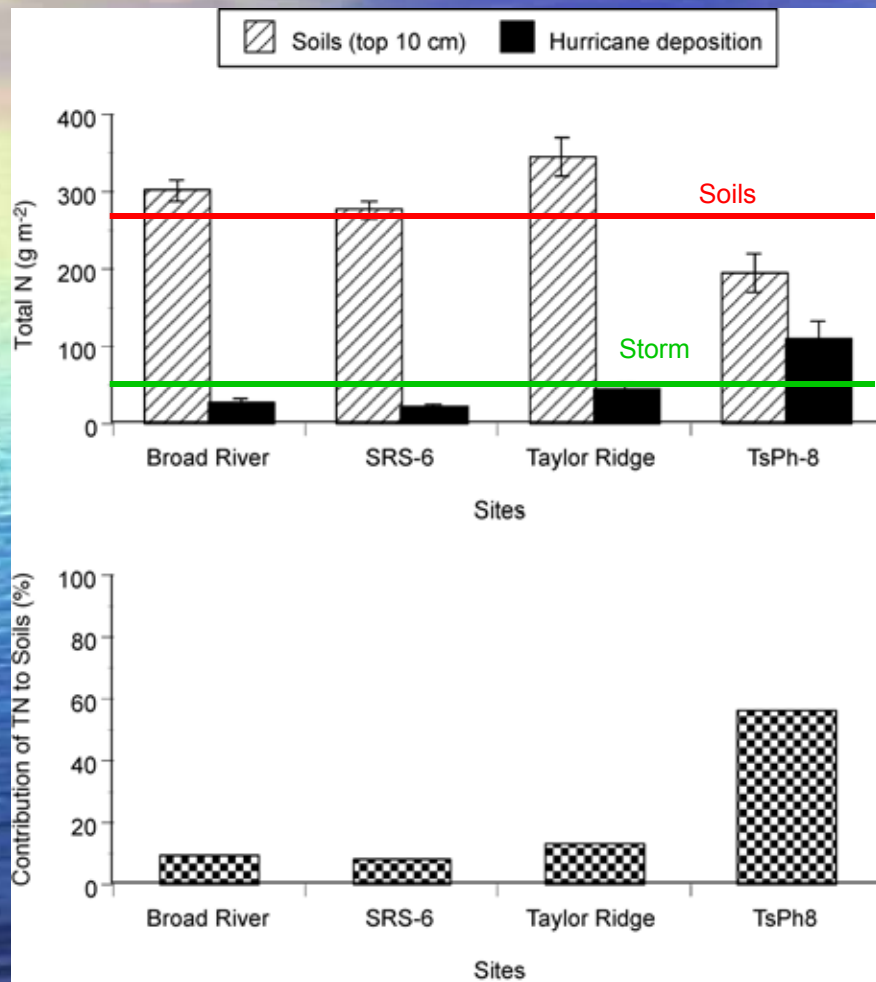
- Soils (top 10 cm): $0.38 \pm 0.2 \text{ g cm}^{-3}$
- Deposition (event): $0.57 \pm 0.1 \text{ g m}^{-3}$

➤ Mean OM content (%):

- Soils (top 10 cm): $44 \pm 13\%$
- Deposition (event): $16 \pm 3\%$

➤ The higher bulk density and lower organic matter content of hurricane deposits relative to soils (top 10 cm), reflect the mineral inputs of hurricane lenses.

Nutrient Inputs (TN) from Hurricane Deposits and Contribution to Mangrove Soils



➤ TN concentrations were consistently higher in the soils (top 10 cm) compared to hurricane deposits in all sites.

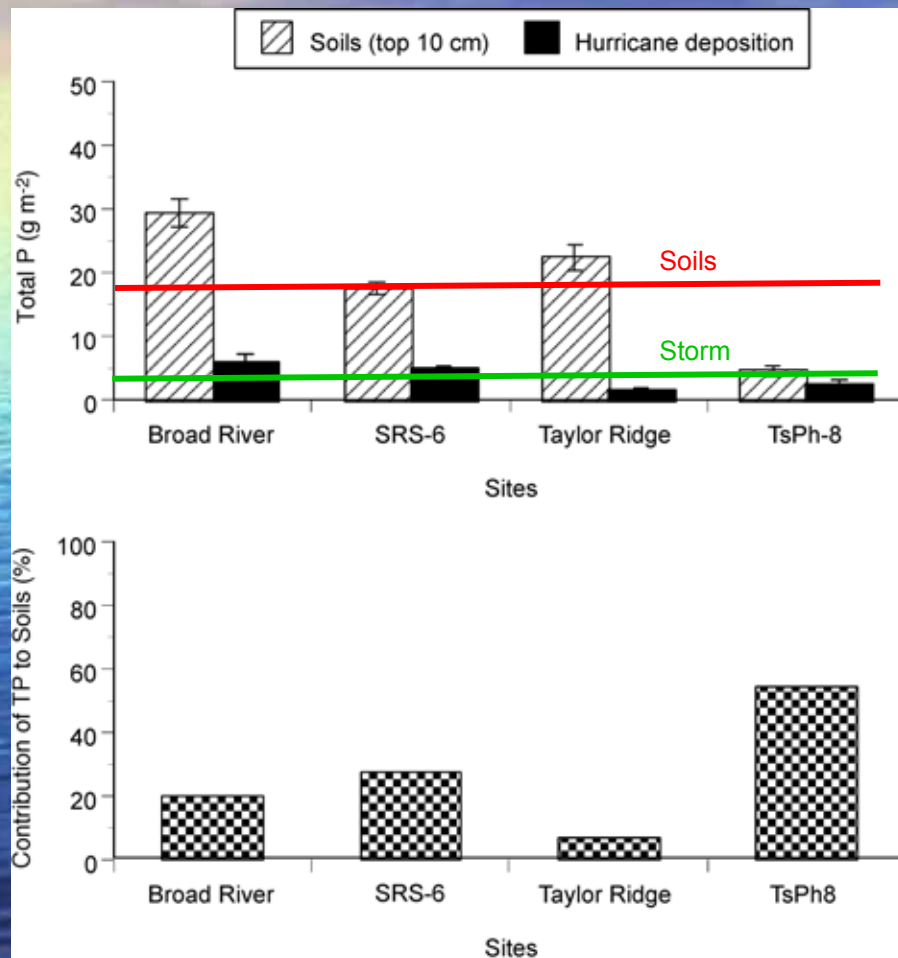
➤ Mean TN:

- Soils (top 10 cm): $279.1 \pm 32 \text{ g m}^{-2}$
- Deposition (event): $50.1 \pm 20 \text{ g m}^{-2}$

➤ The Ridge had the highest TN concentration of hurricane deposits.

➤ The contribution of TN from hurricane deposits to mangrove soils ranged from 8% (SRS-6) to 56% (TsPh-8).

Nutrient Inputs (TP) from Hurricane Deposits and Contribution to Mangrove Soils



➤ TP concentrations were consistently higher in the soils (top 10 cm) compared to hurricane deposits in all sites.

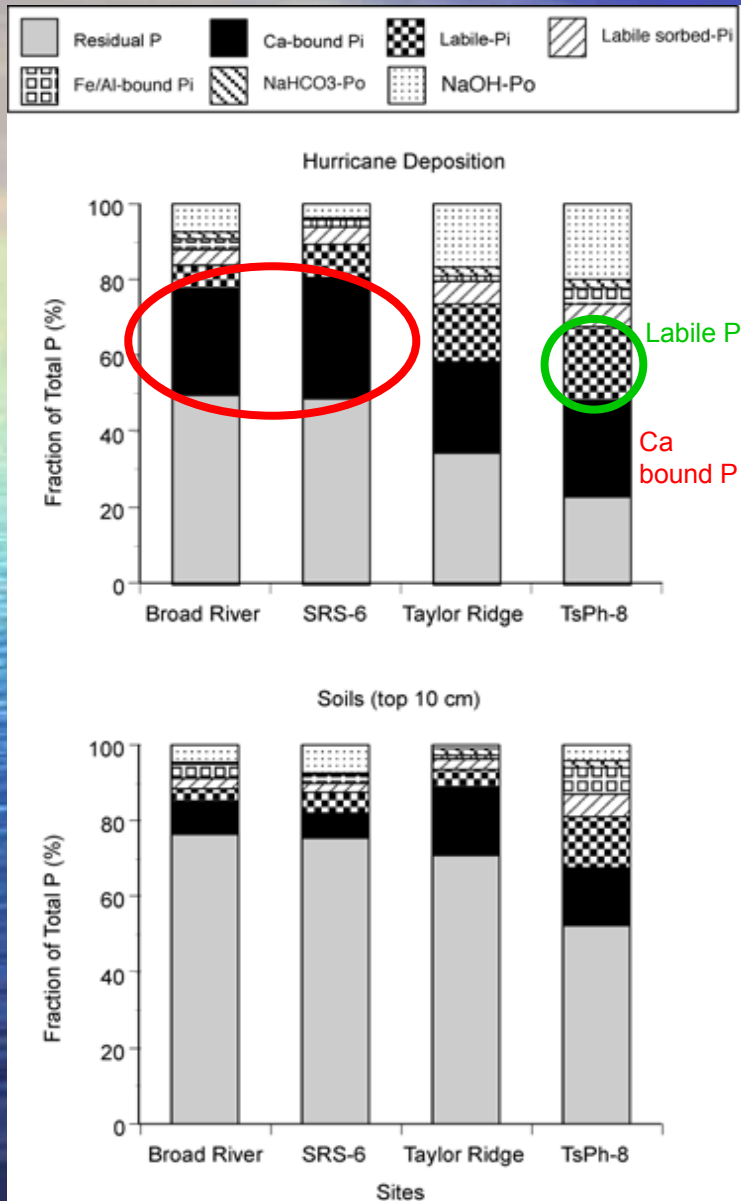
➤ Mean TP:

- Soils (top 10 cm): $18.3 \pm 5.2 \text{ g m}^{-2}$
- Deposition (event): $3.6 \pm 1.0 \text{ g m}^{-2}$

➤ BR had the highest TP concentration in both the soils (top 10 cm) and hurricane deposits.

➤ The contribution of TP from hurricane deposits to mangrove soils ranged from 7% (Ridge) to 55% (TsPh-8).

Inorganic and Organic P Pools



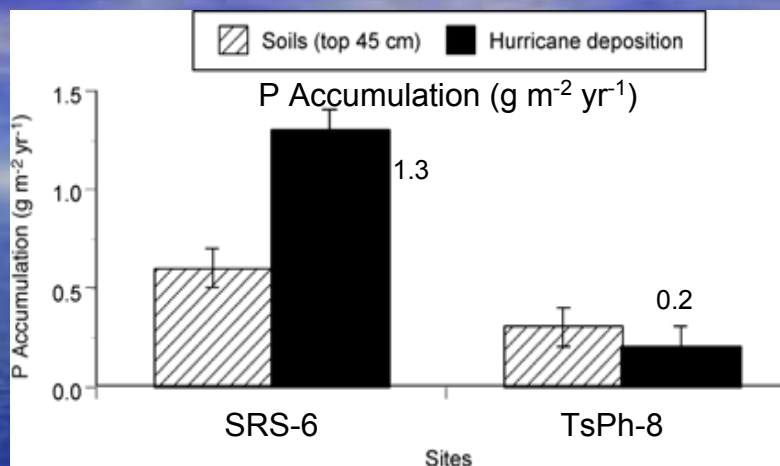
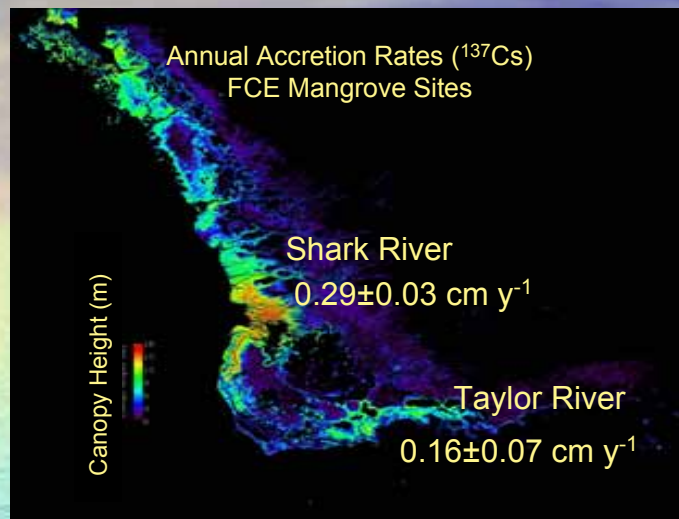
➤ The Ca-bound P fraction was significantly the largest inorganic P fraction of hurricane deposits in all sites, comprising 24% (Ridge) to 32% (SRS-6) of total P.

➤ The labile inorganic P fraction was the second largest pool, and accounted for 6% (BR) to 20% (TsPh-8) of total P.

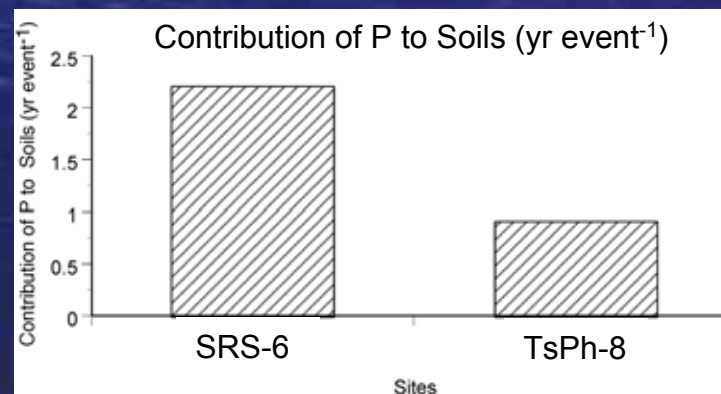
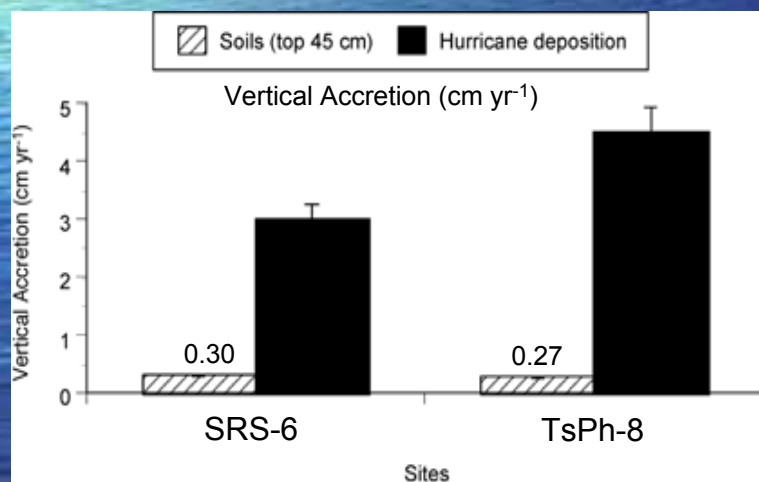
➤ Similar results were observed in the top 10 cm of soils; however, the contribution of the Ca-bound P fraction was smaller ranging from 6% (SRS-6) to 18% (Ridge).

➤ The contribution of the labile P fraction ranged from 3-13% (BR and TsPh-8, respectively).

Contribution of Hurricane Deposition to Vertical Accretion and P Accumulation Rates



- P accumulation Deposition: 0.2 to $1.3 \text{ g m}^{-2} \text{ event}^{-1}$.
- P accumulation Soils top 45 cm: 0.3 to $0.6 \text{ g m}^{-2} \text{ yr}^{-1}$.



Ratio Thickness:Annual Accretion

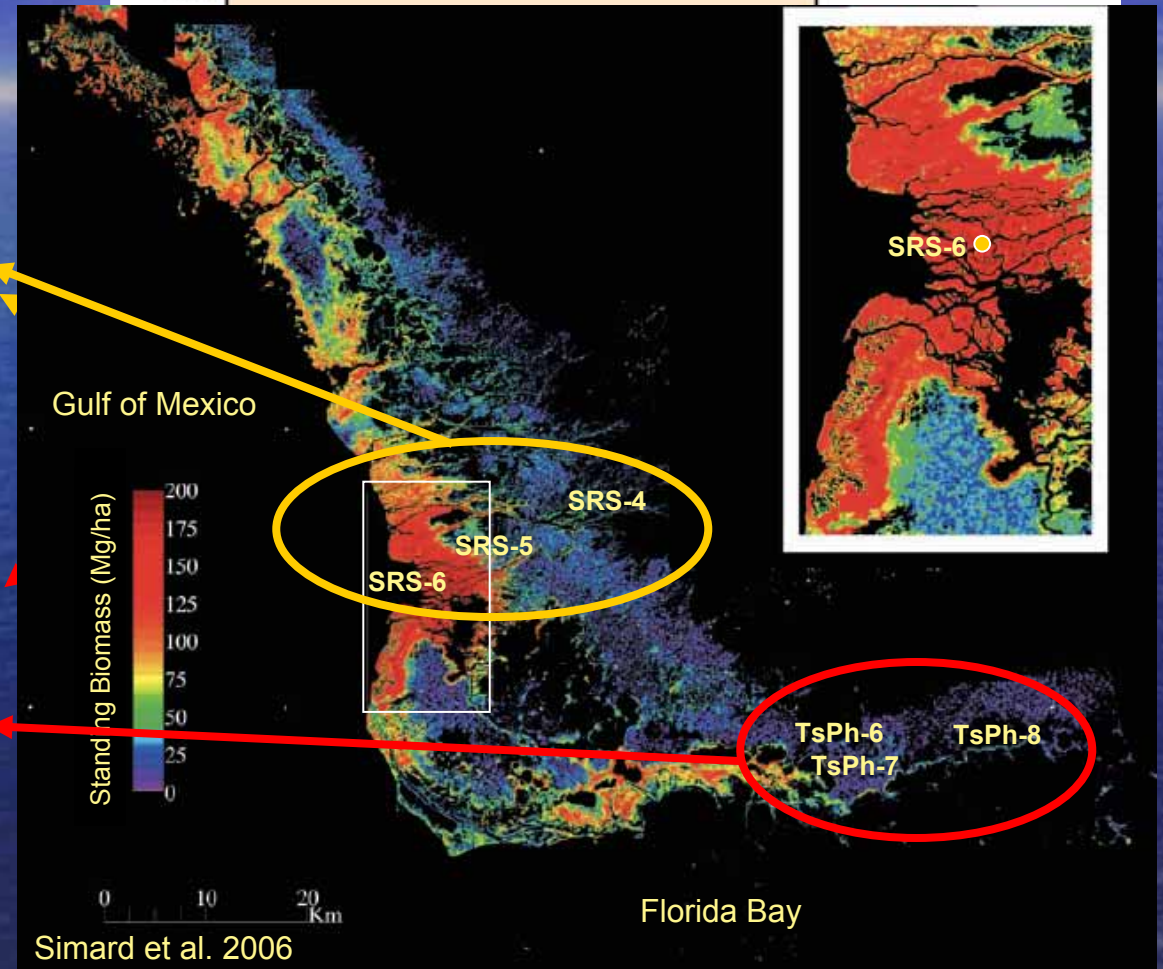
- SRS-6 = 10 yr event^{-1}
- TsPh-8 = 17 yr event^{-1}

Accumulation of P from hurricane deposits was equivalent to **0.9 (TsPh-8) and 2.2 (SRS-6) yr event^{-1}** the average annual soil P accumulation.

Landscape Patterns of Forest Structure and ANPP are Related to P Fertility Gradients in the FCE Mangroves

Basal area of Mangrove Forests relative to Total Phosphorous

50



SRS6 SRS5 SRS4 TsPh8 TsPh7 TsPh6

Site

Castaneda et al. Unpublished results

Conclusions

- Sediment deposition was one of the major hurricane impacts on mangrove forests of FCE, indicating the strong effect of these pulsing events in the dynamic of coastal wetlands.
- Hurricane deposition during one single event was approximately one order of magnitude greater than the average annual vertical accretion rate in mangrove forests of the Everglades.
- The higher bulk density, lower organic matter content, and higher Ca-bound P fraction of hurricane deposits compared to mangrove soils, underscore the contribution of allochthonous mineral inputs to mangrove peat dominated soils during storm events.
- Sediment deposition by Hurricane Wilma had a significant input of nutrients to mangrove soils, which could be an important factor in regulating gradients of mangrove forest structure and productivity in southwestern Everglades.