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Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

Application of lidar data to studies of coastal change hazards

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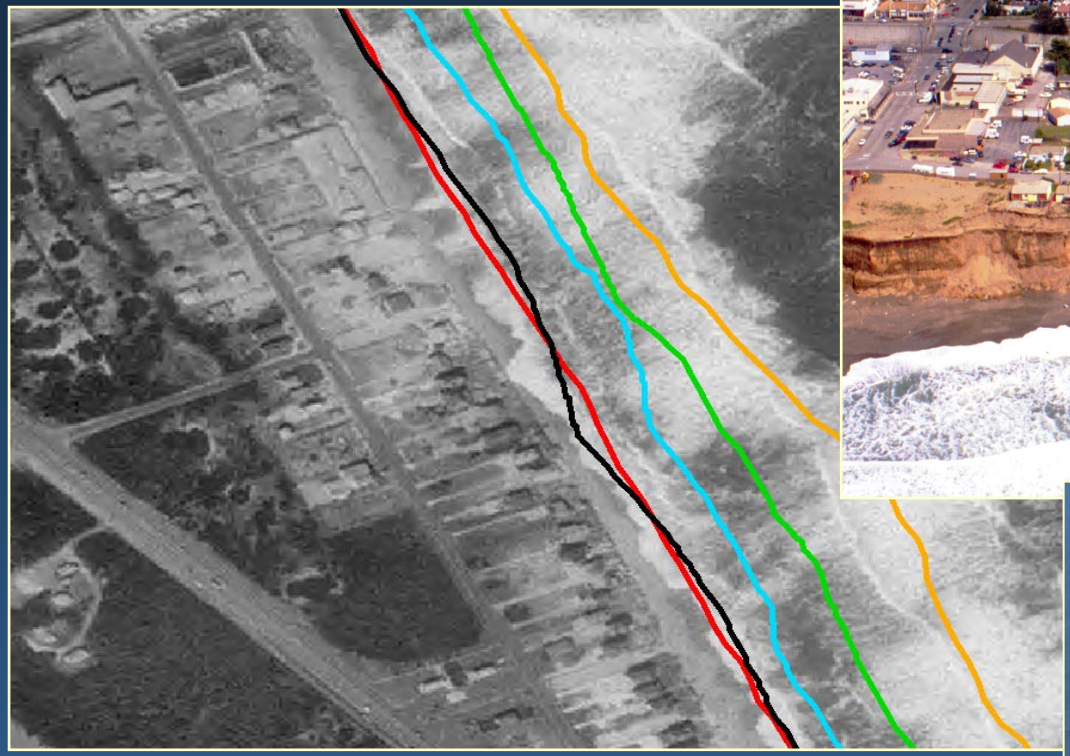
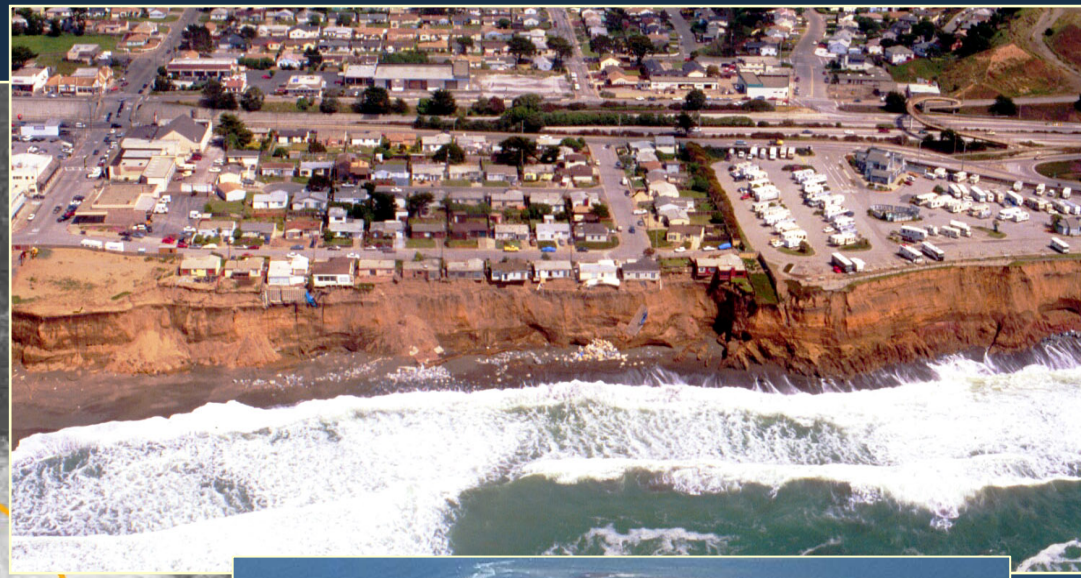
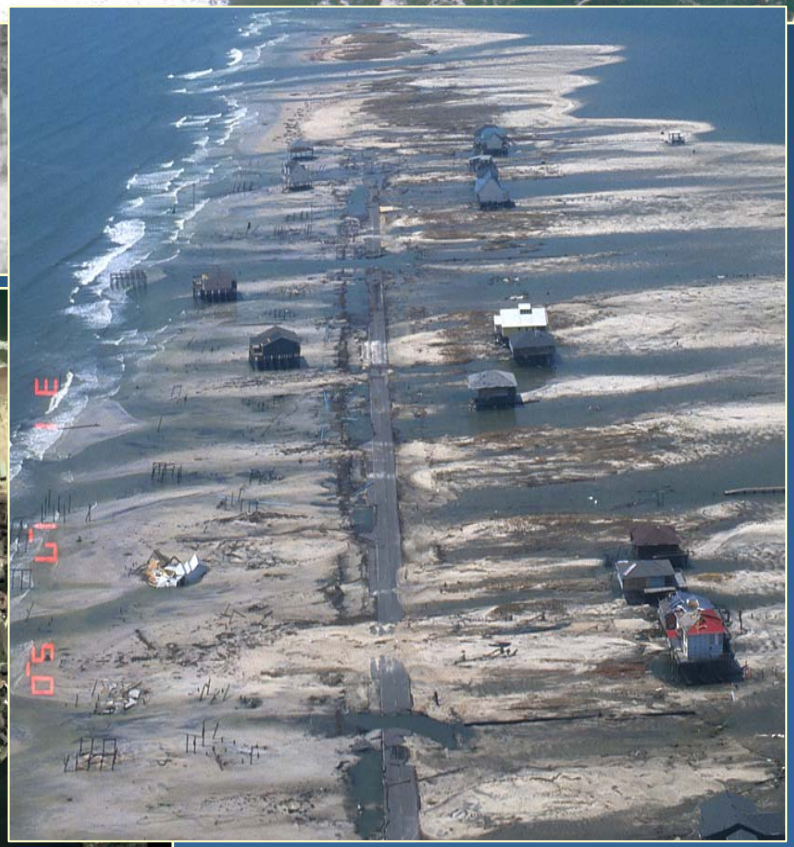
- Introduction to the National Assessment of Coastal Change Hazards
- Historical Shoreline Change
- Impacts of Extreme Storms and Hurricanes
  - –Components of storm-impact scaling model
  - –Prediction of coastal vulnerability to hurricanes
  - –Quantification of hurricane-induced coastal change
  - –Modeling processes responsible for observed change
  - –Testing hindcast accuracy of scaling model
- Conclusions

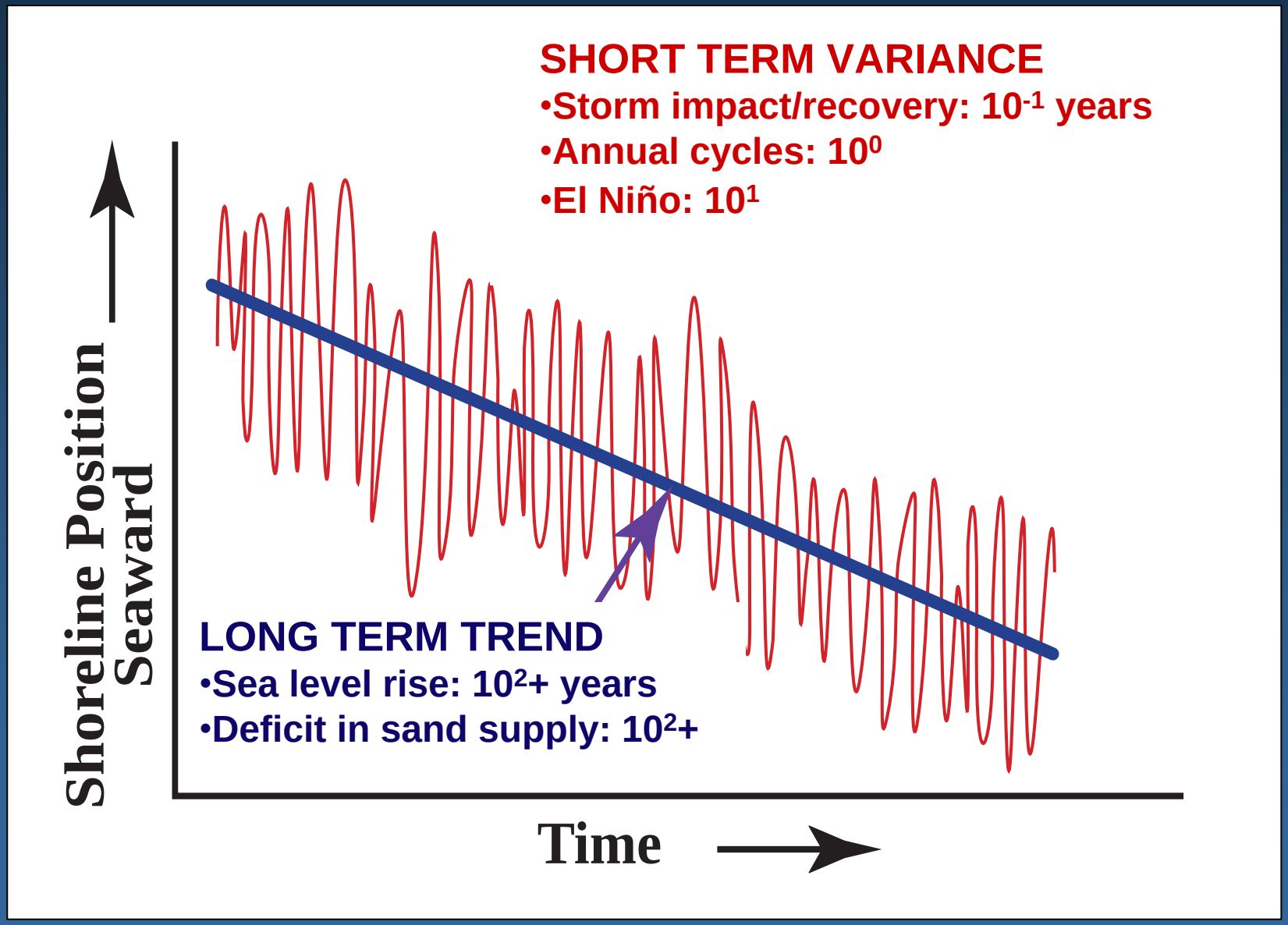
Coastal Change Hazards







Time Scales of Coastal Change



Goals of Coastal Change Studies

1. Identify and quantify coastal change trends and variability
2. Develop an understanding of the processes that control observed trends and variability
3. Develop and test process-based coastal change models
4. Define/predict the vulnerability of U.S. shorelines to coastal change hazards
5. Provide useful science and vulnerability assessment tools for decision-makers

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National Assessment of Coastal Change Hazards

- Ongoing Tasks
  - Coastal vulnerability to sea level rise
  - Long-term shoreline change
  - Impacts of severe storms & hurricanes

GOAL: To identify & quantify the vulnerability of the U.S. shorelines to coastal change hazards

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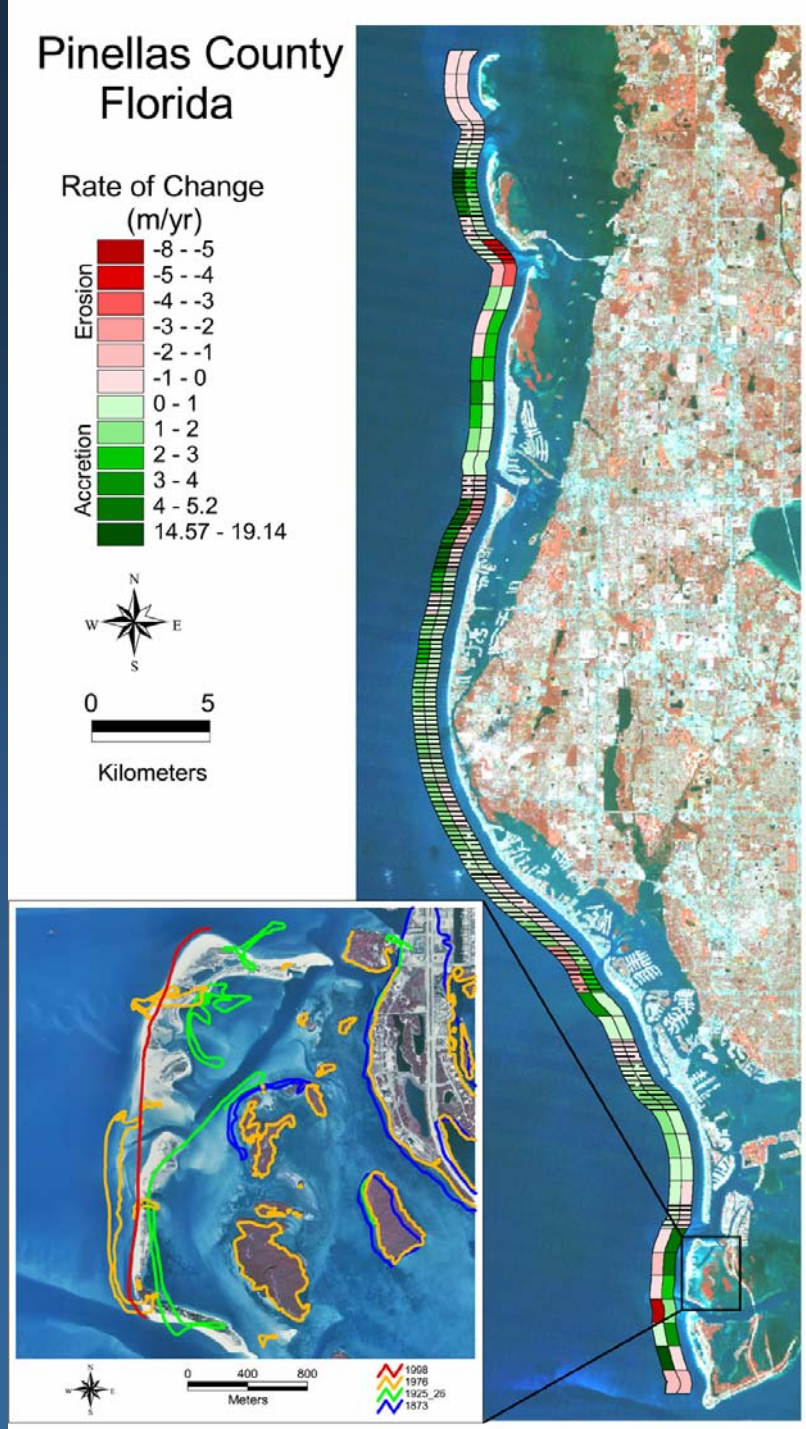
Long-term Shoreline Change

Rob Thieler

Major Goals:

- Develop a *nationwide* standardized and repeatable compilation of long-term shoreline change
- Communicate long-term vulnerability (rates, geomorphologies, etc.)
- Predict erosion hazards



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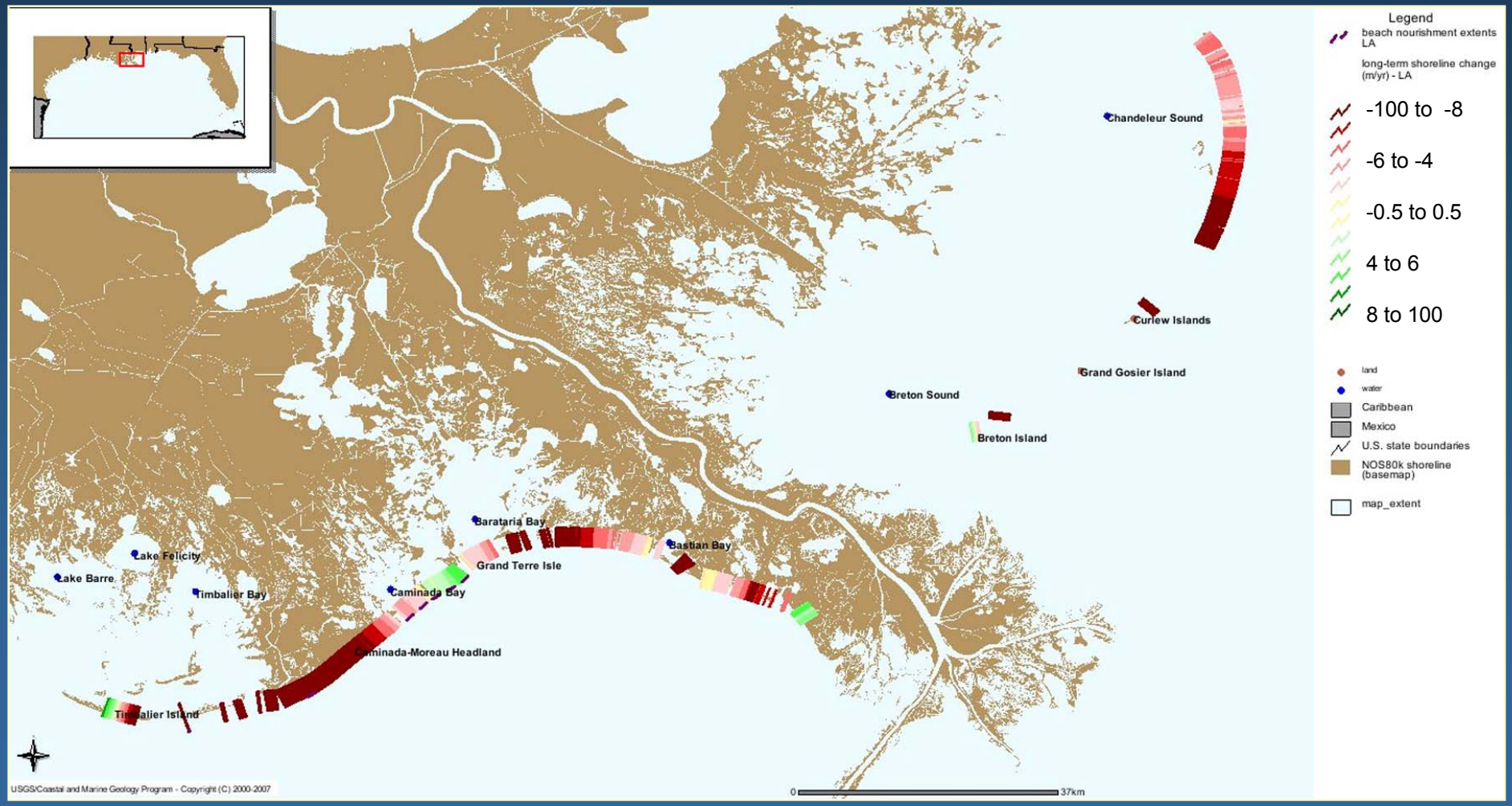
Long-term shoreline change rates (m/yr) for LA barrier islands

Data sources: Historical shorelines (1800,1920, 1970s) – photography, t-sheets
Modern shoreline – lidar derived MHW contour



GIS Data Layers for Louisiana

- Vector shoreline derived from:
  - 1855-1887 source data
  - 1922-1934 source data
  - 1973-1978 source data
  - 2001 source data (lidar-based, MHW shoreline)
- Offshore baseline for generating shore-normal transects
- Shore-normal transects, including
  - long-term rates of shoreline change (and estimate of uncertainty)
  - short-term rates of shoreline change (and estimate of uncertainty)
- Alongshore vector showing spatial extents of beach nourishments

From: T.A. Miller, et al., ***The National Assessment of Shoreline Change: A GIS Compilation of Vector Shorelines and Associated Shoreline Change Data for the U.S. Gulf of Mexico***; USGS Open File Report 2004-108

http://pubs.usgs.gov/of/2004/1089/gis-data.html

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Hurricane and Extreme Storm Impacts

Abby Sallenger

Major Goal:

To develop, test, and implement a rigorous assessment of the vulnerability of U.S. coasts to change during extreme storms.

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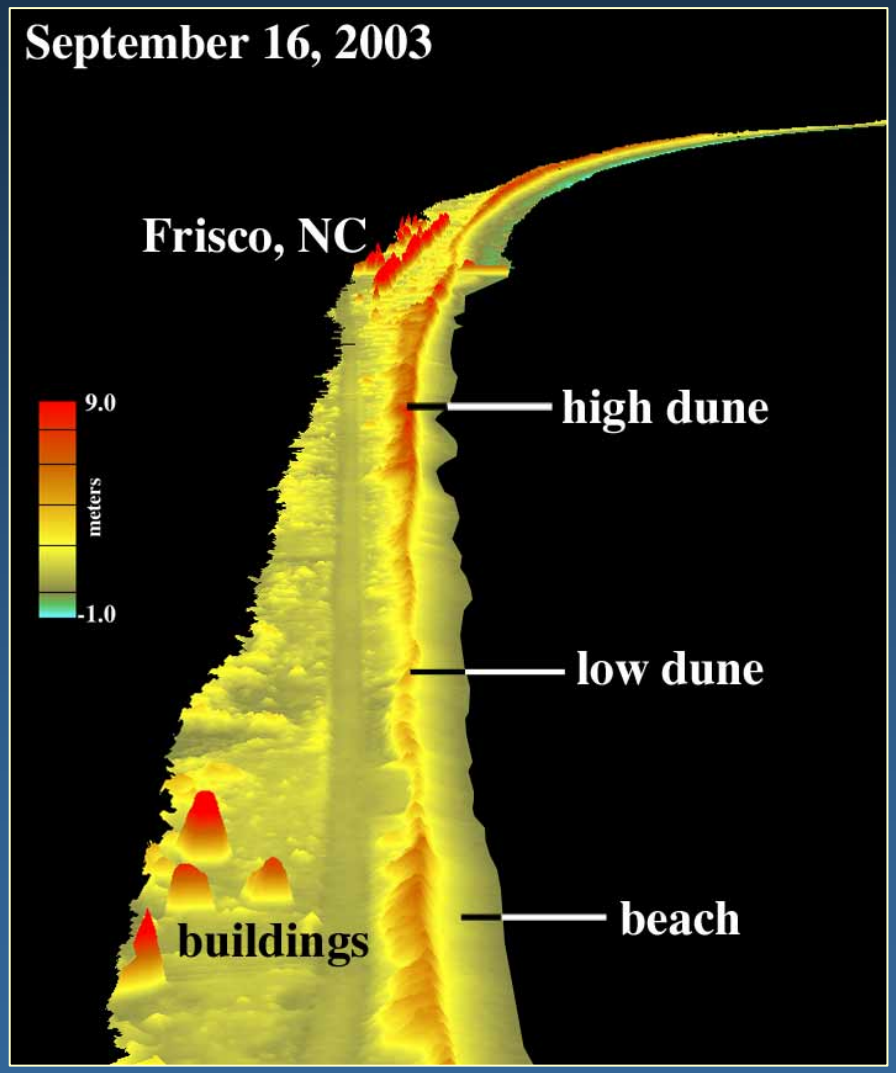
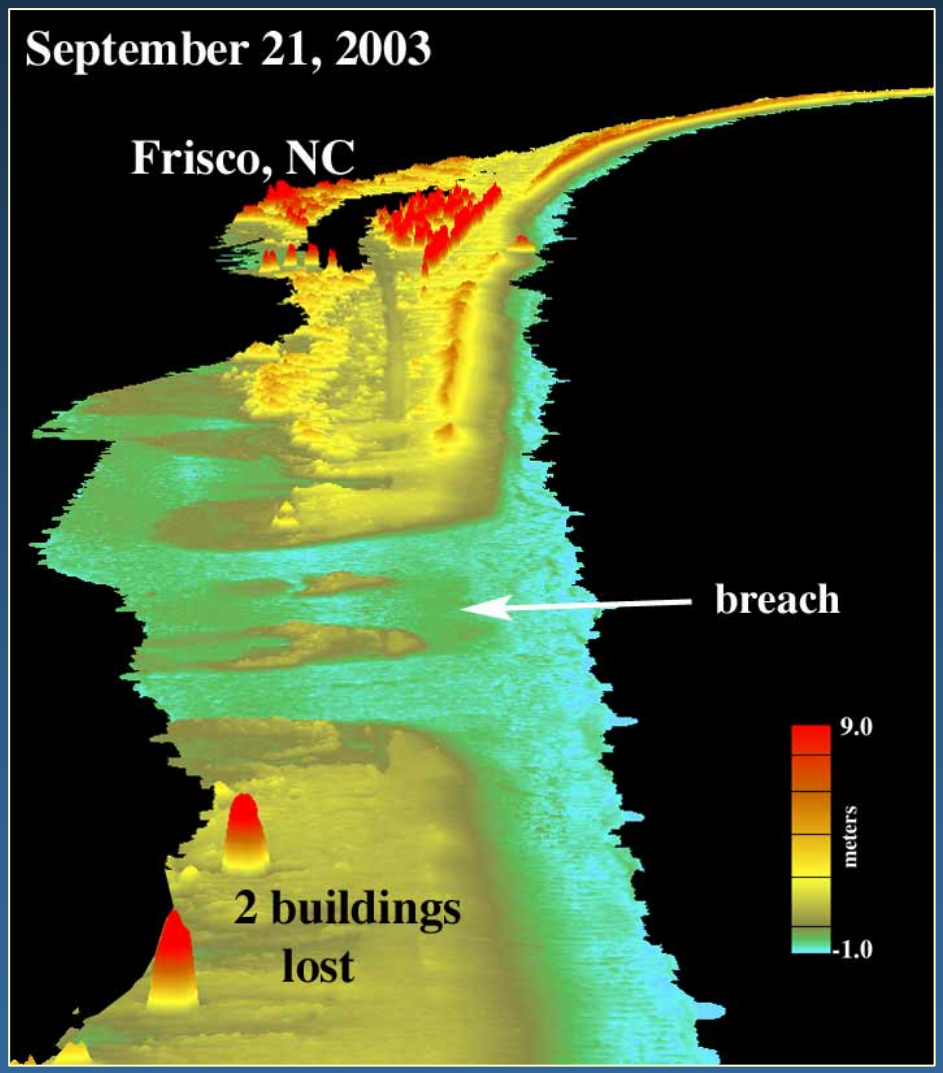
Longshore-variable response to extreme storms
Hurricane Isabel 2003 - Hatteras, NC

Documenting coastal change - Hurricane Isabel 2003





Data source: NASA EAARL

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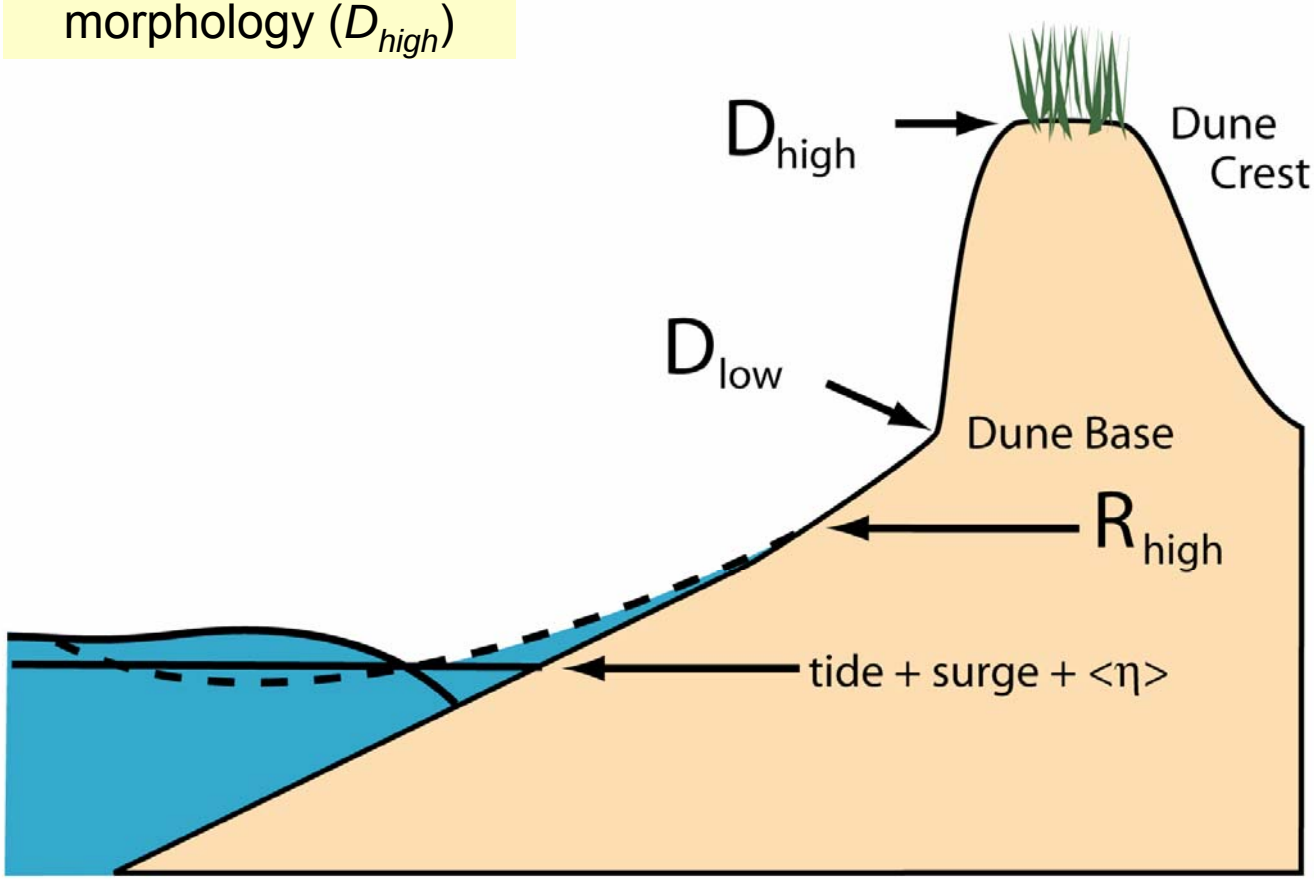
Storm-Impact Scaling Model

$$\frac{\text{fluids } (R_{high})}{\text{morphology } (D_{high})}$$



(modified from Sallenger 2000)

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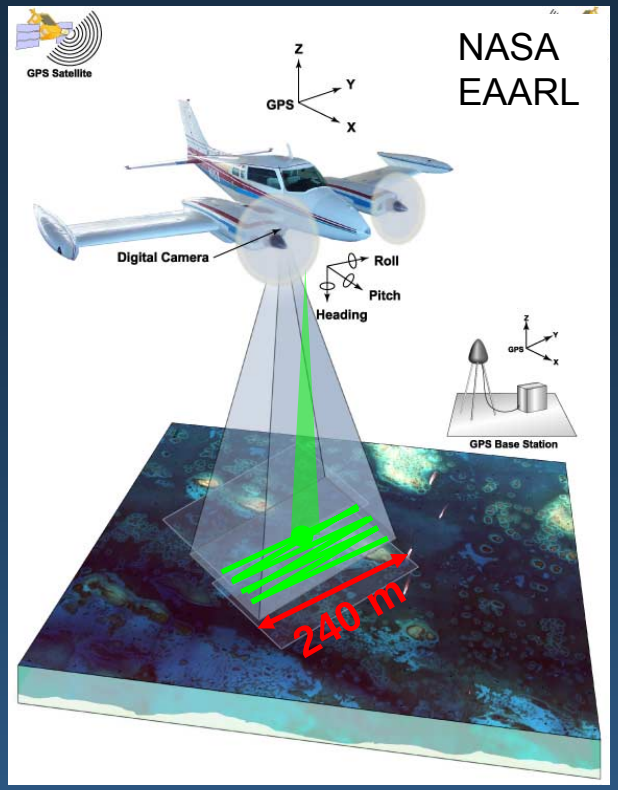
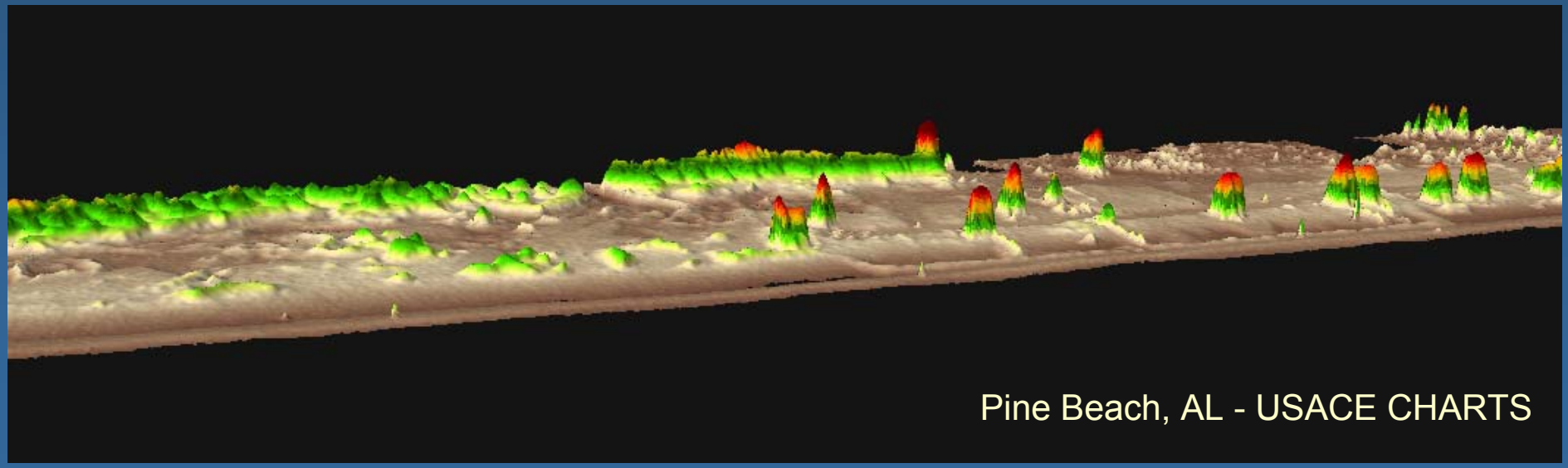
Storm-Impact Regimes

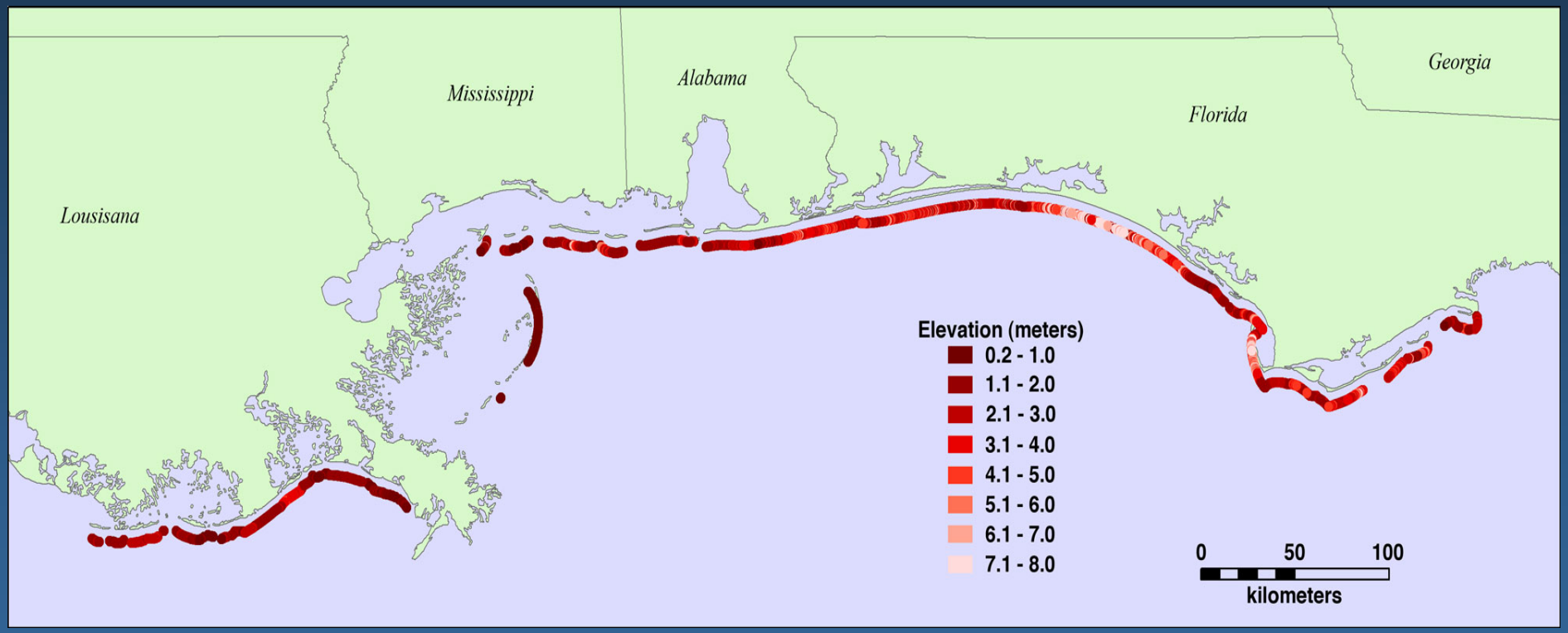


Measuring dune/berm elevations (D_{high})

- GPS-based
- 15 cm rms vertical accuracy
- laser shot collected every ~1 m^2
- surveys 100s of km in one day
- swath width ≈ 350 m



Dune and berm elevations (D_{high}) for the northern Gulf of Mexico



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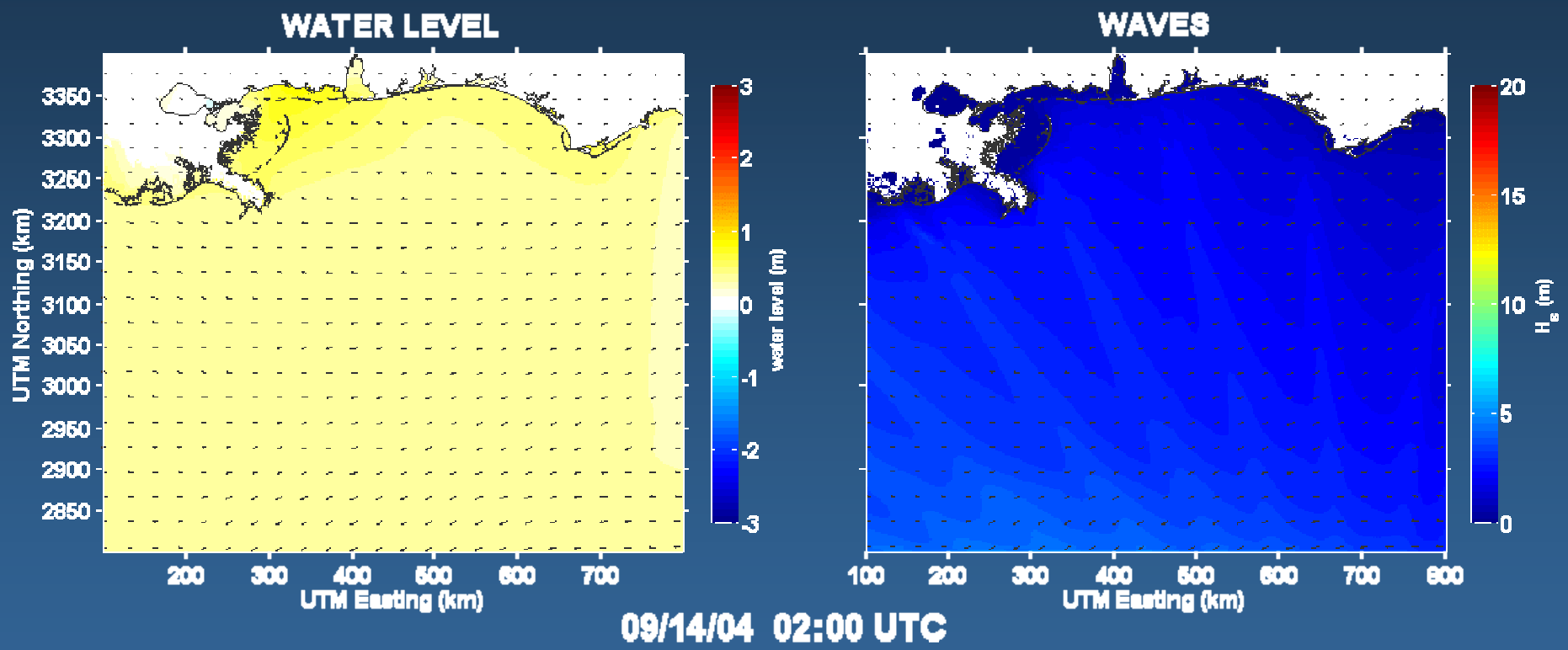
Modeling hurricane-induced water levels (R_{high})

Surge and waves are modeled using Delft3D.



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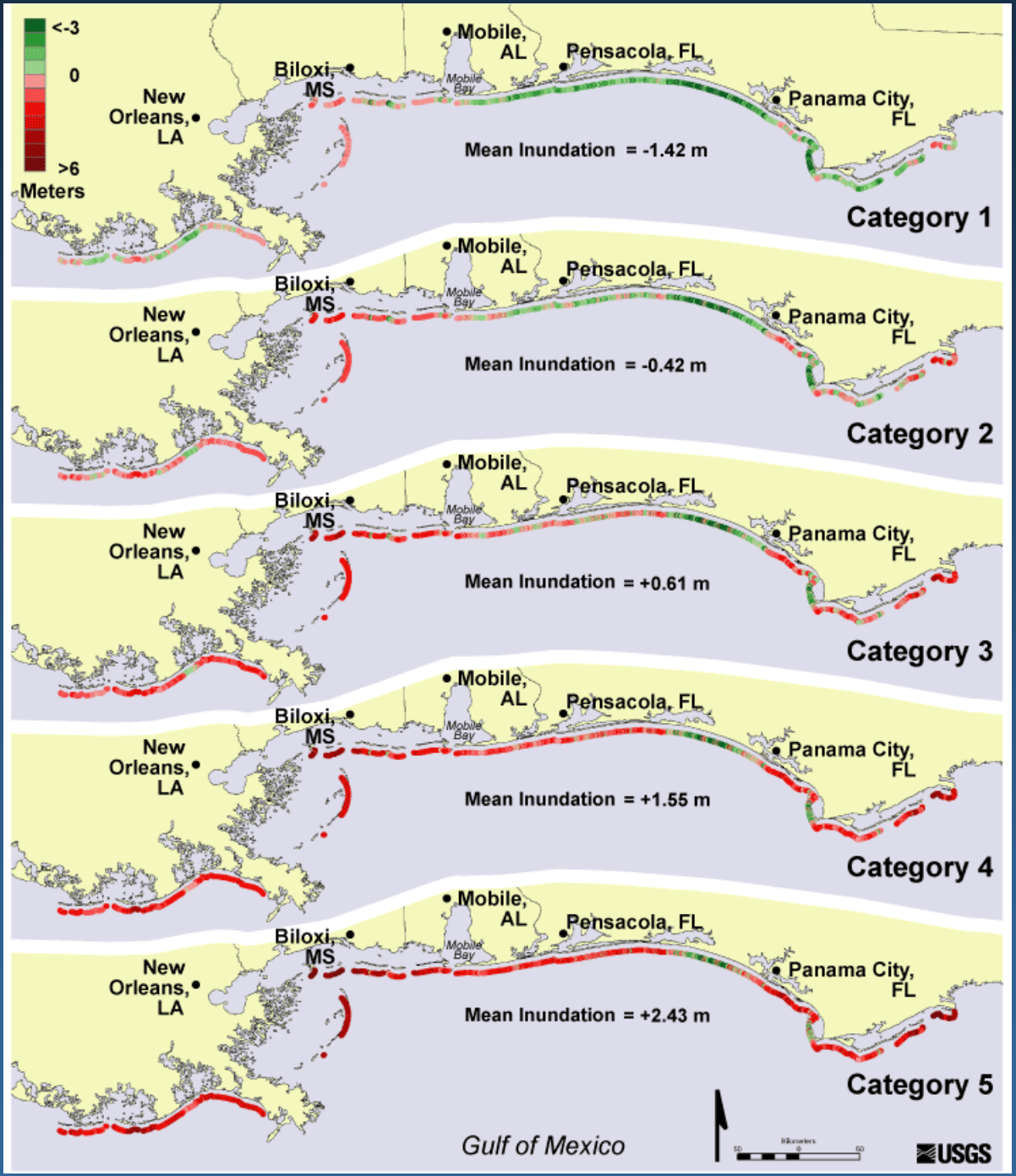
Vulnerability to inundation (R_{low}>D_{high}) during a direct hurricane landfall

- surge < dune elevation
- surge > dune elevation



Recent & Ongoing Activities

(most are dependent on lidar data sets)

tide
+
surge
+
setup
+
swash

Wave modeling

R (water levels)

D (dune elevations)

Observations
Accuracy Tests
Application (predictions)

Techniques/Data

elevation

f(time)

Feedback
Dune erosion modeling

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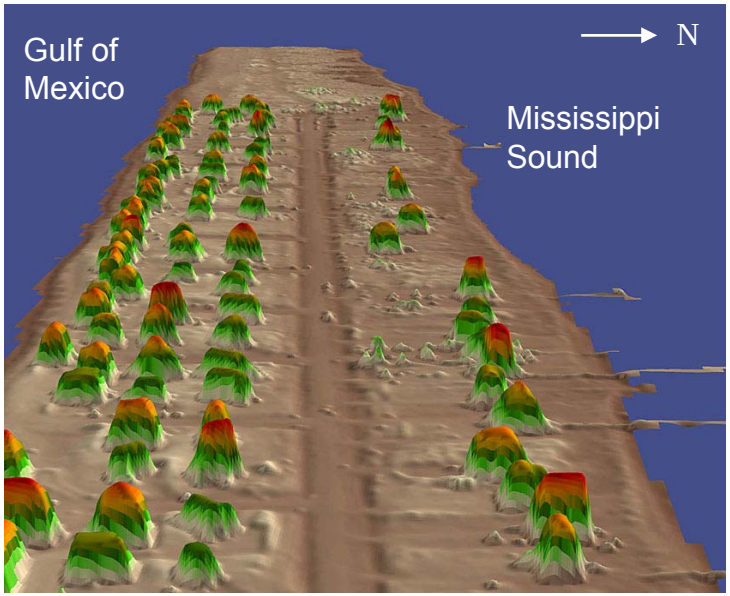
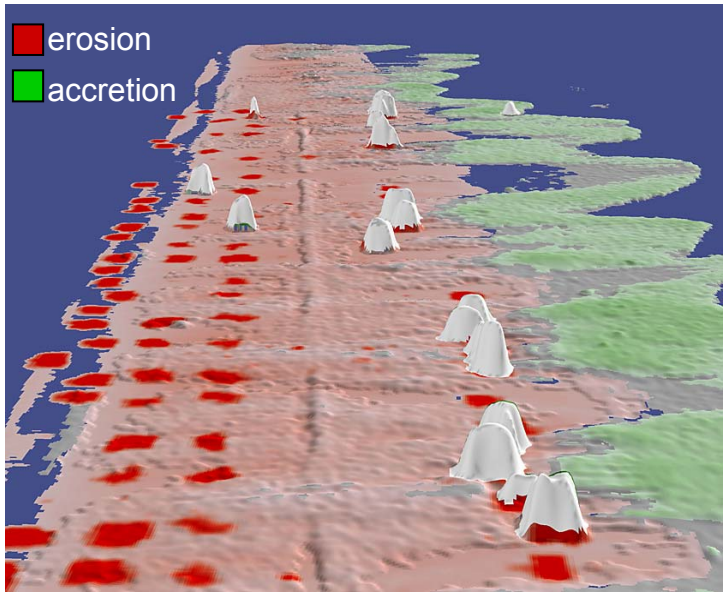
Coastal Response to Hurricane Katrina - Dauphin Island, AL

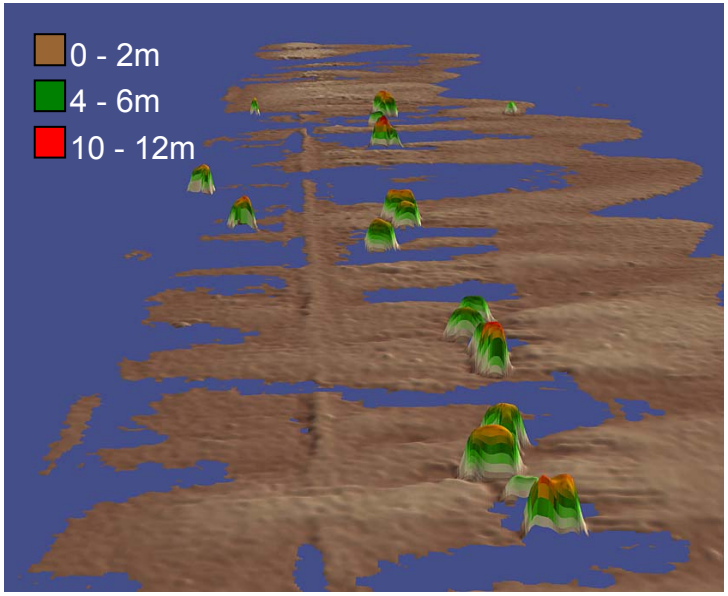
September 2004





difference (2005-2004)

September 2005



September 2005

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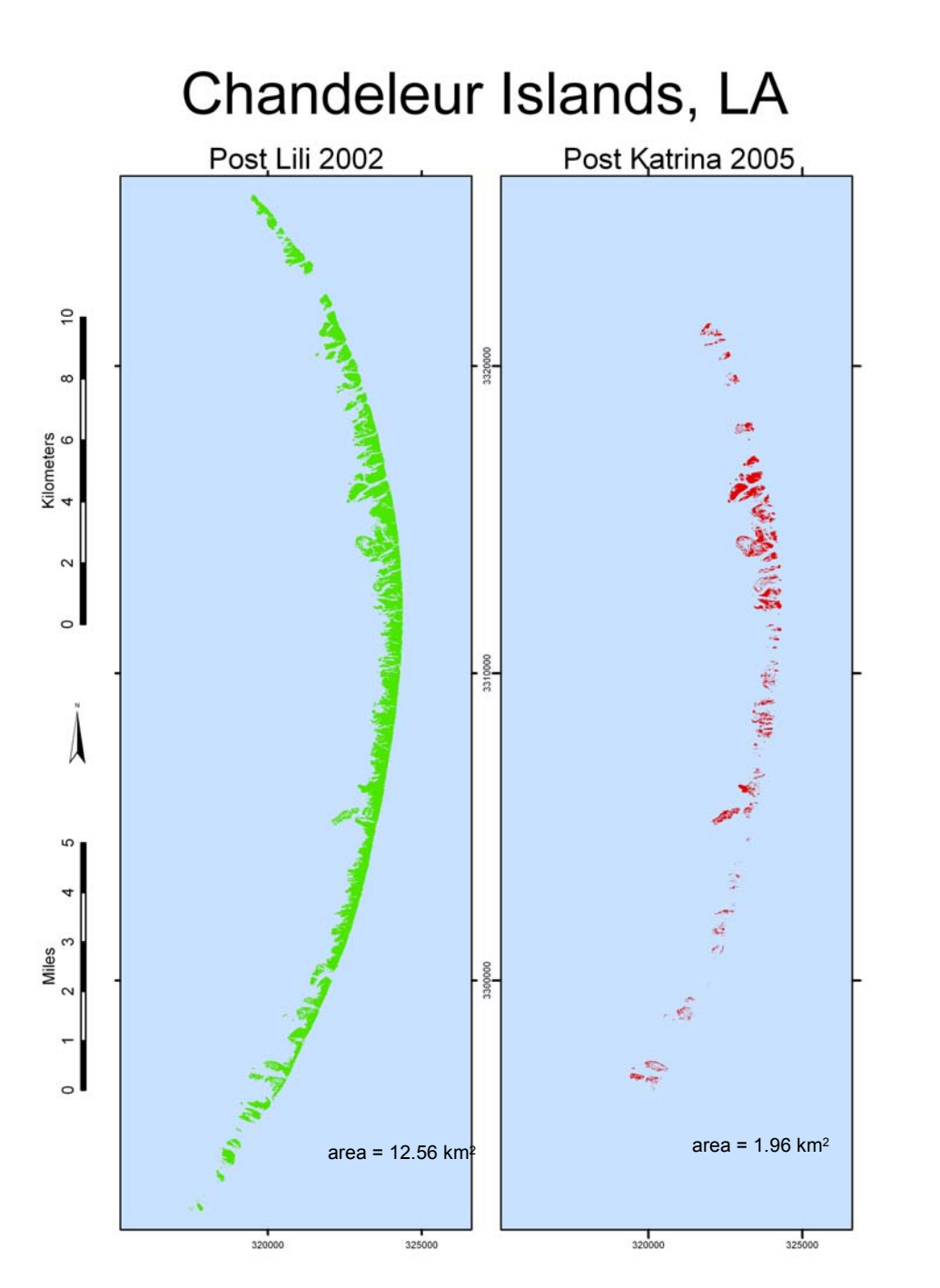
(modified after Sallenger et al, 2005)

Coastal Response to Hurricane Katrina

Island Area and Volume (% change)

$\Delta A = -84.4\%$

$\Delta V = -91.7\%$



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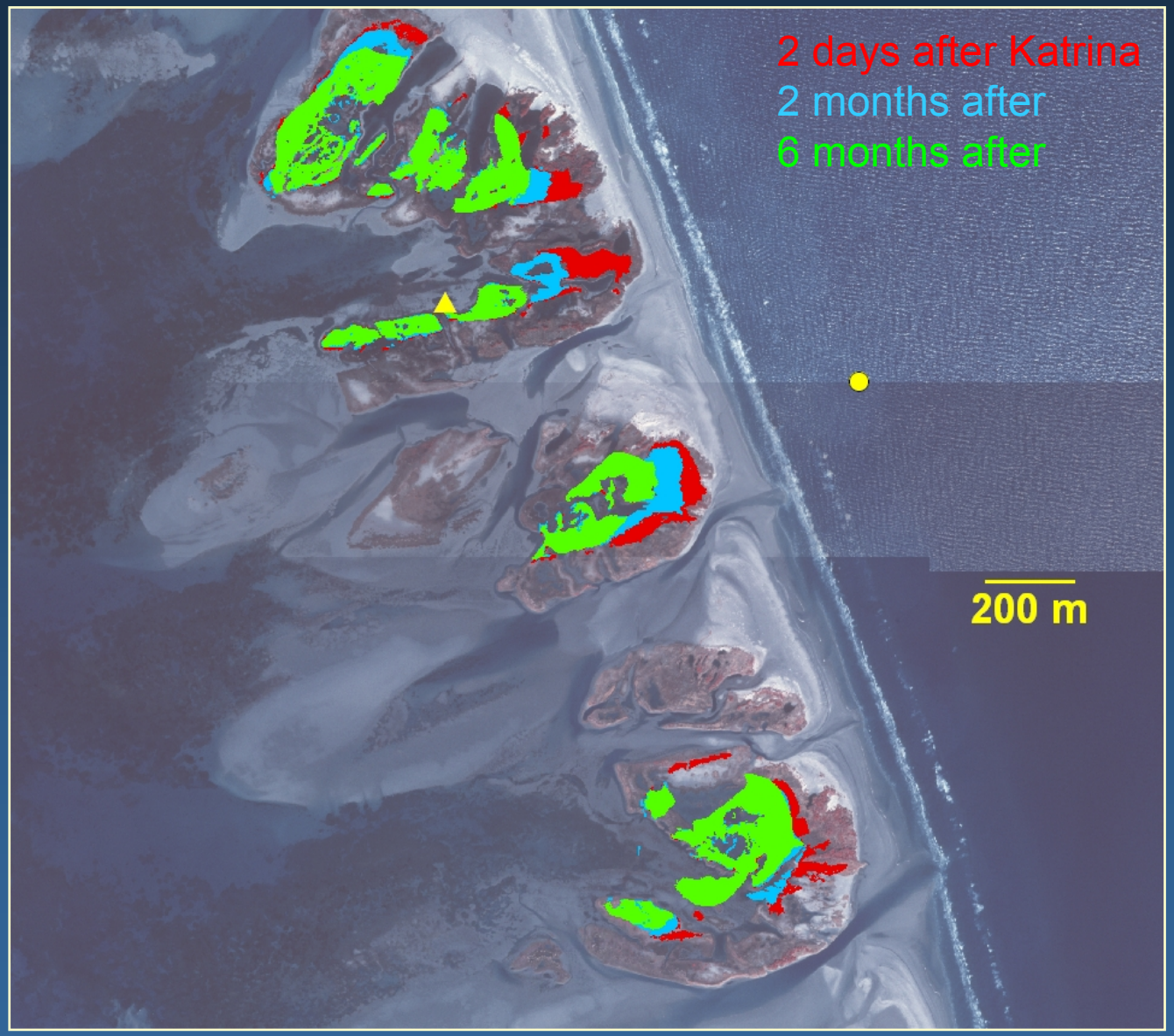
Continued retreat of the marshy areas of the Chandeleur Islands, LA

photo – pre-Katrina; lidar – post-Katrina



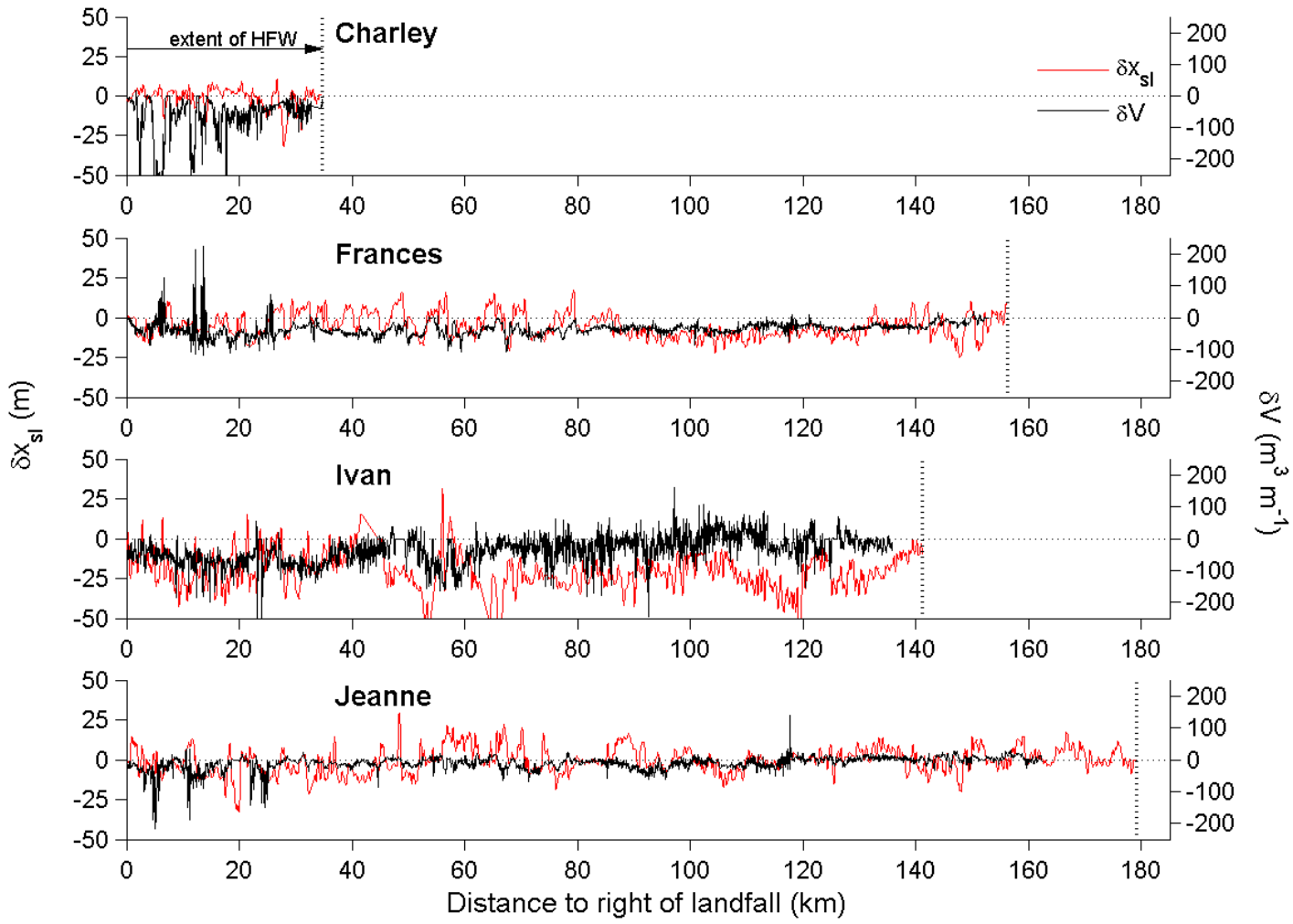
Spatial variability of shoreline and beach volume change during the 2004 hurricanes

Charley
δx_{sl} = 0.78 m
δV = -68.3 m^3/m

Frances
δx_{sl} = -5.0 m
δV = -35.2 m^3/m

Ivan
δx_{sl} = -20.1 m
δV = -35.8 m^3/m

Jeanne
δx_{sl} = -0.59 m
δV = -10.6 m^3/m



(from Sallenger et al. 2006)

Testing hindcast accuracy of the storm-impact scaling model (*R/D*)

hindcasts – pre-storm lidar-derived beach morphology combined with modeled waves and surge

observations – objectively determined through comparisons of pre- and post-storm lidar-derived topography

sensitivity , s = $N_{correct}/N_{observed} * 100$, **($N_{obs}$)**

storm (overall accuracy)	swash ($R_{high}<D_{low}$)	collision ($R_{high}>D_{low}$)	overwash ($R_{high}>D_{high}$)	inundation ($R_{low}>D_{high}$)
Bonnie 1998 (52%)	**1.5 (468)**	**56.0 (273)**	**84.2 (683)**	**Not tested**
Floyd 1999 (59%)	**1.4 (283)**	**55.6 (441)**	**89.7 (583)**	**Not tested**
***Ivan* 2004 (68%)**	**0 (0)**	**77.2 (204)**	**72.4 (2981)**	**51.0 (49)**

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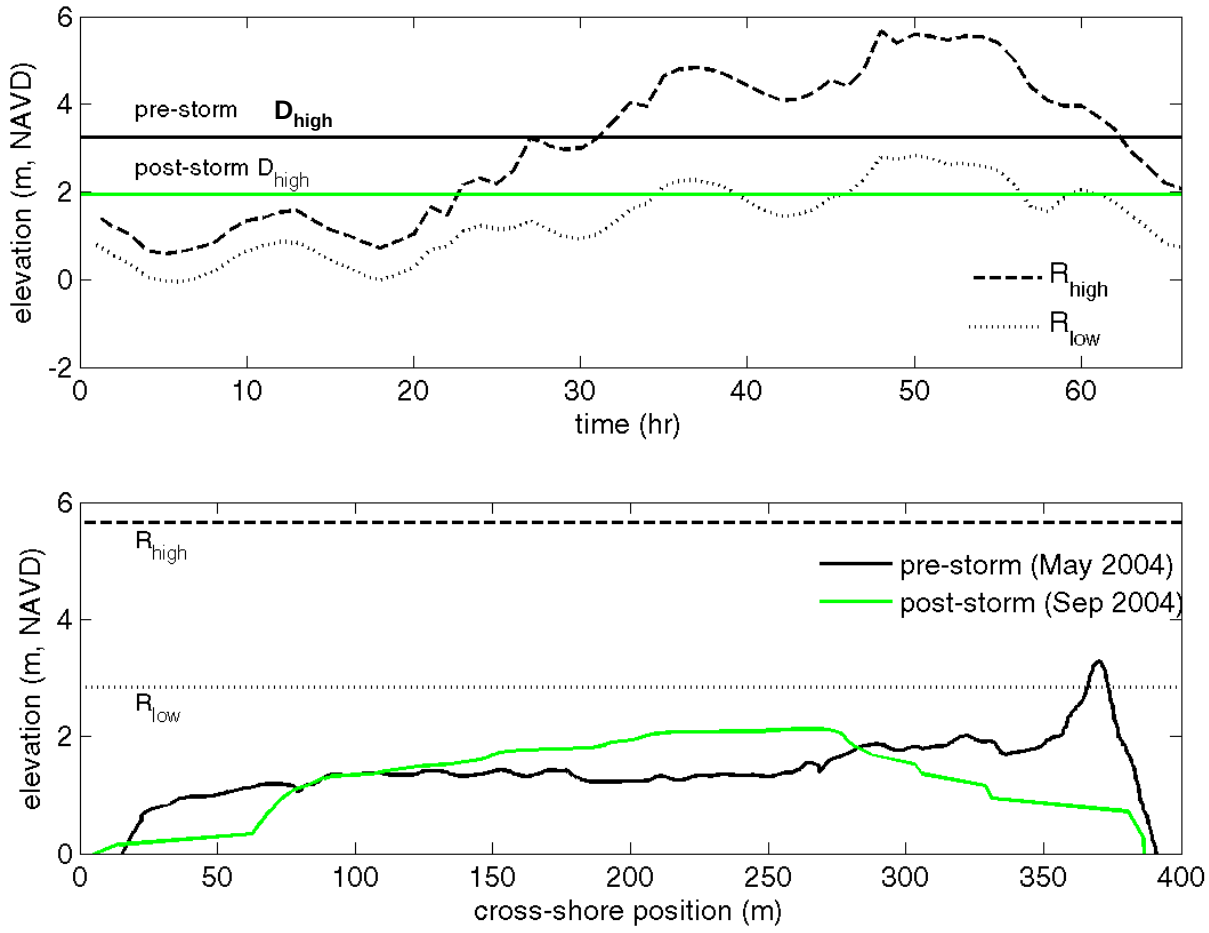
(from Stockdon et al. 2007)

Profile evolution and regime change during a storm...

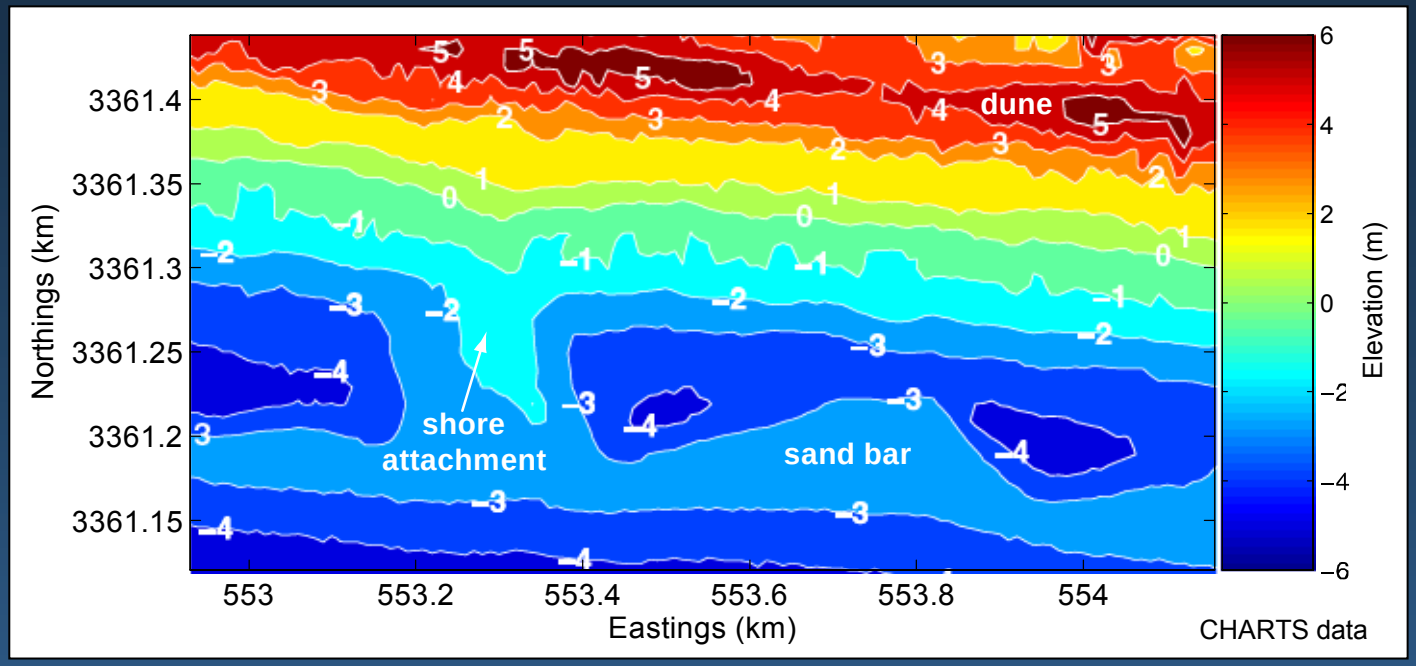
Time series of hurricane-induced water levels

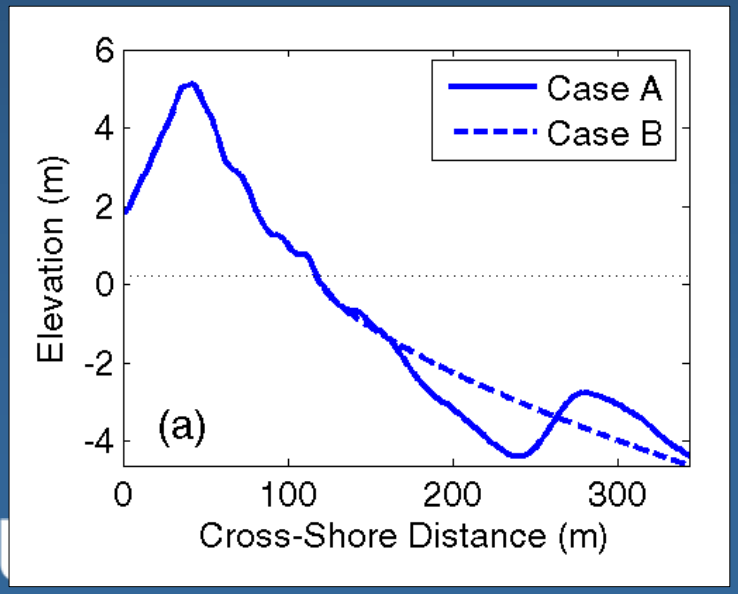
Profile evolution resulting from Ivan



(from Stockdon et al. 2007)

Testing the utility of dune erosion models…





Case A: Run SBEACH with known bathymetry

Case B: Run SBEACH with equilibrium offshore profile (typical configuration).

(from Fauver et al. 2007)

Current work in the northern Gulf of Mexico

- **LADNR** – Barrier island monitoring using ongoing lidar surveys
- **Fish and Wildlife** – Assessment of the stability of the Chandeleur Islands for future habitat
- **USACE**
  - LA – Provide data on island topography for integration into surge modeling
  - MS – Study of the historical change in barrier island shape (Morton) and their recovery since Katrina (Sallenger)

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The goal of our work is to develop a predictive understanding our Nation's vulnerability to coastal change hazards. Lidar assists us in:

- Quantifying the longshore-variable coastal change on our of nation's beaches.
- Modeling the patterns of and the processes responsible for coastal change.
- Developing and testing models for predicting the likely impact of an approaching storm or sea level rise on our coastal areas.
- Creating national maps of vulnerability of coastal change hazards.

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Acknowledgements

- Abby Sallenger – USGS
- Wayne Wright – NASA
- Jeff Lillycrop – USACE
- And their hard-working research teams

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