Coastal Studies Group

CSG

Measuring the Continuum of Coastal Environmental Variability with Remote Sensing

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Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

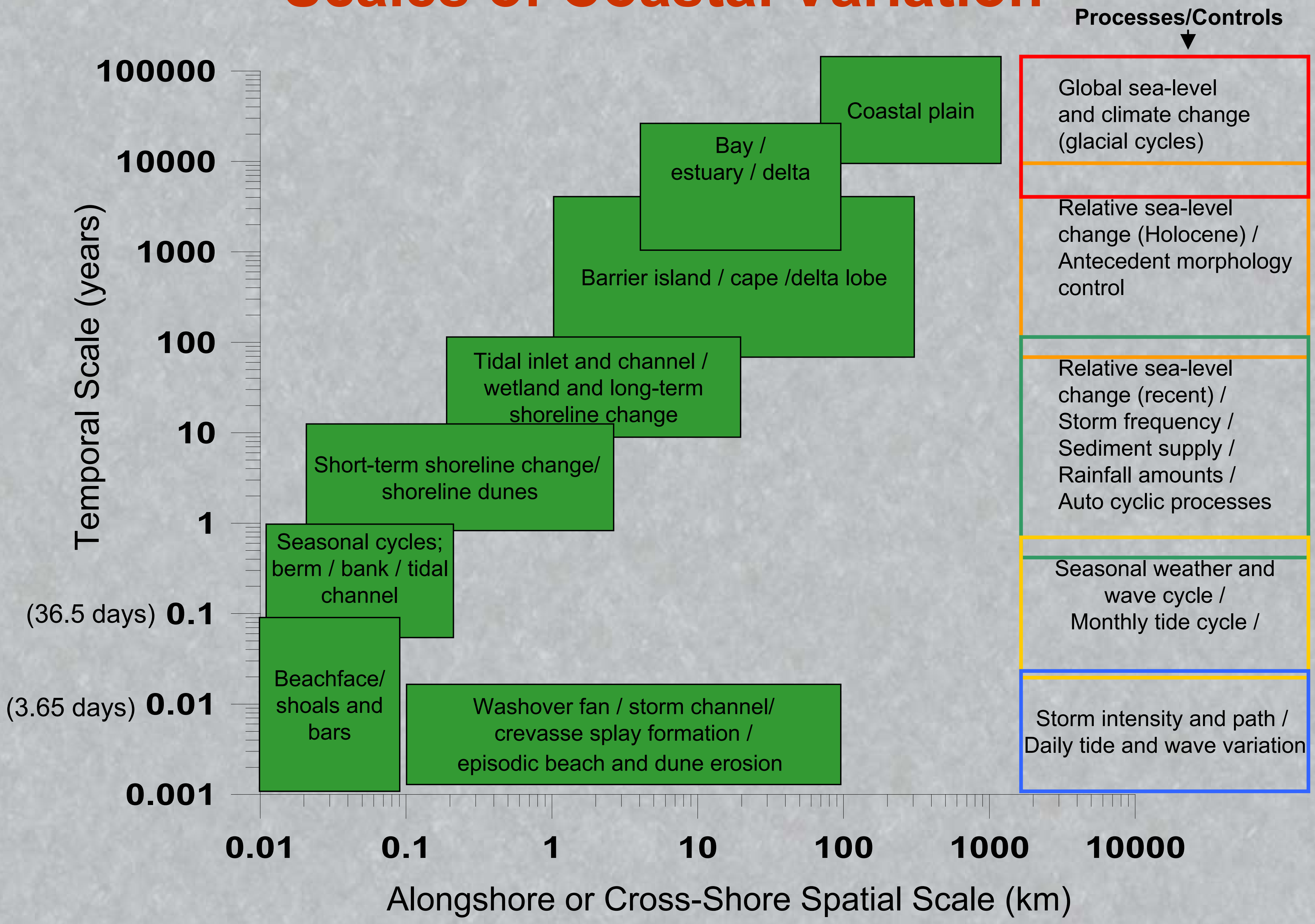
XIII Simposio Brasileiro de Sensoriamento Remoto
Florianopolis, Brazil, April 21 to 26, 2007

Two Key Considerations

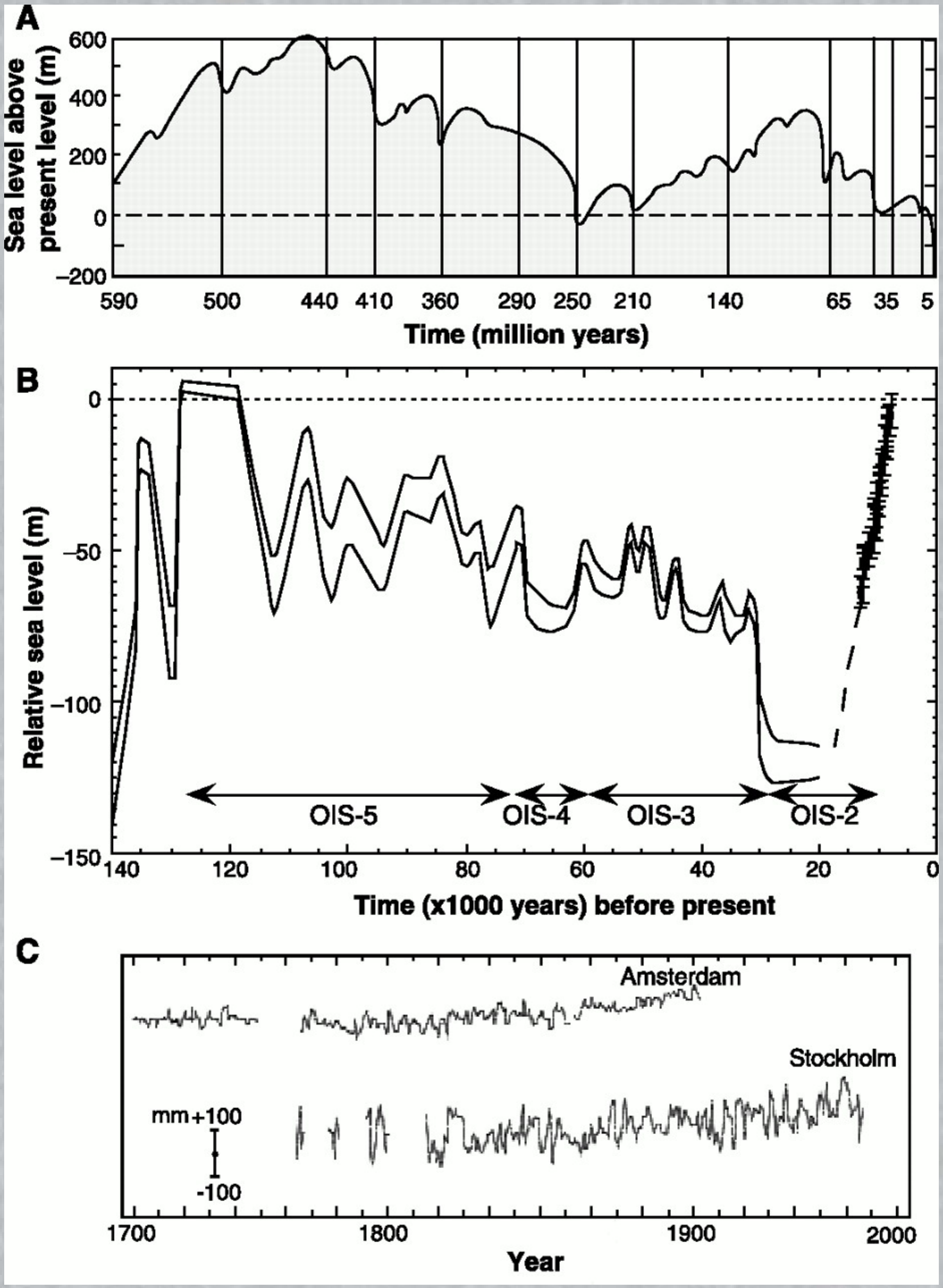
What is the spatial scale of the feature?

What is the temporal scale of the process?

Scales of Coastal Variation



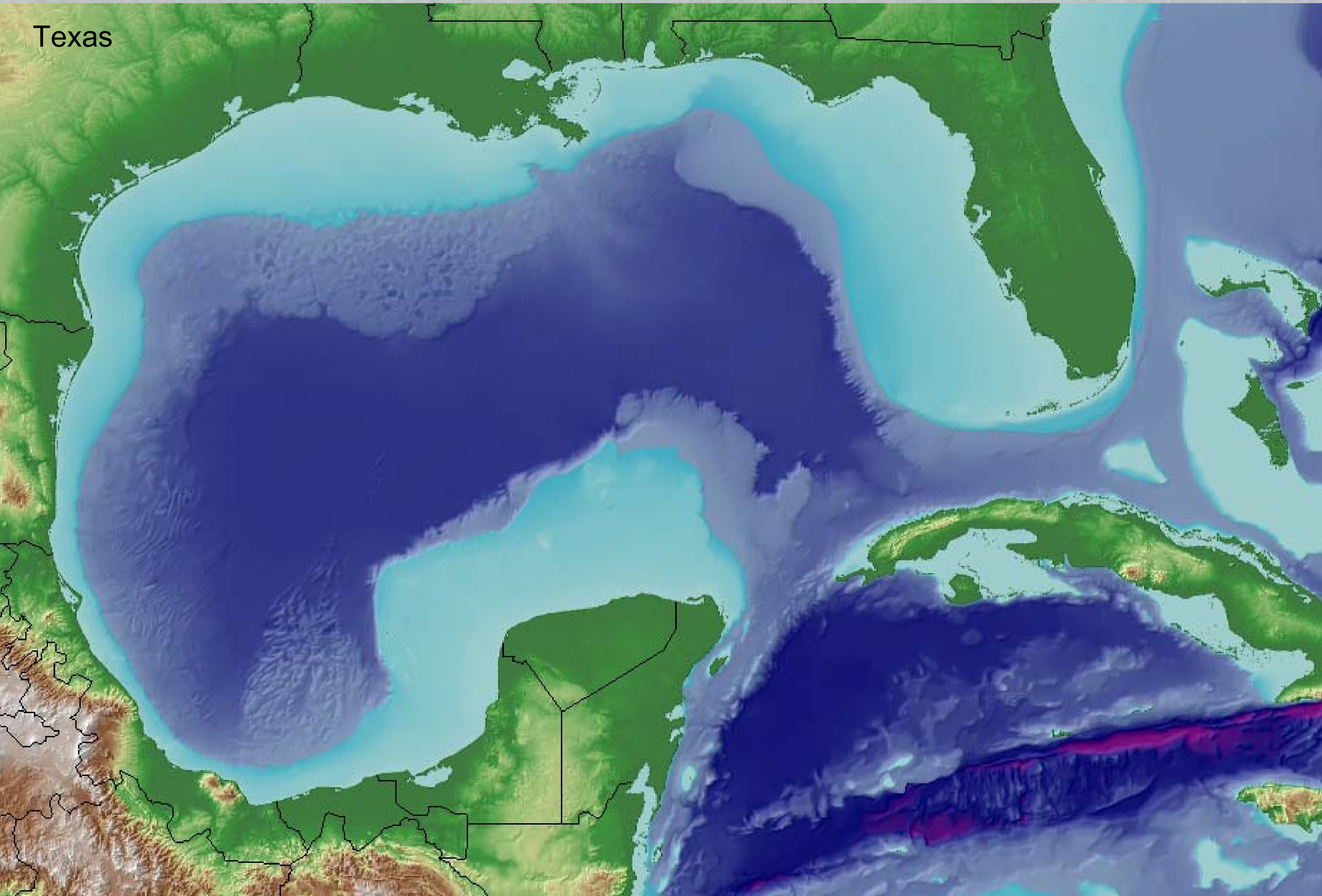
Global Sea-Level Change



K. Lambeck et al., Science 292, 679 - 686 (2001)

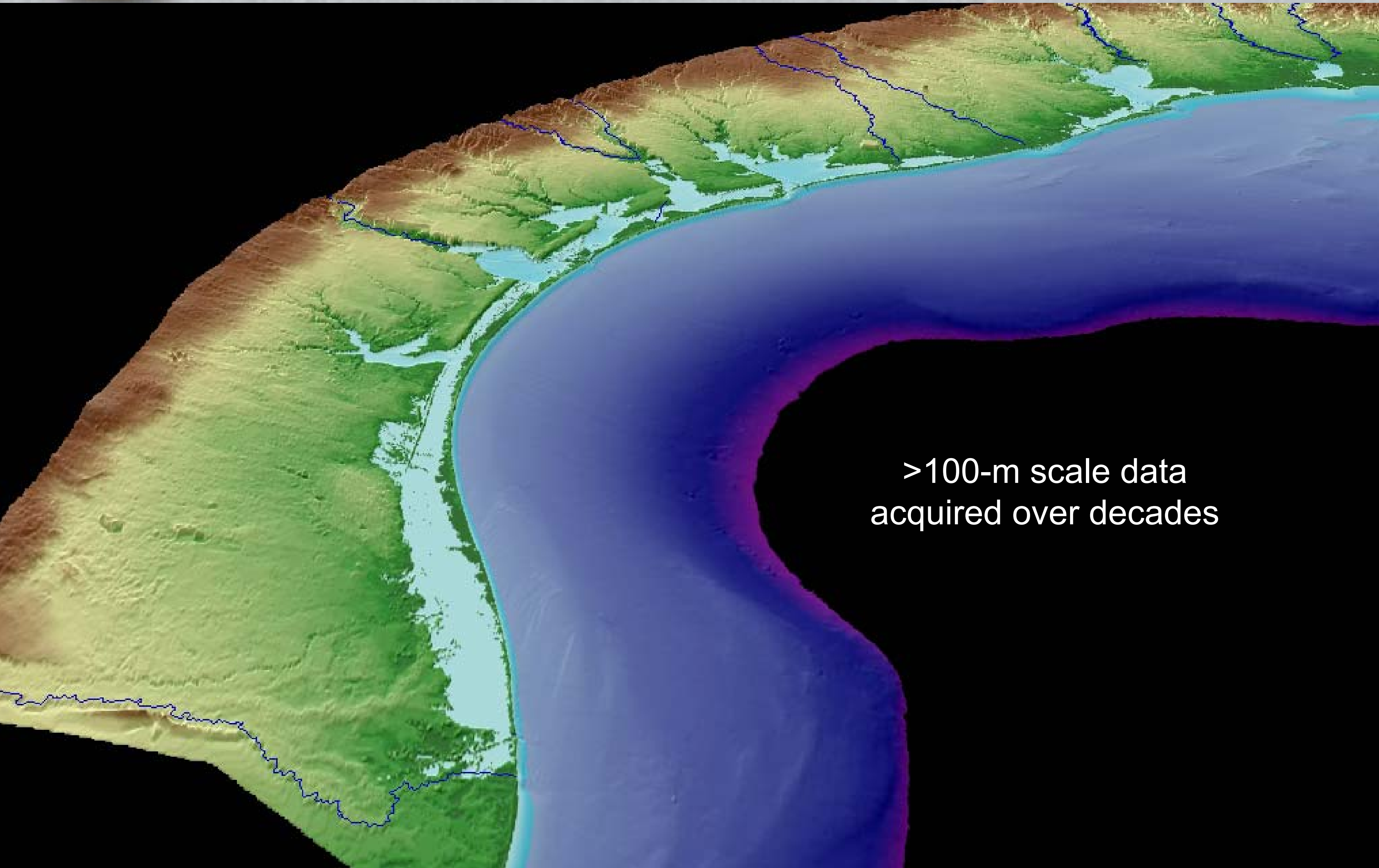
Published by AAAS

Gulf of Mexico



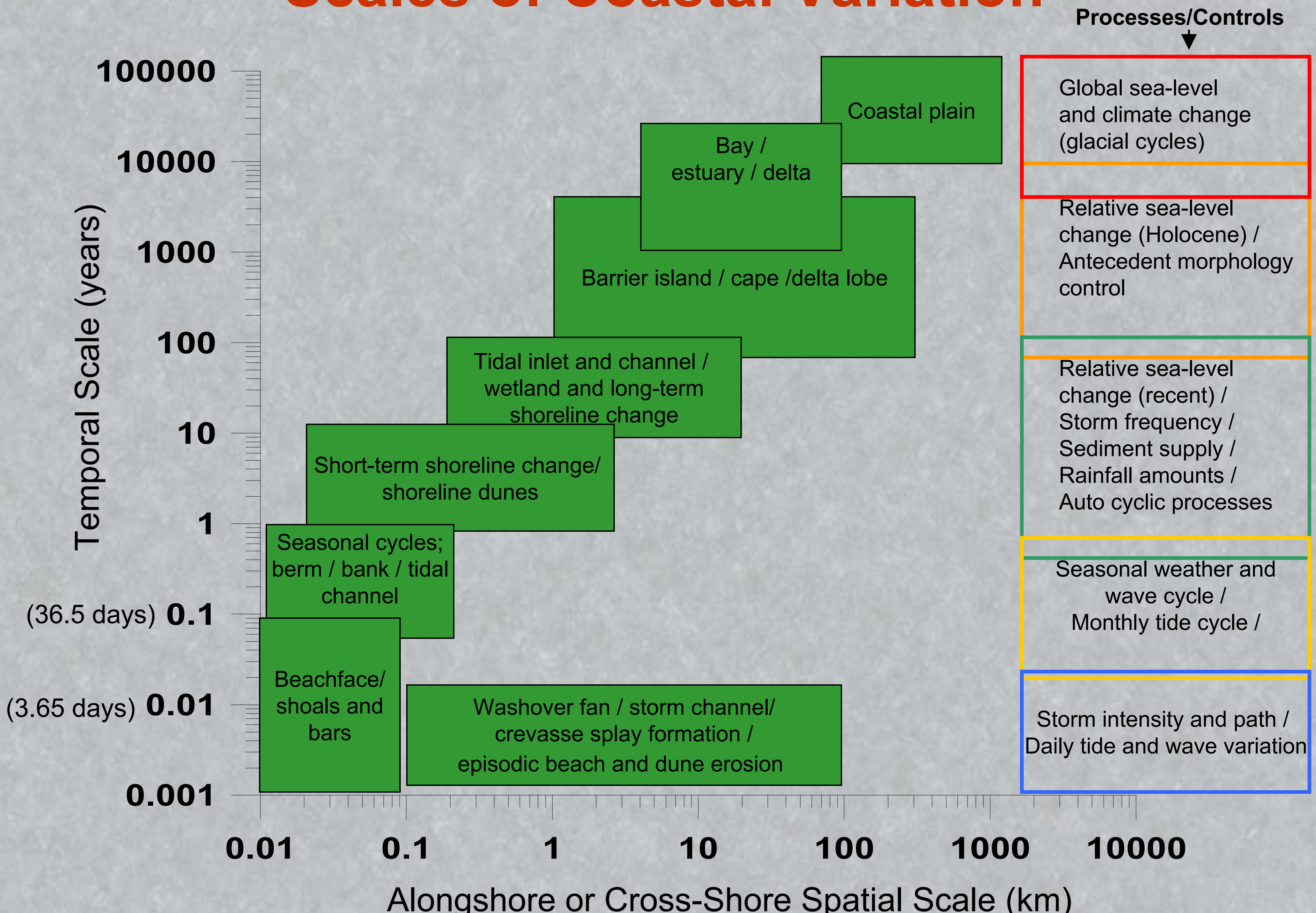
Texas Coast

Texas Coastal Plain Topography/Bathymetry



Landsat Drape

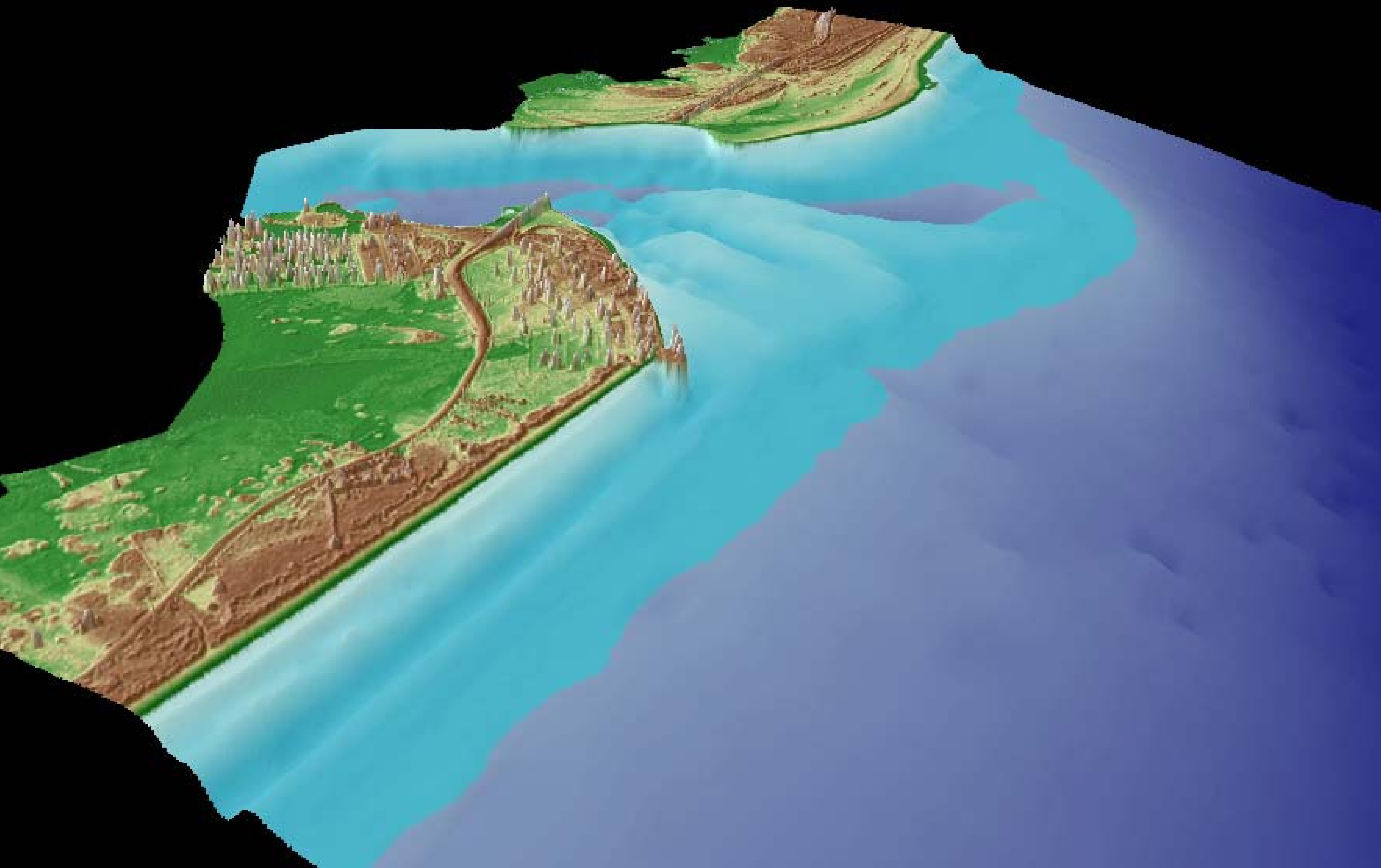
Scales of Coastal Variation



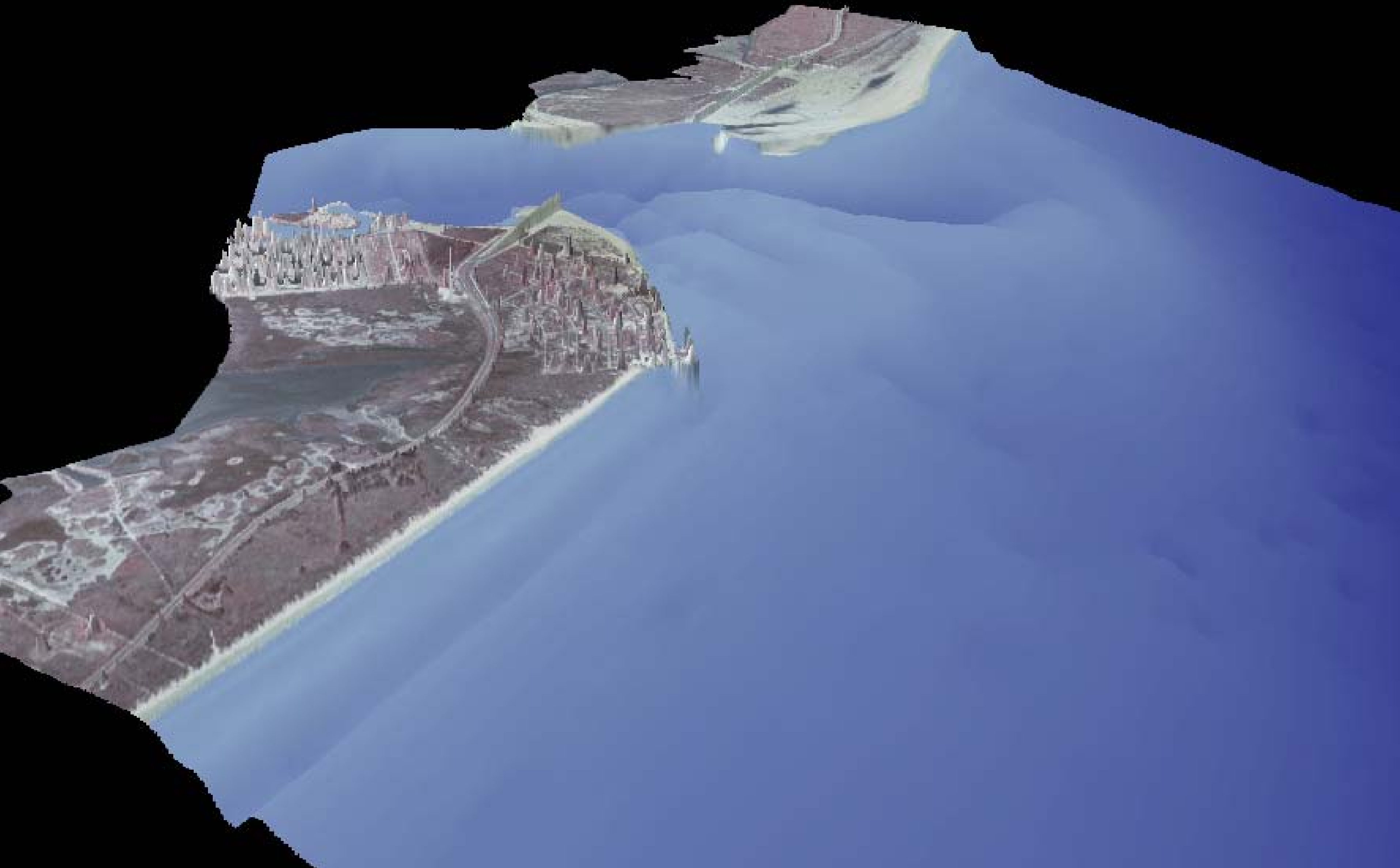
1995 Color-Infrared Aerial Photograph

Shorelines, 1930 - 2002

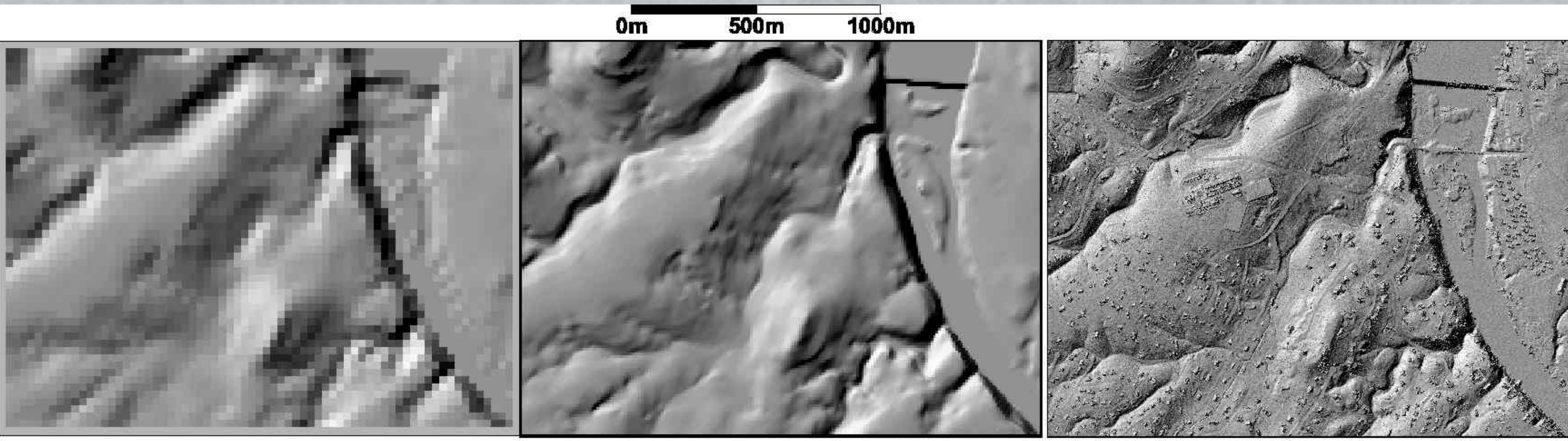
1-m scale topography and bathymetry



Color-Infrared Photograph Drape



Digital Elevation Model (DEM) Resolution



A. 30m USGS DEM

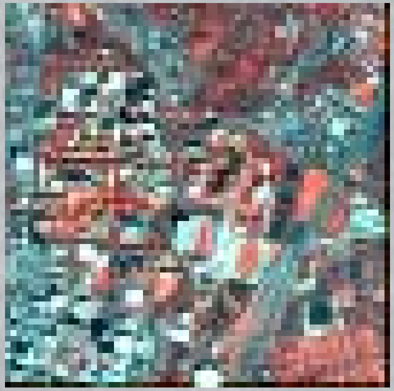
B. 10m AverStar DEM

C. 0.5m Lidar DEM

Imagery Spatial Resolutions*

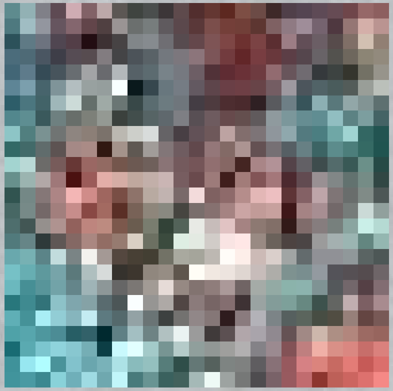
1-2m

QuickBird,
IKONOS



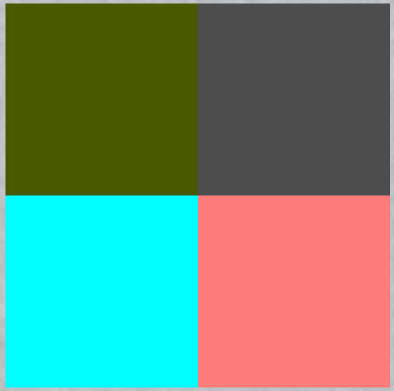
30m

Landsat TM,
ETM+



79m

Landsat MSS



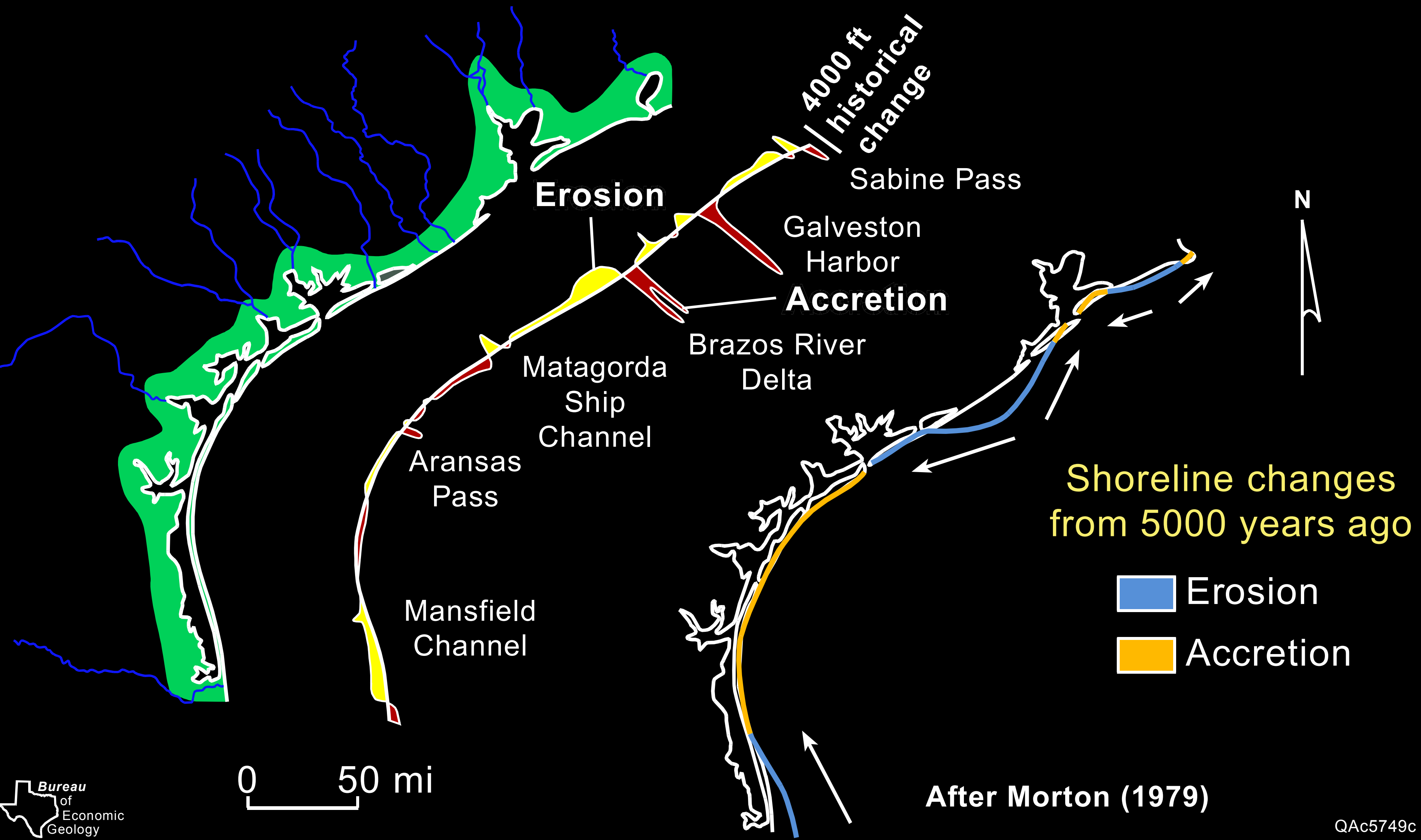
1.1km

AVHRR

*Simulated

Slide courtesy of Amy Nuenschwander, Univ of Texas, Center for Space Research

TEXAS SHORELINE DEVELOPMENT



Goal

Determine how the shoreline is likely to change during the next 60 to 100 years.

- **Compute average annual rate of shoreline change by linear regression of select historical shoreline positions.**
- **Qualitative evaluation of alongshore trend of the standard errors of linear regressions at each transect.**
- **Exclude earlier shorelines from calculation based on above evaluation and knowledge of sediment-budget altering engineering works.**

Shoreline Change Analysis

- Mapping past and current shorelines
  - Early maps
  - Aerial photography
  - Ground kinematic GPS
  - Airborne lidar – shoreline plus beach and dune topographic mapping
- Calculating “average annual rate of change” and projecting future shoreline position
  - GIS-based Shoreline Change and Projection Program (SSAPP)
- Beach profile ground surveys
- Data availability and public awareness
  - Online reports
  - Web-based GIS using ArcIMS software

Early Shoreline Surveys

Planetable surveying in the Philippines

Photos courtesy of Dave Doyle, NGS

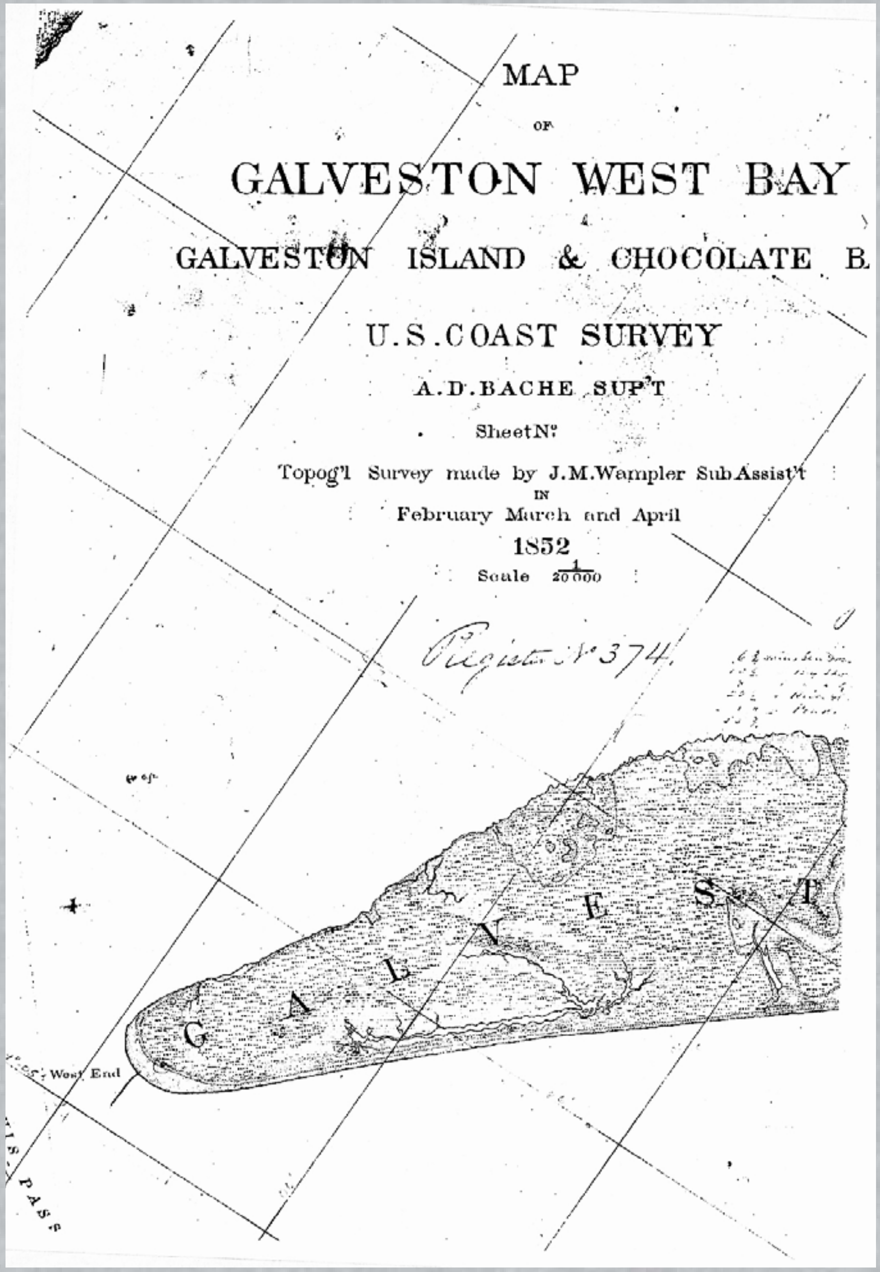
Data Sources

Before 1930:

Maps from the mid to late 1800's produced by the U.S. Coast Survey.

Not always used:

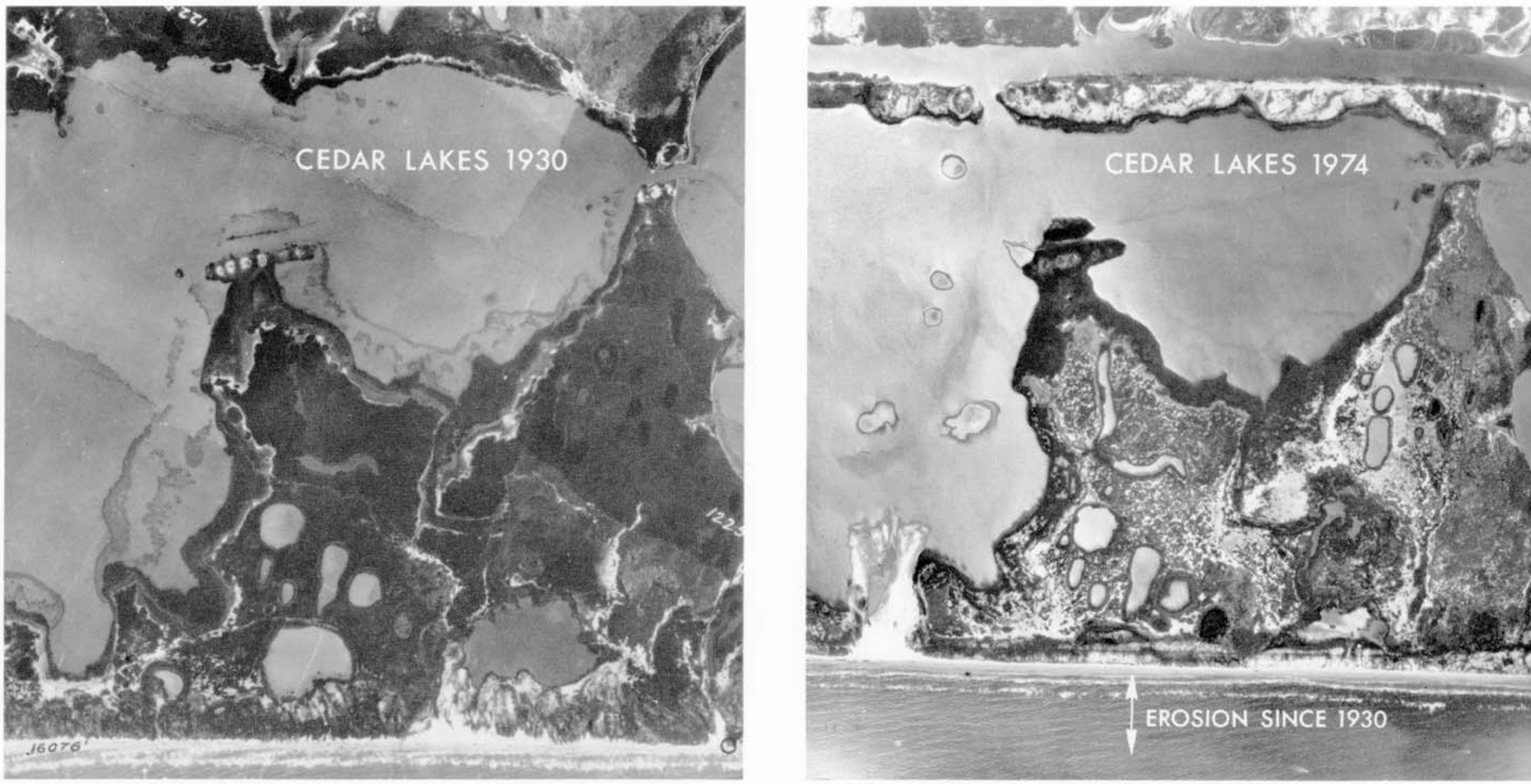
Engineering structures altered sediment budget since 1900.



Sand Trapped by Jetty, Southwest end of Bolivar Peninsula (08/07/98)

Data Sources

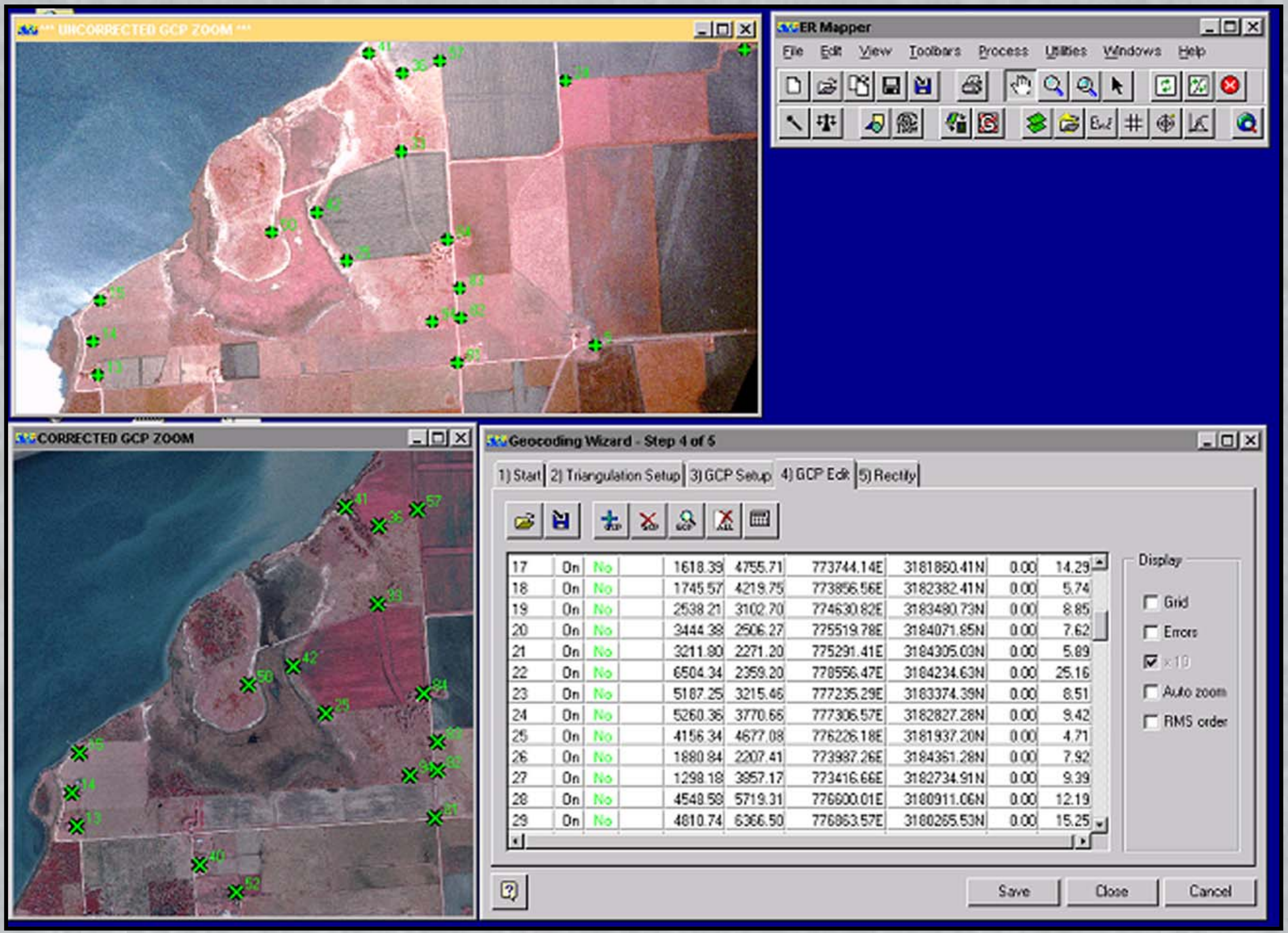
1930’s to 1990’s - Vertical Aerial Photographs



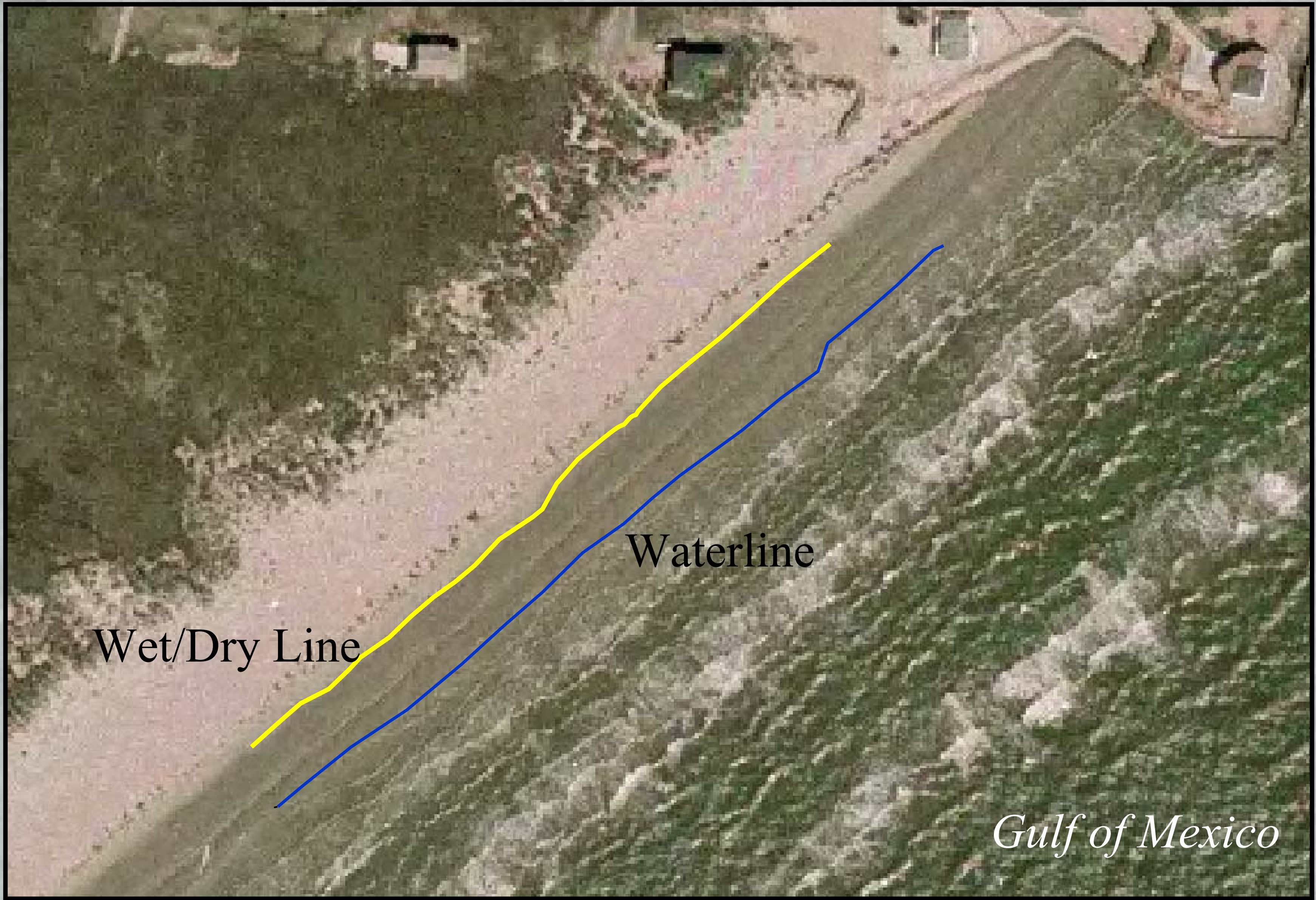
Digital Photo Rectification
(ER-Mapper Software)

1995 Digital Orthophoto Quarter Quads Serve as Base Maps

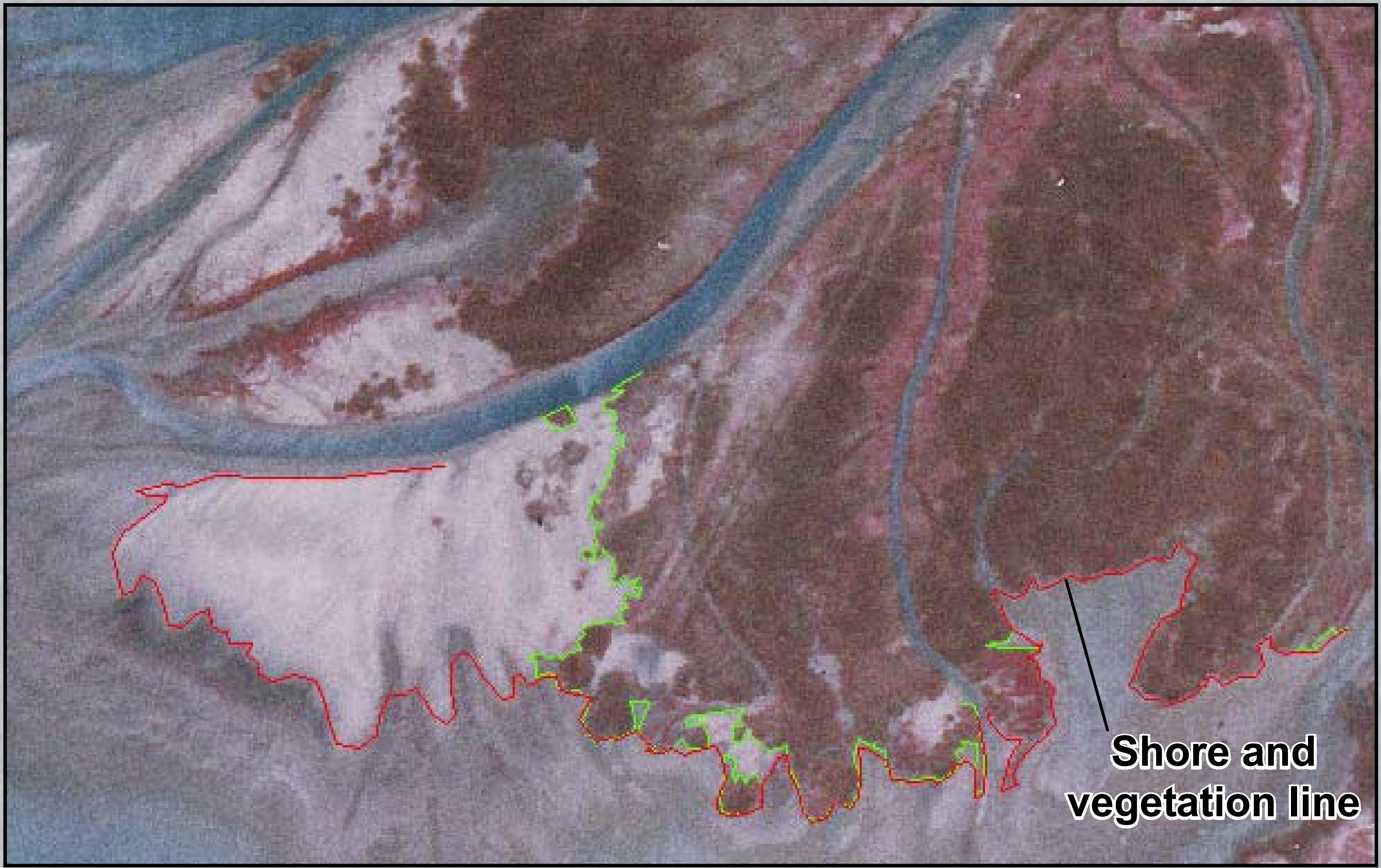
- **USGS/Tx Orthophoto Program**
- **Scanned color IR film, 1-m resolution**
- **Meet 1:12,000 map accuracy standards (90% of test points within10 m)**
- **Our tests show typically within 5 m**



Shoreline Interpretation
Wet/Dry Line



Shoreline Interpretation
Shoreline and Vegetation Line

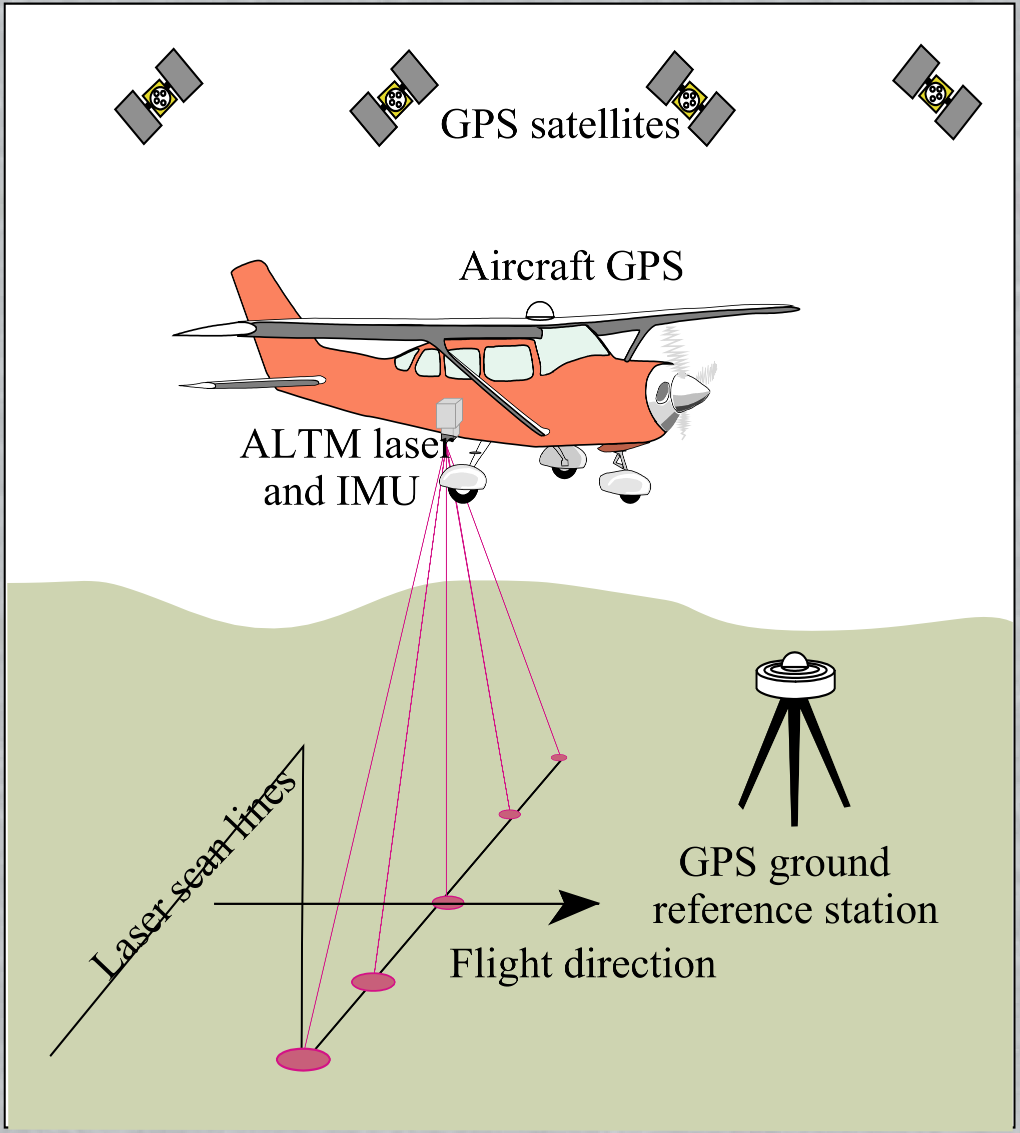


Data Sources

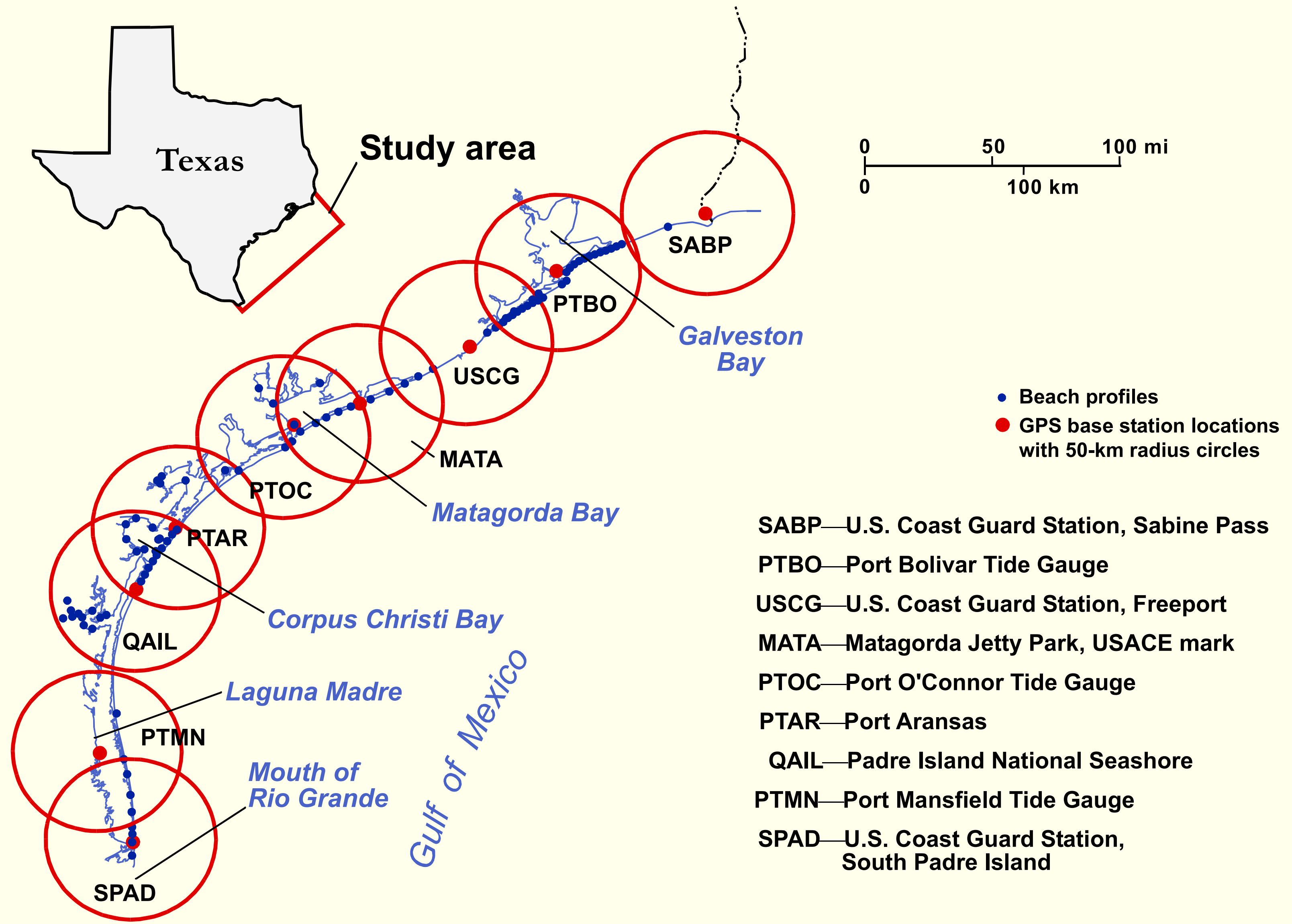
1990's – Kinematic GPS Surveys

UT's Airborne Topographic Lidar (Optech Inc., ALTM 1225)

- Mirror sweeps laser beam across the ground.
- Range to target is determined by measuring time interval between outgoing and return of reflected laser pulse.
- Aircraft position is determined using GPS phase differencing techniques.
- Pointing direction of laser determined with Inertial Measuring Unit (IMU) and recording of mirror position.
- Data streams recorded and synchronized for post processing.



GPS Coastal Network



SABP—U.S. Coast Guard Station, Sabine Pass

PTBO—Port Bolivar Tide Gauge

USCG—U.S. Coast Guard Station, Freeport

MATA—Matagorda Jetty Park, USACE mark

PTOC—Port O'Connor Tide Gauge

PTAR—Port Aransas

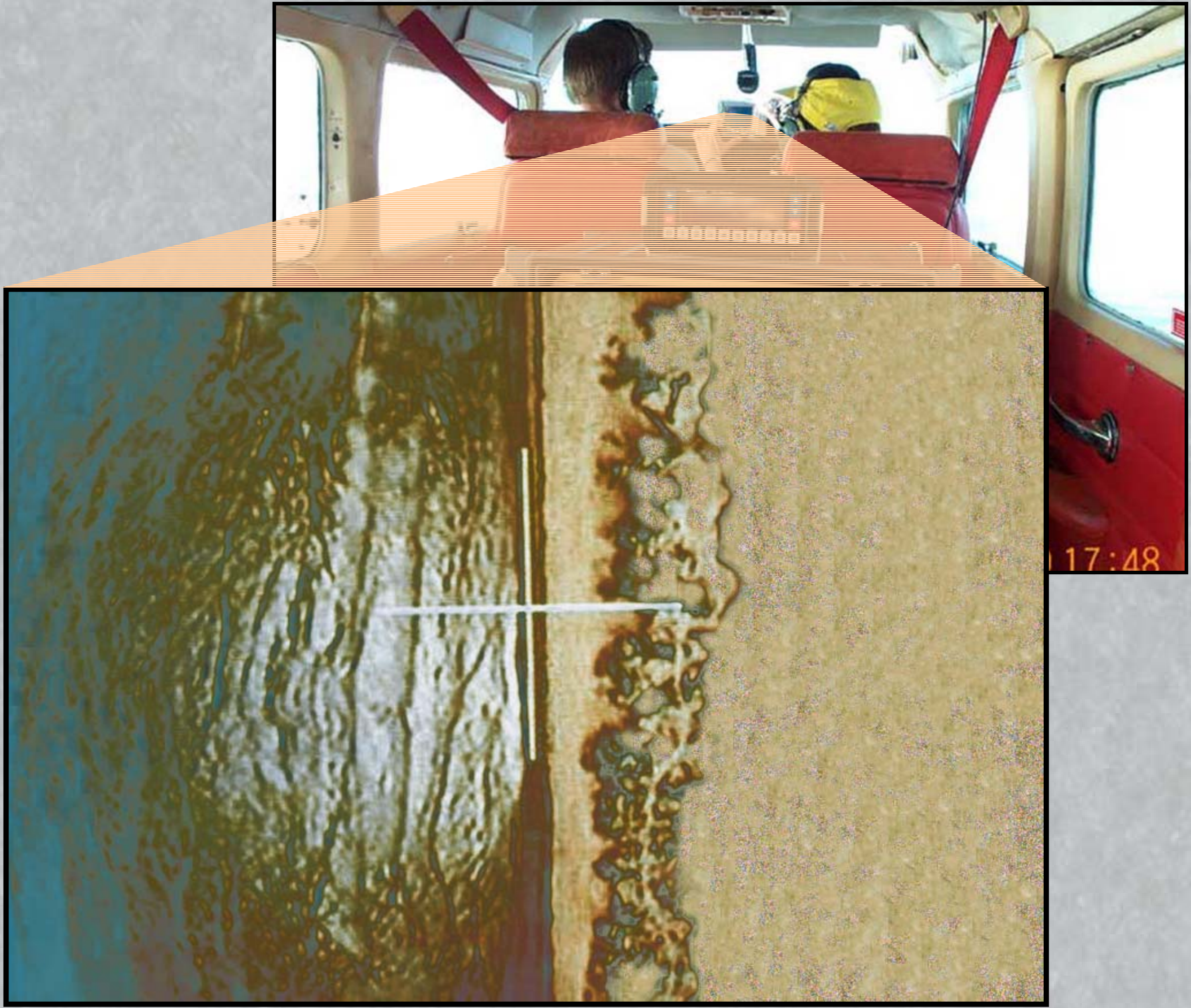
QAIL—Padre Island National Seashore

PTMN—Port Mansfield Tide Gauge

SPAD—U.S. Coast Guard Station, South Padre Island

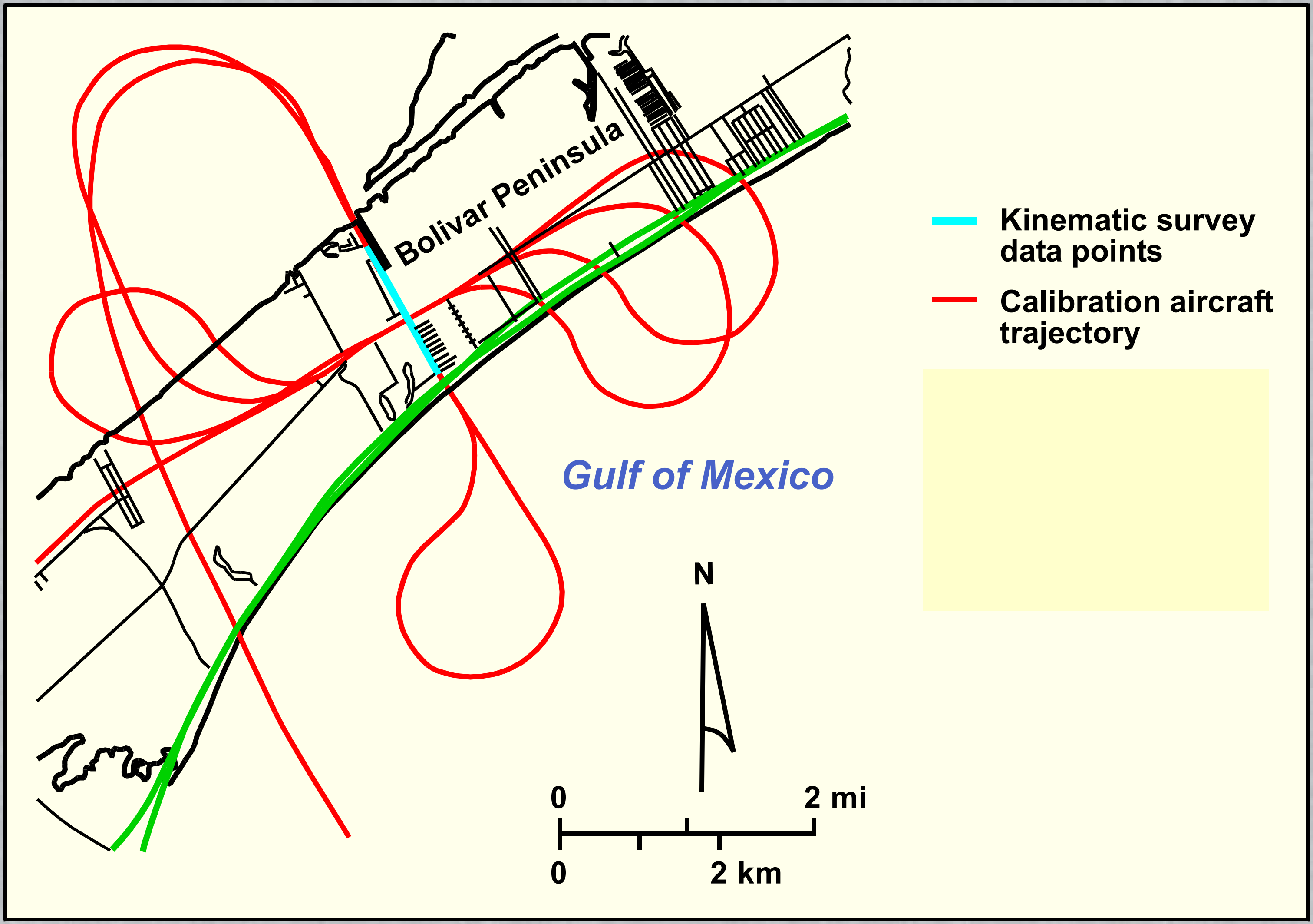
Lidar Instrument in Cessna 206

(Optech ALTM 1225)



Calibration Target

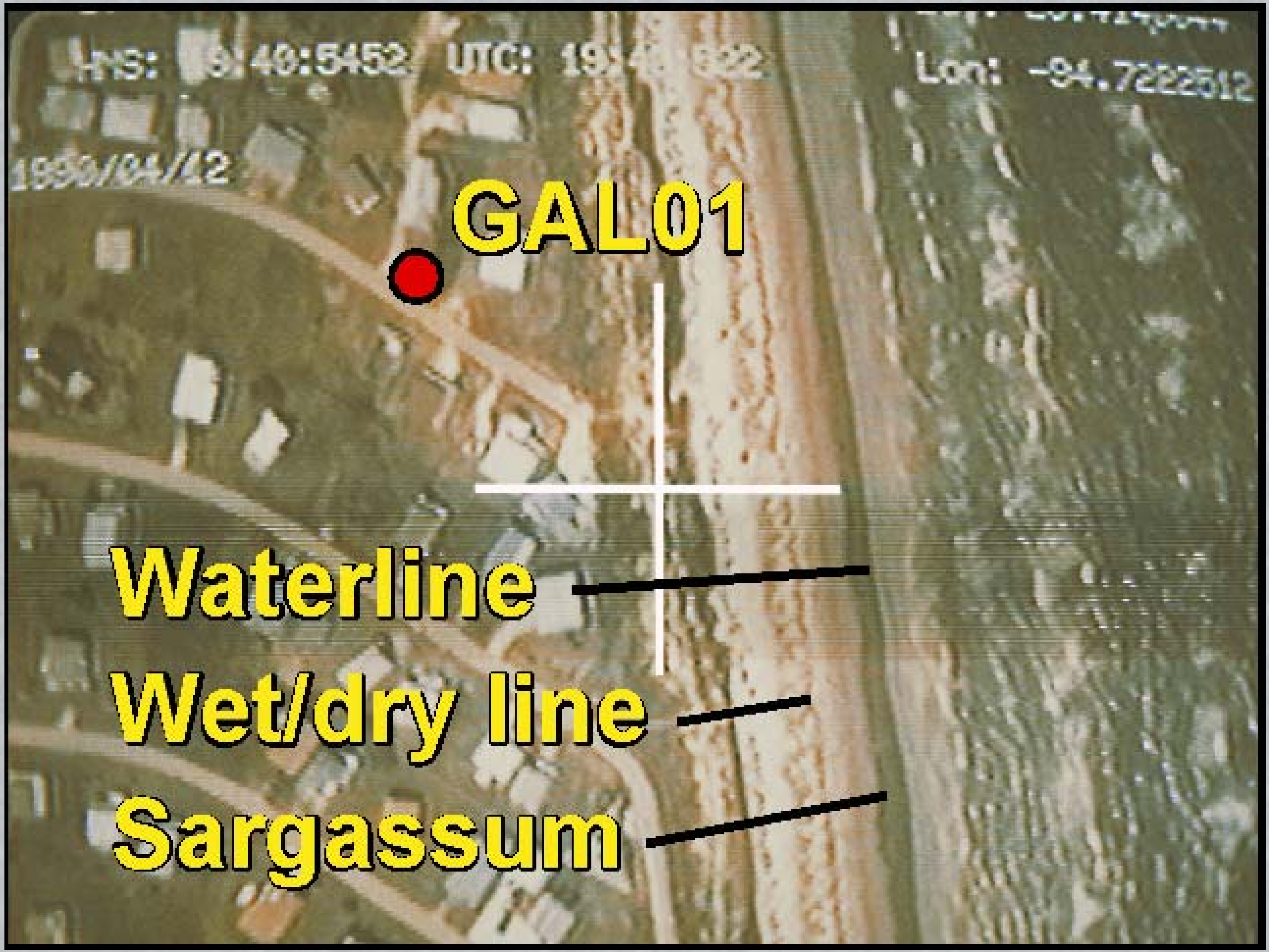
Calibration Flight Lines



Lidar Digital Elevation Model
1 - m grid

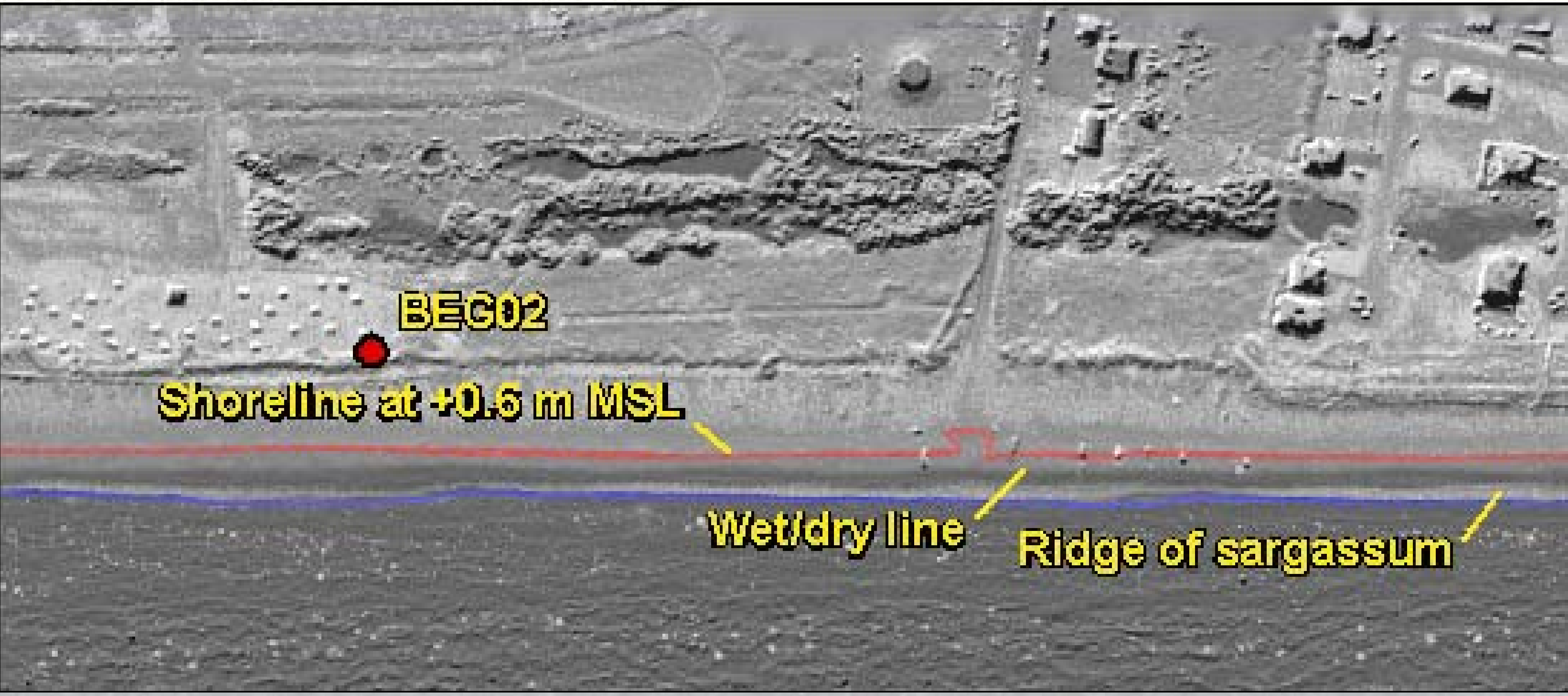
- Ellipsoidal heights converted to orthometric heights (NAVD 88) using GEOID99 gravity model.
- Local mean sea level (MSL) correction applied.

Lidar Survey Video

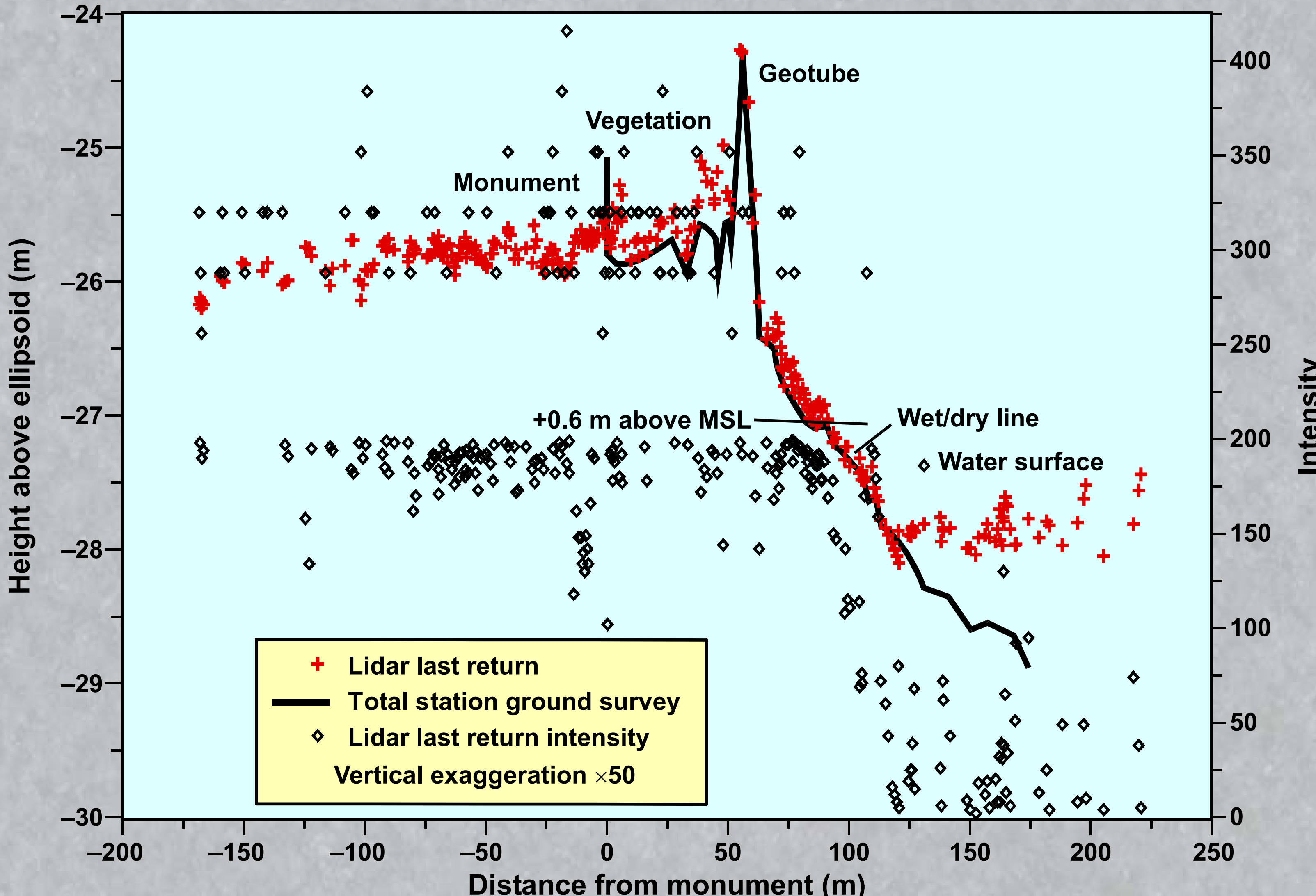


Galveston Beach

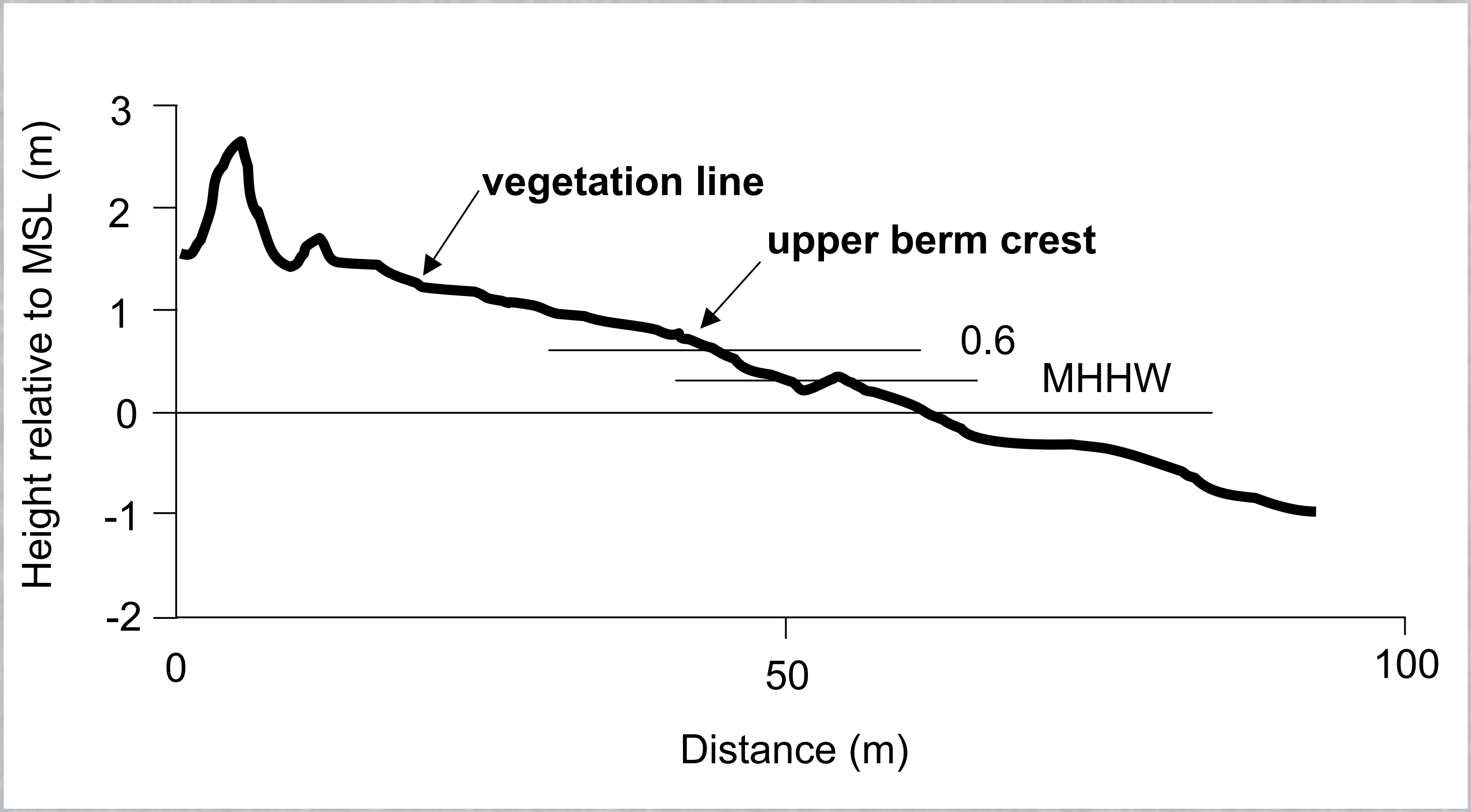
Lidar Intensity Drape on DEM



Galveston Island Profile



Representative Wet/Dry Elevation
0.6 m along Upper Tx Gulf Coast



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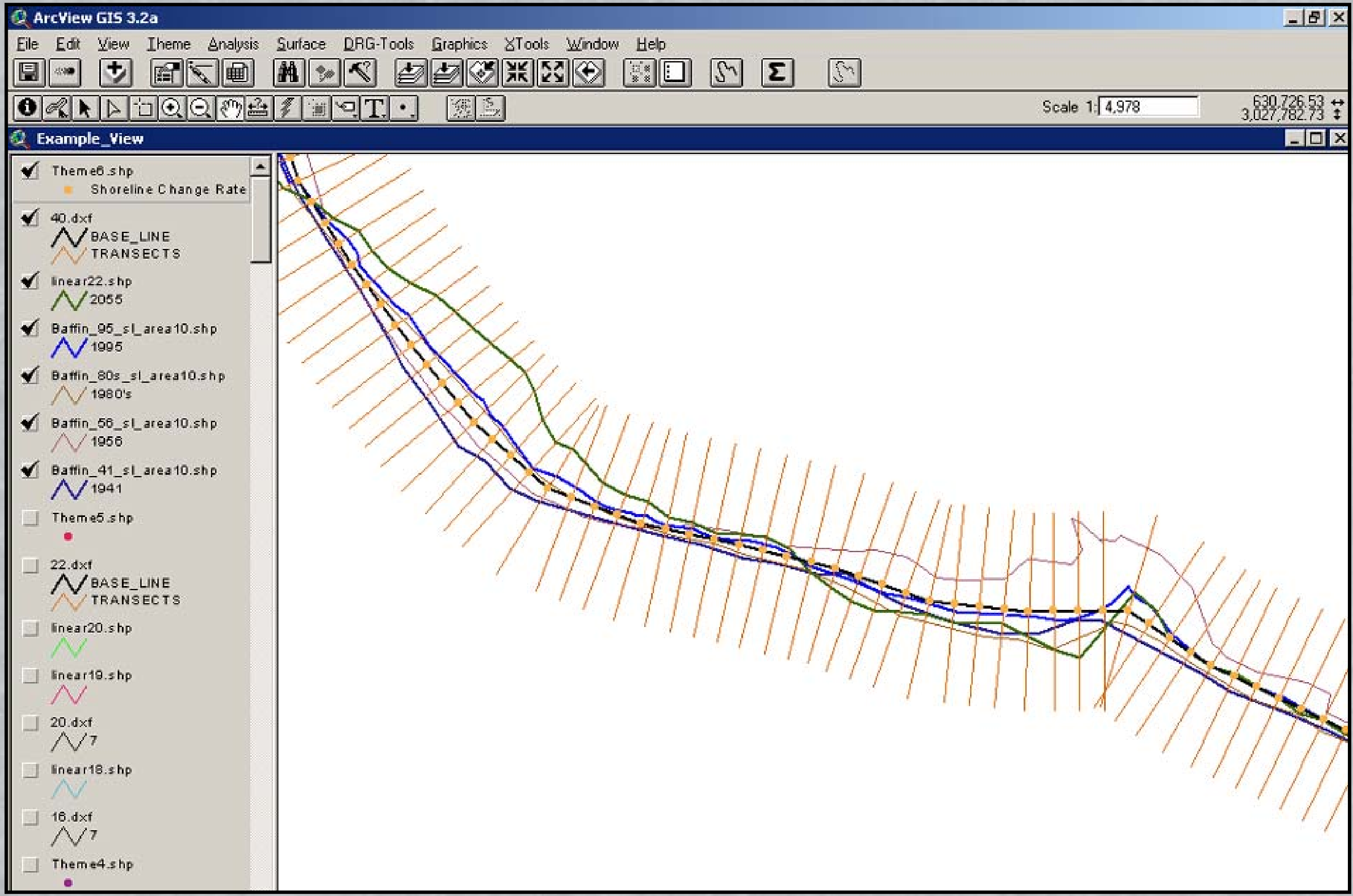
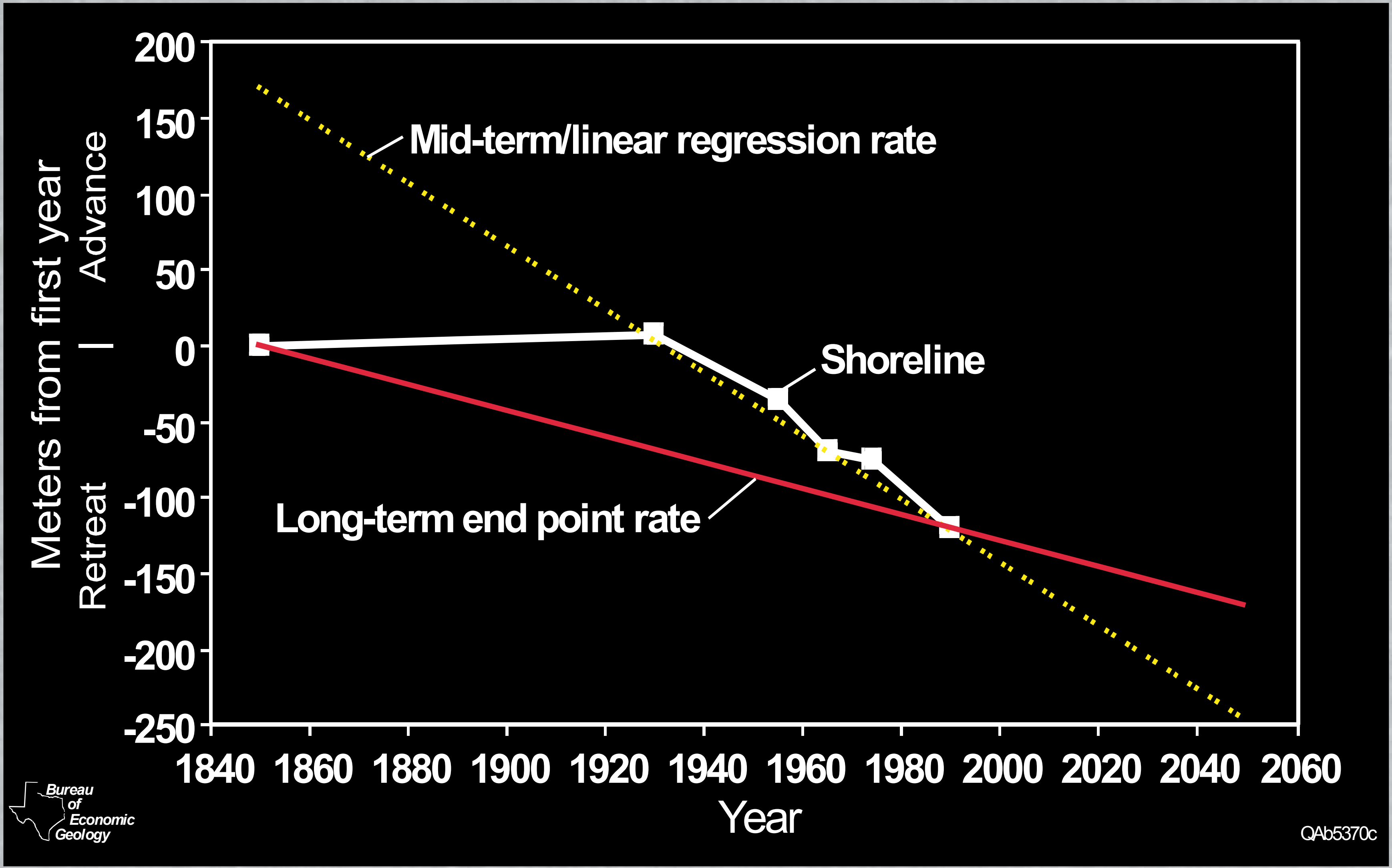
- Beach profile ground surveys
- Data availability and public awareness
  - Online reports
  - Web-based GIS using ArcIMS software

Shoreline Change and Projection Program

ArcView Interface



Shoreline Change Rate



Projected Shoreline
Galveston Island

Shoreline Change Analysis

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  - GIS-based Shoreline Shape and Projection Program (SSAPP)
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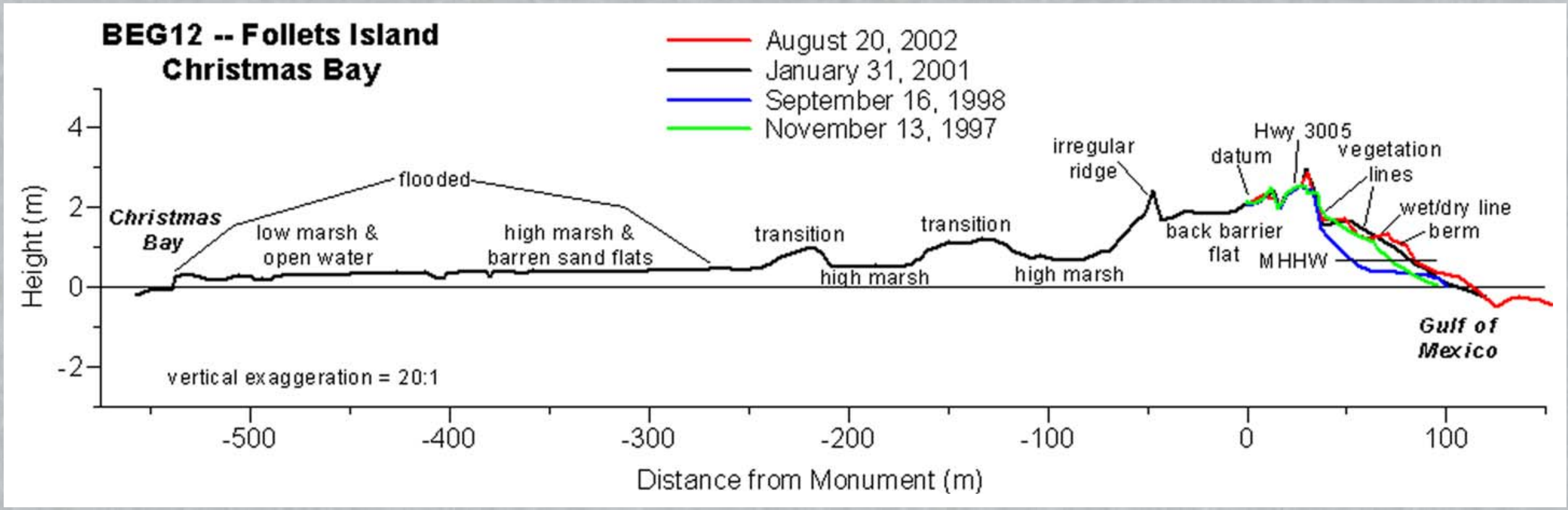
Ground Survey

Beach Profile
Annotated



Shoreline Change Analysis

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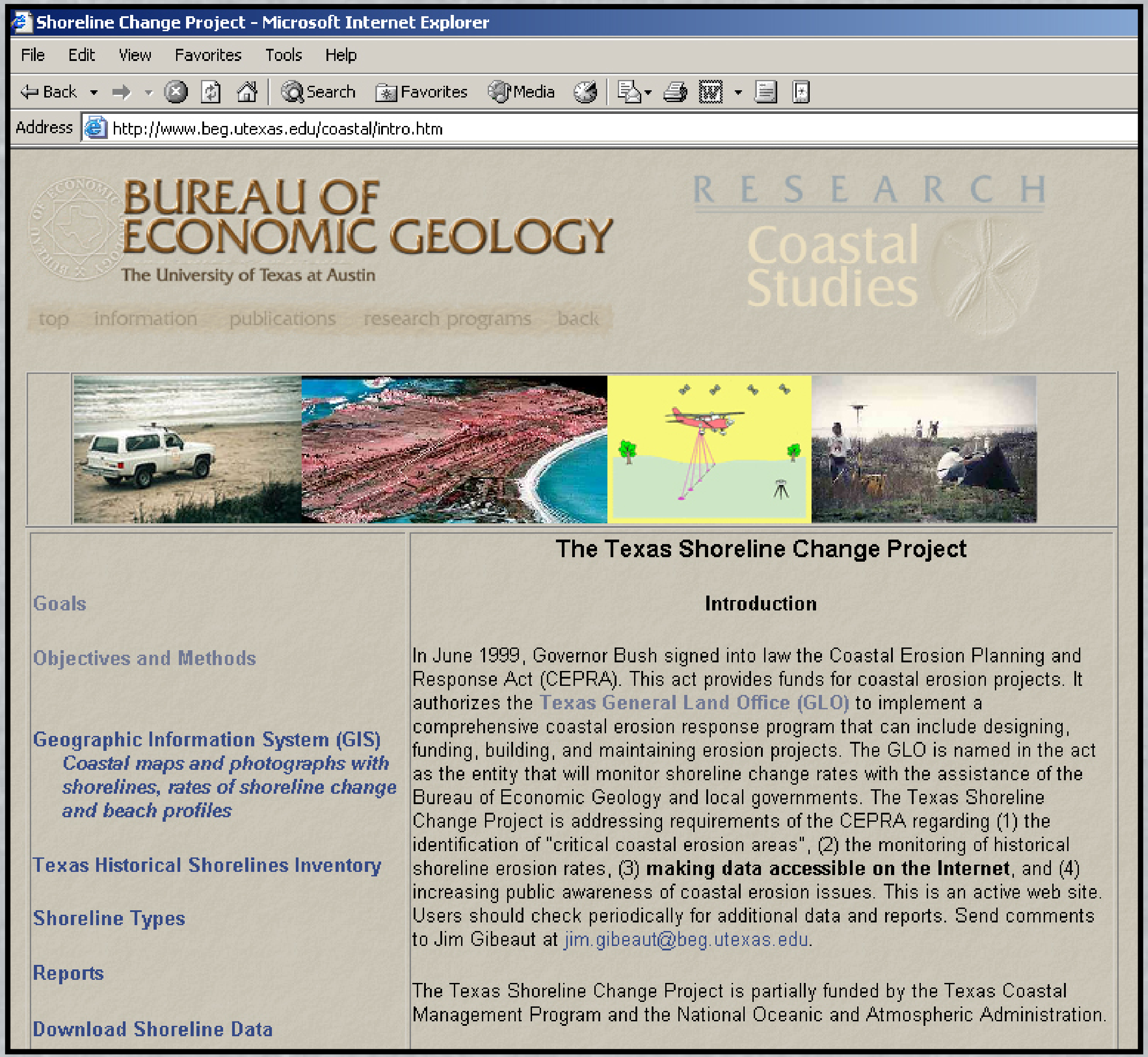
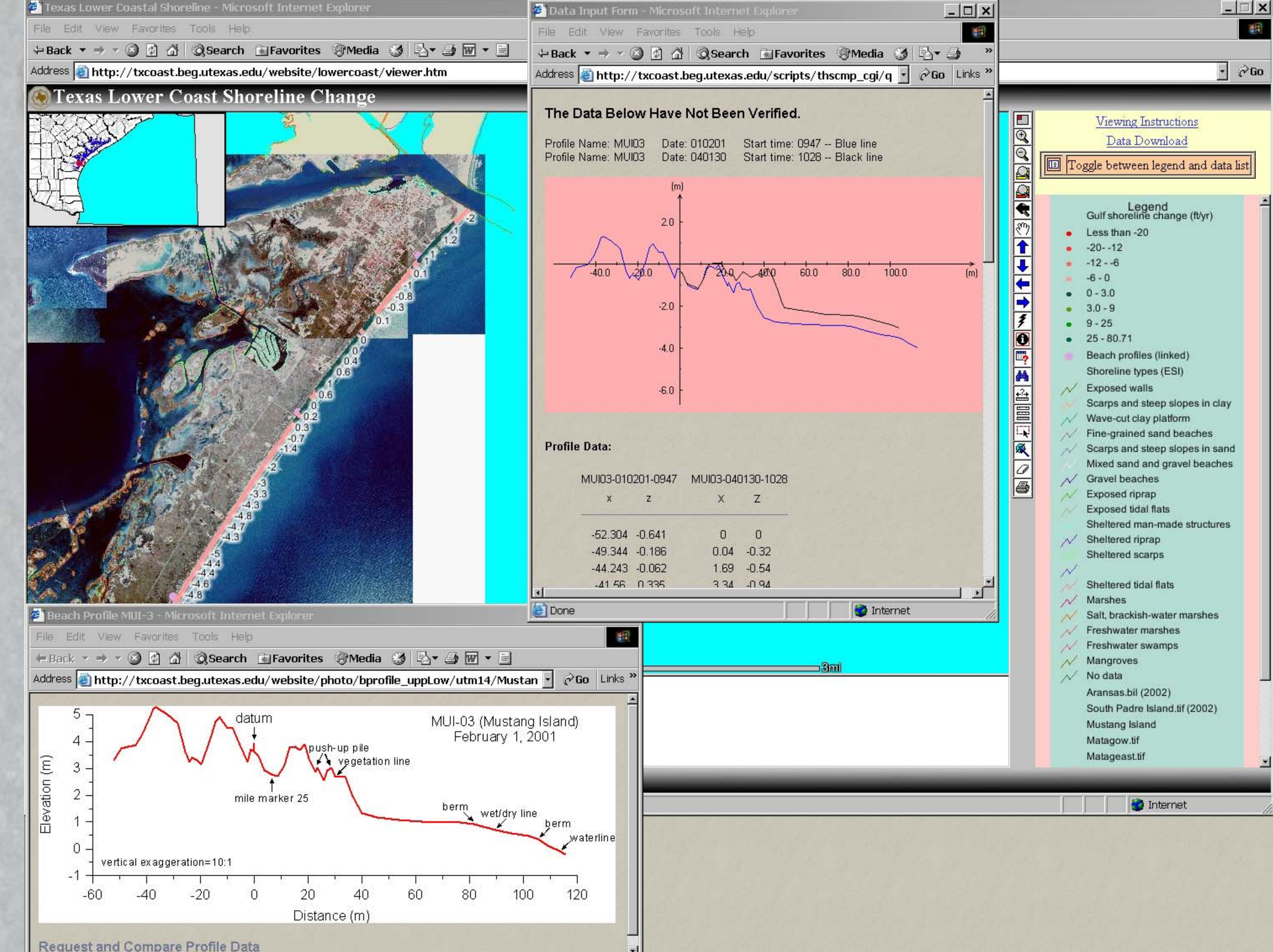
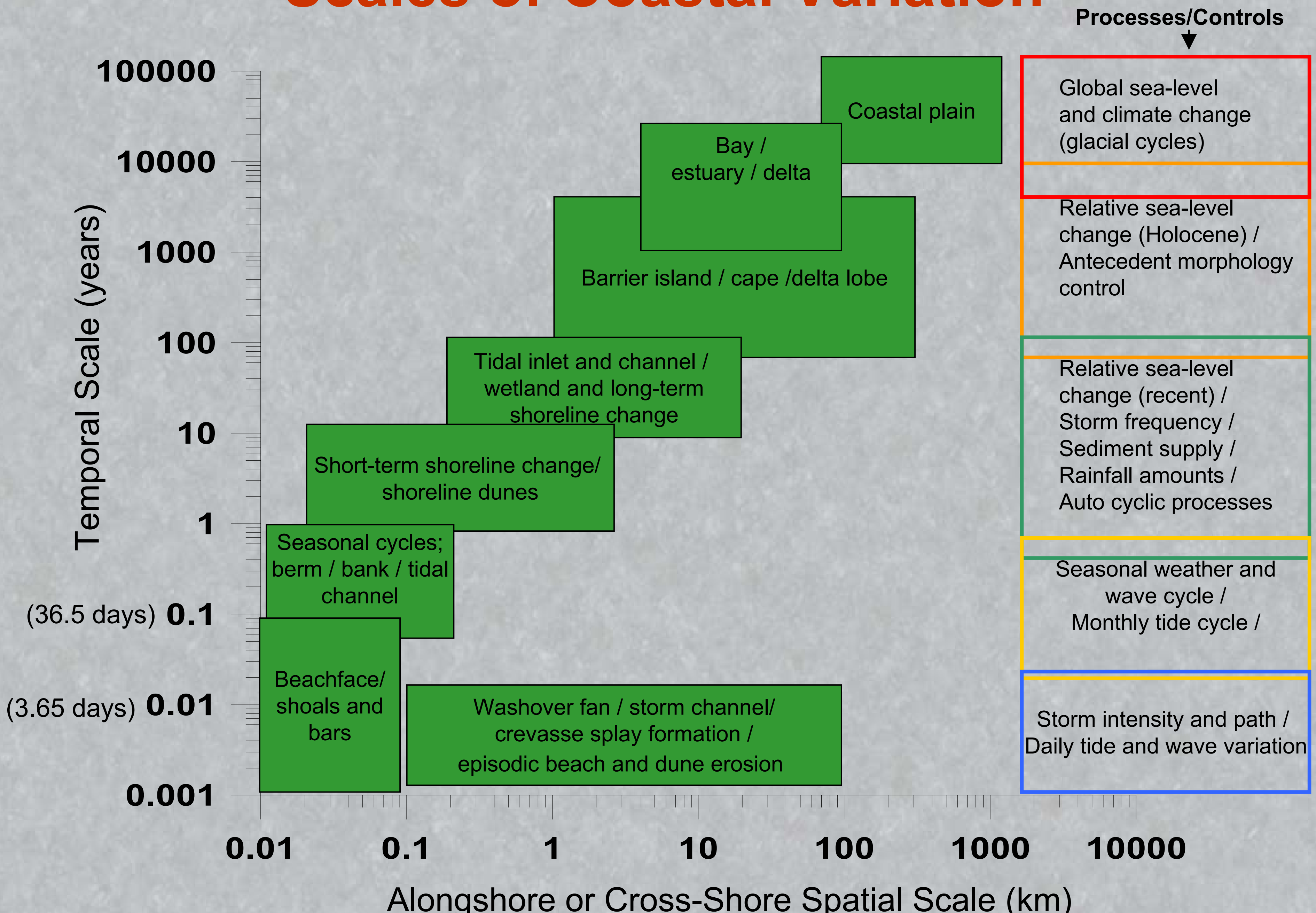
www.beg.utexas.edu/coastal/coastal01.htm

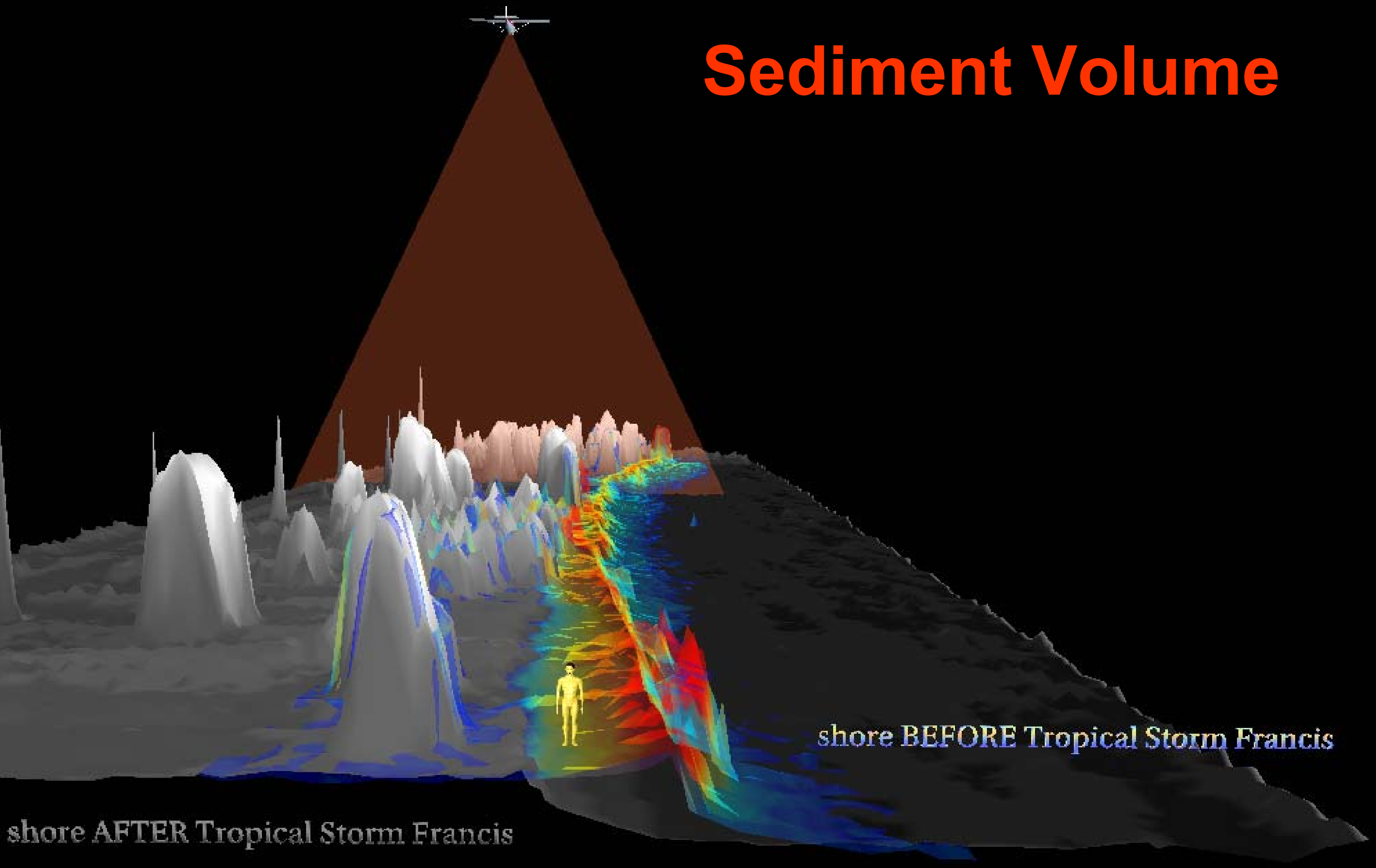



Texas Lower Coastal Shoreline - Microsoft Internet Explorer
http://txcoast.beg.utexas.edu/website/lowercoast/viewer.htm
Texas Lower Coast Shoreline Change
Data Input Form - Microsoft Internet Explorer
http://txcoast.beg.utexas.edu/scripts/thscmp_cgi/q
The Data Below Have Not Been Verified.
Profile Name: MUI03 Date: 010201 Start time: 0947 -- Blue line
Profile Name: MUI03 Date: 040130 Start time: 1028 -- Black line
Profile Data:
MUI03-010201-0947 MUI03-040130-1028
x z x z
-52.304 -0.641 0 0
-49.344 -0.186 0.04 -0.32
-44.243 -0.062 1.69 -0.54
Viewing Instructions
Data Download
Toggle between legend and data list
Legend
Gulf shoreline change (ft/yr)
Less than -20
-20 - -12
-12 - -6
-6 - 0
0 - 3.0
3.0 - 9
9 - 25
25 - 80.71
Beach profiles (linked)
Shoreline types (ESI)
Exposed walls
Scarps and steep slopes in clay
Wave-cut clay platform
Fine-grained sand beaches
Scarps and steep slopes in sand
Mixed sand and gravel beaches
Gravel beaches
Exposed riprap
Exposed tidal flats
Sheltered man-made structures
Sheltered riprap
Sheltered scarps
Sheltered tidal flats
Marshes
Salt, brackish-water marshes
Freshwater marshes
Freshwater swamps
Mangroves
No data
Aransas.bil (2002)
South Padre Island.tif (2002)
Mustang Island
Matagow.tif
Matageast.tif
Beach Profile MUI-3 - Microsoft Internet Explorer
http://txcoast.beg.utexas.edu/website/photo/bprofile_uppLow/utm14/Mustan
MUI-03 (Mustang Island)
February 1, 2001
datum
push-up pile
vegetation line
mile marker 25
berm
wet/dry line
berm
waterline
vertical exaggeration=10:1
Elevation (m)
Distance (m)
Request and Compare Profile Data

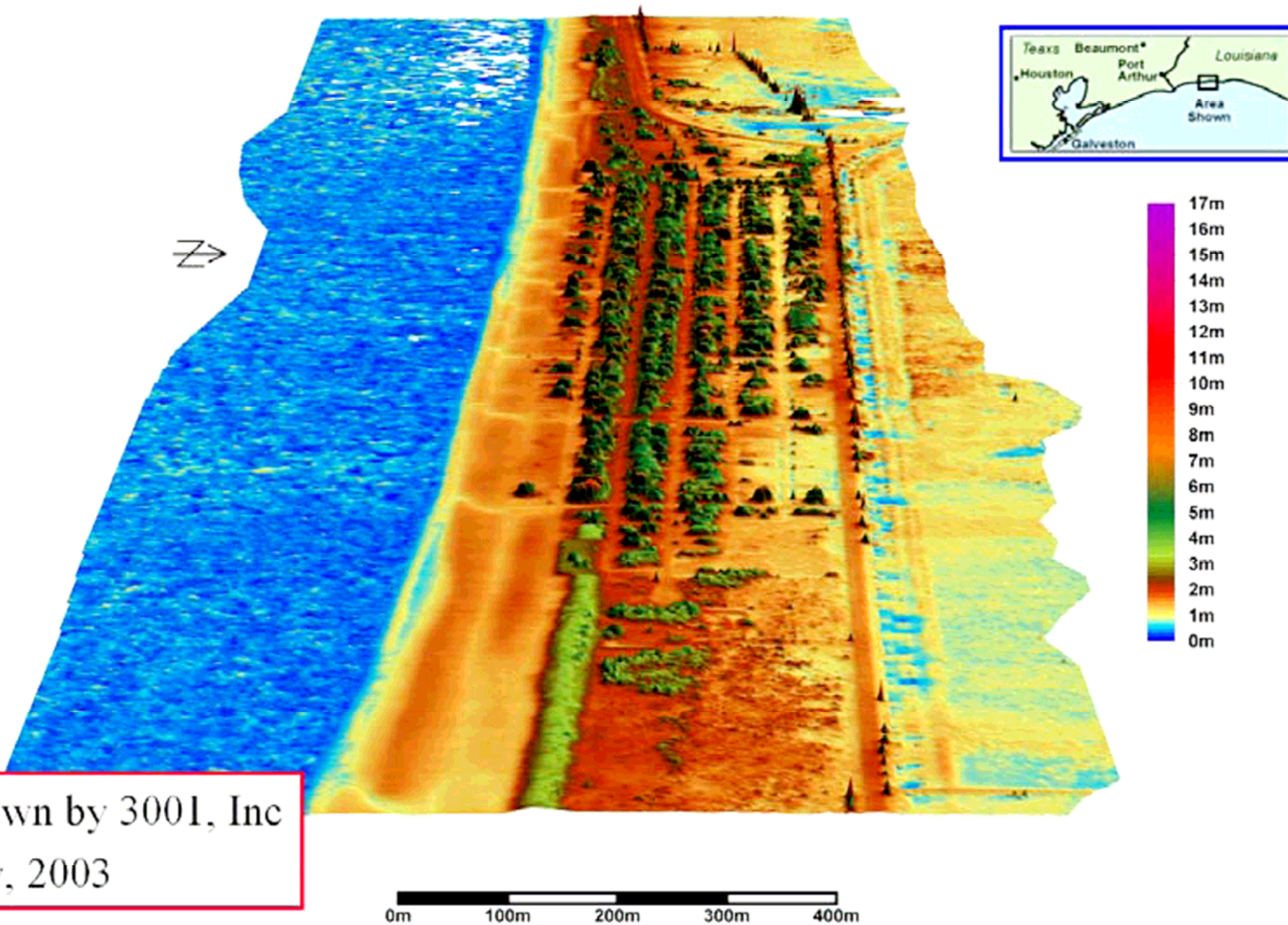
Scales of Coastal Variation



Sediment Volume

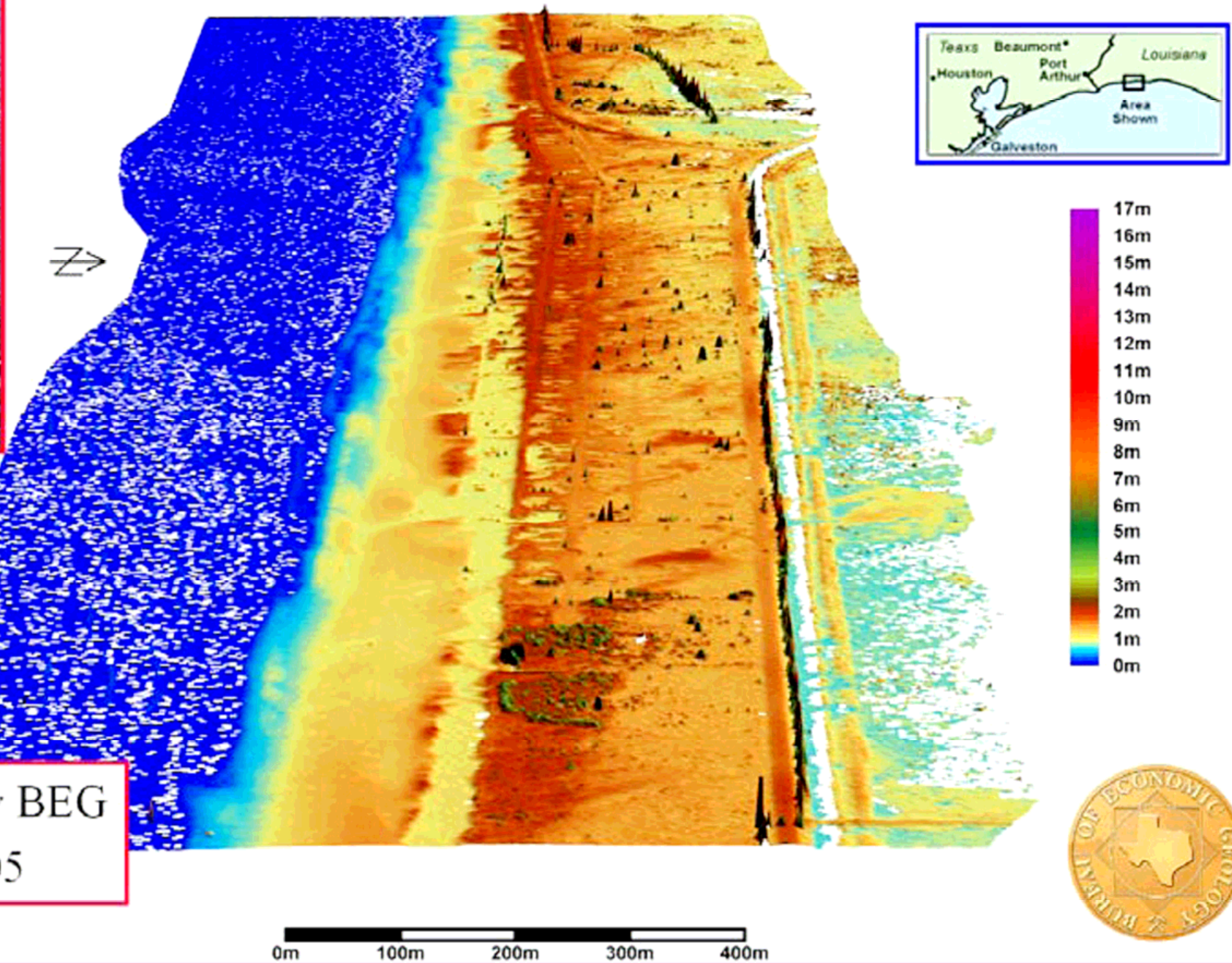


Holly Beach , Louisiana

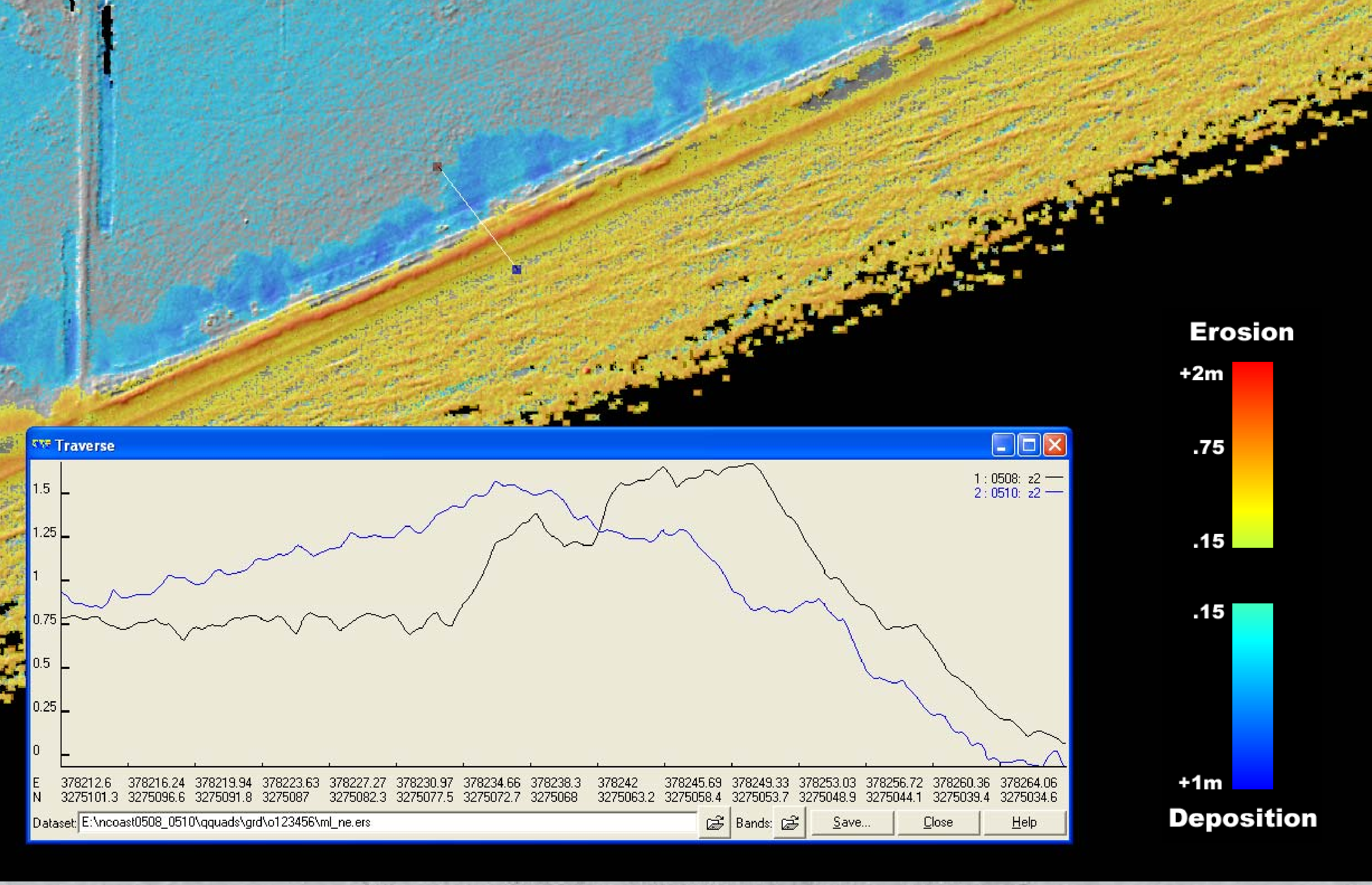


Lidar flown by 3001, Inc
February, 2003

Holly Beach , Louisiana

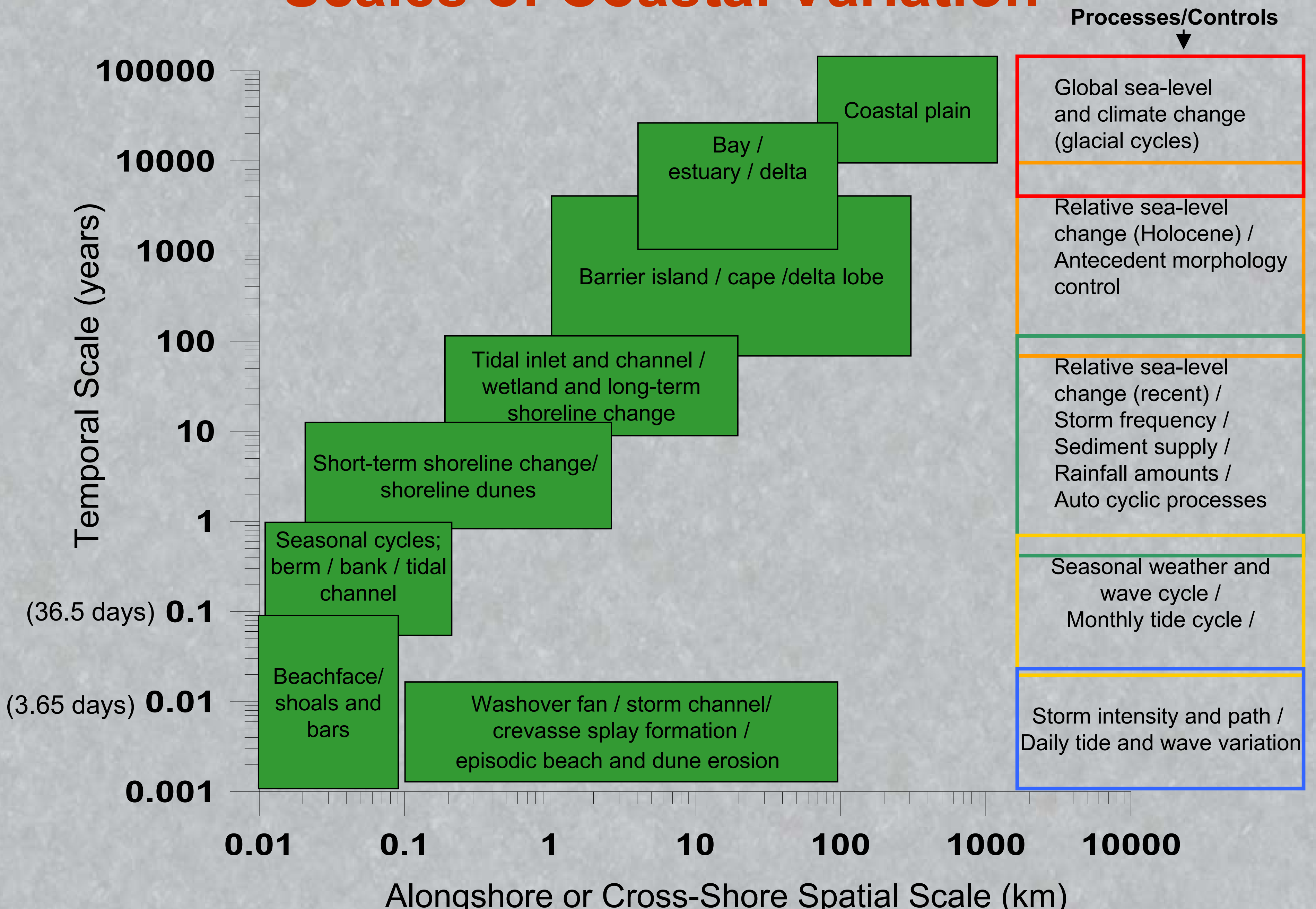


Lidar flown by BEG
6 October, 2005



Traverse
1 : 0508: z2
2 : 0510: z2
1.5
1.25
1
0.75
0.5
0.25
0
E 378212.6 378216.24 378219.94 378223.63 378227.27 378230.97 378234.66 378238.3 378242 378245.69 378249.33 378253.03 378256.72 378260.36 378264.06
N 3275101.3 3275096.6 3275091.8 3275087 3275082.3 3275077.5 3275072.7 3275068 3275063.2 3275058.4 3275053.7 3275048.9 3275044.1 3275039.4 3275034.6
Dataset: E:\ncoast0508_0510\qquads\grd\o123456\ml_ne.ers
Bands:
Save...
Close
Help
Erosion
+2m
.75
.15
.15
+1m
Deposition

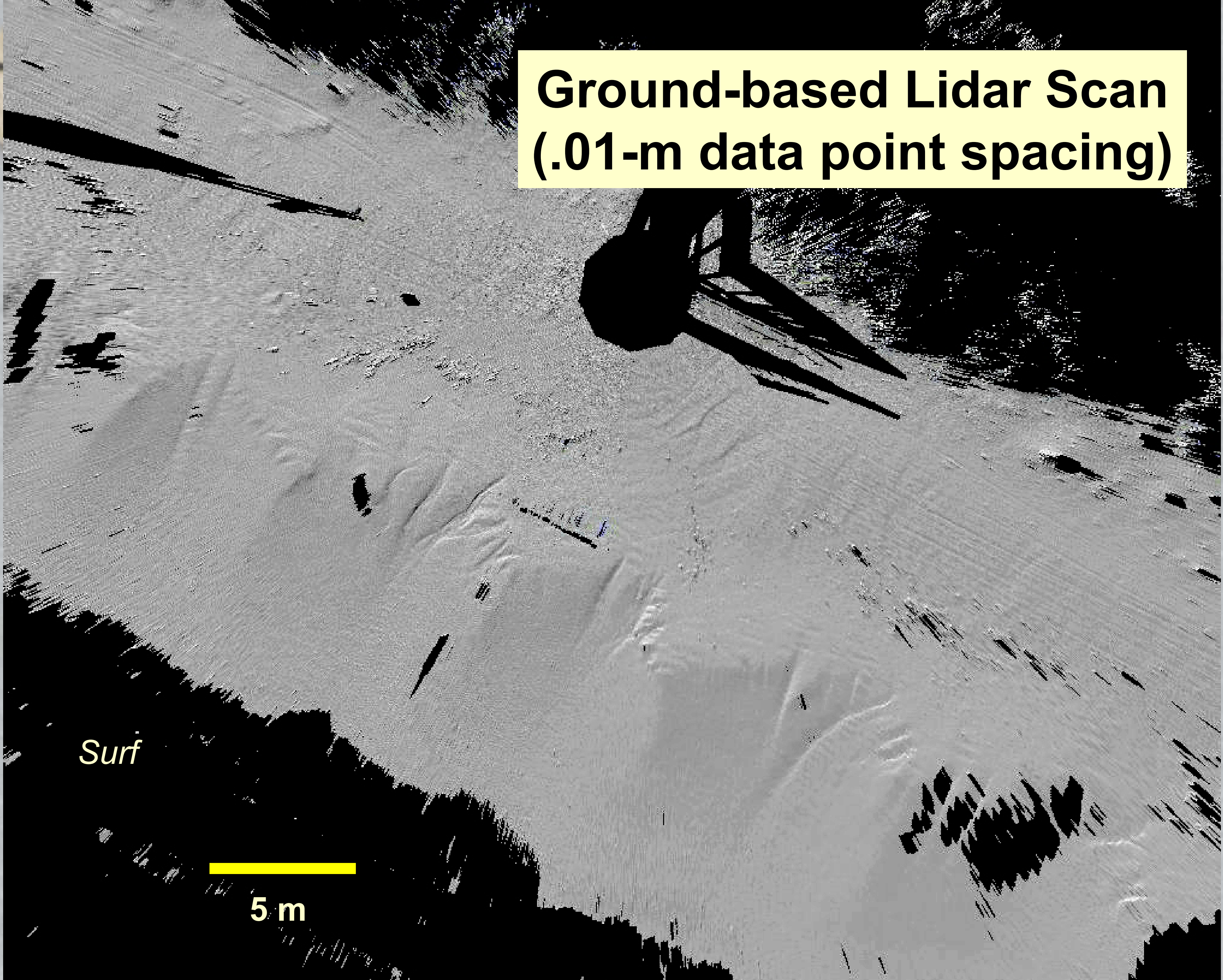
Scales of Coastal Variation



Ground-based Lidar Mapping

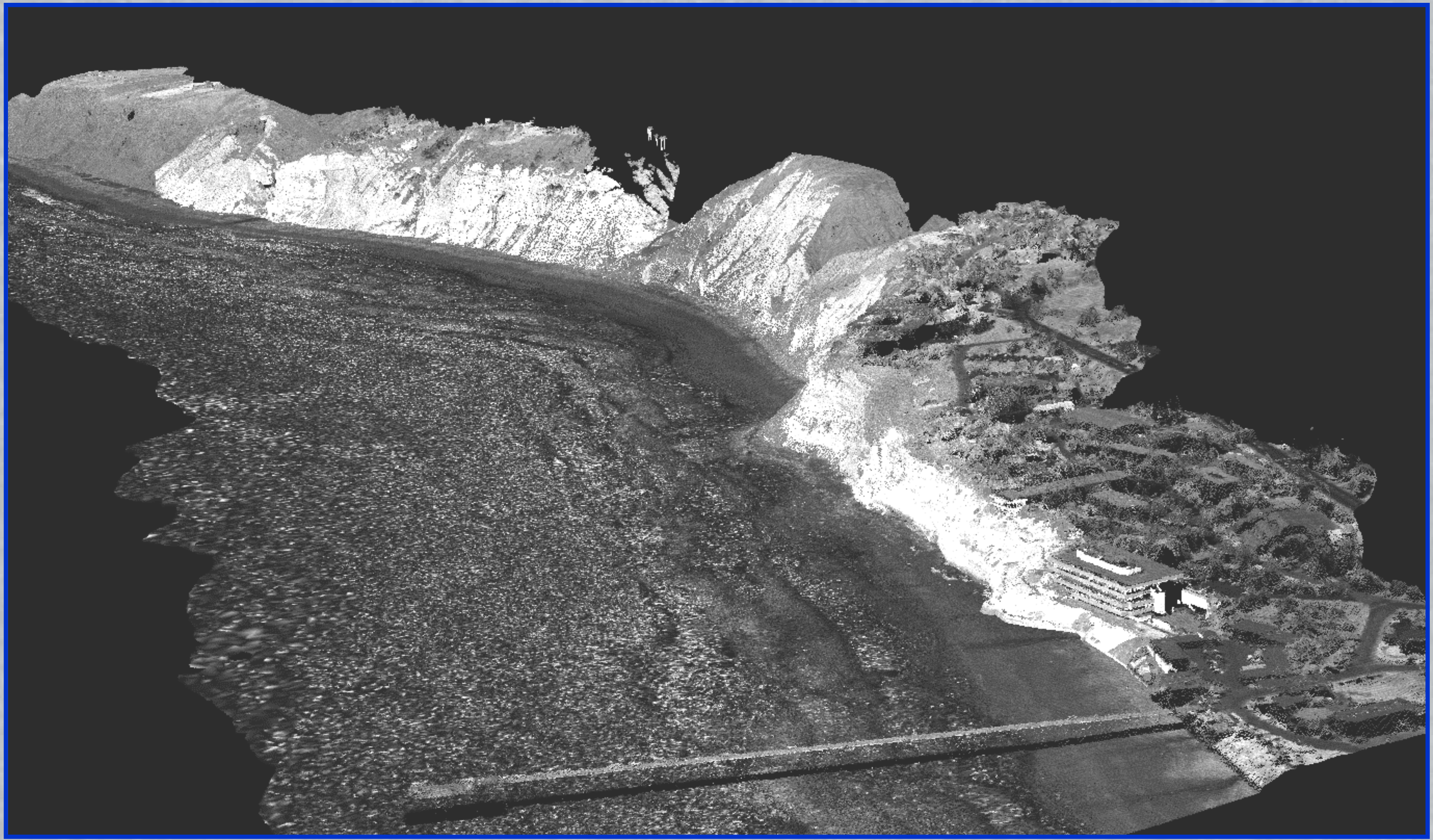
(Opetch Inc., ILRIS Instrument)

Ground-based lidar scanners are capable of capturing data at a rate of 2,000 points per second. Laser point spacing is between 2 and 10 centimeters with individual scans covering 10’s to 100’s of meters. Depending on the distance between the scanner and the target and the target rugosity, 100’s of meters to kilometer can be scanned and merged in one day.


Ground-based Lidar Scan
(.01-m data point spacing)
Surf
5 m


Ashtech

Merged Airborne and Ground-Based Lidar, La Jolla, California



Last Slide

We need to start or continue to build a data set of adequate spatial and temporal resolution.

www.beg.utexas.edu/coastal/coastal01.htm

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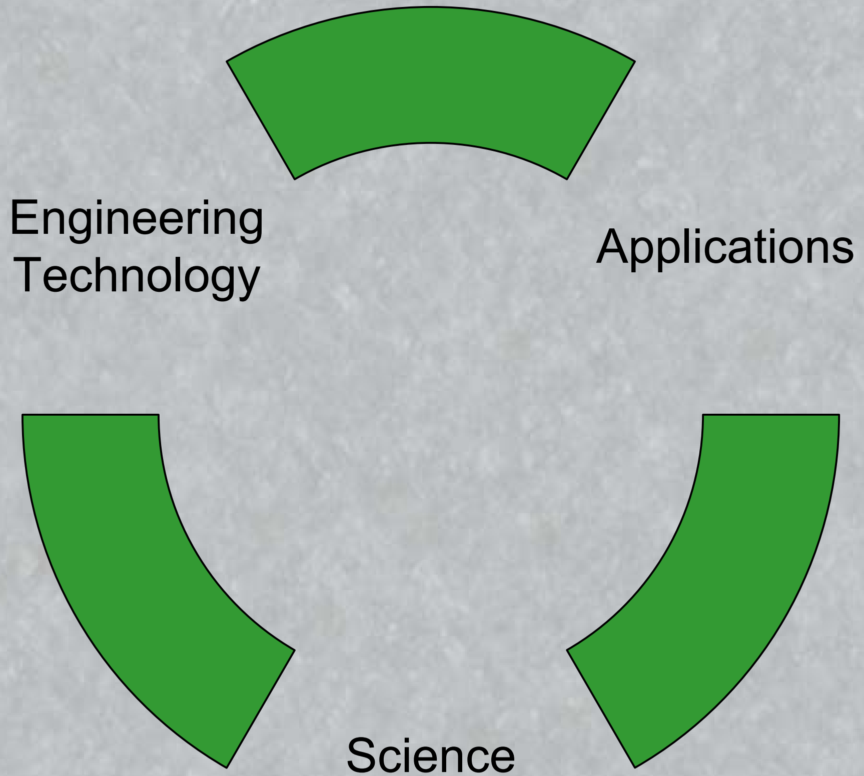
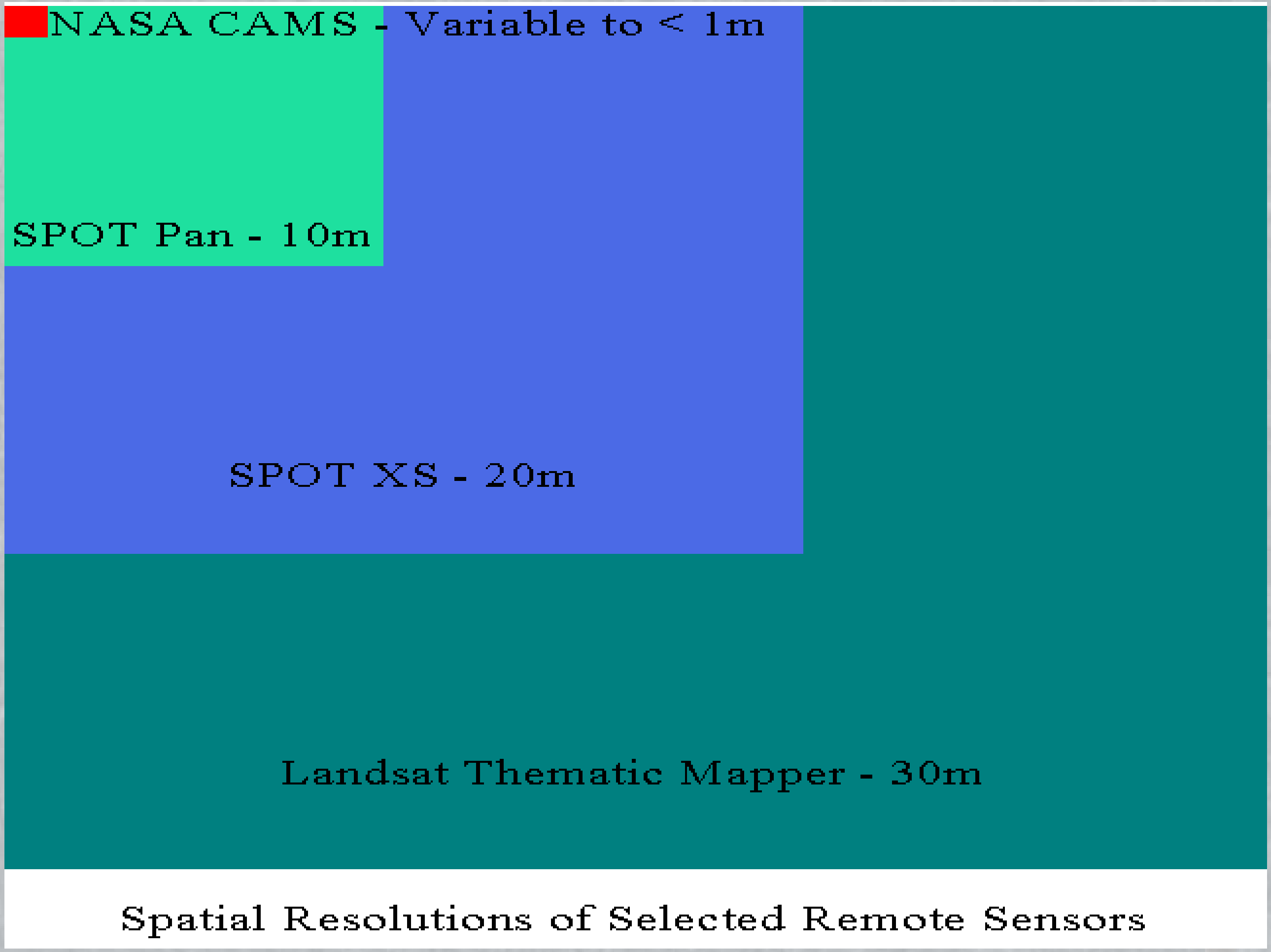
BUREAU OF ECONOMIC GEOLOGY

CSG

Problem Solving Cycle

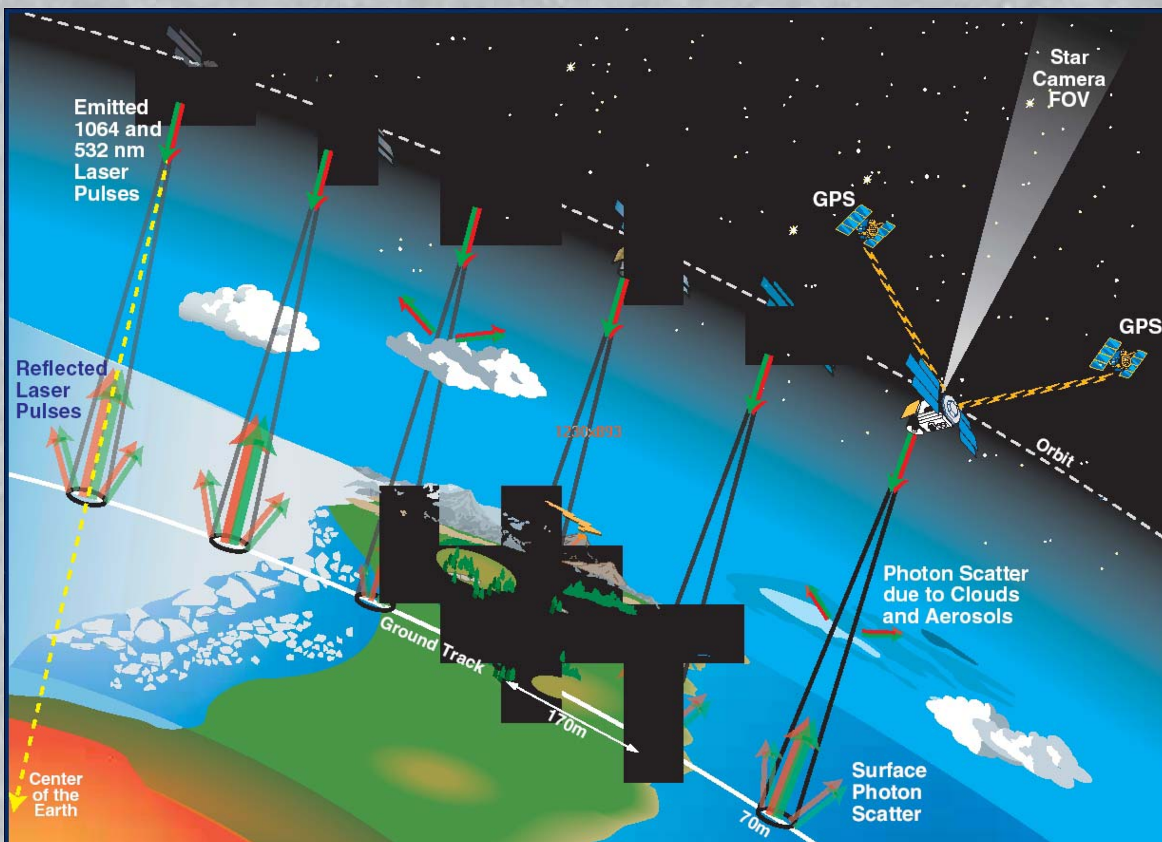


Spatial Resolution of Remote Sensors



From Jensen and Jackson, University of South Carolina

Space - Based Lidar
GLAS
Geoscience Laser Altimeter System



Graphic by Deborah McLean

Carried on the Ice, Cloud and land Elevation Satellite (ICESat)

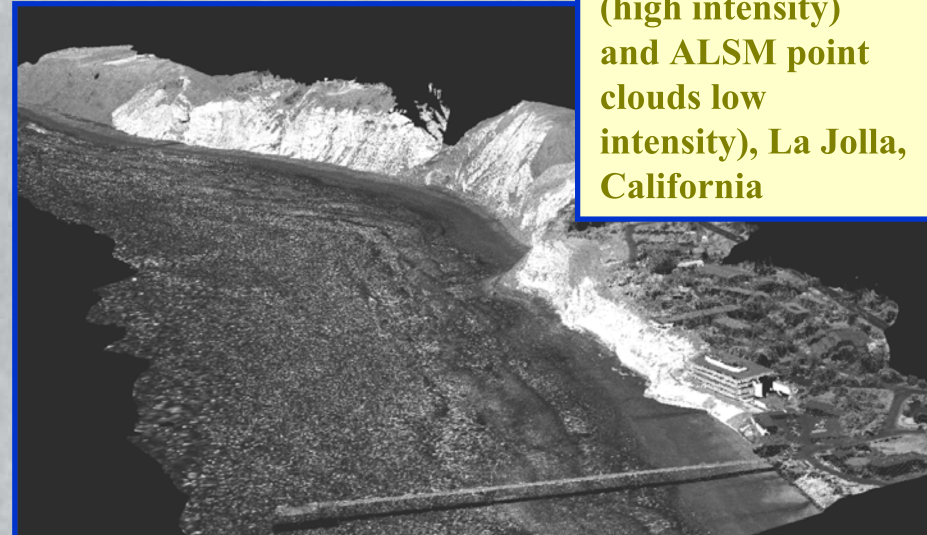
70 - m diameter spot size and 175 - m spacing between spots

Launched January 2003

www.csr.utexas.edu/glas/

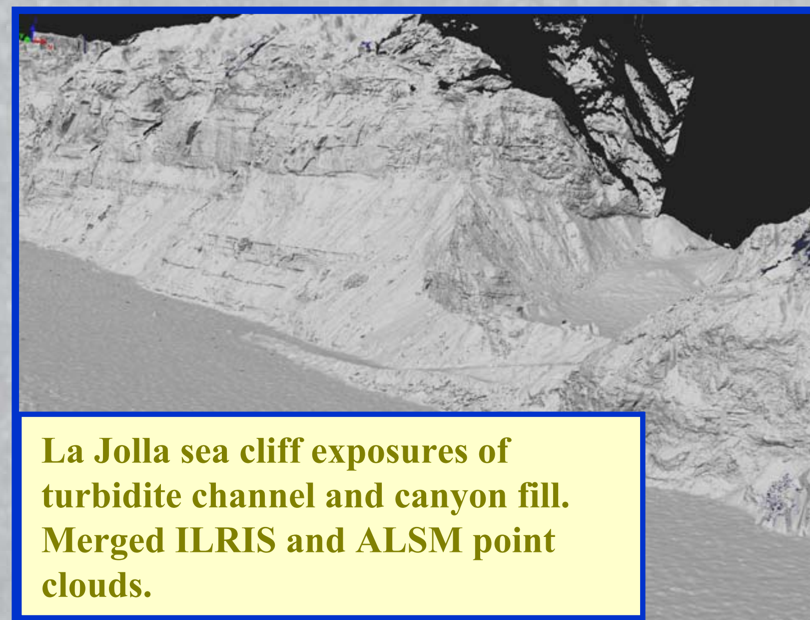
Ground-based Lidar Mapping

Ground-based lidar scanners are capable of capturing data at a rate of 2,000 points per second. Laser point spacing is between 2 and 10 centimeters with individual scans covering 10’s to 100’s of meters. Depending on the distance between the scanner and the target and the target rugosity, 100’s of meters to kilometer can be scanned and merged in one day.



Merged ILRIS (high intensity) and ALSM point clouds low intensity), La Jolla, California

Jerome Bellian on Seal Point, north Scripps. Upper Eocene Scripps Formation is well exposed along the beach cliffs.



La Jolla sea cliff exposures of turbidite channel and canyon fill. Merged ILRIS and ALSM point clouds.

Air – Based

Coastal Studies Group

THE COASTAL ZONE

- Area of population concentration
- Center of:
  - Urbanization
  - Recreation
  - Industry
  - Transportation

Coastal Studies Group

Also site of:

- Critical natural land and water resources
- Dynamic processes, both natural and human induced

Coastal Studies Group

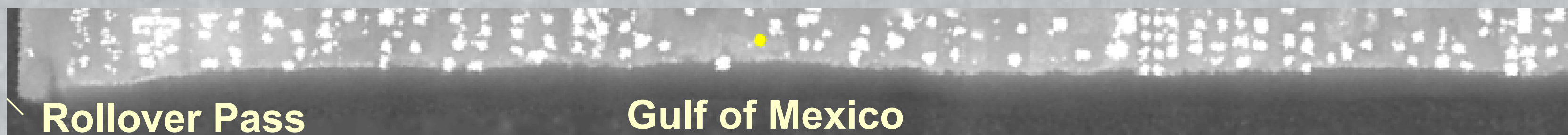
Understanding the interaction of natural processes and human activities on land and water resources of the coastal zone is essential in their prudent use, management, and conservation

Geomorphic/Engineering Change

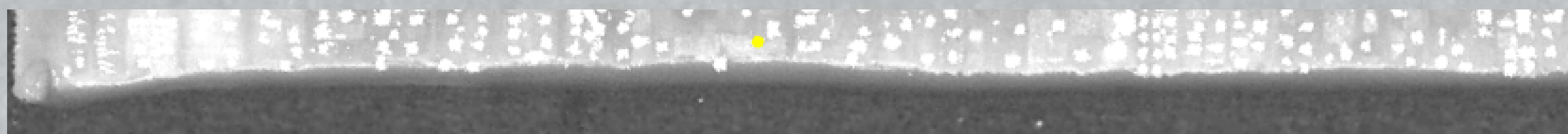
Bolivar Peninsula, Texas

1,000 ft

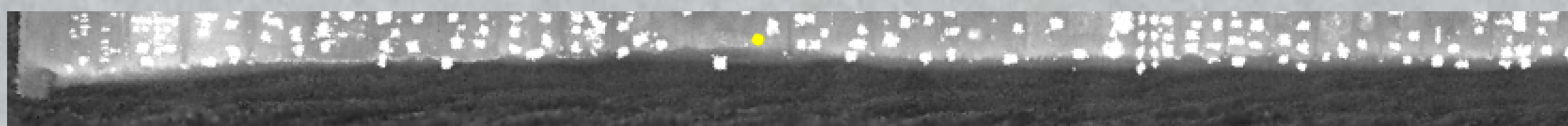
1997 Nov



1998 Pre-Frances

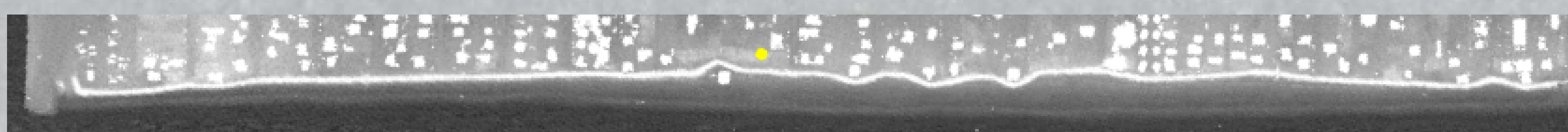


1998 Post-Frances



2000 Geotube installed

2001 July

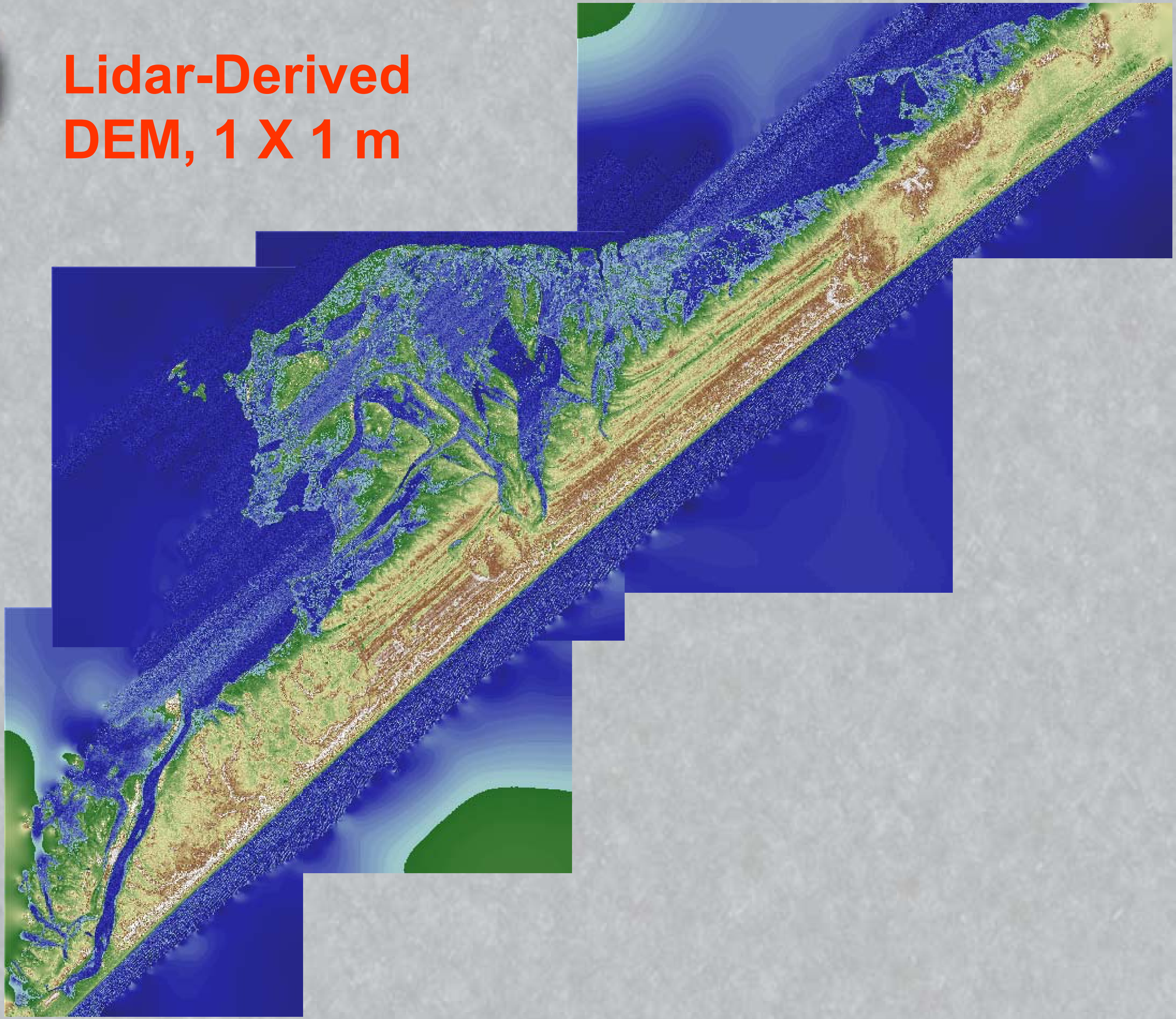


The Lidar Advantage

Historically, coastal scientists and engineers conducted regional studies using sparse data or local studies using detailed data. Lidar makes it possible to acquire detailed, accurate topographic data over a broad region, allowing geomorphic analysis across the continuum of the spatial scale.

DEM, 30 X 30 m
From National Elevation Data

Lidar-Derived DEM, 1 X 1 m



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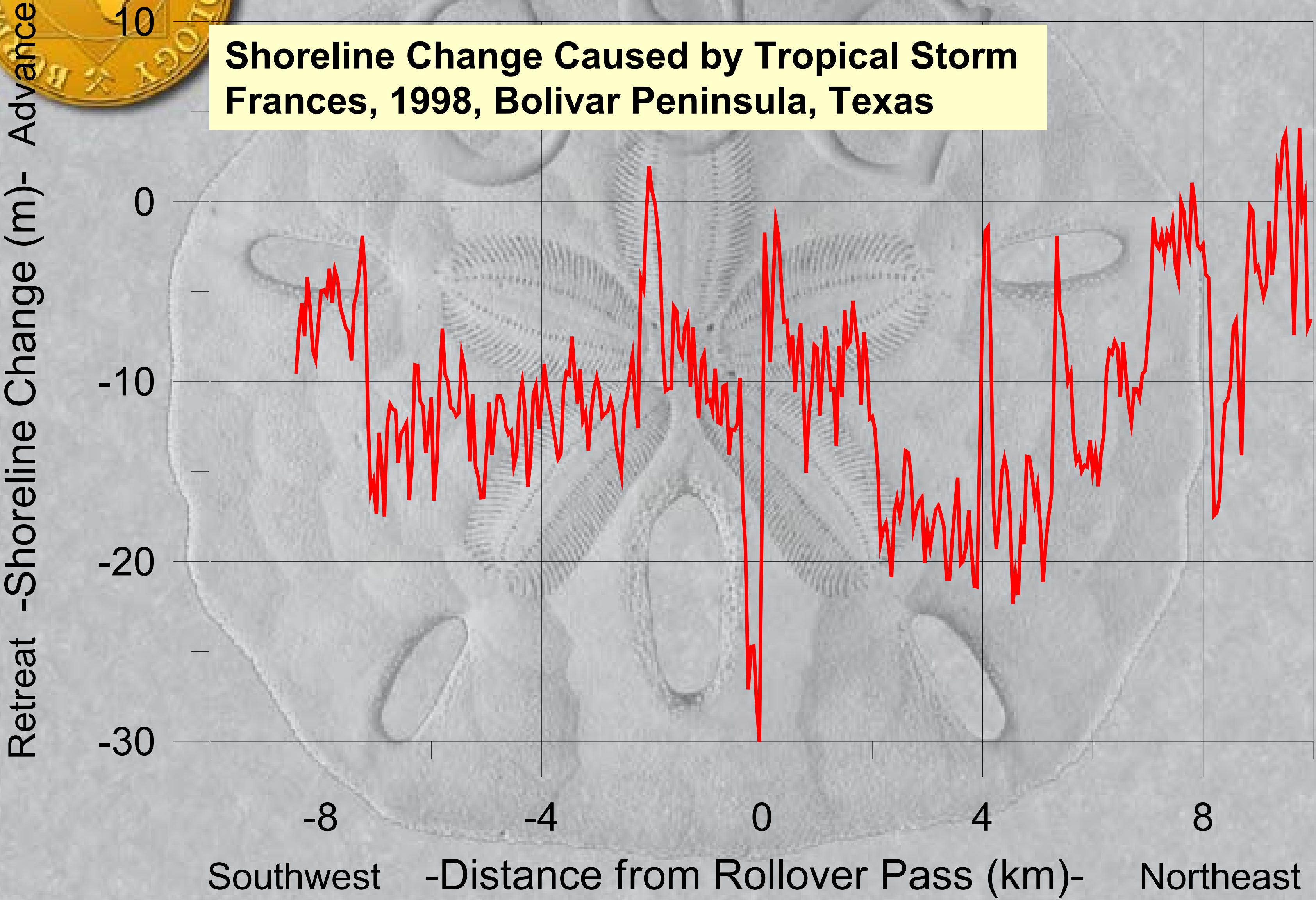
Shoreline Change Based on Elevation



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Mapping the Shoreline and Comparing Beach Widths

Shaded Relief Topographic Lidar Image
Galveston Island, Texas

Coastal Studies Group

Mapping the “Natural” Vegetation Line

Storm-Surge Inundation

Color IR Photography Draped On Lidar DEM

Storm-Surge Inundation

9.5 ft. Storm Surge

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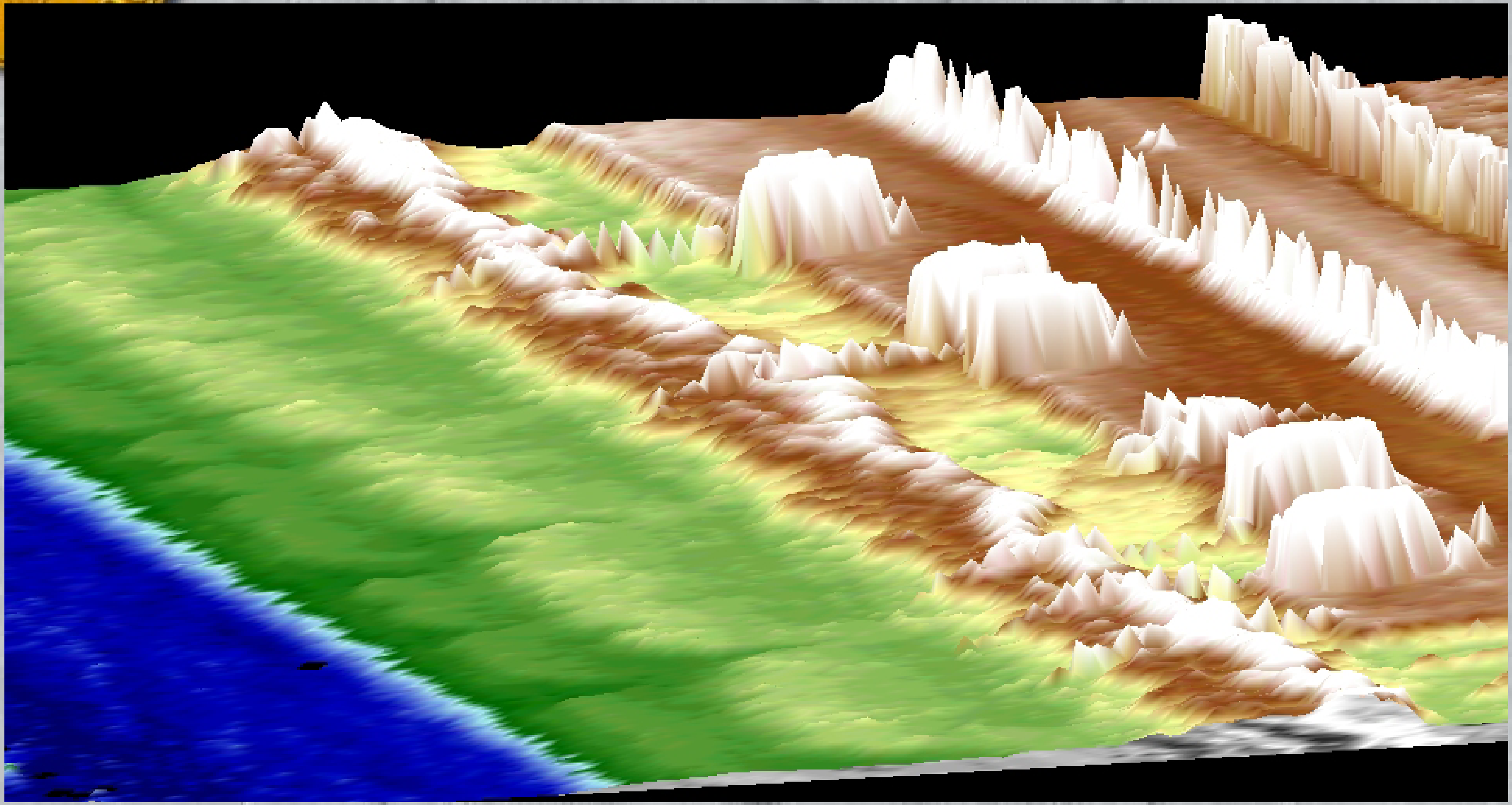

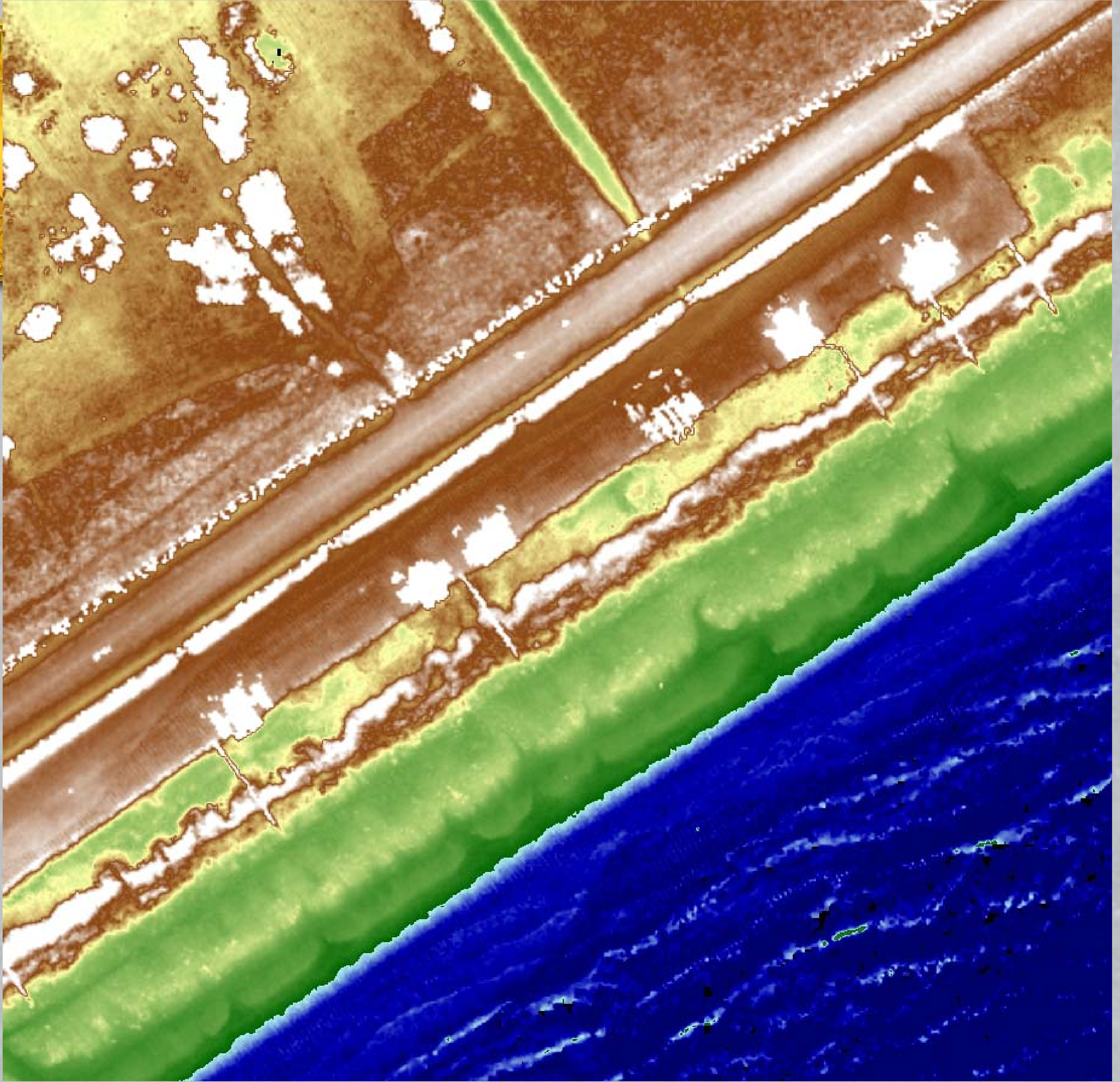

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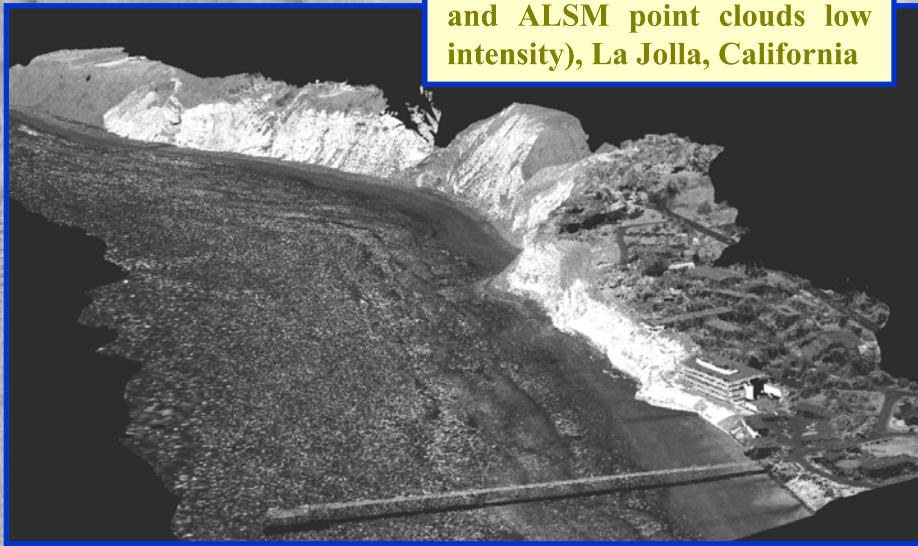
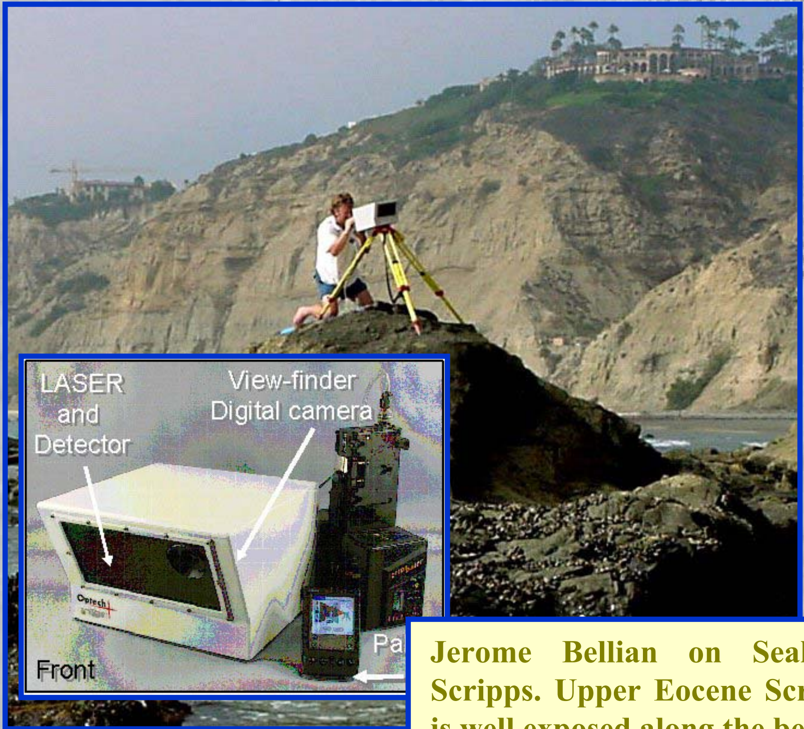
Galveston Beach

Ground-based Lidar Mapping

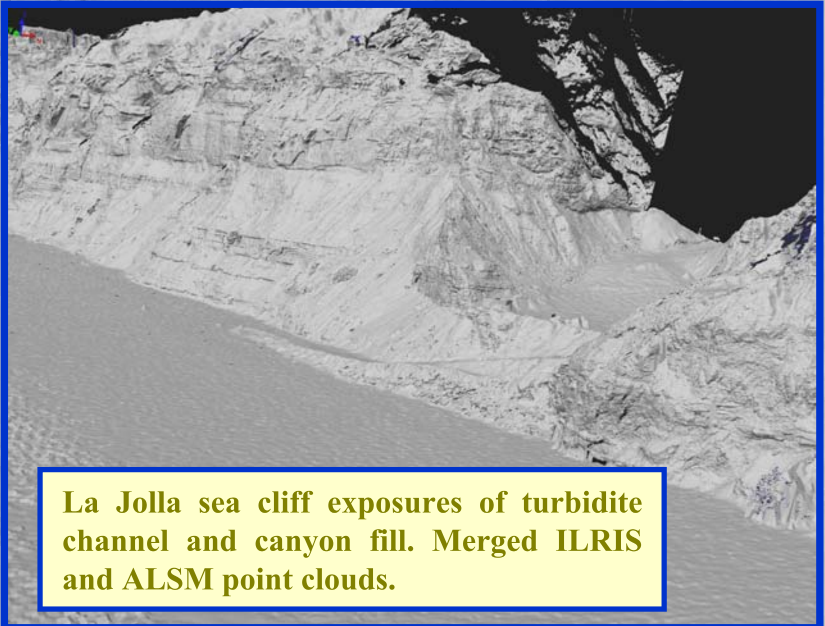
Ground-baesd lidar scanners are capable of capturing data at a rate of 2,000 points per second. Laser point spacing is between 2 and 10 cms with individual scans covering 10s to 100s of meters outcrop exposure. Depending on the distance between the scanner and the outcrop and the outcrop rugosity, 100s of meters to kilometers of outcrop can be scanned and merged in one day.



Merged ILRIS (high intensity) and ALSM point clouds low intensity), La Jolla, California



Jerome Bellian on Seal Point, north Scripps. Upper Eocene Scripps Formation is well exposed along the beach cliffs.



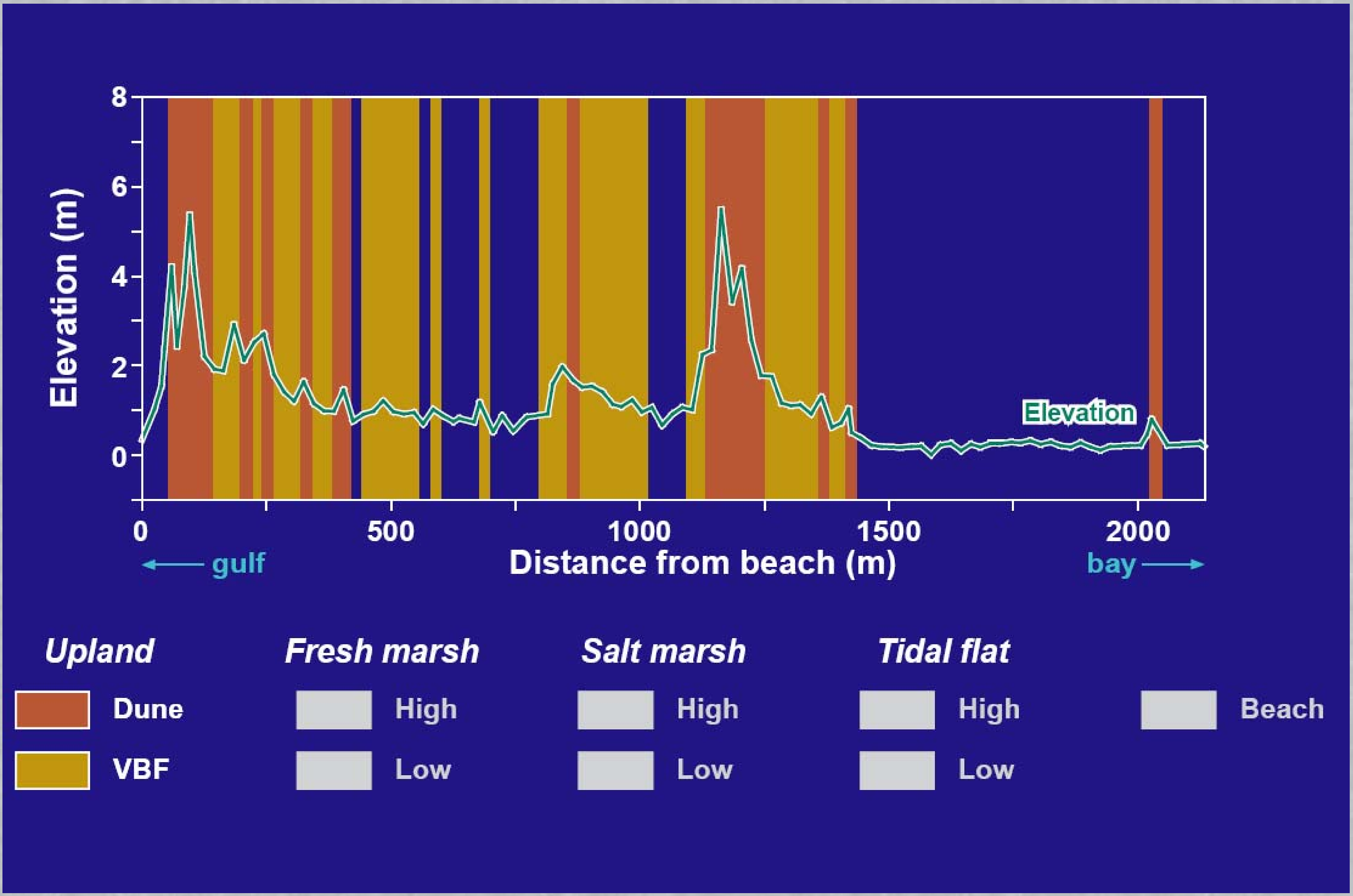
La Jolla sea cliff exposures of turbidite channel and canyon fill. Merged ILRIS and ALSM point clouds.

Changing Barrier Island Environments

1979

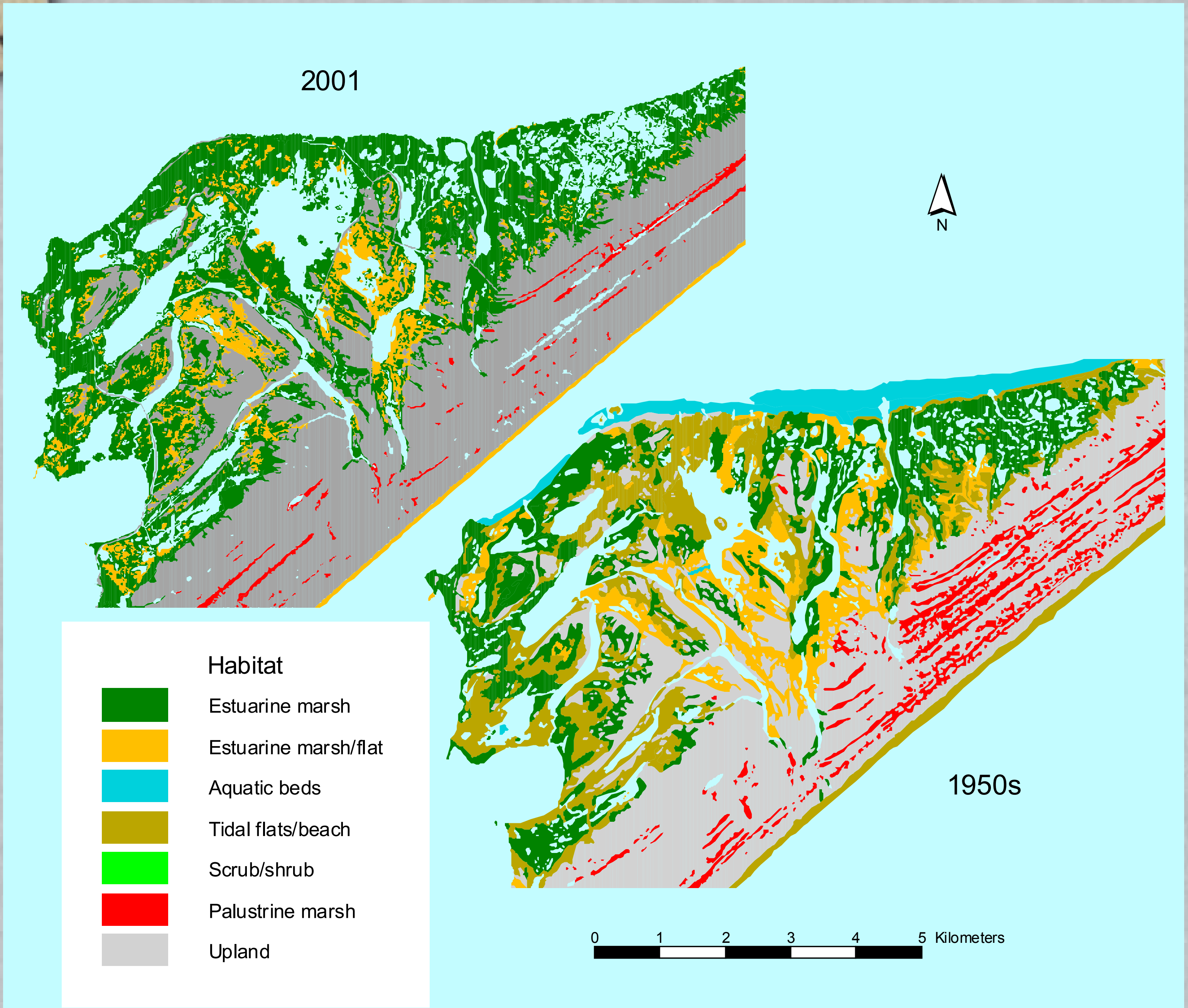
2004

Mustang Island, Texas

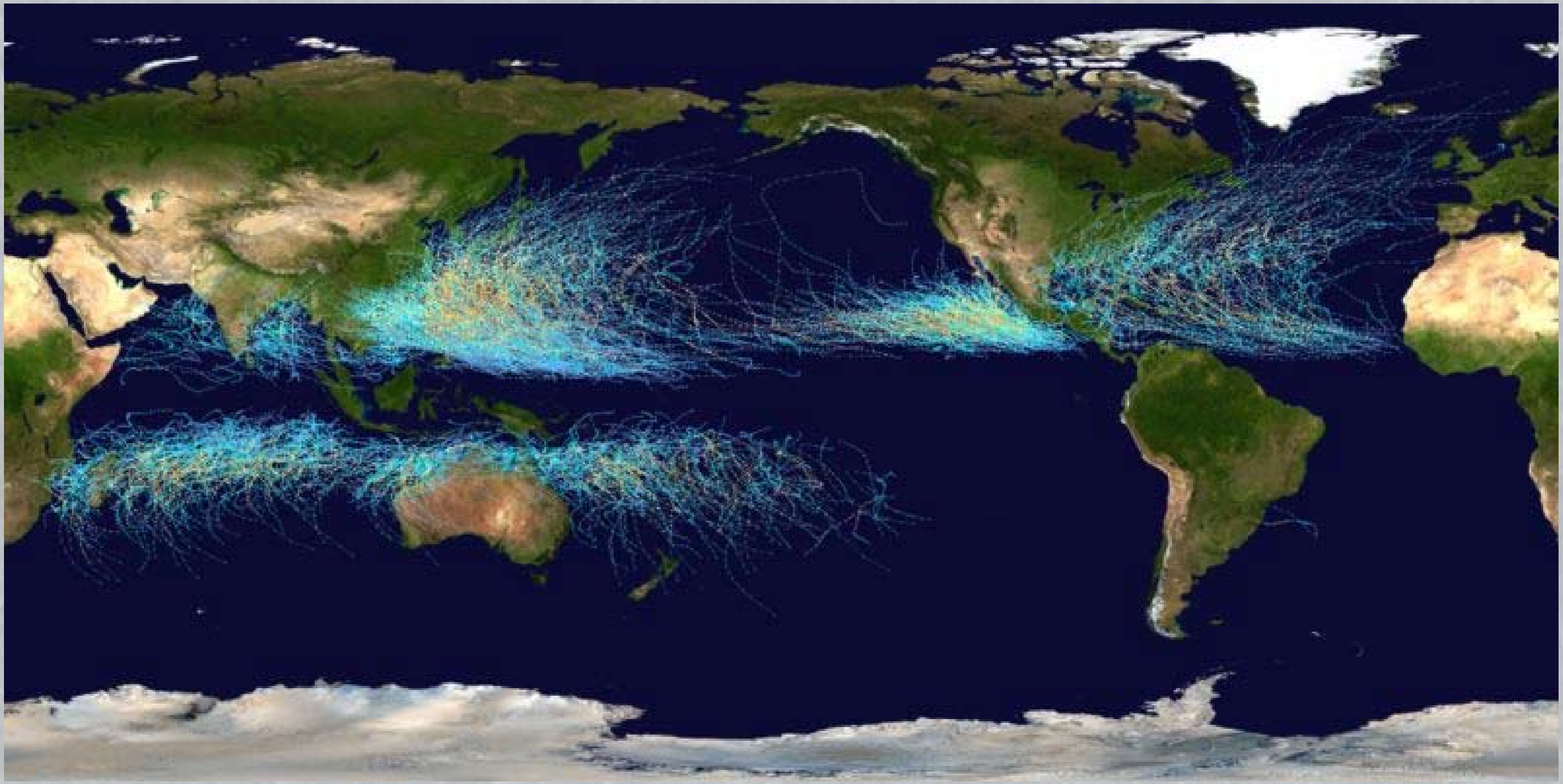


8
6
4
2
0
Elevation (m)
Elevation
0
500
1000
1500
2000
Distance from beach (m)
gulf
bay
Upland
Fresh marsh
Salt marsh
Tidal flat
Dune
High
High
High
Beach
VBF
Low
Low
Low

Habitat Change Since 1950's



Global Tropical Cyclones:
20 Years of Tracks (1985 – 2005)



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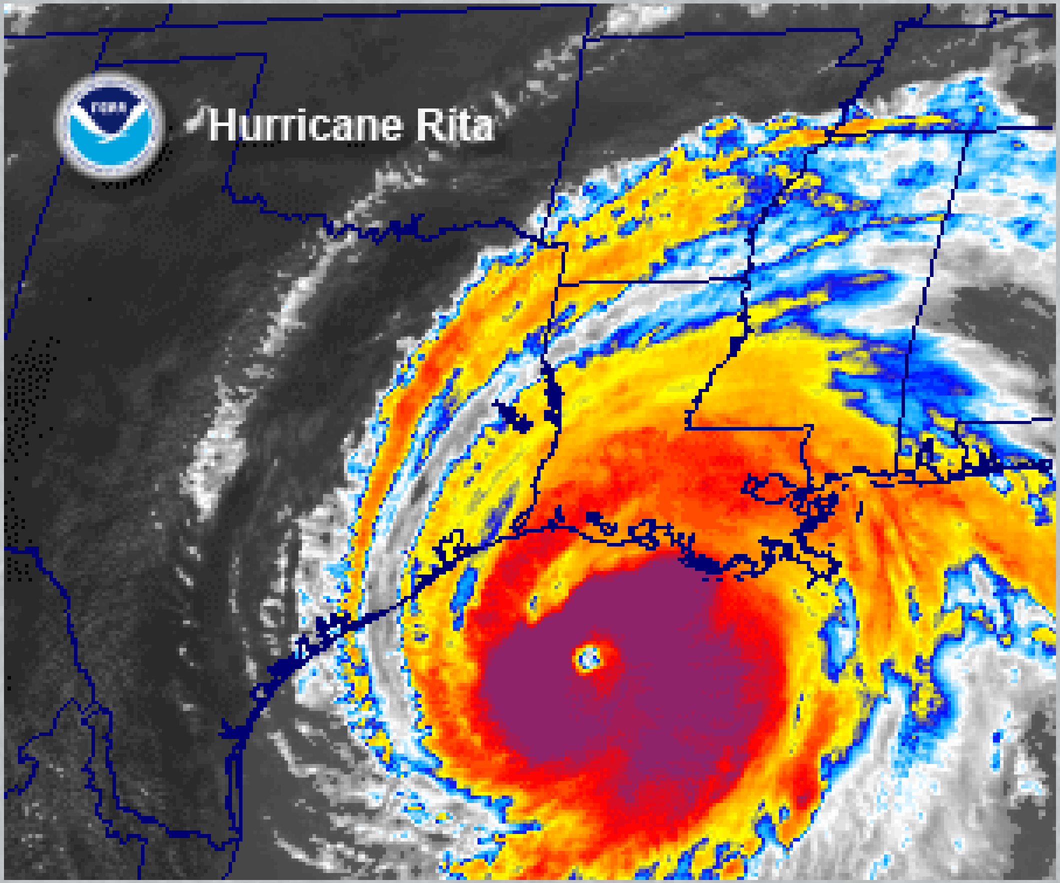
BUREAU OF ECONOMIC GEOLOGY

CSG


Hurricane Rita

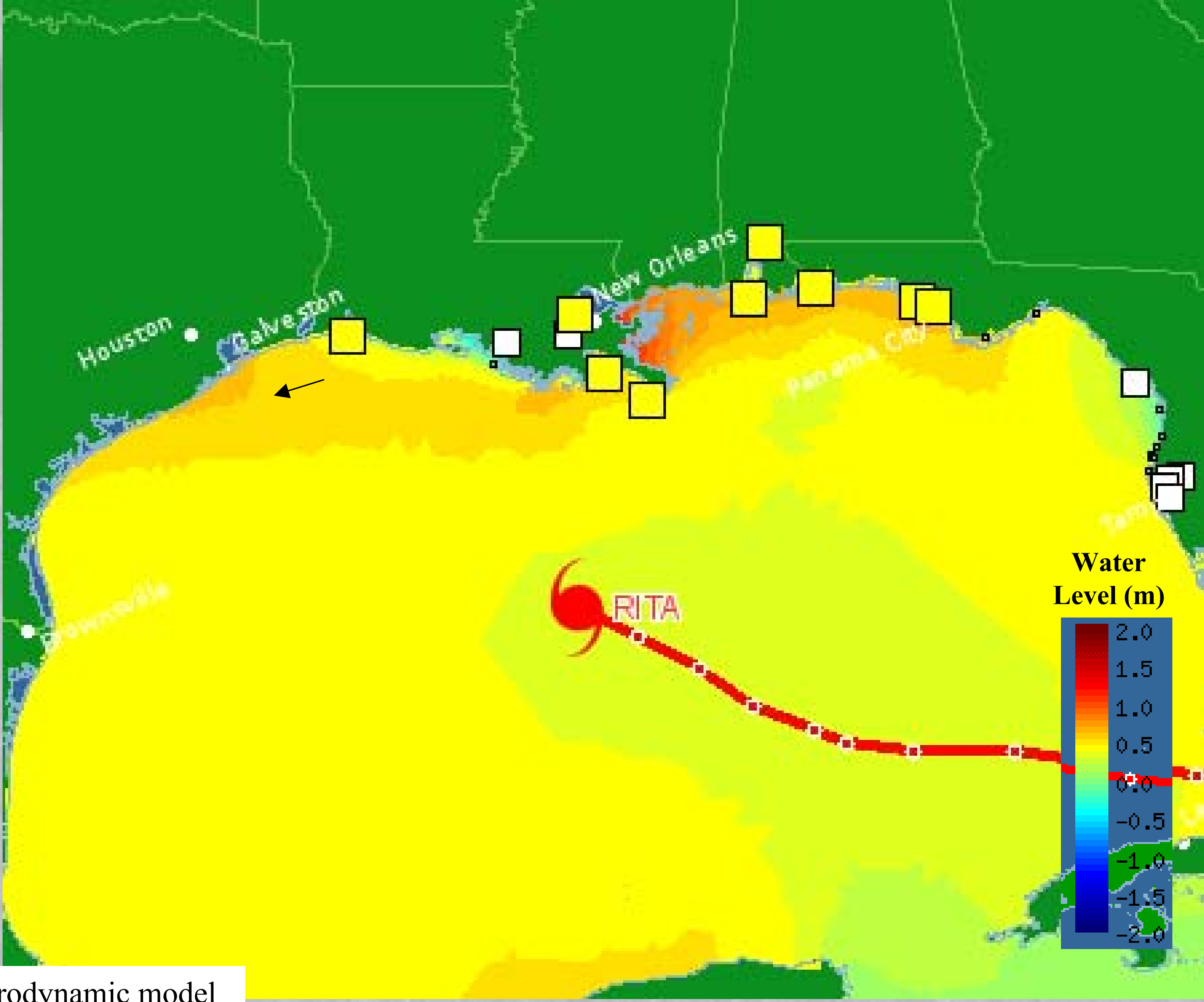
Modeled Water Level

Wind Direction & Relative Speed Measured at offshore buoy #42035

ADCIRC hydrodynamic model
University of North Carolina

9/22 21:00

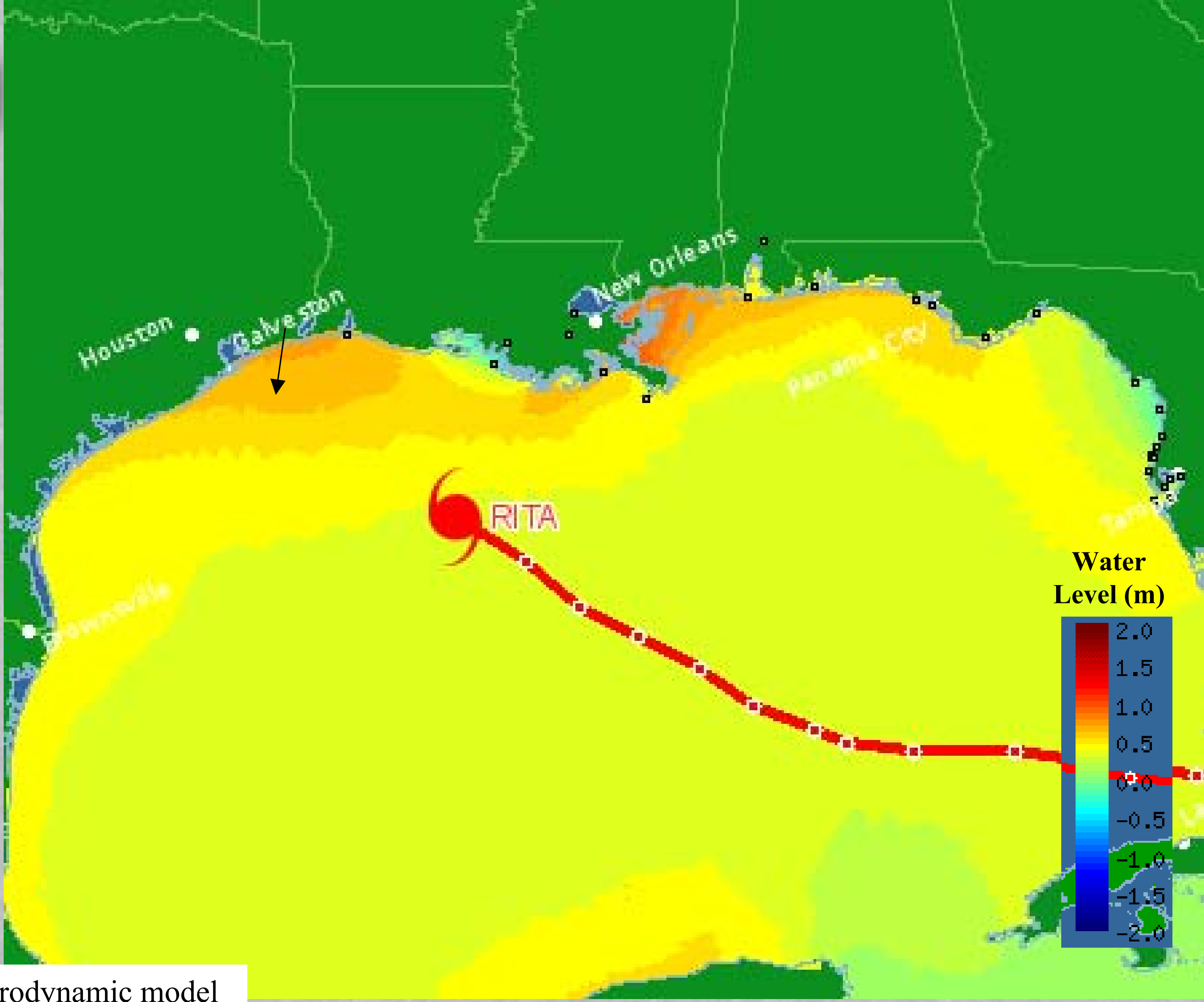
Modeled Water Level



ADCIRC hydrodynamic model
University of North Carolina

9/23 03:00

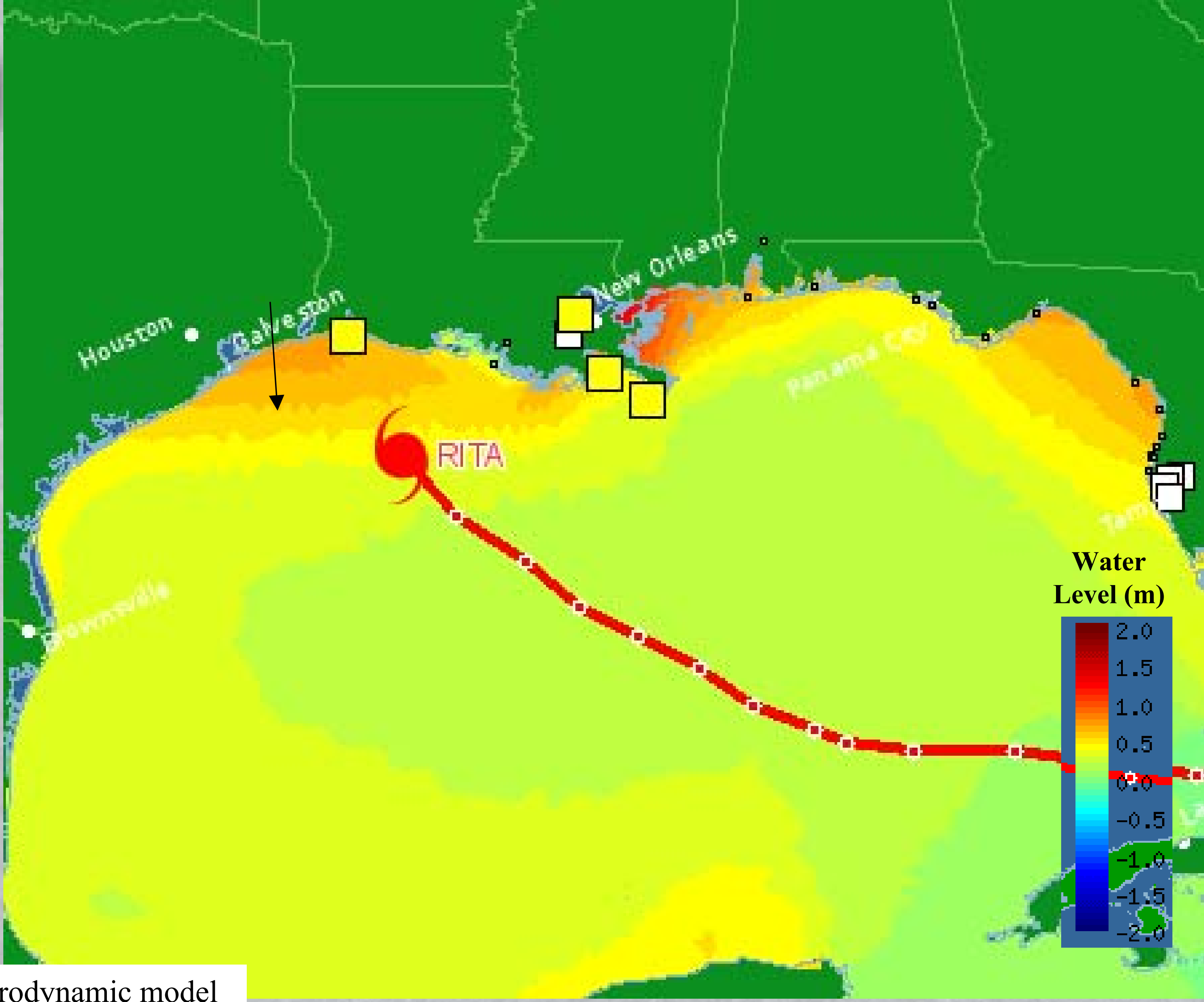
Modeled Water Level



ADCIRC hydrodynamic model
University of North Carolina

9/23 15:00

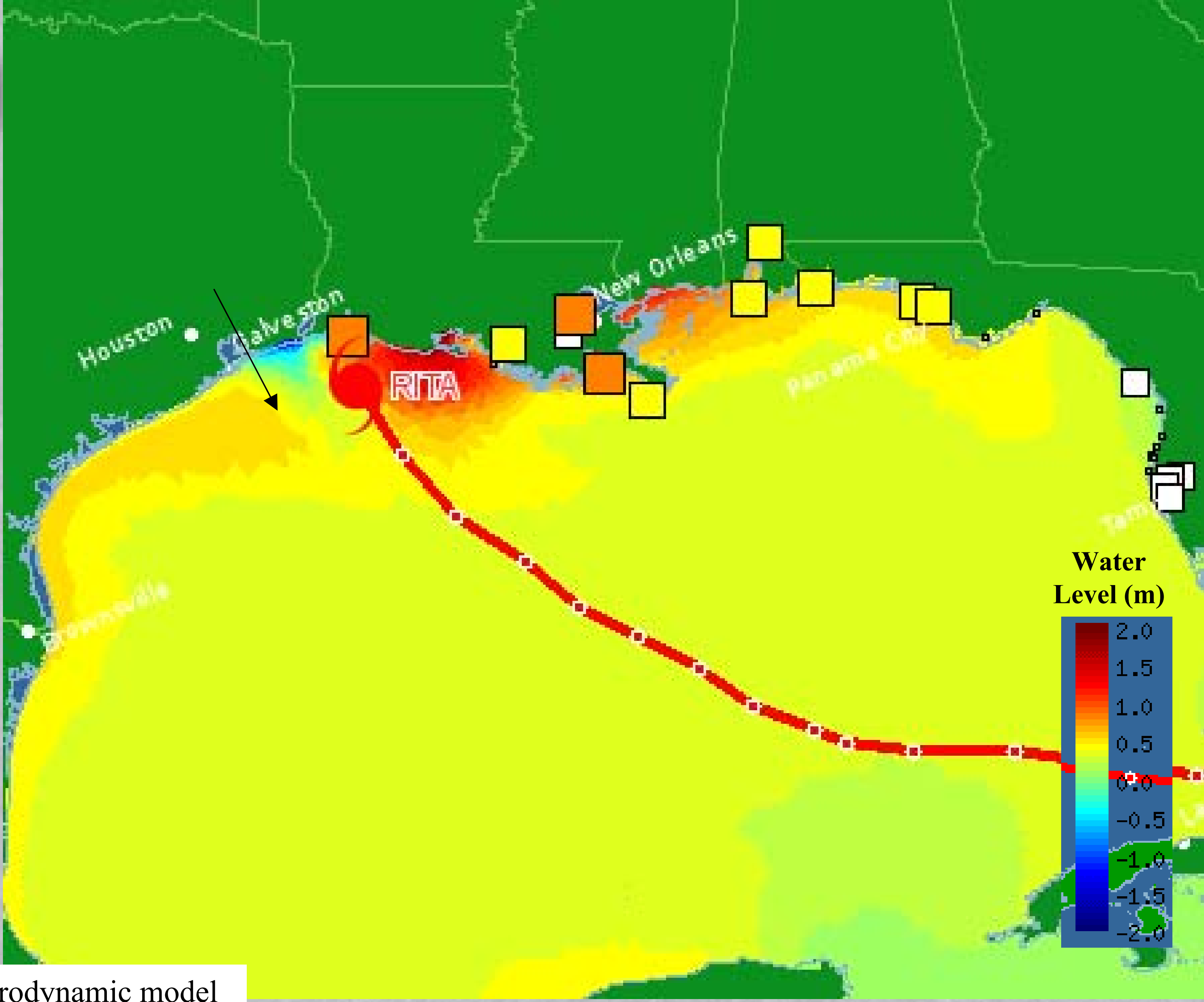
Modeled Water Level



ADCIRC hydrodynamic model
University of North Carolina

9/23 21:00

Modeled Water Level



ADCIRC hydrodynamic model
University of North Carolina

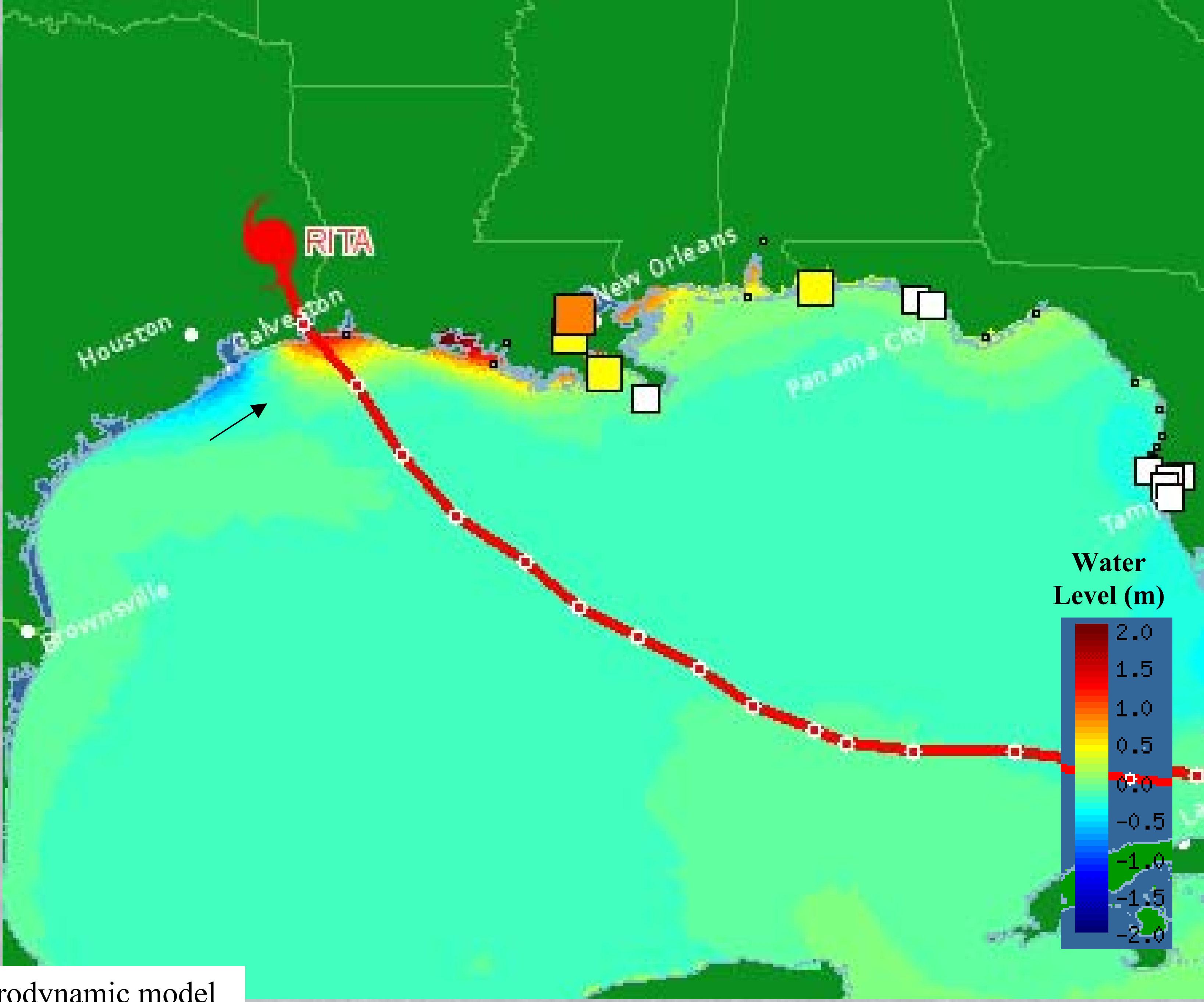
9/24 03:00

Modeled Water Level

ADCIRC hydrodynamic model
University of North Carolina

9/24 09:00

Modeled Water Level



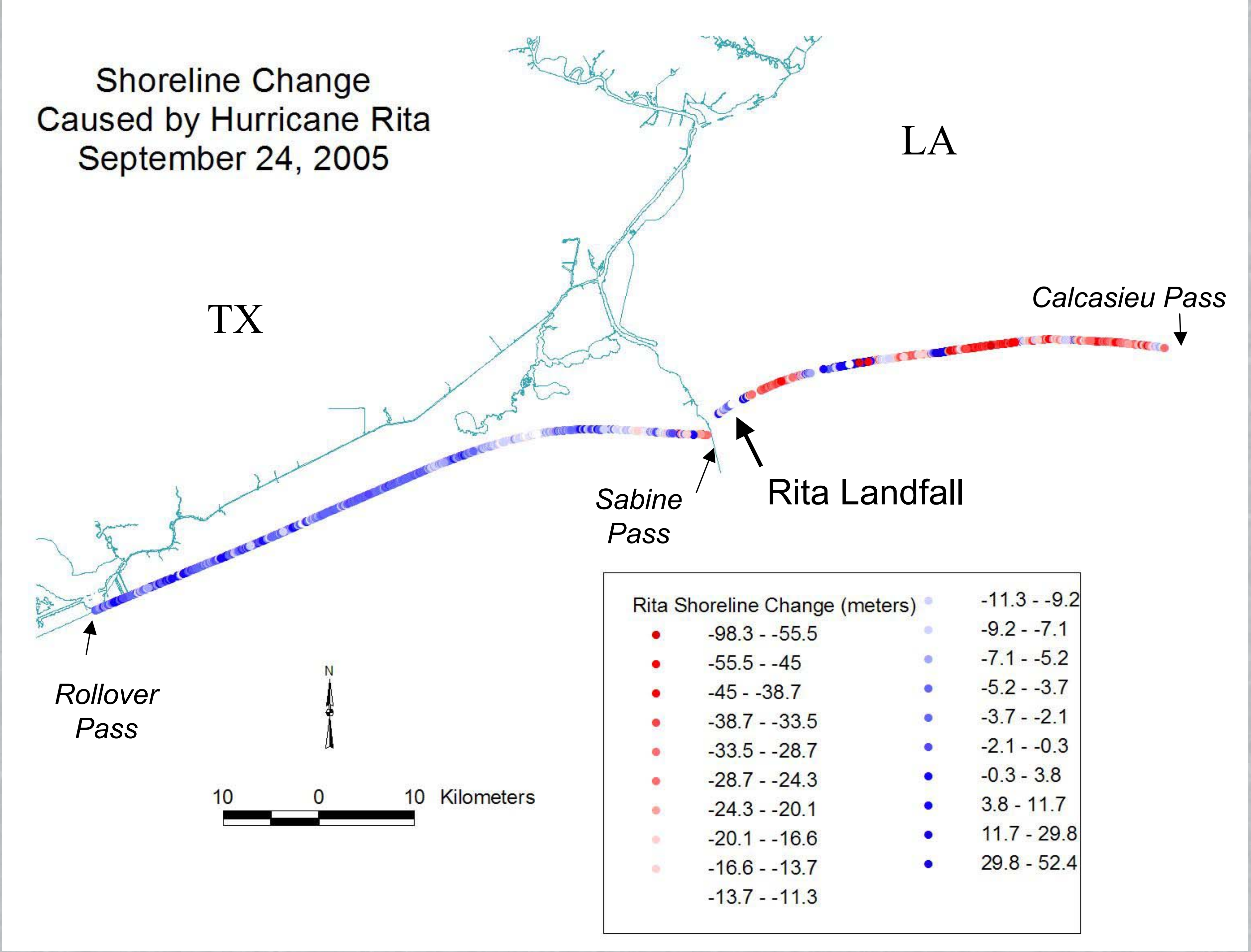
ADCIRC hydrodynamic model
University of North Carolina

9/24 15:00

Modeled Water Level

ADCIRC hydrodynamic model
University of North Carolina

9/24 21:00


Shoreline Change
Caused by Hurricane Rita
September 24, 2005
LA
TX
Calcasieu Pass
Sabine Pass
Rita Landfall
Rollover Pass
N
10 0 10 Kilometers
Rita Shoreline Change (meters)
-98.3 - -55.5
-55.5 - -45
-45 - -38.7
-38.7 - -33.5
-33.5 - -28.7
-28.7 - -24.3
-24.3 - -20.1
-20.1 - -16.6
-16.6 - -13.7
-13.7 - -11.3
-11.3 - -9.2
-9.2 - -7.1
-7.1 - -5.2
-5.2 - -3.7
-3.7 - -2.1
-2.1 - -0.3
-0.3 - 3.8
3.8 - 11.7
11.7 - 29.8
29.8 - 52.4