Measuring the Continuum of Coastal Environmental Variability with Remote Sensing

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Two Key Considerations

What is the spatial scale of the feature?

What is the temporal scale of the process?
Scales of Coastal Variation

Processes/Controls

- Global sea-level and climate change (glacial cycles)
- Relative sea-level change (Holocene) / Antecedent morphology control
- Relative sea-level change (recent) / Storm frequency / Sediment supply / Rainfall amounts / Auto cyclic processes
- Seasonal weather and wave cycle / Monthly tide cycle /
- Storm intensity and path / Daily tide and wave variation

Temporal Scale (years)

- Coastal plain
- Barrier island / cape / delta lobe
- Tidal inlet and channel / wetland and long-term shoreline change
- Short-term shoreline change / shoreline dunes
- Seasonal cycles; berm / bank / tidal channel
- Beachface / shoals and bars
- Washover fan / storm channel / crevasse splay formation / episodic beach and dune erosion

Alongshore or Cross-Shore Spatial Scale (km)
Global Sea-Level Change

Published by AAAS
Texas Coast

Gulf of Mexico
Texas Coastal Plain
Topography/Bathymetry

>100-m scale data acquired over decades
Landsat Drape
Scales of Coastal Variation

Temporal Scale (years)

100000
100000
10000
1000
100
10
1
0.1
0.01
0.001
(36.5 days)
(3.65 days)

Alongshore or Cross-Shore Spatial Scale (km)

0.01 0.1 1 10 100 1000 10000

Processes/Controls

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Coastal plain

Barrier island / cape / delta lobe

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Shorelines, 1930 - 2002
1-m scale topography and bathymetry
Digital Elevation Model (DEM) Resolution

A. 30m USGS DEM
B. 10m AverStar DEM
C. 0.5m Lidar DEM
## Imagery Spatial Resolutions

<table>
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<tr>
<th>Resolution</th>
<th>Data Sources</th>
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<tr>
<td>1-2m</td>
<td>QuickBird, IKONOS</td>
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<tr>
<td>30m</td>
<td>Landsat TM, ETM+</td>
</tr>
<tr>
<td>79m</td>
<td>Landsat MSS</td>
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<tr>
<td>1.1km</td>
<td>AVHRR</td>
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*Simulated

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

Shoreline changes from 5000 years ago

- Erosion
- Accretion

After Morton (1979)
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

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 within 10 m)

• Our tests show typically within 5 m
Shoreline Interpretation

Wet/Dry Line

Waterline

Gulf of Mexico
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

- Calibration aircraft trajectory
- Shoreline aircraft trajectory
- Kinematic survey data points

Gulf of Mexico
Bolivar Peninsula

Environmental sensitivity index
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

- BEG02
- Shoreline at +0.6 m MSL
- Wet/dry line
- Ridge of sargassum
Galveston Island Profile

- Lidar last return
- Total station ground survey
- Lidar last return intensity
- Vertical exaggeration ×50

Legend:
- +0.6 m above MSL
- Wet/dry line
- Water surface
- Geotube
- Vegetation
- Monument
- Water surface
- Distance from monument (m)
- Height above ellipsoid (m)

Graph shows data points with labels and markers for different survey methods.
Representative Wet/Dry Elevation
0.6 m along Upper Tx Gulf Coast

Height relative to MSL (m)

Distance (m)

vegetation line

upper berm crest

MHHW
Shoreline Change Analysis

- Mapping shorelines
  - Aerial photography
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  - 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
Shoreline Change and Projection Program
ArcView Interface
Shoreline Change Rate

Mid-term/linear regression rate

Long-term end point rate

Bureau of Economic Geology
Projected Shoreline
Galveston Island

Photographed: January, 1995
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Ground Survey
Beach Profile
Annotated

BEG12 -- Follets Island
Christmas Bay

- August 20, 2002
- January 31, 2001
- September 16, 1998
- November 13, 1997

vertical exaggeration = 20:1
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### The Texas Shoreline Change Project

#### Introduction

In June 1999, Governor Bush signed into law the Coastal Erosion Planning and Response Act (CEPPA). This act provides funds for coastal erosion projects. It authorizes the Texas General Land Office (GLO) to implement a comprehensive coastal erosion response program that can include designing, funding, building, and maintaining erosion projects. The GLO is named in the act as the entity that will monitor shoreline change rates with the assistance of the Bureau of Economic Geology and local governments. The Texas Shoreline Change Project is addressing requirements of the CEPPA regarding (1) the identification of "critical coastal erosion areas", (2) the monitoring of historical shoreline erosion rates, (3) making data accessible on the Internet, and (4) increasing public awareness of coastal erosion issues. This is an active web site. Users should check periodically for additional data and reports. Send comments to Jim Gibeaut at jgm.gibeaut@beg.utexas.edu.

### Goals

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<th>Geographic Information System (GIS) Coastal maps and photographs with shorelines, rates of shoreline change and beach profiles</th>
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The Texas Shoreline Change Project is partially funded by the Texas Coastal Management Program and the National Oceanic and Atmospheric Administration.
Scales of Coastal Variation

Temporal Scale (years)

- 100000
- 10000
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- 100
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- 1
- (36.5 days) 0.1
- (3.65 days) 0.01
- 0.001

Alongshore or Cross-Ship Spatial Scale (km)

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Coastal plain
Bay / estuary / delta
Barrier island / cape / delta lobe
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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)
We need to start or continue to build a data set of adequate spatial and temporal resolution.

www.beg.utexas.edu/coastal/coastal01.htm
Problem Solving Cycle

Science

Applications

Engineering
Technology

Science
Space - Based Lidar
GLAS
Geoscience Laser Altimeter System

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/

Graphic by Deborah McLean
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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.

Merged ILRIS (high intensity) and ALSM point clouds low intensity), La Jolla, California.
Air – Based

LIDAR

• Light Detection and Ranging
THE COASTAL ZONE

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

- Critical natural land and water resources
- Dynamic processes, both natural and human induced
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.
Geomorphologic/Engineering Change
Bolivar Peninsula, Texas

1,000 ft

1997
Nov
Rollover Pass
Gulf of Mexico

1998
Pre-Frances

1998
Post-Frances

2000
Geotube installed

2001
July

Rollover Pass
Gulf of Mexico

Gibeaut_CCC_Jan31_2002
QAd496
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
Shoreline Change Based on Elevation

Shoreline Change Caused by Tropical Storm Frances, 1998, Bolivar Peninsula, Texas
Mapping the Shoreline and Comparing Beach Widths

Shaded Relief Topographic Lidar Image
Galveston Island, Texas
Mapping the “Natural” Vegetation Line
Storm-Surge Inundation

Color IR Photography Draped
On Lidar DEM
Storm-Surge Inundation

9.5 ft. Storm Surge
Galveston Beach

Wet/Dry Line
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 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.

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

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

Merged ILRIS (high intensity) and ALSM point clouds low intensity), La Jolla, California.
Changing Barrier Island Environments

Mustang Island, Texas
Global Tropical Cyclones: 20 Years of Tracks (1985 – 2005)
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 15:00
Modelled Water Level

ADCIRC hydrodynamic model
University of North Carolina

9/23 21:00
Modeled Water Level

ADCIRC hydrodynamic model
University of North Carolina
Modeled Water Level

ADCIRC hydrodynamic model
University of North Carolina

9/24 09:00
Modeled Water Level

ADCIRC hydrodynamic model
University of North Carolina
Modeled Water Level

ADCIRC hydrodynamic model
University of North Carolina

9/24 21:00
Shoreline Change
Caused by Hurricane Rita
September 24, 2005

TX
LA

Calcasieu Pass
Sabine Pass
Rita Landfall
Rollover Pass

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

10 0 10 Kilometers