Measuring coastal wetland shoreline change with remote sensing

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U.S. Geological Survey

USGS mission:

To monitor, analyze, and predict current and evolving Earth-system interactions; deliver actionable information at scales and timeframes relevant to decision makers; and provide science about natural hazards, natural resources, ecosystems and environmental health, and the effects of climate and land-use change.

At the **USGS St. Petersburg Coastal and Marine Science Center**, we work to provide coastal and marine research to help our nation understand, restore, and protect communities and natural resources.
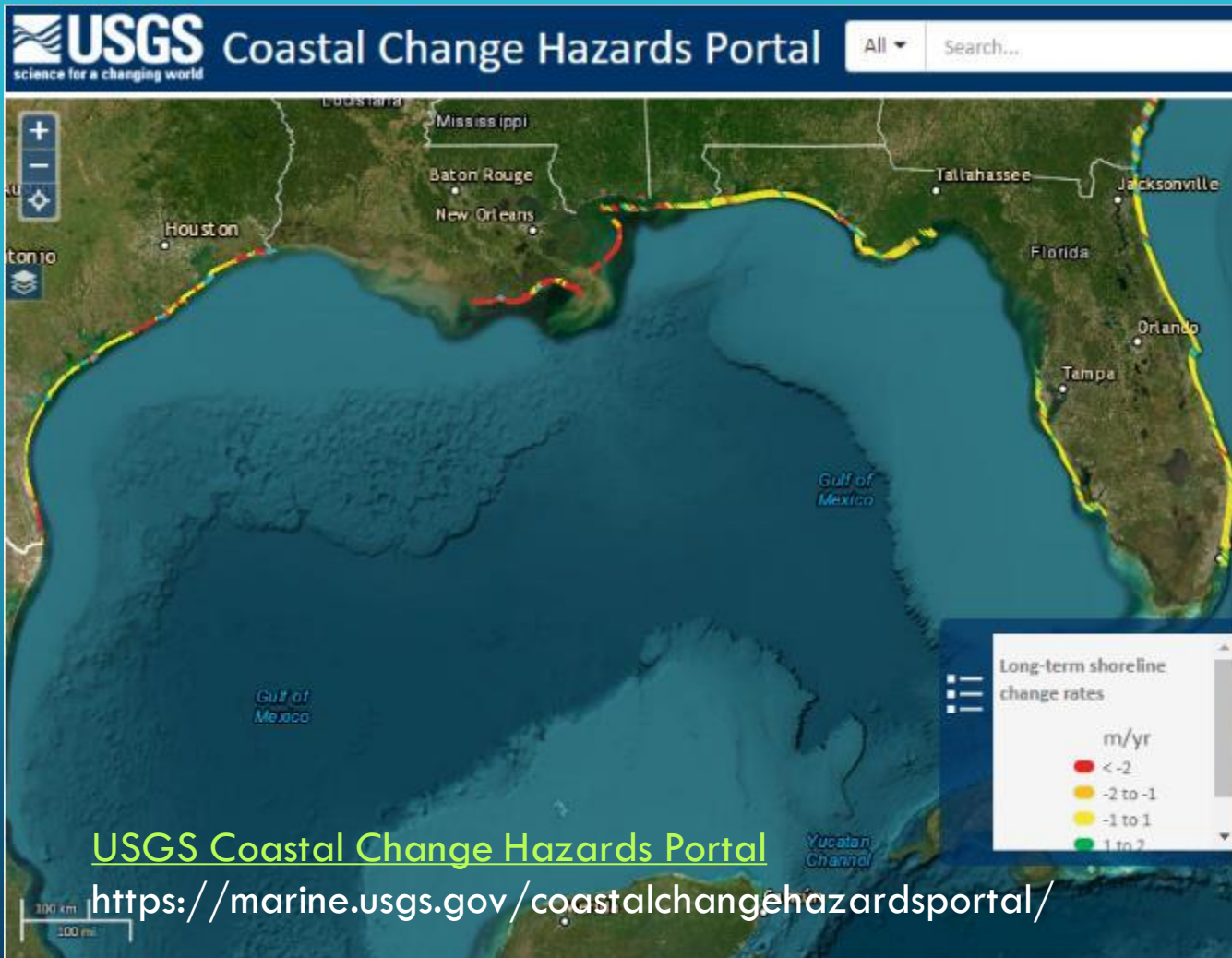
Coastal Hazards

Biological Threats

Climate Research

Estuarine Shoreline Change Project
https://bit.ly/USGS_ESLC

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ESTUARINE SHORELINE CHANGE (ESLC) PROJECT

USGS Coastal Change Hazards Portal
https://marine.usgs.gov/coastalchangehazardsportal/

- Shoreline change: the loss or gain of land area or change to the landscape on the marine edge (NPS)

- Accretion < SLR = less resilient to future changes/hazards

- Project Goals:
    - Compile modern and historic shoreline data
    - Calculate shoreline change rates for wetlands and estuaries
    - Develop novel remote sensing techniques to map wetland shoreline position
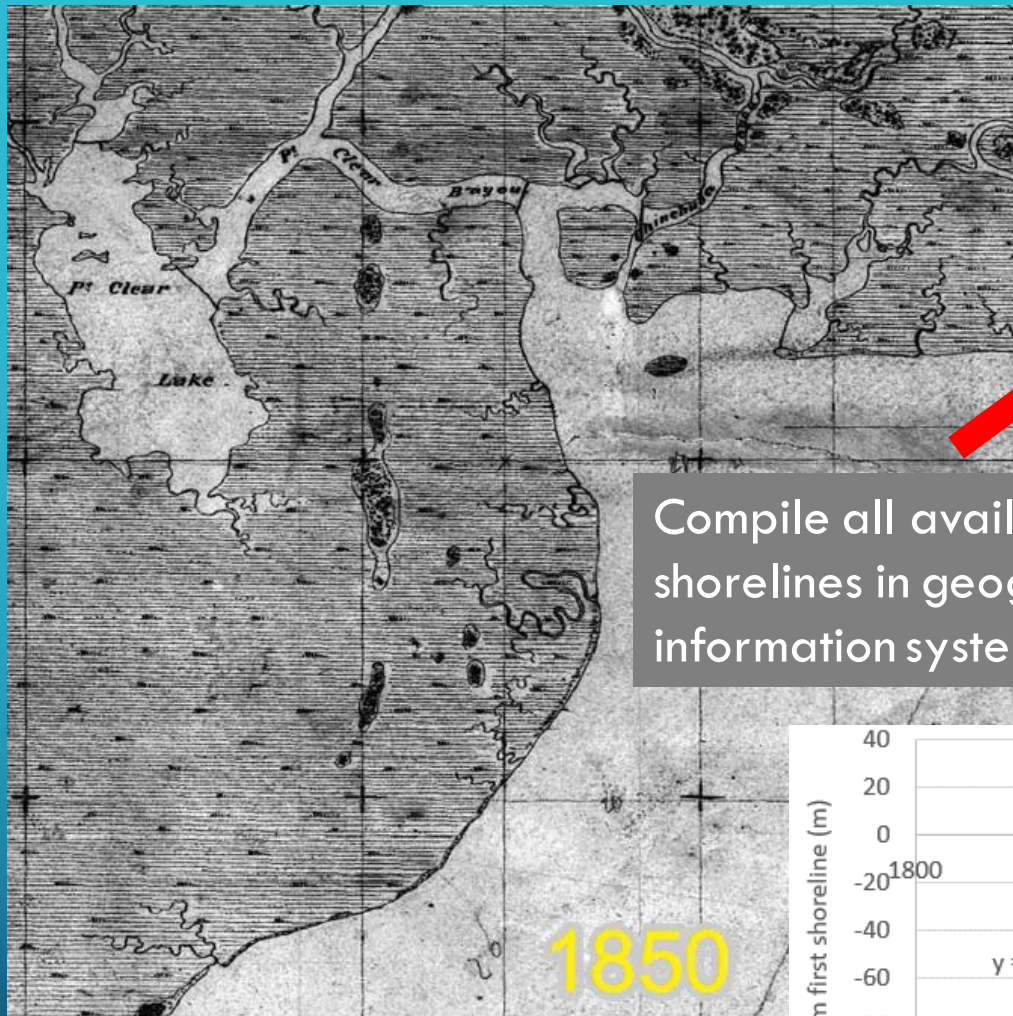
Compile all available shorelines in geographic information system (GIS)
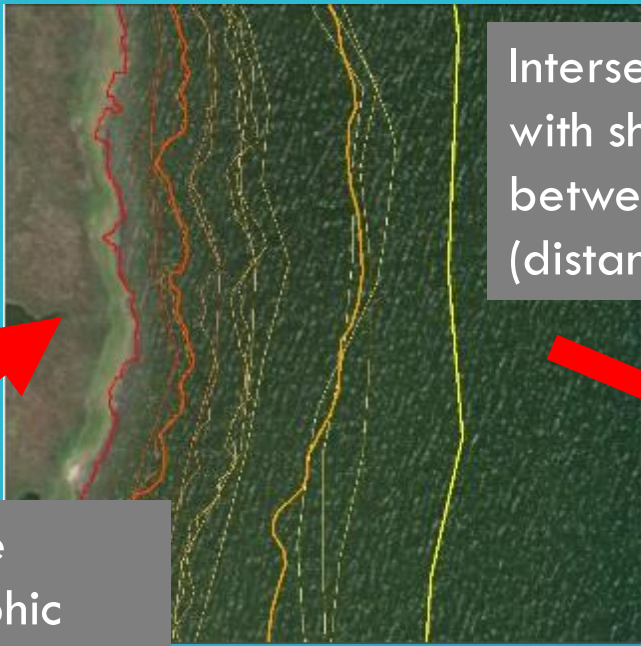
Intersections of cross-shore transects with shorelines provide distances between each dated shoreline (distance along the line)
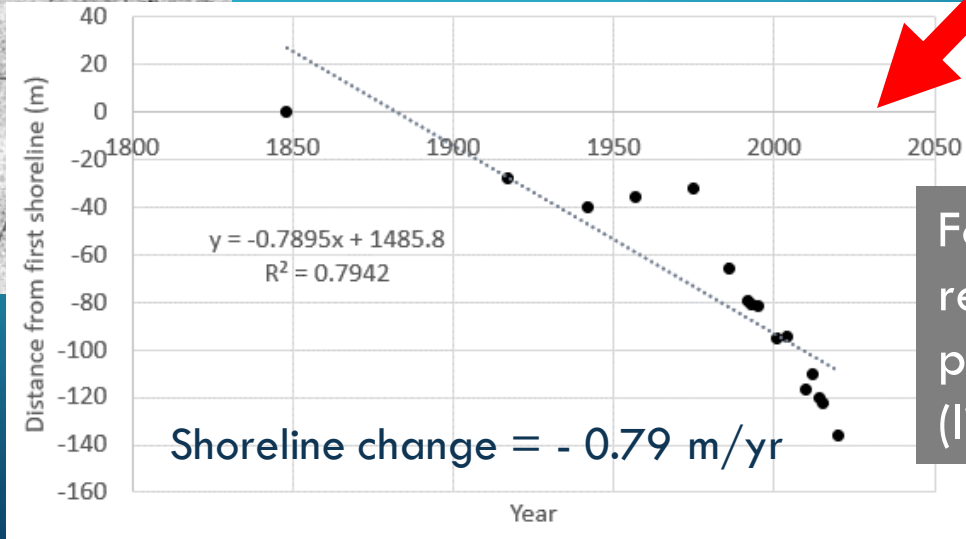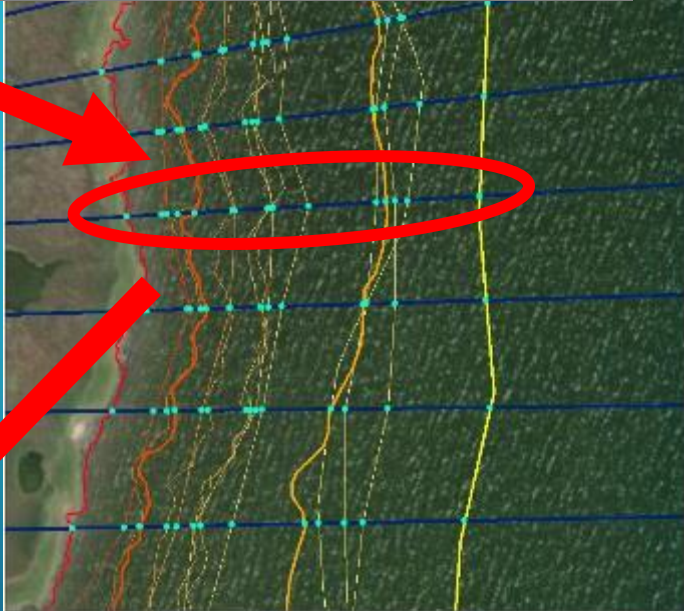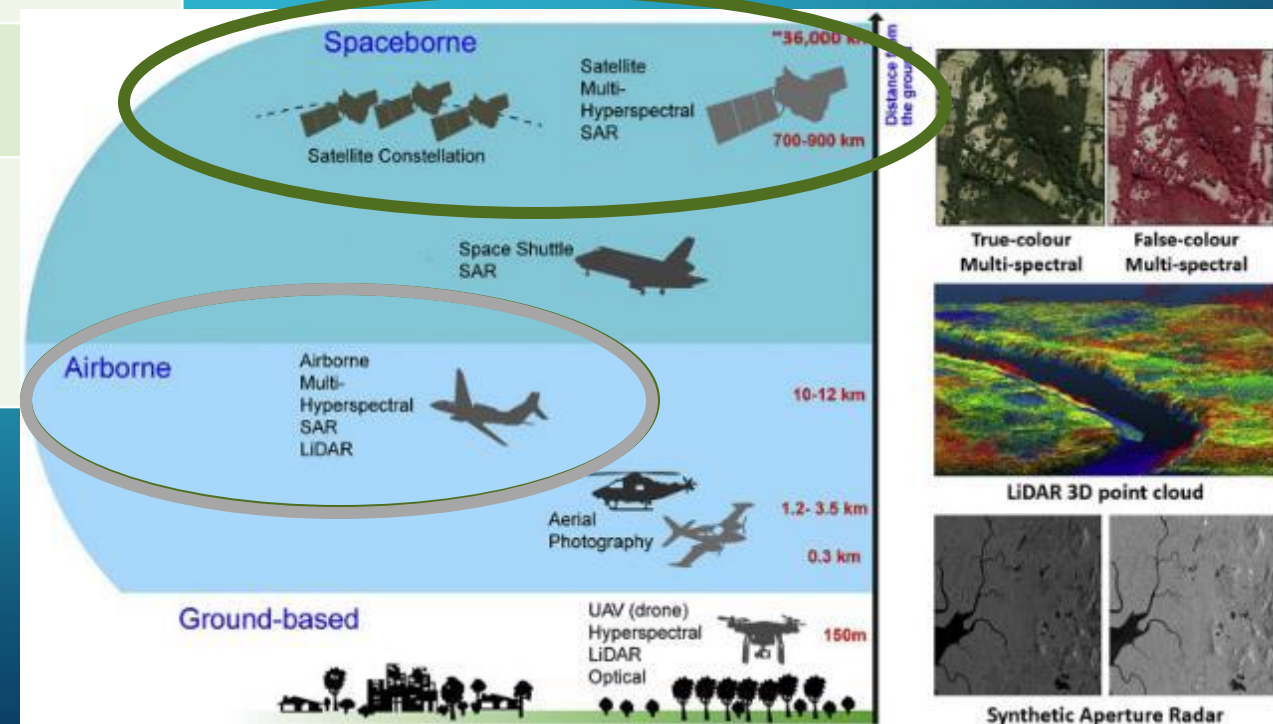
For each transect, linear regression of time (years) provides the rate of change (liner regression)

$y = -0.7895x + 1485.8$
$R^2 = 0.7942$

Shoreline change = - 0.79 m/yr

SHORELINE DATA SOURCES

Source	Time period	Uncertainty (m)
Topographic sheets	1800-1940s 1950-1980s	10 - 12* 6 - 10*
Aerial photos Digital ortho-imagery	1970s to 2000s	3 - 10*
Lidar	Late 1990s to present	< 3*
Satellite imagery Landsat (30m) Sentinel (10-20m) High-res (<5m)	1970s to present 2015 to present 2000s to present	???

*Sources: https://doi.org/10.3133/ofr20101118
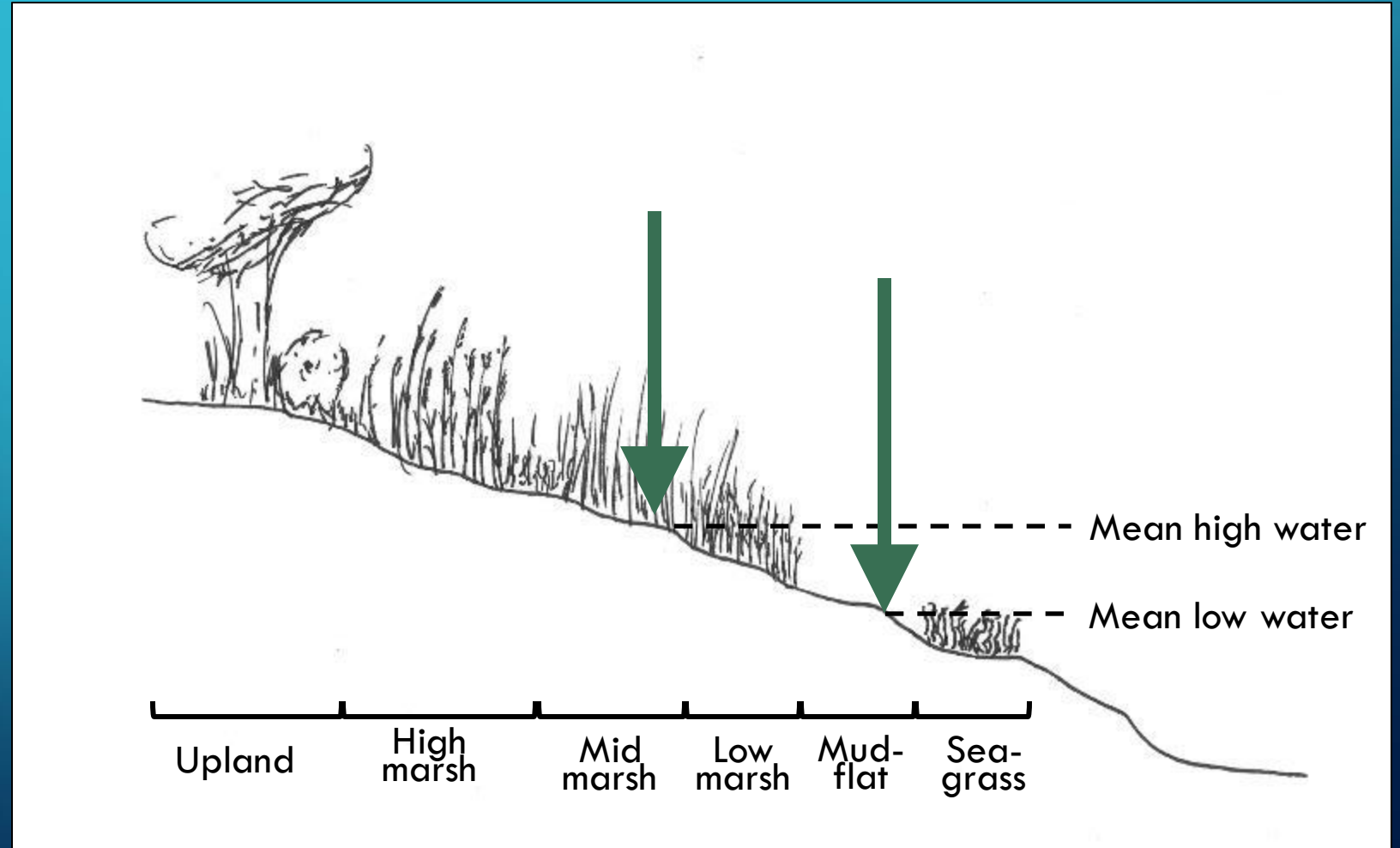https://doi.org/10.3133/ofr20041043

https://doi.org/10.1016/j.oneear.2020.05.001

FACTORS TO CONSIDER

- Time of day (tides)
- Slope/elevation
- Vegetation height
- Waves and wind
- Season
- Scale

Mean high water

Mean low water

Upland | High marsh | Mid marsh | Low marsh | Mud-flat | Sea-grass

ESLC PROJECT GOALS

- Compile modern and historic shoreline data

- Calculate shoreline change rates for wetlands and estuaries

- Develop novel remote sensing techniques to map wetland shoreline position

WHY?

- Modern shoreline is a baseline data set
  - Coastal planning and habitat management
  - Storm surge and hydrodynamic modeling
  - Long- and short-term erosion hazards
  - Evaluating risk/vulnerability/resilience

- Existing spatial data gaps

- Data production lag time

- Shoreline changes are highly variable

- Consistency between methods

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GOALS

- Identify a simple, repeatable method for digitize shorelines from high-resolution satellite imagery (Worldview).

- Evaluate precision in comparison to other shoreline data
  - Most accurate available data (field-based GPS)
  - Shorelines derived from aerial imagery

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WORLDVIEW SATELLITE IMAGERY

Worldview-2

- Launched October 2009

- Revisit time: 1.1 day

- Swath width of 16.4 km at nadir

- Up to 1 million km^2/day

| Description	Band ID	Spectral resolution (nm)	Spatial resolution (WV2)	Spatial resolution (WV3)
Coastal Blue	1	400-450	1.85 m	1.24 m
Blue	2	450-510	1.85 m	1.24 m
Green	3	510-580	1.85 m	1.24 m
Yellow	4	585-625	1.85 m	1.24 m
Red	5	630-690	1.85 m	1.24 m
Red-edge	6	705-745	1.85 m	1.24 m
NIR1	7	770-895	1.85 m	1.24 m
NIR2	8	860-1040	1.85 m	1.24 m
Panchromatic Band	1	450-800	46 cm	31 cm

Worldview-3

- Launched Aug 2014

- Revisit time: <1 day

- Swath width of 13.1 km at nadir

- Up to 680,000 km^2/day

- Also has 8 short-wave infrared (SWIR) and 12 CAVIS (Clouds, Aerosols, Water Vapor, Ice and Snow) bands

Maxar – Worldview
USGS EROS Archive – Commercial Data Purchase

GRAND BAY NATIONAL ESTUARINE RESEARCH RESERVE AND WILDLIFE REFUGE

- Est. 1992 (NWR)/1999 (NERR)

- 18,000 acres of wet pine savanna, maritime forests, tidal creeks, salt pans, wetlands, bayous, and bays

- Home to sea turtles, bottlenose dolphins, migratory birds, waterfowl, commercially and recreationally important fish species, endangered plant communities

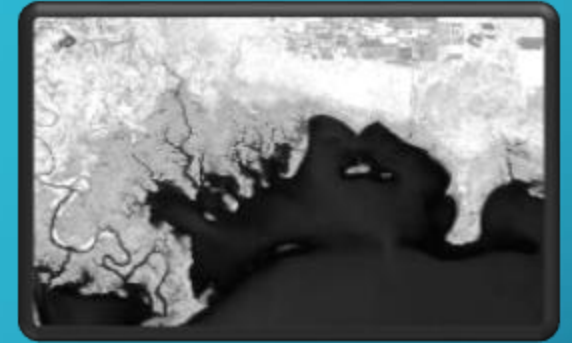- Focus on stewardship, conservation and research
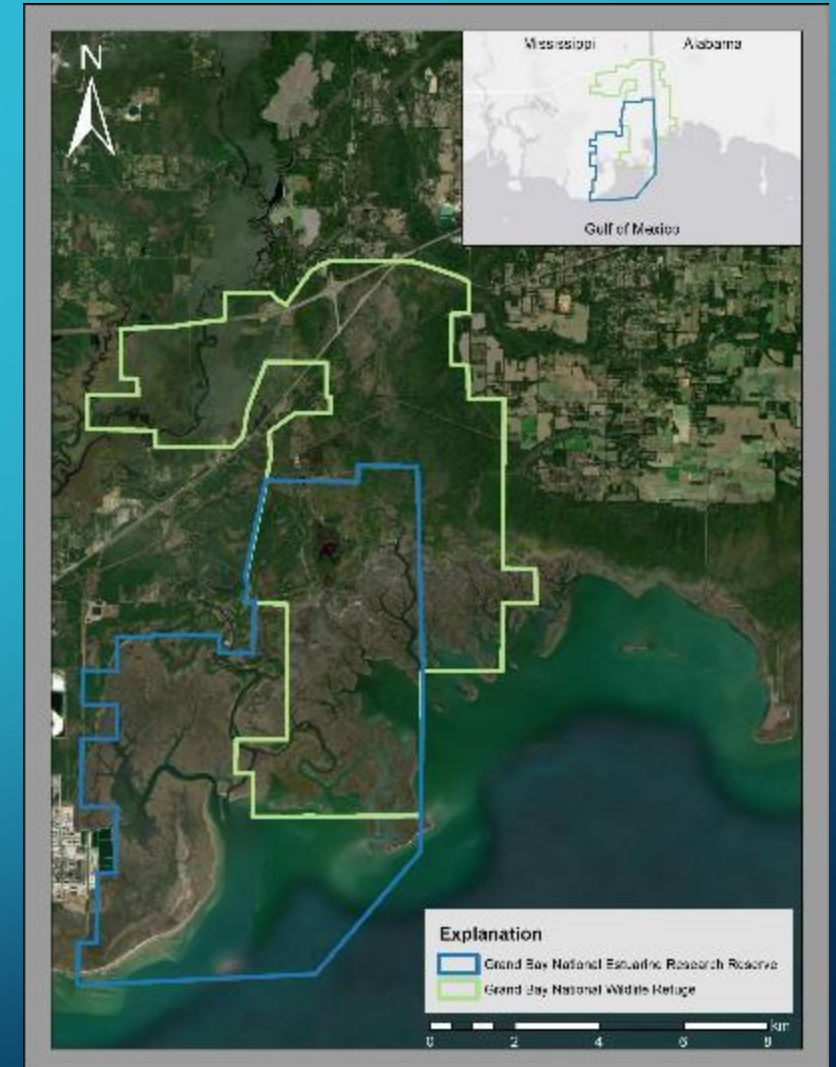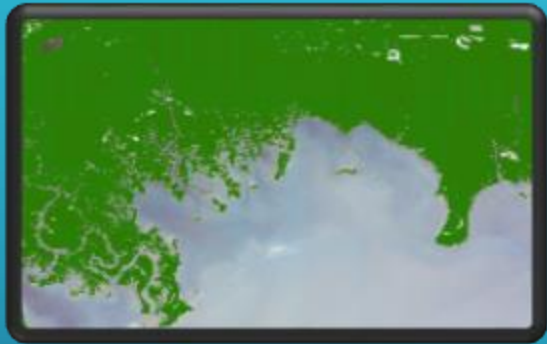
SHORELINE MONITORING SITES
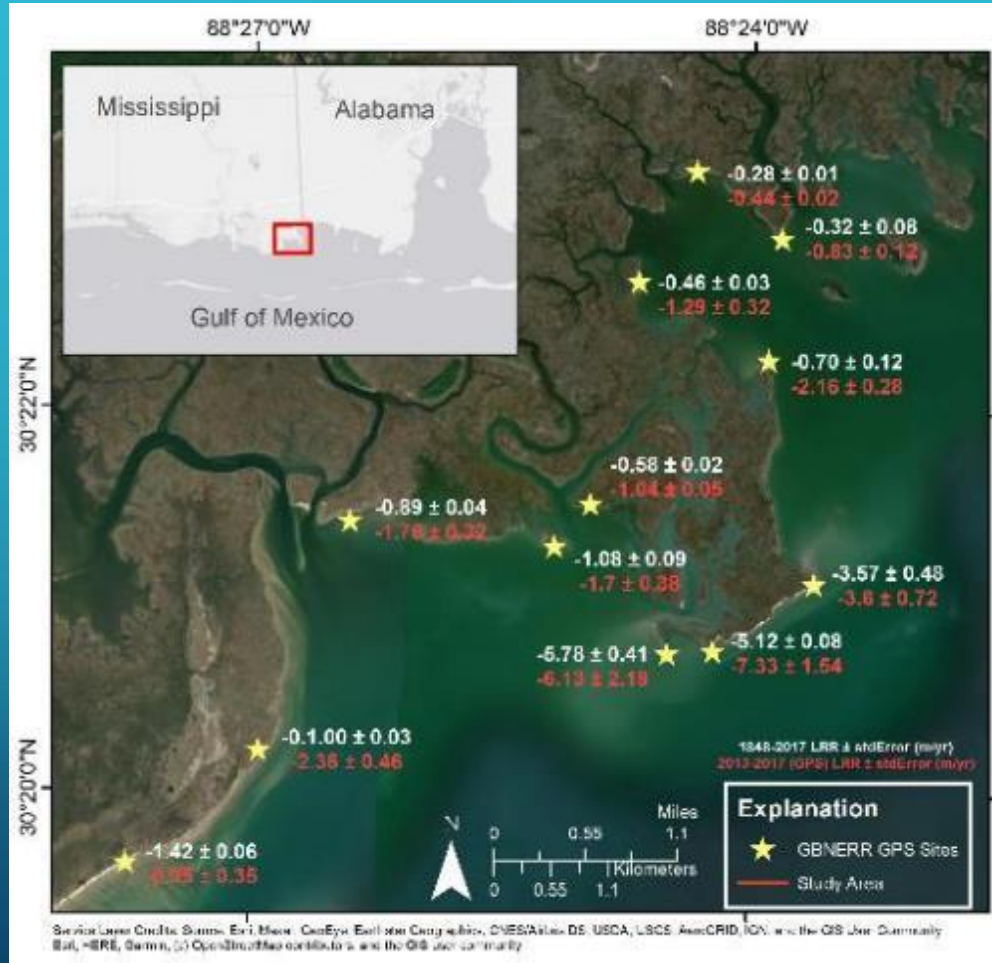
Preprocessing
- Radiometric & atmospheric correction
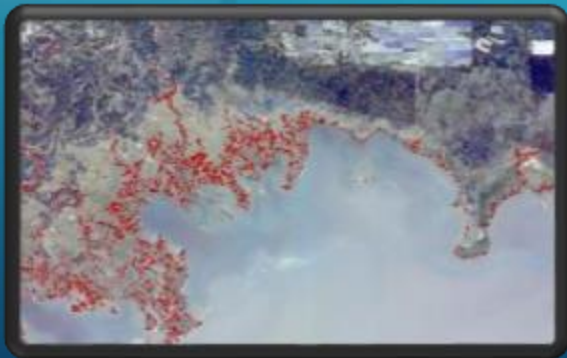- Spatial adjustment

Classification
- NDVI*
- Land-water reclass
- Beach class merge

Vectorization
- Raster simplification
- Raster to poly to line
- Shoreline selection

Modified from Maglione et al. 2014.

*Normalized Difference Vegetation Index

https://doi.org/10.3390/rs13153030

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CONCLUSIONS

- A simple procedure to semi-automatically define marsh shorelines from Worldview (WV) imagery is possible

- WV shorelines compared to GPS data indicate precision is less than 2 m (w/o adjusting for water level or date differences), only slightly higher than shorelines derived from digitizing boundaries in aerial imagery

- Because the method focused on veg-water optical properties, shorelines with sparse vegetation or affronted by sandy beaches had the highest error

FUTURE WORK

- PLANET
    - NASA Commercial Smallsat Data Acquisition (CSDA) Program
    - Acquires more than 300 million km^2 of optical imagery daily
    - Dove, Skysat, Rapideye satellites
    - PlanetScope (200 CubeSats called DOVEs)
        - 3 to 4.1m resolution
        - Daily repeat cycle
        - 8 bands
- PARTNERS : Test methods in other locations

Coastal Blue: 431 - 452 nm

Blue: 465 – 515 nm

Green I: 513 - 549 nm

Green: 547 – 583 nm

Yellow: 600 - 620 nm

Red: 650 – 680 nm

RedEdge: 697 – 713 nm

NIR: 845 – 885 nm

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ACKNOWLEDGEMENTS

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Thank you!

- USGS Estuarine Shoreline Change Project
  - https://www.usgs.gov/centers/spcmsc/science/estuarine-shoreline-change-research-project
- Smith et al. Coastal Wetland Shoreline Change Monitoring: A Comparison of Shorelines from High-Resolution WorldView Satellite Imagery, Aerial Imagery, and Field Surveys. *Remote Sens.* 2021, *13*, 3030. https://doi.org/10.3390/rs13153030
- USGS National Shoreline Change Geonarrative
  - https://geonarrative.usgs.gov/cch-shline/
- COMING SOON! USGS Coastal Change Hazards: Coastal Wetlands Geonarrative

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