Storm-driven Morphodynamics of a Sandy Beach in Florida

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Introduction

- High quality beaches are an attraction to tourists and are a significant generator of revenue for coastal communities
- Private beachfront real estate is highly sought after in our community
- Public beaches draw tourism and provide recreation for locals.
- Our beaches dunes and coastal vegetation serve as wildlife habitat.

Introduction

- **Florida's gulf coast has one of the most morphologically diverse barrier island systems in the world,**
- **Significant morphological responses can arise because of natural phenomena such as hurricanes, as well as from the impact of anthropogenic activities and engineering projects.**

Pre & post Hurricane Charlie, North Captiva Island

Introduction

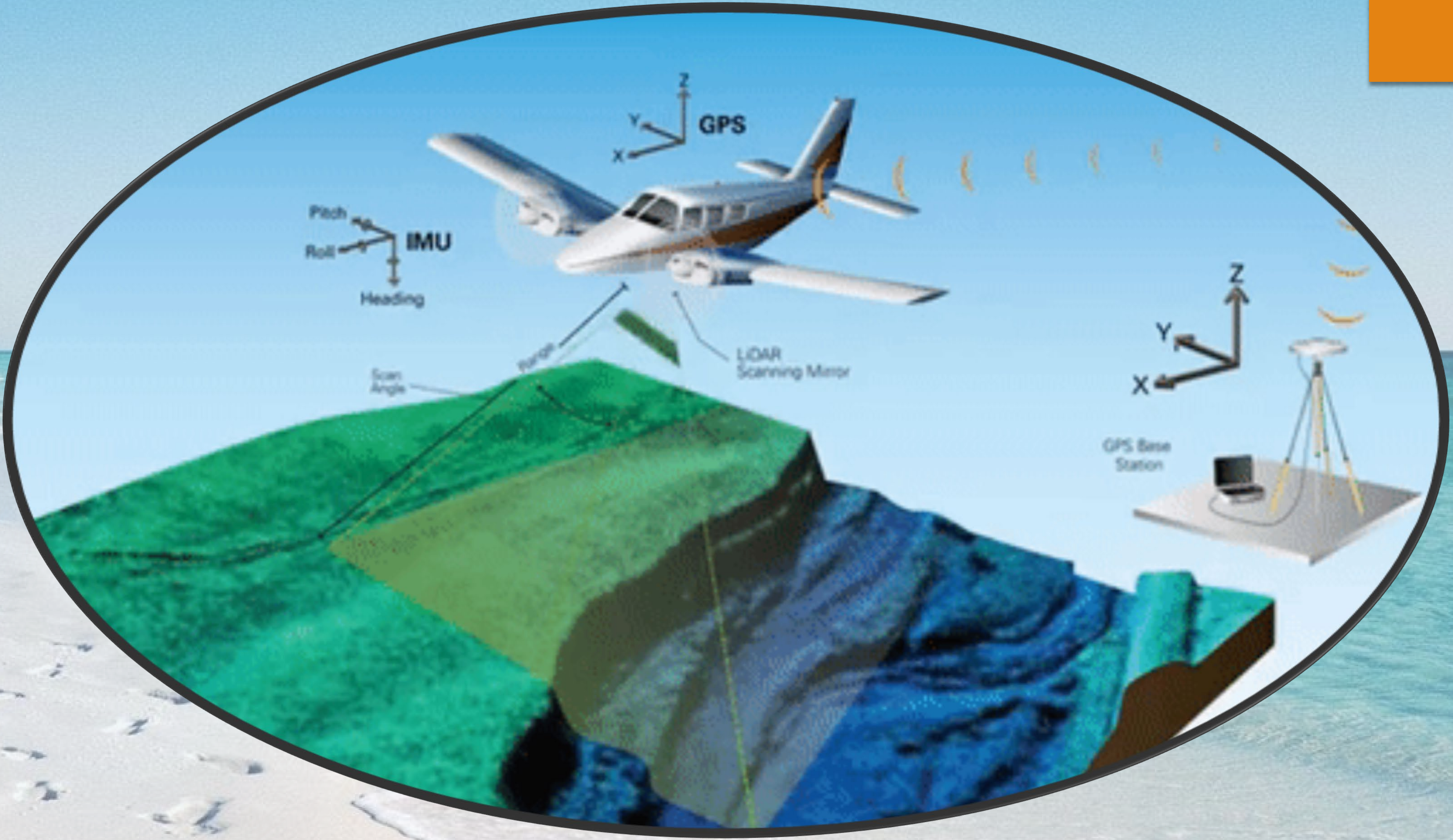
- The gulf coast of the state was severely impacted during the 2004 Atlantic Hurricane season when four major Hurricanes including: Charley, Frances, Ivan and Jeanne made landfall (FDEP 2018).
- The focus of this study is on Casey Key in Sarasota County Florida
- The aim of this study is to utilize available LiDAR data from multiple years to assess long term morphological and volumetric changes to Casey Key in response to major storms and anthropogenic activities.

Study Area

- **Casey Key Sarasota County Florida**
- **(FDEP) has established benchmark monuments at 1000-feet (304.8 m) intervals along the entire Florida coast**
- **Represented by FDEP R-monuments R-78 to R-114**
- **Purple areas on the map indicate beach re-nourishments north and south of the study area**

Methodology (LiDAR)

- LiDAR .las datasets were acquired from NOAA Digital Coast repository https://coast.noaa.gov/dataviewer/#/lidar/search/
- Five LiDAR Missions are available. Data sets for: 2015, 2010, 2006 post-Hurricane Wilma, 2004 post-Hurricane Ivan, and 2004 pre-Hurricane Ivan were analyzed for the study.
- Using Arc GIS the .las datasets were further filtered by returns that represent bare earth and the immediate coastal bathymetry. A terrain model was created with a spatial resolution of 2 m X 2 m and five levels of pyramid structure for optimized zooming. A DEM was created for all five datasets using a spatial data analysis protocol



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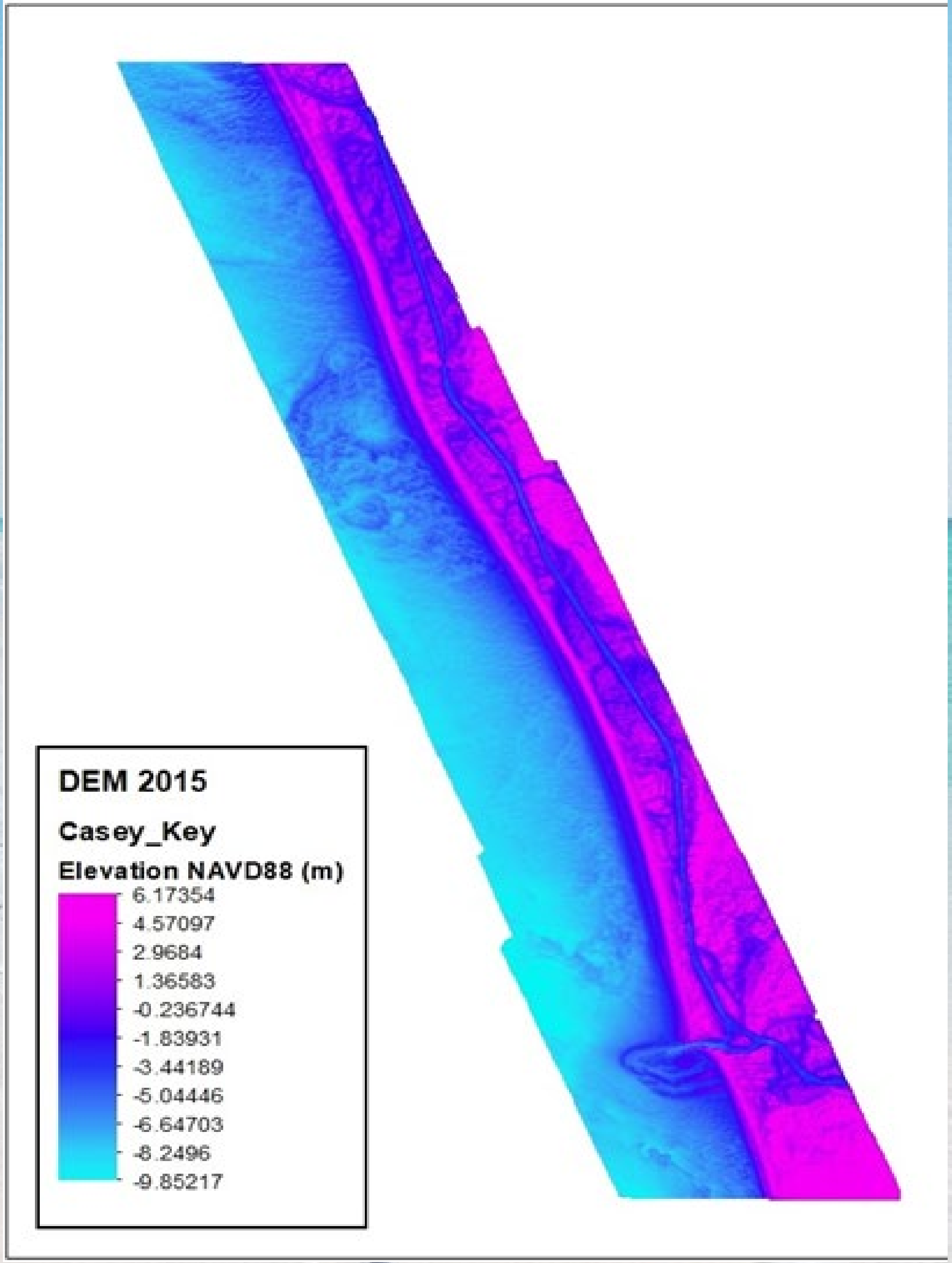
What is LiDAR?

- **LIDAR (Light Detection and Ranging) is a remote sensing method that uses lasers to generate precise, three-dimensional information of Earth and its surface characteristics.**
- **A LIDAR instrument consists of a laser, and a GPS receiver. Airplanes are the most commonly used vehicles for acquiring data over vast areas.**
- **LIDAR can be used to produce more accurate shoreline maps and make digital elevation models (DEM's)**

(DEM) Digital Elevation Model



- FDEP R-monuments were overlaid on the raster converted DEM's
- Beach transect lines, anchored at the R-monuments on the landward side and extended seaward to 8-10 m water depth, were created for the entire study area.
- profile data were extracted from DEMs, exported to Microsoft excel, where profile graphs for all datasets were overlaid to display changes in the profiles over time

Methodology (Sands Analysis)

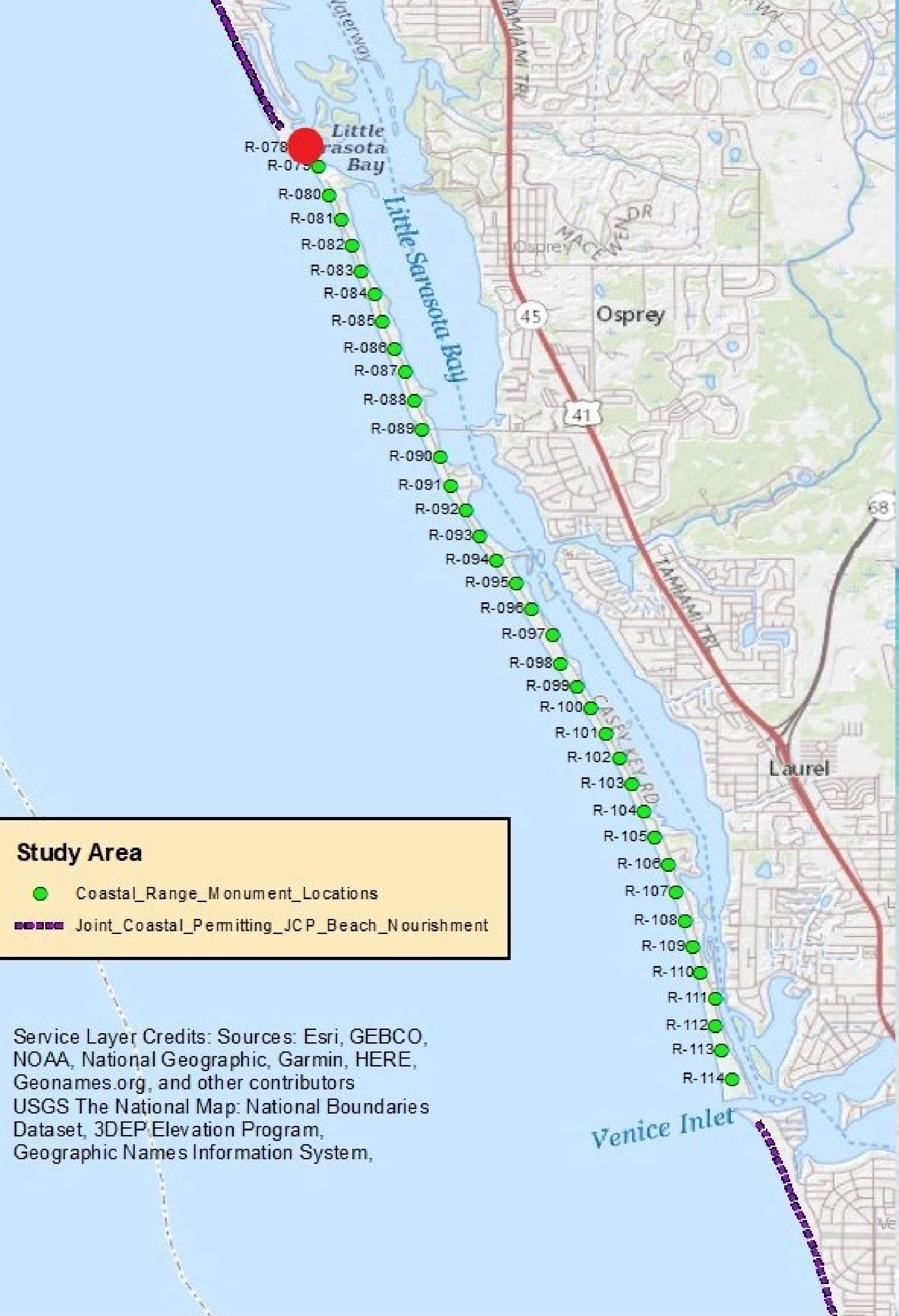
- **Sediment volume was analyzed for Casey Key using "SANDS", an Asset Management System developed by CH2M HILL. Profile data was compared for volumetric change from 2004-2015**

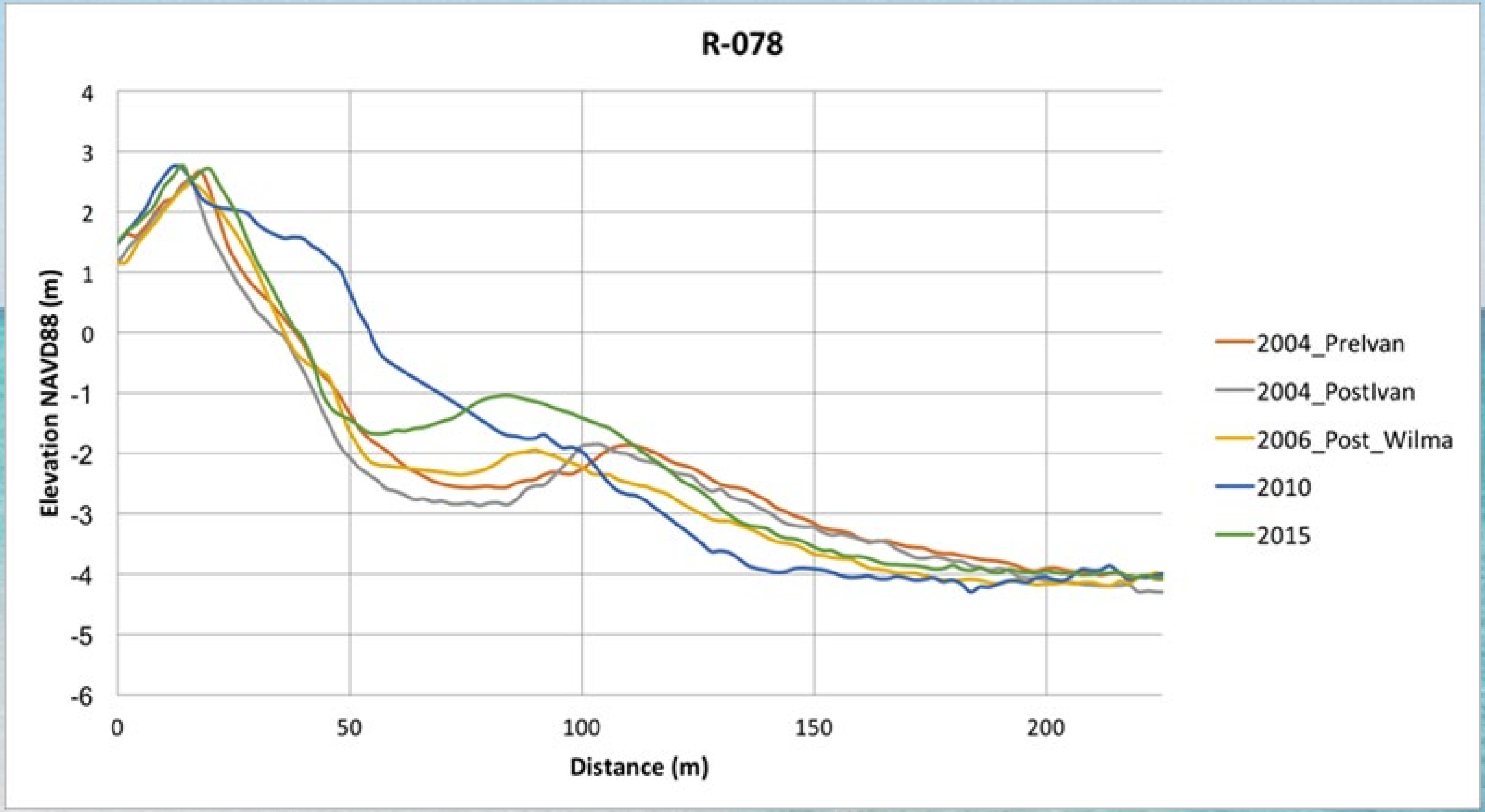
- **SANDS calculates beach volumes by comparing the beach profile to a selected reference profile (Master profile) and the cross-sectional area is then calculated for all profiles.**

Methodology (Google Earth)

- Google Earth Pro was used to create maps depicting the changing shoreline. Available historical imageries since 1995 were used to trace the shoreline of the barrier island. Tidal variations are not accommodated in these imageries and hence the traced line could be considered as representing littoral zone. These traced shorelines were overlaid with the most recent 2019 image from google earth to display the evolution of the shoreline over the last 24 years.

Results: Northern Casey Key

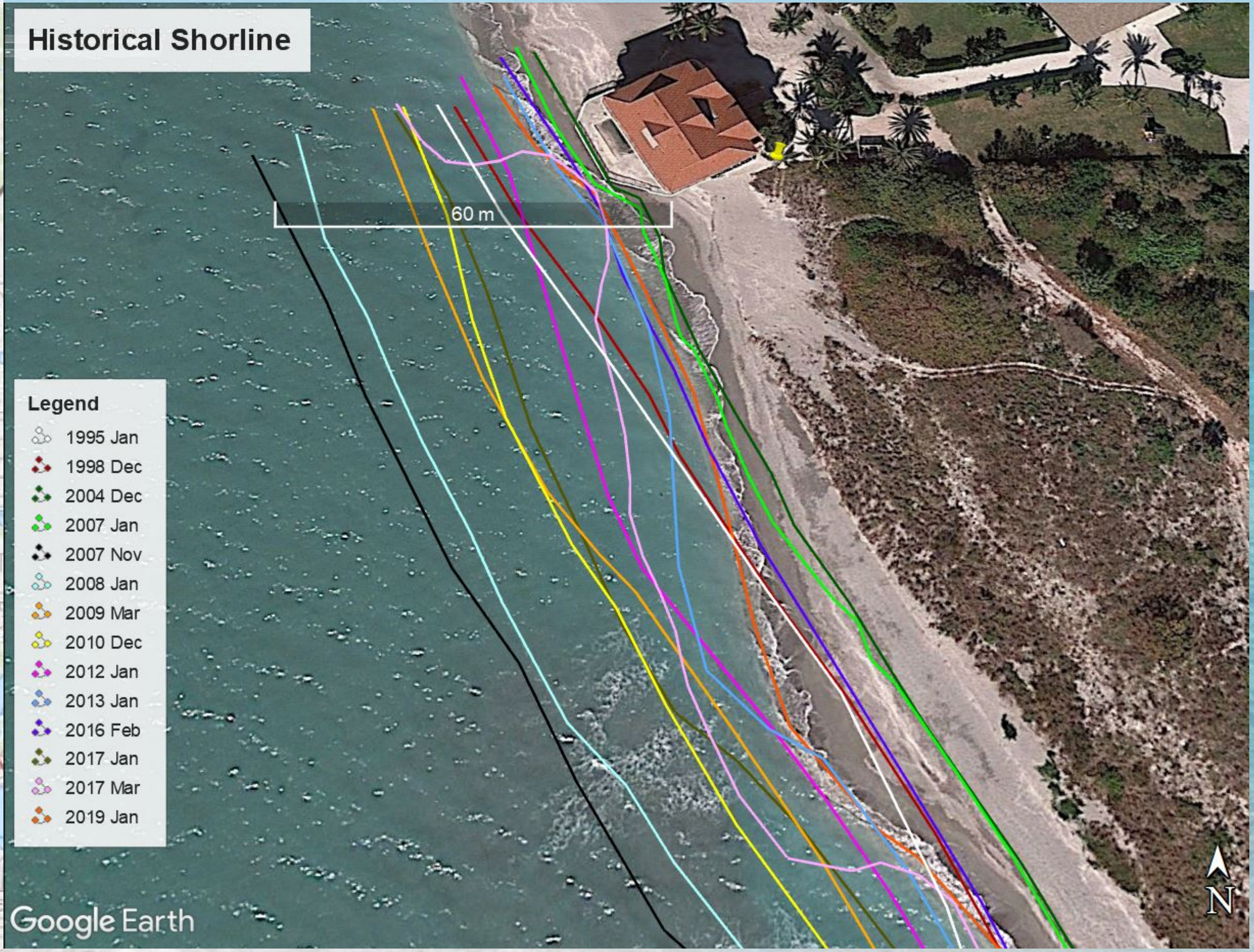




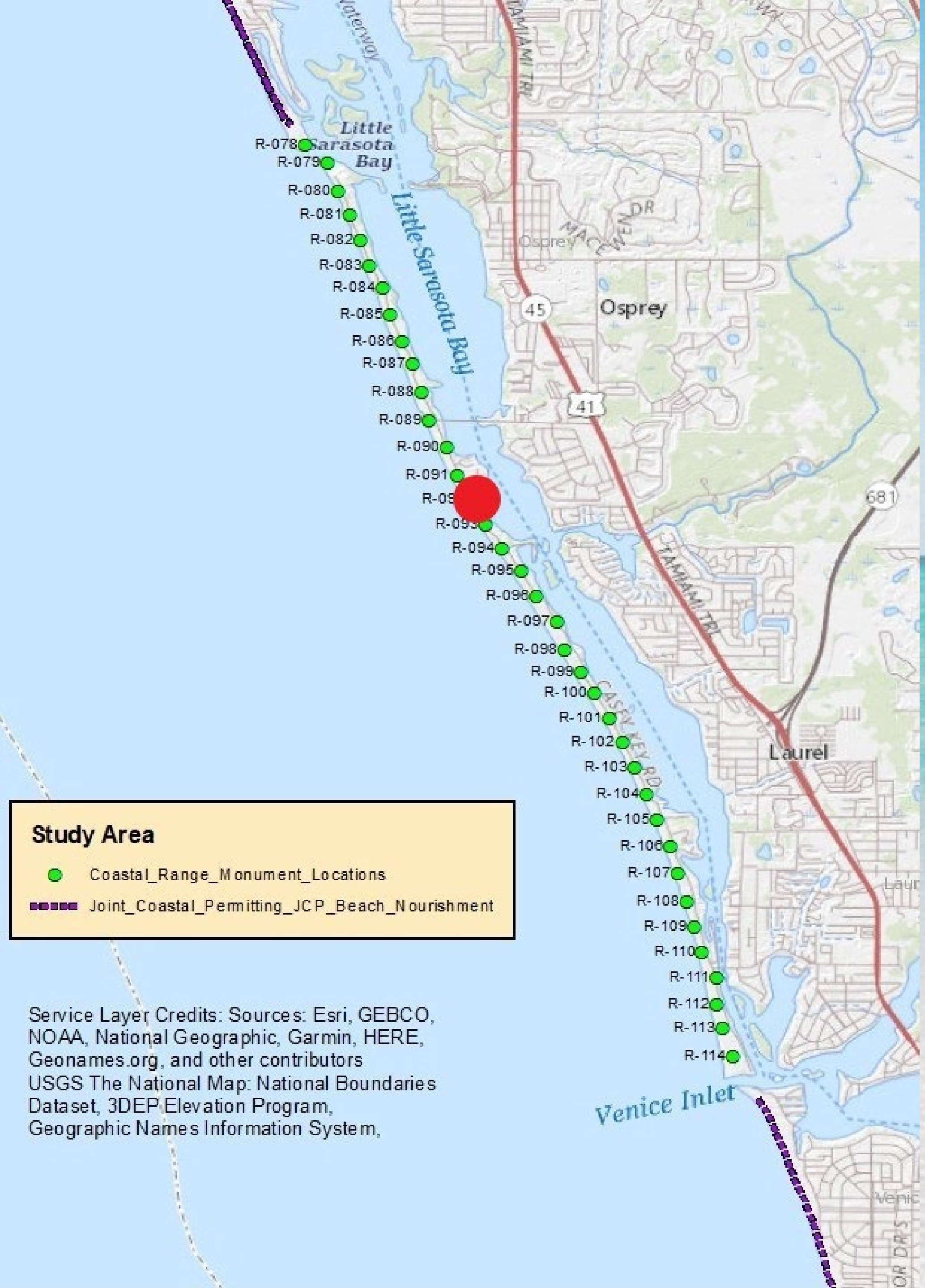
Estimated Change in Beach Volume

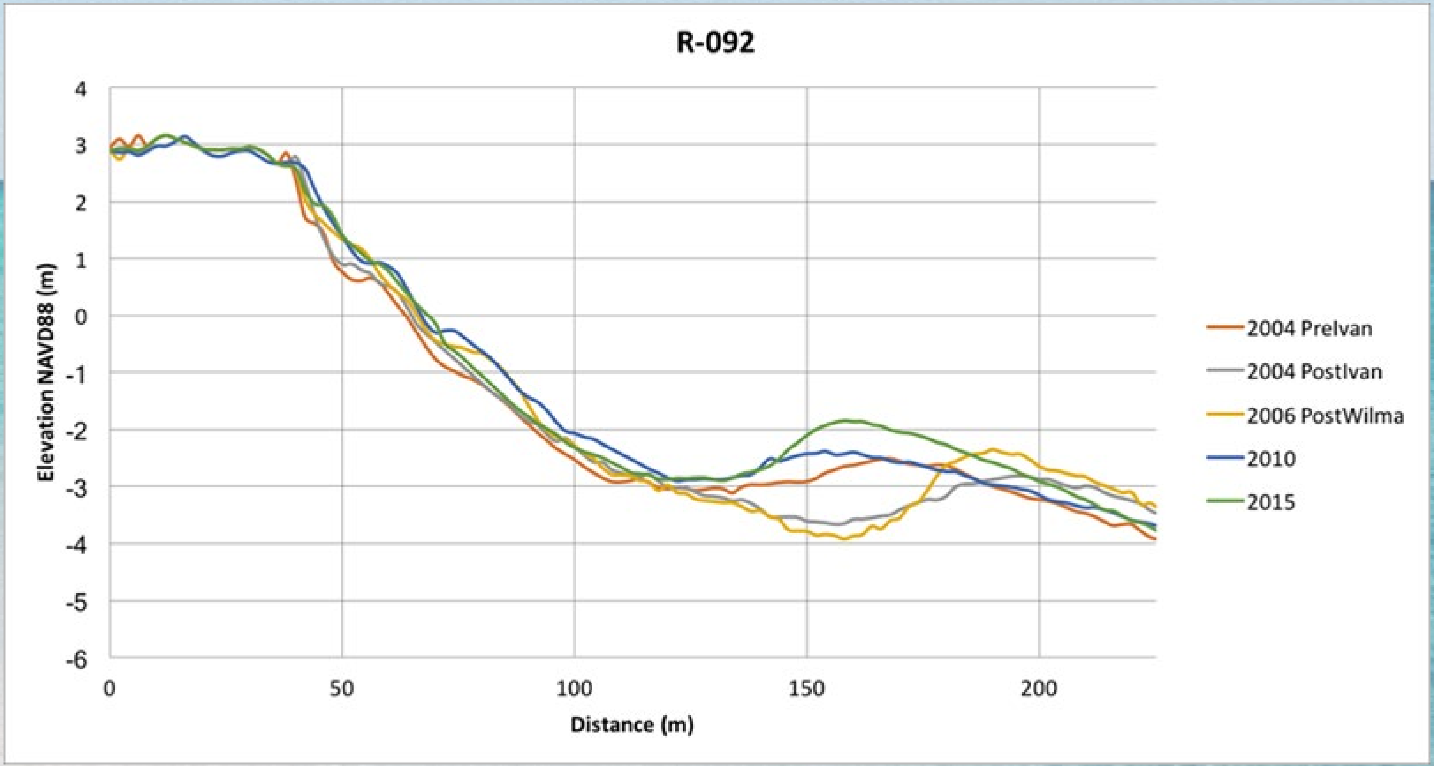
Changes Between Locations		Casey Key Northern - Volume Changes Above MP							
		2004-04-01 to 2004-11-01		2004-11-01 to 2006-05-28		2006-05-28 to 2010-06-20		2010-06-20 to 2015-06-06	
Location 1	Location 2	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change
R-078	R-079	-15822.86	-2.9	1379.71	0.26	19379.25	3.65	1445.03	0.26
R-079	R-080	-15305.88	-2.19	13.92	0	23113.97	3.37	2411.32	0.34
R-080	R-081	-16110.66	-2.94	6547.02	1.23	18244.73	3.39	3815.14	0.69
R-081	R-082	-26838.45	-4.46	14669.79	2.55	24072.41	4.08	7017.87	1.14
R-082	R-083	-20139.18	-3.7	9961.45	1.9	13352.61	2.5	6498.44	1.19
R-083	R-084	-11191.85	-1.97	8257.16	1.48	-75.08	-0.01	5195.99	0.92
R-084	R-085	-8494.05	-1.4	9514.87	1.59	-547.35	-0.09	-5245.48	-0.86
R-085	R-086	-8384.99	-1.2	9379.06	1.36	1679.61	0.24	-15351.45	-2.19
R-086	R-087	-10238.99	-1.8	4488.95	0.8	10596.14	1.88	-10455.47	-1.82
		-132526.91	Av=-2.51%	64211.93	Av=1.24%	109816.29	Av=2.11%	-4668.61	Av=-0.04%
			Min=-4.46%		Min=0.00%		Min=-0.09%		Min=-2.19%
			Max=-1.20%		Max=2.55%		Max=4.08%		Max=1.19%

Northern Casey Key



Results: Middle Key

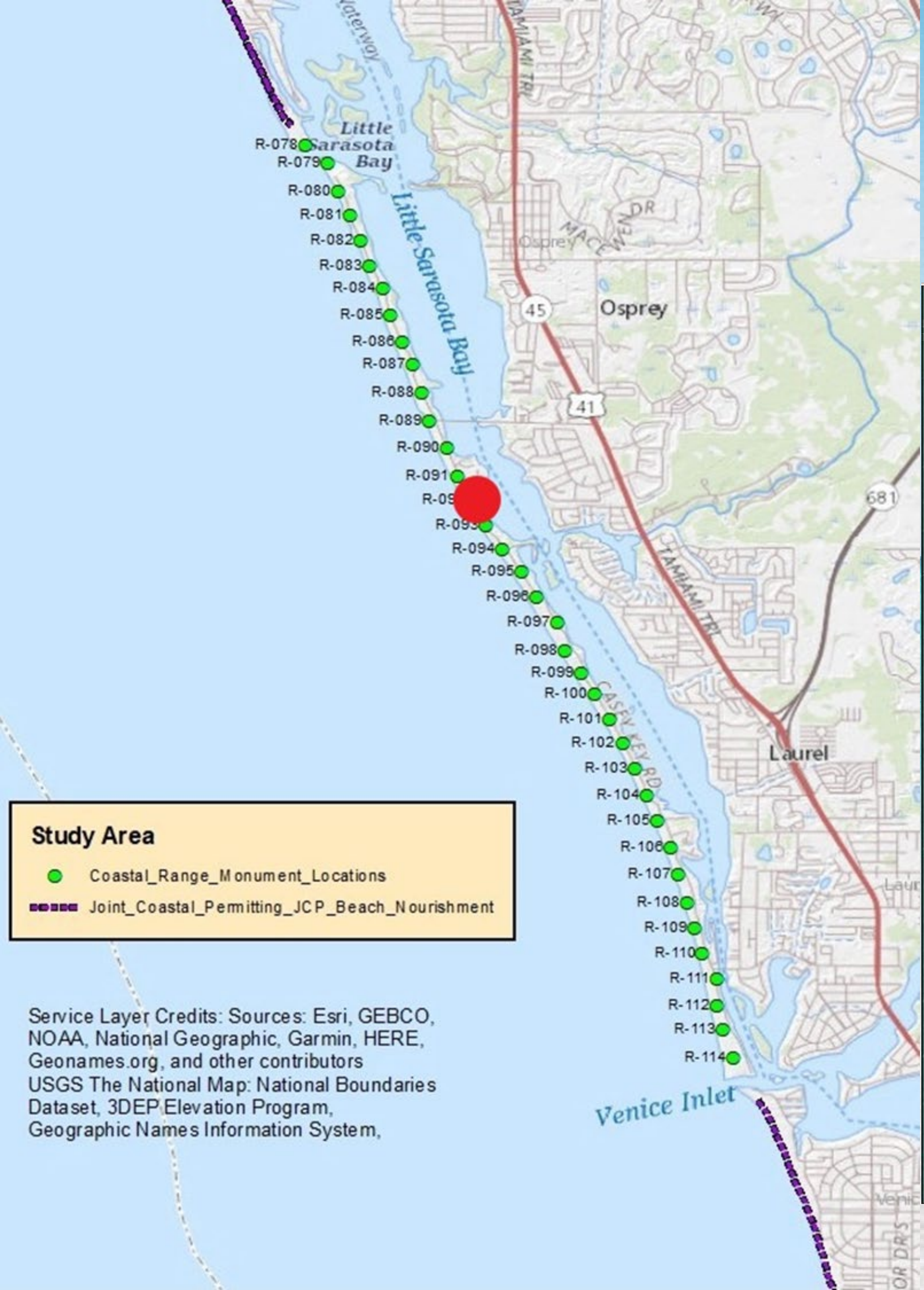




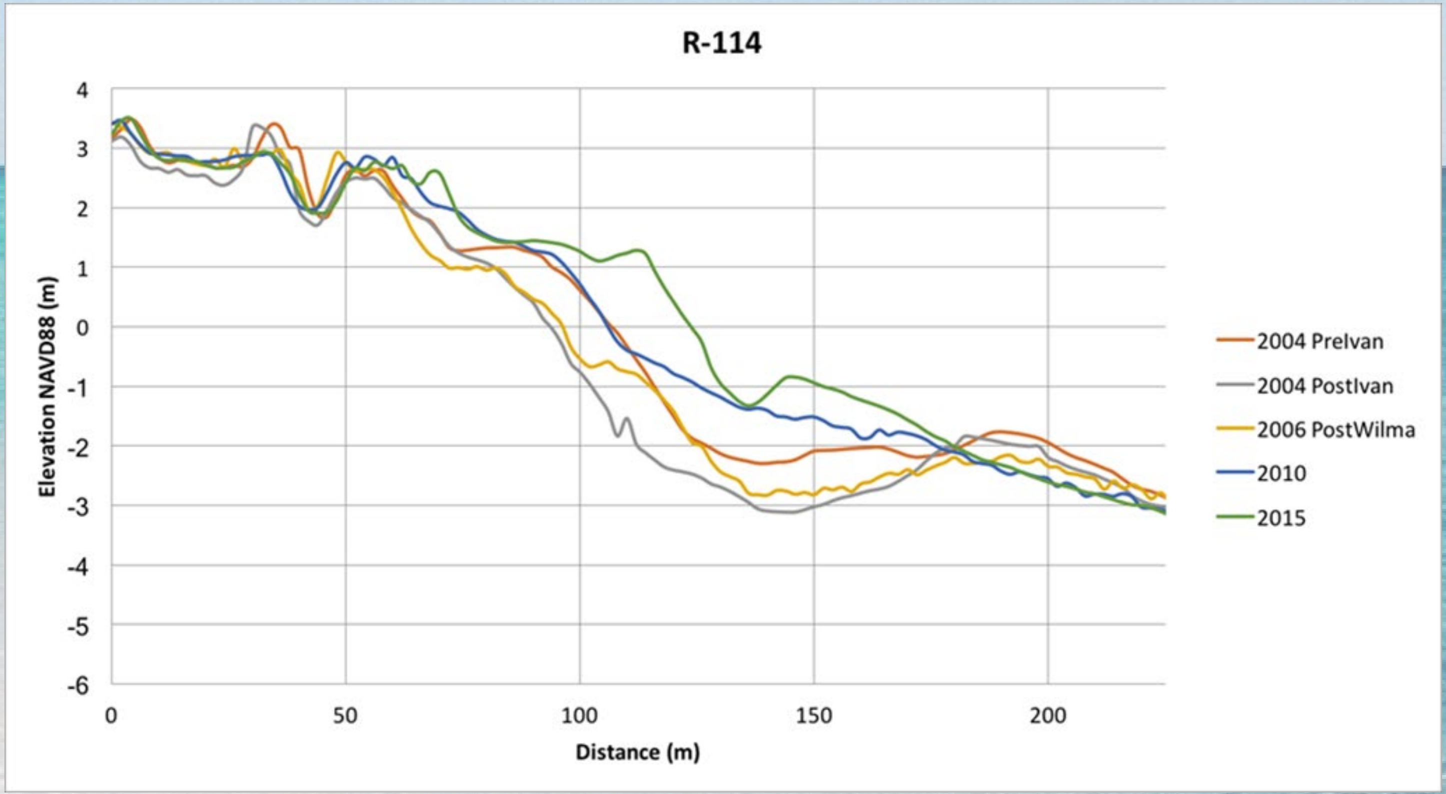
Estimated Change In Beach Volume

Changes Between Locations		Casey Key Middle - Volume Changes Above MP							
		2004-04-01 to 2004-11-01		2004-11-01 to 2006-05-28		2006-05-28 to 2010-06-20		2010-06-20 to 2015-06-06	
Location 1	Location 2	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change
R-088	R-089	-16049.1	-2.28	-463.17	-0.07	17917.31	2.61	-5847.37	-0.83
R-089	R-090	-20224.77	-2.92	5299.48	0.79	22528.07	3.33	-5288	-0.76
R-090	R-091	-29251.04	-4.19	17368.85	2.59	32330.18	4.71	-9401.68	-1.31
R-091	R-092	-19212.91	-2.92	19488.41	3.05	21097.47	3.21	-2161.91	-0.32
R-092	R-093	-10699.17	-1.94	10705.63	1.97	14376.66	2.6	8528.37	1.5
R-093	R-094	-13211.33	-2.1	8049.21	1.31	13693.02	2.2	22409.27	3.52
R-094	R-095	-8058.3	-1.15	13591.52	1.96	14278.82	2.02	34553.53	4.79
R-095	R-096	-18339.01	-3.27	18880.92	3.48	18147.65	3.23	17806.27	3.07
R-096	R-097	-21889.85	-3.13	17831.7	2.63	5584.67	0.8	9634.4	1.38
		-156935.48	Av=-2.66%	110752.55	Av=1.97%	159953.85	Av=2.75%	70232.88	Av=1.23%
			Min=-4.19%		Min=-0.07%		Min=0.80%		Min=-1.31%
			Max=-1.15%		Max=3.48%		Max=4.71%		Max=4.79%

Middle Casey Key



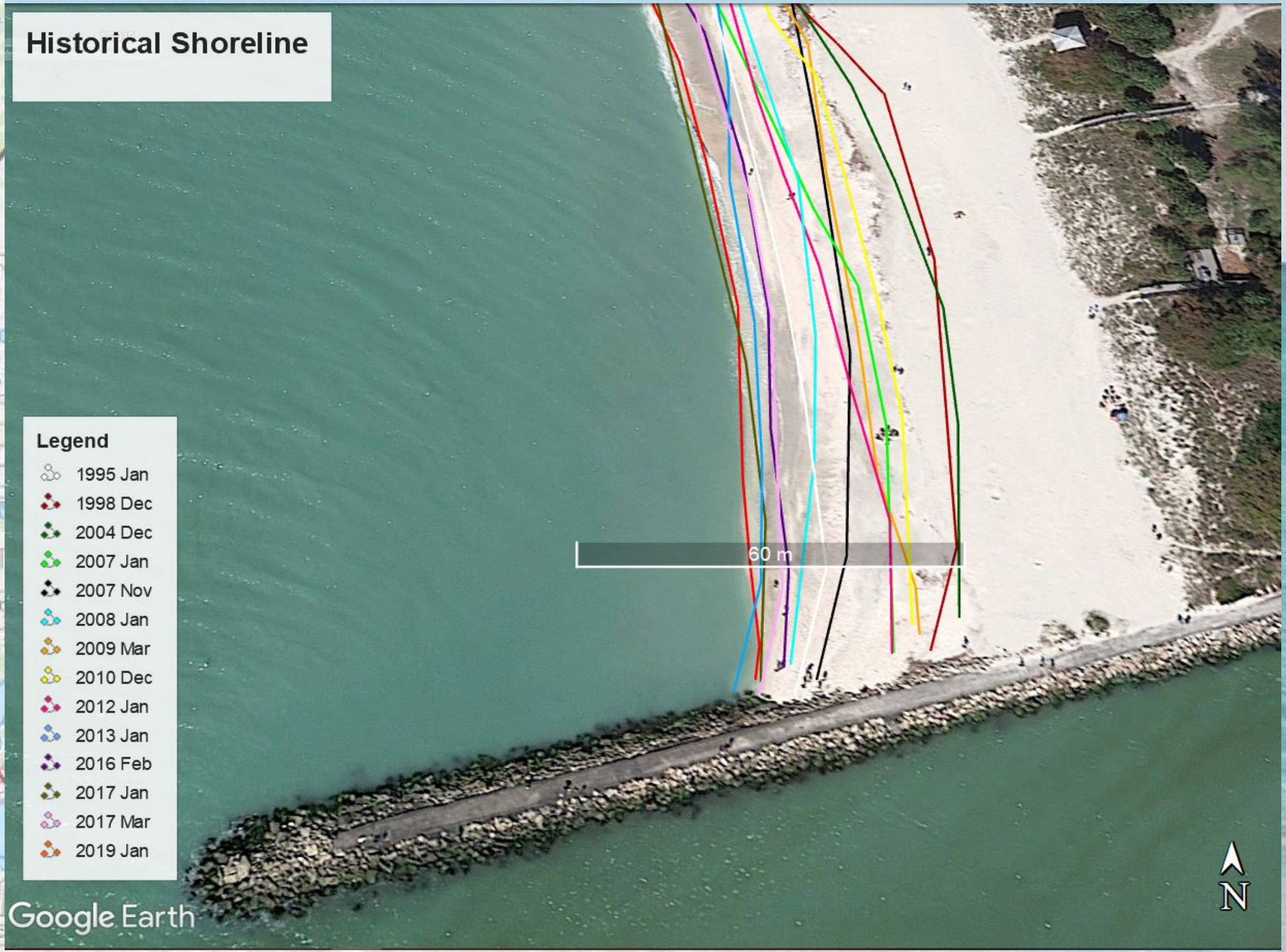
Results: Southern Casey Key



Estimated Change In Beach Volume

Changes Between Locations		Casey Key Remaining - Volume Changes Above MP							
		2004-04-01 to 2004-11-01		2004-11-01 to 2006-05-28		2006-05-28 to 2010-06-20		2010-06-20 to 2015-06-06	
Location 1	Location 2	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change	Vol Diff (m3)	% Change
R-108	R-109	-24545.54	-4.84	12962.1	2.68	26310.31	5.31	5077.22	0.97
R-109	R-110	-21267.03	-4.23	15481.54	3.22	27157.11	5.47	5903.85	1.13
R-110	R-111	-13562.42	-2.1	21201.6	3.36	25284.67	3.87	11712.18	1.73
R-111	R-112	-9048.54	-1.55	30065.84	5.23	28205.08	4.67	15008.27	2.37
R-112	R-113	-12981.28	-2.68	30703.81	6.52	28301.79	5.64	20386.25	3.85
R-113	R-114	-28338.16	-4.36	22530.25	3.62	30499.49	4.73	23578.08	3.49
		-109742.97	Av=-3.29%	132945.14	Av=4.11%	165758.45	Av=4.95%	81665.85	Av=2.26%
			Min=-4.84%		Min=2.68%		Min=3.87%		Min=0.97%
			Max=-1.55%		Max=6.52%		Max=5.64%		Max=3.85%

Nokomis Beach



Discussion

- Based on our study, extensive erosion was experienced along the entire key during 2004.

- Between April 2004 and November 2004, the study area experienced effects from multiple major hurricanes. Charley Ivan, Frances, and Jeanne.

- A volume of 608,094 m3 of sand was estimated to be lost during this period.

- Notable changes in the northernmost portion of the key during the 2004 erosion event. There are some critically eroded areas, and the shoreline is highly variable. This threatens homes constructed near the water.

- The shoreline for the middle portions of the key exhibit more uniformity in the response of to hydrodynamic conditions. This is likely due to extensive nearshore beach stabilization projects including rock revetments for protecting the coast.

- The southern portion near the jetty was highly variable. The jetty structure is an obstacle for the refraction of waves and longshore sediment transport, which is predominantly southerly. Which makes this area variable due to the obstruction of normal processes.

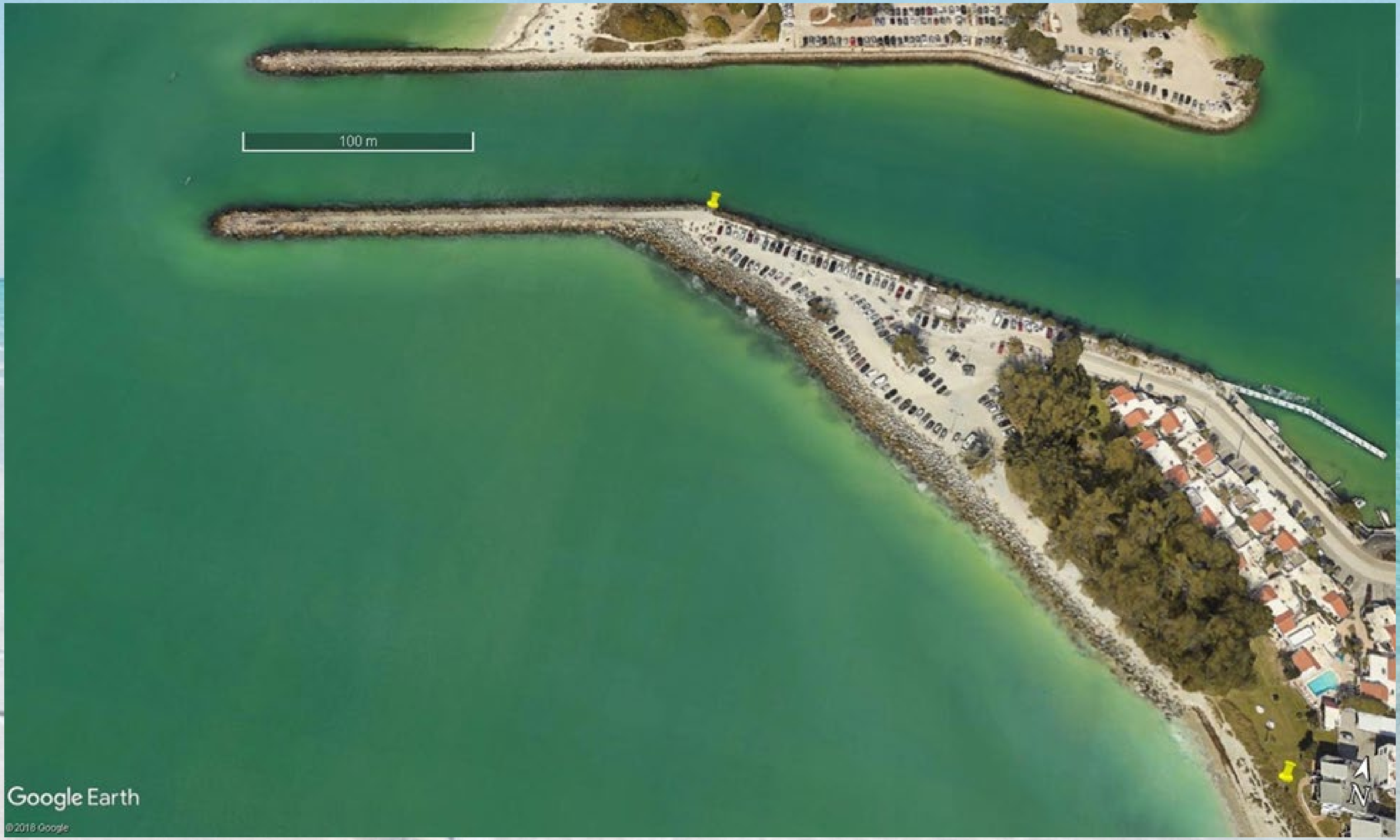
Resiliency of Casey Key

- Casey key overall has proved to be resilient to erosion, despite the battering of the 2004 hurricane season the key appears to be overall stable, and even received unintended benefits from nourishment projects to the north. This could be partly due to the longshore bar formation just offshore of the barrier island. With increased wave energy during winter storms and hurricanes, this bar may be providing a buffer causing waves to break and lose energy before approaching the shore.

Consequences of Coastal Engineering Projects

- **The southern portion of the key at Venice inlet exhibits the most significant sediment accretion in the study area.**
- **Construction of bulkheads and jetties can affect normal coastal processes. The northern jetty of Venice inlet seems to be trapping south bound longshore sediment transport and causing it to accumulate on the beach.**
- **The jetty is probably depriving sediments welding to Venice beach south of the study area; as a result, there are extensive rock revetments protecting that beach and additional beach nourishment projects to supply sediment.**

Venice Inlet



Nourishment Projects

- Between 1994 and 2005 a two-phase nourishment project and additional maintenance supplied 1,984,178 m^3 of sand nourishment on Venice beach south of Venice inlet.
- There was a beach nourishment between December of 2006 and March of 2007 in which southern Siesta Key received 705,149 m^3 beach and dune fill. Since the completion of the project in March 2007, approximately 193,967 m^3 of the beach fill has been lost.

Conclusions

- Evidence of erosion were depicted in the 2004 hurricane season as more frequent surveys were available for that year. It would be useful if more frequent LiDAR data sets were publicly available to perform a more precise evaluation.

- We found results that are important for identifying problem areas and assessing the success of management practices and engineered structures.

Conclusions

- **LiDAR has proven to be an efficient way to model the beach and extract profiles for volumetric analysis and sediment budget estimation. Studies should continue as more datasets become available to monitor the beaches that have been nourished and continue to implement successful management practices to preserve these valuable assets.**


Questions?