Formational history and geomorphic preservation of sea level highstands over the last 150 ky near Cape Canaveral, Florida, USA

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Abstract

Cape Canaveral, Florida, is perhaps one of the most important stretches of coastline in the United States of America (USA) due to its critical strategic role in the pursuit of space exploration and as the locus of advanced technological innovation. Due to its geographical setting, the entirety of Cape Canaveral, including its infrastructure, facilities, and important natural habitats (e.g., wetlands, estuaries and dunes) is vulnerable to coastal hazards such as continued sea level rise, storm surges, erosion and flooding. As such, accurate sea level characterization and coastal resiliency predictions are essential to promoting long-term coastal planning and sustainability in the area. This study aims to better understand the temporal and spatial evolution of this area with the purpose of more accurately documenting historical sea level fluctuations and calibrating more localized projections at this site.

The Cape Canaveral coastline is situated on a passive margin mostly affected by oceanic (sea level change and wave impact) and atmospheric (aeolian) alteration. This sector is part of the east Florida coast microtidal (1.2 m) setting and low wave energy (1.2-1.6 m and 6.1-8.2 sec for average significant waves) regime and is defined by a well delineated set of beach ridge or cape systems. While the name "Cape Canaveral" is often used as a generic term to describe the geographic area, it is actually an amalgamation or complex of multiple preserved capes. The preserved Cape Canaveral beach ridge plain has largely documented the paleo-sea level highstand history over the last 150 ky. High-resolution mapping of these beach ridges is completed using GPS, LiDAR, aerial, as well as satellite imagery. In order to reconstruct the formational history of the Cape Kennedy Complex and the preserved record of sea level highstands, these detailed geomorphological observations are integrated with OSL and C14 dating techniques.

The chronological framework delineated by the OSL dates coupled with detailed geomorphological mapping allows for the creation of high-resolution calibrated site-specific sea level curves that reflect the local environmental and geological conditions. This refinement has the potential to improve the understanding of past sea level variability which is crucial for predicting future trends and assessing the impacts on coastal regions such as Cape Canaveral.

Future Work

Updated and Detailed Geochronology (OSL and/or C14)

-Beach-ridge sets on the far west (Pamlico shoreline)
-The entirety of the western Cape complex
-False Cape
-Leverage updated dates to better understand modern Cape complex migration
-How fast is modern Cape moving to the south? Can we better understand Cape tip migration for the Cape Kennedy Complex?

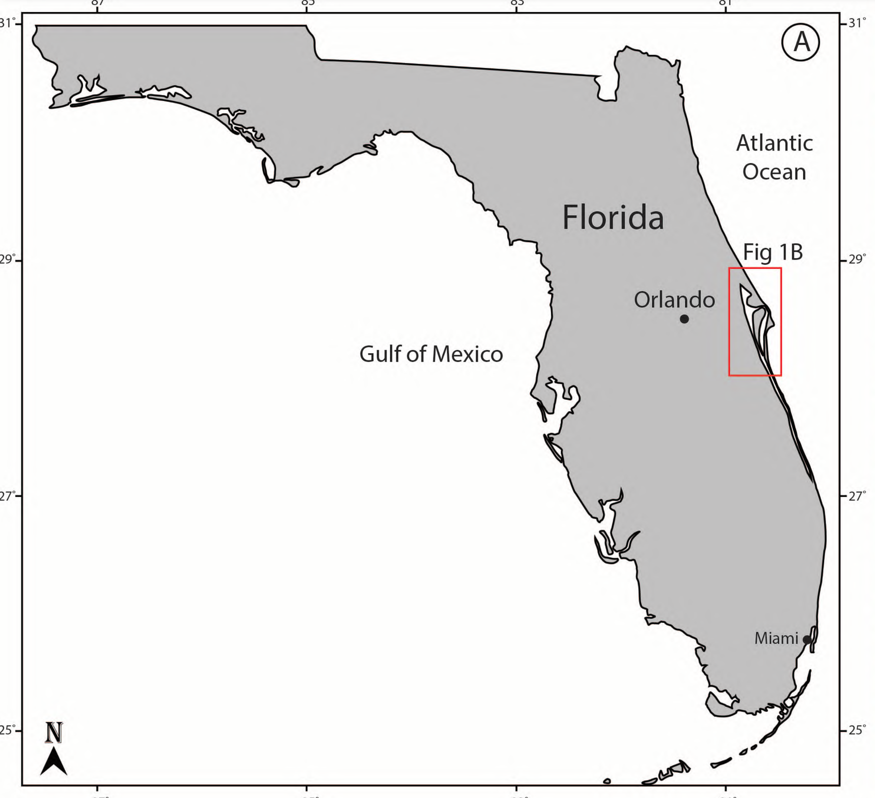
Imagery and Surveys

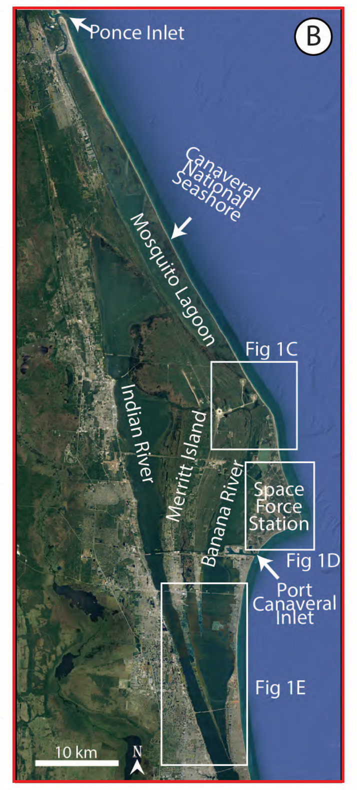
-Geophysical surveys across cape boundaries to map subsurface structures
-Groundtruthing of aerial LiDAR sets with mobile LiDAR systems and dGPS

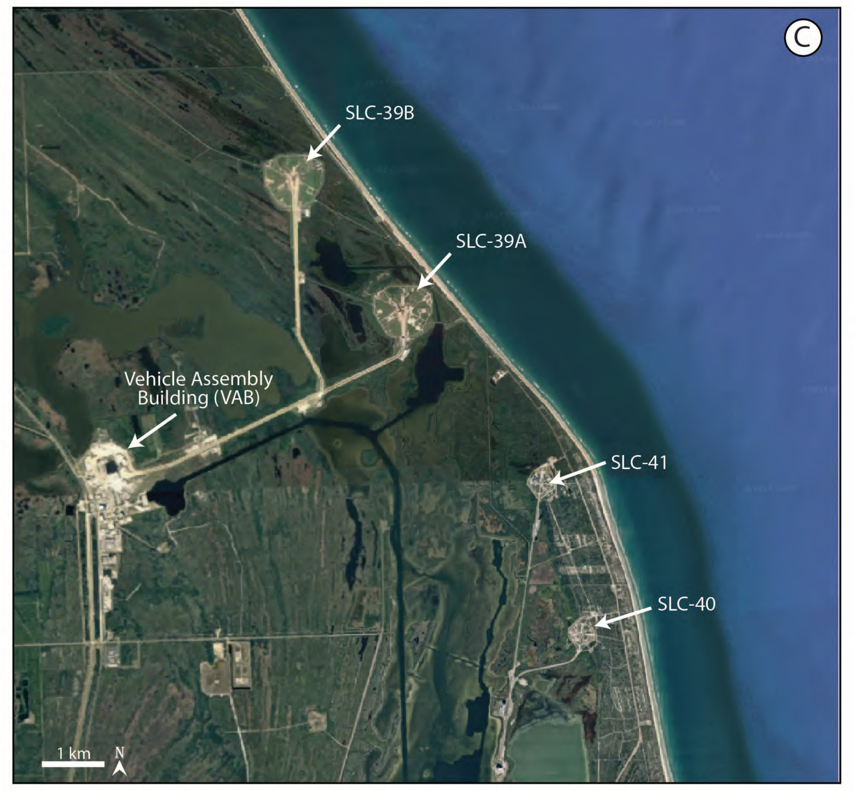
Geomorphological Characterization and Calibration

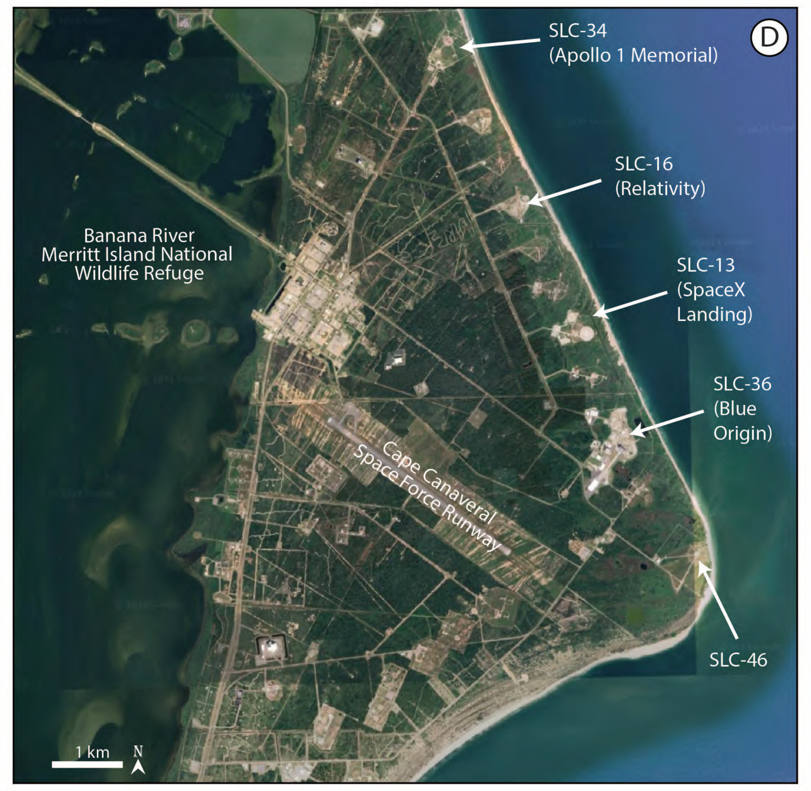
-Continued analysis of the detailed geomorphological evolution of the Cape Complex leveraging high-resolution imagery through time
-Leverage borehole data to calibrate imagery datasets
-Analyze the texture and composition of sediment across the Cape Complex focused on interpreted Beach-ridge sets.

Area of Interest and Critical Infrastructure









Google Earth Imagery (2024) of AOI.

A) Map of Florida indicating the position of the Cape Canaveral Complex located on the passive, mesotidal, margin Atlantic Coast.

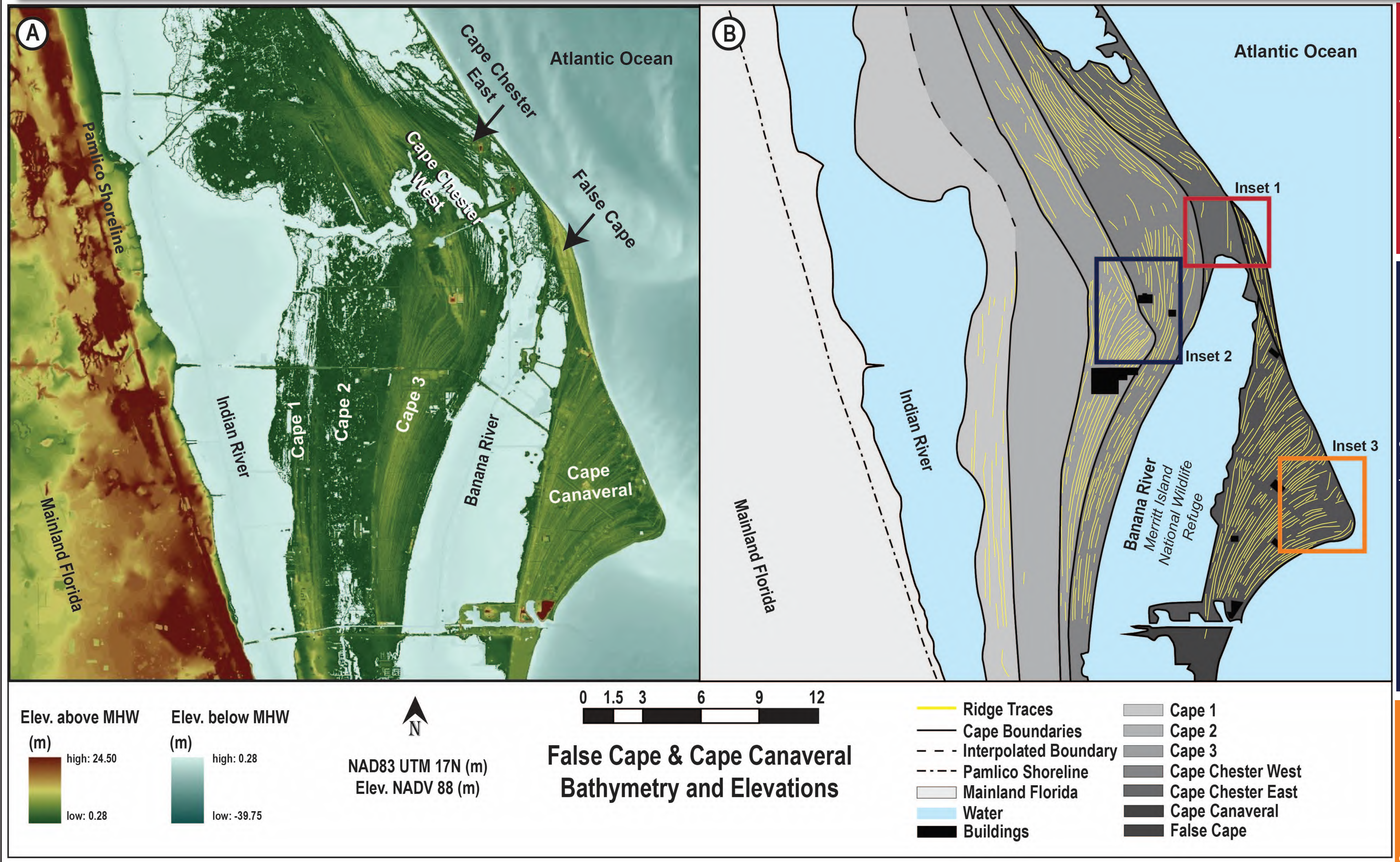
B) Satellite image of the Cape Canaveral Complex.

C) Northern area of the Cape Canaveral Complex showing the northern set of rocket launch facilities.

D) Current growth area of the Cape Canaveral Complex showing the southern stretch of rocket launch facilities.

E) "Cape Tails" of the far southern end of the Cape Canaveral Complex showing West and East Merritt Island interpreted as either a local change in sea level between the two cape tail formations or a depositional hiatus between the two.

Cape Kennedy Complex Formational History

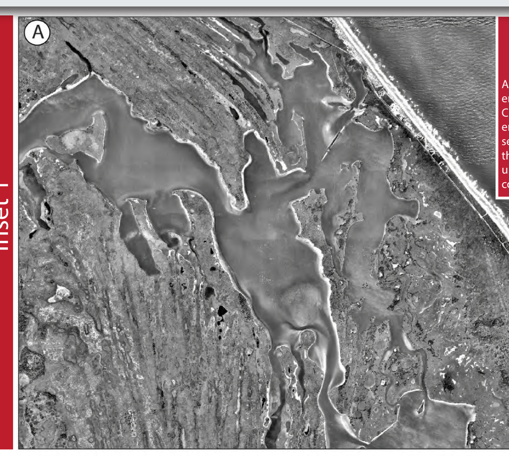


Overview of the Cape Kennedy Complex which includes the area from the Pamlico Shoreline in the west through to the present day Atlantic shoreline in the east. The complex includes Capes 1-3, Cape Chester West, Cape Chester East, Cape Canaveral and False Cape and is likely the largest sand ridge plain in North America and perhaps the world.

Part A) Digital Elevation Model (DEM) colored by meters of elevation above mean high water (MHW) of the entirety of the Cape Kennedy Complex.

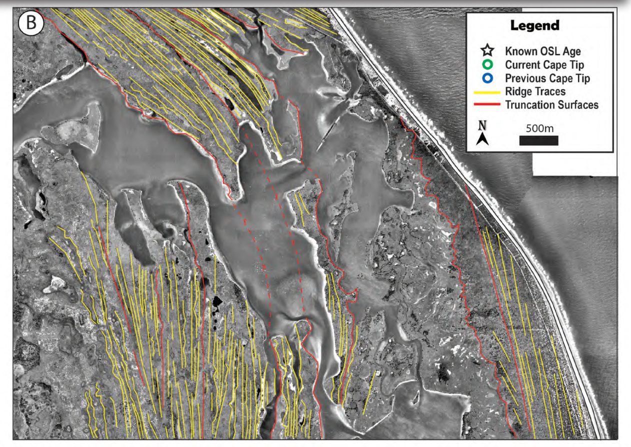
Part B) Schematic line drawing of the Cape Kennedy Complex showing the different cape geoforms identified by morphology and OSL dating.

Inset 1



Inset 1: Cape Chester East to False Cape

Aerial image of the erosional ridges of Cape Chester, the northern end of the modern ridge sets of False Cape and the paleo flood tide delta upon which LC-39B was constructed.

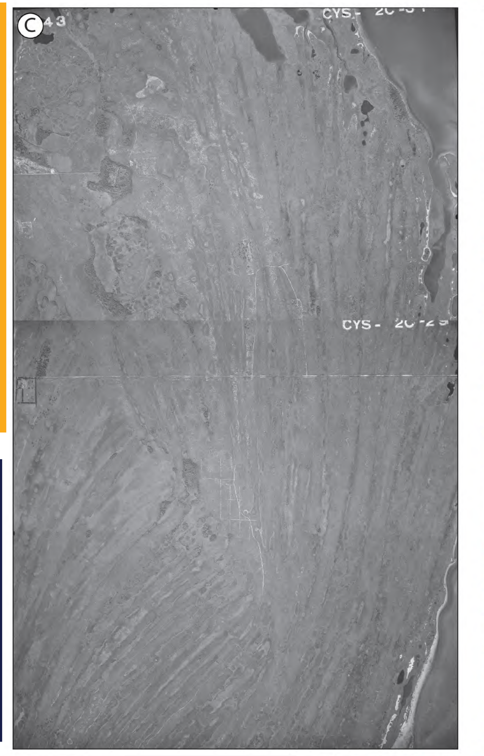


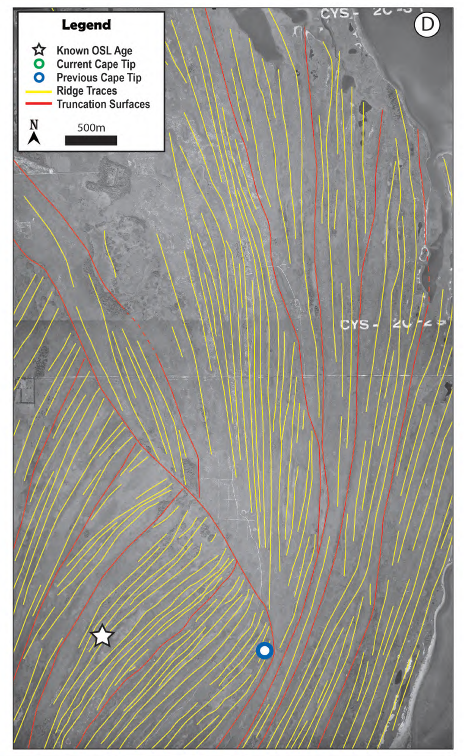
Inset 2

All Insets – *Aerial images were taken on Feb. 14, 1943, prior to the construction of the Kennedy Space Center. Yellow lines indicate individual ridges while red lines indicate bounding ridges. Red line ridges bound changes in geometry from older, truncated ridge sets.*

Inset 2: Cape 3 to Cape Chester West

Aerial image of the preserved "Cape Tip" of Cape #3 with the ridges of West Cape Chester. Blue dot on right image indicates the location of the preserved cape tip.

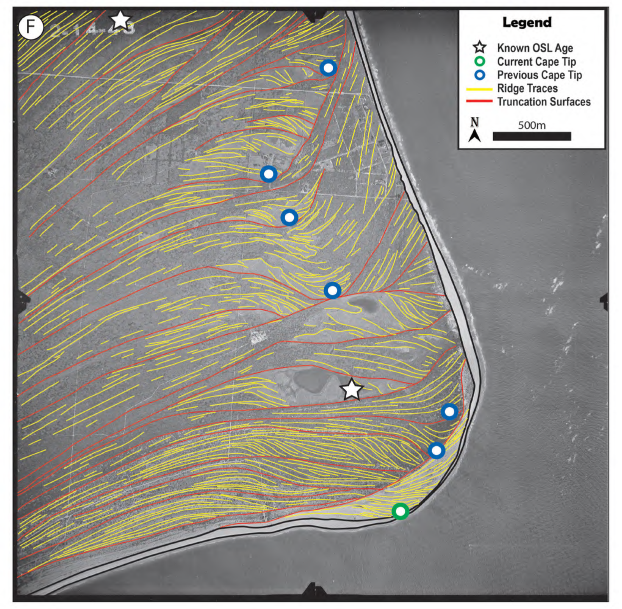




Inset 3

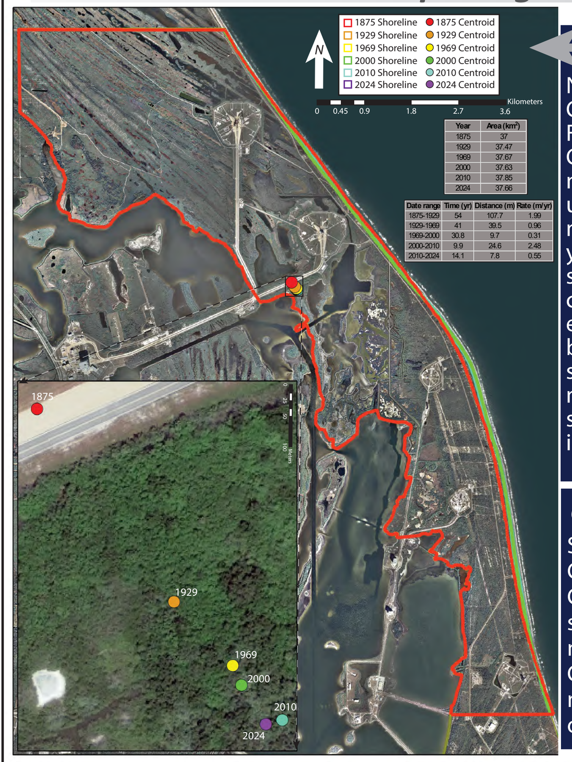
Inset 3: Cape Canaveral

Aerial image of the modern southward migrating Cape Canaveral showing multiple preserved cape tips and cape tip ponds. Blue dots on right image indicate the best approximation of the preserved cape tips along its southward migration. Green dot indicates current cape tip position.



Cape Migration and Sea Level Implications

Cape Migration- False Cape and Cape Canaveral



False Cape

Northern Cape Canaveral (Cape Chester eroding shorelines and False Cape formation) – Centroid movement of the northern Cape Canaveral area using shoreline change to map migration route. In the last 150 years migration begins to the south but as False Cape continues to form moves more easterly. Recent storms, beginning with Hurricane Sandy show a change pushing cape migration to the west. Analysis shown on 2015 satellite imagery.

Cape Canaveral

Southern Cape Canaveral – Centroid movement of the Cape Canaveral area using shoreline change to map migration route. Cape Canaveral proper shows a migration directly to the south over the last 150 years.

Cape Kennedy Complex Sea Level Implications

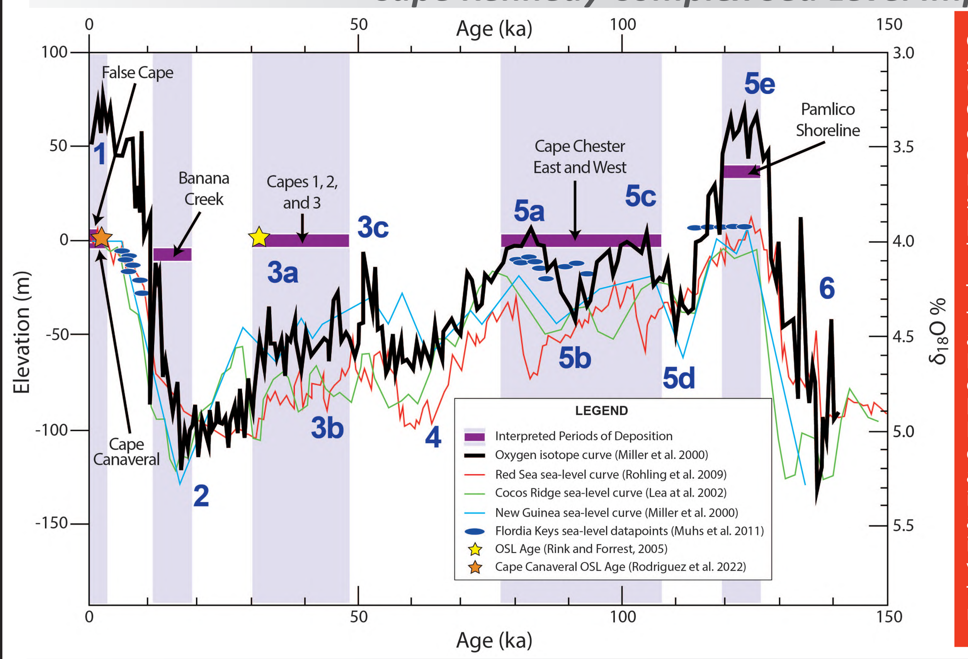
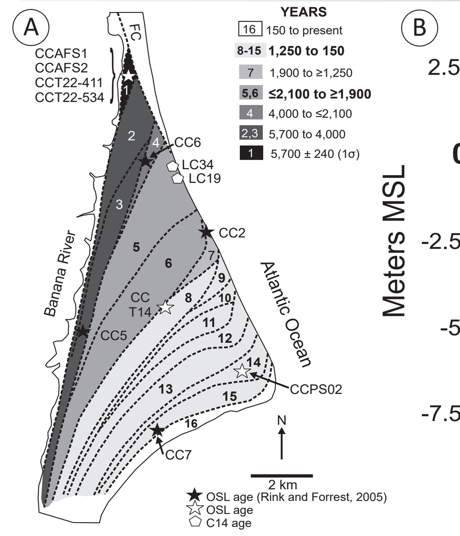
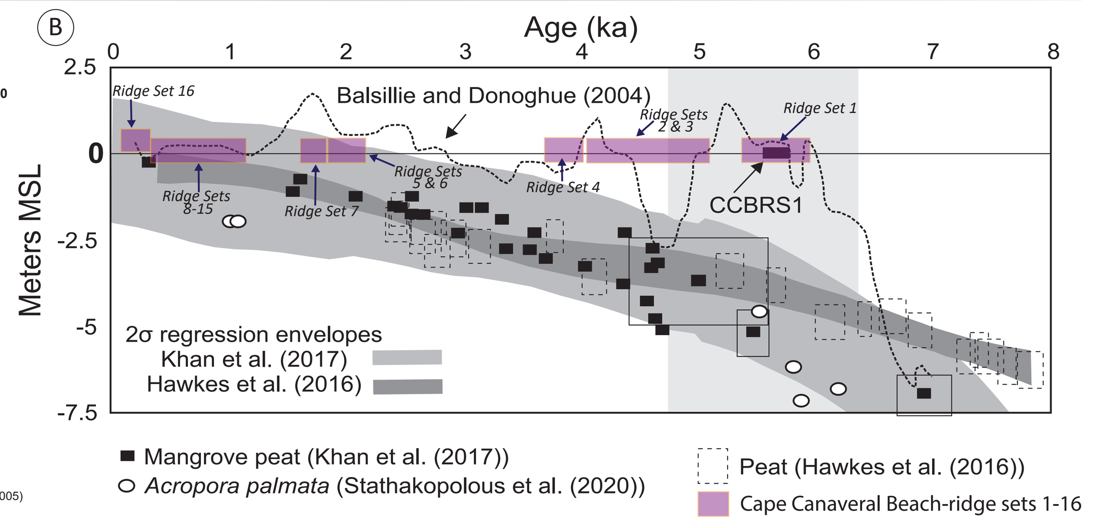


Chart showing several global and more regional sea level curves in relation to locally derived data (elevations and ages) from the Cape Kennedy Complex. Purple boxes delineate the approximate elevations for particular areas of the Cape Kennedy Complex and stars denote OSL ages. Interestingly, ridge sets tend to be preserved at higher relative sea-level fluctuations and the geomorphology preserved at the Cape Kennedy Complex contrasts the regional sea level curves.

The juxtaposition observed in the more regional trends (global to region specific sea-level curves) and the local data (i.e., OSL ages, high-resolution DEM elevations, and preserved ridge geomorphology) suggests there is a need for a better calibrated site-specific model at the Cape Kennedy Complex which reflects the local environmental and geological conditions. Further analysis and refinement of the geomorphology integrated with detailed geochronological (OSL and C14) dating techniques has the ability to improve the understanding of past sea level variability which is crucial for predicting future trends and developing appropriate coastal impact mitigation plans.

Cape Canaveral Sea Level Implications





A) Figure from Rodrigues et al., 2022 showing the interpreted beach ridge sets 1 through to 16 with associated ages at Cape Canaveral with locations of both C14 and OSL datapoints delineated.

B) Figure modified from Rodrigues et al., 2022 showing the Cape Canaveral Beach-ridge Set 1 position versus the sea-level curves of (1) Hawkes et al. (2016) for northeast Florida and Khan et al. (2017) for southeast Florida, both based on subsurface data and (2) the Balsillie and Donoghue (2004) curve, a 7-point floating average, based on onshore data from the northern Gulf of Mexico and south Florida. Four OSL ages with a mean of 5680±240years provide the chronometric estimate of the depositional age of the Cape Canaveral Beach-ridge Set 1. Additional Beach-ridge sets 2-16 (purple boxes) are schematically plotted from calibrated OSL dates reported in Rodrigues et al., 2022. Important to note that all ridge sets sit close to or slightly above the 0 m MSL marker.

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