MAPPING HISTORICAL CHANGES IN FLORIDA'S COASTLINE FROM 1875 TO 2000

Tucker Hindle, Hongbo Su, Tsung-Chow Su & Tobin Hindle

Charles E. Schmidt College of Science

Abstract

Florida's beaches are highly dynamic coastal features. They are vulnerable to accretion and erosion over time due in part to human interaction and climate change stressors such as storm activity. This study used the USGS Digital Shoreline Analysis System (DSAS) to calculate a long-term change rate from 1875 to 2000 and a short-term change rate from 1950 to 2000 of Florida's coastline from the NOAA Historical Surveys data set. The results show that Florida's coastline has not retreated in the past 50 years with overall long and short-term change rates of 0.014 m/yr and 0.110 m/yr of accretion respectively. Although the overall rates imply minimal change, coastline variability at a local level is prevalent. The data set of mapped historical change rates created during this research provides quantitative data that can be used to make local decisions to improve beach stability.

Keywords: Florida's coastline, historical changes, NOAA Historical Surveys, DSAS

I Introduction

Florida's beaches are highly dynamic coastal features that are subjected to erosion, accretion, or inundation due to natural processes and human activity. Both short-term and long-term natural processes such as tidal currents and sea level rise have affected Florida's coastline. Short term effects on the coastline are, in part, due to an increase in the population of coastal counties. The recent influx of human activity, such as coastal development and beach nourishment, has exacerbated beach erosion and accretion. Erosion of Florida's beaches poses a growing threat to coastal infrastructure and the increasing population of coastal counties (Ruggiero et al., 2013).

Florida's coastal counties are sought-after for their beaches and are home to sixty-six percent of Florida's population. However, they only account for thirty-seven percent of Florida's total land area. This high population density is quantified as seventy-eight percent denser than the state average (Esteves et al., 1998). The popularity of these areas' beaches has led to a public demand for a better understanding of the accurate positions and movement of Florida's coastline throughout history. This research responds to this problem by calculating change rate statistics that represent coastline movement relative to time. Change rates were calculated from digitized historical shorelines provided by the U.S. Geological Survey (USGS). The shorelines were then overlaid onto georeferenced original scans of historical land surveys supplied by the National Oceanic and Atmospheric Administration (NOAA). Long-term change rates for coastline movement were calculated using coastline positions established from land surveys that dated from 1875 to 2000, while short-term change rates were based on coastline positions that dated from 1950 to 2000. Net movement was also calculated between the following dates: 1875, 1930, 1950, 1970, and 2000. The results were then used to assess the effects that natural processes and human activity may have had on Florida's coastal environments.

A few studies have mapped historical coastlines to provide data that could be used to improve efforts that seek to maintain the position of coastlines. One such study, the Texas Shoreline Change Project, determined shoreline change rates to assist in the effort to combat beach erosion along the Texas coast. Historical aerial photographs were used to extract accurate shoreline positions. More recent data were collected using airborne lidar. Long-term net movement of the 590 km coast was calculated by measuring 11,749 transects, spaced at 50 m intervals, that crossed the shorelines. It was found that the coastline experienced an average erosion rate of 1.26 m/yr; consequently, nearly eighty percent of the Texas Gulf shoreline experienced a net retreat (Paine et al., 2014). A similar study conducted by the USGS included a national assessment of shoreline change. One region that was assessed in this series was the Pacific Northwest. The coast was mapped to determine long and short-term shoreline change rates. The positions of the shorelines throughout history were determined using aerial photographs and scans of historical land surveys. The long-term shoreline change rate for Oregon and Washington's coasts were calculated by measuring 8,823 transects. These coastlines experienced 0.9 m/yr of progradation; thirty-six percent of the transects measured were determined to display erosion (Ruggiero et al., 2013). These studies were used as a reference to develop a methodology to map the historical changes in Florida's coastline from 1875 to 2000.

I Methodology

Accurate positions of Florida's coastline throughout history are needed to understand its movement relative to time. Information about coastal movement serves as the basis to assess the condition of the state's beaches. A relationship can then be established between the effects that coastal development that coastal that coastal development and natural processes may have that coastal development and natural processes may have had and the areas that have undergone a large amount of coastal movement. NOAA has created a data set composed of historical surveys (topographic sheets) that is accessible to the public for shoreline change analysis. Numerous historical surveys, 7,800 in total dating back to 1841, have been directed by NOAA to obtain coverage of the shoreline in the United States. The resulting data set has been made available for access in Google Earth. Each conducted survey is displayed in the viewer with links to download the shoreline data, original scans of the surveys, and metadata about the accuracy of each survey. The spatial reference used for these surveys was a geographic coordinate system and the North American Datum of 1983 ("NOAA Historical Surveys (T-Sheets)", 2016).

These historical surveys have been used to digitize features, such as the coastline and adjacent waterways, along the coast of Florida. A geographic information system (GIS) was used to clean up the data by extracting the coastline from the digitized coastal areas. The process was repeated to digitize a single coastline for specified years. The digitized coastlines represent different positions of Florida's coastline throughout history. The coastline was defined as the mean high-water line. This is the line where the land and the water at an elevation of mean high-water meet (Ruggiero et al., 2013). The digitized lines were overlaid onto georeferenced scans of land surveys to visualize the positions of the coastline over time. The historical positions of the coastline were identified for the following periods: pre-1900, 1920 – 1939, 1940 – 1959, 1960 – 1980, and 1998 – 2001.

The digitized coastline positions are only as accurate as the original scans of the historical land survey maps. This was due to the process of using the original scans to derive the digital data of coastline positions. Each land survey was conducted separately from the others, so each survey has its own accuracy report. The accuracy reports are included in the metadata of each scan, along with other important data about the survey. For example, a survey conducted in Delray Beach, Florida in 1945 includes digital positional data and a positional accuracy report. This survey had a root mean square error for x-coordinates of 0.346 m and 0.430 m for y-coordinates. One can expect accurate positional data for each historical survey conducted by NOAA. In figure 1, the extracted coastline position in Delray Beach in 1945 has been overlaid onto the corresponding original scan to illustrate the typical positional accuracy found in NOAA Historical Surveys ("NOAA Historical Surveys (T-Sheets)", 2016).

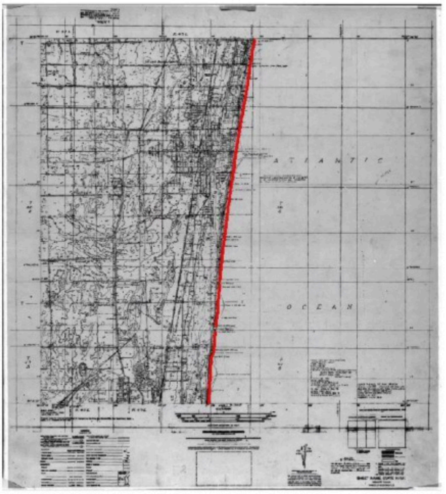

Figure 1. Digitized coastline overlaid onto original scan of survey

Long-term, short-term, and net movements were calculated. Long-term movement was found by calculating the movement of the coastline between the years 1875 and 2000 (125 years), while short-term movement was assessed between the years 1950 and 2000 (50 years). Net movement represents the distance between the most landward and seaward positions of the coastline that took place independent of the year. In all three measurements, the digitized coastlines were overlaid onto the original scans of land surveys from corresponding years. The USGS Digital Shoreline Analysis System (DSAS), a software extension to Esri ArcGIS, was used to calculate change rate statistics (Thieler et al., 2009). The DSAS workflow as described in the DSAS instruction manual is shown in figure 2.

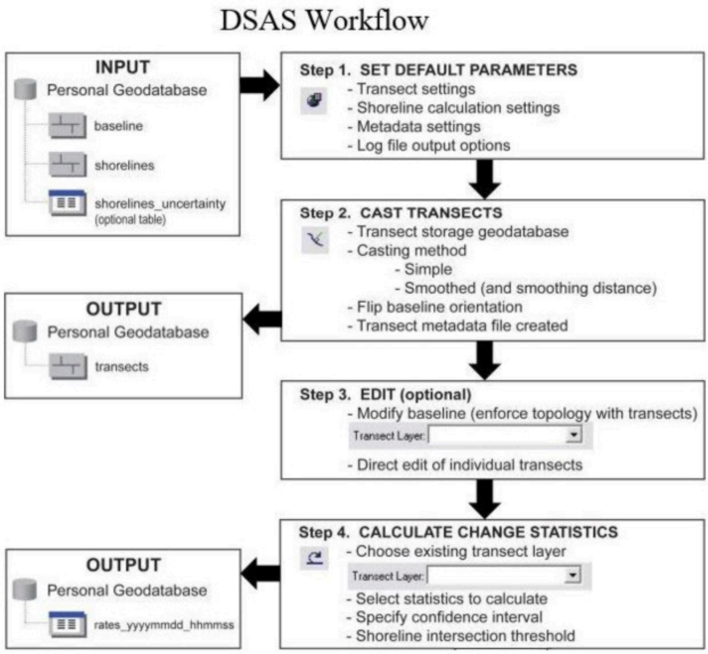

Figure 2. DSAS Workflow

Coastline position data for the desired years were stored as polyline feature classes in ArcGIS. A baseline was created parallel to the coastline to use with the DSAS toolbar. Transects were cast perpendicular from the offshore baseline and crossed the digitized coastlines. Transects extended 2,000 m from the baseline to cross all the coastlines and were spaced at 50 m intervals as shown in figure 3.

Figure 3. Unclipped transects

The original transects were clipped to include only the parts of the transects that were completely within the coastlines. The length of the clipped transects represents the distance between the coastlines. The clipped transects are shown in figure 4.

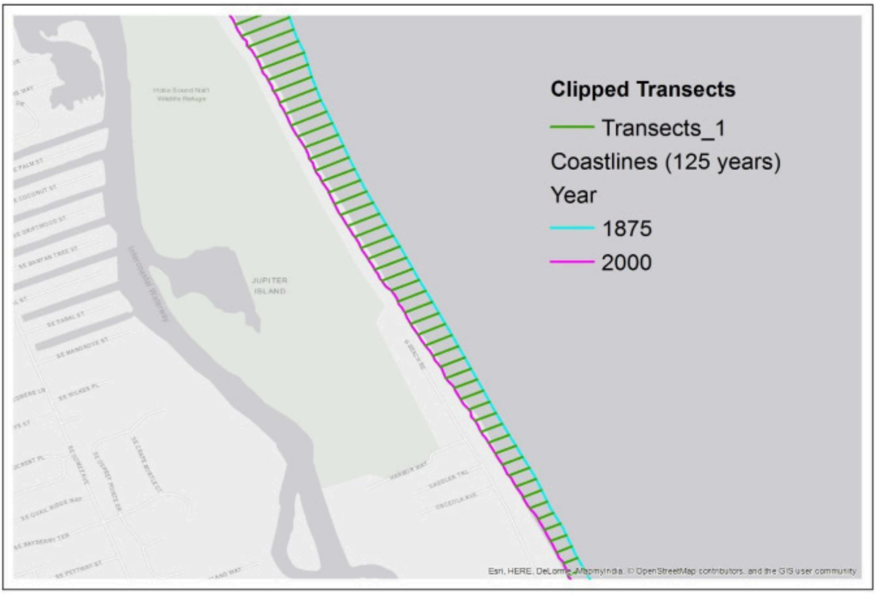

Figure 4. Clipped transects

Coastline movement relative to time in meters per year was found by editing the symbology of the transects' length and using the number of years between the earliest and latest coastline as a normalization for the data. Further analysis aimed to locate beaches with large amounts of coastline movement to determine the beaches at greatest risk for erosion caused by human activity and natural processes.

III Results and Discussion

Net movement rates show the high activity of change that occurred in Florida's coastline. Coastline positions were defined for the following periods: pre-1900, 1920 – 1939, 1940 – 1959, 1960 – 1980, and 1998 – 2001. Net change rates represented the distance between the most seaward and most landward coastline positions that occurred between the years 1875 and 2000. In this representation of change, movement is independent of the year of the coastlines' position. These change rates are useful for determining coastlines with trends of high variability. This movement was calculated at 25,403 sites along the coast of Florida. These areas experienced a median movement of 63.56 meters. The net change, in this case, does not consider whether seaward advance or landward retreat of the coastline occurred. With the time and direction of movement independent of the distance moved, identification of beaches experiencing high variability is simplified. This is due to the resulting data displaying a simple and single variable, net distance moved. Variability can then be related to the effects that coastal processes and human activity may have had on the coast. Results displaying the net movement that occurred are shown in figure 5.

Florida's Coastline: Net Movement 1875 to 2000

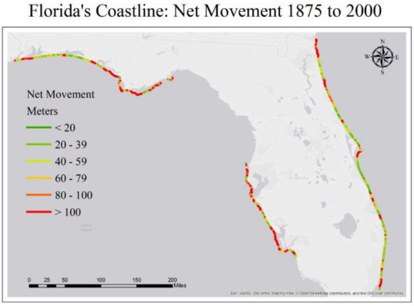

Figure 5. Net movement from 1875 to 2000

Long-term rates of change in Florida's coastline between the years 1875 and 2000 averaged 0.014 m/yr of seaward advance. Rates were calculated at 20,975 sites along the coast of Florida spaced at 50 m intervals. Net advance occurred at 10,875 of these sites (51.85 percent). These areas experienced a mean seaward advance of 0.69 m/yr during the 125-year period. Net landward retreat occurred at 10,100 sites (48.15 percent). These areas saw a mean retreat of 0.72 m/yr. While the average change was an advance of the coastline, the areas experiencing a net retreat changed at a slightly higher rate. This long-term rate reflects change over a large amount of time. Factors that may have brought about large change in short amounts of time such as increasing population, development, and storm activity are normalized by the large number of years observed. Observing change rates for the past 125 years will help to establish trends in the movement of the coast. Ultimately, this will provide a basis to model future changes in Florida's coastline. The long-term change rate results are shown in figure 6.

Florida's Coastline: 1875 to 2000

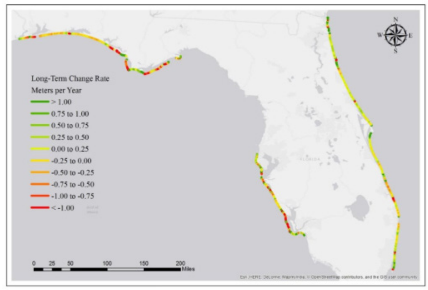

Figure 6. Long-term change rate from 1875 to 2000

Short-term rates of change were calculated between the years 1950 and 2000. This 50-year period experienced an average seaward advance of 0.110 m/yr. Rates were calculated at 20,098 sites spaced at 50 m intervals along the coast of Florida. Net advance occurred at 9,888 sites (49.20 percent) and changed at a rate of 1.00 m/yr. Net landward retreat occurred at 10,210 of the sites (50.80 percent). These areas retreated at a rate of 0.75 m/yr. The average rate of seaward advance was greater than that of retreat, so the 50-year period saw an overall advance of the coastline despite a higher percentage of sites experiencing a net retreat. Human presence in coastal counties has increased in recent history and has likely affected the beaches in Florida. Short-term change rates better represent change that is, in part, due to increases in population and coastal development that have occurred in recent history. Results of the short-term change rates are shown in figure 7.

Florida's Coastline: 1950 to 2000

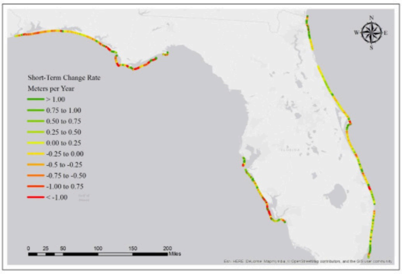

Figure 7. Short-term change rate from 1950 to 2000

Changes in Florida's coastline are best represented using historical positions of the coastline spanning periods greater than 100 years to eliminate any bias introduced by short-term influxes of movement (Galgano et al., 1998). However, short-term change rates are useful to represent the increase in population and development that has occurred in recent history and the beach nourishment projects that have been conducted by coastal communities. Many beaches have lost land due to erosion; consequently, coastal counties have made efforts to replace the lost land on the beaches with sand from other locations. Land is lost to the constant impact from waves, wind, and sea-level rise (Finkl, 1996). Coastal counties often depend on the technique of beach nourishment to maintain their beaches and to provide a buffer to protect the surrounding areas from storm activity. This solution is often viewed as only a short-term fix to the problem of retreating coastlines (Leatherman, 2003).

IV Conclusion

Coastline change analysis is dependent on reliable data for the positions of the coastline throughout history. NOAA Historical Surveys were used to calculate net movement, long-term, and short-term change rates in Florida's coastline. Net movement of the coastline provides a better understanding of areas that experienced high variability, which can be related to beaches that may have been affected by human activity and natural processes. Long and short-term change rates provide insight for the changes that have occurred in Florida's coastline throughout history. While the overall long and short-term change rates averaged 0.014 m/yr and 0.110 m/yr of accretion respectively, the results show high variability of accretion and erosion at a local scale. For example, seven counties located between Franklin and Escambia County on the north coast of Florida have experienced a rate of erosion of 0.31 m/yr. This is a significantly higher rate of change than the average short-term change rate of the entire state. Averaged change rates at a state-wide level are less relevant than those at a county level, which provide more meaningful insight to the variability of Florida's coastline. The data set created during this research provides quantitative coastline change data that can be utilized to make local decisions to improve beach stability. This quantitative data could also be used to conduct a cost benefit analysis to identify areas that require significant beach nourishment or that are particularly vulnerable to sea level rise.

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