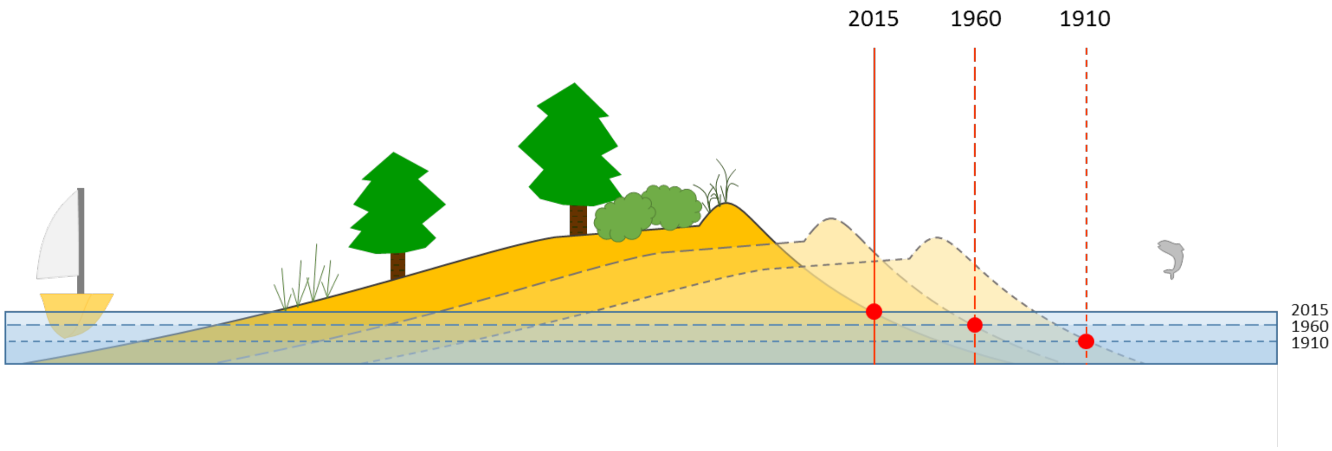
Coastline Change App: Historical Data



Beaches and barrier islands are dynamic, which means they move in response to processes that erode, transport, and deposit sand. This section of the app uses a robust dataset that covers 165 years of observed shoreline changes along the Assateague and Virginia barrier islands to show rate and direction of shoreline change over time.

Historical shorelines are derived from aerial photographs, maps, and charts for various years. Shoreline positions are the intersection of transects with those historical shorelines. For the Virginia and Assateague barrier islands, 165 years of shoreline positions spanning the time period 1850-2014 was used to derive the historical shorelines and rates of change, while 34 shoreline positions spanning 1849-2014 were used for Assateague Island.

Long-term shoreline change rate is the trend of movement (in m/yr) a shoreline has displayed over the longest range for time where data are available along transects spaced 50 meters along the shore. Negative rates of change indicate **landward movement** of the shoreline and positive rates of change indicate **seaward movement**. Shorelines can switch from landward to seaward or vice versa over time leading to a shorter term rate of change that may differ from the long-term rate. **Shorter-term rates of change** indicate that significant changes occurred to the long-term movement direction during a shorter window of time.

Historical Shoreline Change Data included in Coastline Change App

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Shorelines are the intersection of land and sea and move constantly over sandy coastal environments such as beaches and barrier islands. Shorelines move (or migrate) in response to oceanographic and geologic processes that operate over a variety of time scales. On one end of the time spectrum, everyday waves and the currents set up by the change in daily tides move sediment (sand) that can make shorelines move. On the other end of the time spectrum, changes in sea level (rise or fall) and/or to the supply of sand (increases or decreases) influence the direction and rate that shorelines move.

The current state of scientific knowledge does not enable a cause and effect analysis of shoreline movement (or migration). In other words, we can measure the rate at which shorelines move, but cannot conclusively explain "Why?" they move. Consequently, coastal scientists, land managers and planners use the rates of shoreline movement (in meters or feet per year) as a proxy for (or representation of) the processes that erode, transport and deposit sand and to assess the mobility of beaches and barrier islands. In other words, measurements of the rate and direction of shoreline movement (i.e., migration) provide insight into the mobility of beaches and barrier islands and to the processes that are responsible for causing shorelines to move.

The data used to calculate the rate and direction of shoreline movement over a particular time period come from a variety of sources. These sources include aerial photographs taken perpendicular to the land surface (orthophotographs), beach surveys on the ground using Global Positioning System (GPS) technology or other survey technology (e.g., beach profiles), historical maps and T-sheets (nautical charts) and more recently, airborne Light and Detection and Ranging (LiDAR) technology. Most scientists agree that the HWL, i.e., the boundary between the wet and dry parts of a beach, is the best representation of a shoreline. However, maps, T-sheets and LiDAR can use other reference lines as the shoreline (e.g., mean high water, MHW; mean low low water, MLLW, etc.). Fortunately, the amount of error introduced into shoreline rate-of-change calculations by comparing "different" reference shorelines decreases as the amount of time between the earliest (oldest) recorded shoreline and latest (most recent) recorded shoreline increases.

Click here to view a scientific paper on shoreline change methods by Dolan and others (1991).

Shorelines from all sources were entered into sophisticated software programs such as Geographic Information Systems (GIS) software which position them accurately in space (on a map). An additional software program (Digital Shoreline Analysis System, DSAS) determined each shoreline's position distance away from a baseline (in meters) at shore-perpendicular transects spaced 50 meters apart along the coast (Figure 1). The transects are "cast" every 50 meters at right angles from the baseline which is situated offshore and approximately parallel to the shoreline. At each transect, the distance from the baseline to the intersection of each shoreline provides the data necessary to calculate a shoreline rate-of-change statistic and direction of movement (i.e., seaward or landward) using a linear regression (or best fit line) analysis (Figure 2). While DSAS can also calculate shoreline rates of change, we used an additional program that calculates both rates of change, any short-term changes to long-term rates of change and the direction of shoreline movement (and possible changes to the direction).

Click here to view a scientific paper on DSAS by Theiler and others (2009).
http://woodshole.er.usgs.gov/project-pages/DSAS/version4/

Figure 1:

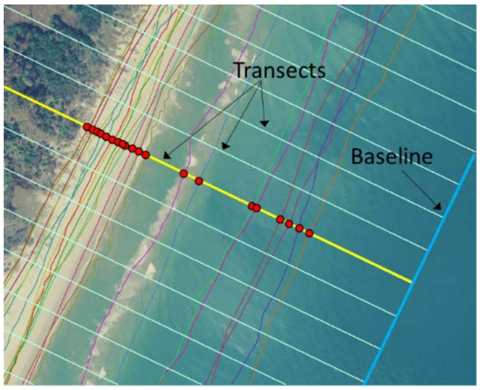
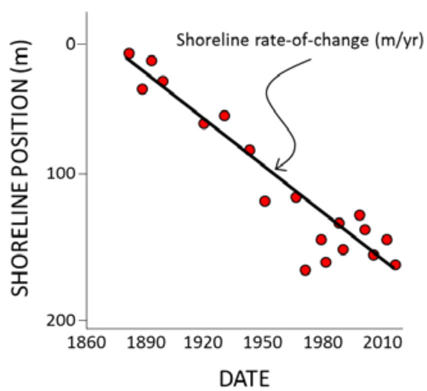


Figure 2:



This method, known as the Minimum Description Length (MDL), assesses the complexity of successively increasing functions that best fit the data against its accuracy to determine if either one, two, or no changes in the long-term trend occurred:

Minimum Description Length (MDL) Modeling Criterion

Accuracy ⟷ Complexity

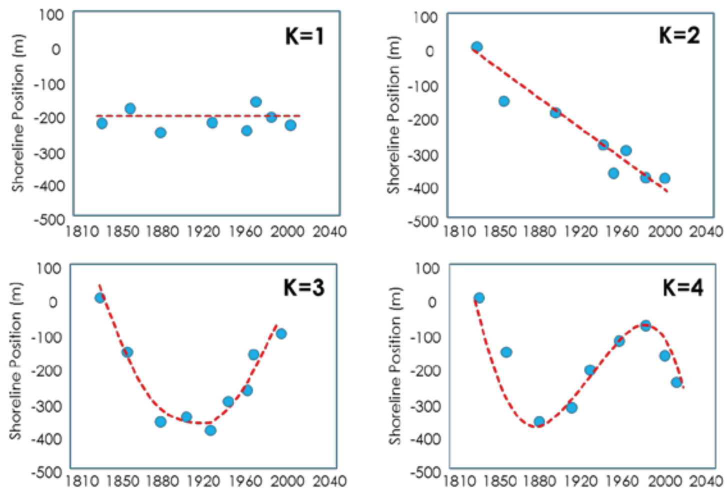
$$MDL_k = MSE_k + \frac{\ln(N)\, x\, K\, x \sigma_p^2}{N}$$

where…
MSE_k is mean squared error
N is the number of positions
K is the number of parameters in the model

σ_p^2 is the given prior noise variance

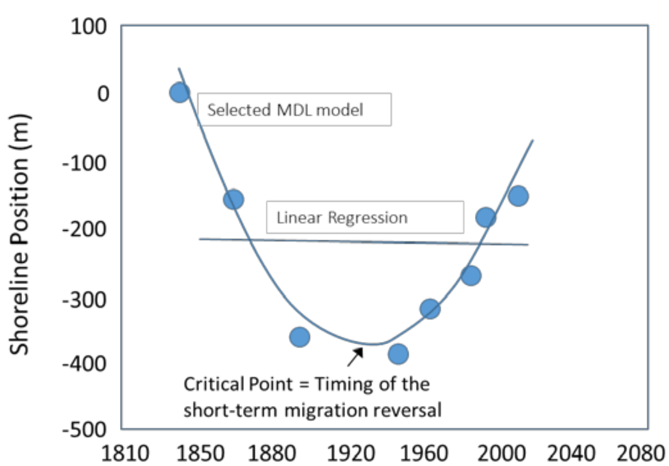
The minimum value of that analysis determines whether a constant (a stable shoreline with no landward or seaward migration), linear (a trend that does not change), quadratic (one short-term change in the long-term trend occurred) or cubic (two short-term changes in the long-term trend occurred) function best represents the historical shoreline migration history (Figure 3).

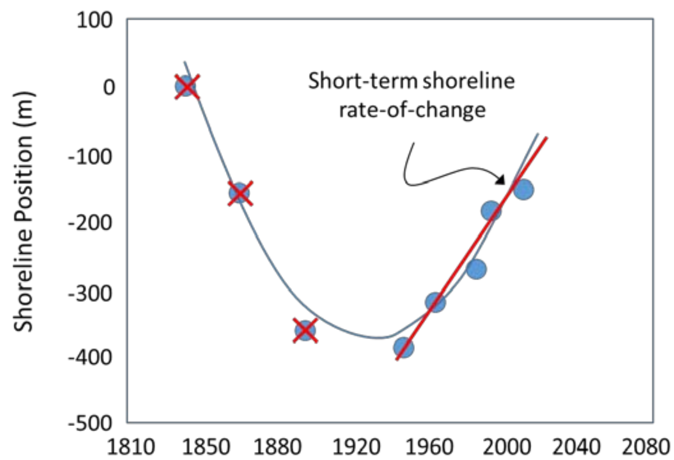
Figure 3:



If one short-term change occurred to the long-term trend, the MDL method uses a mathematical method to determine when the historical trend change occurred (called the critical point) and what the rate-of-shoreline change became after the shoreline migration reversal occurred (Figure 4). If two short-term changes have occurred to the long-term trend, only the shoreline position data of the most recent reversal were used to calculate a short-term linear regression rate-of-change.

Figure 4:





Click here to view a scientific paper on the methods used to determine short-term changes (or reversals) in the long-term shoreline rate trends by Fenster and others (1993).

DEFINITIONS:

Number of shoreline positions: The total number of shorelines positions that were used by the linear regression (or best fit line) to calculate the long-term rate of coastline change at each transect, or to calculate the short-term rate of coastline change (if the coastline migration history had one or two short-term changes in the long-term trend).

Landward shoreline movement: The coastline has moved toward the mainland and away from the ocean during a given time span (aka, coastline "retreat"). In the shoreline change plot shown in Figure 2, a downward oriented best fit line (negative rate-of-change) indicates that the shoreline moved landward.

Seaward shoreline movement: The coastline has moved toward the ocean and away from the mainland during a given time span (aka, coastline "advance"). A positive rate-of-change indicates seaward movement has occurred over time.

The tables below show the databases used for the coastline change analyses conducted for the Virginia barrier islands and Assateague Island. For the Virginia barrier islands, a subset of an unprecedented 38 individual (unique) years of partial or complete shorelines spanning the time period 1850-2014 was used for analyzing the rate of shoreline change at each transect. For Assateague Island 34 shorelines spanning 1849-2014 was used. The sources of shoreline data included "in house" (i.e., digitizing orthophotographs in ArcMap or with GPS) or came from well-known repositories of shoreline data including the University of Virginia, the United States Geological Survey, and the National Park Service.

VIRGINIA BARRIER ISLANDS DATABASE:

Date	Type	Source	Datum	Coverage
1850s	T-Sheet	USGS	HWL	Partial
1860s	T-Sheet	USGS	HWL	Partial
1870s	T-Sheet	USGS	HWL	Partial
1880s	T-Sheet	USGS	HWL	Partial
1905	T-Sheet	USGS	HWL	Partial
1910	T-Sheet	USGS	HWL	Partial
1911	T-Sheet	USGS	HWL	Partial
1915	T-Sheet	USGS	HWL	Partial
1919	T-Sheet	UVA-LTER	HWL	Partial
1921	T-Sheet	USGS	HWL	Partial
1933	T-Sheet	USGS	HWL	Partial
1934	T-Sheet	USGS	HWL	Partial
1942	T-Sheet	USGS	HWL	Partial
1943	T-Sheet	USGS	HWL	Partial
1949	Aerial Photo	UVA-COASTS	HWL	Full
1953	T-Sheet	USGS	HWL	Partial
1955	Aerial Photo	UVA-COASTS	HWL	Full
1959	Aerial Photo	UVA-COASTS	HWL	Partial
Apr-62	T-Sheet	USGS	HWL	Partial
Jul-62	Aerial Photo	UVA-COASTS	HWL	Full
1967	Aerial Photo	UVA-COASTS	HWL	Full
1975	Aerial Photo	UVA-COASTS	HWL	Full
1977	Aerial Photo	UVA-COASTS	HWL	Full
1980	Aerial Photo	USGS	HWL	Partial
1982	Aerial Photo	UVA-COASTS	HWL	Partial
1985	Aerial Photo	UVA-COASTS	HWL	Partial
1986	Aerial Photo	UVA-COASTS	HWL	Partial
1988	Aerial Photo	UVA-COASTS	HWL	Full
1994	DOQQ	Radford	HWL	Full
1997	Lidar	USGS	MHW	Full
2002	VBMP	VGIN	HWL	Full
2003	GPS	C. Smith	HWL	Partial
2006	GPS	M. Fenster	HWL	Full
2009	VBMP	VGIN	HWL	Full

ASSATEAGUE ISLAND DATABASE:

Date	Island	Source
06/01/1849	Assateague	ASIS
06/01/1850	Assateague	ASIS
08/01/1859	Assateague	ASIS
11/1/1908	Assateague	ASIS
6/1/1915	Assateague	ASIS
6/1/1933	Assateague	ASIS
8/15/1942	Assateague	ASIS
4/28/1962	Assateague	ASIS
9/7/1980	Assateague	ASIS
4/1/1994	Assateague	CBruce
4/1/1994	Assateague	CBruce
3/1/1997	Assateague	ASIS
4/12/1998	Assateague	ASIS
11/1/1998	Assateague	ASIS
10/1/1999	Assateague	ASIS
4/1/2003	Assateague	ASIS
11/30/2005	Assateague	ASIS
3/1/2006	Assateague	ASIS
11/1/2006	Assateague	ASIS
11/19/2007	Assateague	ASIS
10/8/2008	Assateague	ASIS
9/30/2009	Assateague	ASIS
4/14/2010	Assateague	ASIS
11/30/2010	Assateague	ASIS
4/28/2011	Assateague	ASIS
4/29/2011	Assateague	ASIS
12/7/2011	Assateague	ASIS
3/20/2012	Assateague	ASIS
12/5/2012	Assateague	ASIS
12/6/2012	Assateague	ASIS
4/1/2013	Assateague	ASIS
11/21/2013	Assateague	ASIS
11/22/2013	Assateague	ASIS
9/27/2014	Assateague	CBruce