# Coastline Change App: Historical Data Fact Sheet

VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

Historical shoreline change along a Virginia Barrier Island


Illustration: © Vin Reed/Vin Design

## What is the Historical Data module in the Coastline Change app?

Beaches and barrier islands are dynamic systems that move constantly in response to processes that erode, transport, and deposit sand. The Historical Data module of the Coastline Change app in the *Coastal Resilience* tool uses a robust dataset that covers 165 years of observed shoreline changes along the Virginia barrier islands (including Assateague Island), allowing users to explore how much and in which direction these shorelines have changed over this time period.

## Who should use it?

Organizations and agencies who manage barrier islands, research scientists, local governments, and citizens who want to learn about the dynamic nature of Virginia's barrier islands may benefit from viewing the historical data that provides useful context for understanding the barrier islands as they continue to evolve in the future.

## How does it work?

The Historical Data module in the Coastline Change app allows users to view two kinds of data: (1) the geographic location of past shorelines, and (2) the calculated change rates (in meters per year) for shorelines over short- and longer-term time ranges. Users can explore the historical shorelines by playing an animation that illustrates sequential shoreline locations over the years for which data exist or by manually selecting multiple shorelines to display side by side.

Users can also view shoreline change rates at multiple spatial and temporal scales. Shoreline change was measured at transects spaced 50 meters apart and approximately perpendicular to the shoreline. **Long-term rates of change** are based on an analysis of all historic shorelines from the earliest to most recent dates. Sometimes, a change in the long-term trend is observed. Where this is the case, a **short-term rate of change** has been calculated from the time the change occurred to the most recent date available.

When viewing change rate data in the app, the percent seaward and landward movement is summarized at the scale of the entire Virginia Eastern Shore or of individual islands. Negative rates of change indicate **landward movement** of the shoreline (erosion) and positive rates of change indicate **seaward movement** (accretion). Shorelines can switch from landward to seaward movement, or vice versa, over time, leading to a short-term rate of change that may differ from the long-term rate.

Additional data about shoreline trends are available for individual transects on the islands, including the rate of change in meters per year, the time span of the earliest and latest date, and the number of shoreline positions measured to calculate the change rate.

## What are strengths and limitations?

The historic shoreline data presented in the Coastline Change app are among the most comprehensive and long-term datasets describing shoreline change anywhere in the world, including 38 unique years of data spanning 1850-2014. However, it is important to recognize that quantifying shoreline positions is only a proxy for how coastal processes such as sea-level rise, storms and sediment dynamics impact barrier islands and cause them to move in space and time. While a good proxy for island movement—and a proxy used by many federal and state coastal management agencies—shoreline change rates do not provide correlations with, or information about, the coastal processes that produce the shape changes to islands over time.

In addition, there are sources of error in these data. Digitizing shorelines from paper maps may introduce more error into shoreline rate of change calculations than digitizing shorelines from aerial photos because the on-ground survey techniques did not always use the same techniques or the same sea-level datum. Aerial photographs (or orthophotographs) provide actual imagery of a beach, but contain potential distortion error. Fortunately, the amount of error introduced into shoreline rate of change calculations by comparing different shorelines decreases as the amount of time between the earliest (oldest) recorded shoreline and latest (most recent) recorded shoreline increases.

## Who developed it?

The Historical Data module of the Coastline Change app was developed by a partnership between Randolph-Macon College, University of Mary Washington, The Nature Conservancy, NASA-Wallops Flight Facility, National Park Service Assateague Island National Seashore, U.S. Fish and Wildlife Service Chincoteague National Wildlife Refuge, the Accomack-Northampton Planning District Commission, and the Virginia Coast Reserve Long Term Ecological Project.

For general info about the Virginia Eastern Shore *Coastal Resilience* project: **coastalresilience.org/virginia**

To access the Virginia Eastern Shore *Coastal Resilience* mapping portal: **maps.coastalresilience.org/virginia/**

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# Coastline Change App: Historical Data Supplemental Information

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## Introduction

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, daily waves and the currents resulting from the change in 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 into the processes that are responsible for causing shorelines to move.

## Description of Shoreline Change Database

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 Detection and Ranging (LiDAR) technology. Most scientists agree that the high water line (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.

For the Virginia barrier islands south of Assateague Island, a subset of 38 individual (unique) years of partial or complete shorelines spanning the time period 1850-2014 was used for analyzing the rate of shoreline change. For Assateague Island, 34 shorelines spanning 1849-2014 were used. These shoreline data were developed "in-house" or came from well-known repositories of shoreline data, including the University of Virginia, the United States Geological Survey, and the National Park Service.

## Shoreline Change Analysis

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 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).

Figure 1:

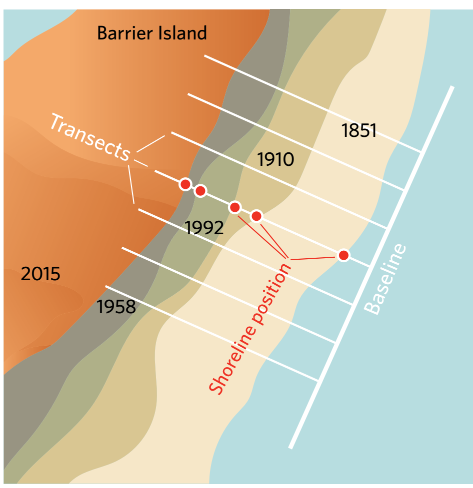
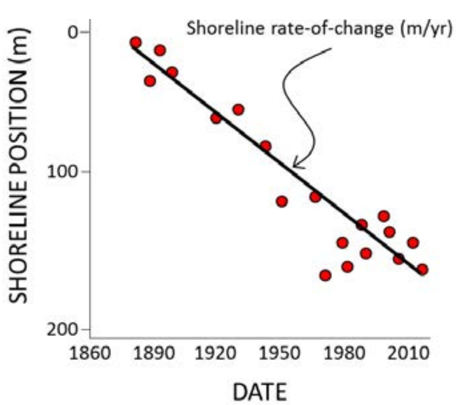



Figure 2:




While DSAS calculates shoreline rates of change, an additional program was used to calculate both rates of change, any short-term changes to long-term rates of change, and the direction of shoreline movement (and possible changes in direction).

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

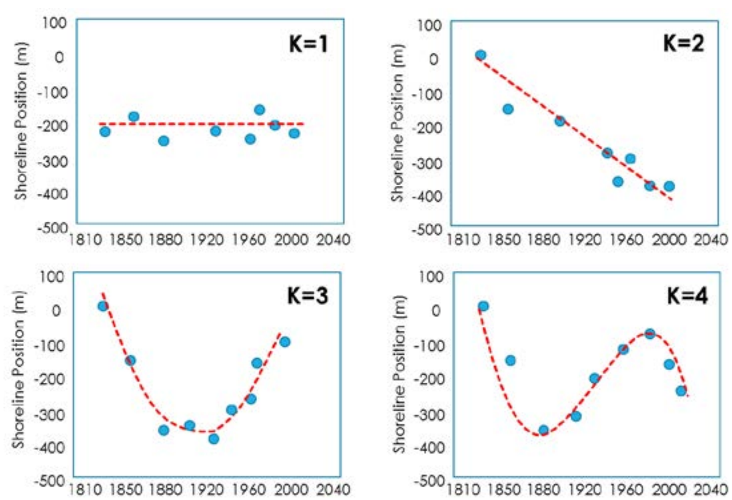
$$MDL_k = MSE_k + \frac{\ln(N)\, x\, K\, x \sigma_p^2}{N}$$

**Accuracy** ⟷ **Copmplexity**

WHERE...
*$MSE_k$* is mean squared error
*N* is the number of positions
*K* is the number of parameters in the model
$\sigma_p^2$ is the given prior noise variance

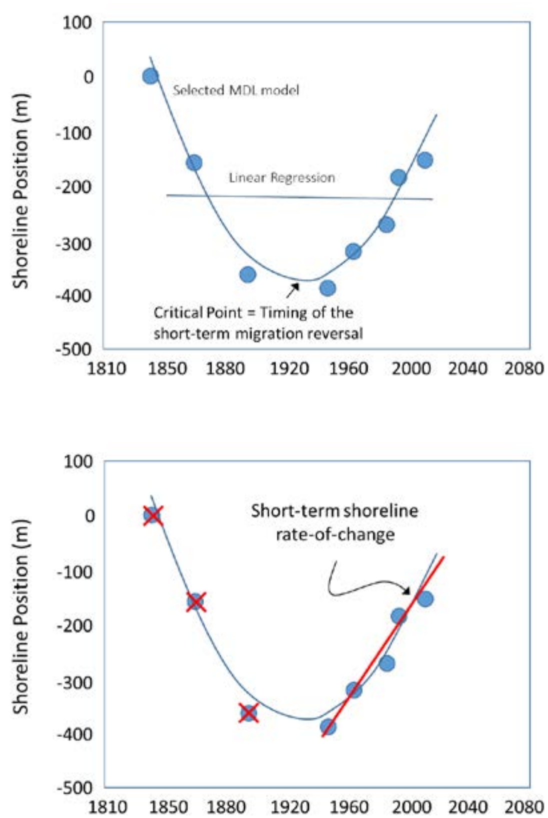
The minimum value of that analysis determines whether a constant (i.e., stable shoreline with no landward or seaward migration), linear (i.e., trend that does not change), quadratic (i.e., one short-term change in the long-term trend occurred) or cubic (i.e., two short-term changes in the long-term trend 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, which occurs when the first derivative of a function is equal to zero) and the rate-of-shoreline change 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:




Using this approach, both long-term and shorter term change rates (when K=3 or 4) using linear regression are represented in the Coastline Change app for each individual transect along the Virginia barrier islands and Assateague Island. Additionally, the Coastline Change app provides info on the number of shoreline positions used in both the long- and short-term calculations as well as the earliest and latest date (time span) used to calculate the long-term trend.

## Overall Conclusions from Historic Shoreline Database

The Virginia barrier islands constantly change in area (two dimensions) and volume (three dimensions) in response to sediment erosion, transportation and deposition resulting from coastal processes that affect the beach synergistically and operate over various temporal and spatial scales. These processes include sea-level changes, storm surges, storm waves, tidal inlet migration, tidal currents, and non-storm ("everyday") waves.

Shoreline movement along the Virginia barrier islands has had a complex history during the past 165 years. Individual islands have rotated clockwise and counter-clockwise, moved entirely landward or moved simultaneously both landward and seaward along their lengths. Furthermore, these patterns have changed over time. For example, most of the shorelines have had one or two short-term reversals in their longer-term trends. Preliminary analyses of these data show that nearly 91% of the Virginia barrier islands have experienced two changes in their long-term shoreline migration trend history, a little more than 6% of the shorelines have migrated linearly (monotonically or without a reversal) and only 1.5% have been stable. Of those shorelines that experienced a short-term trend reversal, the most recent change apparently occurred in the late 1880s toward landward migration. These data also show that an "arc of (perpetual) erosion" along the northern 35 km of the Virginia barrier islands (Wallops Island to Cedar Island) has apparently extended southward to Parramore Island during the past decade.

## References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