National Assessment of Shoreline Change—Summary Statistics for Updated Vector Shorelines and Associated Shoreline Change Data for the Gulf of Mexico and Southeast Atlantic Coasts

By Emily A. Himmelstoss, Meredith G. Kratzmann, and E. Robert Thieler

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter per year (m/yr)	3.281	foot per year (ft/yr)

Datum

Horizontal coordinate information is referenced to the World Geodetic System (WGS 84).

Abbreviations

CI	confidence interval
DSAS	Digital Shoreline Analysis System
USGS	U.S. Geological Survey

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Abstract

Long-term rates of shoreline change for the Gulf of Mexico and Southeast Atlantic regions of the United States have been updated as part of the U.S. Geological Survey's National Assessment of Shoreline Change project. Additional shoreline position data were used to compute rates where the previous rate-of-change assessment only included four shoreline positions at a given location. The long-term shoreline change rates also incorporate the proxy-datum bias correction to account for the unidirectional onshore bias of the proxy-based high water line shorelines relative to the datum-based mean high water shorelines. The calculation of uncertainty associated with the long-term average rates has also been updated to match refined methods used in other study regions of the National Assessment project. The average rates reported here have a reduced amount of uncertainty relative to those presented in the previous assessments for these two regions.

Introduction

U.S. Geological Survey National Assessment of Shoreline Change Project

Sandy ocean beaches are popular tourist and recreational destinations in the United States and constitute some of the most valuable real estate in the country. These dynamic interfaces between water and land are often locations of concentrated residential and commercial development and are frequently subjected to a range of natural hazards, which include flooding, storm effects, and coastal erosion. In response, the U.S. Geological Survey (USGS) is conducting a national assessment of coastal change hazards. One component of this research effort, the National Assessment of Shoreline Change project, documents changes in shoreline position as a proxy for coastal change. Shoreline position is one of the most commonly monitored indicators of environmental change (Morton, 1996), and it is an easily understood feature marking the location of a beach through time.

A principal component of the USGS National Assessment of Shoreline Change has been to develop a consistent methodology for calculating shoreline change rates and reporting results that may be periodically updated when additional data or improved techniques are available. Results have been organized and presented by coastal regions and include analyses and descriptive reports for the U.S. Gulf of Mexico coast (Morton and others, 2004), the Southeast Atlantic coast (Morton and Miller, 2005), the California sandy shorelines (Hapke and others, 2006) and California coastal cliffs (Hapke and

Reid, 2007), the New England and Mid-Atlantic coasts (Hapke and others, 2011), parts of the Hawaii coast (Fletcher and others, 2012), the Pacific Northwest (Ruggiero and others, 2013), and parts of Alaska (Gibbs and Richmond, 2015).

This report is an update to the original Gulf of Mexico (Miller and others, 2004) and Southeast Atlantic (Miller and others, 2005) data and includes revised rate-of-change calculations based on additional shoreline position data, improved rate metrics, and application of a proxy-datum bias correction that quantifies potential bias and errors associated with integrating shorelines referenced to different proxies (Ruggiero and List, 2009). To be consistent with previous work, the Gulf of Mexico and Southeast Atlantic (fig. 1) study areas were organized by State for analysis.

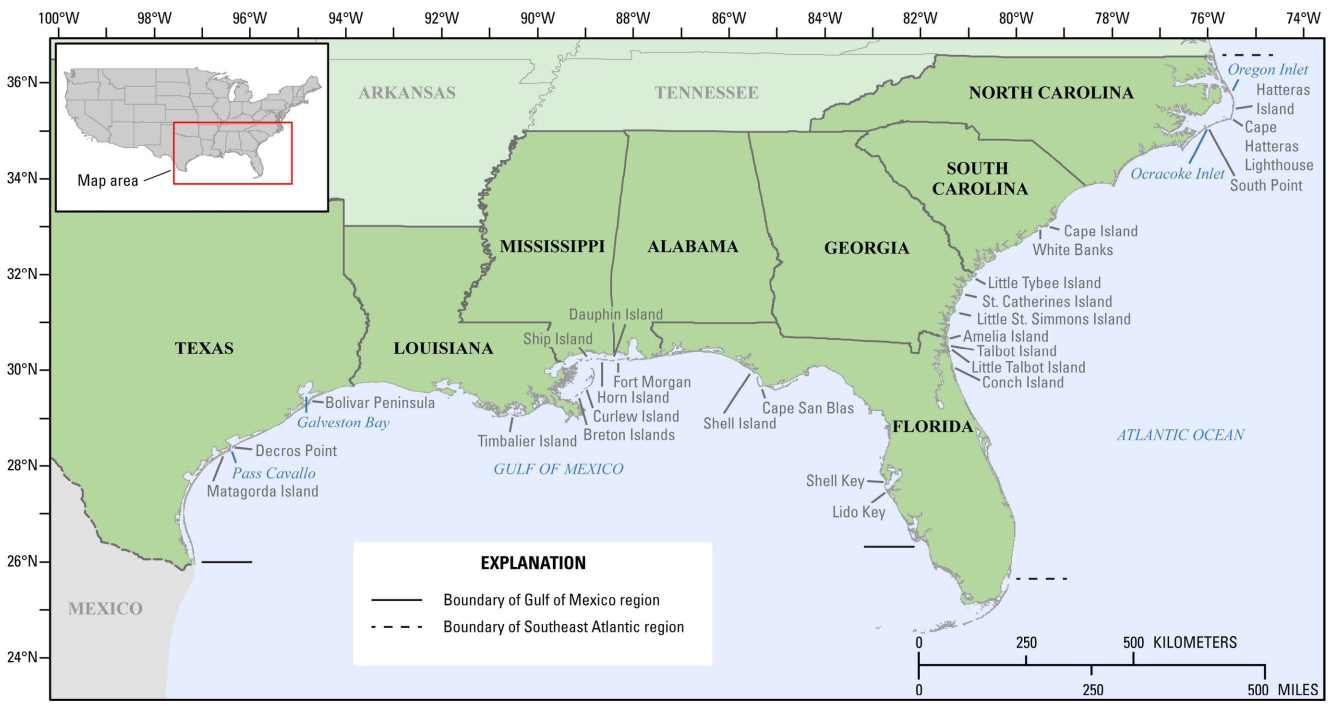

Figure 1. Map of the five States within the Gulf of Mexico region and the four States within the Southeast Atlantic region.

The USGS National Assessment of Shoreline Change analysis for the Gulf of Mexico and Southeast Atlantic coasts incorporates shoreline positions from a variety of data sources covering a range of dates. Data from the previously published National Assessment of Shoreline Change studies for these regions (Morton and others, 2004; and Morton and Miller, 2005) were the starting point for this update. In the initial reports, shoreline data were compiled for each State with the criterion of using only a single shoreline date within each of four specific time periods to compute rate metrics. Any additional shoreline data were omitted in an attempt to maintain consistency in the number of shorelines used for analysis among regions. The purpose of this update is to add all available shoreline data for each State into the National Assessment of Shoreline Change database and to compute updated shoreline rates of change that include the proxy-datum bias correction (Ruggiero and List, 2009; Ruggerio and others, 2003) that corrects for the bias between high water line and mean high water type shorelines. These data were incorporated from the National Oceanographic and Atmospheric Association, numerous universities, and State departments, which are listed in the metadata files for each shoreline dataset available in the data releases complementary to this report (Himmelstoss and others, 2017; Kratzmann and others, 2017).

The shoreline change results and products prepared by the USGS are not intended for detailed site-specific analysis of shoreline movement, nor are they intended to replace any official sources of shoreline change information identified by local or State government agencies or other federal entities for regulatory uses. Rates of shoreline change presented in this report represent shoreline movement under past conditions. The results are not intended for predicting future shoreline positions or future rates of shoreline change. Rates of shoreline change published in this report are for the purpose of a regional characterization of shoreline behavior through time. Individual measurement transects for the entire Gulf of Mexico (Himmelstoss and others, 2017) and Southeast Atlantic (Kratzmann and others, 2017) regions, as well as the other open-ocean shoreline regions along the United States coast, can be viewed in the U.S. Geological Survey Coastal Change Hazards Portal (https://marine.usgs.gov/coastalchangehazardsportal/).

Calculation and Interpretation of Shoreline Change Rates

Rates of long-term (>80 years) and short-term (20–50 years) shoreline change for the Gulf of Mexico and Southeast Atlantic coasts were produced by using the linear regression and end point rate calculation methods included in the Digital Shoreline Analysis System (DSAS), versions 4.2 and 4.3 (Thieler and others, 2012). For this study, DSAS was used to generate orthogonal transects at 50-meter spacing along the coast and to subsequently calculate change statistics. The shoreline change rates and rate uncertainties at individual transect locations are available in data releases for the Gulf of Mexico and Southeast Atlantic regions respectively (Himmelstoss and others, 2016; Kratzmann and others, 2016). This report provides State-averaged rates of long-term shoreline change and the associated average rate uncertainty as a measure of broader scale trends. Maximum values of erosion and accretion are reported for both long- and short-term rates at individual locations for each State.

Regionally Averaged Rate Uncertainty

Following the approach of Ruggiero and others (2013), we estimated that each transect rate uncertainty was partially independent of the others. To estimate the regionally averaged uncertainty of partially independent transect rates, we first evaluated the effective number of independent uncertainty values, n^*. Following Garrett and Toulany (1981), we found n^* on the basis of the spatially lagged autocorrelation of each measure of shoreline change rate uncertainty. In all States, this method resulted in a large reduction in the original sample size, n, shown in table 1. Assuming that the uncertainty of a region can be represented by $\overline{U}_R$, we found the uncertainty of a regionally averaged change rate ($\overline{U}_{R_{q^*}}$) as follows:

$$\overline{U}_{R_{q^*}} = \frac{1}{\sqrt{n^*}}\,\overline{U}_R. \qquad (1)$$

The reduced effective sample size (n^*) was also determined for each region (Gulf of Mexico as one sample and all of the Southeast Atlantic as another) by summing the n^* values for individual States within the region. Average uncertainty values found using equation 1, as reported in table 1, are generally much smaller than the arithmetic mean confidence interval (CI) but larger than the quadrature-averaged CI.

Table 1. Average long-term shoreline change rates, percentage of transects eroding, and average rate uncertainties for the Gulf of Mexico and Southeast Atlantic regions.

[Uncertainty numbers in **bold** are confidence interval values that are less than the average rate, indicating that the rates are statistically significant. m/yr, meter per year; m, meter; *n*, sample size]

State	Number of measurement transects	Percent of total transects measuring erosion	Average rate (m/yr) with average uncertainty (m/yr) for all transects		Independent *n*	Average rate (m/yr) with uncertainty (m/yr) reduced for independent *n*	
Gulf of Mexico region							
Texas	11,942	65	-0.6	±0.9	31	-0.6	**±0.2**
Louisiana	3,789	89	-7.7	**±6.2**	46	-7.7	**±0.9**
Mississippi	970	35	0.2	±1.6	58	0.2	±0.2
Alabama	1,457	74	-0.5	±0.9	22	-0.5	**±0.2**
Florida	11,901	58	-0.1	±1.03	161	-0.1	**±0.08**
Total	30,059	65	-1.7	±2.1	319	-1.7	**±0.02**
Southeast Atlantic region							
North Carolina	10,192	71	-0.5	±0.9	275	-0.5	**±0.06**
South Carolina	5,833	54	-0.6	±2.7	43	-0.6	**±0.4**
Georgia	2,944	41	0.7	±2.5	65	0.7	**±0.3**
Florida	11,790	43	0.1	±0.6	203	0.1	**±0.04**
Total	30,759	54	-0.07	±1.7	586	-0.07	**±0.01**

Results from Analysis of Historical Shoreline Change

Regionally averaged rates of long-term shoreline change and the associated average values of rate uncertainty for the Gulf of Mexico and Southeast Atlantic coasts are presented in table 1. These are updates of values from the previously published reports for the study regions, in which the geomorphology and coastal characteristics are described in detail (Morton and others, 2004; Morton and Miller, 2005). Nearly all State-averaged long-term rates are statistically significant in this update, resulting in a more scientifically robust dataset.

The State with the greatest average erosional rate of shoreline change in the Gulf of Mexico region is Louisiana (−7.7 ± 0.9 meters per year [m/yr]), where erosion occurred at 89 percent of the measurement transect locations (table 1). The greatest maximum long-term erosion rate at an individual measurement transect within the entire Gulf of Mexico region is for a transect in Louisiana (−32.3 ± 32.4 m/yr; table 2). The greatest maximum long-term accretion rate at an individual measurement transect within the Gulf of Mexico region is for a transect in Texas (33.5 ± 13.5 m/yr; table 2).

The State with the greatest average erosional rate of shoreline change in the Southeast Atlantic region is South Carolina (−0.6 ± 0.4 m/yr), where erosion occurred at 54 percent of the measurement transect locations. North Carolina, however, has the greatest percentage of transects with erosional rates (71 percent; table 1). The greatest maximum long-term erosion rate at an individual measurement transect within the entire Southeast Atlantic region is for a transect in South Carolina (−17.4 ± 7.01 m/yr; table 2). The greatest maximum long-term accretion rate at an individual measurement transect within the Southeast Atlantic region is for a transect in South Carolina (27.4 ± 14.1 m/yr; table 2). The updated long-term average rates for each State are statistically significant, meaning the average rate plus or minus the uncertainty associated with the rate reports a range of values that are entirely negative, indicating erosion, or entirely positive, signifying accretion through time.

Table 2. Long-term maximum erosion and accretion rates and uncertainties for the Gulf of Mexico and Southeast Atlantic regions.

[Maximums in **bold** are the greatest erosion and accretion rates for each region. m/yr, meter per year; m, meter]

State	Maximum erosion (m/yr)	± (m)	Location	Maximum accretion (m/yr)	± (m)	Location
Gulf of Mexico region						
Texas	-15.4	1.1	Matagorda Island, near Pass Cavallo	**33.5**	13.5	Decros Point
Louisiana	**-32.3**	32.4	Palos Island	19.6	19.4	Timbalier Island
Mississippi	-13.0	6.4	Horn Island	9.1	9.9	Horn Island
Alabama	-3.9	4.4	Fort Morgan	8.5	2.2	West end of Dauphin Island
Florida	-10.6	26.4	Crooked Island	12.4	19.4	Honeymoon Island
Southeast Atlantic region						
North Carolina	-9.5	1.1	Bodie Island, Oregon Inlet	11.5	6.1	Hatteras Island, south of lighthouse
South Carolina	**-17.4**	7.01	Lighthouse Island	**27.4**	14.1	North end of Cape Island
Georgia	-8.01	1.2	St. Catherines Island	23.3	9.0	Little Saint Simmons Island
Florida	-5.84	2.1	Long Island	11.9	4.8	North end of Conch Island

Short-term (20–50 years) changes, measured as the distance between the oldest and most recent shoreline features within the time period, are presented in table 3. The number of shorelines available at individual transect measurement locations in the short-term timespan varied significantly, and the linear regression rates could not be calculated completely across each State. Therefore, the short-term results are reported as distances between the oldest and most recent shoreline positions. The greatest maximum short-term erosional distance at an individual measurement transect within the Gulf of Mexico region is for a transect in Louisiana. The shoreline moved 2,847 meters landward between 1978 and 1996 (table 3). The greatest maximum short-term accretional distance for the Gulf of Mexico region is for a transect in Texas. The shoreline moved 1,584 meters seaward between 1962 and 2001. The greatest maximum short-term erosional distance at an individual measurement transect within the Southeast Atlantic region is for a transect in South Carolina. The shoreline moved 904 meters landward between 1962 and 2000 (table 3). The greatest maximum short-term accretional distance for the Southeast Atlantic region is also for a transect in South Carolina. The shoreline moved 1,814 meters seaward between 1962 and 2000.

Table 3. Short-term maximum erosion and accretion distances and locations for the Gulf of Mexico and Southeast Atlantic regions.

[Maximums in **bold** are the greatest erosion and accretion distances for each region. m, meter]

State	Maximum erosion (m)	Time period	Years	Location	Maximum accretion (m)	Time period	Years	Location
Gulf of Mexico region								
Texas	-701	1965–2001	36	Matagorda Island, near Pass Cavallo	**1,584**	1962–2001	39	Bolivar Peninsula, near Galveston Bay
Louisiana	**-2,847**	1978–1996	18	Timbalier Island	1,578	1978–2001	23	Breton Islands
Mississippi	-576	1966–2001	35	Ship Island, west side of Camille Cut	315	1966–2001	35	West end of Horn Island
Alabama	-238	1981–2001	20	Fort Morgan	140	1981–2001	20	West end of Dauphin Island
Florida	-335	1977–1998	21	East side of Cape San Blas	817	1971–1998	27	South end of Lido Key
Southeast Atlantic region								
North Carolina	-655	1974–1997	23	South Point, Ocracoke Inlet	811	1963–2009	46	South side of Cape Hatteras Lighthouse
South Carolina	**-904**	1962–2000	38	Center of Cape Island	**1,814**	1962–2000	38	North end of Cape Island
Georgia	-381	1971–1999	28	Little Tybee Island	613	1971–1999	28	Southernmost end of Little Tybee Island
Florida	-383	1973–1999	26	South end of Amelia Island	901	1963–1999	36	North end of Little Talbot Island

Mississippi

In addition to adding more shoreline position data at locations already covered in the previous report (Morton and others, 2004), data covering more than 16 kilometers of coast not mapped previously were added to the data for Mississippi. Some of this new shoreline position data measured accretion. This resulted in an updated accretional (positive) long-term State average for Mississippi, whereas the original study reported an erosional (negative) State average. This is the only State for which the average rate in this updated report has a different sign than the original long-term State average from the previous study.

Summary

The U.S. Geological Survey updated calculations of long-term rates of shoreline change for the Gulf of Mexico and Southeast Atlantic regions as part of the National Assessment of Shoreline Change project. The updated calculations incorporate additional shoreline position data for locations where the original rates were calculated from only four shorelines. In most States, the updated shoreline data extend coverage along the State coastline, meaning these updated averages provide a more comprehensive measure of shoreline change along the coast. The change measurements for the long-

term rates also incorporate the proxy-datum bias correction to account for the high water line shorelines being biased onshore relative to the mean high water shorelines. The calculation of uncertainty associated with the long-term average rates has also been refined. As a result, the new average rates have less uncertainty than those presented in the original reports. Individual measurement transects for the entire Gulf of Mexico and Southeast Atlantic regions, as well as the other open-ocean shoreline regions along the United States coast, can be viewed in the U.S. Geological Survey Coastal Change Hazards Portal (https://marine.usgs.gov/coastalchangehazardsportal/).

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