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Louisiana Coastal Zone Sediment Characterization; Comparison of Sediment Grain Sizes for Samples Collected in 2008 and 2015–2016 From the Western Chenier Plain to the Chandeleur Islands, Louisiana—Louisiana Barrier Island Comprehensive Monitoring (BICM) Program

By Stephen T. Bosse, James G. Flocks, Julie C. Bernier, Ioannis Y. Georgiou, Mark A. Kulp, and Michael Brown

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Figures

Tables

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
micron (µm)	0.00003937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)

Special Characters

Φ	phi units
σ	sigma
µ	micron

Abbreviations

ASTM	American Society for Testing and Materials
BICM	Barrier Island Comprehensive Monitoring Program
CPRA	Louisiana Coastal Protection and Restoration Authority
DoC	depth of closure
GPS	Geographic Positioning System
LPBF	Lake Pontchartrain Basin Foundation
MLW	mean low water
MRDP	Mississippi River Delta Plain
MRGO	Mississippi River Gulf Outlet
NAIP	National Agriculture Imagery Program
UNO-PIES	University of New Orleans Pontchartrain Institute for Environmental Studies
USGS-SPCMSC	U.S. Geological Survey St. Petersburg Coastal and Marine Science Center

Louisiana Coastal Zone Sediment Characterization; Comparison of Sediment Grain Sizes for Samples Collected in 2008 and 2015–2016 From the Western Chenier Plain to the Chandeleur Islands, Louisiana—Louisiana Barrier Island Comprehensive Monitoring (BICM) Program

By Stephen T. Bosse[1], James G. Flocks[2], Julie C. Bernier[2], Ioannis Y. Georgiou[3], Mark A. Kulp[3], and Michael Brown[3]

Abstract

Repeated sampling and grain-size analysis of surficial sediments along the sandy shorelines of Louisiana is necessary to characterize coastal-zone sediment properties and evaluate sediment transport patterns within the nearshore environments. In 2008, and again in 2015 and 2016, sediment grab samples were collected along the shorelines of the western Chenier plain, the Isles Dernieres (Raccoon, Whiskey, Trinity and East Islands), the Lafourche delta (Timbalier Islands, Caminada Headland, and Grand Isle), the modern delta (Grand Terre Islands from Chaland Headland to Sandy Point), and the Chandeleur Islands (from Curlew Island to Hewes Point). The samples were collected as part of the Louisiana Coastal Protection and Restoration Authority (CPRA) Barrier Island Comprehensive Monitoring (BICM) Program in collaboration with the U.S. Geological Survey St. Petersburg Coastal and Marine Science Center (USGS–SPCMSC) and the University of New Orleans Pontchartrain Institute for Environmental Studies (UNO–PIES). Physical properties of the samples (sediment grain size and sorting) were measured and provided in data reports to CPRA. Additional samples collected by the USGS from around Breton Island in 2014 and 2015 supplemented the 2015–2016 BICM data to complete the coastwide dataset. This report compares the results of the 2008 and 2015–2016 sedimentologic analyses and documents changes in composition (percent sand) and mean sediment grain size between the two time periods. At most sample sites, differences in mean grain size varied by less than ±0.25 Φ. The largest changes occurred at sites located near tidal inlets or along rapidly eroding shorelines.

Introduction

The Louisiana Coastal Zone consists of more than 600 kilometers (km) of muddy and sandy shorelines, salt marshes, and tidal inlets. The morphology of the modern shoreline reflects the complex history of deltaic and marine processes during the Holocene. These environments are undergoing some of the highest erosion and subsidence rates in the nation, resulting in shoreline retreat, wetland loss, and reduction in barrier-island area (Penland and others, 2005; Kindinger and others, 2013). The focus of the Barrier Island Comprehensive Monitoring (BICM) Program is to monitor these changes through

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comprehensive spatial and temporal measurements of elevation, shoreline position, and environmental and physical characteristics, with emphasis on sandy beach and barrier-island environments.

Louisiana's sandy beaches mostly occur on barrier islands along the Mississippi River Delta Plain (MRDP) or along the mainland coastline of the western Chenier plain. The MRDP was constructed by sediment deposited in overlapping, prograding delta lobes (Kolb and van Lopik, 1958; Frazier, 1967) and is a sand-limited environment; following abandonment of a delta lobe through river avulsion, little additional sediment is supplied to the abandoned system. As a result, during this transgressive phase of the delta cycle, waves, within a regime of relative sea level rise, rework deltaic headlands into flanking and detached barrier deposits and lead to the eventual submergence of the barrier islands (Penland and others, 1988). In contrast, the Chenier plain in western Louisiana was constructed by primarily alongshore processes that formed broad mudflats with intervening narrow, sandy beach ridges (cheniers) (Gould and McFarlan, 1959; Penland and Suter, 1989).

Coastal deposits consisting of predominantly (greater than 70 percent) sand are constrained to the beach and shoreface, with mud dominating the offshore and back-barrier environments (Kulp and others, 2011a, 2011b). As part of BICM, these coastal sandy deposits were sampled using standard techniques and their physical properties (for example, grain size and sorting) were characterized using laser diffractometry. Sampling and analysis techniques and sample-distribution maps are provided in Kulp and others (2011a, 2011b, 2017a, 2017b), Georgiou and others (2017a, 2017b), and Bernier and others (2018). This report compares the sedimentologic results from the two sampling efforts and provides maps displaying changes in sediment grain size.

Methods

Sediment data were collected from five geographic regions along the Louisiana coast (fig. 1) that were defined based on geologic and physiographic setting, such as their position relative to former delta complexes and modern environments. These areas include the western Chenier plain (fig. 2), the Isles Dernieres (early Lafourche or Teche delta, fig. 3), Lafourche delta (fig. 4), the modern delta (fig. 5), and Chandeleur Islands (fig. 6). Detailed sediment sampling guidelines, techniques, sample curation, and analyses are described in Kulp and others (2011a, 2017a) and Georgiou and others (2017a).

Field Methods

Sediment samples were collected across several depositional environments along sandy mainland and barrier-island coastlines including: (1) washover platforms, (2) back-barrier marsh, (3) dune, (4) beach berm, (5) upper shoreface at the mean low water (MLW) line, (6) middle shoreface, and (7) approximately at the base (toe) of the shoreface or depth of closure (DoC). A network of shore-normal transects with a 914.4-meter (m) (3000-feet [ft]) spacing was used to define the 2008 planned sample locations. Planned sample locations for the 2015–2016 survey were selected to reoccupy the 2008 sample sites. Planned transects and sample locations were occasionally relocated at the time of collection to more effectively capture the desired cross-sectional profile characteristics and (or) capture shoreline retreat or the impacts of restoration efforts undertaken between 2008 and 2015. The base of the shoreface (defined by a change in profile slope, where the relatively steeply-sloping shoreface transitions to the flat inner continental shelf) along each transect was determined from BICM bathymetric data acquired in 2006 and 2007 (Miner and others, 2009a, 2009b). The middle shoreface was selected as the midpoint along the profile between the base shoreface and MLW. A total of 1,500 and 1,846 samples were collected across coastal Louisiana in 2008 and 2015–2016, respectively (table 1). The 2015–2016

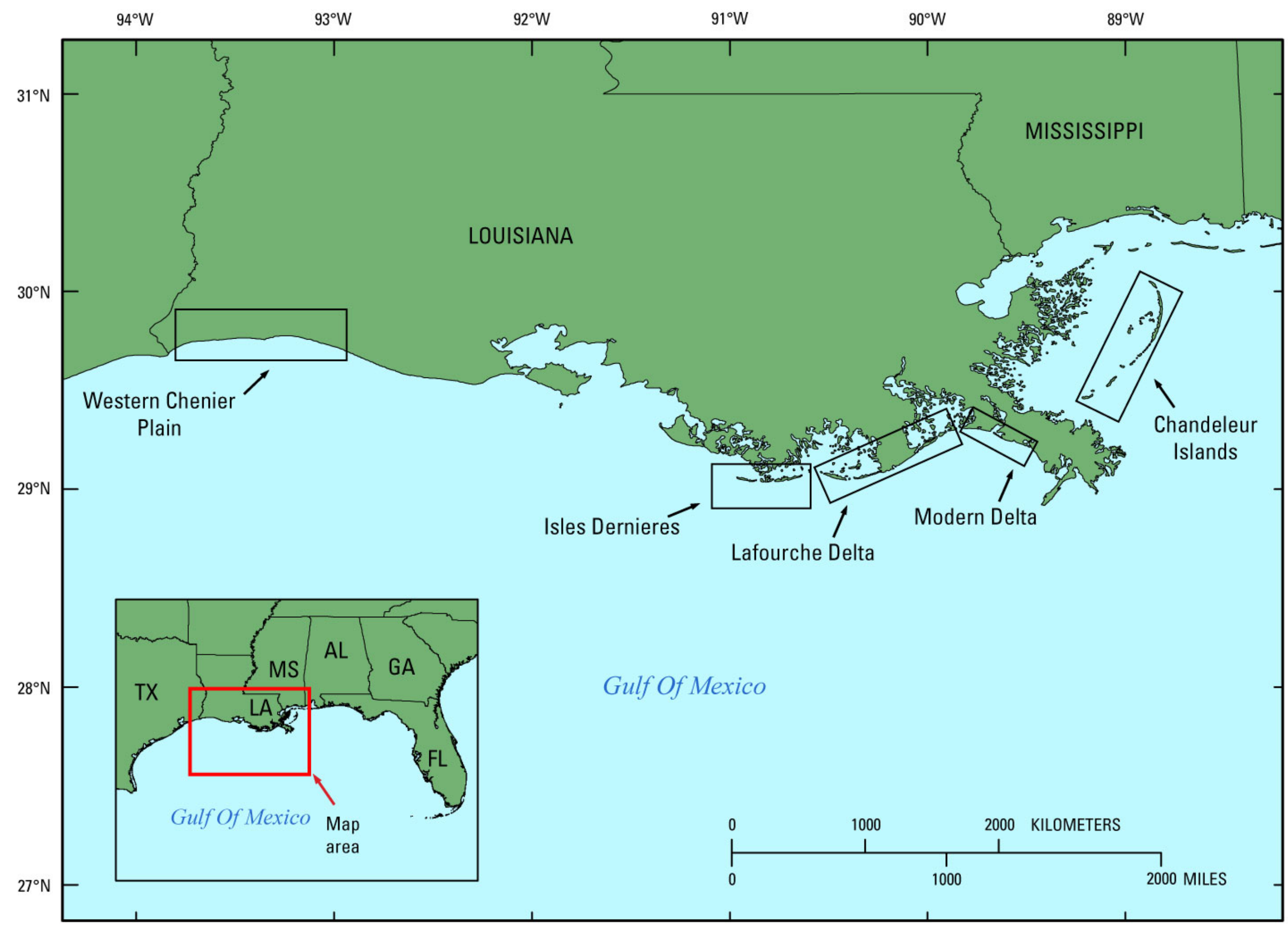


Figure 1. Study location map showing each of the five sampled regions. Base map is a U.S. Geological Survey coastal map from www.data.gov.

BICM sampling effort did not include reoccupation of 2008 sites from around Breton Island at the southern end of the Chandeleur Islands (fig. 6) because sediment samples were collected there by the USGS in 2014 and 2015 as part of a separate study (Bernier and others, 2017). A total of 97 surface-sediment samples from vibracore, sand auger, and grab samples around Breton Island (Bernier and others, 2017) supplemented the 2015–2016 BICM data to complete the coastwide dataset.

The 2008 and 2015–2016 BICM sediment samples were collected using either hand scoops in subaerial and shallow water environments or a Petite-Ponar sampler deployed manually from a boat at subaqueous sites. At each sample location, geographic coordinates were recorded using Geographic Positioning System (GPS) receivers. Each sample was placed in a plastic bag, labeled, sealed, and transported to UNO–PIES for initial processing and analysis. Sampling methods for the 2014–2015 Breton Island samples are described in Bernier and others (2017).

Grain-Size Analysis

At the completion of each BICM field effort, the samples were visually described, including sediment color, sediment type (for example, sand, mud, shells, or organics) and the estimated percent abundance of each sediment type that was present was recorded. Size classification of sediment was based on

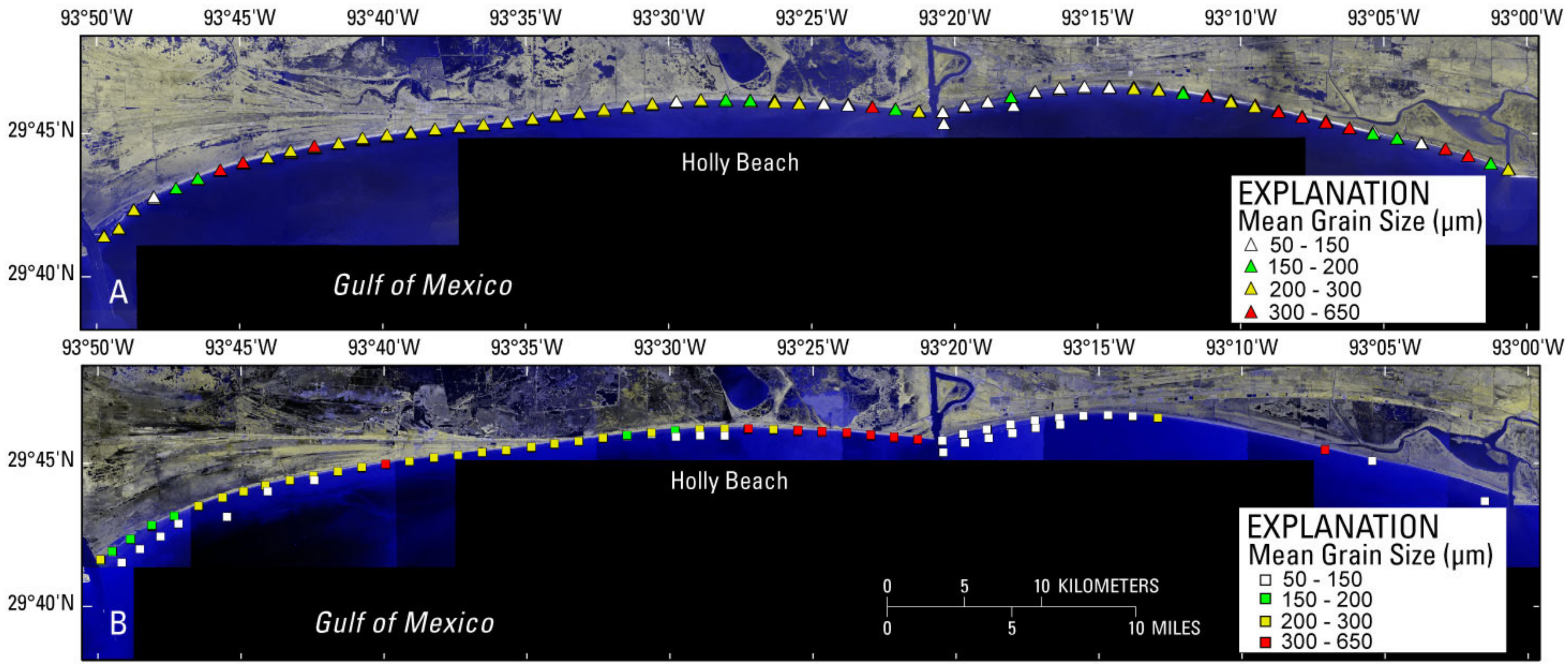


Figure 2. Regional map showing the mean grain size (in microns, µm) from various sample sites along the western Chenier plain in (A) 2008 and (B) 2015–2016. Background images are (A) 2008 Digital Orthophoto Quarter Quadrangle and (B) 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; false-color imagery uses bands 4,4,2.

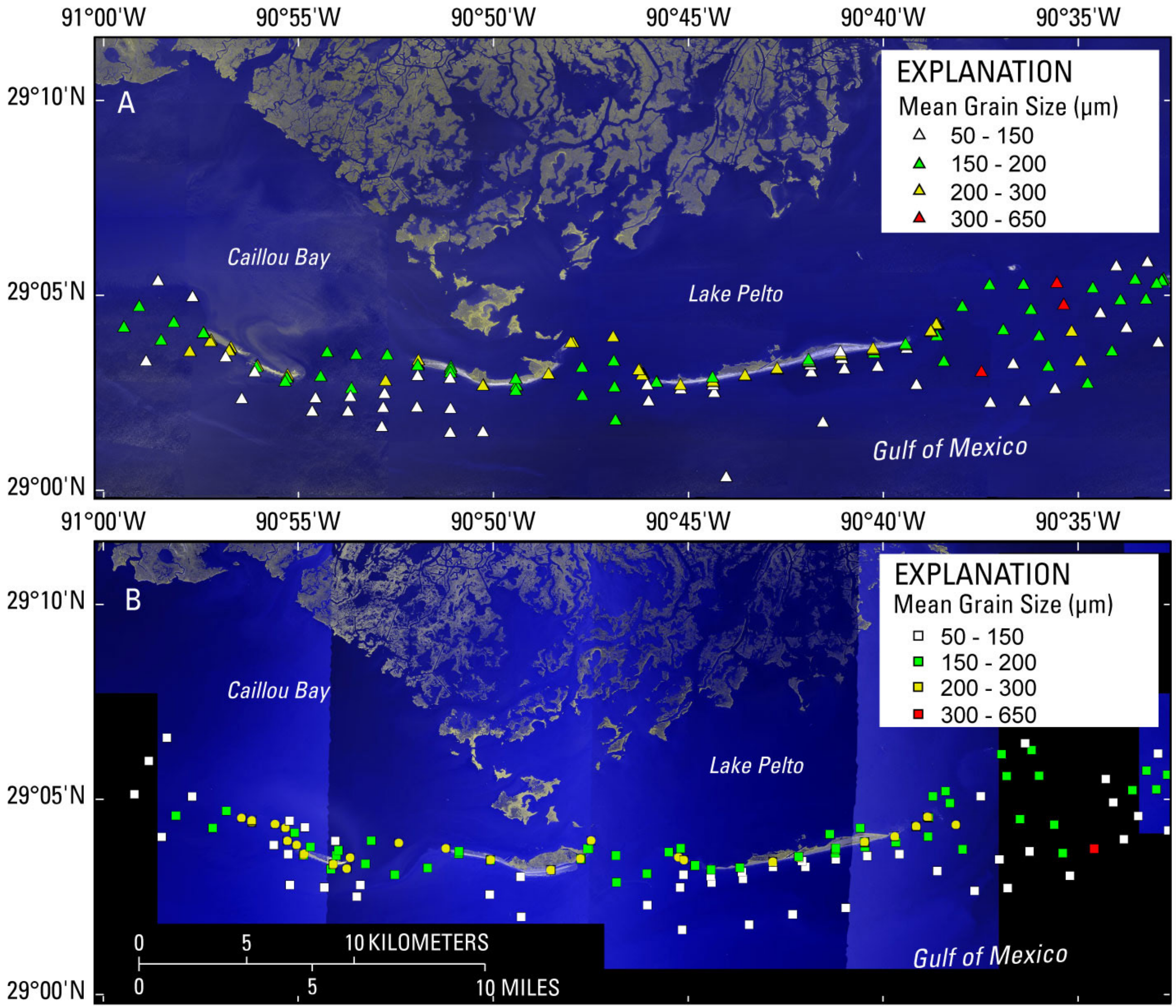


Figure 3. Regional map showing the mean grain size (in microns, µm) from various sample sites along the Isles Dernieres in (A) 2008 and (B) 2015–2016. Background images are (A) 2008 Digital Orthophoto Quarter Quadrangle and (B) 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; false-color imagery uses bands 4,4,2.

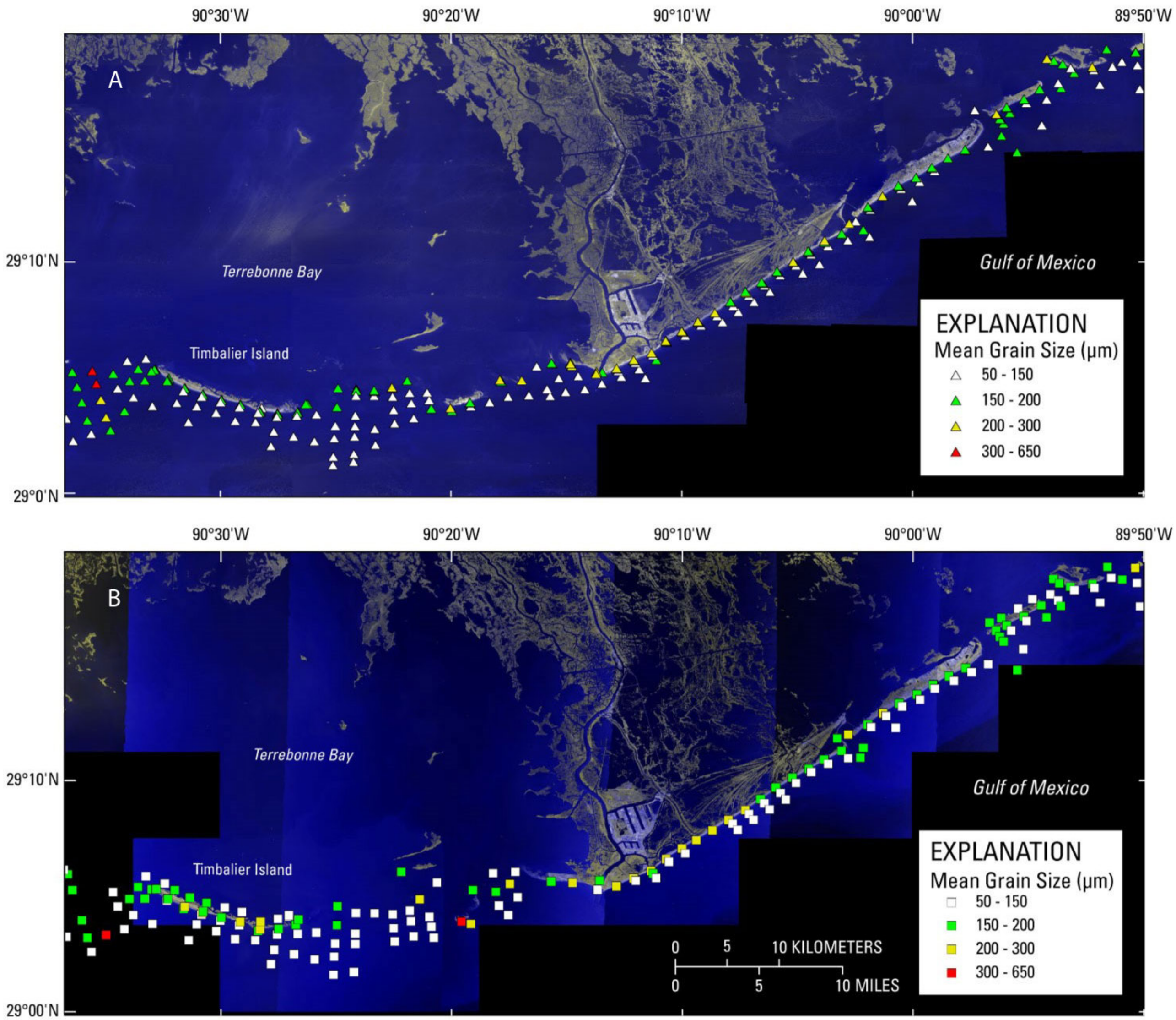
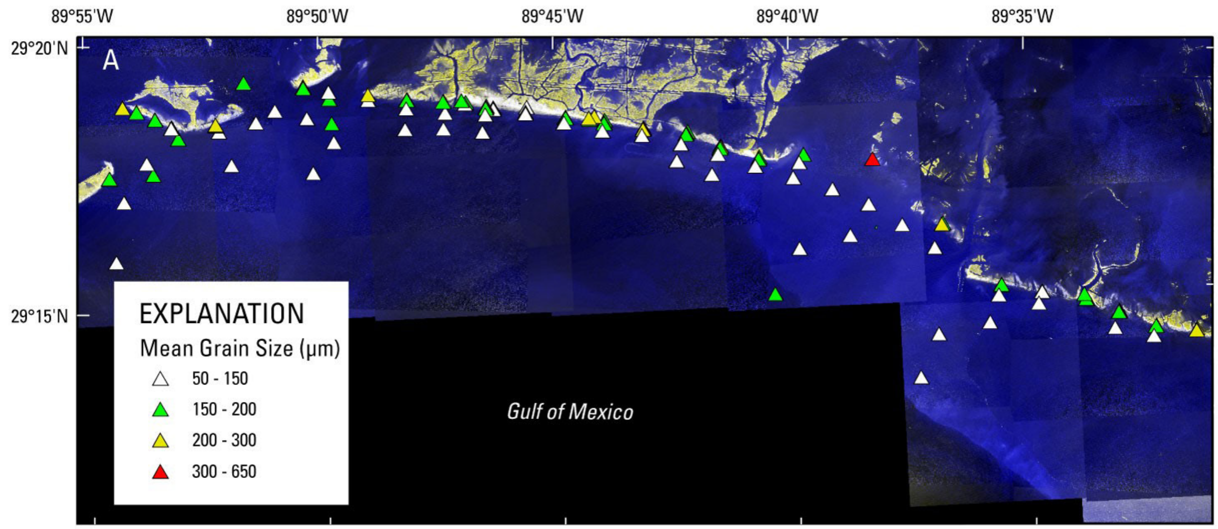


Figure 4. Regional map showing the mean grain size (in microns, μm) from various sample sites along the Lafourche delta in (A) 2008 and (B) 2015–2016. Background images are (A) 2008 Digital Orthophoto Quarter Quadrangle and (B) 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; false-color imagery uses bands 4,4,2.



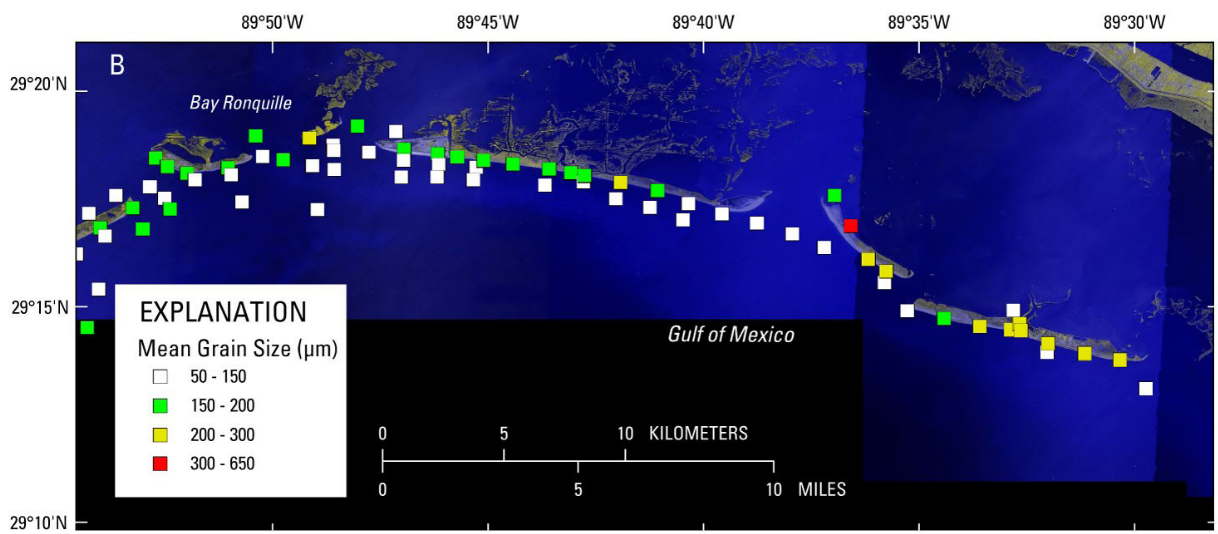


Figure 5. Regional map showing the mean grain size (in microns, µm) from various sample sites along the modern delta in (A) 2008 and (B) 2015–2016. Background images are (A) 2008 Digital Orthophoto Quarter Quadrangle and (B) 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; false-color imagery uses bands 4,4,2.

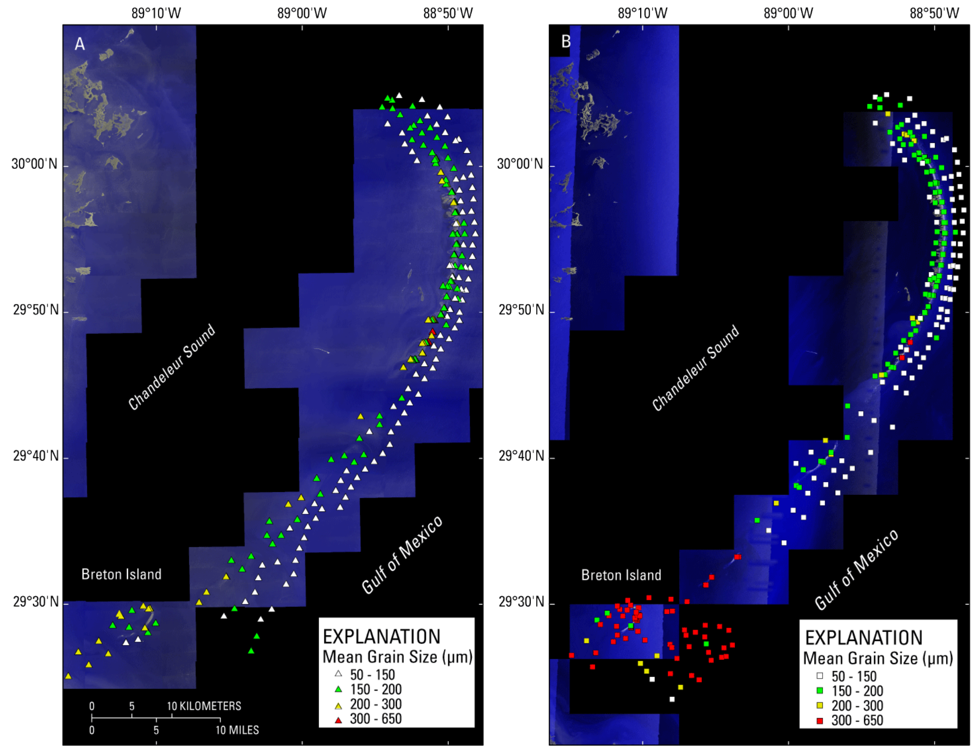


Figure 6. Regional map showing the mean grain size (in microns, µm) from various sample sites along the Chandeleur Islands in (A) 2008 and (B) 2014–2015/2016. Background images are (A) 2008 Digital Orthophoto Quarter Quadrangle and (B) 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; false-color imagery uses bands 4,4,2.

the Wentworth (1922) classification system. All samples that were visually estimated to contain at least 70 percent sand were shipped to USGS–SPCMSC in St. Petersburg, Florida, for subsequent analysis.

At the SPCMSC sediment laboratory, each sample was quantitatively analyzed using a Coulter LS 200 particle-size analyzer, which uses laser diffraction to measure the size distribution of sedimentary particles between 0.4 microns (µm) and 2 millimeters (mm) (clay to coarse sand). Two

Table 1. Total number of samples collected, number of samples analyzed on the Coulter LS 200 particle-size analyzer, and number of samples at reoccupied sites used in the change analysis from each region for the 2008 and 2015–2016 surveys.

[The 2015–2016 BICM dataset includes 97 samples collected in 2014 and 2015 from around Breton Island at the southern part of the Chandeleur Islands region.]

Region	Collected in 2008	Collected in 2015–2016	Analyzed in 2008	Analyzed in 2015–2016	Change analysis
Western Chenier plain	397	675	205	163	103
Isles Dernieres	209	365	151	157	63
Lafourche delta	358	347	269	223	155
Modern delta	235	215	135	100	52
Chandeleur Islands	301	244	271	231	99
Total samples	1,500	1,846	1,031	874	472

subsamples (sets) from each sample were processed (three runs per set) through the LS 200 particle-size analyzer, which measures the particle-size distribution of each sample by passing sediment suspended in solution between two narrow panes of glass in front of a laser. Light is scattered by the particles into characteristic refraction patterns measured by an array of photodetectors as intensity per unit area and recorded as relative volume for 92 size-related channels (bins). To prevent shell fragments and coarse material from damaging the LS 200, particles greater than 2 mm in diameter were separated from each subsample prior to analysis using a number 10 (2,000 µm [2 mm]) U.S. standard sieve, which meets the American Society for Testing and Materials (ASTM) E11 standard specifications for determining particle size using woven-wire test sieves. The 2014–2015 Breton Island samples were processed using the same methodology, except that all samples were analyzed regardless of estimated sand content, and the vibracore samples were analyzed using a Coulter LS 13 320 particle-size analyzer (Bernier and others, 2017).

The raw grain-size data were run through the free software GRADISTAT (Blott and Pye, 2001), which calculates the geometric (in metric units) and logarithmic (in phi units, Φ; Krumbein, 1934) mean, sorting, skewness, and kurtosis of each sample using the Folk and Ward (1957) method as well as the cumulative particle-size distribution. GRADISTAT also calculates the fraction of sediment from each sample by size category (for example, clay, coarse silt, fine sand) based on a modified Wentworth (1922) size scale. A macro developed by the USGS was applied to calculate the average and standard deviation of each sample (six runs per sample) and identify runs that varied from the set average by more than plus or minus (±) 1.5 standard deviations. Excessive deviations from the mean are likely the result of equipment error or extraneous material in the sample and, therefore, are not considered representative of the sample. Those runs were removed from the results and the sample average was recalculated using the remaining runs. The results of the sediment grain-size analyses are presented as maps showing percent sand and (or) D50 (median) grain size in Kulp and others (2011b, 2017b) and Georgiou and others (2017b).

Change Analyses

To compare changes in sediment grain size between survey years, the 2015–2016 sample locations were joined spatially to the 2008 sample locations in Esri ArcGIS version 10.5.1 using the Generate Near Table tool. A search radius of 25 meters (m) was used to identify the reoccupied 2008 sites. This tool was successful for most locations along the sample regions; however, for locations where samples were closely spaced along the cross-shore transects (for example, along beach and upper shoreface environments; fig. 7), more than one site was identified as a possible match in the resulting near table. At these sites, possible matches were aligned manually based on visual inspection of the datasets. Manual matching was also used in areas where the 2008 and 2015–2016 reoccupied sites were spaced more than 25 m apart. Once the datasets were joined, the differences in mean grain size, median grain size (D50), percent sand, and distance (between 2008 and 2015–2016 samples) at each reoccupied sample site were calculated.

Results and Discussion

The results are presented as maps showing differences in mean grain size (figs. 8–12) and are summarized in table 2. At most sample sites, differences in mean grain size varied by less than ±0.25 Φ. The largest changes occurred at sites located near tidal inlets (fig. 9) or along rapidly eroding shorelines (fig. 11).

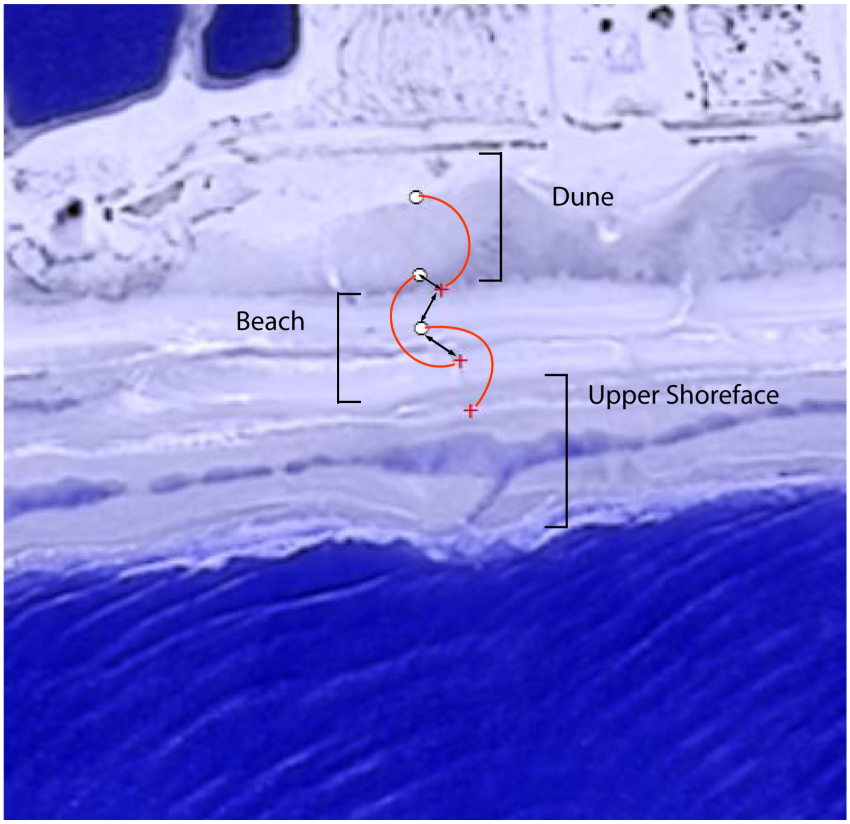


Figure 7. Image showing the offsets between 2008 and 2015–2016 sample sites along the western Chenier plain; white circles represent 2015–2016 sample sites, red crosses represent 2008 sample sites, black arrows represent potential mismatched sample sites, and red curved lines represent where the sample sites were manually matched.

All five regions experienced a mean decrease in sand percent from 2008 to 2015–2016. Although the western Chenier plain and Lafourche delta regions show a slight increase in mean grain size (table 2), these increases are much smaller than the 1-sigma distribution between samples. West of the Calcasieu inlet in the western Chenier plain (fig. 8), several samples (8) along the upper shoreface and beach berm show relatively high increases in mean grain size (<-0.5 Φ). Between 1996 and 2005, the stretch of coast along Holly Beach experienced significantly higher erosion rates (average -16.6 ft/yr) than shoreline reaches to the east and west (Martinez and others, 2009).

Overall trends from the modern delta and Isles Dernieres are opposite to that of the western Chenier plain and Lafourche delta regions, with more examples of decreasing mean grain size (>0.25 Φ) and fewer examples of increasing mean grain size (<-0.25 Φ), resulting in an overall decrease in mean grain size (table 2). Some of the largest changes in mean grain size in the MRDP occurred near tidal inlets along the Isle Derniers and LaFourche Delta (figs. 9 and 10). Since the early 1900s, high rates of shoreface erosion, coupled with inlet enlargement, have reduced the formerly continuous Isle Derniers to their current configuration (fig. 9) (Miner and others, 2009c; Berlinghoff and others, 2019). Similar changes have occurred at Timbalier Island and in the western Lafourche delta region (fig. 10) (Miner and others, 2009c). Compared with these relict delta shorelines, grain-size changes occur along the entire length of the Modern Delta shoreline (fig. 11), which has experienced high historic shoreline erosion rates (Martinez and others, 2009) as well as extensive interior land loss between sampling efforts (fig. 5).

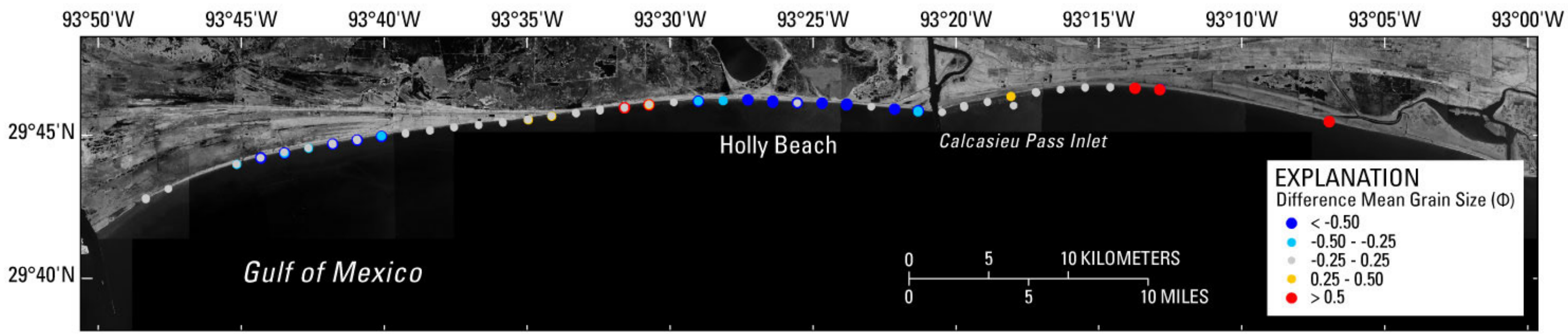


Figure 8. Regional map showing the difference in mean grain size (2015–2016 minus 2008) at reoccupied sample sites in the western Chenier plain. Background image from 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; imagery uses only band 4. Abbreviation: Φ, phi.

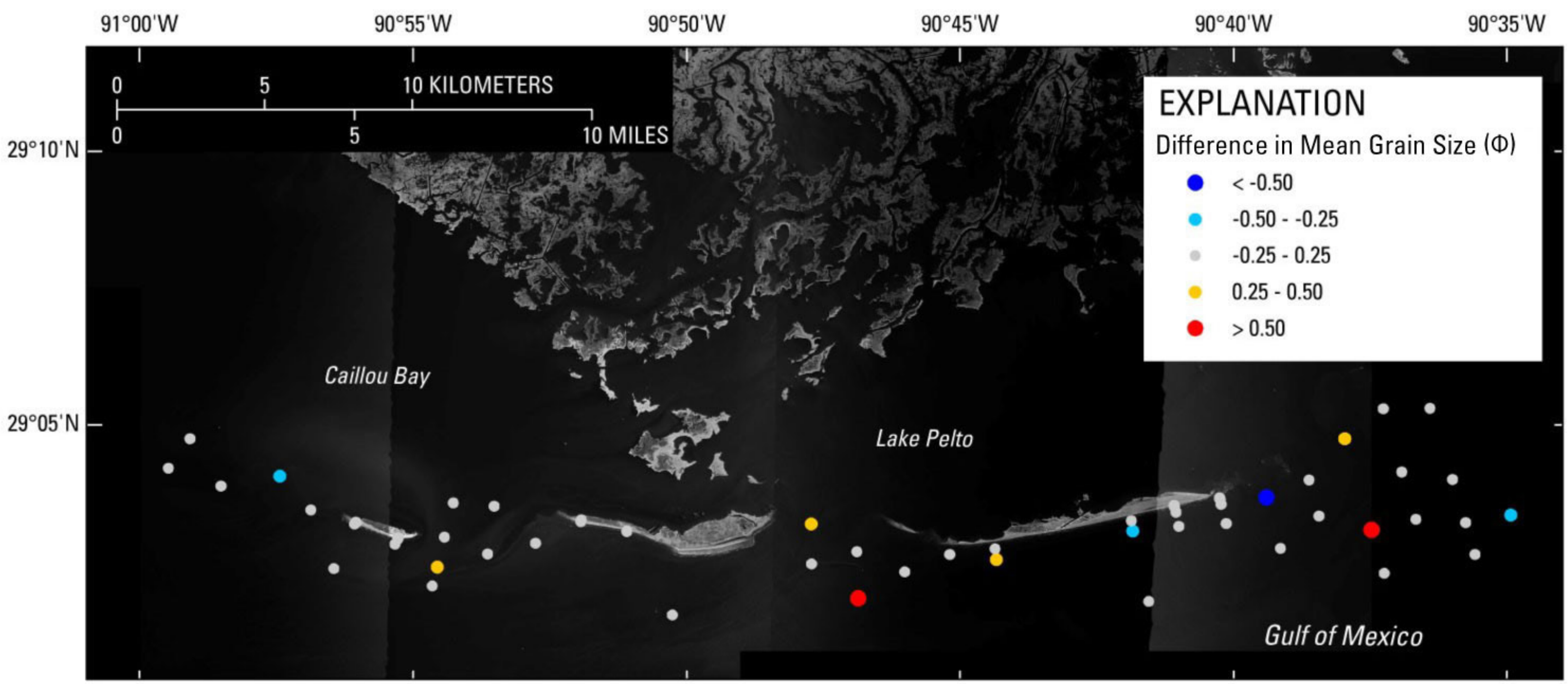


Figure 9. Regional map showing the difference in mean grain size (2015–2016 minus 2008) at reoccupied sample sites in the Isles Dernieres. Background image from 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; imagery uses only band 4. Abbreviation: Φ, phi.

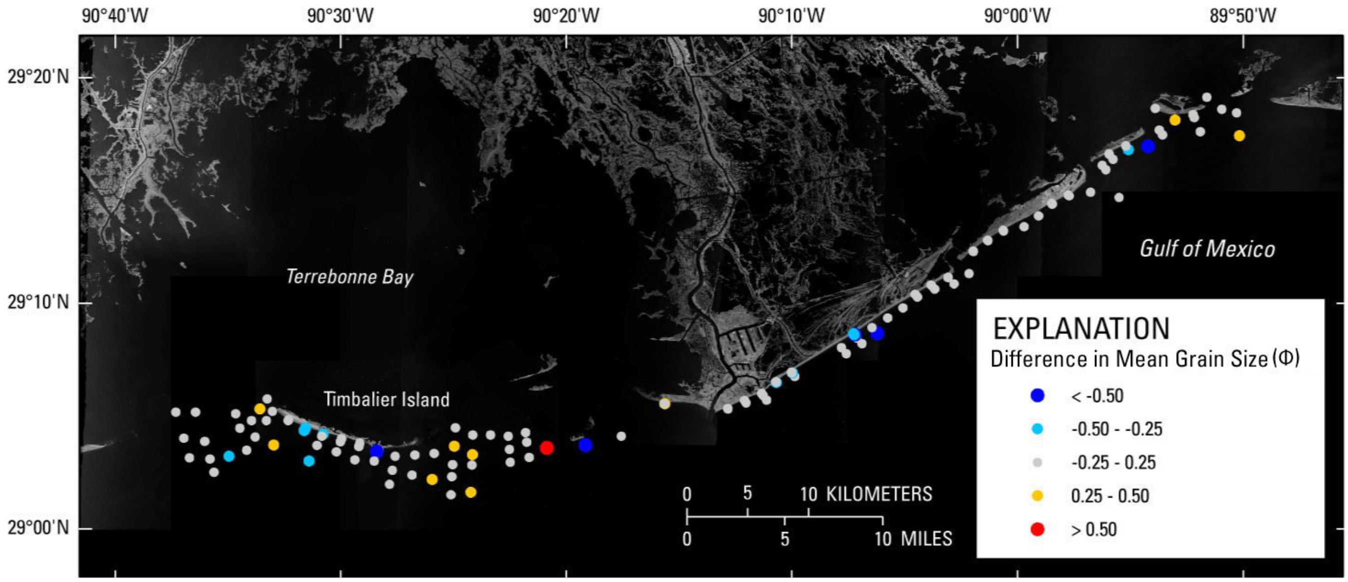


Figure 10. Regional map showing the difference in mean grain size (2015–2016 minus 2008) at reoccupied sample sites in the Lafourche delta. Background image from 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; imagery uses only band 4. Abbreviation: Φ, phi.

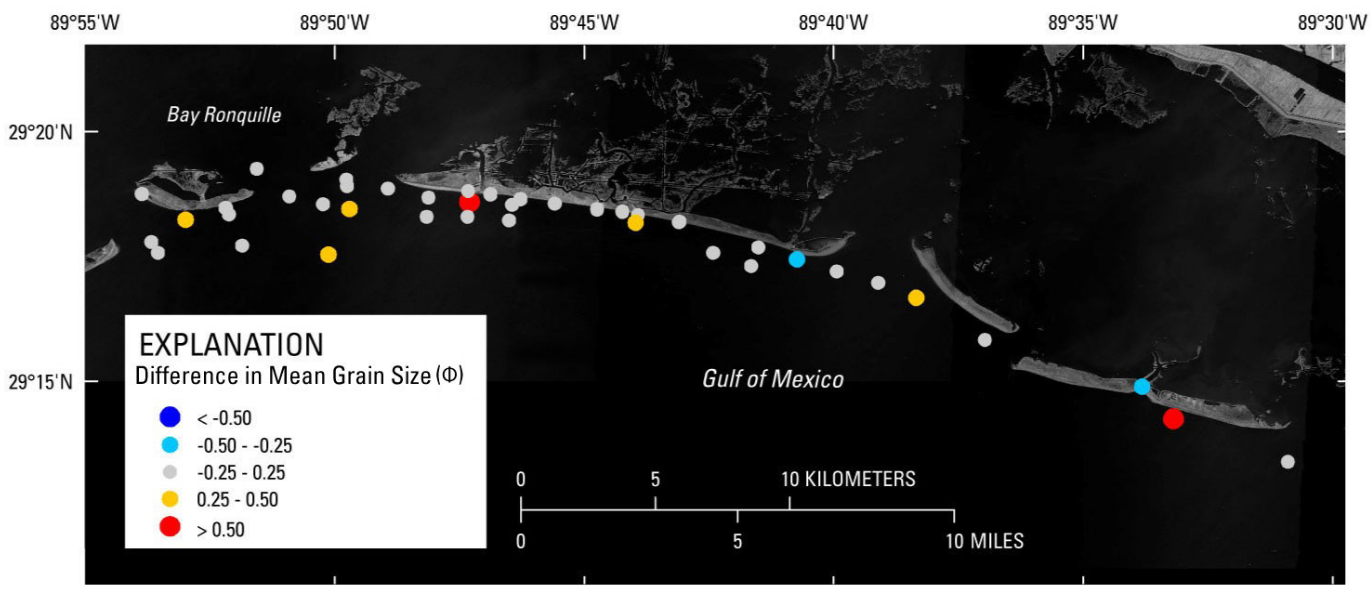


Figure 11. Regional map showing the difference in mean grain size (2015–2016 minus 2008) at reoccupied sample sites in the modern delta. Background image from 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; imagery uses only band 4. Abbreviation: Φ, phi.

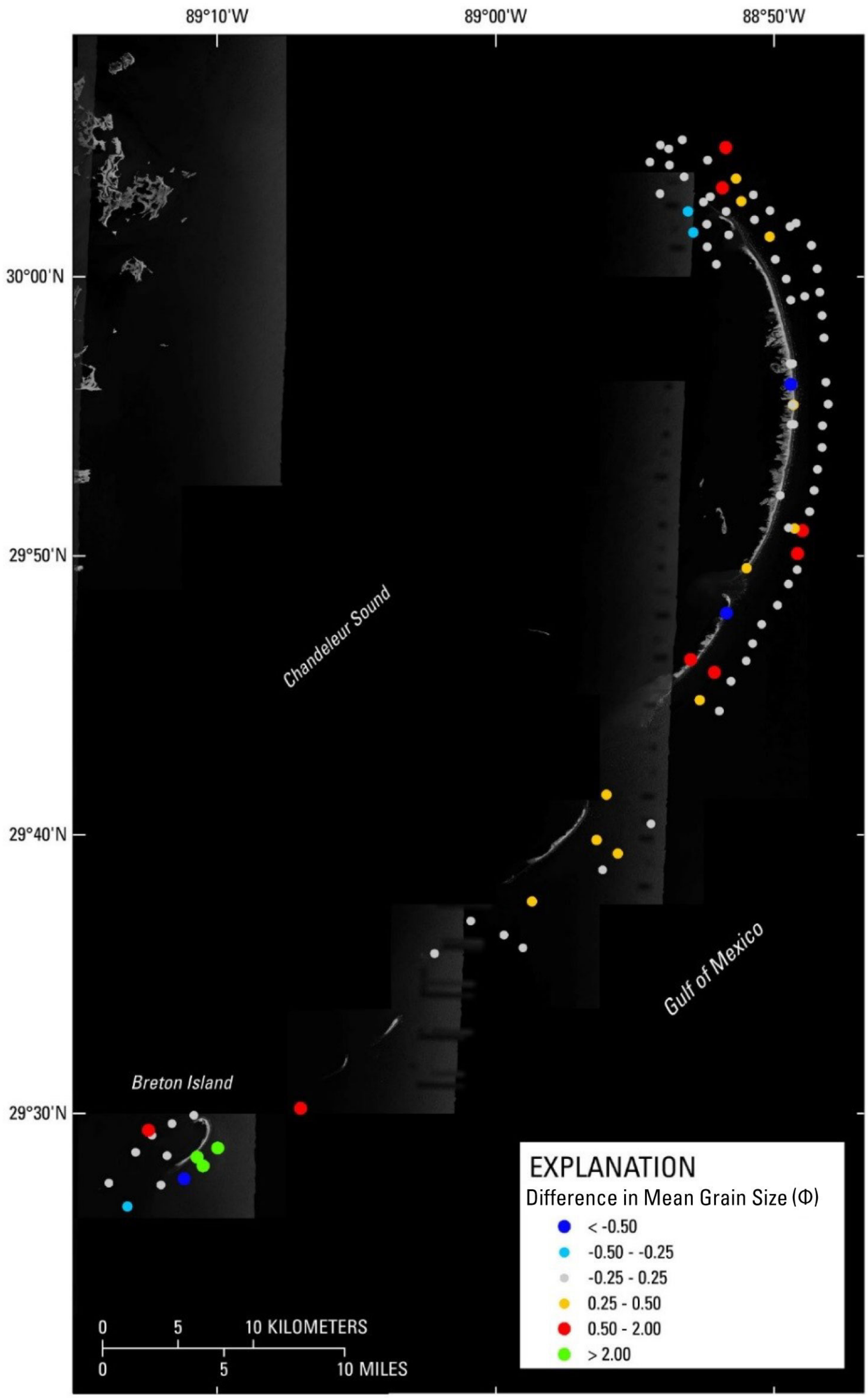


Figure 12. Regional map showing the difference in mean grain size (2015–2016 minus 2008) at reoccupied sample sites in the Chandeleur Islands. Background image from 2017 National Agriculture Imagery Program (NAIP) color-infrared aerial imagery; imagery uses only band 4. Abbreviation: Φ, phi.

Table 2. Summary statistics showing differences in grain size between 2008 and 2015–2016 (2015–2016 minus 2008) at reoccupied sample sites for each geographic region.

[Abbreviations: Φ, phi units; σ, sigma (standard deviation); D50, median grain size; μm, micron; Min, minimum; Max, maximum; m, meters.]

	Differences in mean grain size (Φ)			Differences in D50 (μm)		
Region	Mean ± 1σ	Min	Max	Mean ± 1σ	Min	Max
Western Chenier plain	-0.15 ± 0.44	-1.65	0.87	30.29 ± 71.79	-137.88	268.61
Isles Dernieres	0.03 ± 0.27	-0.67	1.53	-5.99 ± 51.24	-382.07	87.83
Lafourche delta	-0.02 ± 0.20	-0.84	0.60	2.56 ± 22.48	-63.74	112.11
Modern delta	0.03 ± 0.20	-0.49	0.57	-2.50 ± 18.41	-48.99	44.77
Chandeleur Islands	0.18 ± 0.57	-1.07	3.39	-10.53 ± 39.65	-187.12	147.00
	Differences in percent sand			**Differences in distance (m)**		
Region	Mean ± 1σ	Min	Max	Mean ± 1σ	Min	Max
Western Chenier plain	-0.79 ± 3.83	-8.95	19.51	24.52 ± 15.02	1.82	66.52
Isles Dernieres	-0.84 ± 4.22	-11.35	18.00	25.71 ± 17.07	3.33	84.66
Lafourche delta	-0.25 ± 4.05	-14.91	21.38	25.48 ± 16.71	0.59	72.31
Modern delta	-1.38 ± 4.08	-14.91	12.84	30.63 ± 19.28	2.05	69.54
Chandeleur Islands	-4.01 ± 11.70	-80.51	11.90	29.54 ± 19.04	1.42	76.55

The Chandeleur Islands (fig. 12) experienced the greatest changes, with a slight fining in mean grain size (0.18±0.57 Φ) and loss of sand fraction (-4.1±11.70 percent) (table 2), although there are large variations between samples. In 2010, a sand berm was constructed along the northern Chandeleur Islands to protect the islands from oiling from the Deep Water Horizon oil spill. Despite this, much of Chandeleur Islands continued to undergo significant land loss and shoreline retreat during the sampling period (2008 to 2015–2016) (FitzGerald and others, 2015). Due to this loss, some 2008 sampling sites that were formerly emergent or located on the upper shoreface at MLW likely were submerged in 2015. Similarly, continued shoreface erosion may have resulted in deepening of middle shoreface sample sites, resulting in a lower energy sediment distribution pattern. There are statistically very high decreases in sediment grain size at three locations across the Gulf side of Breton Island (fig. 12), which could be the result of decommissioning the Mississippi River Gulf Outlet canal (MRGO) following Hurricane Katrina in 2005. Since its closure, the MRGO has been filling with primarily medium-size silts and it is possible similarly sized sediments could have been deposited seaward of Breton Island through north-south littoral transport (Flocks and Terrano, 2016). Another factor that might contribute to the observed decreases in grain size could be related to extremely high historic shoreline-erosion rates (-143 ft/yr) (Martinez and others, 2009; Terrano and others, 2016), which could have resulted in shoreface erosion exposing buried fine-grained marsh platform sediments.

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