

Extreme Changes to Barrier Islands Along the Central Gulf of Mexico Coast During Hurricane Katrina

By Asbury Sallenger, Wayne Wright, Jeff Lillycrop, Peter Howd, Hilary Stockdon, Kristy Guy, and Karen Morgan

Hurricane Katrina caused extreme changes to the barrier islands of the central Gulf of Mexico coast. Dauphin Island, Ala., migrated landward and stranded the remains of its oceanfront row homes in the sea. Chandeleur Islands, La., were completely stripped of their sand, leaving only marshy outcrops in the storm's wake.

Introduction

The U.S. Geological Survey (USGS) is developing the means to predict the coastal geologic impacts of extreme storms, such as hurricanes, on the coasts of the United States. For example, USGS scientists are working towards predicting where maximum coastal erosion will occur, where storm surge and waves will overtop beaches, where sand dunes will retreat landward, and where breaches will sever barrier islands and create new inlets.

As part of this research, the

USGS works closely with the National Aeronautics and Space Administration



(NASA) and the U.S. Army Corps of Engineers (USACE) to survey the elevations of beaches and barrier islands both before and after storm landfall. These data are compared to quantify coastal change during the storm and are used to test predictions and hypotheses of change.

The data are also made available to local, State, and Federal agencies involved in emergency management and damage assessment in the aftermath of hurricane disasters.

During the 2005 hurricane season, the USGS and its partners in NASA and USACE surveyed coastal change resulting from Hurricanes Dennis, Katrina, Rita, and Ophelia. Elsewhere in this volume, we provide preliminary interpretations of those data related to changes on mainland Mississippi during Katrina (see Hansen and others, this volume) and western Louisiana during Rita (see Stockdon and others, this volume). In this article, we focus on extreme changes that occurred to barrier islands offshore of Alabama and Louisiana during Katrina (fig. 1).

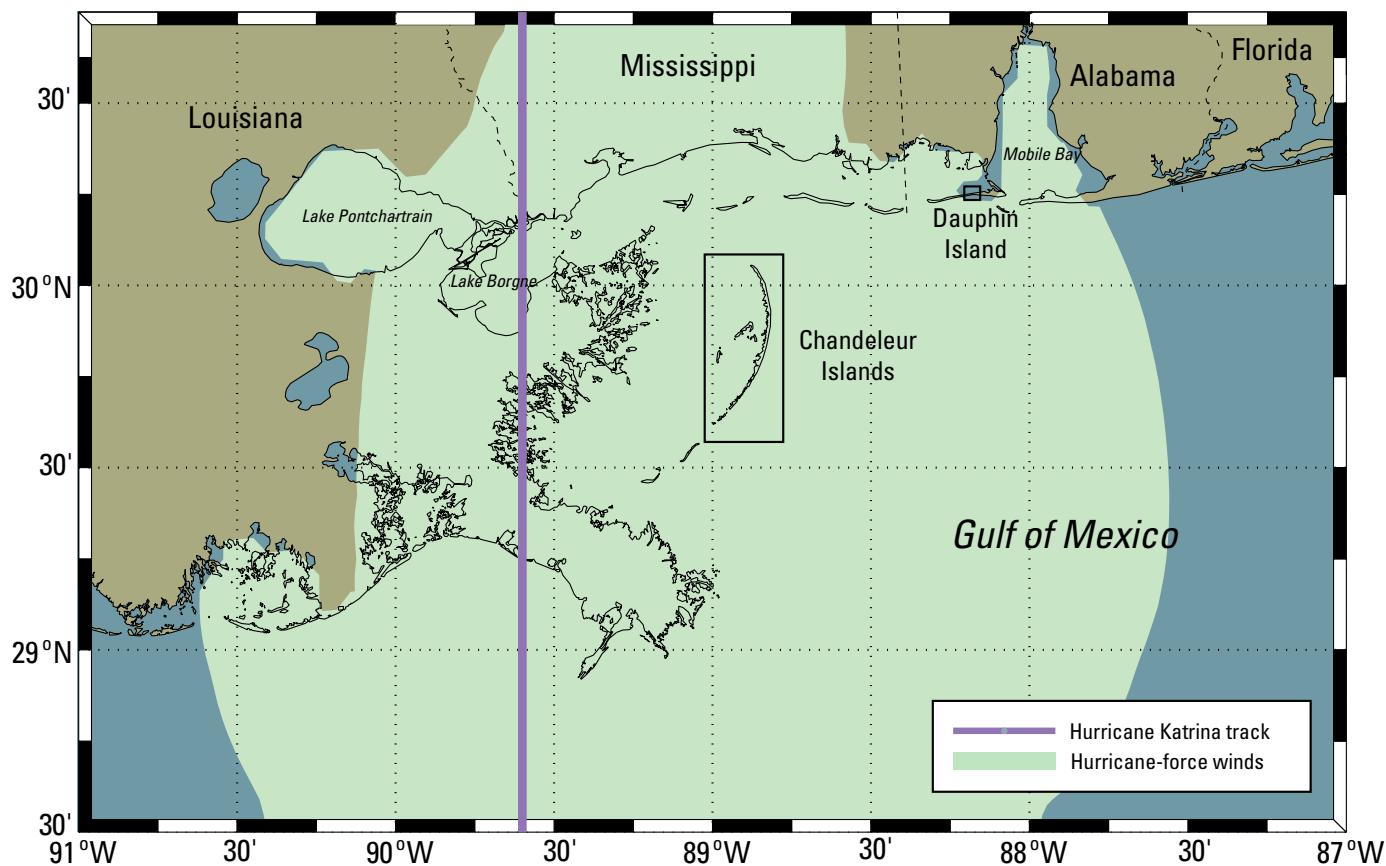


Figure 1. Track of Hurricane Katrina as the storm made landfall in Louisiana in 2005, and spatial extent of hurricane-force winds as calculated by the National Oceanic and Atmospheric Administration's Hurricane Research Division. Note that the two barrier islands that we focus on here, Dauphin Island, Ala., and Chandeleur Islands, La., were located in the right-front quadrant of the hurricane-force winds, the zone of strongest onshore winds and highest storm surge.

Airborne Lidar

Light detection and ranging (lidar) is an excellent tool to survey beaches and coasts before and after extreme storms. The application of this laser surveying technology to coastal change is relatively new and has been used extensively for only the past decade (e.g., Sallenger and others, 1999, 2005). The primary advantages of this technology over standard ground surveys are the speed of data acquisition and the high spatial density. In a few hours, an airborne lidar system, using laser pulses reflecting from Earth's surface and the Global Positioning System, can survey a swath several hundred yards (meters) wide along several hundred miles (kilometers) of coast (fig. 2) (Wright and Brock, 2002). Lidar systems can obtain a measurement of elevation in about every square yard (or square meter) of land surface. To duplicate 1 day's airborne lidar survey with traditional ground surveys would take months or years.

Coastal change is detected by comparing poststorm lidar surveys to a baseline of prestorm surveys. For the 2005 hurricanes, we used two different systems to provide

these surveys. One system was called CHARTS (Compact Hydrographic Airborne Rapid Total Survey) developed by the USACE, the U.S. Navy, and their contractors. The other system is called EAARL (Experimental Advanced Airborne Research Lidar) and is under continued development by NASA (fig. 2) (Wright and Brock, 2002). Lidar systems used for coastal mapping generally have vertical accuracies of about 6 inches (about 15 cm) (Sallenger and others, 2003).

In addition to lidar, the USGS acquired prestorm and poststorm oblique aerial photography and video to visualize coastal change and to assist in interpreting the lidar data. Example photography from each of the 2005 hurricanes, as well as initial results of the lidar surveys, can be seen at <http://coastal.er.usgs.gov/hurricanes>.

Initial Results

Barrier islands are narrow strips of sand that form along most of the U.S. Atlantic and Gulf of Mexico coasts from Rhode Island to south Texas; these islands tend to be among

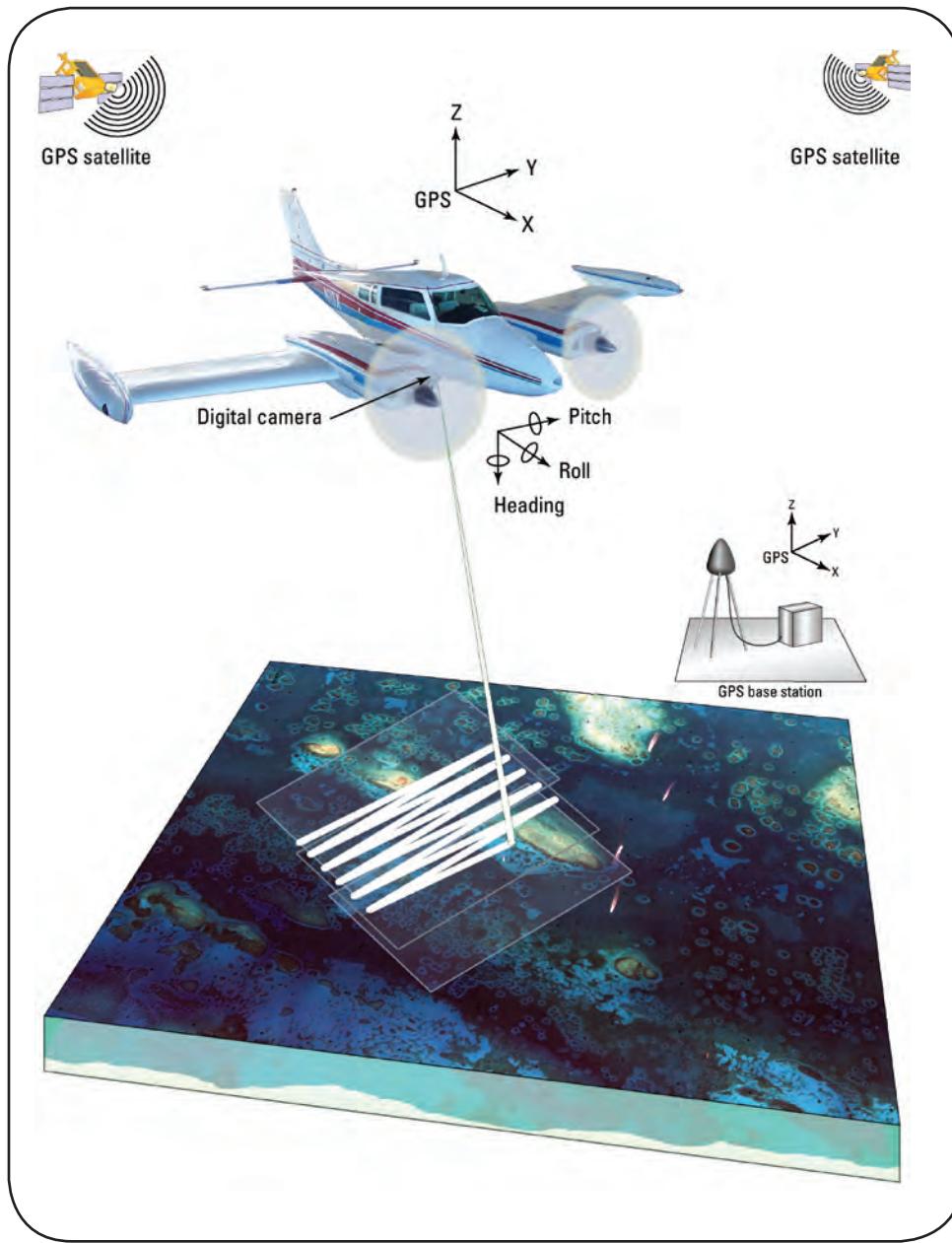


Figure 2. Schematic of NASA's Experimental Advanced Airborne Research Lidar (EAARL), a scanning laser altimeter that measures both topography and bathymetry. A laser is fired from the aircraft (depicted by white line) and scans Earth's surface. The aircraft's position is determined from Global Positioning System satellites and a fixed base station on the ground. With these data and knowledge of the speed of light, elevations on Earth's surface can be calculated. For details of how the system operates, see Wright and Brock (2002).

the most dynamic of coastal landforms. Hurricane Katrina's right-front quadrant, the location of a hurricane's strongest onshore winds, swept across the nearly continuous string of barrier islands from Dauphin Island in western Alabama to the Chandeleur Islands in eastern Louisiana (fig. 1). In general, the Chandeleur Islands, as the closest island chain to landfall, would have experienced the strongest winds and maximum storm surge, that is, the rise of sea level along the

coast caused mostly by the push of wind against the sea's surface. Storm surge at the Chandeleur Islands was estimated at about 10 ft (about 3 m) by the National Hurricane Center's model simulations. The before- and after-storm photography and lidar surveys show distinct differences in response of the Chandeleur Islands compared to that of Dauphin Island, which is located at the outer (easternmost) extent of hurricane-force winds (fig. 1).

During Katrina, Dauphin Island suffered extensive changes even though it is located about 90 mi (145 km) from landfall. Visual comparisons of the prestorm lidar topography and the poststorm topography (figs. 3A and 3B) show that the island was deeply incised and that most of the houses were destroyed. This contrast is seen more explicitly in the change map (fig. 3C): where the first row of houses was positioned prior to the storm (their footprints are shown as red rectangles), there is now water. On the landward side of the island, there is deposition (green) where waves swept across the island, taking sand from the gulfside of the island and depositing it on the bayside. In essence, the barrier island "rolled over" in the classic sense of landward barrier island migration. Along this part of Dauphin Island, over 90 percent of the houses were completely destroyed and their debris transported, along with the sand, into the back bay (fig. 3D).

In contrast to Dauphin Island, the Chandeleur Islands did not "roll over." Rather, the islands

were stripped of sand (figs. 4 and 5). Prior to the storm, the lidar survey showed a peak elevation on the island of more than 20 ft (6 m); after the storm, peak elevation decreased to less than 7 ft (2.1 m). What remained of the Chandeleur Islands were marsh remnants (figs. 4A and 5B), which, prior to the storm, served as platforms on which the sand of the barrier island laid. The storm changed a 25-mi-long (40-km-long) sandy island into a discontinuous series of marsh fragments.

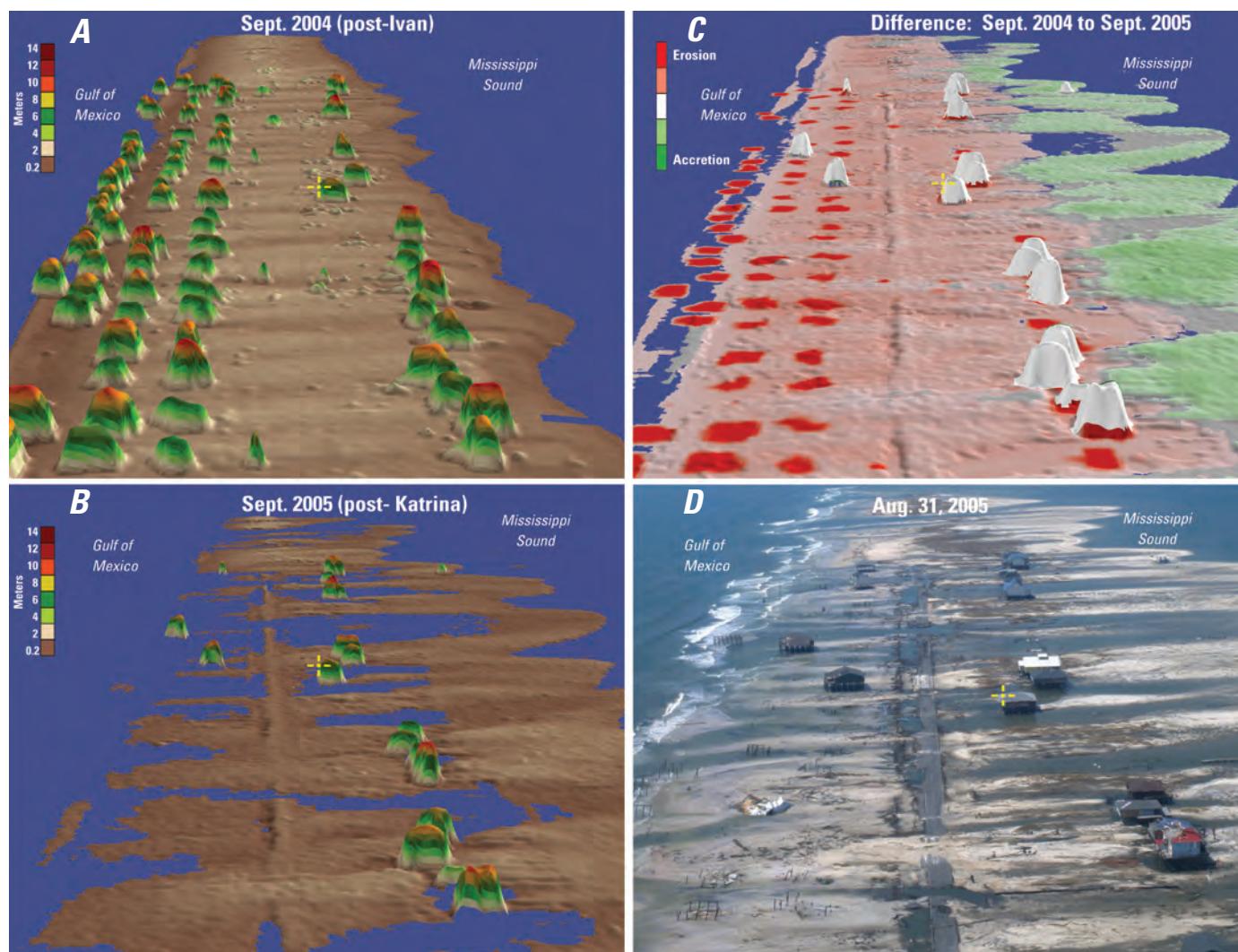


Figure 3. Pre- and post-Hurricane Katrina light and detection ranging (lidar) topography (*A* and *B*), coastal change (*C*), and photograph (*D*) of the central part of Dauphin Island, Ala. In *A* and *B*, the topography is color coded so that hotter colors are higher elevations (e.g., the roofs of houses). Coastal change (*C*) is the difference between prestorm and poststorm topography; red is loss, and green is gain. The bright red rectangles are the footprints of lost houses. The white areas indicate surviving houses. The photograph (*D*) shows the same region as the lidar plots and was taken several days following the storm. In all images, the view is toward the west.

Preliminary results suggest that the processes affecting the two islands were different. For Dauphin Island, the storm surge raised the reach of waves on the beach in such a way that they periodically overtopped it and drove sand landward, eroding sand from the gulfside of the island and depositing it on the bayside. Hence, the entire island migrated landward. In contrast, the waves did not just periodically overtop the Chandeleur Islands: the storm surge became high enough and the islands became low enough that, at some point during the storm, the islands were completely and continuously underwater. Under these conditions, we hypothesize that a strong and persistent current flowing across the island completely removed the sand. A modeling and sediment-sampling program will test hypotheses on the direction of the

flow and whether the sand was lost offshore or onshore of the island.

Conclusion

In the aftermath of Katrina, the USGS, with its partners, will continue to periodically monitor the barrier islands from Alabama to Louisiana to determine whether they will recover or continue to deteriorate. Understanding their condition is important to coastal restoration. For example, in Louisiana, barrier islands are considered natural breakwaters protecting the mainland wetlands and infrastructure from waves and surge. The islands have been greatly diminished, however, as

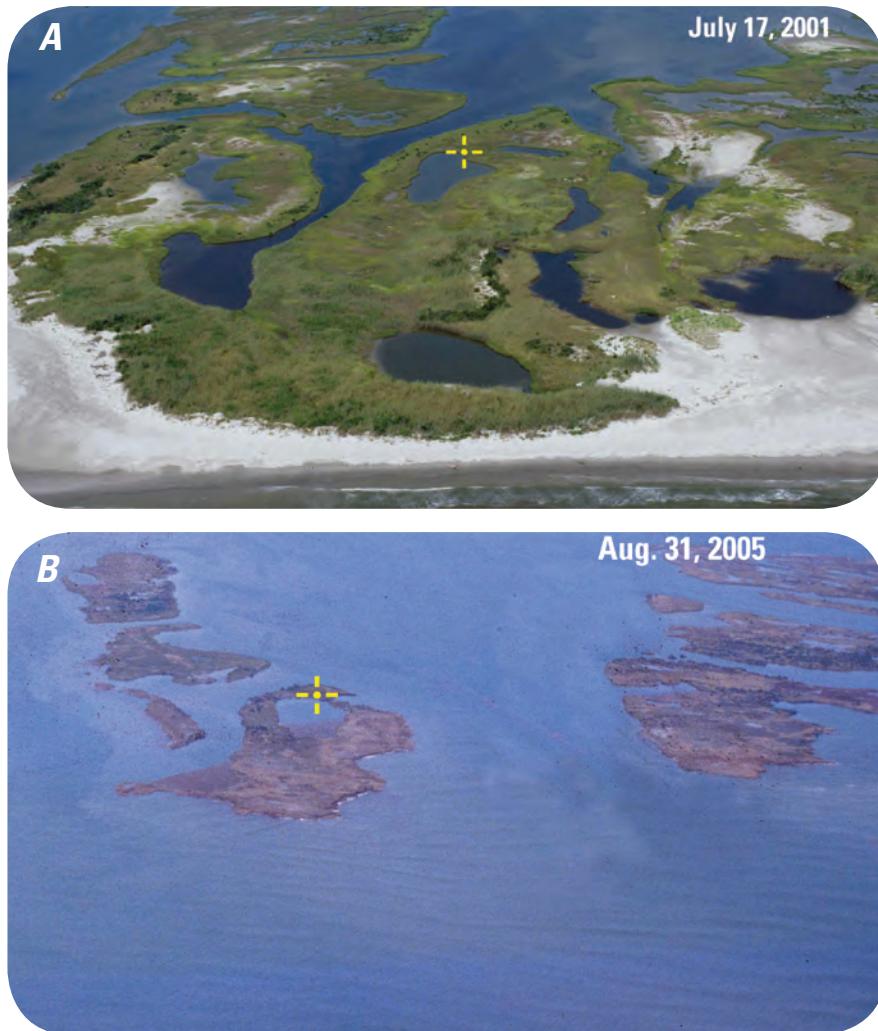


Figure 4. Photographs of the Chandeleur Islands, La., before (A) and after (B) Hurricane Katrina (which made landfall in 2005) showing that all the visible sand was stripped from the island. Photographs were taken by using the same camera lens and from the same elevation. In both images, the view is toward the west.

the Chandeleur Islands have lost 85 percent of their surface area during the storm. A major research question is the degree to which the diminished islands now serve as natural breakwaters protecting the mainland environment.

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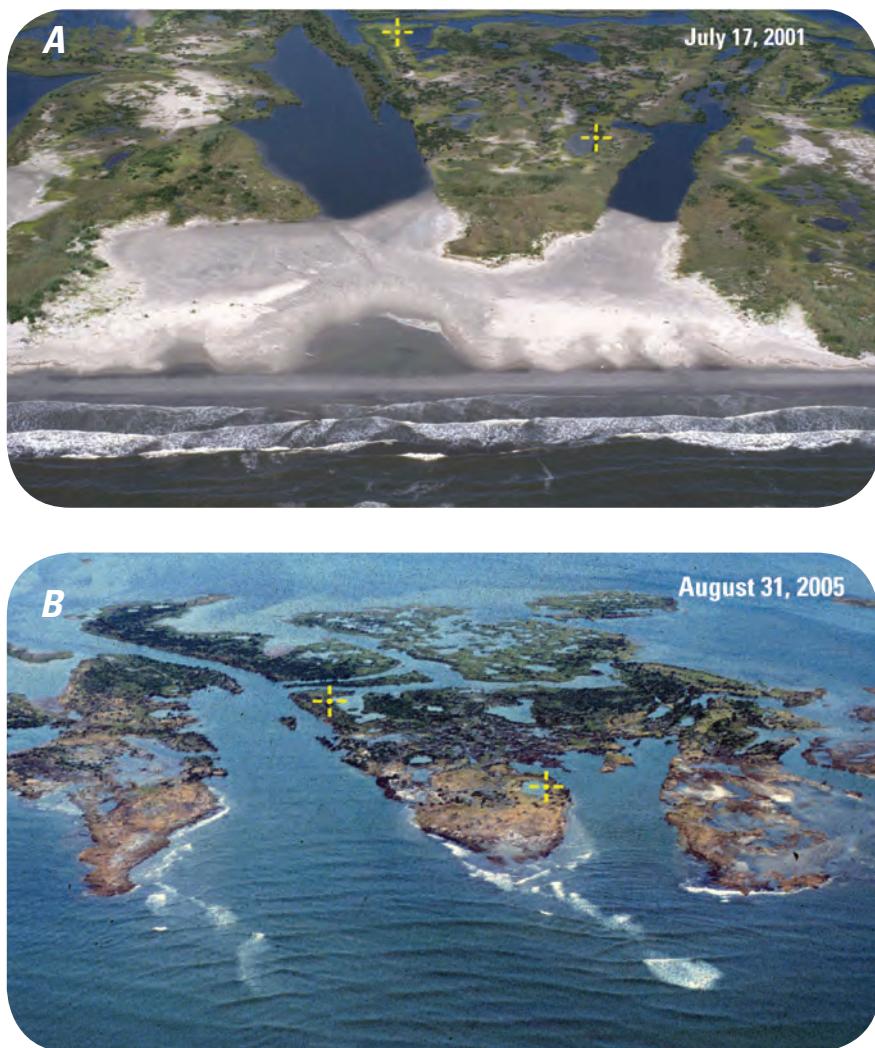


Figure 5. Photographs of the Chandeleur Islands, La., before (A) and after (B) Hurricane Katrina (which made landfall in 2005) showing the sand completely stripped from the island. Photographs were taken by using the same camera lens and from the same elevation. In both images, the view is toward the west.

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