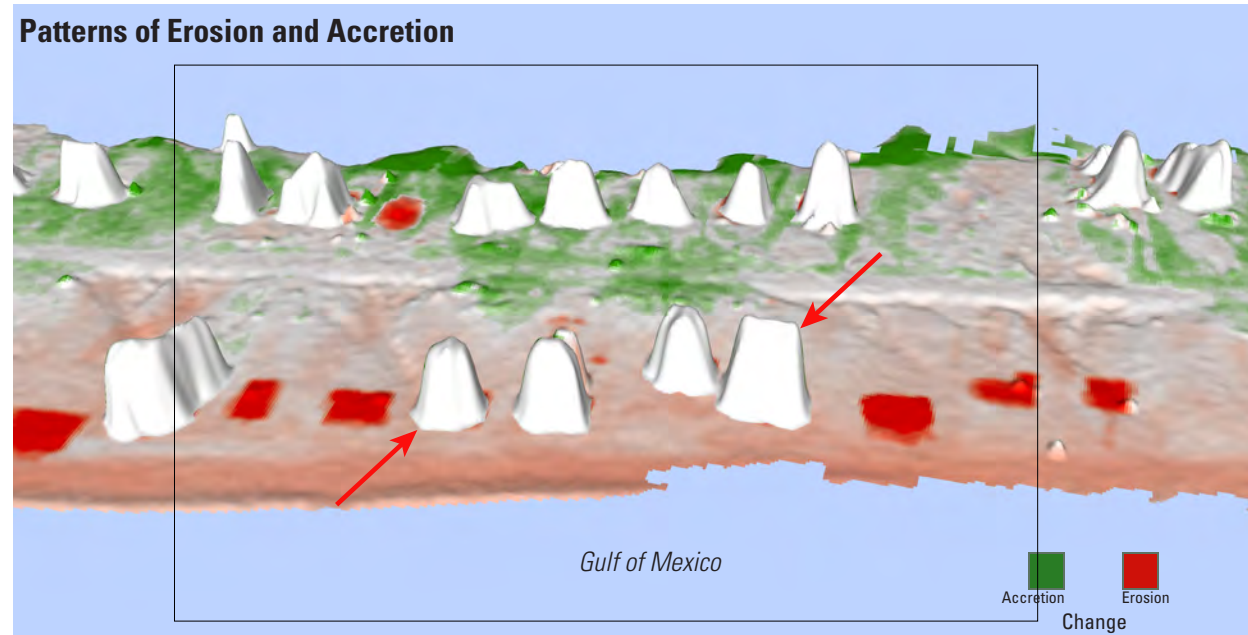
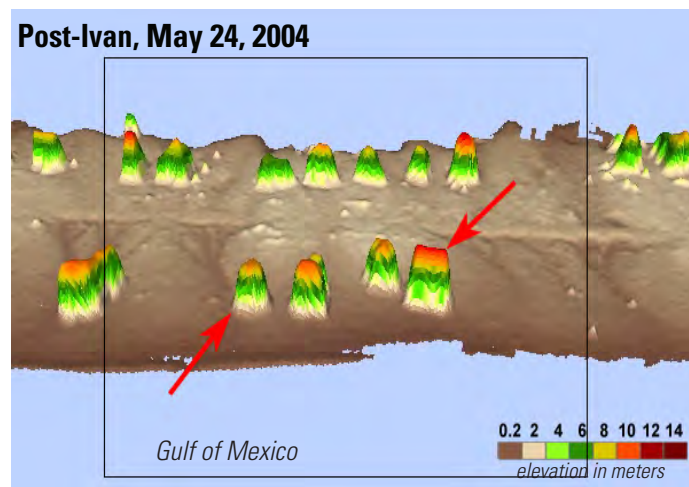
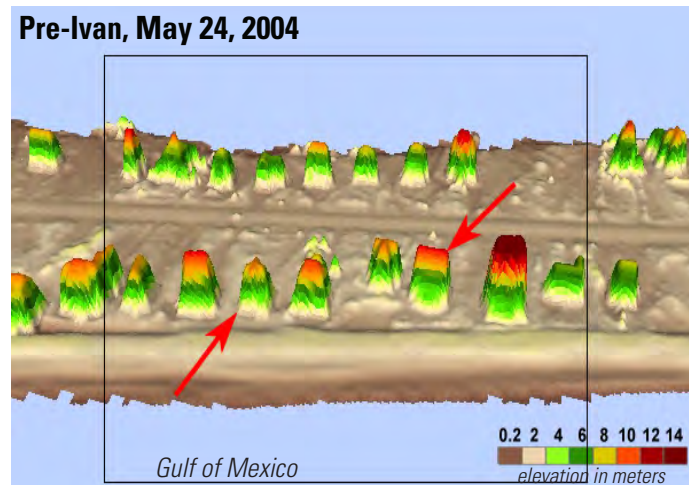


**Figure 3.** Pine Beach, Alabama. Top and Center: Topography/bathymetry measured with lidar before and after the impact of Hurricane Ivan showing a new breach that severed the island. (Note the new houses that were built between the surveys. Houses appear in the topography as rectangular mounds. Their warmer colors indicate higher elevations.) Bottom image: A USGS aerial photograph shows the new breach following landfall. (Arrows in all images point to the same features.)

USGS Photograph



**Figure 4.** Gulf Shores, Alabama. Upper left: USGS before and after aerial photographs showing the loss of houses during Ivan. Upper right: Before and after laser mapping (lidar) topography of the same area shown in the photos (warmer colors represent higher elevations, (for example, houses). Bottom center: Vertical elevation change (erosion and accretion) that occurred as a result of the storm. The red rectangles indicate houses that were completely destroyed and swept from the island into the back bay. (Arrows in all images point to the same features. Black lines in lidar images indicate limits of photos.)

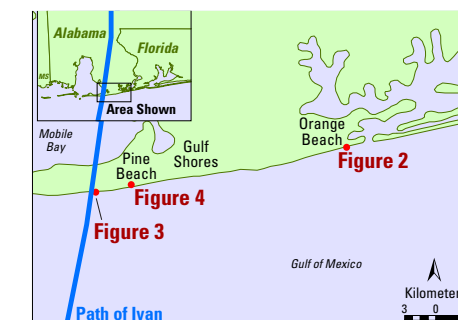
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<http://coastal.er.usgs.gov/hurricanes/>

## Coastal Change During Hurricane Ivan 2004

Category 3 Hurricane Ivan came ashore near Gulf Shores, Alabama, on September 16, 2004. The barrier islands of the northern Gulf of Mexico near the Florida/Alabama border were exposed to the strongest winds. The communities of Gulf Shores, Pine Beach, and Orange Beach, Alabama, are, in places, very low lying with their dunes rising up only several meters. These dunes were unable to contain the 3- to 4-m storm surge.

The U.S. Geological Survey (USGS), National Aeronautics and Space Administration (NASA), and U.S. Army Corps of Engineers (USACE) are collaborating in a research project investigating coastal change during Hurricane Ivan. On Friday, September 17, 2004, the USGS acquired oblique aerial photography to better understand the impact of Ivan on the coastal environment. On Sunday, September 19, 2004, airborne lidar was collected using NASA Experimental Advanced Airborne Research Lidar (EAARL).

Gulf waters driven by hurricane-force winds spilled across the barrier islands as storm surge and created currents strong enough to transport massive amounts of sand landward. These waters undermined buildings and roads and opened new island breaches. On top of the surge, breaking waves nearly as tall as the depth of the surge, eroded dunes and battered structures.



**Figure 1.** Map showing track of Hurricane Ivan.



**Figure 2.** Orange Beach, Alabama. USGS aerial photographs taken before and after the landfall of Hurricane Ivan show the failure of a five-story condominium tower. The only parts of the structure that remain standing after Hurricane Ivan are the elevator and stairwell shafts. Airborne laser mapping data showed that the sand dune on which this building was constructed was subjected to about 3 m of vertical erosion during the storm. (Arrows in all images point to the same feature.)