Assessment of Tropical Cyclone Induced Transgression of the Chandeleur Islands for Restoration and Wildlife Management

Brandie Mitchell, NASA DEVELOP Program, Stennis Space Center, MS 39529; brandie.s.mitchell@nasa.gov
Ross Reahard, NASA DEVELOP Program, Stennis Space Center; rreahard@uno.edu
Amanda Billiot, NASA DEVELOP Program, Stennis Space Center; abilliot2789@gmail.com
Tevin Brown, NASA DEVELOP Program, Stennis Space Center; tbrown7@cableone.net
Lauren Childs, NASA DEVELOP Program, NASA Langley Research Center, Hampton, VA 23681; lauren.m.childs@nasa.gov

The Chandeleur Islands are located south-southeast of St. Bernard Parish, Louisiana. They began as a long island, that has since been segmented into several islets covering 80 km. The Chandeleurs were formed over 2,000 years ago and are uninhabited (Penland 1988). Dozens of hurricanes and other severe storms have fragmented these islands, resulting in severe erosion of the island chain's land mass over time. The islands serve as a migratory stop for birds, provide habitat for nesting bird species, and are part of the second oldest National Wildlife Refuge (NWR) in the United States, Breton NWR.

The Chandeleur Islands are a diverse landscape, composed of beaches, dunes, and marshes. The northern portion of the islands is dominated by beaches that have multiple bars and washover fans that are separated by dune fields. The dunes are vegetated by grasses and shrubs that grade into a high salt marsh, also populated by black mangroves. The southern portion of the islands is more narrow and lower in elevation than the northern portion, leading to shoals separated by tidal inlets and small island fragments.

To the west, over the St. Bernard Delta surface, the Chandeleur Islands are rapidly transgressing (transgressive barrier islands are long and narrow, and gradually migrate towards the main land body they parallel). The long-term Gulf shoreline erosion rates estimate a minimum 2 m/yr loss in the north-central portion and greater than 12 m/yr loss at the northern and southern ends of the islands (Kahn 1986). The deterioration of the islands is caused not only by the frequency of Gulf storms, but also by the subsidence of the St. Bernard Delta sediments, and the absence of a rejuvenating sediment supply. There have also been sea floor landslides, which may have caused stronger waves, and greater erosional impacts to the Chandeleur Islands (Hymel 2007).

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Over the past decade, tropical cyclones have decimated the Chandeleur Islands, destroying pre-existing vegetation, ruining habitats, and eroding the shoreline. In 2004, when Hurricane Ivan passed approximately 95 km east of the islands, it destroyed the restoration progress of the Chandeleur Islands. Almost all of the vegetation on the islands was lost, and the washover channels increased in number from 20 to over 100. The 2005 hurricane season further delayed any rebuilding progress that could have been made in the islands. Hurricanes Dennis, Katrina, Cindy, and Rita all occurred during the 2005 hurricane season, resulting in severe damage to the islands. In particular, Hurricanes Dennis and Katrina reduced and redistributed many terrestrial parts of the islands into sub-surface formations and shoals. Katrina also caused a severe amount of overwash, consequently all of the recent habitat restoration (planting) sites were converted to open water (Hymel 2007).

The 2008 hurricane season marked another disastrous year of hurricane impacts for the Chandeleur Islands, since they had not recovered from Hurricane Katrina by the time Tropical Storm Edouard passed the islands in August. Immediately following Edouard, two major hurricanes, Ike and Gustav, passed or made landfall near the Chandeleurs, further counteracting the small amount of land accretion (accumulation) that had occurred prior to Katrina.

Data utilized. For analysis of island land area change, vegetated area change, and island transgression, Earth observation and ancillary data were acquired from the following sources:

- Landsat 2-4 Multi-Spectral-Scanner (MSS) and Landsat 4 and 5 Thematic Mapper (TM) imagery were downloaded using the U.S. Geological Survey (USGS) Global Visualization Viewer (GloVis) at the Earth Resources Observation and Science Center at http://glovis.usgs.gov/. Images were acquired for path 21, row 39 (World Reference System). The images downloaded cover the Chandeleur Islands, were cloud-free, and were selected from time periods before and after 27 tropical cyclonic events that occurred between 1979 and 2009.
- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (onboard the Terra satellite platform) data were downloaded from the Land Processes Distributed Active Archive Center (LP DAAC) at https://lpdaac.usgs.gov/, using the NASA Warehouse Inventory Search Tool.
- Post-Hurricane Gustav aerial photography was downloaded from the National Oceanic and Atmospheric Administration's (NOAA) National Geodetic Survey Web site, http://ngs.woc.noaa.gov/gustav/.
- Moderate Resolution Imaging Spectroradiometer (MODIS) data (onboard both Terra and Aqua satellites) were obtained from the LP DAAC. Daily images were acquired from 2000 to 2008.
- A QuickBird image from August 22, 2007, was provided by the Pontchartrain Institute for Environmental Sciences, and was used as ground reference data to conduct an accuracy assessment on a 2007 land/water classified ASTER image.
- Hourly Global Surface Data were downloaded from the National Climatic Data Center (NCDC) Web site. Data from 1981 to 2009 were acquired from Buoy 42007. The MATLAB file wind_rose was downloaded from the file exchange on the MATLAB Central Web site (http://www.mathworks.com/matlabcentral/fileexchange/).

Image processing. Unsupervised ISODATA (Iterative Self-Organizing Data Analysis Technique Algorithm) classifications were conducted on Landsat and ASTER datasets using ERDAS IMAGINE on each of the subset images, using 150 classes, 150 iterations, and a convergence threshold of .995. The classified images were then manually aggregated into two classes: water and land. These land and water classifications were used to determine land area. Pixels classified as water were used to create a mask covering the water surrounding the islands for each date, to help ensure that Normalized Difference Vegetation Index (NDVI) calculations did not include surrounding water areas (Rodgers 2009).

MODIS images were processed using the Time Series Product Tool (TSPT), a program created at John C. Stennis Space Center for use in the "automated, rapid, large-scale regional surveillance" of vegetation, free of any atmospheric effects (McKellip 2008). TSPT, designed for use in MATLAB, provides a means to process MODIS data, and other satellite sensor products, by automatically correcting for cloud cover and by removing undesirable pixels. It uses a number of modules to create images that are cloud- and noise-free. The output of the TSPT includes single image displays of satellite imagery, time-series plots for specific locations, or videos that show single images over a specified time frame (Prados 2006).

For this project, TSPT was set to apply MODIS data from the Terra and Aqua platforms. Images collected daily from 2000 to 2008 were used. MOD 09 GQ and GA products were used to aid in tracking the transgression of the Chandeleur Islands over an eight-year period.

Normalized difference vegetation index (NDVI). NDVI is used to measure vegetation health. This project calculated NDVI to assess vegetated area cover change on the islands. Landsat and ASTER data calculations were processed in the ERDAS IMAGINE spatial modeler. During image analysis, values ranging from 0.0 to 0.02 were classified as sand. In calculating vegetated areas, since most of the vegetation on the Chandeleur Islands is sparse grass and shrubs, pixels with NDVI values greater than 0.02 were assessed as vegetation. Measurements of vegetation in hectares were computed in ERDAS IMAGINE for each image.

Land/shoreline change. To display shoreline change for the Chandeleur Islands over the past 30 years, a series of maps was created in ESRI ArcMap. Then water masks from 1979, 1989, 1999, and 2009 were applied to Landsat images of the islands, converted into shapefiles, and compared to visualize land area changes.

Transgression methods. After MODIS data were processed using the TSPT, images were displayed in ENVI. For the analysis of island transgression, three transects were selected in the islands–north, central, and south. Horizontal profiles of the near infrared (NIR) value of each pixel in each transect were compared over time to show the transgression of the islands through movement of the maximum NIR value. The maximum NIR value in the first MODIS image was shown as a solid line in graphs; change in peak NIR value was extrapolated to analyze transgression.

Classification accuracy assessment. Accuracy assessments evaluate the quality of information derived from a particular dataset, and are an essential part of the research to determine how classification methods affect results. Accuracy assessments in remote sensing are performed by selecting a number of points in the classified image and checking them against reference data, such as field survey results or high resolution imagery (where the minimum mapping unit is usually less than 2 m) of the region (Jensen 2005). When adequate ground reference data or aerial photography are not available, visual interpretation of the original data by a skilled individual familiar with the land cover types and ground conditions may be the only reasonable option to conduct the necessary accuracy assessments (Sader 2002). For this study, thematic map accuracy assessment was based upon visual interpretation of Landsat MSS and TM data as ground reference data (Cohen 1998).

Wind data. NCDC hourly wind speed and wind direction data from 1981 to 2009 were input into MATLAB as the variables D and V, respectively. The command Wind-rose (90-D,V) was used to create a wind rose, which illustrates the wind profiles near the Chandeleur Islands. This process was repeated with seasonal data (April–September and October–March) from the same time period to create summer and winter wind roses.

Land and vegetation change. In 1979, the total area of the Chandeleur Islands was assessed at 2588.4 hectares. In 2009, the total area of the islands was 1663.29 hectares. This equates to a 35.7% loss of land area over the entire 30-year study period, with 16.0% lost between 1979 and 1998, and 19.7% lost between 1998 and 2009 (Figure 1).

In 1979, the total vegetated area of the Chandeleur Islands measured 412.92 hectares. In 2009, the total vegetated area of the islands measured 218.43 hectares. This equated to a 47.1% loss over the entire 30-year study period, with 89.7% gained from 1979 and 1998 and 136.8% lost from 1998 to 2009 (Figure 2).

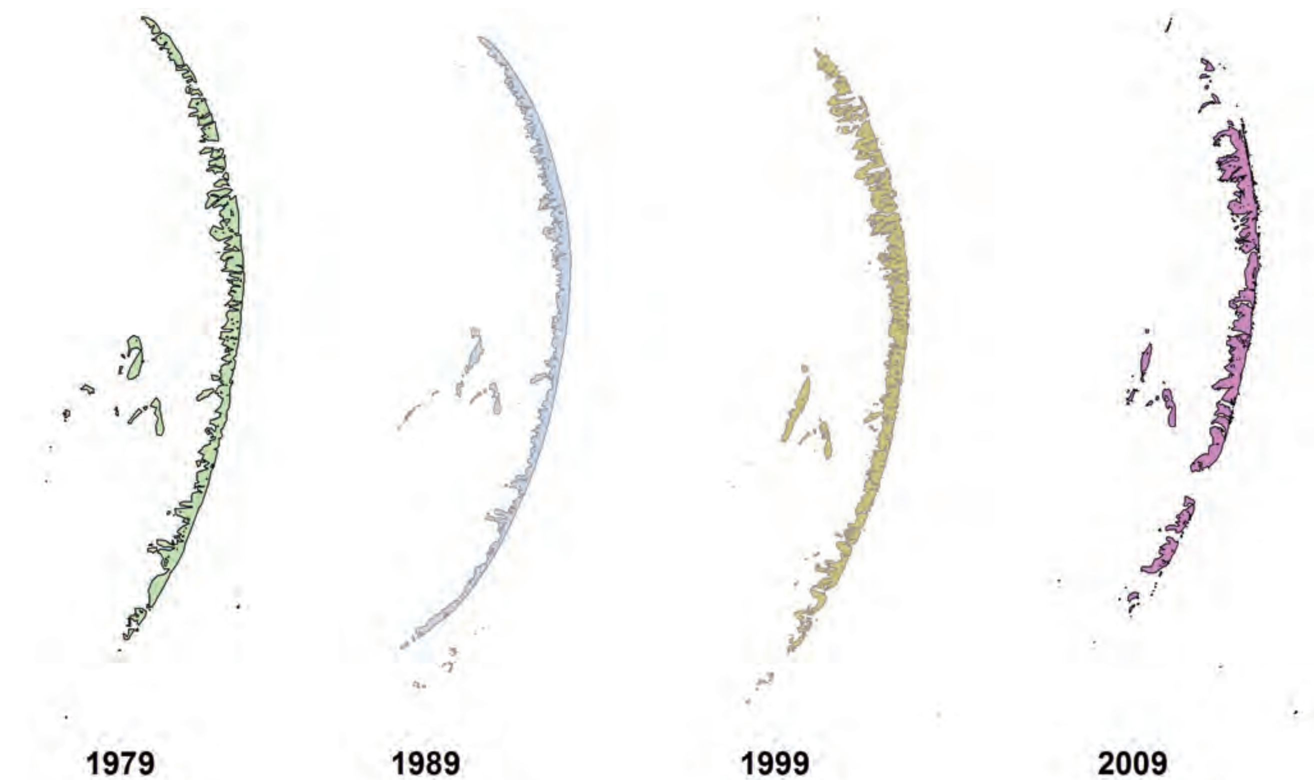

Figure 1. Chandeleur Island shoreline change, 1979–2009.

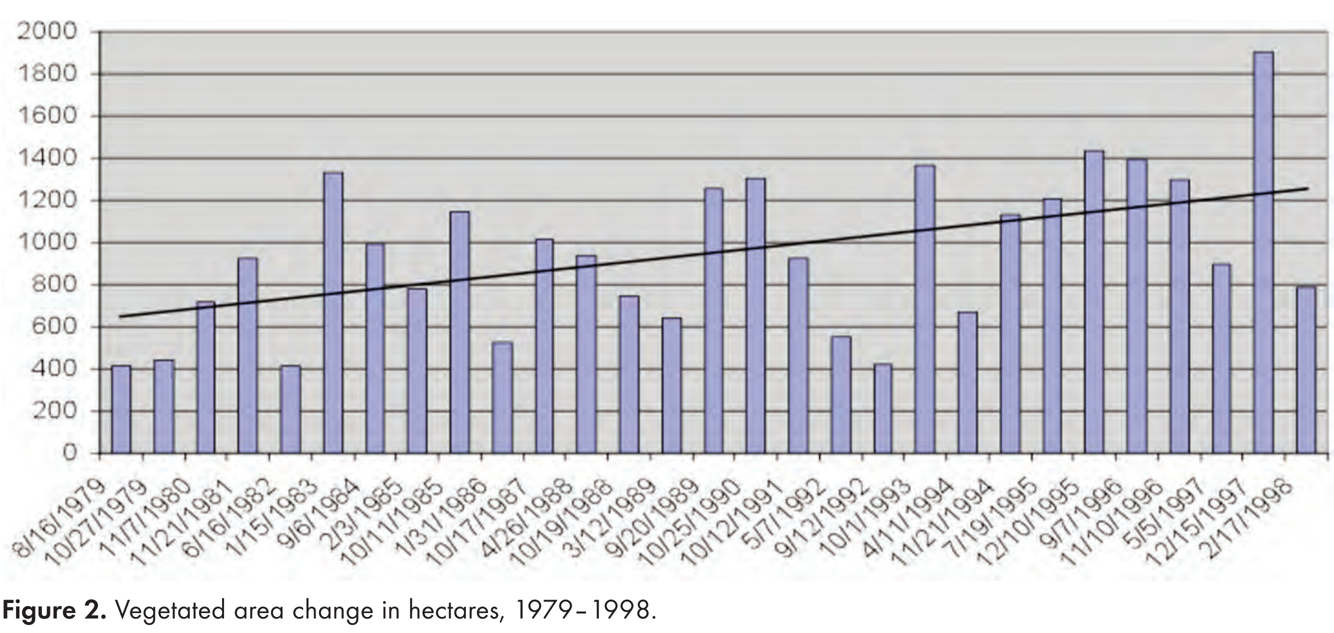

Figure 2. Vegetated area change in hectares, 1979–1998.

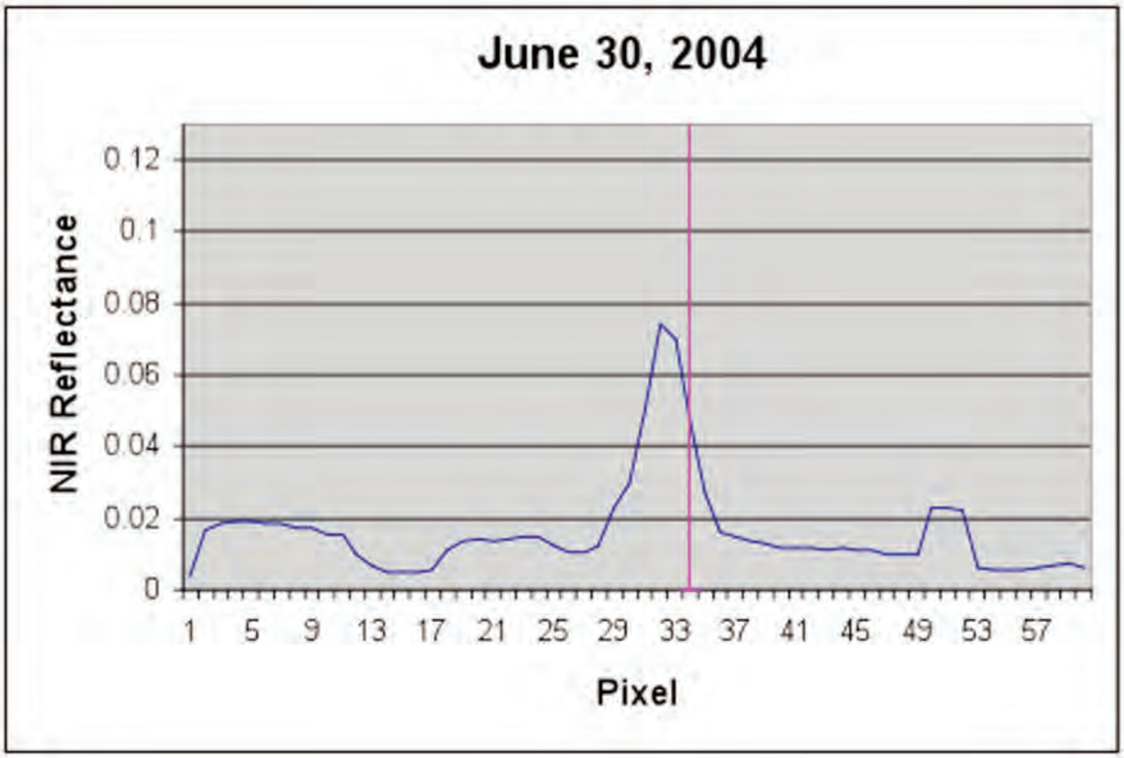

Figure 3. Southern Transect NIR Reflectance June 30, 2004.

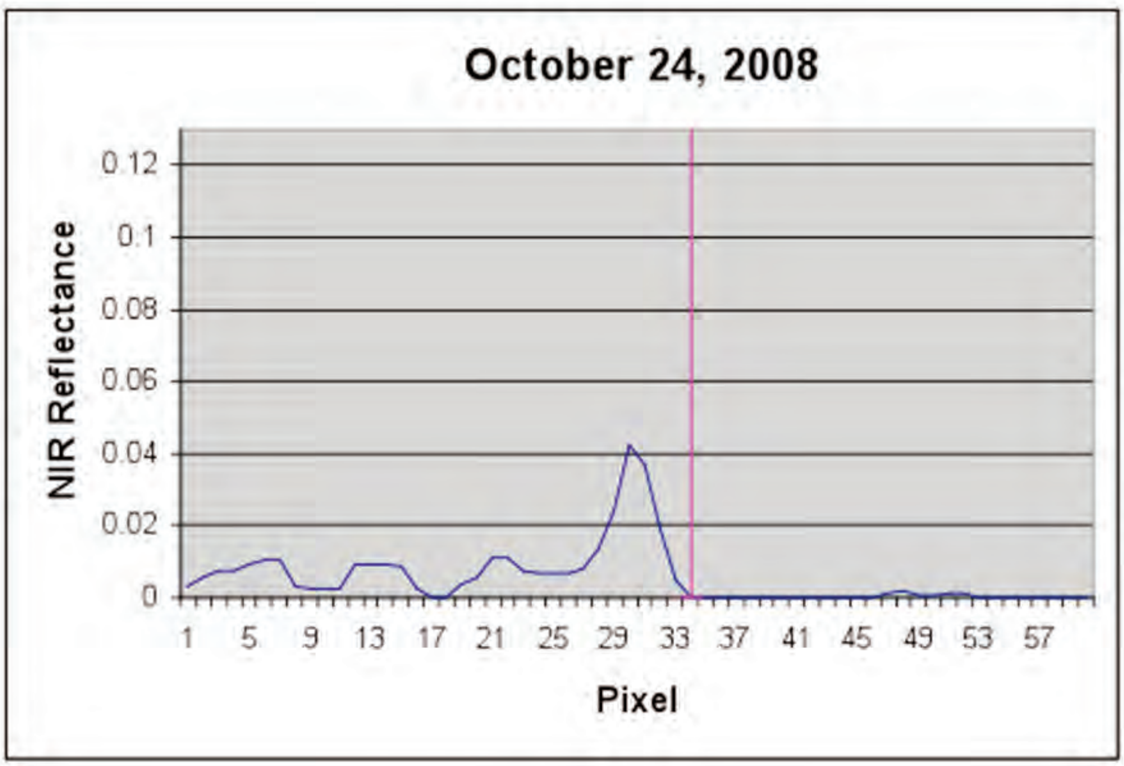

Figure 4. Southern Transect NIR Reflectance Oct. 24, 2008.

Transgression. The northern and middle portions of the islands remained mostly stationary throughout the MODIS study period, except for the time period directly following Hurricane Katrina in 2005. After Hurricane Katrina, the northern and middle portions of the island exhibited a slight transgressive movement. However, Figures 3 and 4 (at left) show that the southern portion of the islands steadily transgressed from 2000 to 2008. The transgression was accelerated by Hurricane Katrina in 2005.

Tides. Tides are an important factor to consider in the study of barrier islands. Tides control the water level, and the movement of water around barrier islands and through tidal inlets. Because of the bathymetry (topography of the ocean floor) and the shallow slope of the Chandeleur Islands, the tidal elevations at the islands are greatly influenced by wind. This process, called wind setup, can cause actual tides to be higher or lower than forecasted tides (Georgiou 2005). The ability to accurately measure tides on the Chandeleur Islands is limited. There are no tidal gauges on the islands, and the closest buoy is located about 9 miles NNE of the islands. The recorded tides at this buoy are not an accurate representation of the actual tides at the Chandeleur Islands. The buoy is located in open water, and is not affected by the same near-shore bathymetry as the islands. Estimated tidal ranges were acquired through the use of the Tides extension to NOAA's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model. The SLOSH Model provides historical predictions of tidal range by hour. Because of the shallow bathymetry near Chandeleur Island, relatively small changes in water level can cover or expose large areas of land, which complicates barrier island remote sensing.

Winds. Winds affect the erosion of the Chandeleur Islands because seasonal wind patterns greatly influence the wave climate along the Louisiana coast. The direction and speed of the winds can determine the erosive energy of the waves. There is a high correlation between wind direction, and direction of dominant wave approach (Georgiou 2005). Southeasterly winds produce waves with the greatest fetch because they can travel the farthest distance. Therefore, waves approaching from the southeast are often the most erosive. The wind profile reflects weather patterns. During the winter, because of cold front passage, the wind often comes from a north-northwesterly direction. This is significant because northwest winds cause waves that erode the back barrier beaches, which are more stable, and usually sheltered from erosive forces. Therefore, the Chandeleur Islands are susceptible to wind-driven erosion throughout the year.

Conclusion

Over the past several centuries, the Chandeleur Islands have been slowly eroding, and moving toward the mainland. As transgressive barrier islands, this is their natural morphology. However, this project found that beginning around 1998, vegetated area and land area began dramatically decreasing. An increase in frequency and intensity of storms over the past decade has hindered regeneration of the islands, and has made them more susceptible to damage from natural phenomena, such as cold fronts, winds, and waves. Hurricane events, such as Hurricane Katrina in 2005, and Hurricane Gustav in 2008, have accelerated the transgression of the island. The northern and middle portions of the island remained mostly stationary throughout 2000-2008, except directly following Hurricane Katrina in 2005. The southern portion of the islands steadily transgressed landward throughout the entire period, but transgression was accelerated by Hurricane Katrina's impact in 2005. TSPT was instrumental in providing analysis, and quantifying transgression of the islands. Without restoration efforts, coastal Louisiana will likely lose these islands, its first line of defense from future tropical cyclonic events.

References

Cohen, W.B. et al. 1998. An efficient and accurate method for mapping forest clearcuts in the Pacific Northwest using Landsat Imagery. *Photogrammetric Engineering and Remote Sensing* 64:4, 293–300.

Georgiou, I.Y., D.M. Fitzgerald, and G.W. Stone. 2005. The impact of physical processes along the Louisiana coast. *Journal of Coastal Research*, *Special Issue* 72–89.

Hymel, M. 2007. Operations, maintenance and monitoring report for Chandeleur Islands Marsh restoration. State Project No. PO-27, Priority Project List 9, Coastal Restoration Division, Biological Monitoring Division. New Orleans: Louisiana Department of Natural Resources.

Jensen, John R. 2005. *Introductory digital image processing: A remote sensing perspective*. Upper Saddle River, NJ: Prentice Hall.

Kahn, J. H. 1986. Geomorphic recovery of the Chandeleur Islands after a major hurricane. *Journal of Coastal Research* 2:3, 337–344.

McKellip, R., D. Prados, R. Ryan, K. Ross, J. Spruce, G. Gasser, and R. Greer. 2008. Remote-sensing time series analysis, a vegetation monitoring tool. *NASA Tech Briefs* 32:4, 63–64.

Penland, S., R. Boyd, and J.R. Sutter. 1998. Transgressive depositional systems of the Mississippi Delta plain: A model for barrier shoreline and shelf sand development. *Journal of Sedimentary Petrology* 58:6, 932–949.

Prados, D., R.E. Ryan, and K.W. Ross. 2006. Remote sensing time series product tool. *American Geophysical Union Fall Meeting Abstracts*, #IN33B-1341. http://adsabs.harvard.edu/abs/2006AGUFMIN33B1341P.

Rodgers, J.C., A.W. Murrah, and W.H. Cooke. 2009. The impact of Hurricane Katrina on the coastal vegetation of the Weeks Bay Reserve, Alabama from NDVI data. *Estuaries and Coasts* 32:496507. DOI 10.1007/s12237-009-9138-z.

Sader, S.A., and E.H. Wilson. 2002. Detection of forest harvest type using multiple dates of Landsat TM imagery. *Remote Sensing of Environment* 20:385–396.