Impact of Hurricane Irma on Keewaydin Island, Southwest Florida Coast

FELIX JOSE[1], MICHAEL SAVARESE[2], ANDREW M. GROSS[3]

Department of Marine and Ecological Sciences, Florida Gulf Coast University, Fort Myers, FL 33912, USA. fjose@fgcu.edu; msavares@fgcu.edu; agross@fgcu.edu

Abstract: *Hurricane Irma made landfall along the southwest coast of Florida on September 10, 2017 with a sustained wind speed of 100 kts, causing extensive coastal erosion and overwash on Keewaydin Island. Pre- and post-LiDAR data analysis shows that the northern and central sections of the island sustained foredune erosion and vegetation loss, while the southern-most spit experienced minimal erosion. Analysis of LiDAR data since 2004 also show persistent erosion for most of the island while southern end is continuously prograding in the direction of the longshore current.*

Introduction

Hurricanes and tropical storms can drastically alter the morphology of barrier islands and frontal beaches, which often act as the first line of defense for the estuaries and mainland behind them. Keewaydin Island is part of the Rookery Bay National Estuarine Research Reserve (RBNERR) and serves as nesting ground for many endangered sea turtles and shore birds (Addison et al., 2002). The southern end of this 11.2 km long barrier island is undergoing rapid progradation with sediment brought in by longshore currents from further north. Increased erosion has been reported from the northern end of the island, as well as from a few hot spots along the mid-section. The island has never been nourished; however, groins were constructed at the northern end for erosion control.

Landfall of Hurricane Irma near Marco Island, Florida on 10th September 2017, with an estimated maximum wind speed of 100 kt (Cangialosi et al., 2018), caused significant modification of Keewaydin Island (Figure 1) and other neighboring barrier islands and beaches. In 2005, this area was affected by the landfall of Hurricane Wilma. Since 1998, the US Army Corps of Engineers (USACE) and United States Geological Survey (USGS) conducted a series of LiDAR mapping surveys for this part of Florida. The high-resolution data (~1 m horizontal and a few centimeters vertical resolution) covered the entire barrier island and the waterbodies surrounding it. LiDAR data sets are available in the public domain and have been proven to be an effective tool in monitoring long-term evolution of barrier islands and frontal beaches. An ArcGIS-based modeling approach has been implemented in this study to quantify the geomorphological alteration of the island from the landfall of Hurricane Irma and previous hurricanes and tropical storms.

Materials and Methods

LiDAR data since 2004 have been analyzed for quantifying the long-term geomorphologic evolution of Keewaydin Island. Also, pre- and post-Hurricane Irma data were analyzed to estimate the effect of a single hurricane on this low-lying, sediment-starved barrier island. Classified LiDAR data were extracted from NOAA Digital Coast archives (https://coast.noaa.gov/dataviewer/#/lidar/search/). Using the LiDAR data processing tools provided in ArcGIS, a terrain model was created with a horizontal resolution of 2 m and 5-levels of pyramid structure for optimized zooming. The terrain model was converted into a raster Digital

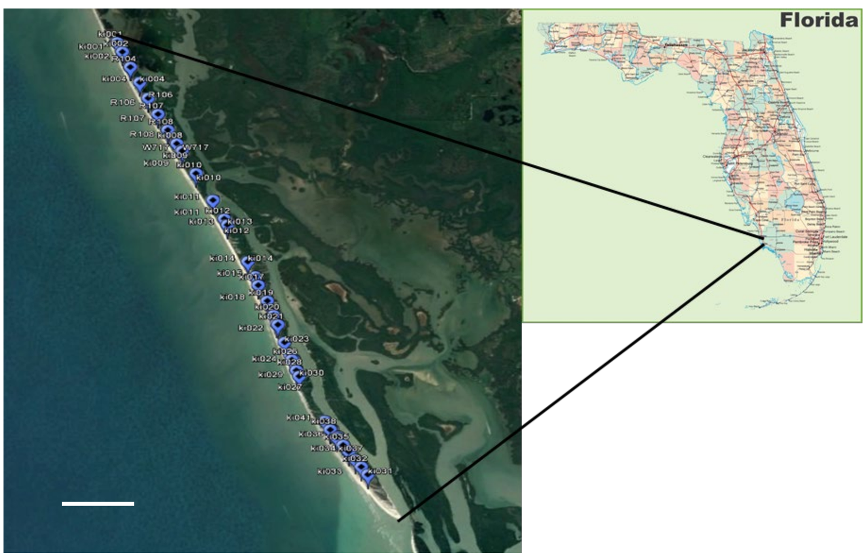

Figure 1. Study area, Keewaydin Island along southwest Florida coast. Post-Irma beach elevation survey points are also marked and labelled. Scale bar 1 km.

Elevation Model (DEM). Florida Department of Environmental Protection (FDEP) has established benchmark monuments at 1000-feet (304.8 m) intervals along the entire Florida coast. These R-monument locations were superimposed on the raster DEM, and shore normal profiles, extending from the R-monument to the seaward extent of the LiDAR foot prints, have been extracted. For the post-Irma LiDAR survey, we compared the generated DEM with that provided by NOAA and found that the accuracy of the DEM development is consistent with that of NOAA's. Results from this analysis are provided in Figure 2.

Another component of the study was to validate the post-Irma LiDAR data with *in situ* measurements using a Trimble RTK differential GPS unit. Extensive beach surveys were conducted at Marco Island, Keewaydin Island, and neighboring beaches of Collier County that were affected by Hurricane Irma. Georeferenced beach and foredune elevation data compared favorably with LiDAR data (Figure 3), demonstrating that post-Irma LiDAR data are of good enough quality for a beach volume study. The dunes and foreshore locations along Keewaydin Island that were surveyed immediately after the hurricane landfall are marked in Figure 1.

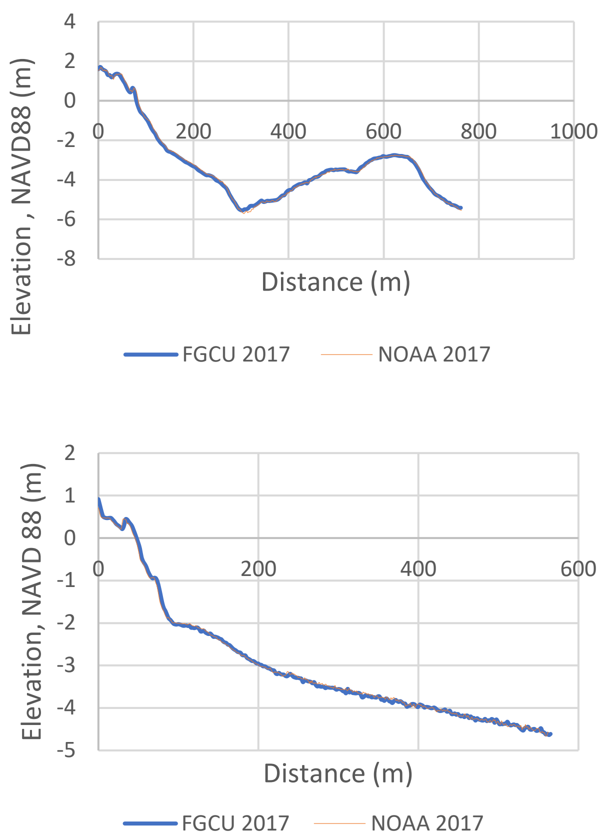

Figure 2. Beach profile comparison for skill assessment of DEM generation. Profiles extracted from the NOAA DEM compared with the DEM generated for this study. Data shown for monuments R-91 (top) and R-130 (bottom).

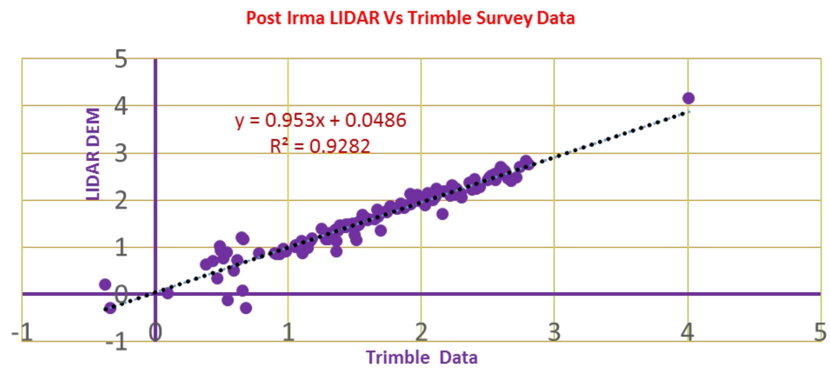

Figure 3. Validation of LiDAR data using post-Irma beach survey from a Trimble RTK unit.

Beach profiles from LiDAR DEMs were overlain to evaluate the extent of barrier island erosion/accretion (both over the long- and short-term) and for delineating the erosion/accretion hotspots. This approach has been widely implemented for volumetric estimation of geomorphologic evolution of barrier islands from a single storm event or for long-term evolution (Gutierrez et al., 2001; Zhang et al., 2005). We have employed all the available LiDAR data from 2004, 2010, 2015, and 2017 for this analysis as we are interested in the long-term geomorphological evolution of the island in response to landfall of hurricanes and tropical storms.

Results and Discussion

Keewaydin Island underwent significant geomorphologic change from the landfall of Hurricane Irma. Extensive beach erosion and overwash occurred at many locations (Figure 4). Points ki037 and ki040 in Figure 4A are located on overwash fans, which were deposited into the swale behind the beach during Hurricane Irma. Fans having thicknesses up to 2 m were observed towards the southern region of the island (Figure 4C). Also, most of the deeply buried stumps of Australian Pine trees, trees that were removed in an restoration effort in the late 1990s, were exposed when the hurricane-generated waves and storm surge stripped sediments from the foreshore (Figure 4B). However, near the southern terminus of the island, no major erosional features were observed, except for some vegetation loss towards the southern end.

In the northern region of the island, a series of detached breakwaters were constructed in 1990's for beach stabilization. Along this section of the Keewaydin Island (R-monuments 92 and 93), foredune receded landward and deflated over time (Figure 5). The dunes present in 2004 were missing from the 2010 survey, indicating that Hurricanes Wilma and Katrina in 2005 caused extensive erosion in this northern region. For mid-island locations (R-110 and 111), foredunes prograded seaward between 2004 and 2010 (Figure 6), but then retreated in 2017. Obviously, this retreat of foredunes from 2017 was due to erosion from the landfall of Hurricane Irma. The foredunes from the southern-most section of the island (Figure 7) show higher elevations in 2017 than previous years as well, with the exception of 2010. It is worth noting that consistent frontal beach erosion has been observed for most of the northern and central sections of the island, and that the eroded materials are being transported southward by longshore currents, resulting in the island's southward progradation, as reported by Novakowski et al., 2001).

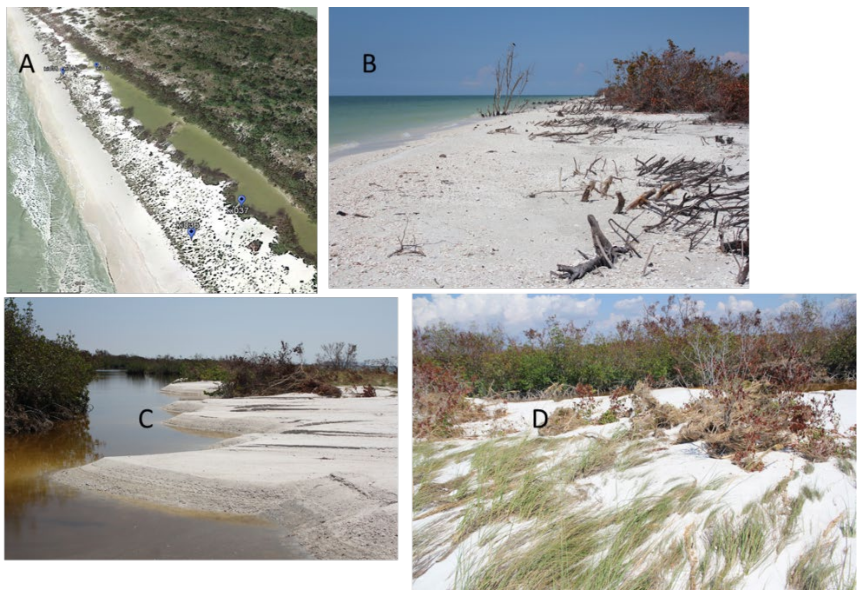

Figure 4. Beach erosion and overwash observed on Keewaydin Island after Hurricane Irma.

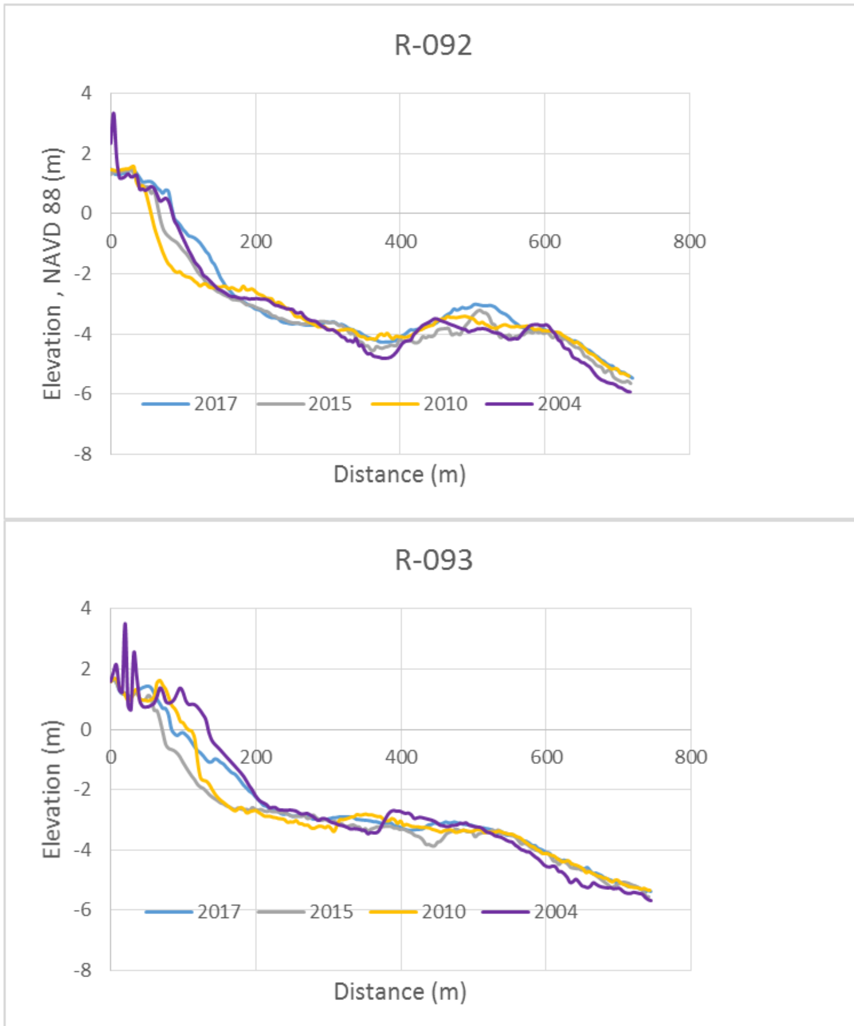

Figure 5. Beach profiles overlain for two northern stations along the Keewaydin Island.

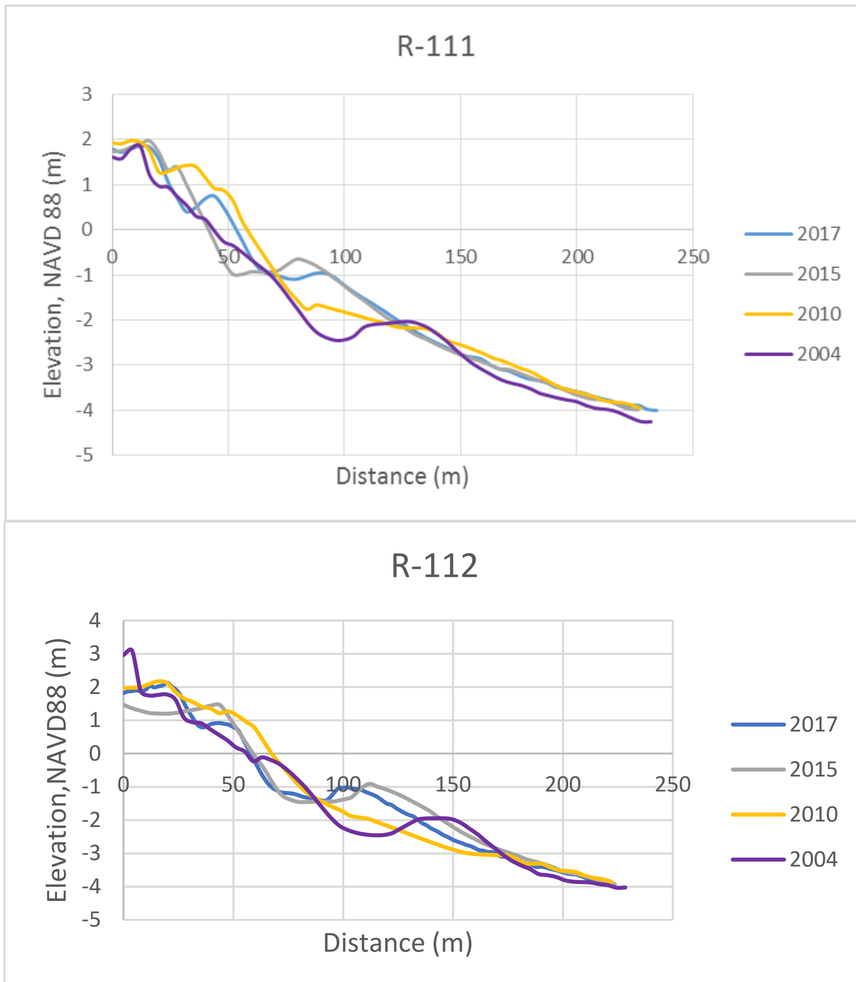

Figure 6. Beach profiles overlain for two erosion hotspots along the central section of the Keewaydin Island.

Georeferenced data from long-term vegetation line mapping (whereby the seaward-most extent of vegetation is mapped) from the southern-most section of Keewaydin Island is provided as Figure 8. It is evident that growth of the spit has continued since 1998. Curvilinear extension of alternating ridges and swales arching around the southern tip can be seen, as reported by Novakowski et al. (2001). Excess sand transported south by the long shore currents are deposited in this region and reworked by the waves resulting in the berm-ridge development (Hine, 1979).

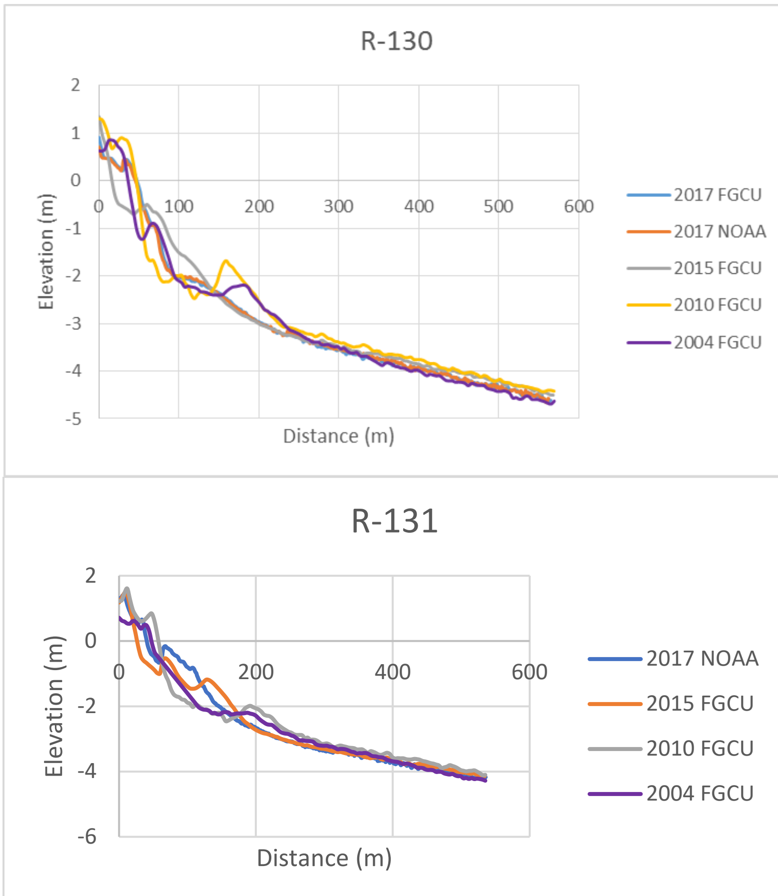

Figure 7. Beach profiles overlain for two locations along the southern-most section of the Keewaydin Island.

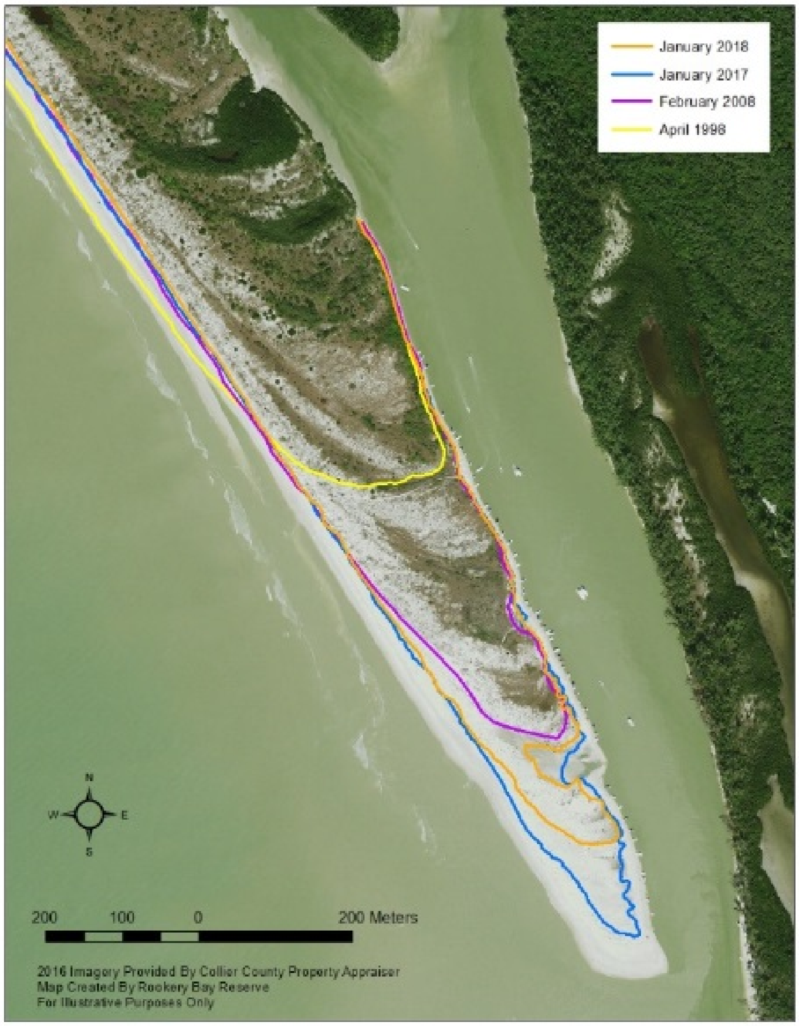

Figure 8. Progradation of the shoreline since 1998, based on annual vegetation line mapping. Data courtesy Jill Schmid, RBNERR.

Acknowledgements

The study has been supported by a NOAA/NCCOS Grant (Award # 2624084). Natalie Harvey from FGCU is acknowledged for helping with beach surveys. RBNERR provided logistical support for surveying the Keewaydin Island after the landfall of Hurricane Irma; special thanks to Jill Schmid, the GIS Spatial Analyst at RBNERR for her assistance and for providing vegetative line mapping data.

References

Addison, D.S., Gore, J.A., Ryder, J. and Worley, K., 2002. Tracking post-nesting movements of loggerhead turtles with solic and rasdio telemetry on the southwest coast of Florida, USA. Marine Biology, 141, 201-205.

Cangialosi, J.P., Latto, A.S. and Berg, R., 2018. National Hurricane Center Tropical cyclone report, Hurricane Irma.

Gutierrez, R., Gilbeaut, J.C., Smyth, R.C., Hepner, T.L. and Andrews, J.R., 2001. Precise airborne lidar surveying for coastal research and geohazards applications, International Archives of Photogrammetry and Remote Sensing, XXXIV- 3W/4.

Hine, A.C., 1979. Mechanisms of berm development and resulting beach growth along a barrier spit complex. Sedimentology, 26 (3).

Novakowski, K.I., Marshall, J.S. and Tedesco, L.P., 2001. Barrier island accretion and geomorphic evolution of Keewaydin Island, Collier county, Florida. Proceedings of the 2nd Biennial Coastal GeoTools Conference, Charleston, SC.

Zhang, K., Whitman, D., Leatherman, S. and Robertson, W., 2005. Quantification of beach changes caused by Hurricane Floyd along Florida's Atlantic coast using Airborne laser surveys, Journal of Coastal Research, 21 (1), 123-134.