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3D Visualization of Coral Reef Habitat

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ABSTRACT

A bathymetric survey was recently conducted in Southeast Florida (Broward County) during April 2001 using the Laser Airborne Depth Sounder (LADS) system. This four-meter resolution survey encompassed from North Dade County, through the length of Broward County coastline, to south Palm Beach County (approximately 43 km) and from the shore eastward to depths of approximately 40 m (2.5-3.5 km offshore). This georeferenced data was sun shaded at various angles and azimuths and draped with a NOAA NAPP 1:24,000 georeferenced air photograph mosaic. The model was zoomed and tipped to the desired orientations and processed into three-dimensional perspectives. Two views, slightly offset, were used to create anaglyphs. The anaglyph provided an actual three-dimensional view of the bathymetry. Multiple view options were useful for identifying benthic features including coral reefs and associated habitats.

1.0 INTRODUCTION

Aerial photography can be scanned, georeferenced, and mosaicked to give detailed, high-resolution digital images of large areas. For visualization of coral habitats, however, useful images are limited to those environments in shallow, clear water (approximately 20m depth) (Finkbeiner, 2001; Hopely, 1996). Furthermore, aerial photography does not provide accurate three-dimensional underwater topographical information (bathymetry). Bathymetric information is a vital tool used by a host of professions for a variety of applications (NOAA/NEDIS/NGDC, 2002). A number of survey methods have been designed to acquire bathymetric information, including single beam sonar, multibeam sonar, sidescan sonar, and laser (Anderson, 2002; Galloway, 2001; Lillicrop, 1996; Twichell, 1996; Wells, 1996). A number of GIS software products can be used to display bathymetric data. Such software can enable the user to depict the data as an image, to sun-shade the bathymetry at any desired angle/azimuth, and to tilt the image at various angles. This allows three-dimensional perspectives of the sea floor, which have recently been used to assist in classifying habitats (Greene, 1999; McRea, 1999).

In this paper we use the capabilities of GIS software to create three-dimensional perspective views as well as anaglyphs of bathymetric data. The anaglyph process is not new. Louis Ducas du Hauron patented the original method in 1891. Anaglyphs can be created on a computer by placing two images (256 gray or color scale) that were taken at slightly different angles of a three-dimensional object into the red and blue/ green channels of an RGB image. When viewed through a pair of red (left eye) and blue (right eye) anaglyph glasses, the mind combines each image into an actual three-dimensional view.

Using GIS software on the computer facilitates construction of perspective views of bathymetric data at various angles. While this is useful alone, anaglyph technology can be utilized to develop previously unattainable three-dimensional views of the sea floor. Gaining an insight on the three

dimensionality of a scene can aid in better understanding bathymetric structure and aid in benthic habitat characterization and mapping where biological and ecological information can be layered onto the bathymetric base.

2.0 METHODS

A bathymetric survey was conducted during April 2001 in Broward County, Southeast Florida by Tenix LADS Corporation, using the Laser Airborne Depth Sounder (LADS) system. This system is recognized as a fast and cost-effective tool for accurate bathymetric survey in coastal waters. According to Tenix, LADS surveys of shallow, complex areas can be up to 20 times faster than survey ships and at 20% of the cost. This method of bathymetric surveying has a sounding rate of 900 Hz (3.24 million soundings per hour), a position accuracy of 95% at 5 m CEP, a horizontal sounding density of 4m x 4m, a swath width of 240 meters, area coverage of 64 Km^2/hr, and a depth range of 70m, depending on water clarity. Tenix was hired by Broward County Department of Planning and Environmental Protection to provide detailed bathymetry of the reefs and other offshore areas of Broward County, FL. This survey encompassed North Dade County, the Broward County coastline, and south Palm Beach County, approximately 43 km, and from the shore eastward to depths of 40 m, approximately 2.5-3.5 km offshore (Figure 1). The entire survey area covered approximately 130 square kilometers of marine habitat. The bathymetry data set was provided as a set of acii (x, y, z as eastings, northings, depth) text files georeferenced to Tranverse Mercator, NAD83 FL East, eastings/northings and was approximately 320 mb with almost 12 million records. We gridded the data by triangulation with linear interpolation using Golden Software's Surfer 7.0 with a grid line geometry setting of 10,000 lines in the Y direction, or a cell size of about 2.5 (the highest resolution Surfer 7.0 would grid this data). This grid was then imported into ER Mapper 6.21 where sun-shading at a 45° angle and azimuth was applied.
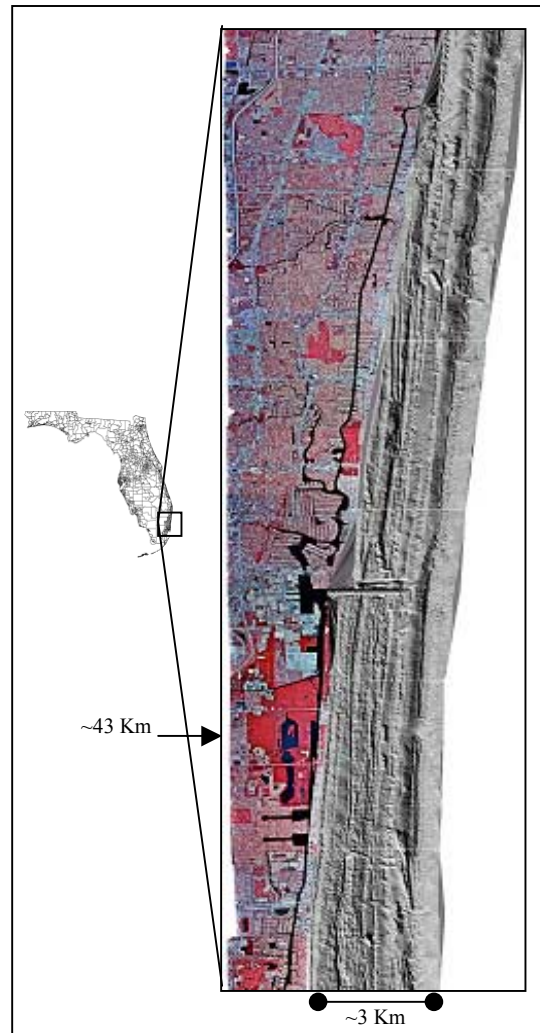

~43 Km

~3 Km

Figure 1. Broward County, FL LADS Bathymetry Data Set in gray scale with an aerial photograph overlay of land areas.

Preceding this bathymetric survey, aerial photography was one of the few useful methods for remotely visualizing coral reef and offshore habitat in Broward County. We created an aerial photography mosaic using 1999 NOAA NAPP 1:24,000 scale color infrared 9-inch x 9-inch diapositives. Sixteen air photograph transparencies of the Broward County coastline from Palm Beach to Dade were scanned at 1600 dpi resolution making each 9x9 image a 300 mb file. Each file was georeferenced in ER Mapper 6.1 by Delaunay Triangulation Orthorectification method using previously acquired 1995 digital orthoquads (DOQ) from the USGS as a geo-position reference. This method allows the user to assign points from the georeferenced photo to a non-georeferenced photo and to rectify the non-georeferenced photo. The accuracy depends on the amount of points used and the original georeferenced photo, which in this case met the National Map Standard of 13.3 meters on the ground. The ground control points only

came from land objects due to the poor water image quality of the DOQs. Specific areas of all sixteen georeferenced images were then selected with the clearest water and least sun glint and mosaicked into one master using ER Mapper's mosaicking wizard.

Viewing of underwater habitat up to 15-20 meters was possible with color correction. The aerial photography was more useful in visualizing shallow bottom features and by helping to provide a spatial perspective to the bathymetry from the land images. We overlaid the aerial photograph mosaic on top of the gridded LADS data. This enabled viewers to relate bottom topography with land features and provided some useful color overlays to the bathymetry. The data set was then viewed in a three-dimensional perspective at various zooms and angles within ER Mapper.

To create anaglyphs, grayscale sections of the bathymetry were viewed in 3D perspective without the aerial photograph overlay. When a desired perspective view was obtained within ER Mapper, an image (.jpg) file was created of that view and noted as the right image. Next a new image was created from a view slightly to the left and another file (.jpg) was created (labeled left). These two images were then merged using a freeware program called 3D Anamaker version 1.06 written by Takashi Sekitani downloaded from www.stereoeye.com. This software allows the user to load the left image into separate channels. After the images are loaded, the software creates a single image anaglyph by merging the left image (red) with the right (blue/green). The user can shift each channel (red or blue/green) along the x or y axis to optimize the 3-dimensional effect before saving the final anaglyph.

Another procedure enables one to create anaglyphs within many image-processing programs (i.e. Adobe Photoshop, Paint Shop Pro, etc.). This method is fairly easy; however, it is less turn-key. The user inserts the left image into the red channel of an RGB photo and the right image into the blue and green channels. The resulting image is the anaglyph. This method does not provide the ability to shift the separate channels.

3.0 RESULTS & DISCUSSION

The anaglyph provides an actual three-dimensional view of the bathymetry that is unattainable by perspective imagery. While color anaglyphs are possible, our color perspectives (Figure 2) did not include land topography data and the juxtaposition of bathymetry with flat bordering areas did not enhance the view. In addition, color images, such as ours, that are dominated by blues and reds are not the best choice for anaglyphs. By utilizing gray scale, however, our anaglyphs provided outstanding three-dimensional imagery. (To view the images properly, wear a pair of 3D anaglyph glasses with the red lens over the left eye and blue on the right.)

We have created anaglyphs of some representative areas of interest in the bathymetric data. Figure 3 shows the perspective views of Figure 2 constructed as 3D anaglyphs. The perspectives and anaglyphs encompass (in three segments) an area from Hollywood Beach north to Fort Lauderdale. The images show many natural and anthropogenic reef features. A prominent feature is the Port Everglades entrance channel (Figure 2c & 3c) as well as the outer "Third" coral reef. (Two inner reef complexes are seen shoreward). Areas of interest shown in more detail are an old breakwater on the north side (right) of the Port Everglades inlet in Figure 4, a sewage outfall pipe traversing the reefs from east to west (Figure 5), a large natural reef gap in the Third Reef (Figure 6), and old sand borrow pits from previous beach renourishment endeavors (Figure 7).

Clearly these perspectives and anaglyphs can be useful in identifying many bathymetric features for a variety of applications. For example, engineers wanting to insert or lay a pipeline or information

cables would find this imagery useful to help identify areas to minimize impacts on the natural reef by possibly utilizing reef gaps. Sand mining operations could get a better view of potential sand sources, and dive operators could identify possible desirable or undiscovered dive sites. We have found the images useful for location, interpretation, classification, and mapping of benthic habitat including seagrass beds, coral reefs of various types, rubble areas, and sand deposits. Many users can benefit from the application of anaglyph technology to detailed bathymetric data sets from laser bathymetry. An added advantage is that the data is georeferenced for use in a geo-bio-spatial context.

4.0 ACKNOWLEDGEMENTS

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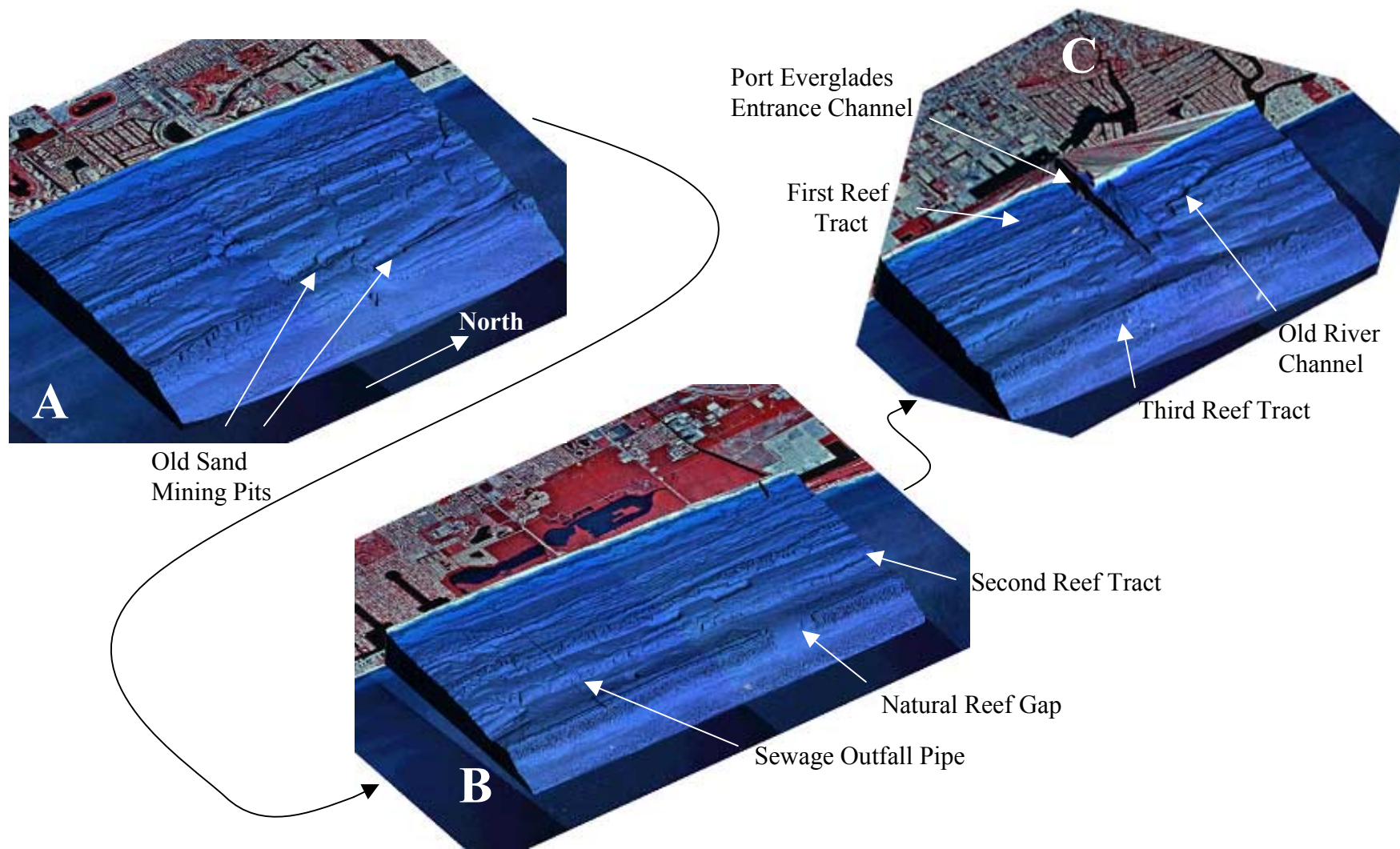
Figure 2. Examples of Broward County sunshaded LADS data overlain by an aerial photograph mosaic. This is a 3D perspective view at various angles. (A) South Hollywood Beach, FL; (B) North Hollywood Beach, FL; (C) Port Everglades inlet.
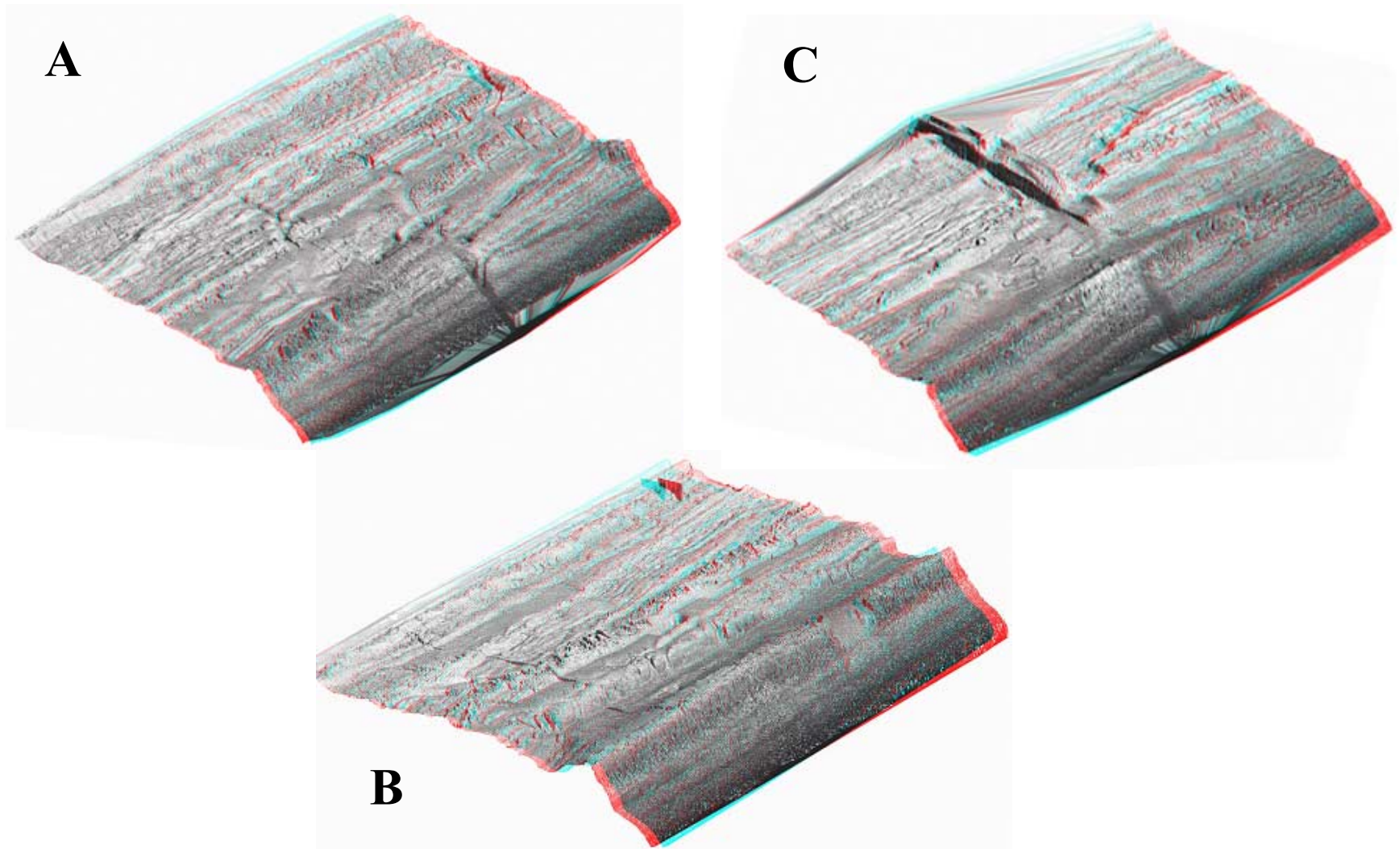
Figure 3. 3D Anaglyph of South Hollywood Beach (A), North Hollywood Beach (B), and Port Everglades Entrance Channel (C). View images by wearing a pair of 3D anaglyph glasses with the red lens over the left eye and blue on the right.
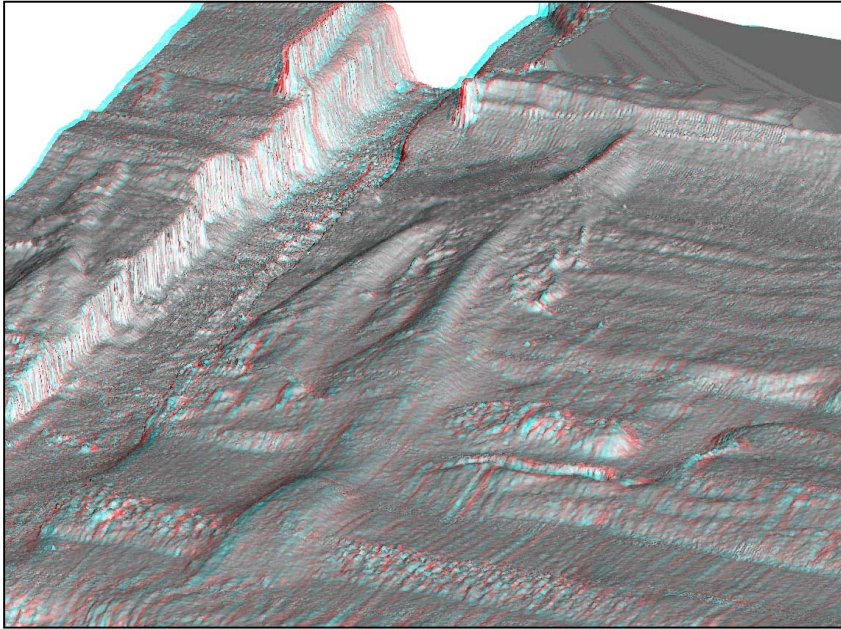
Figure 4. 3D anaglyph of an old breakwater just North of Port Everglades entrance channel, FL
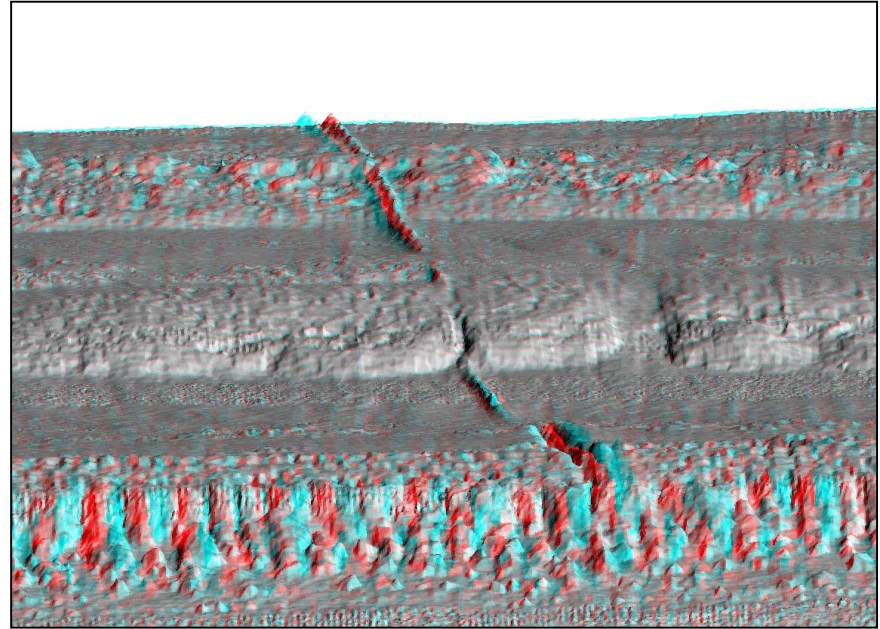

Figure 5. 3D anaglyph of sewage outfall pipe traversing the reefs off Hollywood Beach, FL.
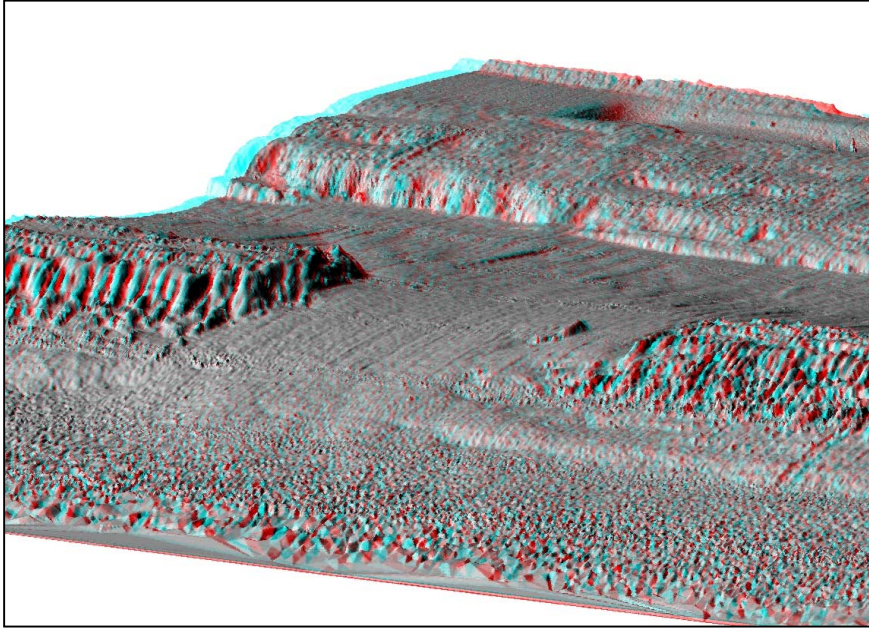
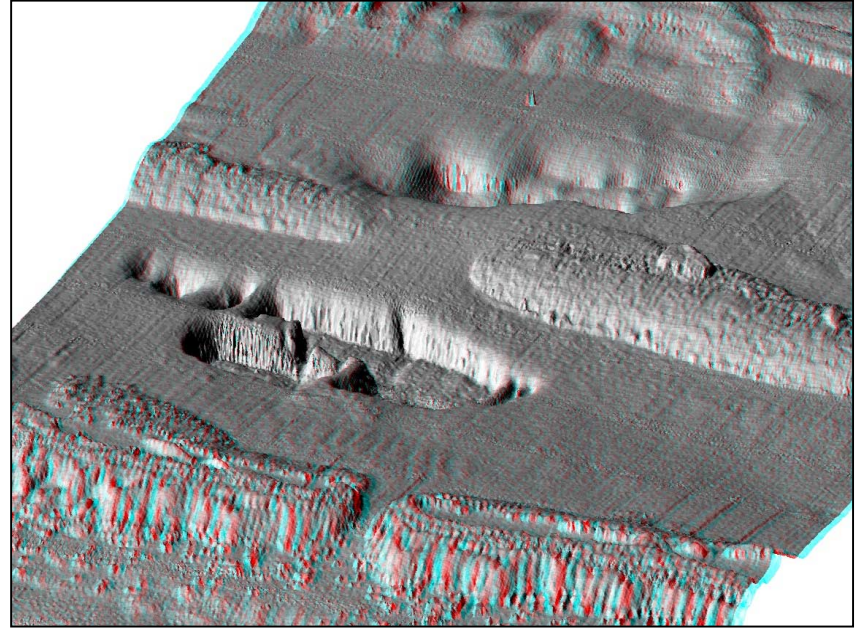Figure 6. 3D anaglyph of a gap in the outer, Third Reef tract off North Hollywood Beach, FL.

Figure 7. 3D anaglyph of Two sand borrow pits in between three reef tracts near Lauderdale-by-the-Sea, FL.