Visualization of Terrestrial Change of Barrier Islands Using Multi-Temporal Digital Elevation Model

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1. INTRODUCTION

Significance: Under effects of sea-level rise and storms, the terrain of barrier islands is subjet to both long- and short-term changes. Since there are many civil and military infrastructures on barrier islands, for long-term resources and engineering management, it is important to understand long-term terrestrial changes of barrier islands under sea-level rise. Visualization of terrestrial changes based on the Digital Elevation Model (DEM) is a vital tool to facilitate the scientific understanding.

Visualization methods: The global mean sea-level has risen about 195 mm between 1870 and 2004. In the 20th century, the rate of sea-level rise is 1.7 ± 0.3 mm yr^{-1} with a significant acceleration of 0.013 ± 0.006 mm yr^{-2}. Some studies present that the sea-level will rise 0.5 to 1.4 meters above the 2010 level until 2100. This will make geographic system change until it balance again; in this period, many geographic factors will be changed.

The Brunn Rule is one of the most widely known models developed for predicting shoreline change driven by sea-level rise on sandy coasts. Concerning a long-term budget of onshore/offshore movement of material, the rule is based on the assumption of a closed material balance system between the beach and nearshore and the offshore bottom profile. As sea-level rises, material eroded from the upper beach is deposited on the nearshore bottom down to a limiting depth between predominant nearshore and offshore material.

(1) There is a shoreward displacement of the beach profile as the upper beach is eroded;

(2) The material eroded from the upper beach is equal in volume to the material deposited on the nearshore bottom.

(3) The rise of the nearshore bottom as a result of this deposition is equal to the rise in sea level, thus maintaining a constant water depth in that area.

This research uses three methods to visualize terrestrial change of barrier islands.

We use five snapshots DEM data of Santa Rosa Island, which are 1969, 2001, 2004, 2005, and 2006, the DEM of 2004 and 2005 are data after the hurricane of Ivan and Dennis.

The data should be edited before experiment, for example, modeling 3D DEM models from Lidar data or other formats data, clipping all snapshots data to same range, and converting all snapshots data to same coordinate and same spatial resolution. Furthermore, an assumption is that the data accuracy doesn't have effect on the results.

2. Profile method

The profile to obtain a beach cross-section is the simplest method to quantify parameters of dunes morphology and to follow dunes evolution. It records the height, width, slope and volume of a dune, while sequential profiles record changes either through time or along island

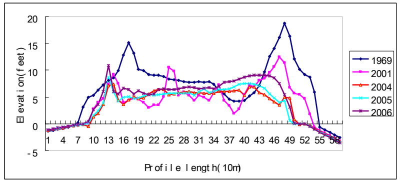

Figure 1. Multi-temporal profiles.

The site of the profile is located on the figure 2 which is a red line, and the profiles line come from 5 snapshots DEM data. In the picture, the left is the bay side, and the right is the sea side (near the Mexico Gulf).

Through figure 1, we could deduce some rules for dune elevation changes on this transaction with the sea-level rise:

(1) In 1969 and 2001, there are two dune peaks on the transaction, but there is one dune peak in 2004 and 2005 after the hurricane of Ivan and Dennis, the foredune was destroyed by the hurricanes. Then it seems like to develop two peaks again in 2006.

(2) The roughness and the length is different comparing to 5 profiles. The curve lines of 2004 and 2005 are more smoothly and shorter than other lines, we could use roughness to express the effect of hurricane (Table 1), the roughness of 2004 and 2005 is lower than other years.

$$R = \frac{\sum l_i}{L} \quad (1)$$

Where R is the roughness of profile line, l_i is the length of each straight line on the profile curve line, and L is the length of profile which is the result that the profile curve line project to the sea-level, and it is the length for a straight line.

Table 1. Roughness of the profile lines.

	1969	2001	2004	2005	2006
Length of curve(meet)	987.23	1023.2	721.69	721.23	786.36
Roughness	1.6453	1.7053	1.2028	1.2020	1.3106

(3) The point on the shoreline near the sea side had a moving tendency from sea to island because of erosion, from 1969 to 2006, this point retreat about 50 meters; and the point on the shoreline near the bay side didn't has obvious tendency.

3. Difference method

The difference method use newer DEM data to minus to older DEM data, then classified to several classes with difference elevation, and colored with different colors (Figure 2).

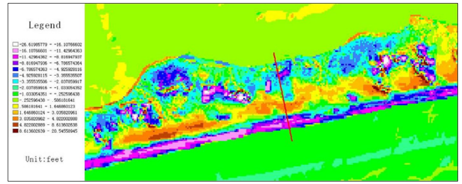

Figure 2. Result of difference method. The image is that 2006 DEM data minus to 1969 DEM data.

In this test, the data is classified to 15 classes after comparing with several results. On the legend, the number shows the elevation changes of between snapshots, if it is a negative number, the area elevation decreased in the period; and if it is a positive number, the area elevation increased in the period.

In order to express the eroded area and piled up area for the test area entirely, we classify figure 2 to two classes, one class is the eroded area, another class is the piled up area (figure 3)

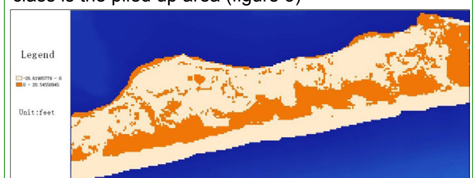

Figure 3. Two classes of difference method. In the image, the blue part is the sea area.

Figure 3 shows that there are three special areas. The first area is near the sea side which was eroded with the sea-level rise, its color is pink or blue, and it seems like a ribbon; the second area is near the bay side which was piled up with the sea-level rise, its color is golden, and it seems like a ribbon too, but which is narrower than the first area, and which is discontinuous clearly; the last area is inside the island, which is the accumulation area near the dunes, because the dunes were moving, so the area near the sea side of the dune was eroded, and the area near the bay side of the dune was piled up. This phenomenon is similar with Brunn Rule (P. Brunn 1962).

Besides figure 2 and figure 3, we also could use profile to express a transaction elevation difference like figure 4.

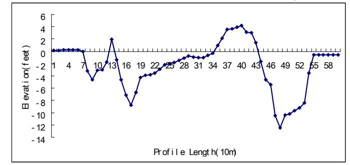

Figure 4. Profile for the difference method, the site of profile is located in figure 2. In this figure, the left is the bay side, and the right is the sea side (near the Mexico Gulf).

4. 3D animation method

The difference method could show elevation changes of an area for two snapshots, but it is difficulty to show elevation changes for three snapshots or more snapshots; the profile method could show elevation changes for three snapshots or more snapshots, but it is difficulty to show elevation changes for an area, these two methods have different advantages and disadvantages.

Three dimensions (3D) animation method makes 3D animation for an area based multiple DEM snapshots, the animation allows us examining terrestrial change from different viewpoints and scales. The animation is made possible by using a linear interpolation algorithm because DEM data usually is collected once a year or once several years for an area.

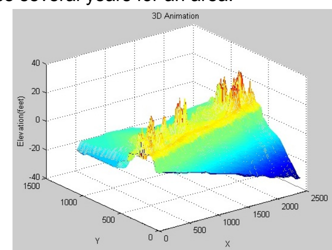

Figure 5. Figure 12. 3D animation.

Those three methods have their own advantages and disadvantages, and could study one question from different perspectives, so we usually could use them together to do our studying. We test those 3 methods for same area of Santa Rosa Island. With rising the sea-level in a long time, the elevation of sea side was decreasing, the elevation of bay side was increasing, and the peak of dunes was moving from sea side to bay side, those phenomena are similar with Brunn Rule.

Acknowledgement

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