2D Shoreline Change Risks and Future Shoreline Change Risk Predictions

There has been significant study on the effects, mainly erosion, of SLR on shoreline change. This short white paper is meant to introduce a new technique in this area of study that accounts for both erosion and accretion on managed or recreational beaches. This includes renourishment, which has been difficult to incorporate in many 'trend based' or modeled shoreline change studies. To accomplish this requires topographic data at high spatial and temporal resolution. Fortunately, this is becoming common in coastal areas of the US and, in large part, is thanks to USACE, NOAA, and USGS. Lidar data has been collected along the shoreline through various joint projects by these organizations since about 1996; yes a full 20 years of shoreline lidar data exists in several locations.

Overview

The Shoreline Risk Technique (SRT) uses 2D results as opposed to a vector representation of the shoreline or a profile. Each pixel (commonly 2-5 meter) has a risk value that is based on the elevation, specific tide level, the history of the pixel (change), and, for future predictions, the potential changes in SLR and the trends occurring there. The beach/shoreline system being analyzed is assumed to be completely represented by the data – it is implicit in the technique that there are no 'outside of the box' events. This also means that a data set collected one year before another has the potential to be as similar as one collected 10 years earlier. This is unique to the SRT, counter to most traditional views of shoreline change, and would limit use in study areas defined primarily by trends – such as purely natural beaches or marsh shorelines – where other techniques such as DSAS are more applicable. This is a technique for the growing number of 'urban beaches' which, like the roads that serve them, are maintained essentially as an infrastructure component.

The inherent assumption is that the past several decades (about 20 years) is representative of both the natural and human changes within the sphere of analysis. In some locations this is a fair assumption; many beaches have a semi-regular renourishment maintenance schedule or have not had any renourishment at all and change within a known range of normal conditions. In the middle are a shrinking number of recreational coastal areas that have had only a random renourishment. Another assumption is that the beach sampling times (dates of data capture) are random. This assumption can be limiting in areas where the majority of data sets are collected based on storm passage (i.e., Post Hurricane Sandy data sets); that said, it is important that post-storm conditions are captured.

The important components of the process are: 1) Morphology Risk, 2) SLR Risk and 3) Trend Risk. Elevation Risk includes both one (1) and two (2); trend risk is used for future projections and includes only the trends.

Elevation Risk

This is the primary risk on most managed beaches and is basically a function of how high a section of beach is and how it has changed in the past. The 'how high' is relation to sea level and its change through time – and forward in time.

Elevation Risk is highlighted by the following

$$f(elev\ risk) = \text{Elev} + \text{Elev Variability (Morphology)} + \text{Water Level} + \text{Varibility (future)}$$

And is based on the equation of Z scores (that is then converted to percentiles).

$$f(elev\ risk) = \frac{Elev^{ave} + \ Water\ Level^{ave}}{\sqrt{Morphology^2 + SLR^2}}$$

Where Elevation and Elevation Variability come from lidar data and are represented by the mean DEM value and the standard deviations of DEM values; water level and its variability come from tide gauges and future SLR predictions.

DEM

The mean DEM is simply the average of all DEM surfaces and represents the historical baseline. The variability is the standard deviation at each pixel and is a measure of the morphological stability or lack thereof. In beach areas with high elevation and low change – the risk is low; where the elevation is lower and change is high the risk increases.

Water Level and future variability

The risk is defined as the chance that the 'shoreline' is located at or landward of the specific pixel (i.e., the pixel is wet). The water level aspect of risk is defined by the choice of tide stage; the entire beach would be at higher risk of being wet during high tide than at low tide. The standard in most cases is mean higher high water (MHHW). Future variability is based on projected SL curves from multiple scenarios (scenario agnostic) and is treated like the DEM variability. The SL change variability has been modeled in this fashion for several projects.

Trends

Including trends is a bit more complex and consist of the addition of two Zscores – one as above and one for the trends. The inter-sample trends are computed between each data set and the average and standard deviation computed for each pixel.

$f(elev\ risk) =$ *Elev + Elev Variability (Morphology)+Trends + Water Level + Varibility (SLR)*

$$\text{Zscore} = \frac{Elev^{ave} - Water\ Level^{ave}}{\sqrt{Morphology^2 + SLR^2}} + \frac{Trends^{ave} - 0}{Trends\ Stdev}$$

The two zscores are summed to produce a final Zscore for the pixel. The Zscore is then converted to a percentage or ratio, which can be mapped as a single shoreline (choice of one risk level) or envelope of risk.

Figure 1. Envelope of shoreline risks

Uses of Risk Data

The primary use of the risk information is to inform maintenance (renourishment) of beaches (infrastructure) in the future. It is also possible to examine scenarios of increased or decreased maintenance, and to gage the existing condition (shoreline) in terms of historical risk levels. Basically any of the stuff you would use in a typical shoreline change application.