Estuarine, Coastal and Shelf Science 150 (2014) 86–91

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Forecasting cyclic coastal erosion on a multi-annual to multi-decadal scale: Southeast African coast

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ARTICLE INFO

Article history:
Received 30 November 2012
Accepted 22 December 2013
Available online 9 January 2014

Keywords:
cyclic coastal erosion
Lunar Nodal Cycle (LNC)
Lunar Perigean Subharmonic (LPS)
Dyer-Tyson rainfall cycle (MAP)
coastal erosion forecasting
longshore sediment transport
Mean Annual Precipitation (MAP)

ABSTRACT

Coastal erosion on the southeast African coastline shows an apparent 18 year cycle which last peaked in 2006. It is in phase with the longshore sediment transport cycle. Both these cycles appear to be in phase with the Lunar Nodal Cycle (LNC). However, the dominant tidal erosion driver on this coast appears to be the 4.4 year Lunar Perigean Subharmonic (LPS). We suggest that the apparent 18 year coastal erosion and longshore sediment budget cycle is a response to the 18 year Mean Annual Precipitation Cycle. This cycle is 180° out of phase with the apparent coastal erosion- and longshore sediment transport- cycles.

The summer rainfall areas, of southeastern Africa show an 18 year MAP cyclicity, which drives river runoff and hence controls sediment input to the coast and nearshore environment. The MAP cycle dominates the coastal sediment budget during the LNC trough and suppresses the LPS coastal erosion cycle during this time. This explains why LPS coastal erosion occurs close to the LNC peak. Thus although the LPS cycle dominates the coastline, it is masked during the wet portion of the 18 year MAP cycle. It seems very likely that the LNC drives the MAP cycle in some way but this process is not known. Nevertheless, these relationships can be used to predict, in a general way, both cyclic coastal erosion and the longshore sediment volume fluctuation. This can be translated into a vital coastal planning tool which has the potential to forecast cyclic coastal erosion and hence significantly reduce the sea-defense expenditure bill. Based on this, severe cyclic coastal erosion is anticipated in 2023 and 2024.

1. Introduction

The southeast African coastline (Fig. 1) has been subject to geological-term coastal erosion (broken only by subordinate Holocene sea-level high stands) throughout the Late Quaternary post-glacial transgression. The sea level has risen 130 m since the Last Glacial Maximum (Ramsay and Cooper, 2002; Waelbroeck et al., 2002; Green and Uken, 2005) and in response the coastline has receded by up to 47 km.

Recent work (Smith et al., 2007, 2010, 2013; Palmer et al., 2011; Corbello and Stretch, 2012a) has underscored the vulnerability of the southeast African coastline to erosion and highlighted the location of many erosion hotspots (EHS) (Fig. 1). Coastal erosion can be episodic, driven by storm or high-swell events (Mather, 2007; Smith et al., 2007), seasonal changes (Smith et al., 2010) and multi-annual to multi-decadal cycles (Smith at al., 2010; 2013) such as the 18.6 year Lunar Nodal Cycle (LNC) (Smith et al., 2010) and the 4.4 year Lunar Perigean Subharmonic (LPS) (Corbello and Stretch, 2012a), especially near the LNC peak (Smith et al., 2013).

In this paper we consider information from the coast (such as empirical relationships between coastal erosion and longshore sediment transport cyclicity) and also explore their relationships with the 18 year Mean Annual Precipitation (MAP) cycle (180° out of phase with cyclic coastal erosion). This work combines extensive geomorphological observations, fieldwork and a literature review. From this we derive a preliminary cyclic coastal erosion forecasting model based on a combination of climatic, tidal, longshore sediment transport and coastal erosion cycles. This model can be used to hindcast bouts of catastrophic coastal erosion and could have predicted the 2011 erosion event ahead of time.

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http://dx.doi.org/10.1016/j.ecss.2013.12.010

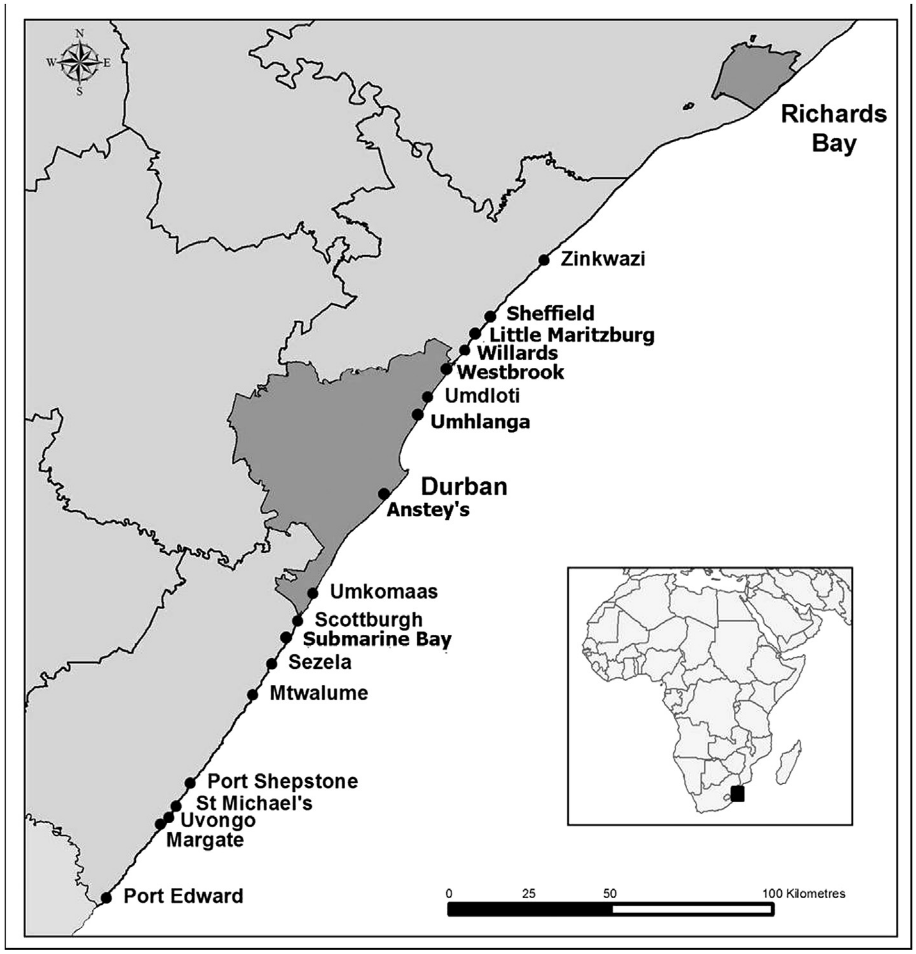

Fig. 1. Location Map showing the global and regional context of southeast Africa and the position of the environmental hotspots recognized.

1.1. Coastal regime

Open ocean swells reaching the southeast African coastline are predominantly southerly to southeasterly (Grundlingh and Rossouw, 1995; Corbello and Stretch, 2012b), although this direction may change from time to time, especially in summer (Smith et al., 2013). In general, the incoming swell intersects the southeast African coastline at a slight angle and produces a net south-to-north longshore sediment transport (Cooper, 1991a; b; 1994). In the austral winter (May–September), waves generally approach from the south to southeast, associated with the passage of cold fronts and cut-off low pressure systems. There is a seasonal eastward swing during the austral summer (Corbello and Stretch, 2012b) due to the seasonal shift in synoptic weather patterns. There is an increase in east-southeast to easterly swells in summer, linked to stronger and more prevalent northeasterly winds, associated with the South Indian Ocean Anticyclone. Occasional tropical depressions, storms and cyclones also contribute easterly swells.

Under normal conditions sediment is recycled between the offshore surf bars and the beach, however for coastal transgression to take place there has to be offshore leakage of sediment beyond the reach of waves as occurred with the return flow during the March 2007 high swell event (Smith et al., 2010). In further support of this, a build-up of sediment on the inshore side of a very prominent, and laterally persistent, submerged offshore reef system (−60 m) off the southeast African coastline has been documented (Flemming, 1981). This sediment build up is probably the result of historic high swell return flows.

High swells are usually generated by cut-off low pressure systems, intense cold fronts or tropical -depressions, -storms or -cyclones. Swell height data has been recorded at Richards Bay (Fig. 1) since 1979 (van der Borch van Verwolde, 2004; Guastella and Rossouw, 2012) and since 1992 at Durban (Fig. 1) (Corbello and Stretch, 2012b). Swell heights (H_{max}) of up to 14 m (2007) have been measured, with significant wave height (H_s) values of 8.5–9 m (2007 & 1984, respectively) being recorded (Guastella and Rossouw, 2012). The average annual H_s for Durban (Fig. 2) is 1.65 m (Corbello and Stretch, 2012a; 2012b). It is also worth mentioning that Salzmann and Green (2012) have calculated H_s wave heights of over 11 m from megalith dimensions from a boulder beach at Mission Rocks. This locality is further to the north within the tropical cyclone belt and suggests the possibility of even higher swells on this coast (Fig. 1).

This research was based on information from the coast of KwaZulu-Natal province on the southeast African coastline. Much of the KwaZulu-Natal coast comprises topographically bound embayments (TBE). Seasonal swell regime change causes beach rotation (Short, 2002) within these bays. This seasonal erosion/deposition is driven by megarip current cells, especially within the lee of TBE headlands, which are themselves driven by the littoral