KwaZulu-Natal coastal erosion events of 2006/2007 and 2011: A predictive tool?

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Severe coastal erosion occurred along the KwaZulu-Natal coastline between mid-May and November 2011. Analysis of this erosion event and comparison with previous coastal erosion events in 2006/2007 offered the opportunity to extend the understanding of the time and place of coastal erosion strikes. The swells that drove the erosion hotspots of the 2011 erosion season were relatively low (significant wave heights were between 2 m and 4.5 m) but of long duration. Although swell height was important, swell-propagation direction and particularly swell duration played a dominant role in driving the 2011 erosion event. Two erosion hotspot types were noted: sandy beaches underlain by shallow bedrock and thick sandy beaches. The former are triggered by high swells (as in March 2007) and austral winter erosion events (such as in 2006, 2007 and 2011). The latter become evident later in the austral winter erosion cycle. Both types were associated with subtidal shore-normal channels seaward of megacusps, themselves linked to megarip current heads. This 2011 coastal erosion event occurred during a year in which the lunar perigee sub-harmonic cycle (a ±4.4-year cycle) peaked, a pattern which appears to have recurred on the KwaZulu-Natal coast. If this pattern proves true, severe coastal erosion may be expected in 2015. Evidence indicates that coastal erosion is driven by the lunar nodal cycle peak but that adjacent lunar perigee sub-harmonic peaks can also cause severe coastal erosion. Knowing where and when coastal erosion may occur is vital for coastal managers and planners.

Introduction

The KwaZulu-Natal coastline (Figure 1) is subject to coastal erosion – an ongoing process that has occurred throughout the latest Quaternary transgression. The sea level has risen 130 m since the Last Glacial Maximum at 18 000 years BP.[1,2] Sea-level rise,[3,4] increasing storminess[5,6] and increasing coastal urbanisation[7] will certainly contribute to increased future coastal erosion and the increased infrastructural costs thereof.

Figure 1: Map showing the location of erosion hotspots along the KwaZulu-Natal coast.

Knowledge of where and when erosion will strike is vital to coastal managers.[8] Recent work[9] has highlighted the KwaZulu-Natal coast's vulnerability to erosion. However, this work did not address the reasons for this vulnerability, nor did it assess the occurrence, future likelihood and prevalence of the phenomenon. In this paper, we aim to assess coastal erosion along the KwaZulu-Natal coast from these perspectives.

The KwaZulu-Natal coastline is subject to a net south-to-north littoral drift.[10-12] The northerly flow dominates but reversals occur (see 15–19 July 2011 swell account), especially in summer as a result of the greater number of easterly winds and swells. The littoral drift is driven by south to southeasterly swells which are generally higher in winter.[5,6] This seasonality drives a net beach rotation[13] within the topographically bound bays (small bays created between two headlands), resulting in beach thinning in the south and thickening in the north during the austral winter, a pattern which reverses in the austral summer.[14]

Along urbanised coastlines, the coast's natural ability to repair itself is compromised by the destabilising effects of built structures and the dysfunctional coastal dune cordon (Figures 2 and 3).[7] Protracted erosion in 2006 and 2007 led to some coastal reaches being artificially defended to protect the adjacent infrastructure. Because of net sediment losses during this erosion event, this coastal buffer was placed 5–30 m shoreward of its pre-2006/2007 position.[7,14] This placement has resulted in the urbanised coastal reaches being more vulnerable than they were prior to 2006.

Recent research[14] suggests that strong erosion events have occurred at or near the peak of the 18.6-year lunar nodal cycle (LNC) when the moon is closest to Earth and spring high tides are unusually high.

Figure 2: (a) Umdloti, (b) Little Maritzburg Road, (c) Ansteys and (d) Umhlanga beaches during a large swell. These locations are known erosion hotspots.

Figure 3: Westbrook Beach rotation on (a) 03 July 2011, (b) 10 July 2011, (c) 17 July 2011 (during an unusual ENE swell) and (d) 28 August 2011.

Austral winter erosion event of 2011

Austral winter erosion along the KwaZulu-Natal coastline is typically complete by September, but the 2011 erosion event continued to the end of November. Beach webcam imagery[15] and fieldwork indicates that the onset of erosion can be placed in the late austral autumn – mid-May for Amanzimtoti and Ansteys Beach (south of Durban) and early June for Umdloti, Umhlanga and Westbrook (north of Durban) (Figure1).

The highest significant wave heights (H_s) of the 2011 coastal erosion peaked at 2.9 m offshore[16] and 4.5 m inshore[17] on 23 June 2011. During the 2011 austral winter the swell remained between 2 m and 3 m (H_s) for significant periods.[16] These swells consistently arose from a southeasterly direction, with periods varying from 12 s to 16 s.[17] During this time, coastal erosion was dominant at the known erosion hotspot (EHS) locations and, although the still-water position (level of the sea on which waves are superimposed) remained relatively low, sediment loss and infrastructure damage was reported. Some EHS coastal defences, constructed in the aftermath of the 2006/2007 erosion event, were exposed, damaged or breached (Figure 2). These effective swells were generated by a series of cold frontal systems moving from west to east, passing to the south of KwaZulu-Natal. Several distinct erosive events were recorded.

A swell period which peaked between 17 and 19 July 2011 is of particular interest as the swell came from a very unusual direction (ENE: $\pm 65^{o}$) for that time of year. This swell resulted in a longshore drift reversal (north-to-south). Under this reversal many EHS localities underwent significant temporary deposition (Figure 3). The storm system which formed this swell had all the characteristics of a tropical low pressure system. These are summer weather systems expected in December–March[18] and are very unusual in winter.

Notably, the 2011 austral winter erosion event did not fall on the LNC peak but did occur in a year coinciding with the lunar perigee sub-harmonic (LPS) peak, a $\pm$4.4-year tidal cycle that is also typified by unusually high tides. The last LNC and LPS peaks were 2006 and 2007, respectively – a period noted for strong coastal erosion.[14]

The 2011 EHS localities were associated with prominent megarip currents, themselves controlled by coastal geomorphology and bathymetry.[14] Megarip currents (identified by large megacusps on the beach) are typically associated with deeper offshore-directed subtidal channels (to the north of headlands). This situation is caused by the complex build-up of water caused by wave action, which is then released by an offshore directed megarip current flow. These deep channels are used as ski boat launch sites.

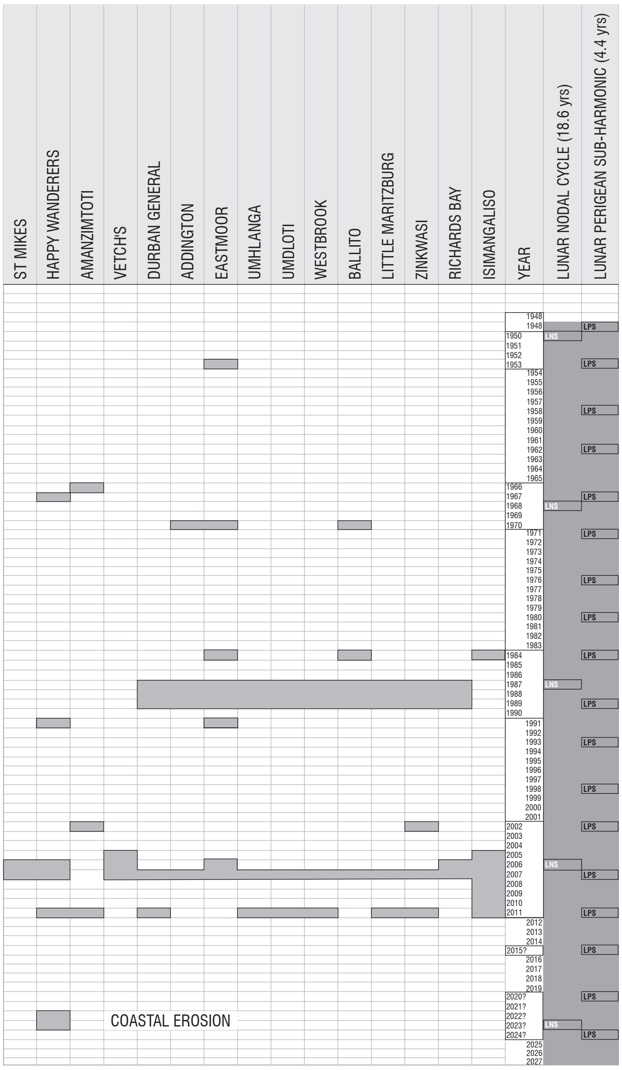
Within most topographically bound bays, deposition occurred to the south of points and megarip head-cutting erosion to the north. Beach rotation is generally seasonal[13] but during austral winter 2011 it was observed to be the net product of multiple shorter-duration, swell events. These beach rotation events were rapid, occurring on the scale of a few days, and could reverse just as quickly with a change in swell direction (Figure 3). The fact that beach rotation was not universal indicates that local factors, such as bathymetry and coastal orientation and configuration, must have played a role.

All the 2011 EHS locations underwent severe erosion during the high swell of March 2007[7] (Figure 1; Table 1). The 2011 austral winter erosion event was driven by sustained swells. Initially, the pattern seemed to follow that of the March 2007 high-swell erosion event. At first, thin beaches (1–3 m) overlying shallow bedrock underwent severe erosion,[6,13] whereas deeper sandy beaches escaped erosion. As the season progressed, the wide and deep sandy beach EHSs became extensively eroded as a result of continuing megarip current activity. From this evidence, two types of EHS are recognised: Type 1 (EHS-1) are beaches underlain by shallow bedrock such as Umdloti, Umhlanga and Westbrook and Type 2 (EHS-2) are wide, sandy, deep beaches such as Amanzimtoti, Submarine Bay, Umkomaas and Trafalgar (Figure 1; Table 1).

Table 1: Locality where coastal erosion occurred in 2007, effects of erosion in 2011 at the same localities and the type of erosion hotspot

2007 Locality	Effects of 2011 erosion event	EHS type
Richards Bay	No infrastructure damage reports	?
Zinkwasi	HWL retreated by up to 20 m	?
Sheffield Beach	Low level beach erosion	EHS-1
Little PMB	Damage to 2007 defence structures	EHS-1
Willards Beach	Noticeable beach erosion	EHS-1
Westbrook Beach	Launch site ramp undercut	EHS-1
Umdloti	Undermining of road repaired and defended in 2007	EHS-1
Umhlanga Rocks	Retaining wall built in 2007 failed	EHS-1
Ansteys Beach	HWL retreated 20 m	EHS-1
Amanzimtoti (Chain Rocks)	HWL retreated 20–30 m	EHS-2
Umkomaas (Windham)	HWL retreated markedly	EHS-1
Scottburgh	No infrastructure damage reports	EHS-2
Submarine Bay	HWL retreated 20–30 m	EHS-2
Sezela	No infrastructure damage reports	EHS-2
Mtwalume	No infrastructure damage reports	?
Port Shepstone	No infrastructure damage reports	?
St Michaels	No infrastructure damage reports	?
Uvongo	HWL retreated 80 m+	EHS-2
Margate	HWL retreated 30–40m	?
Port Edward (Trafalgar)	HWL retreated markedly	EHS-2

EHS, erosion hotspot; HWL, high waterline.



Information was obtained from Smith et al.[14], newspapers and verified witnesses.

Figure 4: Coastal erosion events since 1949 at known KwaZulu-Natal erosion hotspot localities.

Discussion and conclusions

High swells erode coastal sediment and lower the beach profile[19] which leads to general linear coastal erosion and infrastructure loss on a scale of days.[13,14] By contrast, winter erosion acts, via megarip currents, over a longer duration. When compounded over an entire season, these megarip currents can cause catastrophic erosion at specific EHS localities because the megarip current cusp headcuts back into the beach and, in extreme cases, into the coastal dune. Although the overall patterns of the 2007 and 2011 winter erosion events were similar, the coast was better able to withstand the erosion in 2011 than in 2007. In 2007, the coast had been rendered more susceptible to winter erosion by the high swell ($H_s = 8.5$ m)[6] that struck 24 h before the March equinox. The March 2007 high swell eroded a large amount of coastal sediment and conveyed it via a storm-return flow offshore beyond the ability of waves to return it.[14]

The KwaZulu-Natal coastal erosion record goes back to 1937,[10-12] but is reliant on serendipitous imagery and so the timescale is very coarse. Historical research has shown that coastal erosion occurred during the last three LNC peaks (Figure 4).[14] Subsequent research has also shown the occurrence of EHS erosion in 1989 and 1993 – years that both coincided with LPS peaks. Although 1989, 1993, 2007 and 2011 represent only four LPS events, this pattern suggests that there may be some control of erosion around these tidal peaks (Figure 4). This finding is interesting as theoretical work done elsewhere suggests that the KwaZulu-Natal coastline should be dominated by the LPS (±4.4-year) tidal cycle.[20]

Erosion clearly correlates with years in which the LPS and LNC lunar tidal cycles peak (although the latter dominates) – times of unusually high spring tides (Figure 4). This evidence is empirical and the exact causal relationship needs to be better established. Whether the moon is influencing coastal erosion directionally through increased tidal current action[21,22] or indirectly by influencing the weather (and hence the swell climate)[23-26] has yet to be ascertained.

Geofabric bag defences emplaced after the 2006/2007 erosion event largely held in 2011, whereas sand-filled sugar bags (which have no UV tolerance) and geofabric sandbag filled gabions failed. Some seawalls also failed, e.g. Umhlanga (Figure 1). The 2011 coastal erosion was predictable as it struck identified EHSs during a LPS year.

The 2011 erosion was minor in comparison with that of 2006/2007, but serves as a wake-up call to coastal managers. Many of the post-2006/2007 coastline defences and repairs failed in 2011. Coastal erosion on the KwaZulu-Natal coast appears to be steered by lunar aspects (both the LNC and LPS), modulated by megarip currents, swell height, swell duration, swell propagation direction and the still-water level. At its onset, the 2011 austral winter erosion activated the EHS-1 localities, a similar pattern to that of the March 2007 high swell, but as it progressed it followed the pattern of the 2007 austral winter erosion and triggered the EHS-2 localities. However, the 2011 event lacked the antecedent high-swell coastal erosion that preceded the 2007 austral winter event; consequently, the 2011 event was less destructive.

Erosion events, such as those of austral winter 2011, are likely to become more severe as a result of the predicted 3.7-mm/year sea-level rise,[3] coupled with the ongoing destruction of the coastal dune cordon[7,14] and the predicted increase in wave heights.[5,6] Analysis of the historical record suggests that the next serious round of coastal erosion is to be expected in 2015 – when the next LPS peak will occur. On the basis of the empirical evidence presented in this paper, we recommend that coastal planners take this event into account in their planning.

Authors' contributions

A.S. managed and steered the research process; L.A.G. provided oceanographic and field research input and discussion; A.A.M. and S.C.B. provided information on coastal conditions and discussion; and I.D.H. provided details concerning LNC and LPS tidal peaks.

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