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Full Length Research Paper

Morphodynamics and features of littoral cell circulation observed from sequential aerial photographs and Davies drifter along a section of the strand coast East of the Niger Delta, Nigeria

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Sequential aerial photographs taken along a section of the Strand coast (longitude 07°35'00" and latitude 8°30' 20"E) East of the Niger Delta Nigeria were anaylsed to understand tidal inundation and resulting morphodynamic features as well as the littoral cell circulation patterns. Records from a Davis drifter deployed in the Qua Iboe River that traveled parallel to the shoreline were also used to confirm the littoral cell patterns. The analysis of the sequential aerial pictures shows that the cell circulation patterns consist of waves with oblique angles which approach in a Southwesterly direction generating an Eastward flowing longshore current. Rip currents are recognised in the surf zone as seaward flowing surfs. Interpretation of a picture of the exposed beach during low tide shows tidally induced morphodynamic features such as rhythmic ripples, perpendicular sand ridges and runnels (hollows) which tend to be welded to the shoreline. Drifter number 26602 deployed inside the Qua Iboe River on 3 March 2001 at 0300 h confirmed the West to East longshore current direction. Though this study employed the use of short term data, it has enhanced the understanding of oceanographic processes, erosional, and depositional processes in the intertidal zone of the stud area.

Key words: Cell circulation, drifter, longshore currents, Niger Delta, rip currents, waves.

INTRODUCTION

Cell circulation in the littoral zone (wave breaking zone) results from combination of wave, tide and wind-induced currents. As waves move into shallow water, the group velocity becomes small, wave energy per square meter of sea surface increases, and non-linear terms in the wave equations become important. These processes cause waves to steepen, with short steep crests and broad shallow trough. When wave slope at the crest becomes sufficiently steep, the wave breaks. When waves break with their crests effectively parallel to the shoreline, a cell circulation is established (Figure 1), which consists of a shoreward mass transport, longshore currents, and narrow seaward-flowing rip currents that extend through the breaker zone and spread out into rip heads (Shepard and Inman, 1951). Tidal fluctuations coupled with cell circulation system and beach profiles result in several types of shore morphodynamic features such as ridge and runnel structures, ripples and sand bars. The morphology and associated dynamics of these features have been well described by several authors like King et al. (1949) and Masselink et al. (2006) amongst others. Previous authors like NEDECO (1961), Burke (1972), Ibe and Awosika (1986), Awosika et al. (1994, 2000) amongst others have described the general dynamics

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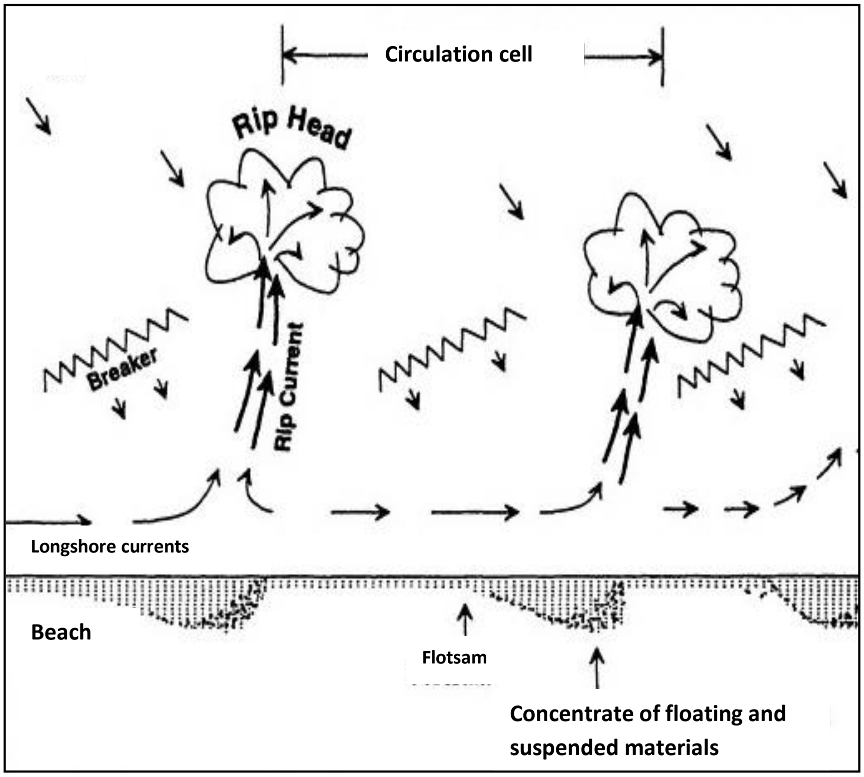

Figure 1. Schematic diagram of nearshore circulation cell consisting of onshore transport by the breaking wave, longshore transport in the surf zone and offshore transport by seaward flowing rip currents (Shepard and Inman, 1951).

along this coast.

Objectives of the study

The primary objectives of this study is to understand the morphodynamics and features of the cell circulation, tidal inundation patterns, and resulting morphological intertidal features along a section of the Strand coast in Nigeria using airborne sequential photographs. Also, trajectory records from a Davies drifter data deployed in the surf zone was used to confirm the littoral cell transport direction.

The study area

The study area lies East of the Qua Iboe River within the Strand coast which is the Easternmost coastal morphological unit in Nigeria (Figure 2). This coastal complex stretches from Imo River Eastwards to the Cross River estuary and within longitude 07°35'00"E and 8°30' 20"E. The coastline is dissected by the Cross, Qua Ibo and Imo Rivers and many small rivulets and tidal creeks. Waves along this coast are wind generated which approach in a South-westerly direction with periods ranging from 8 to 13 s. Tides are generally semi diurnal with two inequalities. Tidal range varies from 1.5 m along the East to 3 m in the Calabar estuary. The study area has a narrow intertidal zone with average of about 100 m. The semi-diurnal nature of the tides affecting this coastline generates tidal currents, are in phase with tidal cycles. The beach is sandy with sediments ranging from fine to coarse sand.

METHODOLOGY

Sequential aerial pictures taken during a helicopter over-flight of the area on 6 November, 2004 were used to identify and verify the dominant circulation patterns along the study area East of the Qua Iboe River. For this analysis, the following oceanographic phenomenon were identified and mapped on the pictures:

i) Wave breaking direction and angle,
ii) Direction of long shore current,
iii) Rip currents.

Rip currents will also be identified by observing the following in the pictures:

a) A channel of churning, choppy water;
b) An area having a notable difference in water color;
c) A line of foam, seaweed, or debris moving steadily seaward and
d) A break in the incoming wave pattern.

The morphodynamics features in the intertidal zone were

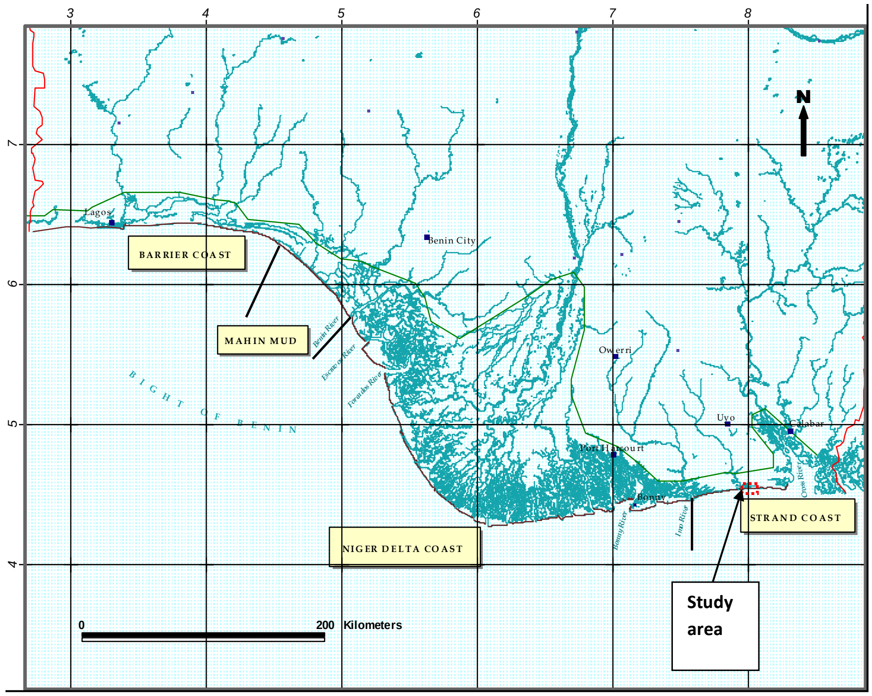

Figure 2. Coastal morphological zones in Nigeria (Awosika et al., 2000) showing the study area.

interpreted from a picture of the shoreline taken during low tide. The direction of the longshore currents within the littoral cell circulation system mapped on the photographs was validated using Davis drifter trajectory records (No. 26602). The drifter (Figure 5) was deployed in the Qua Iboe River on 3 March 2001 at 0300 h. The Davis drifter contained GPS units which transmits coordinates and current direction, and speed to the ARGOS satellites.

RESULTS

Sequential aerial photographs

Analysis of the sequential aerial pictures showed the cell circulation patterns for the study site (Figure 3). The wave trains approaching the shoreline in a South-westerly direction were interpreted in the sequential aerial photographs. The angle of breaking waves also is about 10 to 15°. The resulting direction of the longshore current is West to East. Rip currents between each successive breaking wave train were recognized in the sequential photographs as seaward flowing surf. The rip currents observed from the pictures are narrow but perpendicular to the longshore direction. The rip currents transport material out to the sea but die out within 25 to 50 m seaward of the shoreline.

Using the characteristics (shape, colour tones, and texture) of the morphodynamic ridge and runnel features photographed in the intertidal zone, the dominant tidal direction and patterns have been interpreted. Figure 4 shows the typical beach morphodynamic features (ridge and runnel structures) within the intertidal zone exposed during the low tide. The structures in the picture appear as perpendicular ridges separated by hollows (runnels) which had been shaped by seaward flowing rip currents. The ridges show the toss side facing the ocean and the seaward directional movement of the rip currents. The ridges are rhythmic and tend to weld to the shoreline.

The morphodynamic ridge and runnel structures had been shaped by a combination of flood and ebb tidal currents, longshore, and rip currents. Similar features have also been identified by Short (1999), Short and Aagard (1993) when low waves persist for long periods. Komar (1997) emphasized the importance of low-velocity longshore currents for rhythmic ridge formations with runnels. The hollows (runnels) between the perpendicular sand ridges caused by rip currents shows the competence of the rip current to erode as well as transport materials to sea. Furmanczyk et al. (2002) analysed series of aerial photographs in Pomerainina Bay, Poland and found similar underwater bars and ridges as indicators of rip current activity and circulation system.

Offshore Davis drifter trajectory

Drifter number 26602 was deployed inside the Qua Iboe River on 3 March 2001 at 0300 h. The direction of movement of the Davis drifter is shown in Figure 6. While in the estuary, the drifter was under the ebb currents

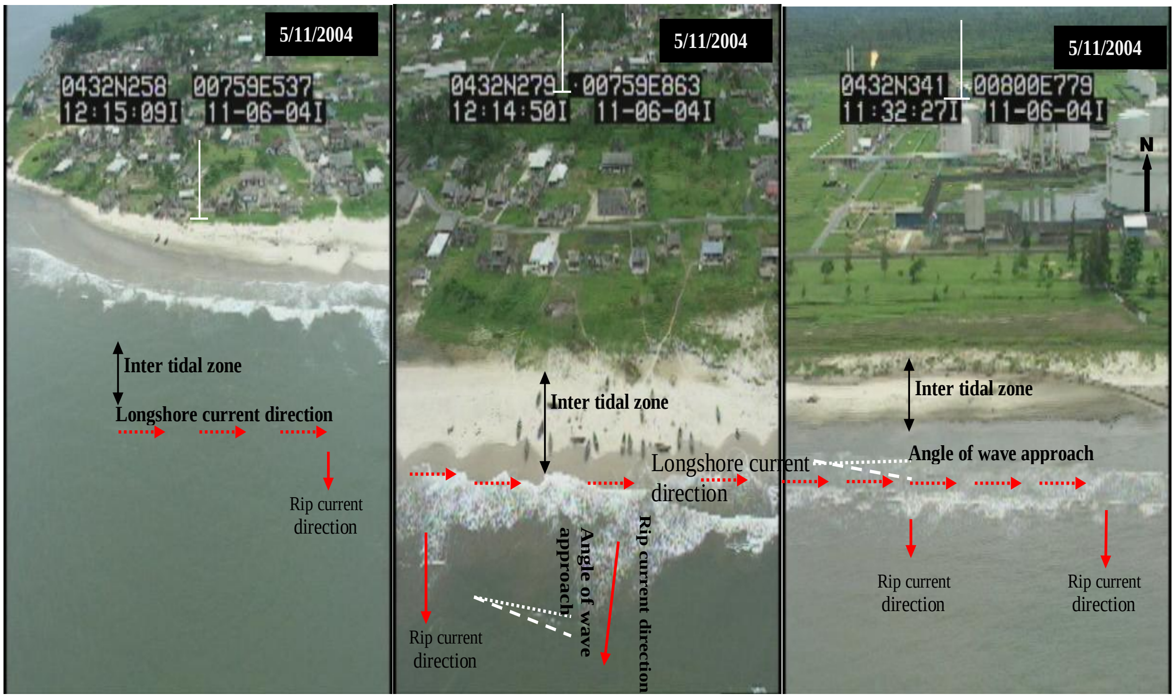

Figure 3. Sequential aerial photograph of a section of the Strand coast east of Qua Iboe River and interpreted cell circulation patterns. (Pictures taken at 4.20 pm on 5 November 2004).

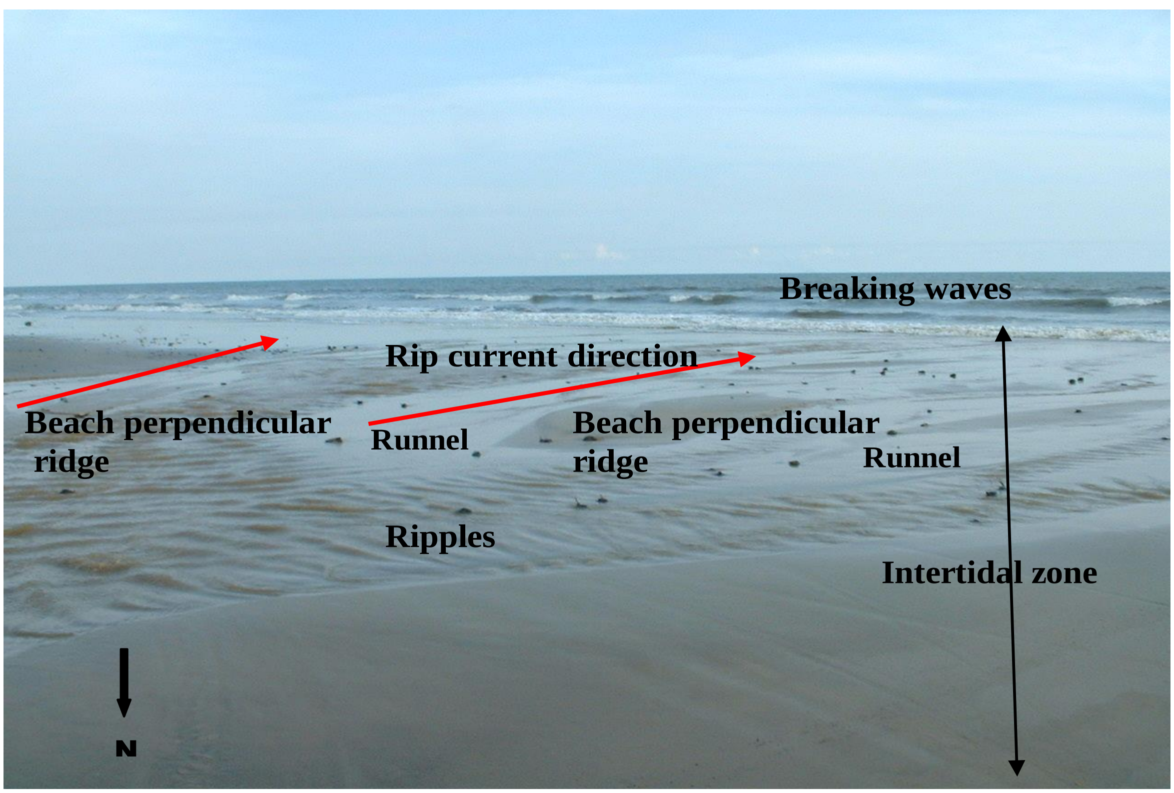

Figure 4. Picture showing morphodynamic features exposed during low tide within the intertidal zone on the shore (Lat. 04°32” 44.3’N; Long. 08°09’59.3”E) East of the Qua Iboe River (Picture taken at 4.25 pm on 5 November 2004).

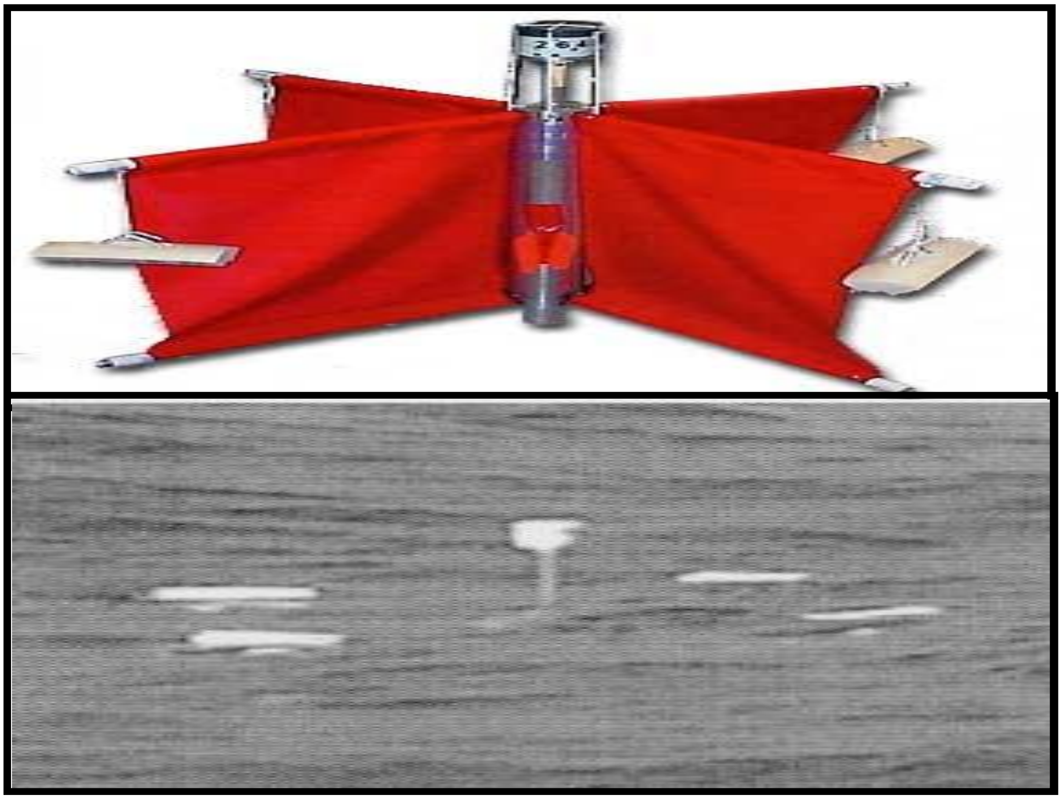

Figure 5. Davis drifter before launch (above) and after launch in water (below).

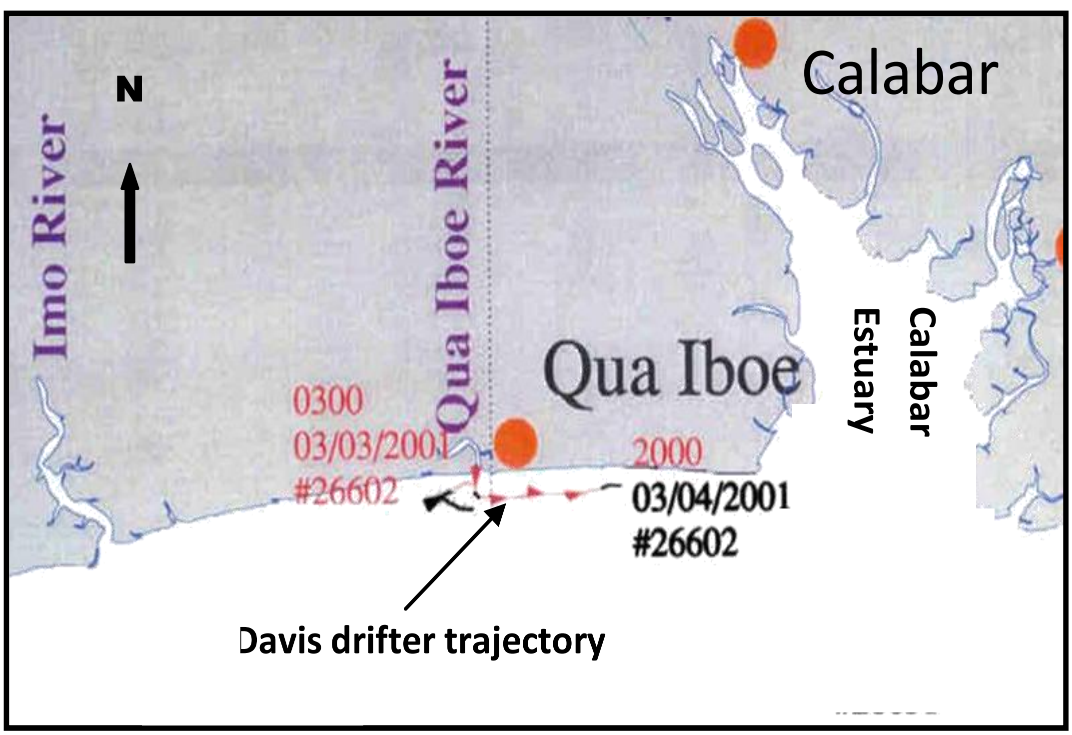

Figure 6. Drifter number 26602 trajectory deployed in the Qua Iboe estuary (Evan Hamilton, Inc., 2001).

which pushed it out of the estuary. The drifter immediately drifted due South out of the Qua Iboe River to sea. Once outside the estuary, the longshore currents were in control which caused it to drift Eastward even during flood tide which would otherwise have reversed the drifter back into the estuary during the next high tide. The drifter maintained this course for the next 24 h and ended its drifting close to the Eastern shore of the Calabar estuary.

DISCUSSION

Waves along the study area are predominantly Southwesterly as a result of the dominant Southwesterly winds. Due to the orientation of the coastline**,** waves arrive on the coast at oblique angles of between 10 to 15° with the waves opening to the East and hence producing a West-east longshore current. This West to East circulation cell is part of the West-east littoral cell of the eastern Niger Delta (Awosika et al., 1994). Sediment supply to the littoral drift is essentially from the Niger Delta tributaries east of the Akassa point. This coastal circulation cell is important for the transport of sediments eroded from the shoreline or transported downstream by the Qua Iboe River.

As ocean surface waves propagate over the continental shelf and break in shallow nearshore areas, their energy is dissipated in the surf zone. The gradients in the wave heights and momentum give rise to the generation of wave-induced nearshore circulation. Wave-forcing of circulation in the surf zone is a major cause of sediment transport and beach morphology evolution. Lipman and Holman (1991) described the spatial and temporal variability of sand bar (ridge) and runnel morphology. The rip currents as observed in this study have a dominant seaward (Southerly) direction and are strong enough to transport materials out of the surf zone to the inner shelf.

Tidal inundation of intertidal zones along the Strand coast also plays important role in the morphology of the beach and beach sand bars. They are also very important for the transport of sediments out to sea and hence of great importance to coastal erosion and its mitigation. Flood current speed in the estuary close to the mouth of the Qua Iboe estuary is estimated at about 0.2 cm/s while ebb tidal currents average 0.6 cm/s (Awosika et al., 2006). Due to the low intertidal, beach topography and tidal range of 1.5 to 2 m, the intertidal zone of the study area as well as a large part of the beach is usually flooded during flood tide. During ebb tide, the waters recede rapidly with currents reach 0.6 m/s. Such tidal patterns are capable of shaping the intertidal zone and producing the ridge and runnel structures observed and described in this study. Similar features have also been observed by Finkl (1994) using satellite imagery.

Conclusion

Surf zones are often neglected in conventional beach surveys due to difficulty of working in this highly dynamic environment. The use of aerial photography to some extent alleviates these constraints by providing remote access to features in a format that is amenable to spatio-temporal analysis.

Relics of the beach morphodynamic structures (ridge and runnel) resulting from the cell circulation patterns and tidal inundation in the study area have also been documented. These morphodynamic structures are controlled by a combination of beach slope, tidal fluctuations, and cell circulations. Though nearshore circulation cell dynamics are normally restricted to the surf zone and the intertidal zone, they play important roles in the shaping of the beach through erosion, transport, and dispersal of sediments to the offshore and general morphology of the beach. Such knowledge is important for coastal erosion mitigation options, transport of pollutants, and oil spill along and especially close to the shoreline. Hence, this pilot study which though utilised one day photos could enhance the understanding of coastal cell circulation pattern along the Strand coast East of the Niger Delta. Future long term series data sets are needed for the holistic understanding of nearshore oceanographic processes and the resulting morphological features in the intertidal Strand coast of Nigeria.

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