Geophysical Research Abstracts
Vol. 18, EGU2016-14630, 2016
EGU General Assembly 2016
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Morphodynamic rotation of an embayed sandy beach in a mud-dominated setting

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The morphodynamics of beaches between bedrock headlands along the muddy French Guiana coast in South America are controlled by rotation induced by the alongshore migration of mud banks from the mouths of the Amazon River. As they migrate alongshore, these mud banks generate changes in shore-incident wave angles, resulting in reversals in longshore drift. A poor appreciation of the problems caused by this process has resulted in the past in damages to the highly urbanized sea-fronts on these beaches, including erosion and flooding. This work enhances our understanding of this rather unusual type of mud-induced rotation based on surveys of the 4 km-long Montjoly beach near Cayenne, in French Guiana, in the course of an approaching mud bank between October 2013 and October 2014.

Our method was based on innovative high-resolution topographic surveys from airborne Structure-from-Motion (SfM) photogrammetry over the beach in October 2013, March 2014 and October 2014. We produced digital surface models (DSM) with a resolution of 10 cm/pixel and an accuracy less than 10 cm from RTK-GPS measurements. We further measured incident wave heights from pressure sensors and conducted a bathymetric survey of the nearshore zone in October 2014. We also modelled high-tide wave propagation over the bathymetry using the REF/DIF v2.5 model.

The results show the transfer of sand from the northern part of beach to the south between October 2013 and March 2014. The October 2013 DSM shows a reflective beach in the north indicative of erosion, with a narrow 50 m-wide upper beach. The southern sector was smoother and up to 90 m-wide. Between October 2013 and March 2014, the beach rotated under the influence of a mud bank, with a 30-m retreat of the berm in the north and an advance of 40 m in the south. We quantified a loss of ≈66,000 m^3 of sand in the north and a gain of ≈22,000 m^3 in the south over this six-month period. The October 2014 DSM shows minor morphological changes, thus indicating the end of the rotation around March 2014 and the beginning of a phase of nearshore mud-bounding of the beach as the mud bank migrated westward. The bathymetric survey showed a 2 m-high and 100 m-wide mud bar in the nearshore zone that dissipated wave energy. Hydrodynamic monitoring between March and October 2014 confirmed this low wave-energy regime (Hs < 0.5 m) compared to a more energetic regime in the neighbouring Montabo Bay beach (Hs up to 1.5 m) located downdrift of the mud bank. The REF/DIF model confirmed the strong wave energy dissipation over the mud bar.

Our study highlights the rapidity and intensity of the morphodynamic changes these beaches can undergo in a muddy context, and the need for continuous and accurate monitoring in order to assess the erosion hazard caused by rotation.

Keywords: Beach rotation; Mud banks; aerial SFM photogrammetry; bathymetric monitoring; hydrodynamic modelling; REF/DIF model.