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The impact of storms in the morphodynamic evolution of a human-impacted semi-sheltered beach (Agadir Bay, Morocco)

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ABSTRACT

This study discusses the morphological changes and evolution of Agadir Bay beach (Morocco) in response to eight storms between January 2014 and March 2014. A comparison is carried out of the evolution and variability of the beach in a sector of the bay protected by the commercial harbour of Agadir relative to a sector down drift of the harbour that is more exposed to waves, and changes affecting the beach following these storms are examined. Wave influence is evaluated using numerical simulations. The results show that despite being of relatively low intensity, the two first storm events, and especially storm 1, are responsible for major beach morphological changes. Three zones were identified as a function of the beach sediment dynamics: (i) a northern zone, representing the sector of the beach protected by Agadir harbour, with a net loss of about 21% of the total sediment, (ii) a southern zone, corresponding to the exposed sector with a net loss reaching74% of the total sediment, and (iii) a sector of residual dune that recorded no significant change during the storms.

1. Introduction

Sandy beaches are some of the most active geological systems in the world and their morphology commonly responds rapidly to high and low-energy conditions (Dubois et al., 2011). On a short-term scale, extreme storms are one of the most important agents of beach erosion and are also responsible for the destruction of coastal properties and engineering structures. Beach morphodynamic responses to storm can also differ. Such differences are controlled by storm characteristics and beach-dune geomorphology. There are numerous factors influencing the beach-dune response, and these include storm occurrence as individual (e.g., Backstrom et al., 2008; Zhang et al., 2001) or group events (e.g., Ferreira, 2005; Callaghan et al., 2009), the height of the foredune relative to storm surge level (e.g., Houser et al., 2008), shoreline orientation (Storlazzi et al., 2000), the antecedent beach state and topography(e.g., Donnelly, 2007; Matias et al., 2009), swash processes (e.g., Stockdon et al., 2007), backshore elevation (e.g., Morton and Sallenger, 2003), nearshore bathymetry (e.g., Ritchie and Penland, 1988; Anthony, 2013), and engineering structures (Hayden and Dolan, 1977). Agadir Bay (Fig. 1) is one of Morocco's major coastal urban poles. The coastal region and the city of Agadir (city population in 2012: 600,000) were struck in 1960 by an earthquake (5.7 on the Ms Scale) that virtually completely destroyed the city and left over 60,000 dead. The rapid reconstruction and strive to achieve economic development in the region in the wake of this earthquake have had, unfortunately, a heavy toll on shoreline stability. Agadir Bay not only crystallizes the effects of dwindling sediment supplies to coastal systems caused by dams and the destruction of aeolian dunes, but has also hosted a rapidly growing city (annual population growth > 10%) of which the twin economic drivers are the commercial harbour and tourism. The construction of a major harbour in 1988 render this bay a particularly pertinent and interesting unit to evaluate erosion processes, during storms, in an inner bay, sheltered by harbour jetties.

2. Characteristics of the study area

Located on the Atlantic coast of Morocco (Fig. 1), Agadir Bay forms the central part of a 35 km-long sandy coastline bound in the north by Cape Ghir and in the southwest by Cape Aglou. The area is

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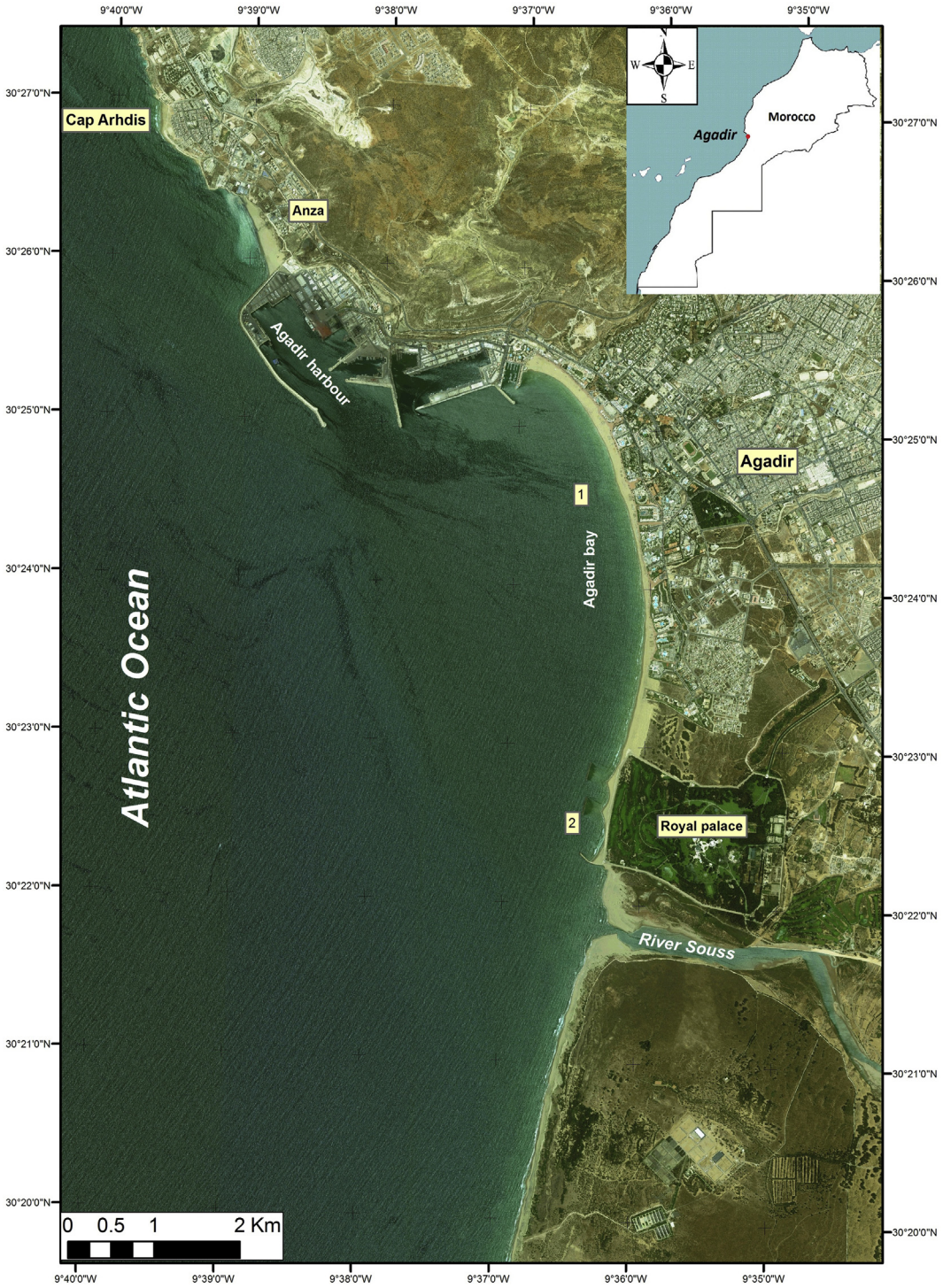

Fig. 1. Agadir Bay on the Atlantic coast of Morocco (Google Earth, 2013).Numbers 1 and 2 show beach breakwater constructed in 1968 and beach defence system composed of two breakwaters and a groyne constructed in 1994.

part of the Souss Massa administrative unit in the central sector of the coast of Morocco and which comprises three watersheds covering about 23,950 km^2. The climate of Souss Massa is arid to semi-arid. The proximity of the ocean and the influence of the cold Canary current mitigate the semi-arid climate in the coastal zone, while the mountain barrier of the Anti-Atlas provides protection against winds from the south (Water Basin Agency, 2003). The Agadir coastline is affected by economic development, with hotels and seafront facilities protected by dikes and breakwaters. Tourism is the man driver of the economy. Agadir is, since its reconstruction after the 1960 earthquake, the first seaside tourist destination of Morocco, with a hotel capacity of 24,000 beds, assuring more than 4 million room nights per year. Shoreline management efforts are mainly focused on preserving areas of the Agadir seafront that generate significant benefit for the regional economy. Therefore, an understanding of the response of the seafront beach in Agadir Bay