The relationship between waves, mud deposition and meteorological events in the Rio Grande do Sul state coastal area (Brazil)

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Introduction

Fluid mud deposits have been found in many coasts, rivers, and estuaries around the world, especially where one or more rivers lead significant amounts of fine sediment in suspension in the sea (Perillo & Kjerfve, 2003). In addition to the availability of continental sediments, the processes of transport and deposition of mud on the inner shelf is a consequence of the interaction between coastal currents generated by winds, associated with the passage of frontal systems, and low tidal range (Drake, 1976).

Resulting from the action of winds on ocean surface, the gravity waves are closely related to atmospheric variations and have high spatial and temporal variability playing an important role in the formation of coastal features. The wind blowing over the water surface induces shear stresses and pressure variations which result in waves that grow in the direction of the wind until a balance arises between the energy input and the dissipation in the wave field (Kinsman, 1965). The properties of the wind field (i.e. speed, direction, and duration) and the geometry of the water body where the waves are being generated (i.e. fetch, bottom type and water depth) determine the wave height, period, and direction. Waves generated by open sea will ultimately reach shallow water, where depth-limited wave breaking occurs and the wave energy is mainly dissipated, resulting in a gradually decay of wave height. When ocean waves approach intermediate and shallow waters, seabed fluid-mud interacts with the waves propagating over it. This interaction exerts influence on both waves and fluid-mud, the seabed fluid-mud produces a gradual dissipation of the wave energy, which promotes the attenuation of the wave heights. On the other hand, the pressure exerted on seabed by waves is the main cause of mud suspension and transportation. Both effects are important, and the interaction between them has long been attracting attention of researches due to the great importance of accurately estimating the sea state conditions for coastal engineering purposes (Holland *et al.*, 2003).

The coast of Rio Grande do Sul state presents a Northeast-Southwest orientation, and is characterized by open sandy beaches exposed to wave action. The coastal topography is complex and influences the physical processes determining the waves and the sediment transport at the coast. Over the whole 640km that separates Torres headland in the north (29.5°S) and the Chui Estuary in the south (33.8°S), the only significant interruption occurs at the entrance of the Patos Lagoon (32°S).

The Cassino Beach, located in the southernmost part of Rio Grande do Sul state, is characterized by extensive offshore mud deposition. Previous studies show that the source of the mud deposited offshore and on the shoreface of Cassino Beach is the Patos Lagoon (Martins, 1972; Martins *et al.*, 1979). The fine sediments are carried out from the rivers located at the north of the lagoon and transported towards the ocean by the wave action and wind driven circulation (Calliari *et al.*, 2007). These sediments are periodically suspended, transported and deposited on shore and on the surf zone, exerting important effects on the short and long features observed at the bottom, and bringing negative ecological and economical consequences for the area. Although the dynamics of the fluid mud deposition is still not fully understood, it seems that during stormy conditions, which are generally associated with the periodic passage of cold fronts over the area, the deposit can be reworked and mud is transported to the surf-zone and foreshore of Cassino Beach (Calliari *et al.*, 2007).

The main objective of this work is to investigate the relationship between meteorological events, the behaviour of waves and the mud deposition in the Rio Grande do Sul state coastal area. This work aims to understand the processes that control the dynamics, sediment transport and periodic remobilization of mud banks present in this region. This information is essential to evaluate the influence of waves in various coastal processes (estuarine hydrodynamics, sediment dynamics, occurrence of fluid mud, etc.) and their implications on nautical, maritime and sports activities in this region.

Methodology

A case study is presented for the Cassino Beach, based on a combination of preterits data and field experiments with numerical modelling. For this work were used wave models that include the formulation of damping effect of the wave due to the presence of mud banks. The use of nesting technique between both models with different scales, the WAVEWATCH III (global and regional) and the SWAN (local), will allow the generation and propagation of waves from offshore oceanic regions (offshore) up near the coast regions. The study will be conducted on the records of occurrences of mud banks on Cassino Beach in the period between 1998 and 2014.

The SWAN model (Simulating WAves Nearshore) is a third-generation wave model for obtaining realistic estimates of wave parameters in coastal areas, lakes and estuaries from given wind, bottom and current conditions. However, SWAN can be used on any scale relevant for wind-generated surface gravity waves. The model is based on the wave action balance equation with sources and sinks. The current version of SWAN (41.01) is a modified version of the model, which considers the mud effects formulated by Winterwerp *et al.*, (2007), which derived the physical and mathematical formulations of Gade (1958) and implemented their two-layer model in the standard SWAN model.

The WAVEWATCH III® (Tolman, 2014) is a third generation wave model developed at NOAA/NCEP in the spirit of the WAM model (WAMDI G., 1988; Komen *et al.*, 1994). This model, however, differs from its predecessors in many important points such as the governing equations, the model structure, the numerical methods and the physical parameterizations. The WAVEWATCH III® solves the random phase spectral action density balance equation for wavenumber-direction spectra. The governing equations of WAVEWATCH III® include refraction and straining of the wave field due to temporal and spatial variations of the mean water depth and of the mean current (tides, surges etc.), when applicable.

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