NEW COASTAL MODELING SYSTEM SMC-BRASIL AND ITS APPLICATION TO THE EROSION PROBLEM ON THE MASSAGUAÇU BEACH (SAO PAULO, BRAZIL)

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A new version of coastal modeling system (SMC) called SMC-Brasil has been developed by the Environmental Hydraulics Institute "IH-Cantabria" from University of Cantabria, University of Santa Catarina (UFSC) and the Oceanographic Institute of the Sao Paulo University (USP), with the support of the International Spanish Cooperation Agency (AECID), the Brazilian Ministério do Meio Ambiente (MMA) and Ministério do Planejamiento, Orçametno e Gestao/ Secretaria de Patrimonio da União (MP-SPU). SMC-Brasil is a user-friendly system specifically designed to assist coastal designers and managers in the analysis of marine and littoral dynamics to understand the changes in coastal caused by those dynamics. The system includes a 60-year reanalysis hourly database of wave climate database (waves, tides and storm surges) and bathymetric information along Brazilian coast, which help in the analysis of coastal morphodynamics along Brazilian coast. This system has been successfully applied to different study cases in Brazil to analyze their erosion or inundation problems and to propose different alternatives to avoid or reduce them. Here the erosion problem on Massaguaçu Beach is presented. SMC-Brasil has a dynamic design and allows the incorporation of future new databases, morphodynamic models and the implementation of new applications to help in the development of coastal projects and the management of the coast.

Keywords: coastal modeling; beach nourishment; climate change assessment; reanalysis database; morphodynamics; wave propagation model

INTRODUCTION

From 1995 to 2002, the Environmental Hydraulics Institute "IH-Cantabria" from University of Cantabria developed a Coastal Modeling System (SMC). This software was designed to help users in the knowledge of coastal dynamics and evolution to design adequate actions to prevent erosion or flooding problems on the coast, to stabilize beaches, etc (Gonzalez et al., 2007).

This system has also been implemented in Spain, Tunisia, and Colombia containing local databases of bathymetries, waves and sea levels, which have been generated for each country according to de available information. SMC has been exported to more than 50 countries such as the United States of America, Costa Rica, Mexico, Algeria, among others, where they use the methodologies and models implemented in this system to deal with diverse coastal problems and design coastal works or management plans.

Since 2009 up to now, a new advanced version called SMC-Brasil has been developed by the IH-Cantabria the Coastal Oceanography Laboratory of the Federal University of Santa Catarina (UFSC) and the Oceanographic Institute of the Sao Paulo University (USP), with the support of the International Spanish Cooperation Agency (AECID), the Brazilian Ministério do Meio Ambiente (MMA) and Ministério do Planejamiento, Orçametno e Gestao/ Secretaria de Patrimonio da União (MP-SPU).

This version includes new methodologies and tools to evaluate future impacts on beaches due to climate changes, coastal flooding and erosion problems. In addition, it includes a database of hourly series of waves, astronomical tide and storm surge, obtained using numerical reanalysis and sea level series along the Brazilian coast (1948-2008). This database has been validated with satellite, tide gauges, and buoys data. Downscaled tools have been implemented in the system to transfer offshore wave data towards the shoreline and harbors. Furthermore, numerical hydrodynamic and evolution models have been validated with laboratory and several case studies on Brazilian coast.

The aim of this work is to present the new Coastal Modeling System (SMC-Brasil) and show how to apply it to analyze the erosion problem on Massaguaçu Beach (Sao Paulo, Brazil).

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DESCRIPTION OF THE SMC-BRASIL

SMC-Brasil is composed of four methodological documents for specific coastal topics and two user-friendly systems which enclose the numerical models and statistical tools which permit the application of the methodologies and formulations proposed in the documents (see Fig. 1). The methodological documents deal with: (1) beach stability and regeneration methodology; (2) generation, calibration, validation and downscaling of multiannual wave series along the Brazilian coast; (3) sea level reanalysis and coastal flooding; (4) assessment of climatic change on beaches.

The system includes two different numerical tools in order to implement the methodologies for beach studies: SMC and SMC-TOOLS.

SMC-TOOLS was designed to carry out all the pre-process works (data collection, analysis and characterization, wave case selection, etc.) and all the post-process tasks (calculation of wave climate at target points or beach profiles, littoral transport calculation, run-up and flooding calculation, assessment of climatic change on beaches, etc).

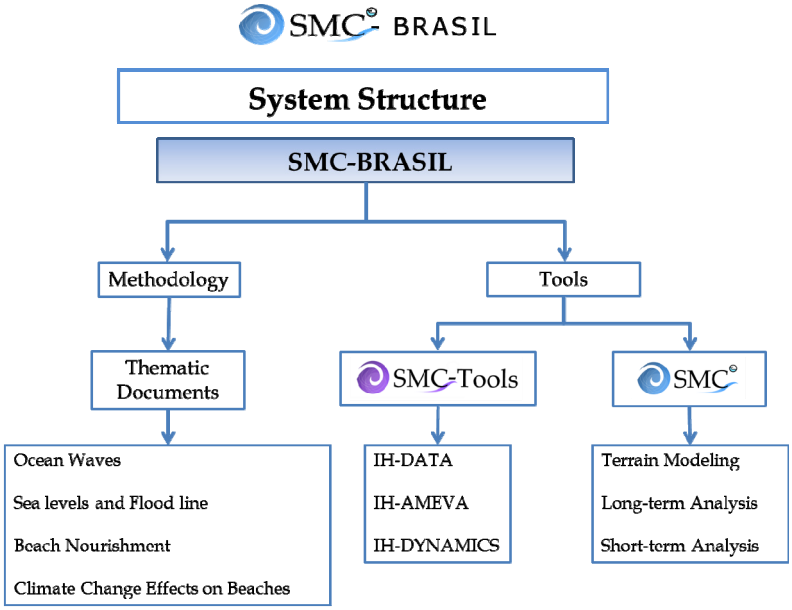

Figure 1. SMC-Brasil Structure.

SMC-TOOLS is structured in three sub-modules:

- IH-DATA stores the required databases to generate a SMC project: waves series in deep waters (Global Ocean Waves, Reguero et al., 2012), coastal wave series (Downscaled Ocean Waves, Camus et al., 2011), astronomical tide series (Global Ocean Tides), storm surge series (Global Ocean Surges, Cid et al., 2014) and bathymetries,
- IH-AMEVA which allows to process all data series in different time and spatial scales and to characterize them from a statistical point of view (wave rose, storm regime, mean regime, etc).
- IH-DYNAMICS which permits to: (a) transfer wave climate from database towards the coast. Automatic algorithms have been developed using wave spectral propagation models to transfer waves to the shoreline (Camus et al, 2011), (b) estimate coastal flooding considering astronomical-tides, meteorological tides and wave run-up which will help in the elaboration of flooding maps in coastal zones, (c) calculate sediment transport in the study area using the local wave climate (d) evaluate the mean energy flux along the coast or near harbors for different time scales(seasonal, multiannual, etc), information relevant to study beach stability; (e) Assess climate change effects and impacts on beach morphodynamic by studying long-term trends of local dynamics (sea level, wave height, flood line, changes in wave height and direction) and their influence in shoreline retreatment and shoreline orientation and coastal flooding.

SMC includes numerical tools to analyze beach stability at different scales based on the time series dynamics previously described. It is composed of different sub-modules: (1) short-term module which includes numerical evolution morphodynamic models in plan (COPLA-2DH) and profile (PETRA-2DV), (2) medium- and long-term module which allows the analysis of seasonal changes and the

system response on a scale of years to decades; (3) the terrain modeling module which permits to manage different bathymetries and merge them with different elements (beach nourishments, coastal structures, etc), which is useful to analyze different proposed alternatives.

THE MASSAGUAÇU EROSIONAL CASE STUDY

SMC-Brasil has been successfully applied to study several problems along Brazilian coast (erosion, inundation problems, etc) and propose different alternatives to reduce the problems. In order to show some skills of SMC-Brasil, some results obtained in the study of Massaguaçu Beach are shown next.

Massaguaçu Beach (North Coast of Sao Paulo) is 7.5 km long with an orientation SE-S. This beach presents an important erosion problem mainly in the central part. Waves on its approximation to the beach interact with several islands (see Fig. 2), which makes it an interesting case to be studied with SMC-Brasil.

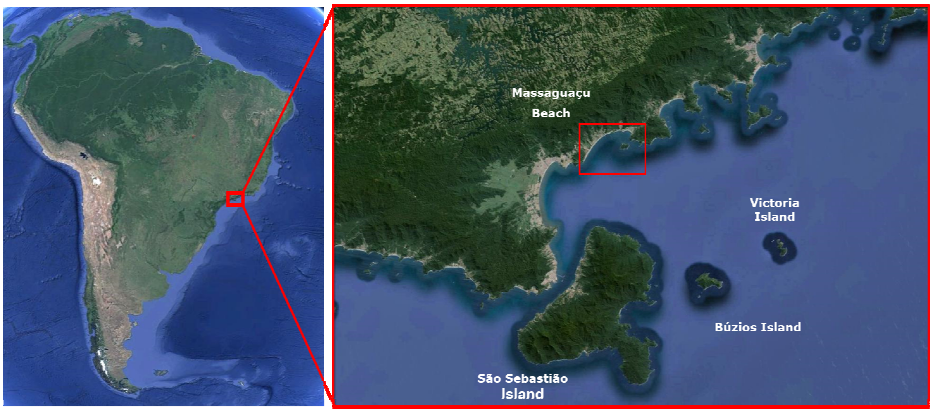

Figure 2. Location of Massaguaçu Beach.

Several studies and actions have been carried out in this area to solve or reduce the problem without good results. Applying methodologies implemented on SMC-Brasil has been possible to understand the causes of the erosion problem, and several solutions have been proposed.

The information about bathymetry and wave climate data needed to carry out this study were obtained from IH-DATA. Bathymetry database contains offshore bathymetry obtained from nautical charts. This bathymetry was enhanced with local bathymetry obtained from Instituto Oceanográfico da Universidade de São Paulo.

The analysis of wave climate obtained from SMC-Brasil (IH-DATA) database reveals that almost the 85% of the offshore waves in the study area come from the sector E-S and the most energetic waves come from sector S-SSE.

This offshore wave climate was propagated toward the coast applying the IH-DYNAMICS tools. Results reveal islands have an important influence in wave propagation and current system along the beach. They generate some wave concentration areas and some protected areas along Massaguaçu beach and, as a consequence, a current pattern that explain the erosion problem in this beach:

- At the south part, currents present different directions depending on the wave direction and there are transversal currents.
- At the central part, there is a reduction of current magnitude and there is an inflection point.
- At northern part, currents increase and they are in general toward the North-East, except at the end of the beach, where a rip current is generated for some wave directions.

These wave dynamics and currents generate a net sediment transport from the central part of the beach toward the extremes of the beach, with a high littoral drift toward the North, generating a “hot spot” in the middle of the beach. This area has had erosion problems historically.

This erosion problem has been confirmed by checking the beach stability using SMC-Brasil. This system permits to fit the planform of Massaguaçu Beach to different equilibrium planform models by knowing the wave climate at control point and the energy flux direction. This analysis reveals that sediment transport toward the North generates retreat of shoreline in central part of the beach.

With the aid of SMC-Brasil several solutions to the erosion problem have been proposed. SMC-Brasil permit to design, analyze and evaluate different configurations as construction of detached breakwaters, jetties, beach nourishments, etc. This makes SMC-Brasil a suitable system to help in the coastal management and decision-making process.

CONCLUSION

SMC-Brasil is a user-friendly system specifically designed to assist coastal designers and managers in the analysis of marine and littoral dynamics to understand the changes in coastal caused by those dynamics. SMC- Brasil also includes hourly reanalysis databases, methodologies and tools to analyze local dynamics and its response on the coast in the different time scales, including an estimation of climatic changes in the future. These characteristics make this system suitable for many coastal engineering applications, such as sediment transport studies along the coast, beach stability, flooding assessment, etc analysis, in order to propose coastal works to reduce the problem.

SMC-Brasil has a dynamic design and allows the incorporation of future new databases, morphodynamic models and the implementation of new applications to help in the development of coastal projects and the management of the coast.

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