Applied Ocean Research 56 (2016) 119–131

Contents lists available at ScienceDirect

Applied Ocean Research

journal homepage: www.elsevier.com/locate/apor

Construction of synthetic ocean wave series along the Colombian Caribbean Coast: A wave climate analysis

Andrés F. Osorio[a,*], Rubén D. Montoya[b,a], Juan Carlos Ortiz[c], Daniel Peláez[a]

[a] OCEANICOS Research Group, Universidad Nacional de Colombia, Sede Medellín, Colombia
[b] GICI, GICAMH Research Groups, Universidad de Medellín, Medellín, Colombia
[c] Geosciences Area, Physics Department, Universidad Del Norte, Barranquilla, Colombia

ARTICLE INFO

Article history:
Received 13 April 2015
Received in revised form
23 November 2015
Accepted 5 January 2016
Available online 18 February 2016

Keywords:
Waves
Synthetic series
Caribbean Sea
Hurricane waves
Colombia

ABSTRACT

In this paper a methodology is applied to generate synthetic wave series during mean and extreme conditions. An analysis is carried out that describes mean and extreme wave behavior for several climatic conditions along the Colombian Caribbean Coast. During mean conditions, the most energetic ocean waves are observed during the DJF season for both ENSO phases (El Niño and La Niña) for most of the Caribbean Sea. During the Niño years, there is a reduction in the speed of the north-east trade winds and their associated waves, but only in the DJF and MAM seasons. However, during the JJA season, this situation is reversed with the highest values occurring during El Niño and low values appearing during La Niña. Toward the east around the Guajira region, this general pattern is shown to change significantly. For extreme conditions, the results show a significant influence of extreme events toward the northwest, around La Guajira and the insular zones of San Andres and Providence when compared with other regions along the coast. All of these results (including the synthetic wave series) provide a design and management tool for the successful implementation of any coastal project (scientific or consulting) in Colombia.

1. Introduction

The world's climate is very changeable. This affects the conditions in coastal areas, impacting engineering applications like port design and industries like fishing and tourism. Issues such as sediment transport and erosion can vary along a specific coastal area.

For the Colombian Caribbean Sea, the relationship between large scale climatology and ocean waves is still not properly understood. This problem is combined with a lack of highly accurate long-term information. The wave climate information currently available is still limited, as it is based on visual observations and therefore does not have a suitable spectral, spatial and temporal resolution. Furthermore, information is not present for extreme conditions. Information from agencies that monitor the climate is available, but some of it does not contain all of the wave parameter details or a high enough resolution for specific coastal areas. Although the wave information provided by satellites allows for the observation of vast areas, it does not permit high temporal resolution data to be obtained for a given point (two data values every 10 days) or the directional wave spectrum to be estimated. The number of buoys moored in deep water near the Colombian coast per kilometer of shoreline is very poor when compared to the number of buoys in the waters of other countries. As a result, repercussions have emerged from an engineering and scientific point of view, such as inadequate designs of coastal structures, poor understanding of coastal dynamics and even loss of human life, among many other issues.

The above information highlights the importance of this research for the Colombian Caribbean coastal area, considering that Colombia has eight main port zones, seven of which are found on the Caribbean coast. These ports handle ninety percent (90%) of the country's imports and exports. The principle mainland ports and tourism areas are located in La Guajira, Santa Marta, Barranquilla, Cartagena and the insular region of San Andres and Providence, which along with the other cities that form part of the Caribbean, produce about 16% of the country's gross national product (GNP). In terms of biodiversity, the Colombian Caribbean has more species than other regions of the country.

Due to the lack of wave information with the required temporal and spatial resolution in the Colombian Caribbean, it is necessary to resort to other sources of data. One possibility is to use synthetic or modeled data, obtained through numerical models that employ wind fields from the past, which can obtain wave information by using reanalysis techniques (Hindcast). These types of analyses have been previously developed for specific cases in the

* Corresponding author at: Universidad Nacional de Colombia, Sede Medellin, Carrera 80N° 65-223 (Bloque M2). Of 209, Medellín, Colombia. Tel.: +57 4 4255142: fax: +57 4 4255100.
E-mail address: afosorioar@unal.edu.co (A.F. Osorio).

http://dx.doi.org/10.1016/j.apor.2016.01.004
0141-1187/

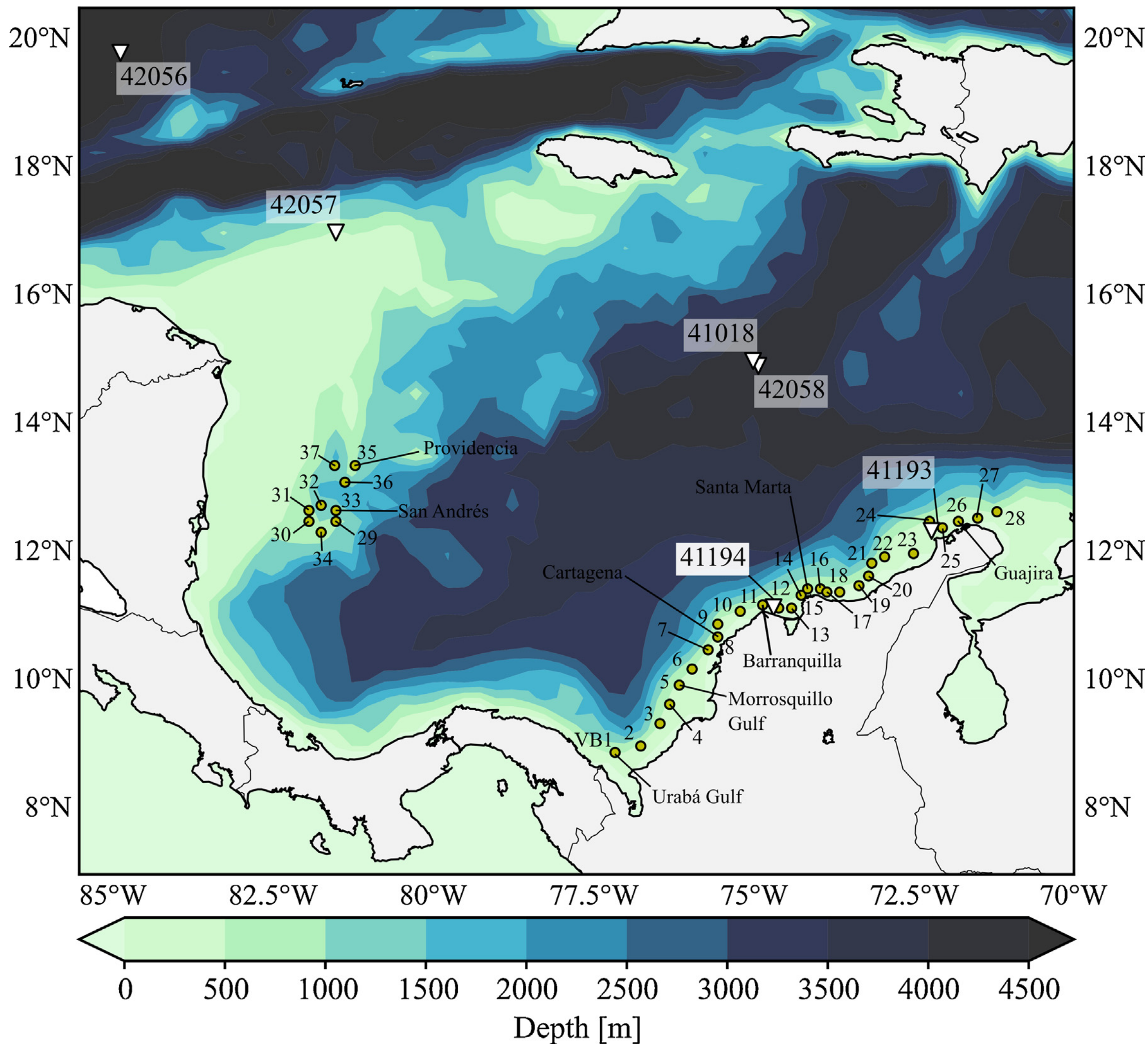

Fig. 1. Location of the virtual buoys (VBs): instrumental buoys used for calibration and validation and to provide bathymetric information for the Caribbean Sea.

Colombian Caribbean, for both mean fields [1–4] and extreme fields [5–7]. However, such approaches do not set modeling parameters that include the physical process of each condition in order to integrate time series data. Furthermore, they do not investigate the behavior of ocean waves along the Colombian Caribbean coast as whole. Around the world, several authors have performed wave climate analysis based on numerical models [8–13], among others.

Large-scale phenomena such as the El Niño/Southern Oscillation (ENSO), among others, affect the characteristics of the Colombian Caribbean climate on different spatial and temporal scales, which includes short-term extreme events such as hurricanes. Therefore, it is necessary to apply new knowledge and technology currently available to reconstruct a historical wave database for the Colombia Caribbean based on numerical modeling that considers the dynamics of interactions between the atmosphere and the ocean for these climatic conditions. The aim is to provide the necessary information to carry out research, develop infrastructure and make reliable decisions regarding coastal and ocean areas. This paper is organized as follows: Section 2 presents a description of the study area, Section 3 gives a description of the general methodology and the data employed, including a description of the blended methodology and calibration process, Section 4 performs a comprehensive analysis of wave climate along the coast, and the last section gives the summary and conclusions.

2. Study area

Since the main aim of this study was to construct reliable wave data for engineering applications in the Colombian Caribbean, 37 sites for Virtual Buoys (hereafter VBs) along a belt that encompasses the whole coastline including the island of San Andres were selected (Fig. 1). This allowed information to be generated close to urban centers of interest, and at the same time achieved an adequate coverage of the coast with a maximum separation of approximately 65 km between the VBs. VBs were selected in deep waters, between 100 and 200 m in depth (oceanic criterion for typical wave periods in the Colombian Caribbean) and the number (37) of VBs was sufficiently dense to obtain reliable reference information from the most important sites of interest along the coast.

Some authors [14,15] describe four climatic seasons in the Caribbean Sea: the main dry season December–January–February (DJF), the secondary wet season March–April–May (MAM), the brief dry season known as the "veranillo" June–July–August (JJA) and the main wet season September–October–November (SON). However, it is valid to talk about only two main climatic periods: (i) the dry season and (ii) the wet season. The dry season is from December to April and is characterized by low precipitation and the predominance of synoptic wind (or trade winds) that blow from the north/northeast. The rainy (or wet) season covers the period from