Prediction of Offshore and Nearshore Storm Waves Using a Third Generation Spectral Wave Model

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ABSTRACT

The third generation wave model TOMAWAC has been applied to hindcast typical stormy events which reached the Atlantic French coasts. Comparison with measurements at sea demonstrates that TOMAWAC is a reliable tool for coastal and offshore engineering applications. The model was also used through a specific methodology whose main purpose is to create a numerical Atlas describing the wave extrema parameters which can be expected at any given location along the shore. Some ways to improve the methodology used finally given

KEY WORDS: waves, model, storm

INTRODUCTION

For several years, the Laboratoire National d'Hydraulique (LNH) of Electricité de France (EDF), in collaboration with the French Ministry of Equipment, has been involved in the characterization of the French shore in terms of extreme wave climates and storm surges. Knowledge of the largest waves associated to typical storm events, and extreme wave climates which can be expected at any sea location, is of great relevance for both offshore and coastal engineering, for instance: design, stability and implementation of oil/gas platforms or pipelines (Moshagen et al., 1997); harbour design; breakwater stability; shore protection. Numerical modelling is one of the ways to obtain this information. The third generation wave model TOMAWAC, developed at LNH (Benoit et al., 1996 and 1997a), solves the wave action balance equation expressed on finite element grids, with the addition of source/sink terms accounting for the main physical processes of concern: wind-induced wave generation, energy transfers through non-linear interactions, white-capping dissipation, depth-induced breaking and bottom friction. First section is devoted to a short description of the basic theoretical aspects used by TOMAWAC. TOMAWAC benefitted from advances in research made by the WAM group (Komen et al., 1994), and has been validated against reference test cases. TOMAWAC is able then to provide the main wave spectral parameters for any offshore location and coastal zone as long as the product "k d" remains greater than 0.5, where k and d are the mean wave number and the water depth at rest respectively.

We applied TOMAWAC in two approaches. First, we hindcasted 2 different typical storms which reached Europe from the Atlantic Ocean or from the North Sea, respectively in October 1987, and November 1991. These two storms are characterized by different evolution in time and space. The second section presents the methodology used for this purpose. This was done using two nested finite element meshes (a coarse mesh and a fine one). The comparison of numerical results with some available measurements at sea (wave buoys) is also presented, highlighting the reliability of the TOMAWAC results for real applications. The aim of the second approach is to undertake the constitution of an "Atlas" of wave extrema along the French Atlantic and Channel coasts (third section). The method consists of exposing the oceanographic basin to a uniform and steady wind, and looking at the shore response for different wind speeds and directions. Sensitivity of the extreme wave parameters to (i) boundary conditions to be prescribed and (ii) the need to account for sea level variations in shallow waters due to tidal forcing, is also investigated in this third section. A way to improve the methodology is discussed in last section, and will lead to further developments in the very near future.

THE TOMAWAC SPECTRAL WAVE MODEL: THEORETICAL ASPECTS

TOMAWAC is a so-called "third-generation" wave model, as it does not require any parameterization of the directional wave spectrum shape, but allows the directional spectrum to develop freely both in time and space under the different hydrodynamic processes concerned. TOMAWAC solves the wave action balance equation on a «finite elements type grid», even if the effective numerical method is based on the characteristics, assuming that waves propagate over a steady current:

$$\frac{\partial (BF)}{\partial t} + \frac{x}{\partial x} \frac{\partial (BF)}{\partial x} + \frac{y}{\partial y} \frac{\partial (BF)}{\partial y} + \frac{\partial (BF)}{\partial \theta} + \frac{\partial (BF)}{\partial \sigma} = BQ \quad (1)$$

with:
$$F(x, y, \theta, \sigma, t) \quad : \quad \text{directional wave variance spectrum}$$
$$\quad \text{in m}^2 \cdot \text{Hz}^{-1} \cdot \text{rad}^{-1}$$

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