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Statistical Behaviour of Directional Bound Long Waves

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The statistical behaviour of bound long waves is deduced from numerical simulations carried out starting from local spectra derived from deep-water directional spectra. The investigation refers both to the time and space domains, in the direction of the wave fronts, that is, alongshore if a normal attack towards a uniform beach is considered. The values of the heights, periods and front lengths of the bound long waves are obtained and compared to those of the nonlinear waves associated with the complete 2nd-order local spectra. The influence of the directional energy spreading is examined, which seems to affect the periods and lengths of the wave fronts more than the heights of the bound long waves. The numerical results of the analysis carried out in a coastal region and illustrated here with reference to field cases taken from Bowers (1992) show the following: The energy density of the bound long waves increases as the depth decreases, being, in any case, about 10% of the local energy density associated with the complete 2nd-order spectra; the spectral mean periods referring to the bound long waves exhibit an increasing trend in decreasing depths; and finally, the characteristic lengths of the wave fronts assume quite the same values whatever the depth. This last result suggests that the beach configuration induced by the bound long waves is affected by the features exhibited by the bound long waves in approaching the coastal region, which depend on the deep-water wave climate rather than the modifications experienced during their propagation shoreward.

INTRODUCTION

Bound long waves may be of great importance in influencing several coastal processes as sediment transport, harbour resonance, ship movements and oscillations in mobile structures (such as the mobile surge barriers planned for placement at Venice's lagoon mouths).

Long waves, also called infragravity waves, with typical periods ranging from 20 s to 200 s, have been observed in field data by several authors, such as Holman (1981), Elgar and Guza (1985), Okihiro et al. (1992), Bowers (1992) and Elgar et al. (1992).

The energy relevant to the range of the long waves may be a significant portion of the total energy in the wave field, especially in shallow water; Herbers et al. (1992) found that it may reach up to 30%.

With collinear free waves, relevant to unidirectional sea states, the bound low frequency waves are 180° out of phase with the wave groups, and their throughs occur beneath the high waves in the groups (see e.g. Longuet-Higgins and Stewart, 1962, and Okihiro et al., 1992), while with directional deep-water sea states the sea surface elevation coupling coefficients which give rise to the bound long waves change sign, and the phase tends to 0°. As the directional spread increases, bound waves have progressively shorter spatial scale in both crossshore and alongshore directions. If the spread is very large, the bound waves may be shorter than the original free waves (Okihiro et al., 1992).

Recently, Reniers et al. (2004), by taking into account the effects of directional spreading, carried out a numerical investigation also related to the influence of infragravity waves on the morphodynamic response of a nearshore beach, noting that these waves do play a role in the transport of sediment.

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Several authors, such as, for example, Bowers (1992), give information on the energy fraction and on the spectral form of the bound long waves, but no research has been carried out regarding their statistical behaviour. One of the purposes of this paper is to investigate this last aspect, noting that some results have already been given by Gentile et al. (2004).

The bound long waves are derived here on decreasing depth by adopting a nonlinear spectral propagation model proposed by Rebaudengo Landò et al. (1999); this takes into account the shoaling, refraction and saturation processes with reference to straight and parallel, slowly varying bathymetry, as usually assumed in approaching an alongshore uniform beach. A normal wave attack is considered.

Numerical simulations are carried out to obtain several time histories of the surface elevation from which the heights and periods of the bound long waves are evaluated by the zero-upcrossing approach. Examined are the statistical behaviour of those waves and that of the relevant characteristic waves (such as mean, significant, one-tenth and so on). Comparisons are made by considering the waves, called nonlinear random waves below, which take into account the primary waves and the secondary long and short waves deduced from the local spectra.

Numerical simulations are also carried out in the space domain in the alongshore direction in order to quantify the length of the wave fronts of the bound long waves, which may be of importance in the development of a beach configuration.

The case study proposed here is related to the deep-water wave climate specified with reference to field data from Bowers (1992), noting that the deep-water mean JONSWAP spectrum (Hasselmann et al., 1973) is adopted, and that both frequency-dependent and frequency-independent directional spreading functions are assumed.

ANALYTICAL DEVELOPMENT

Nonlinear Spectral Propagation Model

The model is based on the deep-water directional spectrum $S_o(f, \phi_o, \phi_{mo})$ associated with a deep-water frequency spectrum