

CASCADE FREQUENCY DOWNSHIFTING IN THE WAVE SPECTRA IN THE COASTAL ZONE

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INTRODUCTION

When waves propagate in the coastal zone they are transformed due to nonlinear, dissipative and breaking processes. The evolution of the wave spectrum represents the change of the parameters and frequency composition of the waves. The wave transformation leads to changing wave parameters, in particular the wave symmetry, which affects the direction and discharge of sediments. Nonlinear transformation is accompanied by the generation of higher and lower wave harmonics reflecting in wave spectrum as additional peaks. In addition, the backward wave energy transfer from higher and lower harmonics to the peak frequency also exist. There is the phenomenon of downshifting - a shift of the spectrum peak frequency to the low-frequency range often observed for waves on deep and shallow water (Fig.1). The main role of nonlinearity in frequency downshifting for deep water waves was shown (Shugan et al., 2019) Many researchers suggest that downshifting in the coastal zone may be due to energy dissipation in the higher frequency part of the spectrum during wave breaking. But there are no detailed experimental or theoretical studies and descriptions of this. How does peak frequency downshifting depend on the initial waves parameters, wave spectrum width and amount of dissipated wave energy during wave breaking?

The variability of the main wave period due to the downshifting process is important for coastal engineering since many calculations assume a constant wave period. Therefore the main aim of this study is to find out details and peculiarities of downshifting of peak spectrum frequency depending on initial wave and spectrum parameters during wave propagation over mild sloping bottom and investigate the role of nonlinear and dissipative processes in frequency downshifting process. The data of the field and laboratory experiments will be used for analysis.

LABORATORY EXPERIMENT

The data of laboratory experiment were used for spectral and bispectral analysis. The laboratory experiment was carried out in the middle size flume of Tainan Hydraulics Laboratory (Tainan, Taiwan). The flume is 200 m long, 2 m width and 2 m depth. During experiment 21 capacity type wave gauges were installed for synchronous measurements of waves with sampling frequency 50 Hz. The transformation of initially bichromatic and monochromatic waves was studied.

RESULTS

Performed investigation has shown that cascade downshifting (with discrete step on frequency) of the wave spectrum peak frequency for waves propagated above mild sloping bottom exists in the field and laboratory experiments. Depending on initial wave

parameters a few cascades can be observed. In the previous studies of waves in shallow and intermediate water depth only one step of frequency downshifting was reported.

Bispectral analysis has shown that cascade downshifting occurs due to nonlinear processes and difference triad interactions between a) main frequencies of wave spectrum and infragravity frequencies and b) frequencies of second harmonics and the new forming low-frequency peak in the main frequency range. The contribution of the frequencies of the second harmonics in the frequency downshifting process was shown for the first time. According to laboratory experimental data, cascade downshifting is determined both by frequency step of downshifting and the number of cascades. The frequency step of downshifting is equal to spectrum width. The wider the initial spectrum of waves, the less the numbers of cascades are observed. Wave energy dissipation due to wave breaking is not a main reason and has no direct influence on frequency downshifting. A decrease of wave height can also be caused by downshifting. Influence of frequency downshifting on sediment transport, and on spatiotemporal homogeneity of wave field was discussed.

The variability of the main wave period due to the cascade downshifting is important to take into account in coastal engineering at calculations by formulas including wave period.

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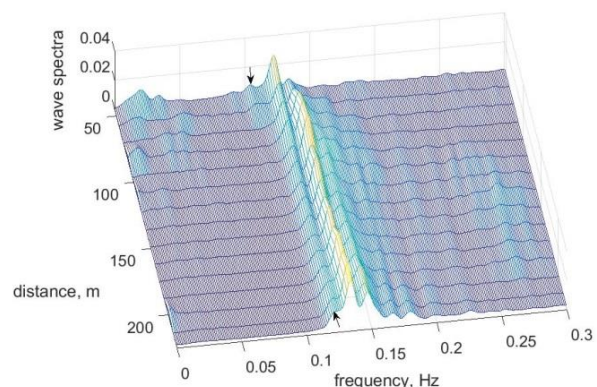


Figure 1 - Example of waves spectra evolution with peak frequency downshifting, field experiment Skorpilovtsy, Black Sea, 28 September 2007. The waves propagate from 222 m to the shore (0 m). The formation of new low frequency peaks are marked by arrows.

REFERENCES

Shugan, Kuznetsov, Saprykina et al. (2019): The Permanent Downshifting at Later Stages of Benjamin-Feir Instability of Waves. *Pure and Applied Geophysics*, 176(1), 483-500.