NONLINEAR ASPECTS OBTAINING OF ORBITAL VELOCITIES FROM WAVES RECORDS

Sergey Kuznetsov, Shirshov Institute of Oceanology, kuznetsov@ocean.ru
Yana Saprykina, Shirshov Institute of Oceanology, saprykina@ocean.ru

INTRODUCTION

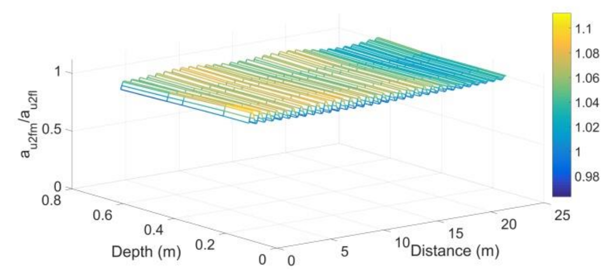
Waves are the main factors determining the dynamics of shelf and coastal zones. Therefore, recently, all over the world, much attention has been paid to global monitoring measurements of wave fields using remote sensing, lidar and satellite technologies. However, simpler methods of wave measurement using pressure sensors and submerged current meters are widely used to solve local problems. According to the linear theory of waves, the measured velocities and pressure can be recalculated into free surface elevations and in relation to each other using the dispersion relation of the linear wave theory. This makes it possible, for example, to measure free surface elevations and, based on these, to obtain velocities at different levels. Of more practical interest is the determination of free surface elevations (waves) from pressure data, because pressure gauges are easier to install for measurements. The accuracy with which records of orbital wave velocities are obtained from measured free surface elevations is very important since, sediment transport in coastal zones is determined by the asymmetry of near bottom wave velocities. During nonlinear wave transformations, multiple higher and lower wave harmonics arise. The generated second harmonic does not satisfy the dispersion relation of the linear theory. This leads to the simultaneous occurrence of waves with different wavenumbers at the same frequency. This paradox is known as the simultaneous existence of free and bound waves (Kuznetsov, Saprykina, 2021). Many researchers noted that the transfer function for obtaining the velocity records from free surface elevations for the second harmonics differs from the linear theory. However, a detailed study of the contribution of free and bound wave components to velocities and pressure, from the point of view of their relations with free surface elevations and variation with depth, has not been carried out. Therefore, the main purpose of our work is to study the relationship between free surface elevations and orbital velocity measurements at different distances from the bottom using the data from a laboratory experiments and numerical simulation to evaluate the contribution of free and bound waves.

EXPERIMENTS AND METHODS

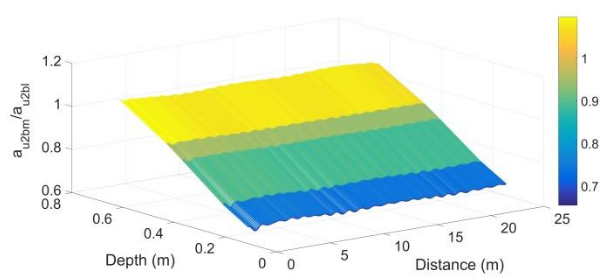
The laboratory experiments were conducted in the wave flumes of Yildiz Technical University (Istanbul, Turkey) and consulting company “Gidrotechnika” (Sochi, Russia). The flumes were 20 m in length, 1 m in width, and 1 m in depth. Waves measurements were taken using capacity-type wave gauges. To measure 3D water velocity fluctuations the high-resolution acoustic Vectrino Profiler (Nortek) was used. For a detailed study of the relationship between the free surface elevations and the velocity, a numerical simulation was carried out using the SWASH model. The methods of spectral and cross-spectral analysis were used.

RESULTS

Analysis of experimental and modelling data reveals that the simultaneous existence of free and bound waves, along with the difference in the laws of their damping and the unknown law of damping of bound harmonics with depth, can be the reason for the inaccurate obtaining of velocities at different depths from the free surface elevations. However, by taking into account the damping of higher harmonics with depth, their contribution to the reconstructed velocities will decrease, making it possible to use the linear theory to describe the velocity field near the bottom. It should be noted that in the case of restoring the free surface elevations from the pressure records at the bottom using the linear wave theory, large errors can occur due to ignorance of the attenuation law of bound waves and neglect of the joint contribution of free and bound waves. To accurately convert free surface elevations into velocity, pressure, and vice versa, further development of a completely nonlinear theory of waves at a finite depth is necessary. Additionally, the transfer function also exhibits spatial fluctuations related to changes in the wave number due to nonlinear processes (Fig.1).



(a)



(b)

Figure 1 – Comparison of the transfer functions for the free (a) and bound (b) second harmonic with the transfer function of the linear wave theory in modeled waves.

REFERENCES

Kuznetsov, Saprykina, (2021). Nonlinear Wave Transformation in Coastal Zone: Free and Bound Waves. Fluids, 6, 347.