Geophysical Research Abstracts
Vol. 21, EGU2019-1499-1, 2019
EGU General Assembly 2019

The wave-mean current problem with a continuous near surface solution

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Commonly applied wave propagation theory employs a velocity potential function obtained for averaged mean sea levels (MSL). The basic linear wave-current problem is composed of a superposition of the velocity potential of finite amplitude waves without current and the velocity potential of a constant current (U_0x). Nevertheless, such a superposition poses an inherent problem as the current's potential fits the boundary conditions of the MSL but not the one of the changing surface. The required adaptation to the changing surface is of linear order in wave slope (ka).

In the common approach, even with no ambient current, the dynamic and kinematic boundary conditions are expanded around the MSL to the first order using Taylor approximation. This process does not provide an accurate behavior in the near surface region (see [1]). For the wave current problem, this limitation poses even a higher discrepancy as the current itself also oscillates in the upper layer in order to account for the changing surface elevation. In order to account for this discrepancy and understand this fundamental wave-current interaction problem, this work presents a continuous solution for the wave and current velocity potential function given for a 2D curvilinear $\{\xi\ ,\ \zeta\}$ coordinate system that follows monochromatic waves in the upper layer, and decays to $\{x\ ,\ z\}$ coordinates with depth. Unlike the traditional approach, the linear problem is solved without a vertical Taylor approximation but rather with a longitudinal one. This suggested solution solved analytically and considered to be more realistic in the near surface as it agrees better with the continuous nature of the flow. It provides an alternative to Airy solution without current and is generalized to account for a mean wave-current problem.

Changes in other basic properties of the flow such as Stokes drift and Lagrangian orbital velocities are also discussed. The importance of this fundamental model to interpretations of wave-current measurements using Acoustic Doppler Current Profilers and Acoustic Doppler Velocimeters will also be discussed.

References

[1] P. B. Smit, T. T. Janssen, T. H. C. Herbers, P. B. Smit, T. T. Janssen, and T. H. C. Herbers. Nonlinear Wave Kinematics near the Ocean Surface. *Journal of Physical Oceanography*, 47(7):1657–1673, 2017.