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A numerical wave-maker for internal solitary waves with timely updated mass source/sink terms

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Abstract: On the basis of the two-dimensional Navier–Stokes equations, a new numerical method is proposed to generate internal solitary waves (ISWs) of expected parameters by adding a source term above the interface and a sink term below the interface into the continuity equation. Fluxes between the source and the sink are balanced to assure mass conservation, and the source/sink regions (the spatial windows over which the sink/source terms are placed) are adjusted as functions of time with the interface motion. Thus, the nonphysical trailing waves can be eliminated, which makes it easy to assure the prescribed ISW parameters. Moreover, a new layout is presented to avoid the difficulty of sizing and positioning the source/sink region, which has been proved to be an intrinsic drawback of the traditional mass source method. Numerical experiments are performed to validate the proposed method by analyzing the wave displacements and vertical profiles of velocity fields. It is shown that the numerical waveform remains stable with much less trailing waves than previous methods, and the numerical results are in good agreement with theoretical and experimental results. In addition, through sensitivity analysis, a reasonable method to determine the width of source/sink region is recommended.

Keywords: internal solitary waves; numerical wave generation; mass source term method

0. Introduction

Internal solitary waves (ISWs) are gravity waves that typically occur in stratified fluids because of the natural density stratification arising from salinity and temperature variations. A large number of observations showed that ISWs occur frequently and exist widely in most of the world's oceans [1]. There are plenty more applications of ISWs such as parameterizing their role in continental shelf energetics, their impact on marine ecology and water quality, their influence on seafloor morphology, and their implications for underwater acoustics. Specifically, ISWs have resulted in severe impacts on operation of offshore engineering structures [2]. With regard to deep-sea oil and gas exploration, ISWs have become a fundamental environmental issue, which should be considered in engineering design [3].

A two-layer representation of the ocean density stratification is a conventional approximation to study ISWs both analytically and numerically [4]. Nonlinearity and dispersion are the two fundamental mechanisms that govern the physics of ISWs. In general, nonlinearity tends to steepen a given waveform during the course of its evolution, while dispersion has the opposite effect and tends to

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