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Modelling Wave Trains from Internal Solitary Waves in South China Sea

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ABSTRACT

Internal solitary waves usually transform into an internal wave train when propagating through the continental shelf/slope. However, such phenomenon is rarely taken into account in previous design of marine structures. This paper aims to construct an evolution model to describe the evolution of internal wave trains. To be specific, in consideration of various influential factors, such as benthic topography, friction, dissipation, et al., a mathematical model is built to describe the evolution of wave trains and numerical experiments are carried out to validate the method by analyzing the leading internal wave and the induced velocity fields. It is shown that the numerical results of the wave train displacement and the velocity fields are in good agreements with the observational data in South China Sea. In the meantime, the sensitivity of dissipation and friction to the model is discussed.

KEY WORDS: internal wave train; dissipation coefficient; friction coefficient; velocity field.

INTRODUCTION

Internal solitary waves propagating over underwater topography, such as a sill or continental shelf/slope can produce internal wave trains. Specific to South China Sea (SCS) , these wave trains propagate westward across the Luzon Basin to South China Sea shelf break, and the corresponding surface expression has been detected with satellite synthetic aperture radar (SAR)(Liu et al., 1998). Many observations showed that internal wave trains occur frequently and exist widely, which has resulted in obvious impacts on the operation of offshore structures. For instance, the investigation of (Xu et al., 2013) has shown the impact of internal solitons on offloading system, and operations need to be assessed during the design of FLNG in soliton active area.

As the foundation for assessing the hydrodynamic action between internal wave trains and floating structures, the characteristics of internal soliton trains have been studied preliminarily by far (Liu et al., 1998). However, many issues are not yet clear. First, the factors such as dissipation, shoaling, and friction play a role during internal soliton evolution. But previous scholars have different opinions about which factor should be added into the Korteweg-de Vries (KdV) equation, which is one of the most popular equations to analytically describe internal solitary waves. Besides, the comparisons are very few between numerical results (especially induced velocity fields) and the observational data from actual sea areas. Finally, selecting the coefficients of dissipation and friction are often subjective due to the lack of clear criterions. Thus, it is necessary to discuss the sensitivity of numerical model to the two coefficients.

In the present paper, we aim to develop a mathematical model to describe the evolution of internal wave trains in consideration of various influential factors, such as benthic topography, friction, dissipation, et al. In addition, the authors attempt to quantify model sensitivity to the coefficients of dissipation and friction based on in-situ data in South China Sea.

NUMERICAL METHOD

In Cartesian coordinates Oxz (the x axis lies at the interface of a two layer ocean and the z axis is opposite to the direction of gravity), we have added key factors (including the higher order nonlinear term, the shoaling effect, the dissipation and friction) into the KdV equation. The modified equation can be expressed as:

$$\frac{\partial\zeta}{\partial t}+c_0\frac{\partial\zeta}{\partial x}+\alpha\zeta\frac{\partial\zeta}{\partial x}+\beta\zeta^2\frac{\partial\zeta}{\partial x}+\mu\frac{\partial^3\zeta}{\partial x^3}+\gamma\zeta+\frac{\kappa}{\mu}\zeta|\zeta|-\frac{1}{2}\varepsilon\frac{\partial^2\zeta}{\partial x^2}=0 \quad (1)$$

where ζ is the waveform of internal solitons, the coefficients (c_0, α , μ) are identical to the ones in KdV equation, and β is the higher order nonlinear coefficient. The calculation formulas of those coefficients was obtained by Liu et al. (1998).

In Eq.1, κ , ε denote the empirical coefficient of the friction and dissipation respectively. Learning from the expression of (Holloway, 1997) the friction term are written as "k/ μ ".

The shoaling coefficient γ can be calculated by

$$\gamma=\frac{1}{4}c_0\frac{\partial h_2}{\partial x}\frac{h_1}{h_2(h_1+h_2)} \quad (2)$$

where h_1 (h_2) is the undisturbed thickness of the upper (lower) fluid layer.