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Editorial

Oceanic Internal Waves and Internal Tides in the East Asian Marginal Seas

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1. Introduction

Inertia-gravity waves or internal waves (IWs) are ubiquitous in the stratified, rotating ocean. These waves are present at all frequencies between the local inertial frequency and buoyancy frequency, sometimes including diurnal and semidiurnal tidal frequencies. The two types of low-frequency IWs that originate from atmospheric disturbances (such as sea surface winds) and ocean tides (e.g., interactions between barotropic tides and bottom topography) are near-inertial waves (NIWs) [1] and internal (or baroclinic) tides (ITs) [2]. The energy of low-frequency IWs at larger scales transfers to smaller scales at higher frequencies. Continuum-frequency waves provide an illustration of this principle, where the characteristics of nonlinear internal waves (NLIWs) or internal solitary waves (ISWs) show that they will ultimately break and dissipate. IWs are known to play a key role in the redistribution of heat, momentum, and materials via turbulent mixing, such as diapycnal mixing [3]. It is clear to researchers that IWs may affect local and global climates [4], biogeochemistry and biological productivity [5], marine engineering and submarine navigation [6], and underwater acoustics [7].

Despite decades of study on IWs in other regions, the scientific understanding of IWs in the East Asian marginal seas is lacking detail. There exists a need for greater clarity on the mechanisms that underlie wave generation, propagation, evolution, and dissipation. In this editorial, we introduce eight publications of this Special Issue [8–15]. The wave types and regional waters covered in this review include ISWs/NLIWs in the Bali Sea; ITs, NIWs, ISWs/NLIWs in the South China Sea; ISWs/NLIWs in the East China Sea; and NIWs in the East Sea (also known as the Japan Sea). We discuss and collate the combined findings, with the aim of improving the understanding of the physical mechanisms of IWs (specifically the characteristics that define wave generation, propagation, and/or acoustic impacts).

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2. Recent Findings in the East Asian Seas

The ISWs/NLIWs are a great threat to submarine navigation as discussed in [8]. In the early morning of 21 April 2021 (local time), the Indonesian Navy Submarine (KRI Nanggala-402) crashed to the seafloor. The authors of [8] analyzed the ISWs/NLIWs in and around the submarine wreck site in the Bali Sea. They surveyed satellite remote sensing data collected from 12 April to 21 April and found that the ISWs/NLIWs had travelled across the deep basin of the Bali Sea [8]. The pathway of the waves passed through the submarine wreck site and then shoaled onto the continental shelf (originating from the Lombok Strait).

Several papers have investigated the three types of IWs found in the South China Sea [9–13]. The study completed by the authors of [9] applied a general ocean circulation model to the ITs in the Luzon Strait. Their work showed the impact of fortnightly stratification variability (as induced by tide–topography interactions) on the generation of ITs. Their contribution has led to a better understanding of the energy transfer between barotropic and baroclinic tides and shown a lead–lag relationship between barotropic tidal forcing and maximum baroclinic response within the fortnightly tidal cycle.

Using hybrid coordinate ocean model re-analysis, the authors of [10] reproduced the NIWs induced by Typhoon Megi in 2010 in the South China Sea. Their results revealed that typhoon-induced NIWs could propagate to a depth of 1000 m. They found that the damping and modal content of typhoon-induced NIWs were site-dependent. The results of their modelling showed that the first three baroclinic modes dominated and damped quickly in the region near the typhoon track, while the e-folding time of typhoon-induced NIWs could be longer than 20 days and higher modes were enhanced several days after the typhoon passage.

The three studies published by the authors of [11–13] addressed high-frequency IWs, particularly ISWs/NLIWs at frequencies close to the buoyancy frequency in the South China Sea. The study published by the authors of [11] investigated the distribution and source sites of ISWs/NLIWs northeast of Hainan Island, using satellite remote sensing data and a wave-front propagation model. Their work identified two types of ISWs/NLIWs originating from the Luzon Strait, spaced at both semidiurnal (northern region) and diurnal (southern region) tidal periods. On 22 May 2011, northeast of Dong-Sha Atoll, the authors of [12] observed strong ISWs/NLIWs with unprecedently large velocities (a peak westward velocity of 2.94 m/s and a peak downward velocity of 0.63 m/s), as measured by shipboard velocity observations. They inferred the wave's amplitude (~97 m) from backscatter observations and propagation speed (1.76 m/s estimated theoretically and 1.59 m/s inferred from the satellite remote sensing data). In further work conducted in the South China Sea [13], the authors reported on the substantial influence of ISWs/NLIWs on underwater sound propagation and ambient noise. Their paper described a passive acoustic monitoring and warning method for the strong velocity induced by ISWs/NLIWs, given that the power spectra of noise generated by the waves at frequencies below 100 Hz was almost 20 dB higher than ambient noise.

The authors of [14] developed a method to estimate the propagation speed and direction of ISWs/NLIWs using shipboard underway and moored observations. Their work applied two methods to estimate propagation speed and direction: apparent observations from a moving ship using the Doppler shift method (measuring change in frequency relative to the distance of the waves from the ship), and the time lag method (observing the distance between two locations of the wave at different times). The authors developed an optimal approach that then was applied to two cases of ISWs/NLIWs as observed in the northern regions of the East China Sea in May 2015 and August 2018.

The work published by the authors of [15] utilized a 21-year-long dataset of moored observations in the southwestern region of the East Sea (the Japan Sea), and focused on the non-seasonal (intra-seasonal, interannual, and decadal) variability of NIW kinetic energy far below the surface mixed layer. Their results identified nine periods of relatively high (*period high*), and seven periods of relatively low (*period low*) NIW kinetic energy. The work statistically revealed that the NIW kinetic energies in specific years and decades were significantly higher than those in other years and decades, in association with mesoscale circulation—NIW kinetic energy was enhanced/favored under conditions of negative relative vorticity and strong total strain.

3. Conclusions

This Special Issue contributes to a better understanding of the types of IWs in the East Asian marginal seas. We paid particular attention to descriptions of the processes that underly the generation, propagation, and/or acoustic impacts of different IWs. However, further aspects of regional IWs remain poorly understood, including specific details on the generation, propagation, evolution, breaking, and dissipation of NIWs, ITs, continuum-frequency waves, and ISWs/NLIWs.

Continuing to advance the scientific knowledge of regional IWs will aid researchers and environmental managers in addressing many local and global concerns, including issues related to climate, biogeochemistry, biological productivity, marine engineering, submarine navigation, and underwater acoustics. We hope that this Special Issue will be of interest to researchers in these fields, and to those scientists who are continuing to work on the impacts of IWs in the East Asian Seas.

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