SURFACE/INTERNAL WAVES GENERATED BY AIR PRESSURE WAVES OVER SEABED TOPOGRAPHY

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INTRODUCTION

Tsunamis were widely observed when the large eruption of Hunga Tonga-Hunga Ha`apai volcano occurred in January 2022 (e.g. Tanioka et al., 2022). In the present study, numerical simulations were generated using a nonlinear shallow-water model of velocity potentials to study the fundamental processes of surface/internal wave generation and amplification by air pressure waves.

SURFACE WAVE EXCITATION

When an air pressure wave propagates over an abrupt change of water depth in the positive direction of the x-axis, the Proudman resonance (Proudman, 1929) creates three types of surface waves: a forced wave, transmitted free waves propagating in the positive direction of the x-axis in the shallower water, and reflected free waves propagating in the negative direction of the x-axis in the deeper water. For example, when the maximum amplitudes of the crests of the transmitted and reflected free waves were a_t = 0.083 m and a_r = 0.019 m, respectively, based on the linear shallow-water theory (Garrett, 1970), a_t = 0.093 m and a_r = 0.023 m from the computation using the present nonlinear model, so the nonlinear results were slightly larger.

AMPLIFICATION OF AN EXISTING SURFACE WAVE BY BEING PASSED BY AIR PRESSURE WAVES

Concerning the amplification of existing surface waves, when an air pressure wave catches up with an existing surface wave that is propagating as a free wave over an abrupt change in water depth, the amplified surface wave propagated in the shallower water. An existing surface wave which is propagating as a free wave over a sloping seabed was also amplified by being passed by air pressure waves.

Moreover, when air pressure waves travel over an abrupt change in water depth, the water surface profile of surface waves in the shallower water depended on both the interval of the air pressure waves and the phase of the surface wave generation process over the change in water depth. The surface wave amplitude in the shallower water increased, as the water depth of the shallower area was decreased and the Proudman resonance was further reduced.

SURFACE WAVE GENERATION DUE TO AN AIR PRESSURE WAVE TRAIN OVER A SLOPING SEABED

When an air pressure wave train with positive pressure travels over a sloping seabed, the amplification of surface wave crests propagating as free waves was controlled by leaving the forced water waves following the air pressure waves. Conversely, the amplitudes of surface wave troughs propagating as free waves increased.

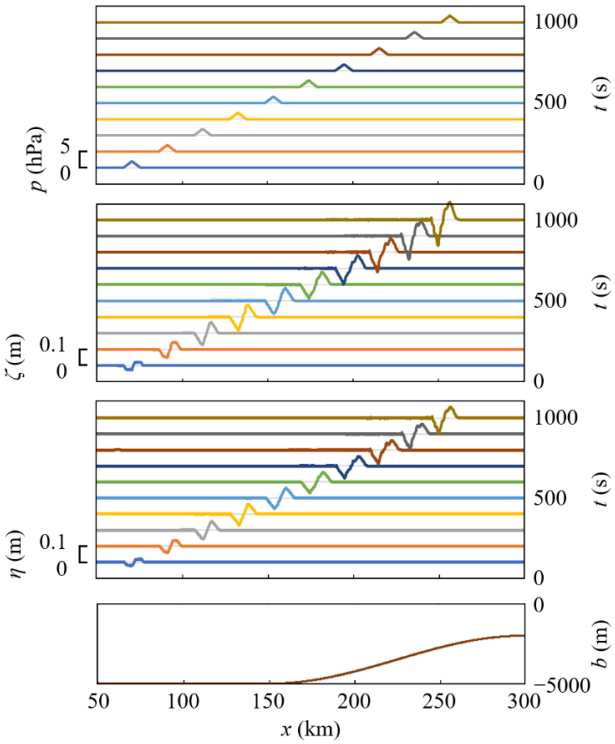

Figure 1 - Time variations of the air pressure distribution, surface profile, and interface profile every 100 s. The initial water depth in the upper layer, h_1, was 1000 m. The wavelength λ, maximum pressure p_m, and speed v_p of the air pressure wave were 10 km, 2 hPa, and 207 m/s, respectively.

SURFACE AND INTERNAL WAVES AMPLIFIED BY BOTH AN AIR PRESSURE WAVE AND SHALLOWING OVER A SEABED SLOPE

Figure 1 indicates that the crests and troughs in the surface mode were excited by the Proudman resonance not only at the surface but also at the interface, because the positions of the surface and interface were relatively close.

As indicated in the figure, the second peaks of water wave crests were generated when the air pressure wave speed approached the surface mode speed on the slope. Moreover, both the water wave crests and troughs were amplified by shallowing on the slope after they moved away from the air pressure wave. It should be noted that the shallowing effect requires water waves that are traveling as free waves apart from the air pressure waves that excited the water waves. The waves traveling as free waves after being excited by the air pressure wave may also be amplified by being passed by subsequent air pressure waves over topography (Kakinuma, 2022).

Furthermore, when the speed of an air pressure wave is

close to that of the internal-mode waves, internal waves in the internal mode were also excited. However, after the air pressure wave stopped, free surface waves in the internal mode hardly appeared, unlike the free internal waves.

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