PYCNOCLINE THICKNESS EFFECT ON INTERNAL WAVE BREAKING OVER A UNIFORM SLOPE

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INTRODUCTION

Internal waves play a significant role in the resuspension and transport of fine sediment adjacent to the sea bottom in the coastal region. Inall (2009) found the horizontal current and diffusion of mass due to the breaking of internal waves in the Fjord by using a fluorescent tracer. Internal waves have been shown to cause crucial mass transport and affect the ecological system. In particular, an internal solitary wave that progresses without changing the profile contributes to mass transport on a sloping bottom. Therefore, it is essential to clarify how an internal solitary wave breaks over a slope and transports mass. When pycnocline thickness is negligible in a two-layer fluid, an internal solitary wave breaking over a slope can be categorized into four breaker types by applying the latest classification based on wave slope, bottom slope gradient and an internal Reynolds number. Aghsaee et al. (2010) demonstrated that an internal solitary wave breaking over a slope can be categorized into four breaker types: surging, collapsing, plunging, and fission breakers using three-dimensional numerical simulations. They used wave slope and bottom slope gradient. However, some plunging and collapsing breakers were not appropriately categorized. Nakayama et al. (2019) solved the classification problem by introducing an internal Reynolds number based on the Korteweg-De Vries equation. However, it remains unsolved if this classification can categorize the breaking of an internal solitary wave under thick pycnocline conditions. This study uses numerical simulations to investigate the applicability of the classification under changing pycnocline thickness (Nakayama et al., 2021).

METHODS

We applied an object-oriented parallel simulator, Fantom, to analyse environmental fluid flows, employing a turbulence closure scheme option, a turbulence closure scheme (Nakayama et al., 2014; Nakayama et al., 2016; Nakayama et al., 2019). A free surface was applied to the top boundary, and a no-slip condition was given on the bottom and sloping boundaries, respectively (Figure 1).

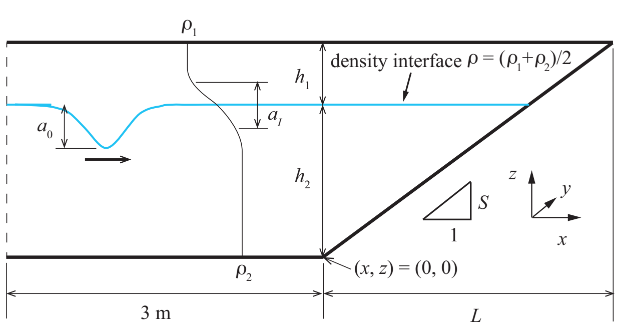

Figure 1 - Computational domain for analysing breaking of an internal solitary wave

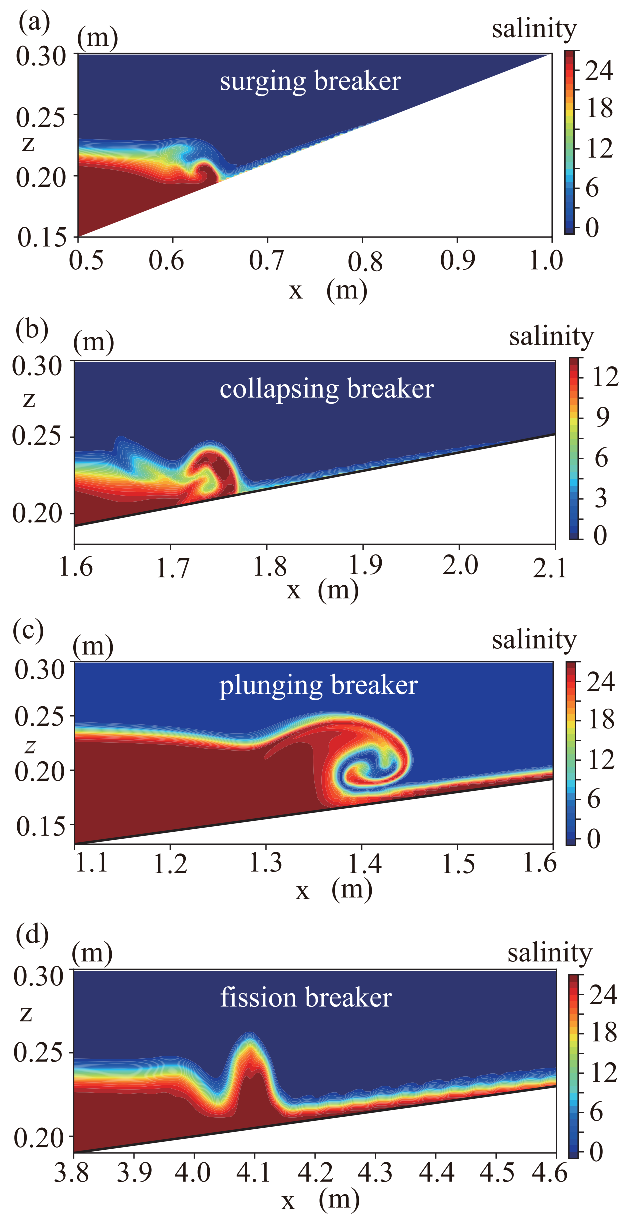

Figure 2 - Breaker types of an internal solitary wave. (a) Surging breaker. (b) Collapsing breaker. (c) Plunging breaker. (d) Fission breaker.

The hyperbolic-tangent function was used to give a vertical profile of density. A flat bottom length was 3m for all cases to generate a stable internal solitary wave. The horizontal and vertical grid sizes over the slope were 0.002m × 0.002m, and the maximum grid size was 0.02

m × 0.01 m adjacent to the flat bottom close to the wave generator. The spanwise single grid size was set at 0.02 m. 0.002 m grid size in the breaking zone is a factor of three compared to the Kolmogorov length scale. Eight different pycnocline thicknesses were given for each breaking type, 0.01 m, 0.02 m, 0.03 m, 0.04 m, 0.06 m, 0.08 m, 0.10 m, and 0.12 m. The kinetic and available potential energies were computed to estimate the effect of wave breaking on the wave reflection from a slope. Also, we investigated the applicability of categorising an internal solitary wave (Figure 2).

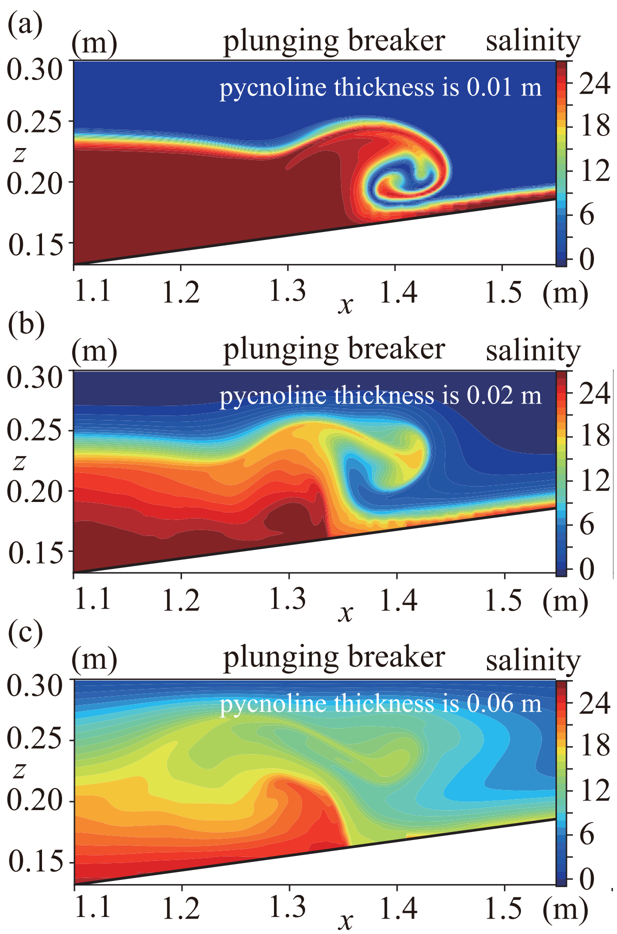

Figure 3 – Plunging breaker. Pycnocline thickness of (a) 0.01m, (b) 0.02m, and (c) 0.06m.

RESULTS AND CONCLUSION

We found that the classification can categorise all breaker types even when pycnocline thickness varies though a combined type of breakers was ignored in this study, such as collapsing-surging and collapsing-plunging breakers (Figure 3). In addition, potential energy was effectively transferred to kinetic energy due to breaking to a greater extent in collapsing, plunging and fission breakers than surging breakers. It resulted in higher energy reflection with surging breakers. Furthermore, thicker pycnoclines resulted in more significant energy loss and onshore mass transport due to internal solitary wave breaking. Energy loss based on an internal solitary wave becomes more significant for collapsing and surging breakers with increased pycnocline thickness due to an offshore shift in breaking points than the other breaker types. In contrast, the total energy loss is constant for plunging and fission breakers under changing pycnocline thickness.

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