Aspects of the spectral-element-based simulation of a model internal swash zone

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Abstract

This study builds on the companion presentation of *Diamessis et al* with a particular focus on a separate application. Specifically, we examine the design and implementation of a numerically simulated *internal swash zone* (ISZ) in a two-layer continuous stratification, in two-dimensions. An ISZ operates over slower timescales and is forced by longer internal wavelengths as compared to its surface counterpart (*Emery and Gunnerson 1973*). Moreover, such wave driven processes energize mixing of near-boundary and bottom boundary layer fluid and its along-isopycnal transport into the ocean interior, a phenomenon known as “boundary-interior exchange”.

The setup and computational investigations are motivated by an on-going field project which focuses on the internal swash zone in energized by the internal seiche in seasonally stratified Cayuga lake in NY state (*Schweitzer 2015*). The lake internal swash zones are an efficient proxy for equivalent physical processes driven by the lower-mode internal tide on the oceanic continental slope.

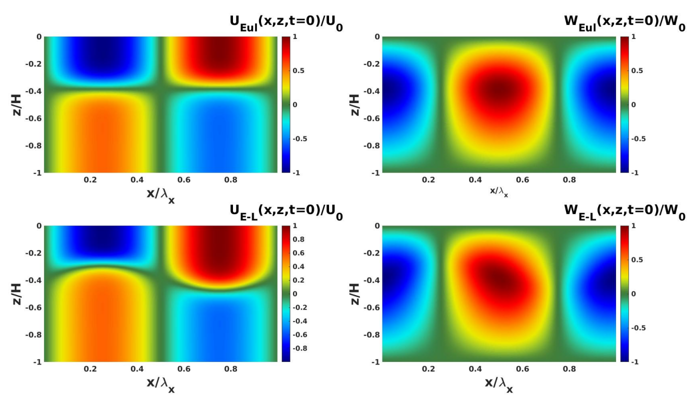

Figure 1: Comparison of the u,w velocity fields in the 2 approaches, top panels are Euler approach and bottom panels are Eulerian-Lagrangian approach

The domain is chosen sufficiently long compared to the incident wavelength to allow the wave to develop before impacting the downstream sloping boundary. An in-house-designed high-accuracy/resolution spectral-element-method stratified incompressible flow solver is used (*Diamantopoulos et al 2022*). The spectral elements method enables a robust wave propagation against numerical dispersion and a flexible resolution of breaking region.

In this presentation, a first topic of focus is the implementation of robust wave-generating boundary conditions at the deep-water boundary with a particular emphasis on the Eulerian Lagrangian approach (Figure 1). We also investigate subtleties of the implementation the zero-flux boundary condition for the density on the downstream linearly sloping boundary through a study of its accuracy as a function of slope and element deformation.

From a physics standpoint, we will study the interaction of the incident created wave with the sloping boundary (Figure 2) for different values of wavelengths, Froude numbers and slope values. We will also discuss the implications of our findings for future three-dimensional simulations of internal-wave-induced transition and turbulence on the deformed sloping boundary. In this context, aspects of parallel implementation will also be considered.

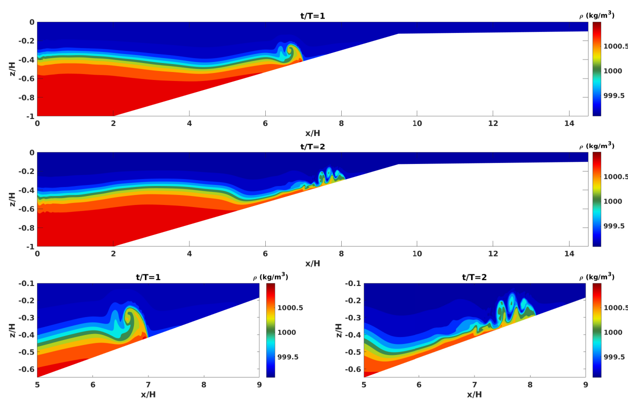

Figure 2: Screenshots of the isopycnal field of a spectral-element-based fully nonlinear and non-hydrostatic simulation of a model ISZ using a wave produced with the Eulerian Lagrangian approach after one wave have impacted the slope. Wave aspect ratio (wavelength/ water column height) is $\lambda/\mathrm{H} = 7$

References

- K. O. Emery, C. G. Gunnerson, Internal swash and surf, Proceedings of the National Academy of Sciences 70 (1973) 2379–2380
- Schweitzer, S. A., 2015. “Physical processes in a long narrow deep lake”. PhD Dissertation. Cornell University.
- Diamantopoulos et al, A high accuracy/resolution spectral element/Fourier-Galerkin method for the simulation of shoaling non-linear internal waves and turbulence in long domains with variable bathymetry, submitted to Ocean Modeling, 2022