

# **Approximating and evaluating higher-order pressure gradient terms from a log-law based Bottom Boundary Layer model, for application in a NSWE model of the swash zone**

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## **ABSTRACT**

This study improves the numerical modelling of the swash zone by addressing limitations of the hydrostatic pressure assumption used in numerical models that rely on the Non-Linear Shallow Water Equations (NSWE). It highlights the importance of higher-order non-hydrostatic pressure terms associated with vertical accelerations occurring during wave run-up and rundown. These terms are approximated using a depth-averaged numerical model coupled with a log-law-based Bottom Boundary Layer (BBL) sub-model that analytically reconstructs the vertical structure of the flow. The approach retains the computational efficiency of NSWE models while capturing the essential physics of vertical accelerations. Validation against laboratory-based experiment and depth-resolving Reynolds Averaged Navier-Stokes (RANS)-based Computational Fluid Dynamics (CFD) model shows analytically reconstructed vertical velocity is more accurate than that from the CFD model when compared to the measurements. The higher-order pressure terms involving accelerations in the vertical velocity are generally comparable with the ones estimated from the CFD model, especially in the backwash phase.

## **1. Introduction**

The accurate prediction of sediment transport and beach morphodynamic evolution remains a critical challenge for coastal zone management. To accurately predict the rates of sediment transport, it is crucial to accurately capture the dynamics of sediment transport, which is characterised by fluctuations in velocity and bed shear stress in the swash zone. In this highly dynamic region, pressure gradient and vertical acceleration are considerable factors that affecting the sediment mobilization and transport.

However, the majority of operational swash zone models rely on the NSWE under the hydrostatic pressure assumption. While this assumption is generally valid in the swash zone, it neglects the minor, non-hydrostatic vertical pressure gradients that involve vertical accelerations occurring during wave run-up and rundown, thereby compromising the accuracy of sediment transport predictions. To address this deficiency, this study highlights the necessity of incorporating higher-order non-hydrostatic pressure terms, especially, terms involving accelerations in the vertical velocity, into the governing equations in addition to the usual hydrostatic term. Thus, the modified higher-order horizontal momentum equation is utilised to re-estimate the bed shear stress for more accuracy representation.

## **2. Methodology**

The methodology consists in aims to approximate and evaluate these higher-order pressure gradient terms using a depth-averaging model equipped with a bottom boundary layer (BBL) model, originally proposed by

Briganti et al. (2011). By analytically resolving the vertical structure of the flow within the boundary layer, a closure for the non-hydrostatic pressure gradients is derived that retains the computational efficiency of NSW models while capturing the essential physics of vertical accelerations. The numerical results from the present model are compared to the experimental ones and to the simulations provided by a more computationally expensive, depth-resolving Computational Fluid Dynamics (CFD) model based on the Reynolds Averaged Navier-Stokes regarding a dam-break case from the literature.

### **3. Results and Discussion**

The initial findings show that the reconstructed vertical velocity is more accurate than that from the CFD model when compared to the measurements. The higher-order pressure terms involving accelerations in the vertical velocity are generally comparable with the ones estimated from the CFD model, especially in the backwash phase.

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#### **References**

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