

Modeling Wave Conditions at the Ericeira World Surf Reserve using the Non-Hydrostatic Navier-Stokes Solver REEF3D::NHFLOW

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INTRODUCTION

The World Surf Reserve (WSR) Ericeira, Portugal was established by the Save the Waves Coalition in 2011. The goal of this initiative is to preserve the surf waves and maintain the local coastal environment without further development. Recently, formal plans for preserving the Ericeira coastline were announced by the WSR Ericeira and the Local Stewardship Council. In this spirit, the EEA Portugal funded project "Coastal Wave Modelling in the World Surfing Reserve of Ericeira" works on delivering detailed wave information using state-of-the-art numerical wave models. With crucial importance to the local community in relationship to surfing, tourism, offshore wind and fishing activities, while maintaining the environmental goals of the WSR, a better understanding of the coastal wave processes is needed.



Fig.1: Ericeira coastline: Ribeira d'Ilhas beach and surf school.

For this goal, we present the new three-dimensional non-hydrostatic model NHFLOW. This model is implemented in the open-source hydrodynamics framework REEF3D (see e.g. Wang et al. 2020a or Wang et al. 2020b). Similar to NHWAVE (Ma et al., 2012), it uses a Godunov-type scheme for shock-capturing properties, albeit with WENO flux reconstruction. In order to achieve good dispersion characteristics, a pressure correction method is used, similar to SWASH (Zijlema et al., 2005). As part of the REEF3D framework, MPI parallelization, hypre's geometrid multigrid solvers and high-order finite difference discretization methods are readily available. In contrast to the existing fully-nonlinear potential flow solver FNPF implemented in REEF3D (Wang et al. 2022), the new model includes the capability to model the dynamic wetting and drying processes in the swash zone.

NUMERICAL MODEL

The new non-hydrostatic model REEF3D::NHFLOW solves the continuity and the Euler equations:

$$\frac{\partial u_i}{\partial x_i} = 0$$

$$\frac{\partial h u_i}{\partial t} + u_j \frac{\partial h u_i}{\partial x_j} = - \frac{h}{\rho} \frac{\partial p}{\partial x_i} - h g_i$$

The dynamic free surface is calculated by integrating the continuity equation over the depth:

$$\frac{\partial h}{\partial t} + \frac{\partial h u_i}{\partial x_i} = 0$$

A conservative Godunov-type scheme is employed to solve for the conserved flow variables. The cell face fluxes are approximated with an HLL Riemann solver and the fluxes are reconstructed using the 5th-order WENO scheme (Jiang and Shu, 1996). The velocities and the free surface are advanced in time with a 2nd-order TVD Runge-Kutta scheme. The wet-dry interface at the coastline is captured dynamically. The model runs stable without a dedicated breaking wave model due to its shock-capturing characteristics. The Poisson equation, originating from the non-hydrostatic pressure correction algorithm, is solved in parallel by a conjugated gradient solver preconditioned with geometric multigrid.

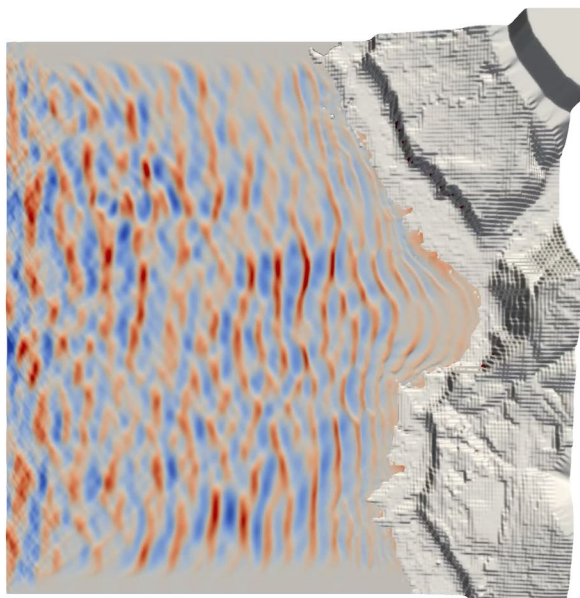


Fig. 2: Waves at Ribeira d'Ilhas beach with NHFLOW.

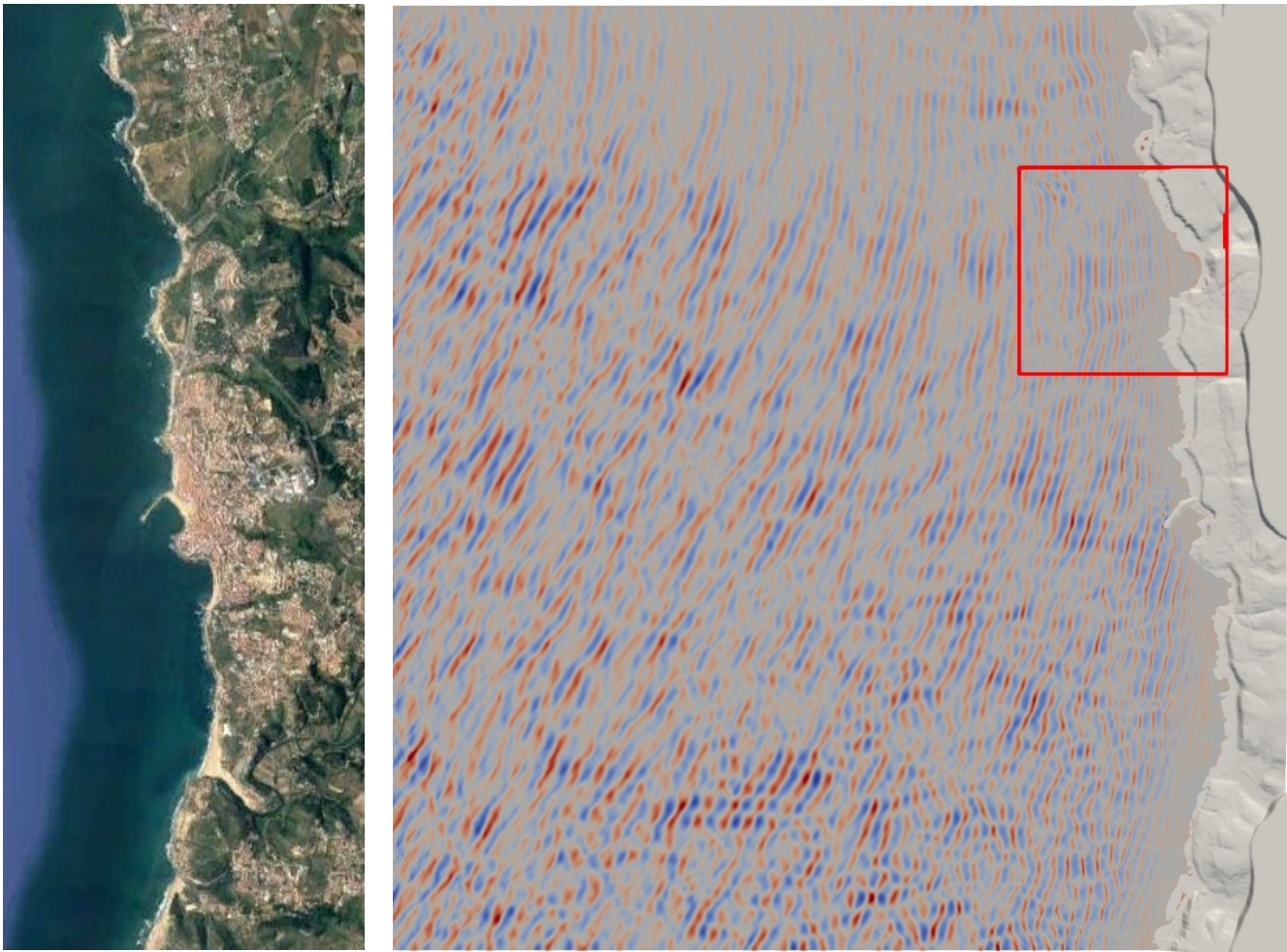


Fig. 3: Waves at Ericeira World Surf Reserve with REEF3D::NHFLOW. The red box shows the area for the result in Fig. 2.

RESULTS

Fig. 3 shows the coastline of the Ericeira WSR with a length of 9km. The numerical domain for the phase-resolved wave simulations is 9 x 9 km large. The bathymetry of the overall area was extracted from EMODNet (115m resolution). A 2011 LiDAR scan of the Portuguese coast covers a narrow strip along the beaches (15m resolution). The numerical mesh for Fig. has a resolution of 1300 x 1377 x 5 cells (ca. 9 mil. cells total, horizontal $dx = 6.7m$). Short-crested irregular waves with an $H_s = 4m$ and $T_p = 12s$ are used as input. Fig. 2 shows the zoomed-in waves for the surfing beach of Ribeira d'Ilhas ($dx = 4m$). The wave transformations induced by the bathymetry (shoaling and refraction) are represented by the numerical model.

CONCLUSIONS

The new non-hydrostatic model REEF3D::NHFLOW has been presented in the current abstract. Its capabilities for large-scale phase-resolved wave modeling have been shown for the Ericeira World Surf Reserve.

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REFERENCES

- Jiang, G. S. and Shu, C. W. (1996). Efficient implementation of weighted ENO schemes. *Journal of Computational Physics*, 126:202-228.
- Ma, G., Shi, F., Kirby, J. T. (2012). Shock-capturing non-hydrostatic model for fully dispersive surface wave processes. *Ocean Modeling*, 43-43:22-35.
- Wang, W. W., Kamath, A., Pakozdi, C., Bihs, H. (2020a). A comparison of different wave modelling techniques in an open-source hydrodynamic framework. *Journal of Marine Science and Engineering*, 8(7):526.
- Wang, W. W., Martin, T., Kamath, A., Bihs, H. (2020b). An improved depth-averaged non-hydrostatic shallow water model with quadratic pressure approximation. *Int. Journal f. Num. Meth. in Fluids*, 92(8).
- Wang, W. W., Pakozdi, C., Kamath, A., Bihs, H. (2022). A flexible fully nonlinear potential flow model for wave propagation over the complex topography of the Norwegian coast. *Appl. Ocean Research*, 122.
- Zijlema, M., Stelling, G., and Smit, P. (2005). Further experiences with computing non-hydrostatic free-surface flows involving water waves. *Int. Journal f. Num. Meth. in Fluids*, 48:169-197.