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Analysis and Development of Oceanographic Models: reaching the Swash Zone

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The swash zone is the part of the beach where the final dissipation of the energy of the incident short waves usually occurs, while low-frequency wave energy is, generally, reflected back to sea.

Swash zone flows are of fundamental importance not only because of their local effects but also because they can affect the surf zone dynamics as a whole. Notwithstanding its importance, typical circulation models do not account for the swash zone dynamics and simplified boundary conditions are often used.

This is achieved by calculating a mean shore line and provide along it shoreline boundary condition (SBCs) which take into account of the swash zone dynamics.

The new boundary condition are based on the Nonlinear Shallow Water Equation which, for a 1-D problem are:

$$\frac{\partial d}{\partial t} + \frac{\partial (ud)}{\partial x} = 0$$

$$\frac{\partial u}{\partial t} + \frac{\partial (uu)}{\partial x} + \frac{\partial (gd)}{\partial x} = \frac{\partial (gh)}{\partial x}$$

where $d = h + \eta$, η representing the free surface, h the still-water level, g gravitational acceleration and u the onshore component of the depth-averaged horizontal velocity. After some significant analytical elaboration, the new boundary conditions to be imposed are:

$$\frac{dx_l}{dt} \approx R_+ - \sqrt{2gH} - \frac{4C_v}{\alpha}\frac{dH}{dt},$$

$$d(x_l) \approx \frac{H}{2},$$

$$\bar{u}(x_l) \approx R_+ - \sqrt{2gH},$$

where $R_+ = \bar{u} + \sqrt{gd}$ is the positive Riemann function, α is the beach slope, $V = C_v \frac{H^2}{\alpha}$ is the volume of water inside the swash zone and $\bar{u}$ is the mean flow velocity. x_l is the envelope of the rundown, here taken to represent the wave-averaged shoreline.

The hydrodynamic model $ROMS$ and the wave driver SWAN have been both run alone into the COAWST modeling system (reference solution $ROMS_{sl}$) and run in conjunction with a purpose-built routine for the calculation of the mentioned SBCs (solution $ROMS_{SBCs}$ to be tested). Forcing was provided by imposing shore-normal waves at the off-shore boundary of the SWAN domain.

Running $ROMS_{sl}$ at really high resolutions, allows to reach the very shallow waters where the artificial shoreline conditions of rigid wall describes well the shoreline motion.

Using the proposed SBCs allowed us to reproduce a shoreline close to the one obtained by $ROMS_{sl}$ with a 0.1 m cross-shore resolution, but using a much coarser grid of 4 m. At the coarser resolution of 8 m also the proposed SBCs cannot properly represent x_l.

The time needed for the simulation run with $ROMS_{sl}$ at 0.1 m cross-shore resolution is in the order of some hours, while the one carried with $ROMS_{SBCs}$ at a 4 m cross-shore resolution in the order of some minutes. Hence, the great advantage, in terms of computational costs, of using the proposed SBCs is evident.

More results will be showed in order to characterize the potential of the new SBCs.