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Some aspects of breaking wave dynamics

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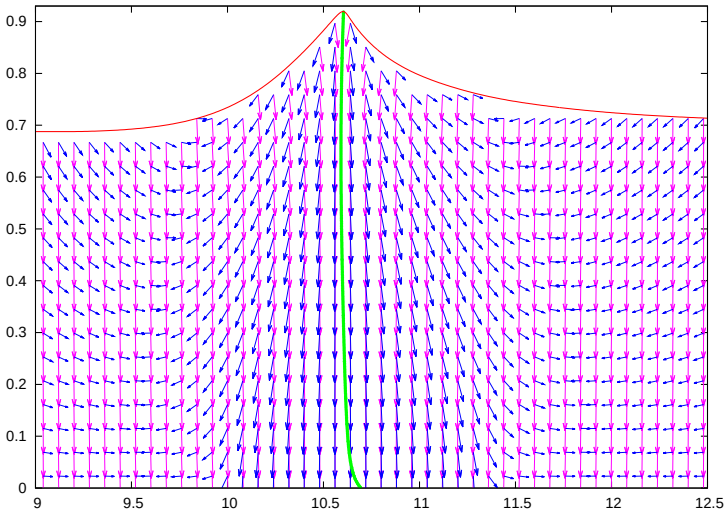
The analysis of the spatial and temporal variations of the pressure –and its derivatives– in a highly nonlinear wave, reveals new aspects of fluid dynamics that are rarely addressed in the literature. In the present analysis, the two-dimensional (2D) fully nonlinear free surface problem is solved in potential theory. Numerically the desingularized technique enables efficient computation of high-order pressure derivatives. This is necessary for accurately evaluating the pressure Hessian up to the free surface.

A line (called backbone) is thus identified by locating the points where the pressure gradient is collinear with one of the eigenvectors of the pressure Hessian matrix. The normalized pressure gradient (magenta) and the eigenvector associated to the single positive eigenvalue (blue) are plotted below. The backbone line (green) is superimposed.



This line provides much information. For example, one can describe the onset of critical jet like flip-through or highly accelerated protrusion in a plunging breaker by tracking local pressure maxima within the fluid domain (see [1]). It also offers a means to capture the fluid dynamics about the transition between non-breaking and breaking waves (see [2]).

The same quantities –gradient and Hessian of pressure– are also computed for threedimensional (3D) purely linear wave fields. Although fully nonlinear 3D breaking waves are not yet routinely computed, it is anticipated that the conclusion drawn for 2D analysis can be extended to any 3D free surface flows.

[1] Longuet-Higgins, M.S., 1980. A technique for time-dependent free-surface flows. Proc. R. Soc. Lond. Ser. A, Math. Phys. Sci. 371, 441451. 10.1098/rspa.1980.0091.
[2] Scolan Y.-M. & Etienne S., 2023, Pressure analysis in nonlinear waves by revisiting the breaking wave onset. European Journal of Mechanics / B Fluids 101, 246–256. 10.1016/j.euromechflu.2023.06.002