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RANS-VOF simulations of breaking waves

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ABSTRACT

For decades Reynolds-averaged Navier Stokes (RANS) models have been coupled with the volume of fluid (VOF) method to simulate breaking waves. One of most known studies is the simulation of the Ting and Kirby (1994) experiments by Lin & Liu (1998). This study generally showed promising results but had un-physically high turbulence prior to breaking. In Mayer & Madsen (2000) it was shown that the model would become unstable in certain scenarios and in Larsen & Fuhrman (2018) the analysis was extended, and it was shown that basically all two-equation turbulence models were un-conditionally unstable prior to breaking. It was likewise demonstrated how such models could be stabilized. The stabilized model showed significant improvements prior to breaking and in the outer surf zone, but was not able to capture the inner surf zone well. In Li et al. (2022) it was shown that the stress-omega model could capture both regions, but the author is not aware of any two-equation model capable of doing this. In this study the work by Li & Fuhrman (2022) will be extended and the impact and interconnectedness of turbulence model stress-limiters, interface treatment and temporal resolution on surf zone processes will be demonstrated and discussed.

As an example of the interconnectedness Figure 1 shows how using large time steps may result in an over-estimation of the velocities in the crest of the wave. Such over-estimation may lead to premature breaking compared to experiments. The pre-mature breaking may, however, be avoided if enough turbulence is produced in the wave prior to breaking as discussed by Li & Fuhrman (2022). Such high turbulence levels could arise due to unstable turbulence models, models without stress limiters or models without interface treatment.

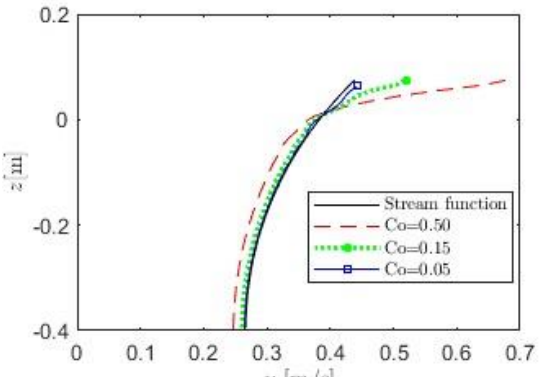

Figure 1: Comparison of analytical and simulated velocity profiles beneath the crest of a wave

Overall, the results indicate that care should be taken when evaluating the performance of turbulence models for breaking waves. The best model might not be right for the right reasons and care should be taken in identifying why the models are right and what parts of the model that makes them better than the other turbulence models. The interface is identified as region requiring further research.

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