

NEW METHODS FOR STABILIZING RANS TURBULENCE MODELS WITH APPLICATION TO LARGE SCALE BREAKING WAVES

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INTRODUCTION

Recently, Larsen and Fuhrman (2018) have shown that seemingly all commonly used (both $k-\omega$ and $k-\epsilon$ variants) two-equation RANS turbulence closure models are unconditionally unstable in the potential flow beneath surface waves, helping to explain the wide-spread over-production of turbulent kinetic energy in CFD simulations, relative to measurements. They devised and tested a new formally stabilized formulation of the widely used $k-\omega$ turbulence model, making use of a modified eddy viscosity. In the present work, three new formally-stable $k-\omega$ turbulence model formulations are derived and tested in CFD simulations involving the flow and dynamics beneath large-scale plunging breaking waves, based on experiments of van der A et al. (2017).

METHODOLOGY

A CFD study of the flow beneath large-scale plunging breaking waves over fixed barred profiles (van der A et al. 2017) has been conducted in OpenFOAM. Four different turbulence closure formulations have been used, namely the modified eddy viscosity formulation of Larsen and Fuhrman (2018), as well as three new formulations involving flow-dependent (rather than traditionally constant) turbulence model closure coefficients, which are made to depend locally on the ratio of the strain-rate to rotation-rate modulus.

DISCUSSION AND RESULTS

Figure 1 depicts snapshots from four CFD simulations. As seen, the original (standard, non-stabilized) version

of the model (upper panel) leads to unphysical turbulence production prior to breaking, while all three stable formulations included (three lower panels) lead to similar breaking sequences. The performance of the various formulations will be systematically compared in terms of surface elevations, turbulence levels, as well as undertow velocity profiles, through the entirety of the surf zone. Generally, it will be shown that the models perform exceptionally well in the tasks of propagating, shoaling and breaking of the waves, while (thus far) the predictions deviate from laboratory observations in the inner surf zone, which proves elusive. Here, e.g. the undertow profile is exaggerated in strength by approximately a factor of two.

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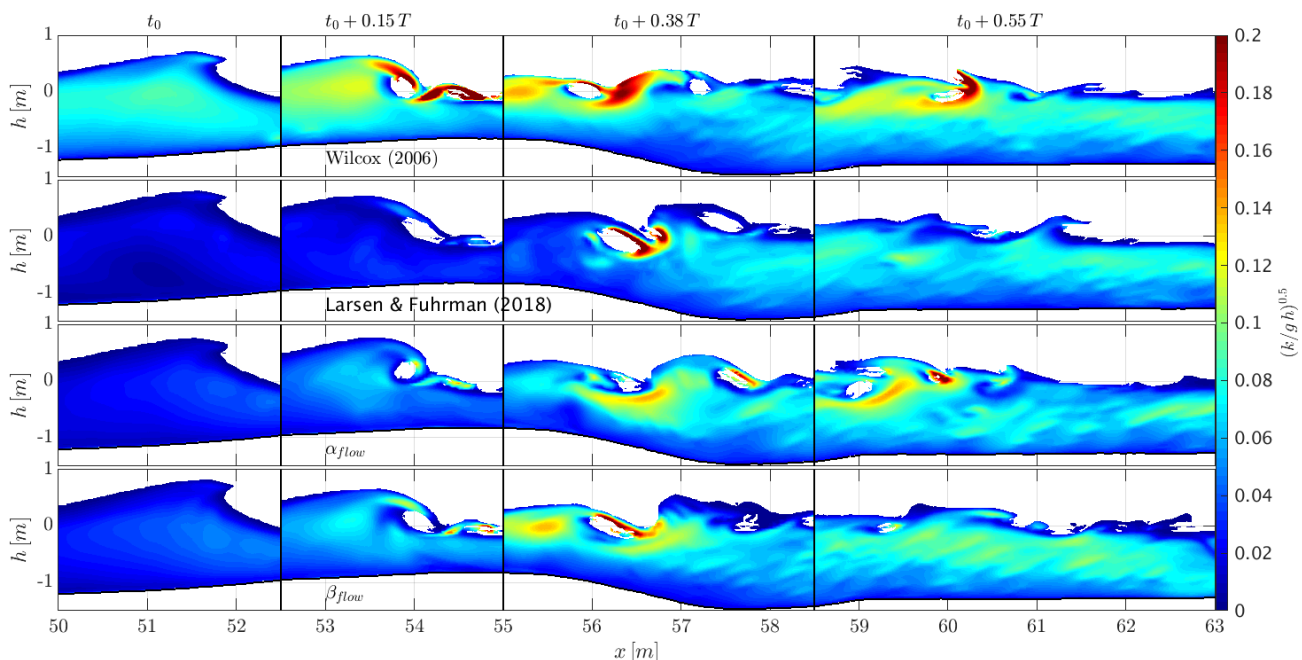


Figure 1 - Snapshots of the breaking process, illustrating the turbulence kinetic energy during four distinct instances, as computed by the original $k-\omega$ model and the three of the four different stable formulations.