

RANS SIMULATION OF BREAKER BAR DEVELOPMENT USING A STABILIZED TURBULENCE MODEL

Bjarke Eltard Larsen, Technical University of Denmark, bjelt@mekd.dtu.dk
David R. Fuhrman, Technical University of Denmark drf@mek.dtu.dk

BACKGROUND AND INTRODUCTION

Accurately predicting cross-shore sediment transport and resulting morphology remains a notoriously challenging task due to the variety of hydrodynamic processes that are involved. These processes are often comparable in magnitude, but may differ in terms of direction, and hence even getting the sign right (i.e. onshore vs. offshore sediment transport) is therefore not always trivial.

Reynolds-averaged Navier Stokes (RANS) models can handle the breaking processes and boundary layer dynamics naturally, and can therefore potentially be used to investigate this problem. Using RANS models to simulate shoaling and surf zone processes is not without difficulties, however. Past studies have shown a tendency to significantly over-estimate turbulence levels in simulations of breaking waves, and this has even been most pronounced prior to breaking. This problem was originally diagnosed by Mayer & Madsen (2000) and was recently solved by Larsen & Fuhrman (2018), who showed that seemingly all widely used RANS models are unconditionally unstable in nearly potential flow regions beneath propagating waves, resulting in exponential growth of the turbulent kinetic energy and eddy viscosity. They demonstrated how such models can be formally stabilized, simply by modifying stress limiting features within the eddy viscosity. Using a stabilized model, Larsen & Fuhrman (2018) showed significant improvements in predicted turbulence levels and undertow profiles, especially prior to breaking and in the outer surf zone. The present study will present the first applications of such stabilized turbulence closure models in simulating full scale boundary layer processes and resulting sediment transport and morphology.

METHODS

A recent experimental campaign conducted in a 100 m long wave flume involving regular waves breaking over a mobile bar (van der Zanden et al., 2016) will be simulated. The model will be using the OpenFOAM solver waves2FOAM (Jacobsen et al. 2012), combined with the $k-\omega$ turbulence model of Larsen & Fuhrman (2018), as well as the fully coupled sediment transport and morphological model presented in Jacobsen et al. (2014).

RESULTS AND DISCUSSION

Figure 1 shows the bar development from the experiments and using both a standard (left subplots) and stabilized turbulence (right subplots) $k-\omega$ model.

With the standard $k-\omega$ turbulence model the breaker bar is slowly migrating offshore, whereas the breaker bar in the experiments is growing more rapidly and migrating in the onshore direction. Conversely, this process seems to be well captured by the stabilized model, which predicts overall growth and evolution of the bar reasonably and at the correct position (though the simulated evolution is slightly slower than was observed).

The failure of the standard model to capture the correct bar development is related to the overproduction of turbulence in the pre-breaking region. As demonstrated in Larsen & Fuhrman (2018), the overproduction of turbulence results in erroneous structure of the undertow velocity profile prior to breaking and in the outer surf zone, which results in some of the sand in suspension bypassing the breaker bar and depositing on the offshore slope of the bar, thereby resulting in deposition rather than erosion.

The stabilized model does not capture the erosion in the trough of the breaker bar, but instead has too much erosion further onshore (in the inner surf zone) compared to the experiments. This image is consistent with the undertow hydrodynamics shown in Larsen & Fuhrman (2018), where the magnitude of the offshore directed undertow velocity was overestimated in the inner surf zone. This presumably leads to an overestimated offshore directed sediment transport in the inner surf zone, which results in deposition rather than erosion on the lee-side of the bar.

CONCLUSION

The results demonstrate the significant advantages of utilizing formally stabilized turbulence closure models in accurately predicting the surf zone dynamics, sediment transport, and breaker bar morphology in the shoaling region and in the outer surf zone using RANS models. Simulated evolution using a stabilized turbulence model is demonstrated to predict cross-shore breaker bar position, growth and evolution. This is in contrast to results using (otherwise identical) standard turbulence closure, which tend to flush the bar further offshore. Further improvements are still needed to increase hydrodynamic accuracy, hence sediment transport and morphological evolution, in the inner surf zone.

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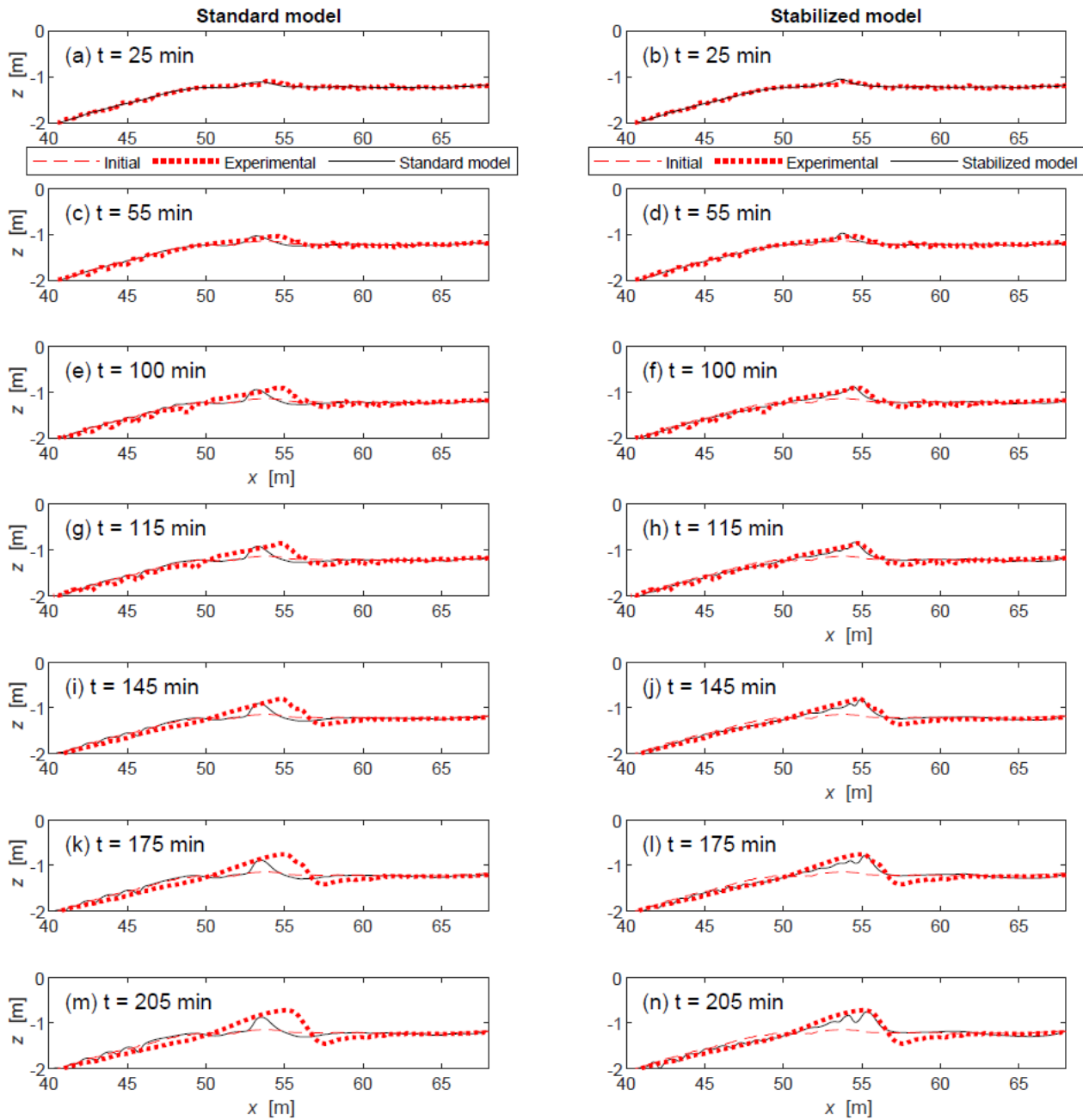


Figure 1: Experimental and modelled morphology at selected times.

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