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RANS-BASED SIMULATION OF TURBULENT WAVE BOUNDARY LAYERS AND SEDIMENT TRANSPORT

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INTRODUCTION

A one-dimensional (vertical) numerical model solving Reynolds-Averaged Navier-Stokes (RANS) equations, coupled with two-equation k-ω turbulence closure, is used for simulation of turbulent wave boundary layer processes (e.g. Fuhrman et al. 2011). The model is additionally equipped with a bed load transport description as well as suspended sediment transport capabilities, based on a turbulent-diffusion model. The model incorporates (often neglected) high-concentration effects of hindered settling in addition to turbulence damping due to density gradients in the water-sand mixture, in line with recent work based on k-ε turbulence closure (e.g. Reussink et al. 2009). Effects of boundary layer streaming are also included, by relating spatial derivatives in convective terms to time derivatives via the wave celerity.

RESULTS

Sediment transport predictions are first compared against oscillating tunnel experiments (i.e. no streaming) having velocity-skewed (O'Donoghue & Wright 2004; Hassan & Ribberink 2005), as well as acceleration-skewed (van der A et al. 2010) free stream signals. The data sets involving velocity skewness contain both net positive (onshore), as well as negative (offshore) sediment transport rates, the latter due to so-called phase-lag effects, which can reverse the sign of net transports for fine sands coupled with sufficiently short wave periods. Comparison with measured sediment flux profiles shows reasonable agreement for both scenarios, as exemplified in Figure 1. For cases involving fine sands the nature of the flux profiles is significantly improved when high-concentration effects are included (Figure 1, left), illustrating the importance of including such effects in practice.

Cases based on progressive wave flume measurements of Dohmen-Janssen & Hanes (2002) are likewise considered, with streaming effects switched on and off, for comparison. For these cases, results suggest that streaming can amplify net transport rates by up to a factor two, with the percentage increase depending on the importance of the wave shape in creating net transports. The potential for streaming effects to modify the direction of net transport for fine sands beneath skewed waves from offshore (as often predicted in oscillating tunnel experiments e.g. Figure 1, left) to onshore is also investigated.

Period-averaged transport rates (measured versus predicted) for all simulations considered are summarized in Figure 2. For all cases considered, the predicted transport rates are in the correct direction, with the vast majority lying within a factor two of measurements. Hence, the present model seems reasonably robust in making net (sheet flow) sediment transport predictions for a variety of wave shapes and sediment conditions.

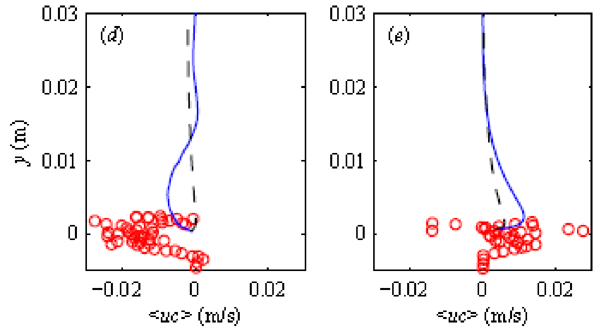

Figure 1 - Comparison of computed (full lines) and measured (circles, O'Donoghue & Wright 2004) period-averaged sediment flux profiles for fine (left) and medium (right) sands. Dashed lines indicated computed results with high-concentration effects switched off.

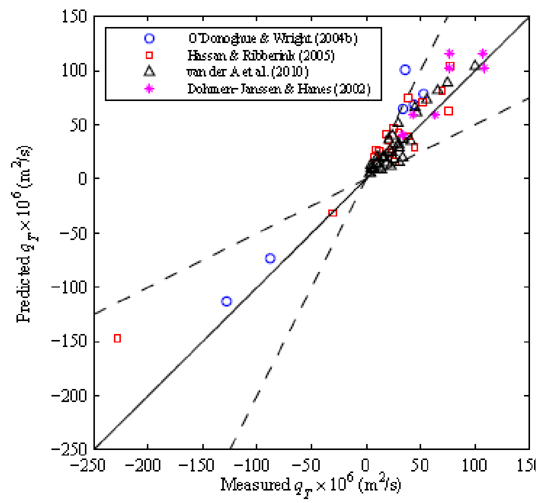

Figure 2 - Summary of measured versus predicted period-averaged sediment transport rates. The solid line represents a perfect fit, while dashed lines indicate plus or minus a factor of two.

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