

MODELING CROSS-SHORE SEDIMENT TRANSPORT PROCESSES WITH A TIME DOMAIN BOUSSINESQ MODEL

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Advances made in the past decade on time-domain modeling of waves and currents across the surfzone have enabled us to obtain improved estimates of instantaneous near bottom fluid velocities. Rakha et al(1997) and Karambas and Koutitas(2002) have both used Boussinesq models to obtain predictions of surfzone hydrodynamics, and have then used averages of the instantaneous quantities to obtain the statistical moments needed to drive wave-averaged transport models.

In contrast, Long and Kirby(2003) have used Boussinesq model predictions to drive an instantaneous transport model, allowing morphology changes to accumulate on a wave by wave basis. Prompted by the work of Drake and Calantoni (2001) but using an instantaneous transport formula, Long and Kirby constructed an acceleration-dependent transport formula given by

$$\begin{aligned}
 i = i_b + i_s &= \rho C_f \frac{\epsilon_b}{\tan\phi} [|u_b|^2 u_b - \frac{\tan\beta}{\tan\phi} |u_b|^3] \\
 &+ \rho C_f \frac{\epsilon_s}{W} [|u_b|^3 u_b - \frac{\epsilon_s \tan\beta}{W} |u_b|^5] \\
 &+ g(\rho_s - \rho) K_a (|u_{b,t}| - u_{b,tc}) \text{sign}(u_{b,t})
 \end{aligned} \tag{1}$$

where i is the total immersed weight sediment transport rate, i_b and i_s are bed load and suspended load respectively, ϕ is the internal angle of friction, $\tan\beta$ is the slope of the bed, C_f is the friction coefficient, W is the sediment fall velocity, $u_{b,t}$ is the time derivative of instantaneous free stream velocity u_b predicted by Boussinesq model, $u_{b,tc}$ is a threshold value, K_a is a dimensional coefficient representing acceleration-dependent transport, ρ is fluid density, and ρ_s is sediment density. ϵ_b and ϵ_s are efficiency coefficients for bed load and suspended load respectively. The formula is equivalent to the work of Bagnold (1966) except for the last term, which is introduced to allow a dependence on fluid acceleration. Long and Kirby calibrated K_a and $u_{b,tc}$ based on simulation of bar motion during the Duck '94 experiment during the week of September 23-30, 1994, and obtained quantitatively accurate representation of onshore bar movement events observed in the field which was also addressed by Hoefel and Elgar(2003) with similar success using data.

While the results obtained by Long and Kirby (2003) are encouraging, the formula used there has no specific mechanical underpinning. The goal of the present work is to use a more appropriate, mechanically-based model for the local boundary layer structure and sediment transport rate over the vertical,

integrated with the Boussinesq model in order to provide a profile evolution model. At present, we are using an approach following Meyer-Peter and Müller(1948), with dimensionless volumetric transport rate defined in terms of the Shields parameter as

$$\psi = C_1(\theta - \theta_c)^n \tag{2}$$

where ψ is defined as $\psi = q/(d\sqrt{(s-1)gd})$, q is volumetric transport rate, d is sediment diameter, g is gravitational acceleration, $s = \rho_s/\rho$ is specific gravity of sediments $\theta = \tau_b/(\rho(s-1)gd)$ is the Shields parameter, and θ_c is threshold value of Shields parameter for initiation of sediment transport, C_1 and n are determined empirically. We are using direct modeling of the boundary layer flow in order to obtain instantaneous bottom shear stress τ_b . The present study is evaluating the effectiveness of this more mechanically based approach by parameterizing τ_b using free stream velocity u_b and acceleration u_{bt} .

References

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