Intra-wave sand flux under acceleration-skewed oscillatory flow

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Introduction

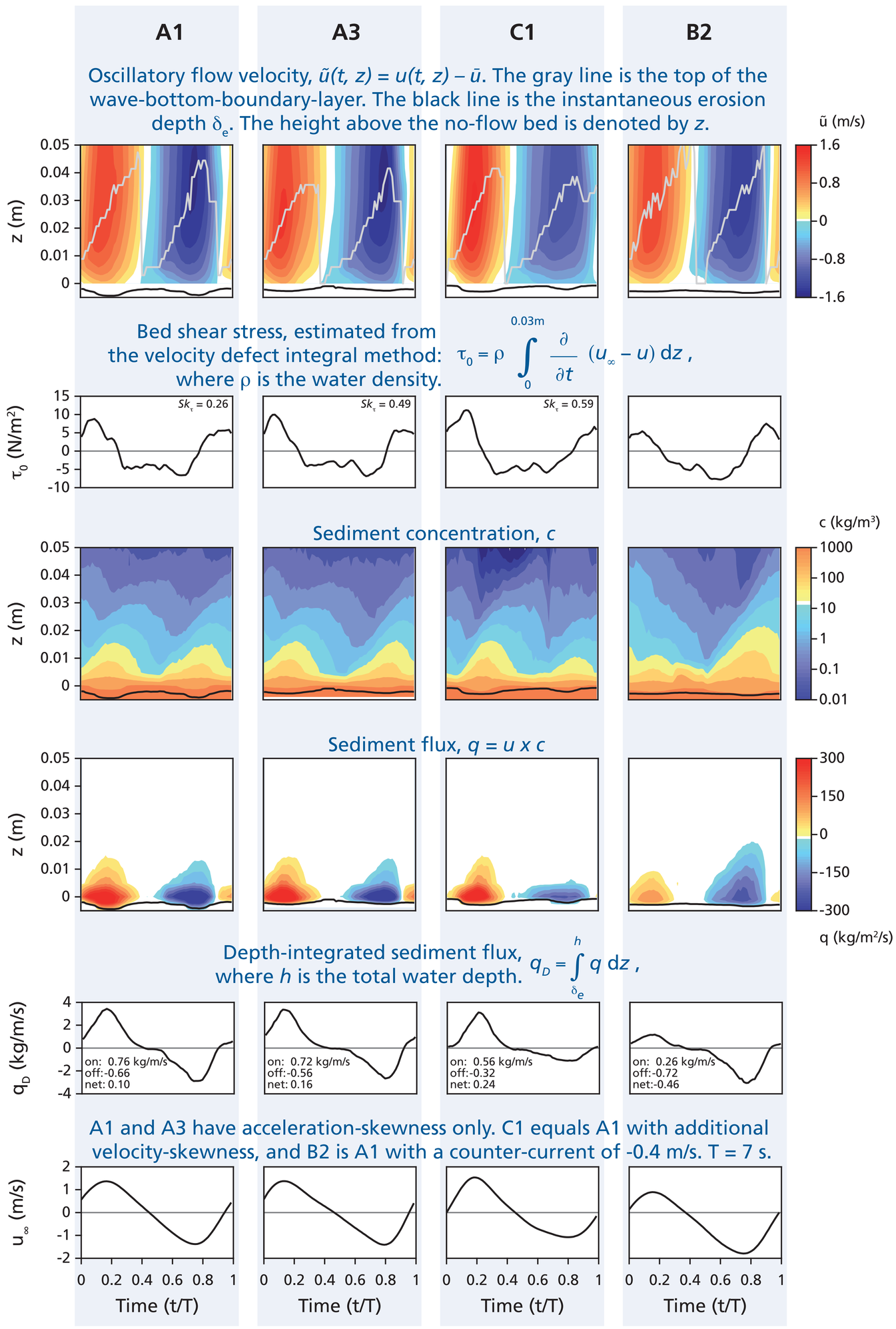
Oscillatory flow in the inner surf zone has zero velocity skewness but non-zero acceleration skewness. Acceleration-skewed ('sawtooth') waves produce net transport in the direction of the largest acceleration (i.e., onshore), as demonstrated in various laboratory experiments. However, our current understanding of acceleration effects on sediment transport is poor, mainly because of a lack of detailed intra-wave process measurements.

The aim of our work is to analyze the effect of acceleration skewness, velocity skewness, and net currents on sediment transport processes. Here we analyze a new dataset of intra-wave velocities, concentrations, and sand fluxes under sheet flow conditions generated by full-scale, regular, acceleration- and velocity skewed oscillatory flows with and without opposing currents.

Experimental set-up

The experiments were conducted in the Large Oscillating Water Tunnel (LOWT) at Deltares|Delft Hydraulics, the Netherlands. The experiments involved 4 flows over a quartz sand with a median grain size of 200 μm and a geometric standard deviation of 1.2. The present work is based on measurements of (i) time-varying concentrations with a Conductivity Concentration Meter and a triple-frequency (1, 2 and 4 MHz) Acoustic Backscatter Sensor and (ii) time-varying horizontal and vertical velocities with a 2-MHz Acoustic Doppler Velocimeter Profiler. The free stream velocity of the four experiments is provided in Figure 1, bottom row.

Figure 1



Findings

Under sawtooth waves (A1 and A3 in Figure 1):

- The wave-bottom-boundary layer (WBBL) is thinner under maximum positive than under maximum negative flow. Accordingly, the bed shear stress is positively skewed, even though the free-stream velocity has zero velocity skewness.
- The skewness in the bed shear stress increases with an increase in acceleration skewness.
- The concentrations and fluxes show two large, almost equal peaks. The net flux is a close balance between the positive and negative flux.
- The net flux increases with an increase in acceleration skewness.

The addition of velocity skewness (C1 versus A1 in Figure 1) results in:

- A smaller difference in WBBL thickness under maximum positive and negative velocity.
- An increase in the skewness of the bed shear stress.
- A decrease in the magnitude of the offshore flux, causing an increase in the net flux.

The strong opposing current (B2 versus A1 in Figure 1):

- Suppresses (enhances) the turbulence kinetic energy under the positive (negative) orbital flow.
- Increases (decreases) the concentration under the negative (positive) flow.
- Produces a net negative flux, which results from the negative current-induced and the negative wave-induced flux.

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