Turbulence under breaking waves

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Introduction

Nearshore sediment transport is often parameterised in terms of the wave height or orbital velocity to some power. This parameterisation does not seem to be applicable to sediment transport under breaking waves, as it is based on the assumption that sediment is suspended by near-bed processes, while surface-generated turbulence is not taken into account. Under breaking waves, turbulence generated at the surface can penetrate downward through the water column, hit the bed, and thus provide an additional mechanism to suspend sediment.

Field experiment

A nearshore field experiment was conducted at Ameland, on the North Sea coast in September and October 2010. Ameland beach is a very low-sloping beach (1:80) with an intertidal bar. The goal of the field experiment was to measure hydrodynamic processes and sediment concentration during breaking-wave conditions. The deployed instruments (Figure 1) were used to measure vertical profiles of the water motion (from turbulence quantities to mean currents), wave characteristics and water depth, seabed configuration (absence/presence ripples), and sediment concentration.

Figure 1: Instrument configuration during the field experiment: 3 Acoustic Doppler Velocimeters (ADVs), 1 pressure sensor, 5 Optical Backscatter Sensors, and a ripple scanner. Measurement were typically performed in bursts of 29 minutes with a sampling frequency of 10 Hz. The cross-shore, alongshore and vertical turbulence fluctuations (u′, v′ and w′ respectively) were estimated from the 3 vertically stacked ADVs. The turbulent kinetic energy k is $k = 0.5 (\langle u'^2 \rangle + \langle v'^2 \rangle + \langle w'^2 \rangle)$. The angle brackets indicate a burst average.

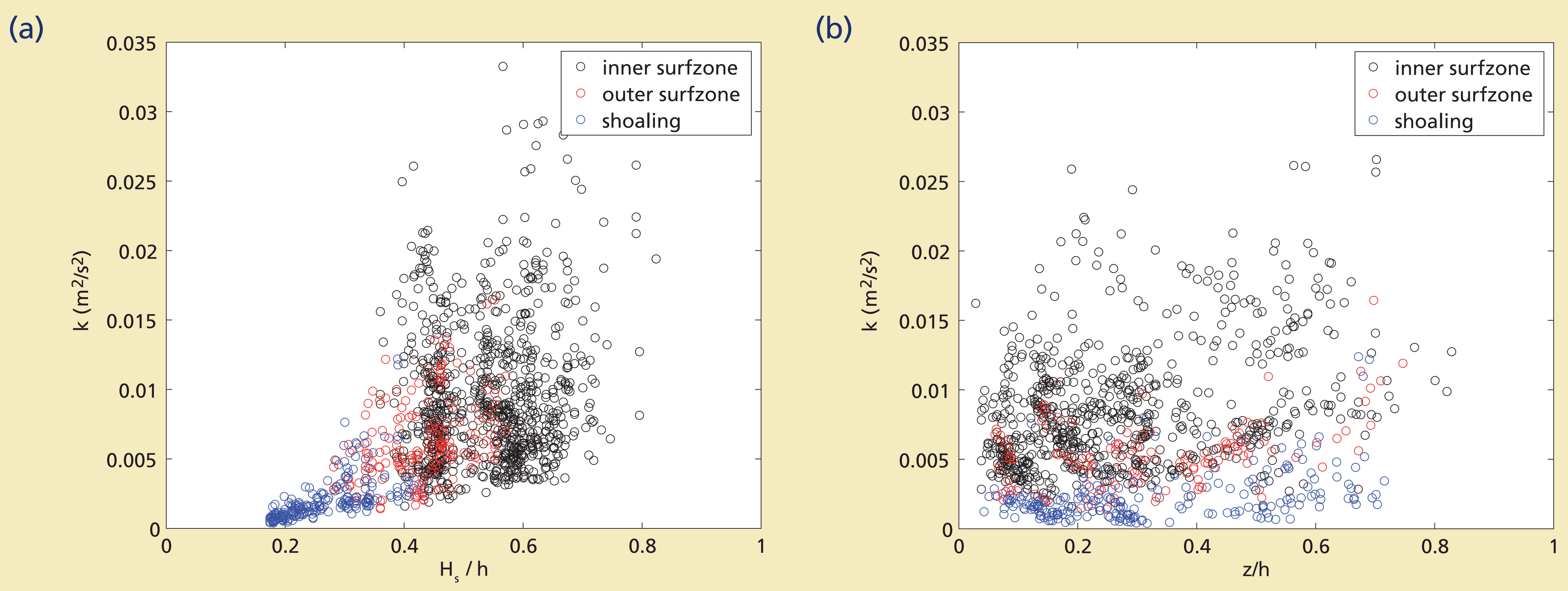

Figure 2: (a) k against H_s/h for inner/outer surf zone and shoaling waves, (b) k against z/h for inner/outer surf zone and shoaling waves. z/h is the relative position of an ADV, z/h = 0 is the sea bed, and z/h ≈ 0.7 is the wave trough level.

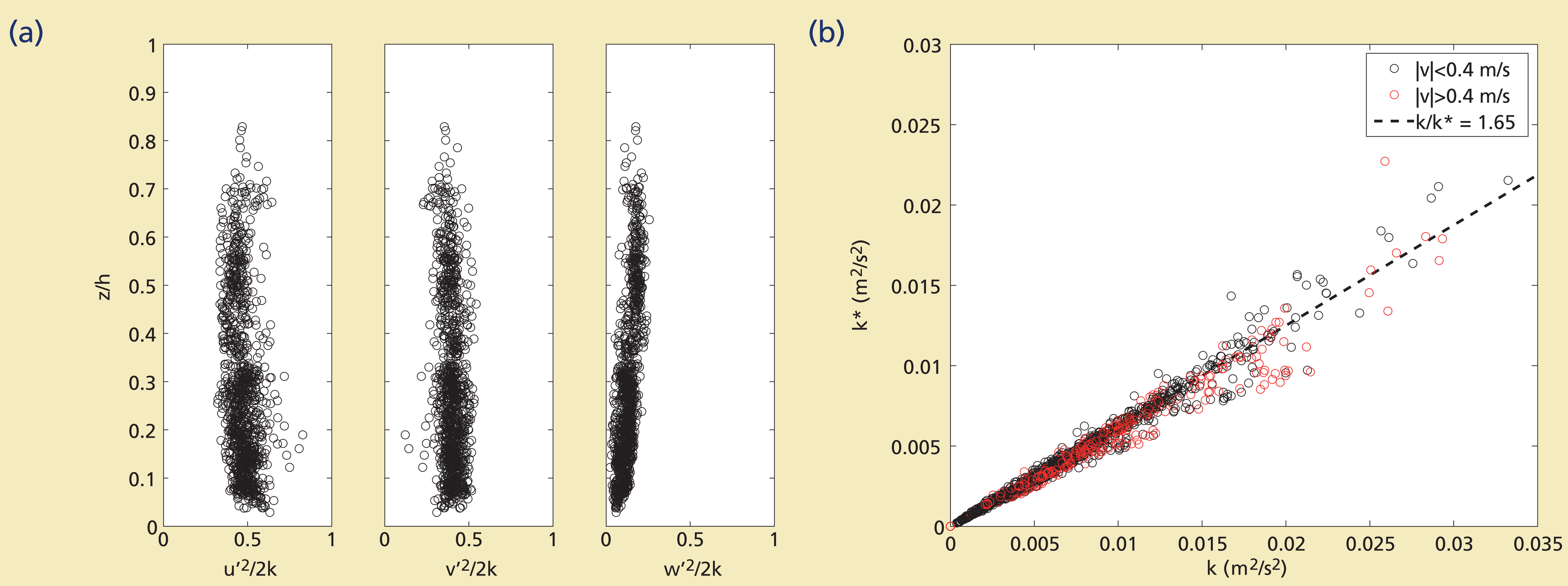

Figure 3: (a) Relative contribution of u'^2, v'^2 and w'^2 to 2k, plotted against normalized instrument height z/h. (b) k against k*.

Findings

- Turbulent kinetic energy k is positively related to the degree of wave breaking, taken here as the ratio of the significant sea-swell wave height to water depth H_s/h (Figure 2a).
- In the shoaling and outer surf zone the turbulent kinetic energy is rather low, while in the inner surf zone it is substantially larger but also more scattered.
- The turbulent kinetic energy does not depend on the relative position in the water column, but clearly on the position relative to the surf zone (Figure 2b). Apparently, k is rather depth uniform.
- The relative contribution u'^2, v'^2 and w'^2 to the turbulent kinetic energy was found to have a ratio of 0.45:0.40:0.15 (Figure 3a).
  This suggests that the vertical component is relatively unimportant, while the contribution of the cross-shore and longshore components is almost equal.
- In laboratory studies, v'^2 is unavailable and k is often estimated as k = 1.33k*, with $(k^*) = 0.5 (\langle u'2 \rangle + \langle w'^2 \rangle)$.
  We find that k = 1.65 k* (Figure 3b), implying that in the field v'^2 is more important than in the laboratory.

Geosciences