Vertical structure of the turbulence dissipation rate in the surf zone

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Introduction

High-energy breaking waves induce major morphological changes of sandy beaches which are not well predicted yet. In particular, it is not known how far breaking-induced turbulence can penetrate through the water column and stir sediment. Hence, we used a recently collected field dataset (1) to determine the vertical structure of the turbulence dissipation in the shallow-water surf zone beneath high-energy breaking waves; and (2) to investigate how this vertical structure is affected by breaking-wave intensity. We see this as the first step to determine the influence of surface-generated turbulence on surf zone sediment transport.

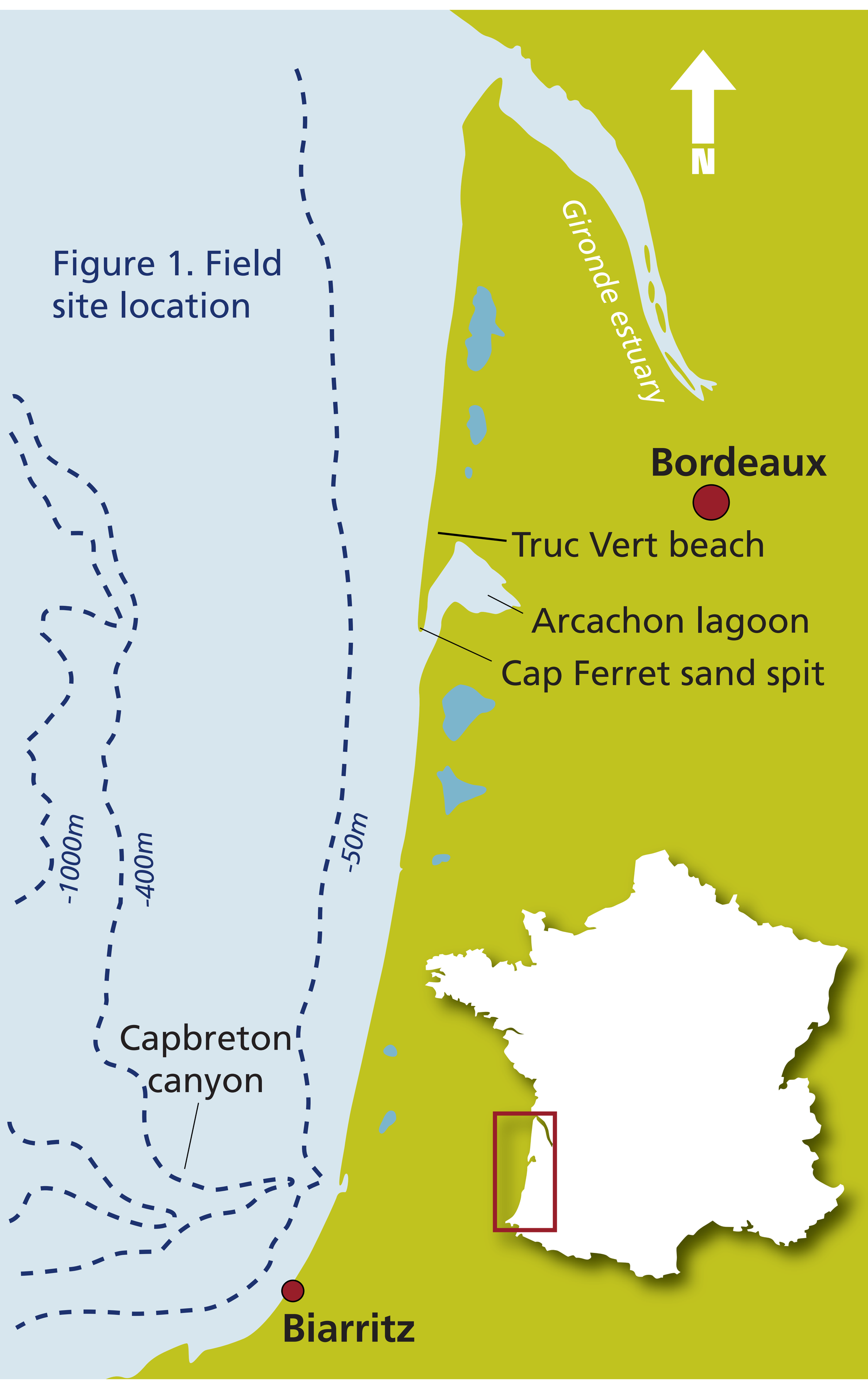

Figure 1. Field site location

Methodology

The field data were collected at the macrotidal Truc Vert beach, France (Figure 1) during a 18-day period in 1–3 m water depth with strong cross-shore and alongshore currents under high-energy wave conditions (offshore significant wave heights reaching 8 m).

Based on a turbulent inertial subrange analysis, the turbulence dissipation rates ε are estimated from 24-min long, 10 Hz, 3-component fluid velocities measured at three elevations between the sea bed and the wave trough level (Figure 2).

In total, 501 dissipation rate observations were available for our study.

Figure 2. Instrumented rig at low tide. Wave velocities are measured by three ADVOs during high tides.

Results

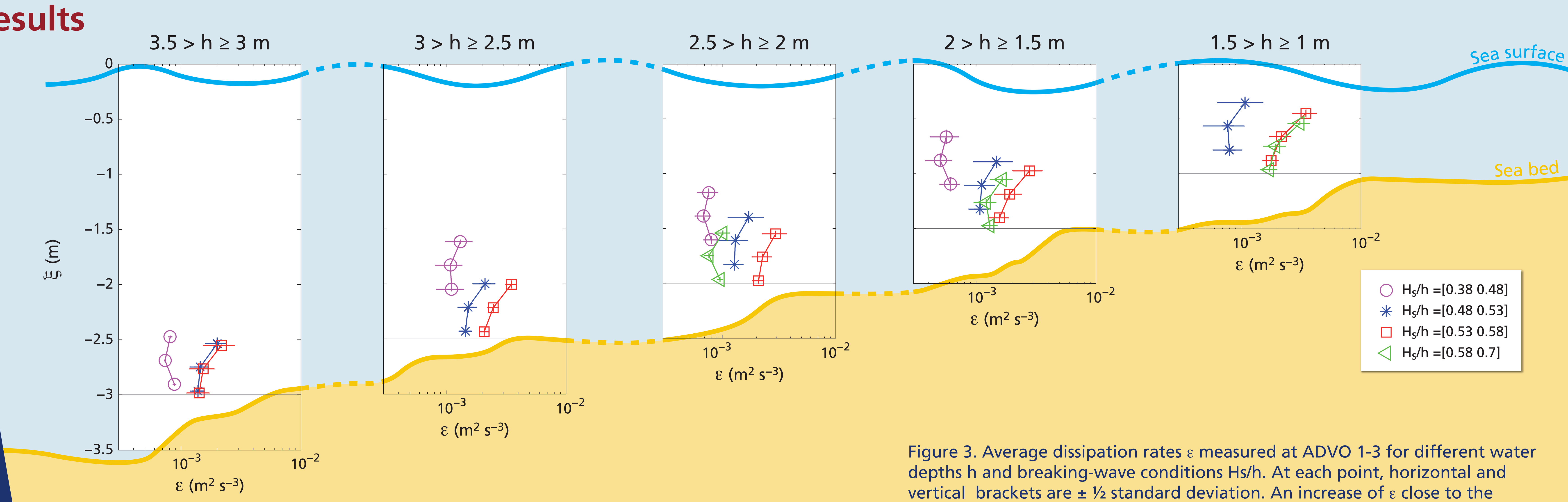

Figure 3. Average dissipation rates ε measured at ADVO 1-3 for different water depths h and breaking-wave conditions Hs/h. At each point, horizontal and vertical brackets are ± ½ standard deviation. An increase of ε close to the sea surface characterizes an increasing importance of the surface-generated turbulence induced by the breaking waves, whereas an increase of ε close to the sea bed characterizes an increasing importance of the bed-generated turbulence induced by the bottom boundary layer.

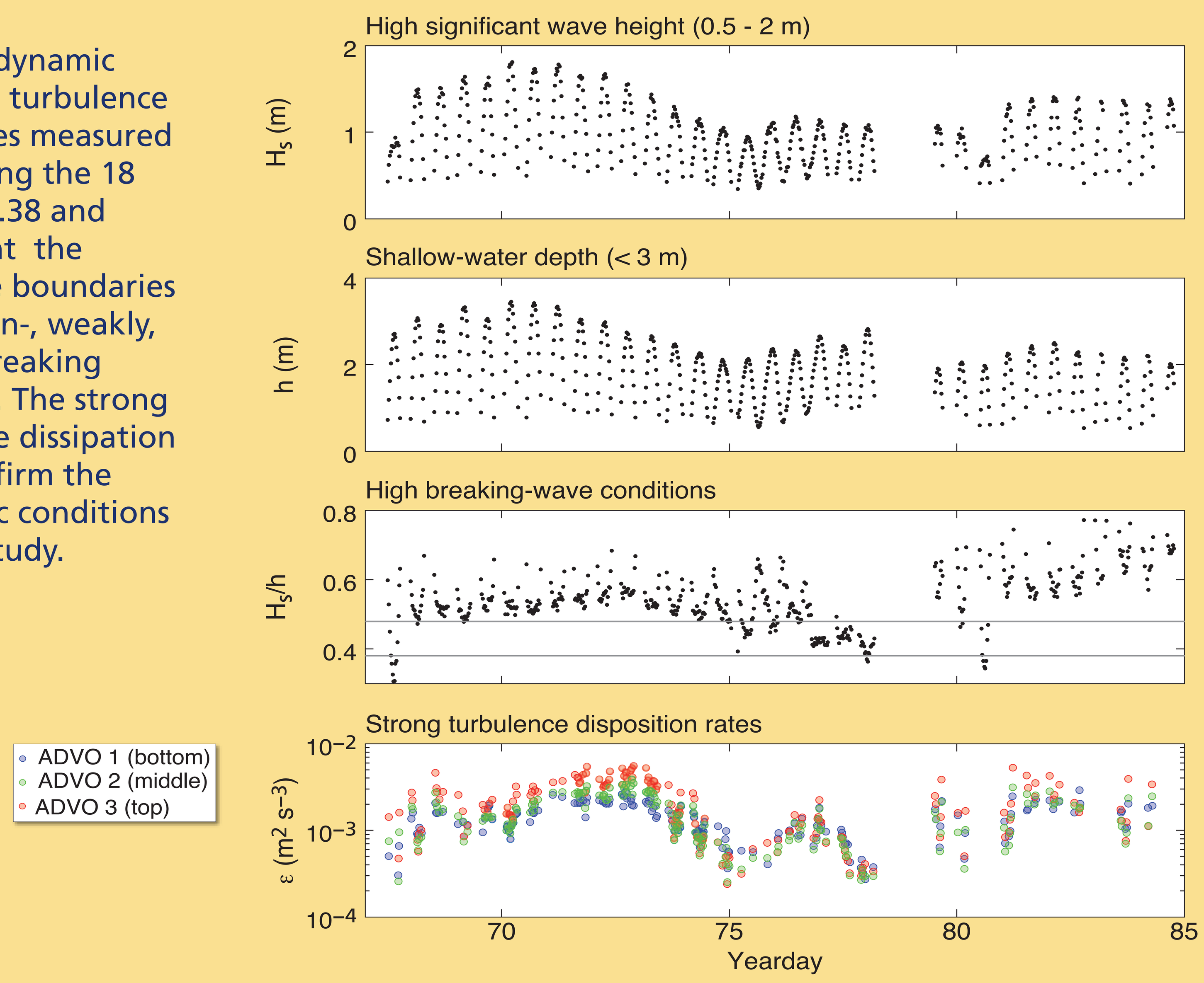

Figure 4. Hydrodynamic conditions, and turbulence dissipation rates measured at the rig during the 18 days. Hs/h = 0.38 and 0.48 represent the approximate boundaries between non-, weakly, and fully breaking conditions. The strong turbulence dissipation rates confirm the energetic conditions of our study.

Conclusions

The vertical structure of the turbulence dissipation rate of our data demonstrates surface-generated turbulence as a dominant source of turbulence, especially for shallow-water conditions.

- The turbulence generated in the bottom boundary layer is not negligible, especially for the lower breaking-wave intensities Hs/h.
- The turbulence dissipation increases with the breaking-wave intensity and then saturates for Hs/h > 0.58.
- This saturation may be due to less vortex injection as waves modify from breakers into bores.

Geosciences