

ON A METHODOLOGY TO MEASURE WAVE BOUDARY LAYER PARAMETERS UNDER IN SITU SURFACE WAVES

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INTRODUCTION

Sand transport predictions represent high social, economic and environmental stakes. Therefore, reliable sand transport models are needed. On a beach, either erosion or accretion can take place. Mechanisms leading to erosion are quite well known whereas accretion is less well predicted. Onshore transport occurs in the Wave Boundary Layer (WBL). Up until now, WBL transport processes have mainly been observed in laboratory conditions, in a controlled environment. This allowed in particular to highlight the three main WBL parameters (near-bed velocity phase shift, non-linearities evolution and WBL thickness) which control bed shear stress and therefore sand transport (Fuhrman et al., 2009). But in order to further improve sand transport models, in situ data are now necessary, to observe what happens under real, full spectrum surface waves. In situ data sets are quite rare because of the difficulty to deploy instruments on beaches, but also because of the metrological challenge bound to the observation of both hydrodynamics and sand transport processes in the Wave Bottom Boundary Layer with high spatial and temporal resolutions in the natural environment. The first in situ deployments, involving a new generation of ultrasonic Doppler sonar system, have been carried out during Winter 2022 at Porsmilin Beach, Brittany, France. This study presents the methodology used to obtain in situ WBL parameters.

INNOVATIVE EXPERIMENTAL SET UP

A stainless steel mooring frame of 0.8m large, 1m high and 1.20 m deep (see Figure 1) has been designed to foster a set of instruments dedicated to the sampling of hydrodynamics parameters across the water column. Among them, a UB-Lab-3C, a high resolution ($dz=O(\text{mm})$, $dt=O(\text{ms})$) velocity and concentration profiler was deployed to sample (at 25 Hz) within the WBL. It was located 30 cm above the sand bed (see Figure 1). This prototype developed by Ubertone is based on the ACVP technology, built in LEGI, Grenoble (Hurther et al., 2011). The mooring was deployed in the intertidal zone of Porsmilin Beach, located in Brittany, Western France. It was set up at low tide to record while located underwater. The UB-Lab-3C, along with the mooring frame, was then retrieved during the following low tide. The day of the deployment, offshore conditions were quite mild ($H_s=0.75\text{m}$, WWIII).



Figure 1 - Mooring (left) and UB-Lab 3C (right, in red)

TREATMENT METHOD FOR UB-LAB 3C DATA

Data recorded with acoustic instruments need to be averaged to reduce noise. In order to obtain intrawave velocity profiles, waves need to be separated and averaged. This technique has been used in laboratory studies (Hurther et al., 2011) but in our case waves are all different, and their separation and averaging require a suitable method. In the present study, only the cross-shore velocity component recorded by UB-Lab 3C is considered. Moreover, thanks to a frequency-based decomposition, only the orbital component U_{orb} is kept. Since the height of the bed can vary a bit during the deployment, velocity data is bed referenced (Fromant et al. 2019). Then, a free stream wave signal is computed using the upper tail of the profiles. A zero-crossing method is then applied on this free stream signal, and the indices are used to cut the time series of velocity profiles into waves. For each wave, hydrodynamics parameters are computed. Waves with similar parameters (in the sense of semi-orbital excursion and asymmetry -that is to say acceleration skewness values) are then grouped. For each group, 19 waves are averaged. For this study, 3 groups of waves are given as an example (see parameters of the waves in Table 1). They correspond to waves with a high value of orbital semi excursion (A), and increasing asymmetry values R_a (group 1 being low asymmetry waves and group 3 higher asymmetry waves).

Wave	1	2	3
T (s)	7.9 / 0.85	8 / 0.69	8.1 / 0.61
R_a	0.61 / 0.04	0.70/0.02	0.52 / 0.06
R_u	0.58 / 0.07	0.5 / 0.06	0.76 / 0.03
A_{orb} (m)	0.6 / 0.17	0.52/0.11	0.57 / 0.12
U_m (m/s)	0.48 / 0.12	0.41 / 0.06	0.44 / 0.1

Table 1 - Parameters of the waves of each group (mean value / corresponding standard deviation value)

RESULTS

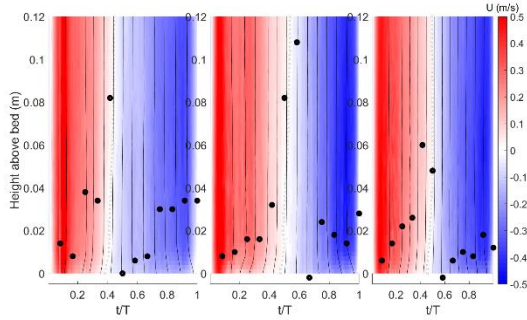


Figure 2 - Intrawave orbital velocity for group 1 (left), 2 (middle) and 3 (right). On each colorplot, the intra-wave evolution of the WBL is represented with black dots.

Figure 2 shows intrawave velocity profiles computed for the three wave cases (see Table 1), between the bottom and 12 cm above the sand bottom. Profiles averaged on 10 wave phases are shown in black. Gray crosses show the phase of onshore-offshore flow reversal along the whole profile, indicating that we recognize the commonly observed velocity phase lead close to the bed (order of magnitude 25°, coherent with previous studies). Also, the black dots represent the wave boundary layer thickness, defined as the first index where the velocity profile reaches 95% of maximum velocity value. The thickness increases more during the crest wave half cycle than during the trough wave half cycle, which had already been observed in Fromant et al., 2019 and Henriquez et al., 2017.

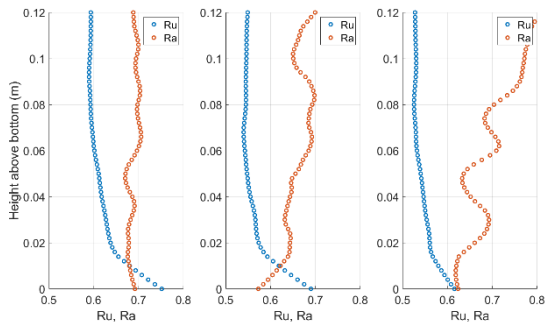


Figure 3 - Non-linearity evolution close to the bed

Figure 3 shows non linearity value evolution computed as approaching the sand bed (R_a , R_u) As anticipated under these asymmetric flow conditions (Henderson et al. (2004); Berni et al. (2013)), skewness values (in blue) tend to increase closer to the bed, while asymmetry values decrease (in orange). Figure 4 shows velocity phase lead values relative to onshore-offshore flow reversal (computed on first harmonic). Points corresponding to groups of waves 1, 2 and 3 (in color) are quite within the order of magnitude of previous laboratory studies.

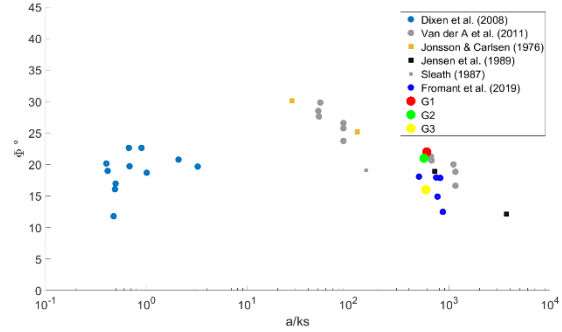


Figure 4 - Phase lead against A/ks ratio

CONCLUSIONS AND PERSPECTIVES

The first in situ high resolution Wave Boundary Layer data have been collected successfully on Porsmilin Beach, Brittany. Furthermore, a method to separate and average in situ real waves has been tested in the surf zone. The method allows to successfully compute the main WBL parameters. Values of phase leads, near-bed non-linearities as well as intrawave WBL thickness evolution are consistent with data from literature. To continue this study, intrawave bed shear stress will be computed. This will lead us to the study of initiation of motion and then, transport computation thanks to concentration estimation with backscattered intensity measurements from UB-Lab 3C.

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