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In situ measurement of hydrosedimentary dynamic in the surf zone : a versatile dedicated mooring.

**Noémie FRITSCH¹, France FLOC'H¹, Guillaume FROMANT²,
Eloi DRONIOU³, Stéphane FISCHER⁴**

1. Domaines Océanique UMR 6538 CNRS, Institut Universitaire Européen de la Mer (UBO), Plouzané, France. noemie.fritsch@univ-brest.fr france.floch@univ-brest.fr
2. Laboratoire d'Informatique Signal et Image de la Côte d'Opale (EILCO-ULCO), Calais, France. guillaume.fromant@univ-littoral.fr
3. DynamOcean, Lannion, France. eloi.droniou@dynamocean.com
4. Ubertone, Schiltigheim, France. stephane.fischer@ubertone.fr

Abstract:

Sandy beaches represent 39% of French coasts. They are submitted to erosion, notably because of the energetic wave conditions observed during extreme events (storms). On the contrary, when moderate wave conditions are observed, the sand tends to be brought back on the beach. Processes controlling erosion are quite well known thanks to numerous studies on the topic. As a consequence, erosion events are quite well predicted by models (VAN RIJN *et al.*, 2011). It is not the case when it comes to accretion; indeed, sand quantities transported onshore tend to be underestimated in predictive models (DALY *et al.*, 2017). In order to improve models, parameters controlling accretion need to be clarified. Onshore transport occurs mainly through bedload in the bottom boundary layer. One challenge still to overcome in coastal dynamic studies is to obtain in situ measurements allowing to observe the whole water column with enough resolution. The new mooring built in the frame of ANR WEST is versatile, easy to deploy in all kinds of areas, solid and allows to insonify the whole water column so as to obtain co-localized current, concentration and granulometry measurements. Thanks to the instrument positions, no acoustic interference is observed. Hydrodynamic parameters can be computed and agree with previous studies. The newly presented mooring is therefore well adapted to surf zone data collection.

Key Words:

Surf zone, Acoustic instruments, Measurement method, Hydrodynamic, Mooring.

1. Introduction

Sandy beaches are among the most dynamic areas on Earth. They owe their existence to hydrodynamic equilibrium which are site-specific (AAGAARD *et al.*, 2021) and result in a balance between onshore and offshore sand transport. Wave energy impacts the shoreline, leading to accretion or erosion. Moreover, the response to a given wave forcing

is strongly impacted by the antecedent beach state (YATES *et al.*, 2009). Erosion mechanisms are quite well-known and parametrized in predictive models (VAN RIJN *et al.*, 2011), which enables a precise prediction of eroded quantities. However, the processes leading to beach recovery are not so well quantified in models. Accretion processes are the consequence of the hydrodynamic disequilibrium following an erosion period, and are linked with onshore transport, mainly observed in the bottom boundary layer. However, the main parameters controlling this phenomenon remain to be clarified (BRENNER *et al.*, 2018). The surf zone is defined as the beach area between the breaking point and the shoreline. It is a really dynamic zone on beaches, which makes measurements in this zone quite complicated. There are therefore few data sets collected under real breaking waves, despite the fact that breaking is known to create turbulence in the bottom boundary layer which will induce suspension of sediment (VAN DER ZANDEN *et al.*, 2016). Since observations in this zone are technically complex, up until now, most experiences to study sediment transport processes in coastal area were realized in laboratory, in oscillatory water tunnels or in large scale wave flumes. However, those experimental facilities only offer a simplified version of the reality. For instance, the irregular waves in the field complicate the application of processing techniques used on data collected in idealized experimental facilities. Moreover, some free surface effects are neglected in oscillatory water tunnels, such as the streaming, known to contribute to onshore sand transport (KRANENBURG *et al.*, 2012). That is why various recent papers point out the need to collect in situ measurements to improve the predictive power of sand transport models (AAGAARD *et al.* 2021, FROMANT *et al.*, 2019). There are two main issues raised in the literature when it comes to coastal dynamics in situ studies: first, the complex logistic needed to deploy instruments in the surf zone and second, the lack of measurement means in the bottom boundary layer. Indeed, it is considered as a complex environment to monitor due to the high sediment concentration measured in this area. In that frame, a versatile mooring has been developed in order to overcome those technical measurement difficulties. It enables to monitor water column hydrodynamics and bottom boundary layer sediment transport in the surf zone, thanks to newly found technical solutions and an innovative acoustic instrument allowing sediment concentration and flow velocity measurement in the bottom boundary layer. First, the mooring is described, followed by experimental hydrodynamic conditions observed on deployment day. Then, some preliminary collected data are presented, and their exploitability and relevance are discussed. Finally, some perspectives for the use of this mooring and data analysis are presented.

2. Experiment

2.1 Site of study

The present study deals with the deployment tests, done on January 28th and February 28th 2022 on a macrotidal embayed beach (Porsmilin), located in western Brittany

(France) (Figure 1). Porsmilin beach is an embayed barrier beach flanked by cliffs to the East and West, and backed by colmated brackish water marshes to the North. The intertidal zone is 200 m wide and 200 m long and the median sediment grain size (d_{50}) is $320 \mu\text{m}$. Porsmilin beach is impacted by moderate southwest waves with an annual mean significant wave height of 0.76 m (BERTIN *et al.*, 2021). Topographic and bathymetric surveys are regularly done on this beach, since it is one of the observation beaches of Site National d'Observation DYNALIT.



Figure 1. Orthoimage of Porsmilin Beach, Brittany, France with mooring deployment place (orange point). (©SNO DYNALIT).

2.2 Mooring presentation and instruments

In order to monitor hydrodynamic processes and the induced sediment transport over the whole water column, including the Wave Bottom Boundary Layer, a versatile mooring dedicated for surf zone monitoring has been designed (Figure 2). The structure is 1 m high and 80 cm large. In the framework of the ANR WEST (Wave and Sediment Transport under Natural Breaking Waves, directed by France Floc'h) project, 9 instruments are fixed on the platform. The UB-Lab 3C (Figure 2, a) (©Ubertone) is placed at the front on the right side of the platform. It is a bistatic high resolution profiler (based on the Acoustic Concentration and Velocity profiling technique (HURTHER *et al.*, 2011)). It allows to obtain colocalized sediment concentration and velocity profiles and is adapted for sediment flux profiling in the bottom boundary layer (HURTHER & THORNE, 2011). 3 Acoustic Doppler Velocimeters (ADV, ©Nortek) are installed vertically, at 0.60 m, 0.78 m and 0.96 m above the mooring bottom which enables to study velocity time series at various heights in the water column (Figure 2, b). Indeed, ADVs enable measurements of flow speed in three directions on a single point, with an acquisition frequency of 64 Hz. Their heads are deported from the structure of 30 cm to avoid flow disturbances, as long as the hydrodynamic is cross-shore directed (distance

prescribed by the constructor). A current profiler (Aquadopp profiler 1MHz, ©Nortek) is placed on the bottom of the mooring (Figure 2, c), top-looking. It insonifies the water column from bottom to top, so as to obtain flow velocity profiles (cell size 0.25m). Its head is deported from the structure of 20 cm. A multifrequency sediment profiler (Aquascat, ©Aquatec) is placed higher on the structure, bottom-looking, and is tilted so as to observe sediment concentration profiles in the flow before it reaches the structure (Figure 2, d). A laser granulometer (©LISST) is placed on the lowest part of the mooring (Figure 2, e), aiming at checking the sediment size deduced from the Aquascat. A pressure sensor (©OSSI) is installed just next to it (Figure 2, f), principally aiming at measuring the water height. A camera completes the instrument installation (Figure 2, g). It records the insonification zone of the UB-Lab 3C in order to help with the interpretation of some singular echoes.

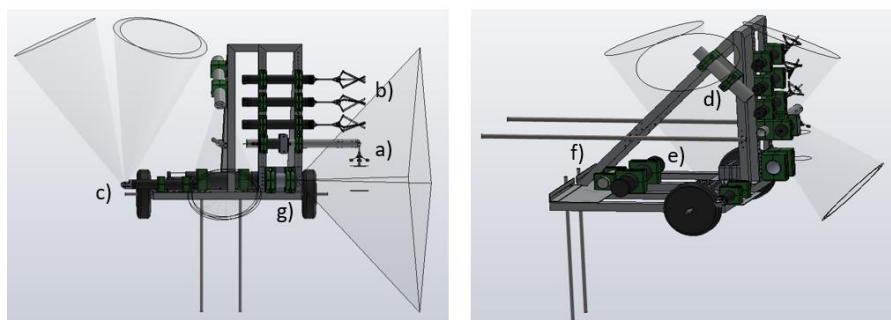


Figure 2. Drawing of the WEST platform (©DynamOcean). Instruments placed on the platform (with letters referenced in the text). Insonified areas are represented with circles.

2.3 Data processing

Data collected with UB-Lab 3C have high temporal and spatial resolution ($O(\text{ms})$, $O(\text{mm})$). They are processed as described in FROMANT *et al.*, (2019). The three velocity components collected with ADV have been reoriented so as to obtain u (cross-shore velocity component), v (long shore velocity component) and w (upward velocity component) (see Figure 3 for mooring orientation at Porsmilin beach). Velocity measurement precision is 0.004m/s with ADVs. Velocity data is cleaned using the despiking method described in GORING & NIKORA, (2002). The Aquapro allows to obtain current profiles in the water column thanks to 3 transducers. All 3-components velocity profiles have been reoriented so as to obtain a cross-shore, long shore and up velocity profile. Aquascat allows to retrieve backscattered intensity. Following the method described in FROMANT *et al.*, (2017), concentration profiles are obtained by applying an implicit inversion. With the four different frequencies used by the instrument, it is also possible to obtain the particle median radius. The LISST from Sequoia is the only instrument on the platform working with optical technology. Information on sediment grain size are obtained with this instrument, to check the radius obtained with

Aquascat data. Pressure data are processed with the method described in ROCHA *et al.*, (2017) to obtain water elevation measurements and non-linearity parameters.



Figure 3. Second deployment of the WEST mooring at Porsmilin, on February 28th 2022 (©France Floc'h). Cross-shore and long-shore directions are indicated for clarity.

2.4 Deployment

Data presented below comes from the deployment that took place on February 28th 2022. The mooring was placed in the intertidal zone on the beach at low tide (see Figure 1). The mooring is removed at the next low tide. According to pressure sensor data, water level has reached 1.8 m at high tide (around 14:30 UT) allowing the instruments to record the dynamics of several areas (swash zone, inner then outer surf zone, breaking area) so as to investigate the whole beach dynamics. UB-Lab3C data were not recorded in the present study.

2.5 Experimental conditions

In Table 1, wave conditions relative to February 28th 2022 are displayed, obtained 2 kilometers seaward of Porsmilin beach by Wave Watch III model on deployment day (Previmer model, Ifremer). On the day of the deployment, we observed that waves were mostly breaking.

Table 1. Experimental conditions at sea obtained with Wave Watch III model.

Wave period (s)	15
Hs (m)	1.25

3. Results and perspectives

3.1 Deployability and versatility

After some tests, it turns out that two people can easily deploy the platform in the intertidal zone on their own (see Figure 4). The removable wheels facilitate the deployment of the platform on the beach. Thanks to its low weight, it can easily be transported from the laboratory to the measurement



Figure 4. Platform deployment(©France Floc'h).

zone. According to measurement needs, different instruments can be fixed on the platform, which makes it a really versatile tool.

3.2 Exploitability of the results

One of the main concerns when deploying many instruments working with acoustic technology on the same platform is the appearance of interferences between acoustical signals. It turns out that this problem doesn't seem to appear in the data sets that have been collected yet. Indeed, all deployed instruments run with different frequencies. Moreover, they all have a specific acoustic directivity, and are oriented so that the insonified areas don't interfere with each other (see Figure 2 for the insonified cones). Visual inspection was done on all acoustic data sets and no interference was observed.

3.3 Mean parameters

In table 2, mean wave height parameters and Ursell parameters are displayed. Hs is the mean significant wave height, and HsIG corresponds to the significant height of the infragravity frequencies (below 0.04 Hz). The Ursell parameter is computed with the formula in DOERING & BOWEN, (1995) and allows to parametrize skewness and asymmetry values (RUESSINK *et al.*, 2012), see next paragraph.

Table 2. Mean wave height and Ursell parameters.

Hs (total) (m)	HsIG (m)	Ur
0.51	0.08	12.16

3.4 Hydrodynamic parameters

In order to investigate sediment transport processes in the wave boundary layer, it is important to link them with hydrodynamic conditions, and this is why it is so important to monitor the whole water column thanks to the WEST surf zone dedicated mooring. On Figure 5, values are displayed when the instruments were underwater (between 13:00 and 16: 00 UT). Infragravity waves were removed from the signal before computing hydrodynamic parameters (RUESSINK *et al.*, 2012). Since changes in beach morphology are predominantly a response to cross-shore processes (DALL *et al.*, 2000), only the cross-shore velocity component is considered here. First, the water height evolution is displayed, then the skewness value (Figure 5, 2nd graph) computed with ADV (in blue) and pressure (in orange), with the same colors for the asymmetry values (Figure 6, 3rd graph). On those graphs, the dotted line corresponds respectively to the skewness and asymmetry computed with Ursell number with parametrization from RUESSINK *et al.*, 2012. The turbulent kinetic energy (TKE) values are displayed for each ADV. To compute the latter, it was chosen in this case to first remove the mean component from the signal, and then to compute the orbital component with a low pass filter with a cut frequency at 1Hz, and then removing the obtained signal from the original signal. The

same was done for each of the velocity component. Then, TKE was computed with the usual formula: $\langle k \rangle = 0.5(\langle u'^2 \rangle + \langle v'^2 \rangle + \langle w'^2 \rangle)$ and values of the same order of magnitude as VAN DER ZANDEN *et al.*, (2016) were found. By studying these parameters variation, it is hoped to correlate high sediment concentration (and therefore presence of suspended sediment) with breaking. This would therefore help to understand how turbulence interacts with suspended sediment and how this participates in sediment transport.

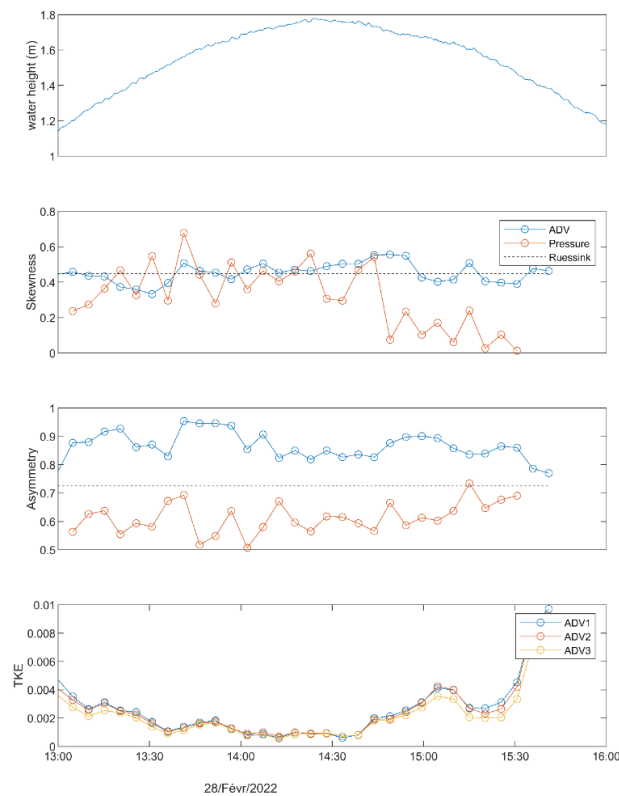


Figure 5. Hydrodynamic parameters computed on cross-shore component from ADVs.

4. Conclusion

A new mooring dedicated to surf zone measurements has been deployed in the frame of ANR WEST, in order to monitor hydrodynamics and sediment transport in the whole water column. The mooring is versatile, easy to deploy and aims at solving the main challenges of in situ sediment dynamics measurements, thanks to a world first colocalization of sediment multifrequency profiler and current meters. Tests deployments allowed to collect a first dataset, offering preliminary results. Interferences don't appear to be cause for problem. The measurement protocol described above is adapted to collect data to observe surf zone dynamics. Future deployments with UB-Lab 3C, allowing to obtain high resolution co-localized concentration and velocity profiles in the Wave

Bottom Boundary Layer, will give more information about sand dynamics in the surf zone of sandy beaches.

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