VERY LOW FREQUENCY RIP CURRENT PULSATIONS DURING HIGH-ENERGY WAVE CONDITIONS ON A MESO-MACRO TIDAL BEACH

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Very Low Frequency (VLF) rip current pulsation investigations are still poorly documented in the literature. In this paper, we analyse data acquired during an in-situ field experiment on Truc Vert beach, on the Aquitanian coast. This beach was exposed to high energy wave conditions during a spring tide cycle and has high tidal range and gentle slope. VLF motions were observed within the surf zone, with a characteristic frequency of 6 10^{-4} Hz which corresponds to a 27 minute period. These VLF motions were associated with high velocity. This paper shows that the VLF velocity pulsations were larger in the inner surf zone and increased with increasing offshore wave energy. We found that the significant wave height and the velocity evolved in-phase. These results are in good agreement with Callaghan et al. 2004. This paper also suggests that wave groups might have generated these VLF pulsations.

INTRODUCTION

This paper presents in-situ field experiment results about Very Low Frequency (VLF) rip current pulsations. Many authors have been interested in rip currents over the past 3 decades (MacMahan et al., 2006), but to our knowledge, the VLF contribution has not been so well documented.
Two recent papers in 2004 investigated these VLF motions, both of them involving in-situ field experiment. MacMahan et al. (2004) made some observations on a beach exhibiting quasi-periodically spaced rip current channels at Sand City, in the southern Monterey Bay (California, USA). These observations took place during the RIPEX field experiment from April to May 2001. The beach face was relatively steep (slope of about 1:10). They showed that the VLF motions were located outside the gravity restoring region, and are believed to be related to surf zone eddies. They also showed that the VLF root mean squared velocity was constant within the surf zone. Callaghan et al. (2004) also investigated these current pulsations in another type of environment. The experiment took place on a beach exhibiting a Transverse Bar and Rip (TBR) system on the eastern coast of Moreton Island (Queensland, Australia). Moreton Island is a sand barrier east of Brisbane and exposed to Pacific Ocean high wave energy. The bathymetry is conformed to the classic rip-feeder system, with two feeder channels inshore of an inner bar converging to the rip channel. All of

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these authors agreed with the fact that VLF velocity pulsations are increasing with increasing wave energy. But Callaghan et al (2004) pointed out that, in contrast with MacMahan et al. (2004), the VLF wave energy pulsations were synchronized with both the cross-shore and the alongshore velocity pulsations.
We get interested in that question and we analyse data acquired during an in situ field experiment on the Aquitanian coast, in particular on Truc Vert Beach. The specificities of this site are high wave energy, high tidal range with a gentle sloping beach. Figure 1 shows an aerial photograph of a typical intertidal Transverse Bar and Rip (TBR) system on the Aquitanian coast, with the presence of a wave-induced rip current. This rip current plays a key role in nearshore morphodynamics and is also responsible for beach safety issues during the summer months. This rip current, with an approximately 300 m alongshore wavelength (Fig. 1), is associated with complex circulation cells.
This complexity is well shown in the frequency domain. A typical cross-shore velocity spectra of the rip system of the Aquitanian coast is represented on Figure 2. One can notice the different energetic contribution. The swell contribution is in the frequency band 0.04-035 Hz and the infragravity contribution (IG) is in the frequency band 0.004-0.04 Hz (see Bonneton et al (2004)), the very low frequency (VLF) is in the frequency band 0.0005-0.004 Hz.
On figure 3, you can see the time evolution of the five minute averaged cross-shore velocity.

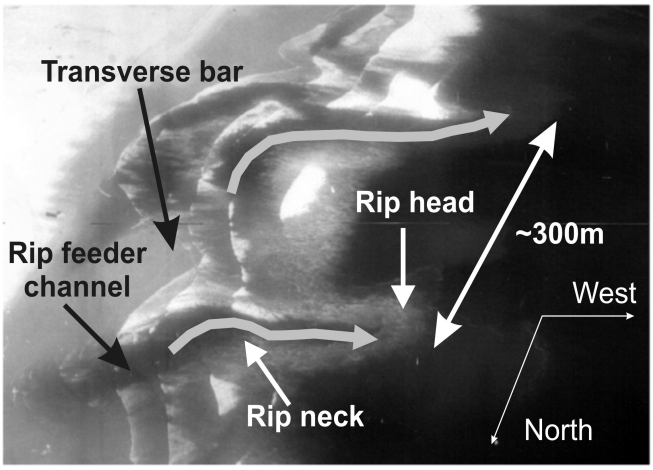

Figure 1. Aerial photograph of a typical Transverse Bar and Rip (TBR) morphology on the Aquitanian coast (Castelle and Bonneton (2006)).

We can notice that the cross-shore velocity is high with a maximum of about 1

m/s which is quite strong. Figure 3 shows cross-shore velocity oscillations of large amplitude. For example, at the time t=200 minutes, the cross-shore velocity oscillations, that is to say **ΔUx** is about 90 cm/s. We can clearly observe, with the naked eye, a period of this velocity which is roughly estimated at 25 minutes, and which corresponds to very low frequency motions.
In this paper, we will discuss the physical processes associated to VLF motions, observed during the Truc Vert beach field experiment.

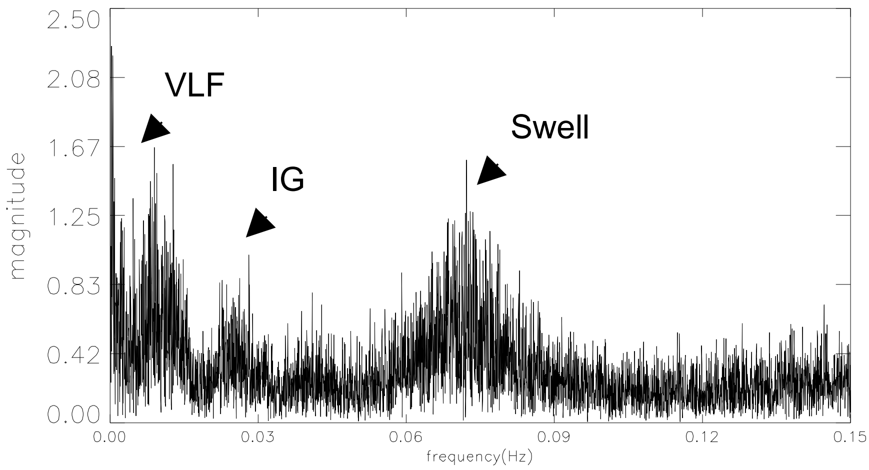

Figure 2. Cross-shore velocity spectra.

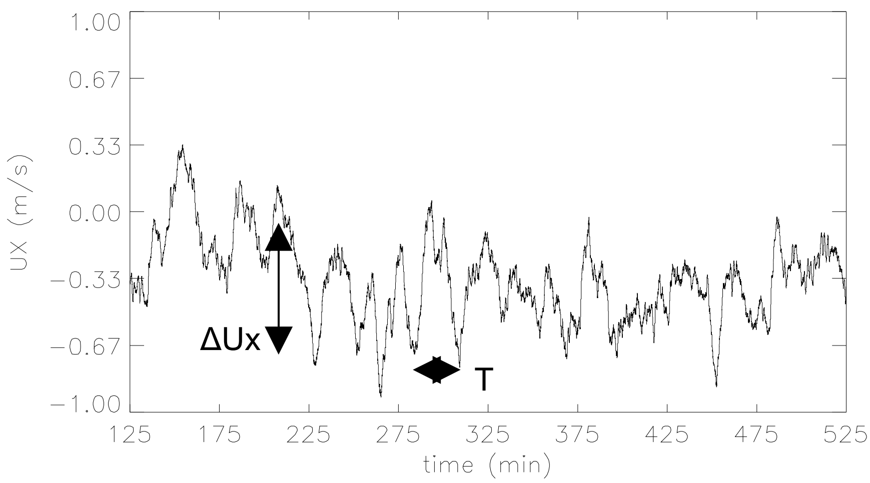

Figure 3. Five minute averaged cross-shore velocity.

FIELD SITE

The experiment took place from the 14th to the 19th of October 2001. The nearshore area was characterized by the presence of two distinct sandbar systems. The outer bar exhibited crescentic patterns and a TBR system connected to an inner crescentic bar system (see Fig. 4). The present study focuses on hydrodynamics over the TBR system. Three transect lines were positioned along which pressure sensors were deployed to provide the alongshore variability of the cross-shore distribution of wave heights. Three bottom-mounted directional wave current meters were deployed. Two S4 positioned at the end of each transect and one ADV (see Figure 4). Such instrument deployment was undertaken in order to assess the 2-dimensional variability of both waves and wave-induced currents. A Triaxys directional wave rider, moored approximately 15 km offshore, provided the incident wave conditions.

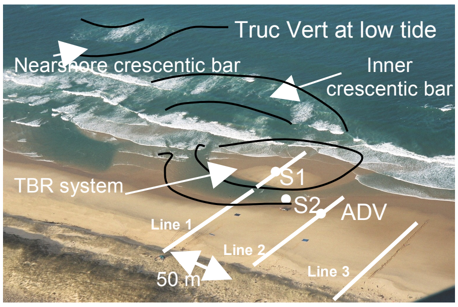

Figure 4. Instrument deployment at Truc Vert Beach during PNEC 2001 field measurement.

During this experiment, the wave conditions were energetic. For this study, we focus on the 18th of October when offshore significant wave heights reached 3 m with a shore-normal incidence.

The wave-induced current patterns during this field experiment were investigated by Castelle et al. (2006) with a time and depth averaged (2DH) modeling approach. Figure 5 shows an example of undertaken simulation on the 18th of October, showing the presence of complex circulation cells over the three-dimensional bedform features. In particular, a strong narrow seaward oriented current is observed with a maximum mean flow velocity of about 1 m/s. Castelle et al. (2006) showed that rip current was favoured by the presence of shore-normal wave incidence and that the maximum rip current flow velocity occurred at mid-tide for low-energy to moderate wave-energy conditions

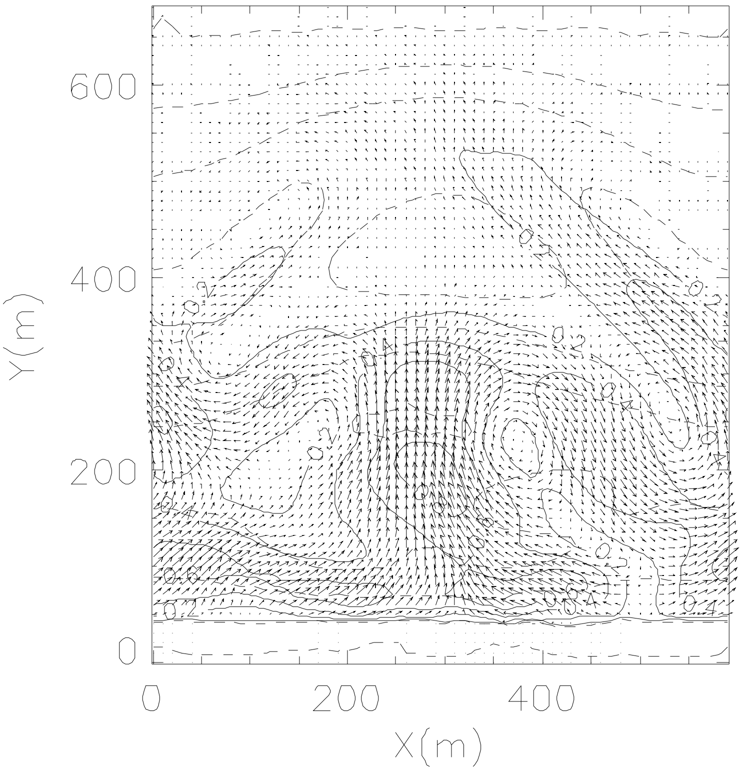

Figure 5. Simulation of mean wave-induced current during the 18th of October 2001, the solid lines represent the iso-values of mean current velocities in m/s, the dashed lines correspond to the bathymetry (Castelle et al., 2006).

RESULTS

You can observe on Figure 6 the time evolution of both the cross-shore (Ux) and alongshore (Uy) velocity during the first tide cycle on the 18th October 2001, when the significant wave height (Hso) was in order of 3 m. The cross-shore velocity intensity is negative if the current goes offshore, and the alongshore velocity intensity is positive in the north direction.
For this very high wave intensity conditions, the cross-shore current can reach the value of 1 m/s, which is quite large.
We observe very low frequency motions with a period in order of 25 minutes and notice quasi-periodic oscillations with very large amplitude for both the cross-shore and alongshore velocity components (see figure 6). To study this VLF motions more precisely, a spectral analysis of the cross-shore velocity has

been done. The Ux spectra are computed from the autocorrelation function where the white noise has been filtered (see figure 7). This analysis showed clearly a very energetic peak at f = 6 10^{-4} Hz which corresponds to a period equal to 27 minutes

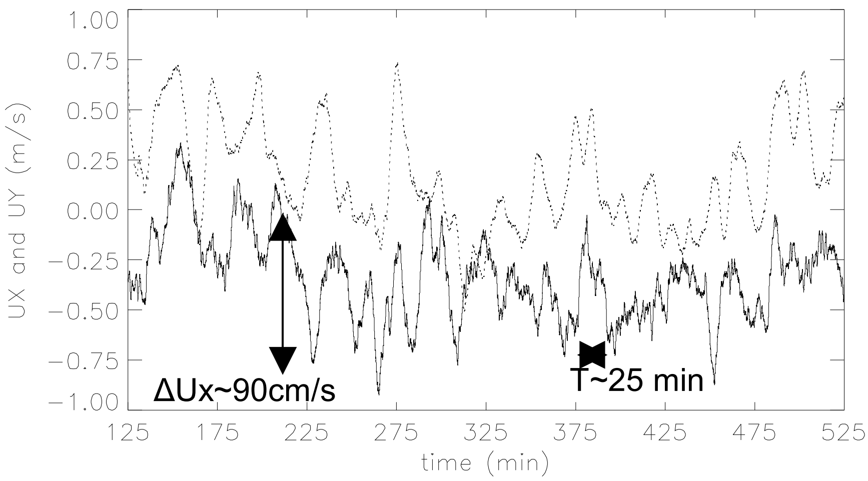

Figure 6. Time evolution of the 5 minute averaged cross-shore velocity (Solid line) and alongshore velocity (dashed line), during the 18th of October 2001.

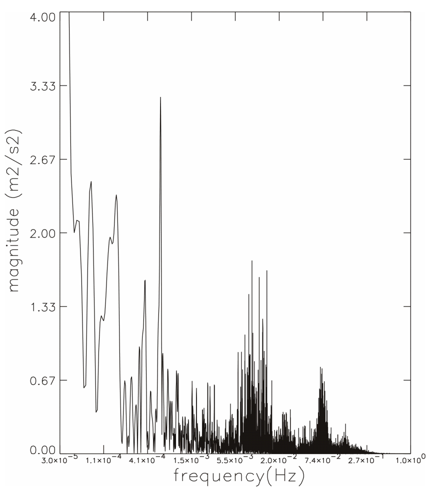

Figure 7. Cross shore velocity spectra.

The five minute averaged cross-shore and alongshore velocity are represented on figure 8. Figure 8 (a) and (b) show respectively their time evolution for the first tide and the second tide of the 18th of October. For both tides, the wave were frontal, the significant wave height was high, up to 3m (Hso=3m) for the first tide and more moderate for the second tide (Hso=2.3m).
We notice that the intensity of these oscillations is larger when the offshore wave conditions are more energetic.
Sénéchal et al. (2004) have shown that the minimum value of γ = Hs/hm (where Hs is the significant wave height and hm the mean water depth) is equal to 0.5 within the inner surf zone. When γ is smaller than 0.5, the S4 is located outside the inner surf zone. For the first tide (see figure 8 (c)), the instrument was always in the inner surf zone, and for the second tide (see figure 8 (d)), the instrument was outside the inner surf zone from 950 minutes to 1150 minutes. We remark that both the Ux and Uy oscillations intensity are larger in the inner surf zone.

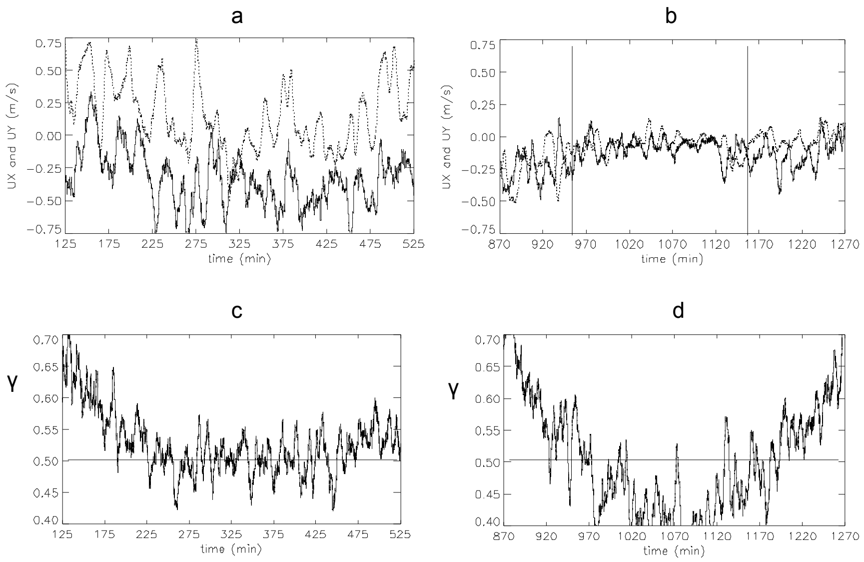

Figure 8. Five minute averaged Ux in solid line and Uy in dashed line during the first tide (a) and the second tide (b), and γ during the first tide (c) and the second tide (d).

On Figure 9 is plotted in solid line, the time evolution of the five minute averaged water depth and in dashed line, the time evolution of the significant wave height for the second tide of the 18th of October. The five minute averaged water depth presents no oscillation. On the contrary, the significant wave height oscillates, with a period in order of 25 minutes, the same as we already pointed out for the cross-shore velocity.

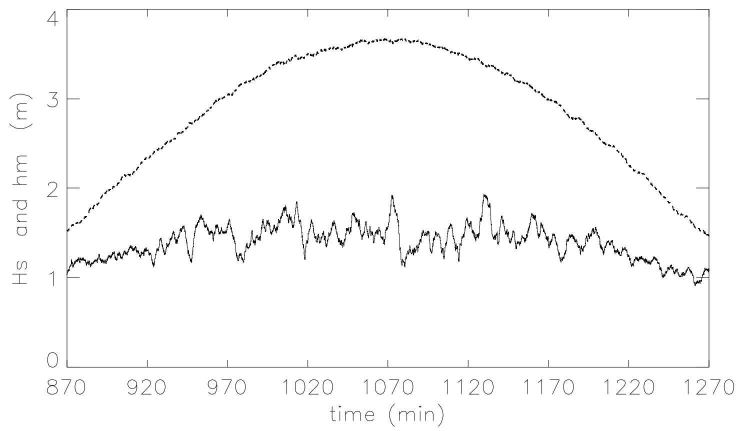

Figure 9. Significant wave height (solid line) and five minute averaged water depth (dashed line).

If we superimpose the significant wave height and the velocity intensity during the second tide of the 18th of October (Figure 10), we find that the significant wave height and the velocity intensity are evolving in-phase. This result is in agreement with Callaghan et al. (2004) observations and indicates that the VLF motions are probably generated by wave groups.

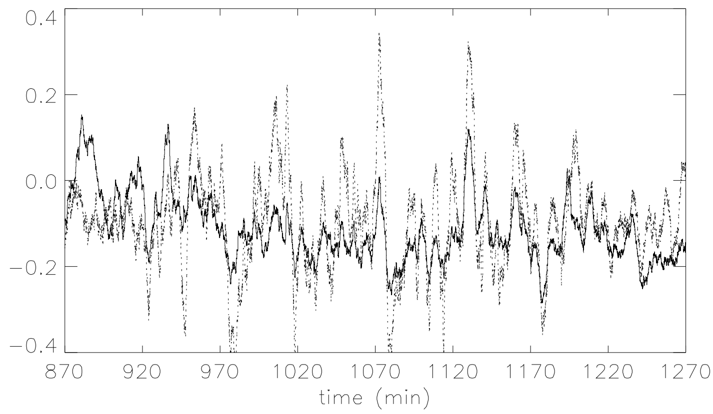

Figure 10. Significant wave height (dashed line) and Velocity intensity (solid line) during the 18th of October 2001.

CONCLUSION

A field experiment was undertaken at Truc Vert Beach during a spring tide cycle for high energy wave conditions. VLF motions are observed in the surf zone with a peak energy frequency of about 6 10^{-4}Hz. These VLF motions are characterized by high velocity (in order of 1m/s) and very large amplitude velocity pulsations. We have shown that the VLF velocity pulsations are larger in the inner surf zone, and increase when the offshore significant wave height is increasing. We found that the significant wave height and the velocity are well correlated. These results are in good agreement with Callaghan et al. (2004). The mean water depth has no oscillations. It seems that wave groups might have generated very low frequency currents.

A new international field experiment on Truc Vert beach in 2008 will be organized to have a better understanding in wave induced hydrodynamic and sand bar morphodynamic. One of the components of that experiment will try to answer to the role of the wave groups on the VLF motions and to confirm or invalidate the relation between large horizontal vortices and VLF motions proposed by Mac Mahan et al (2004). For that, accurate offshore conditions will be accessible.

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