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LOW FREQUENCY WAVE ENERGY DISTRIBUTION IN A CORAL REEF-LAGOON SYSTEM

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1 INTRODUCTION

In a coral reef system, the reef barrier protects the lagoon from incoming ocean waves favoring the development of a relatively calm ecosystem in the middle of a much more energetic domain. Incident sea-swell waves (SS) are filtered and transformed while passing over the reef ; and simultaneously long waves (with usually wave periods greater than 20 s in such a context) are generated. These long waves are important drivers for marine submersion along low-lying islands. Thus, for several years, the scientific community has increased its effort in the understanding of reef-lagoon wave energy spectral distribution. In particular, works have focused on the origin of infragravity waves (IG) classically observed in the frequency band [0.004 ; 0.04] Hz. It has been shown that IG are forced mainly by wave groups, either through the release of incoming bound waves or through the oscillation of the breaking point. Waves and IG overpassing the reef might also drive the emergence of much longer waves termed VLF (Very Low Frequency) waves, some of which being possibly resonant waves (Gawehn et al., 2016), a category of long waves that are still poorly understood in reef-lagoon context.

The aim of this study is to explore a set of pressure time series measured on a reef-lagoon system in French Polynesia in order to characterize the spatial, frequency and temporal distribution of IG / VLF energy. An additional purpose is to create a methodology capable of identifying, in pressure time series, any type of long wave developing in the IG / VLF bands.

2 METHODOLOGY

Unlike that of IG which is now pretty well established, the methodology for the analysis of VLF waves in pressure time series remains exploratory and is thus deeply discussed in this work. At first, the choice of the duration of the burst used for calculating the energy density spectrum is pivotal: the signal must be sufficiently long to contain the very long oscillations being sought; and at the same time it must be short enough to avoid too much signal variability in the burst. Phenomena located lower than VLF in the frequency domain, such as tides, are subtracted from the signal before deriving the frequency spectrum. Generally, relevant spectra are obtained from a Fourier transform of 3 hour long bursts taken from the previously filtered signal. For each burst, a central spectrum is calculated, as well as three other spectra on either side of the main one from data segments shifted in time with an overlap of 50% between each of them. The average of the 7 partly superimposed spectra results in a final mean spectrum estimated over 12 h of data. Then, this final mean spectrum is divided into four main bands: sea swell (SS) from 0.04 Hz to 0.3 Hz, IG from 0.01 Hz to 0.04 Hz, low frequencies (LF) from 0.005 Hz to 0.01 Hz and very low frequencies (VLF) down to 0.0001 Hz. Such frequency domains are set following Gawehn et al. (2016) and Shimonozo et al. (2022) ; they are also adjusted so that they fit frequencies at which energy minima are clearly identified in the total spectrum calculated after the sum of all the spectra produced at all bursts and at various representative stations in the reef-lagoon system. Then, for each mean spectrum, significant peaks are selected where the energy exceeds a given threshold (here the mean plus one standard deviation). The spatial persistence of these peaks through the reef-lagoon system is then evaluated by calculating the number of times a significant peak occurs per frequency bin for a selected set of sensors spread over the system. Plotted on what we call *threshold correlograms* (see figure), this strategy offers a simple and efficient tool to explore the combined time/ spatial/ frequency distribution and co-occurence of long waves within the reef-lagoon system.

3 RESULTS

This original methodology is applied to a dataset collected island-wide of Maupiti in French Polynesia. In the SW reef, 5 stations recording the pressure at 10 Hz (OSS02 to OSS06) were placed in a cross-reef transect facing the main ocean wave forcing and 3 others (CPT08_F2 to CPT10_F2) were aligned in the shallow lagoon from the reef-lagoon boundary to the coast of the inner volcanic island. First of all, for the four frequency bands, significant height Hs for a storm period of about 4.5 days are calculated and averaged, and then displayed as colored bars in a normalized histogram for each station (see figure). The device at the reef crest (OSS02) has 46% of its spectral energy content in the SS domain (Hs = 0.41 m) while it decreases to 21% (Hs = 0.04 m) at the end of the transect (OSS06). The innermost device on the island (CPT10_F2) contains practically the same amount of energy in the long wave band, but a greater proportion is in the VLF band (37% at CPT10_F2 versus 29% at OSS06). Threshold correlograms are computed in the VLF band for two groups of devices, those on the cross-reef transect (B) and those in the lagoon (A). In the two resulting threshold correlograms (see figure), VLF energy persists in time and space around 0.001 Hz (approx. 17 min). The threshold correlogram of the transect B shows also some persistence of VLF at 0.0024 Hz (approx. 7 min) for 5 distinct devices; nevertheless, the correlation is not fully maintained over the covered period. In addition, this VLF pulsation appears to be specific to the reef flat, as there are no apparent dominant peaks at the two most onshore sensors on transect A (see figure).

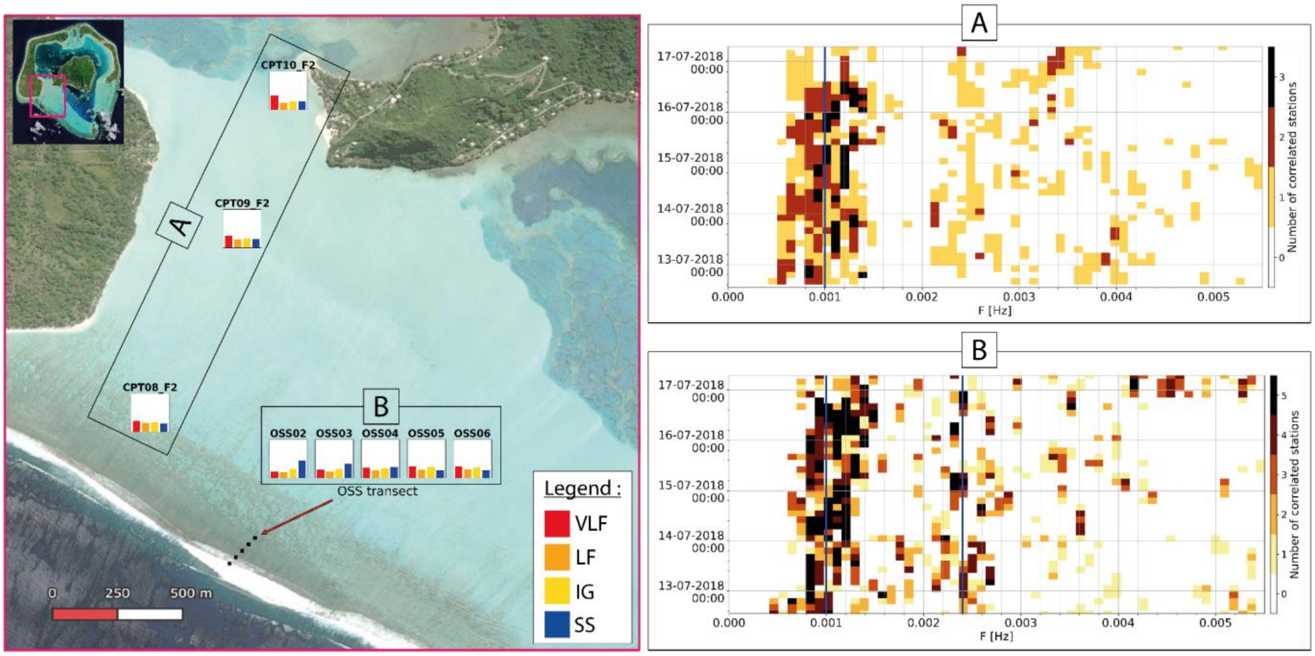

Figure 1. Left : mean Hs for a 4.5-days represented by normalized histograms on a map. Right : threshold correlogram for the 3 stations of transect A (top) and the 5 stations of transect B (bottom)

This preliminary exploration of the long waves in a reef-lagoon system with a full time/spatial/spectral methodology demonstrates that the energy distribution classically concentrates in IG frequency domain but can also be dominated by a VLF signature (see compared Hs in the figure), which make very strategic a more detailed analysis of the mechanisms at the origin of a combined emergence of IG and VLF. Further works must detail the energy transfers toward IG and VLF frequency domains while SS content degenerates over the reef and within the lagoon. This perspective is currently explored, and the use of threshold correlograms is now applied systematically to many other stations of the Maupiti campaign, and will be soon generalized to other reef-lagoon field campaigns.

REFERENCES

Gawehn, M., A. van Dongeren, A. van Rooijen, C. D. Storlazzi, O. M. Cheriton, and A. Reniers (2016). “Identification and classification of very low frequency waves on a coral reef flat”. In: Journal of Geophysical Research: Oceans 121.10, pp. 7560–7574

Shimozono, T., R. Shibata, S. Onaka, T. Mori, and Y. Awazu (2022). “Variability of shoreline water levels on an atoll in the Maldives”. In:Journal of Geophysical Research: Oceans 127.5, e2021JC017880