A FIELD OBSERVED PHENOMENON OF WAVE PEAK FREQUENCY DOWN-SHIFTING IN A REEF AREA

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INTRODUCTION

Long waves have been received many attentions because they could induce modulations of sediment transport, and contribute to instability in the coastal environment(Liu et al., 2023). In general, the generation mechanism of long waves is mostly through wave-breaking (Péquignet, Becker, & Merrifield, 2014), wave-current interaction(Ho, Merrifield, & Pizzo, 2023), and harbor resonance(Gao et al., 2021). Dissipation of short waves might also cause wave peak frequency down-shifting in shallow reef regions (Huang et al., 2012).

We found a field observed phenomenon of wave peak frequency down-shifting (WPFDS) in a reef area based on a yearly long-term monitoring of waves in shallow waters by pressure sensors and in offshore open sea by wave buoy over a reef area, Taoyuan, Taiwan (Figure 1). The local water depth is about 3 meters. We found that the peak wave period in shallow water regions (blue and green line) is similar to that of the offshore buoy (black line). The peak wave period is mostly from 5 to 10 seconds. However, the peak period in shallow water areas will be higher than 10 seconds under certain periods (red boxes), while the peak wave period in the open sea is still at about 5 seconds. The phenomenon of WPFDS to low frequency occurs, indicating the formation of long waves or dissipation of higher short waves in the shallow coast area.

This study aims to reported and try to clarify the mechanism and factors for the new observed phenomenon of wave peak frequency down-shift at the algal reef.

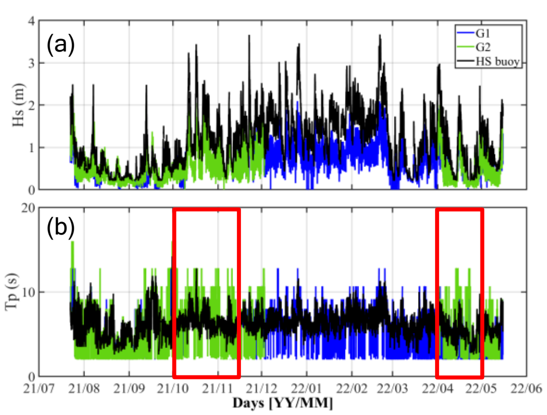

Figure 1 - Wave conditions during the field experiment at G1 (blue line), G2 (green line), and Hsinchu buoy (black line). (a) Significant wave height ;(b) Wave peak period. The red boxes refer to the wave frequency down-shifting events.

FIELD EXPERIMENTS

The study area is located near the new built liquefied natural gas (LNG) receiving industrial port at Taoyuan Coast, Taiwan. Taoyuan coast of Taiwan has a unique algal reef ecosystem that provides a variety of biological habitats and covers the endemic species of *Polycuathus chaishanensis*(Kuo et al., 2020).

A long-term field experiment was conducted from 2021/07 to 2022/06. The instruments were deployed in the Taoyuan coast as presented in Figure 2. We deployed two Acoustic Doppler Current Profilers (Nortek Signature1000) at two locations (G1, G2), which are in the similar water depth of approximately 3 m on the reef to measure waves and currents. The pressure sensor in the ADCP was set to record a 17-minute data burst at 4 Hz every hour.

We collected the offshore data from the Hsinchu buoy operated by Marine Meteorology Center of Central Weather Administration, which is adjacent to the study area. The buoy data was set to record 10-minute data at 2 Hz every hour and was in a water depth of approximately 23 m in the open ocean.

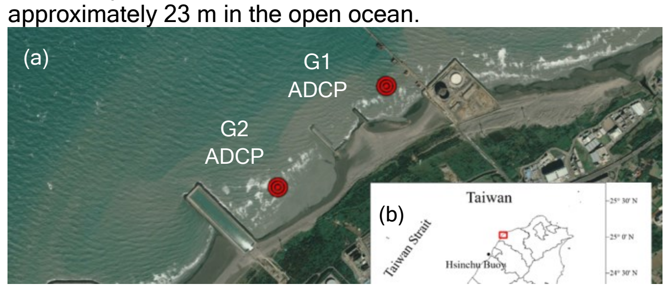

Figure 2 - (a) The location of the Taoyuan coast with the sites of the instruments relevant to this study (red dots). Two Acoustic Doppler Current Profiler (ADCP) was deployed at locations of G1 and G2. (b) Taiwan map; the red square indicates the study location. The block dot is the Hsinchu buoy location.

RESULTS

The long-term monitoring of waves results are show in Figure 1. We found that the WPFDS is mostly occurred in the seasonal transition periods such as autumn (Sept. to Nov.) and spring (Apr. to May). In addition, it can be found that this phenomenon is both observed in the instruments deployed in both of the locations G1 and G2. The results indicated that this phenomenon might be not due to the wrong measurements by the instruments.

From the statistical analysis of data for the entire year, we can identify several characteristics of events in which the WPFDS. Figure 3 shows the time series of the tide, and wave conditions during one wave peak frequency down-shifting event from 28 Sept. to 04 Oct. The recorded water level is presented in Figure 3 a. The data show that when the WPFDS occur commonly in the neap tide period.

In order to confirm whether the WPFDS is due to the energy loss of short waves, we computes the frictional dissipation rate and breaking parameter, γ, as presented in Figure 3d and Figure 3e. We used an simple empirical parameterization formula to estimate the frictional dissipation rate was proposed by (Huang et al., 2012) with the form

$$D_f = C_f \rho u_b^3 \quad (1)$$

where C_f is the coefficient of bottom friction, ρ is the water density and u_b is near-bed velocity.

The breaking parameter, γ, refers to the ratio of wave height to water depth and is a primary determinant of the occurrence of depth-limited wave-breaking (Hardy & Young, 1996). A commonly value of $\gamma_c = 0.5$ is suggested as critical breaking parameter. According to the above results, we can find that when WPFDS occurs, the frictional dissipation rate is less than 5 W/m^2. and the breaking wave index is less than 0.5. The result shows that the occurrence of WPFDS is not due to wave breaking.

Discussions on how the events of WPFDS occurring solely from a statistical perspective of water depth and breaking index is not satisfactory. Wave spectra provide comprehensive information on wave energy distribution at different frequencies. Figure 4 shows two typical examples of the variation of the spectra from the offshore buoy and ADCP. Figure 4(a) is the case that the WPFDS does not happen, and Figure 4(b) is the case WPFDS does happen. Under normal conditions (Figure 4(a)), the wave spectrum is a single-peak spectrum, and wave energy is dissipated from the open sea to the near shore. During events of the WPFDS, the wave spectrum becomes a shape that contains multi-chromatic wave modes and there is no obvious energy dissipation from the open sea to the shallow coastal regions.

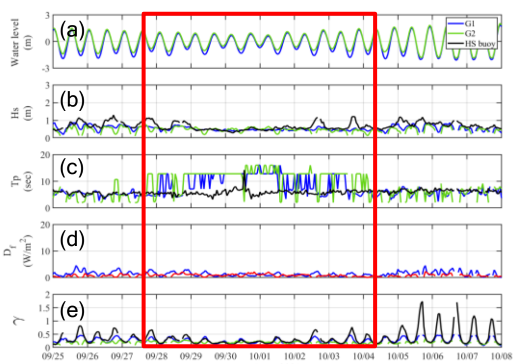

Figure 3 – Tide, wind, and wave conditions during events of the wave frequency down-shifting at G1 (blue line), G2 (green line), and Hsinchu buoy (black line). (a) Tidal elevation ;(b) Significant wave height ;(c) Peak period ;(d) frictional dissipation rate ;(e) breaking parameter, γ =Hs/h$_{G2}$. The red box refers to the wave frequency down-shifting event.

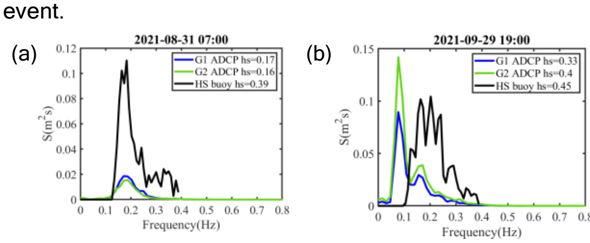

Figure 4 –The variation of the spectra at different locations for different periods (a) Normal condition; (b) events of the WPFDS

CONCLUSIONS

This work presents that a new field observed phenomenon of wave peak frequency down-shifting (WPFDS) in a reef area based on a yearly long-term monitoring of waves. We have checked the instruments; the results confirmed that this phenomenon is not caused by the failure of the instruments. The phenomenon commonly occurs during the neap periods. The result shows that the occurrence of WPFDS is not due to wave breaking and only occurs during small wave events. During events of the WPFDS the wave spectrum becomes a shape that contains multi-chromatic wave modes and there is no obvious energy dissipation from the open sea to the shallow coastal regions. More detailed results and discussions on the phenomenon of WPFDS will be presented in the conference.

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