ESTIMATION OF WAVE HEIGHT BY USING COASTAL SOUND

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1. Introduction

In the research field of coastal engineering, while several researchers reported the physical mechanism or occurrence mechanism of the sound of breaking waves, the estimation of the wave height by using sound of waves has not been done.

Thus, in this study, we have developed a method to estimate the wave height at a sandy beach using the observed pressure level of coastal sound spreading all around the coastal area.

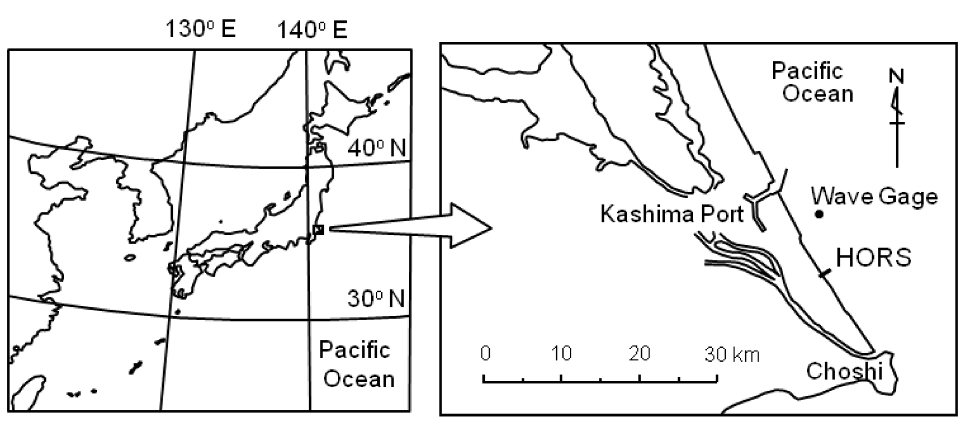

Figure 1. Location of Hazaki Oceanographical Research Station (HORS).

Picture1. A research facility (HORS) and a sound pressure level meter.

2. Data Description and Method

Beach profile data were obtained at Hasaki Oceanographical Research Station (HORS, Fig. 1, Pic. 1), which conducts field measurements of various phenomena in the nearshore zone on the Hasaki coast of Japan. An ultrasonic weave gage (USW) sensor was mounted at a water depth of 23.4 m offshore of the Port of Kashima (Fig. 1).

The field observations were conducted for two periods, first one from 12:50 JST on July 30 to 12:10 JST on September 14, 2009 (total 46 days), and the second one from 13:50 JST on September 14 to 10:10 JST on November 2, 2009 (total 50 days), at HORS. In order to measure coastal sound, a sound level meter (NL-21, RION) was fixed on the top of the research facility (Pic. 1). Data of sound pressure level were recorded every 5 minutes (5 minutes averaged value), and the frequency correcting circuit was set as the flat characteristics. The wave data, which were used for comparative discussion, were observed by an ultra-sonic type wave gage (UH-401, KENEK) at the tip of the pier (362.1 m seaward from the averaged shoreline position).

In this analysis, 20 minutes averaged data of sound pressure level, and the significant wave height and the corresponding significant wave period were used.

3. Results and Discussions

(1) Observed data:

The time series data of sound pressure level, significant wave height (Hs), significant wave period (Ts) and wind speed during the first period (from July 30, 2009 to September 14, 2009) were shown in Fig. 2.

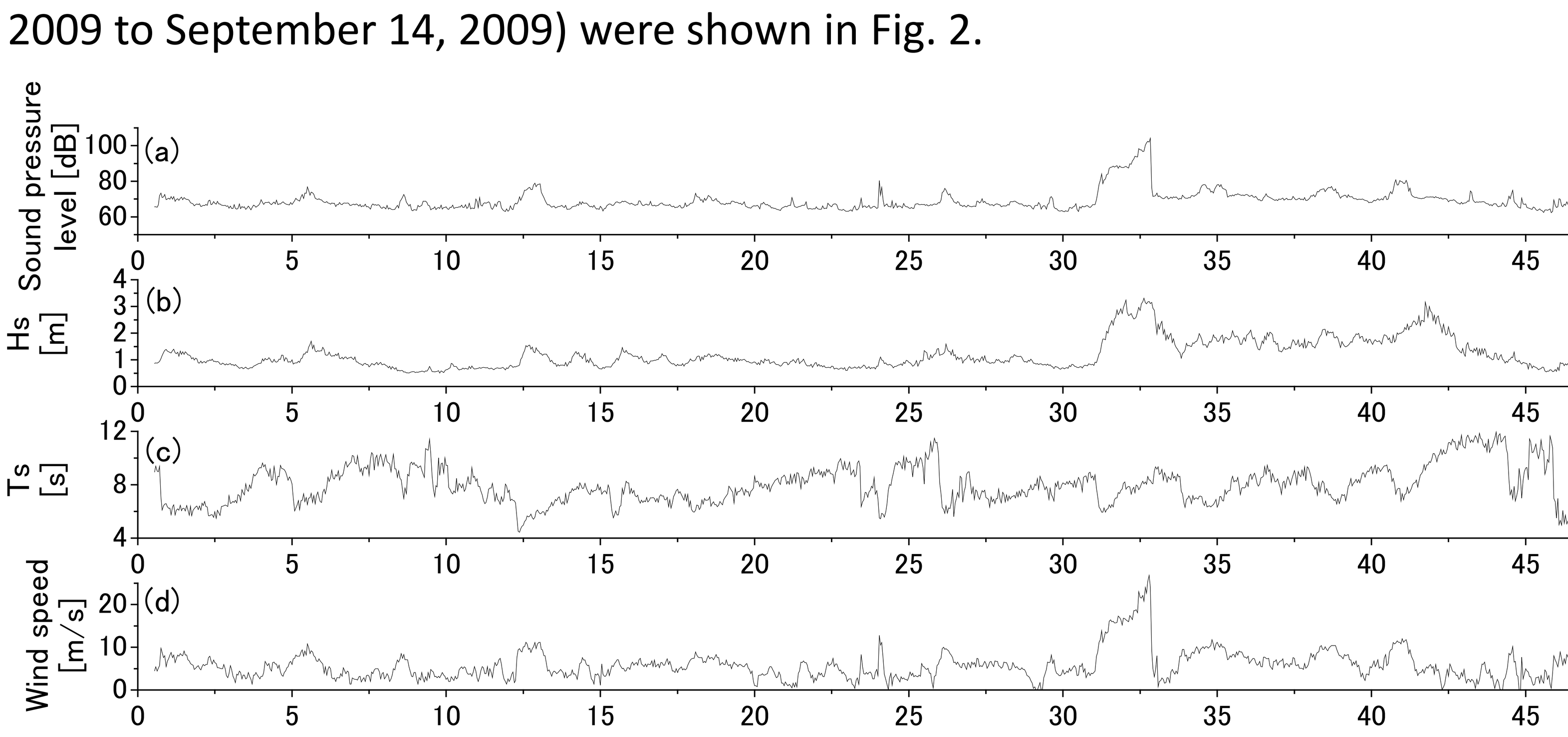

Figure 2. Time series data of (a) Sound pressure level, (b) Significant wave height, Hs, (c) Significant wave period, Ts and (d) Wind speed.

(2) Relationship between coastal sound and significant wave height:

Figure 3 shows the relationships between the coastal sound pressure level and the significant wave height (Hs) divided by the range of the significant wave period (Ts). The coastal sound pressure level and the Hs basically have a positive correlation. The distribution, however, shows high dependence on Ts.

From the data of Hs, the values tend to reach the ceiling around 3 m, which can be considered as the effect of water depth at the observation point (around 5.3 m). Since wave breaking would occur at the offshore side of the observation region during high waves, we used the data less than 3.0 m of Hs and correspondence Ts and coastal sound pressure level so that we only consider waves breaking within the observation region.

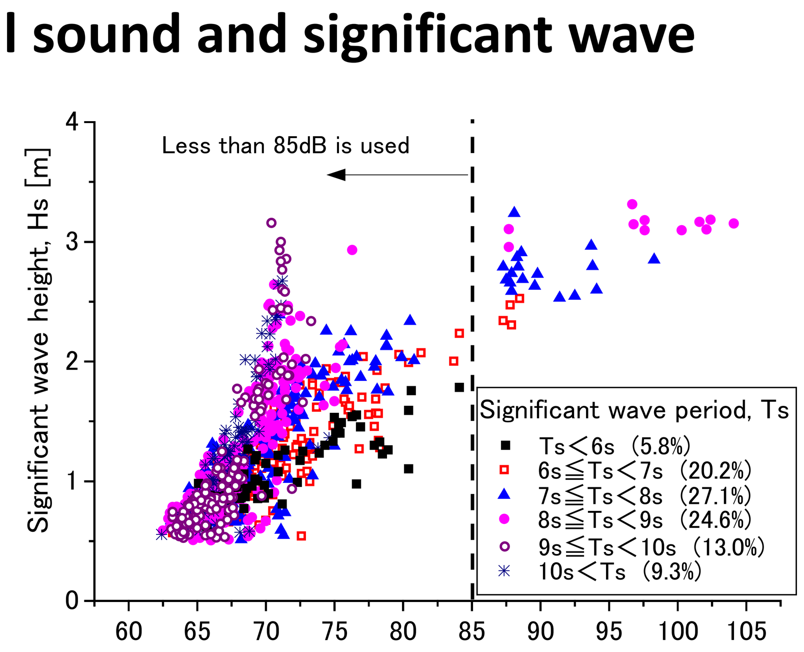

Figure 3: Significant wave height compared to the sound pressure level

Acknowledgements

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Figure 4 shows linear correlations between the coastal sound pressure level and Hs as a function of Ts band. The gradient of the linear correlation is found to increase with increasing Ts, which is due to a shift from wind waves to swell.

Figure 5(a) and (b) indicate the relationship between the Ts and the corresponding values of slope and intercept for the linear correlation lines in Figure 3. The value of slope increases with increasing Ts while the value of intercept decreases with increasing Ts.

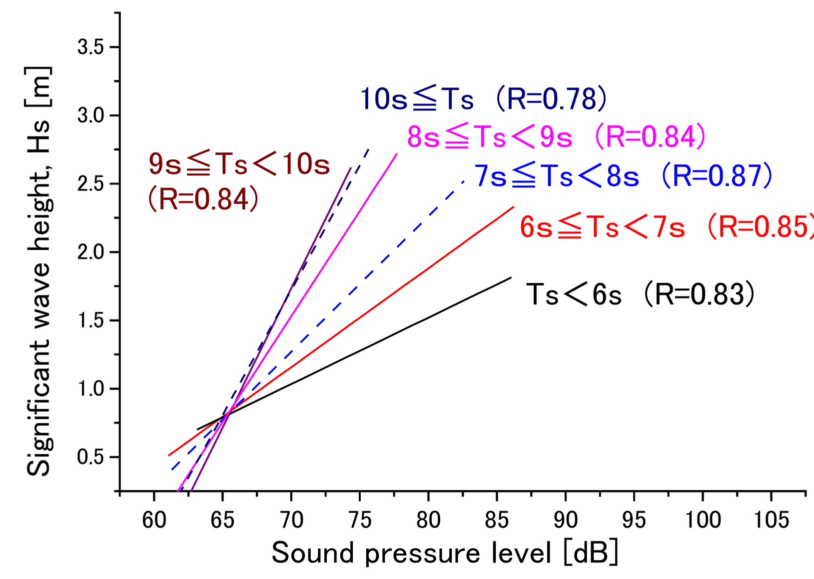

Figure 4: Linear correlation lines between the coastal sound pressure level and Hs as a function of Ts band.

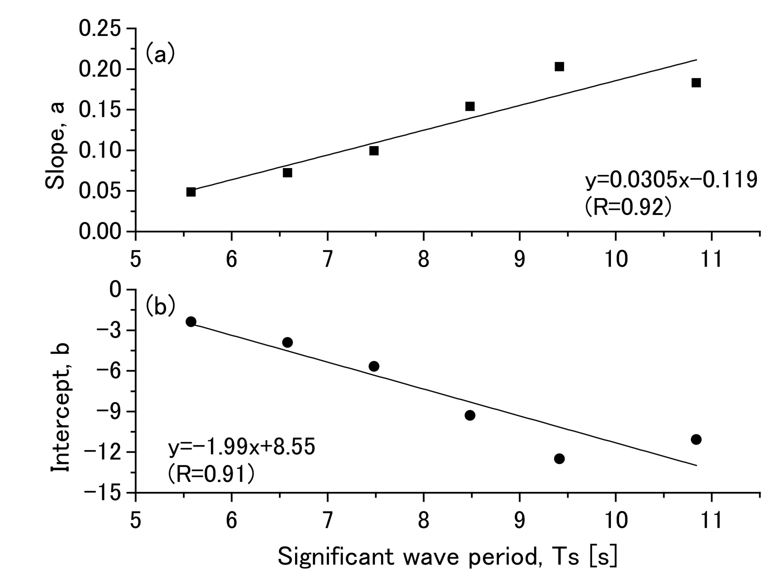

Figure 5: Relationship between the Ts and the corresponding values of slope and intercept for the linear correlation lines in Figure 2

(3) Estimation of significant wave height:

Form the results shown in 5(1), the Hs can be estimated by using the coastal sound pressure level and Ts:

$$H_s = (0.0305T_s-0.119)S_w+(-1.99T_s+8.55) \quad \text{(Eq. 1);}$$

where the Sw is the coastal sound pressure level. Figure 4 shows a comparison between the measured and estimated Hs. The Hs are well estimated by using the Eq. 1 in overall trend (Fig. 6, R = 0.83). However, when the measured Hs are larger than 2.0 m, the estimated values are underestimated. One of the reasons of this discrepancy can be considered that the equation could not fully include the effect of the swell.

Next, we applied this equation to another period, from Sep. 14, 2009 to Nov. 2, 2009. Even in the different period, the proposed equation can reproduce the measured Hs well (R = 0.82) in a qualitative sense.

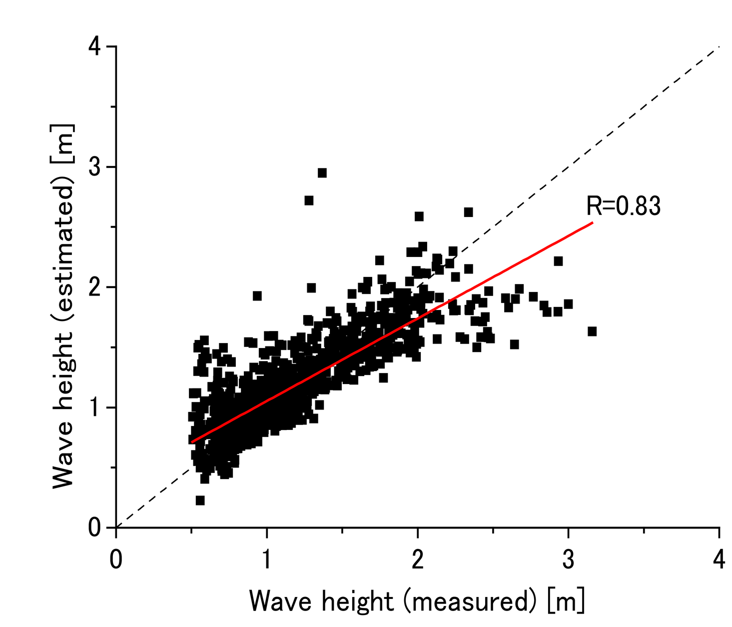

Figure 6: Relationship between measured and estimated results of Hs.

4. Current work (Takayuki Suzuki , Taku Hosoya and Jun Sasaki)

Estimation of wave height using the difference in percentile noise level of coastal sound:

We proposed an equation for estimating the Hs using the sound pressure level, S_w, and the difference in percentile noise level of coastal environment sound, S_{WL} (difference between the percentile noise level of 5% and 90%)(Fig. 7).

$$H_s=0.183S_w+0.512S_{WL}-0.0088S_wS_{WL}-10.927 \quad \text{(Eq. 2);}$$

The results of the proposed equation showed a good correspondence to the observed results (Fig. 8, R = 0.87). Also, the equation was applied to a different period and also showed a good correspondence (R = 0.87).

From the comparison with the field data and the consideration of the parameter universally, the difference in percentile noise level is a better parameter for estimating the Hs.

Figure 9a shows the time series distributions of the estimated and observed Hs. The overall trend, the Hs are well estimated. However, from 6-11th, and 44-45th are underestimated. During these periods, the difference in percentile noise levels is small (Fig. 9b). It can be considered that one of the reasons of largely estimated error of these periods is because of the non-linearity between the sound pressure level and Hs. From the above, it can be concluded that in order to estimate the Hs by a simplified prediction using the sound pressure level, it is better to use the difference in percentile noise level.

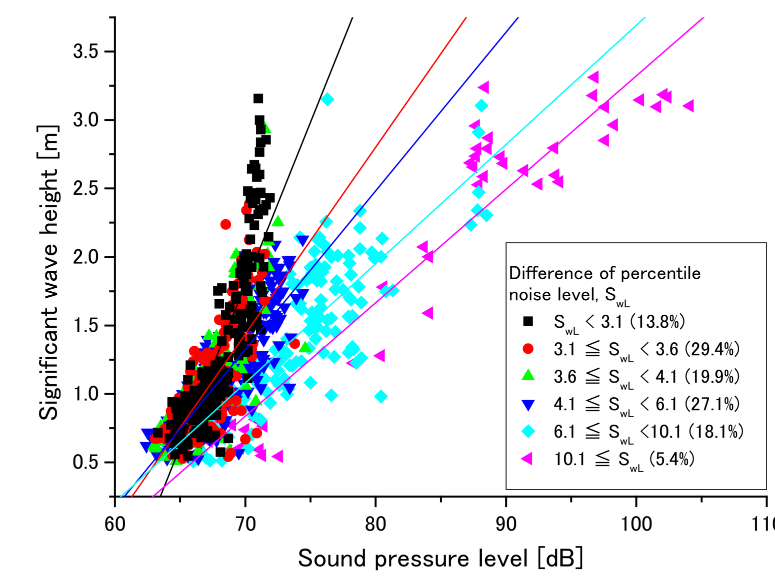

Figure 7. Correlation between the Hs and the sound pressure level banded with the levels of difference in percentile noise level

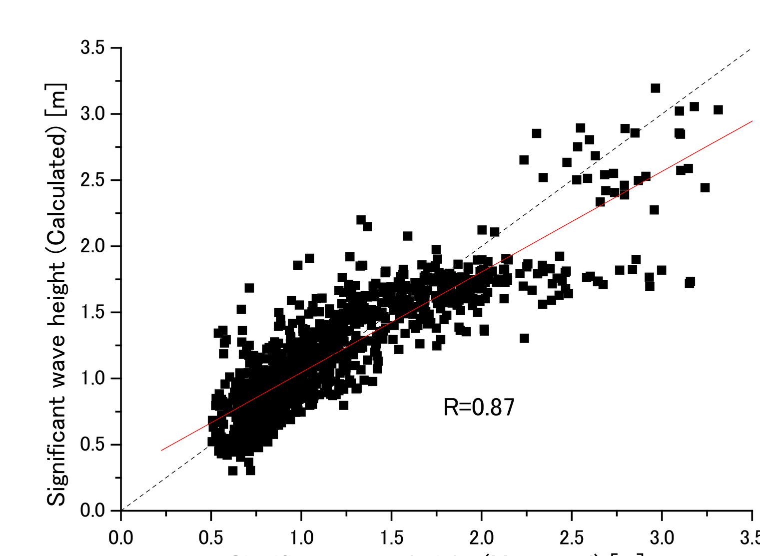

Figure 8. Correlation between the calculated Hs by using the difference in percentile noise level and the observed Hs.

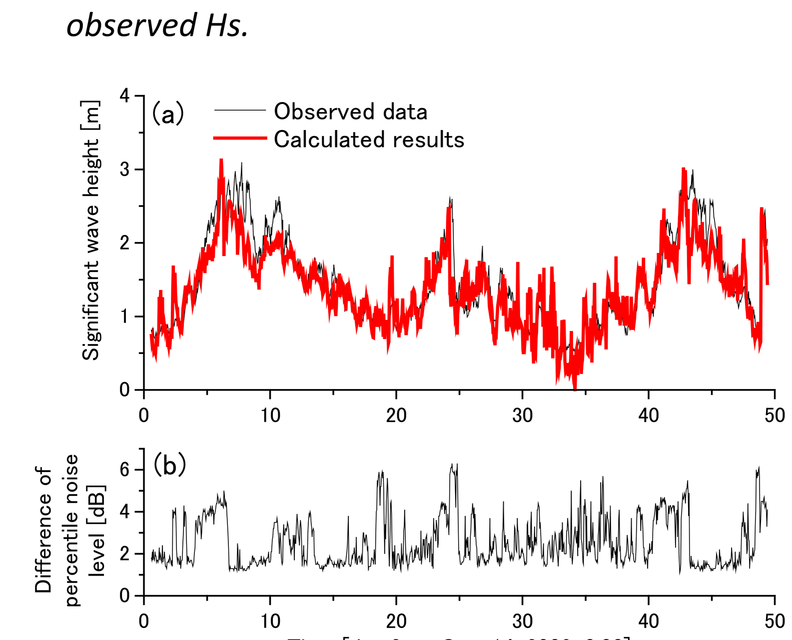

Figure 9. Time series variation of the data of the second period (from Sep. 14, 2009 to Nov. 2, 2009), (a) Observed and calculated Hs, (b) Difference in percentile noise level