

STUDY OF METHODS FOR DETECTING OCCURANCE OF RIP CURRENT USING IMAGE ANALYSIS

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There are from 2,000 to 3,000 rescues every summer at bathing beaches in Japan, and the main cause of drowning accidents is rip currents. To analyze the rip current, a method for visualizing rip currents with average images can be used. However, in case of the investigation over a long period, such as several months, it is necessary to confirm the occurrence of rip currents through thousands of averaged images by human eyes. In this study, we suggested a new method for detecting the occurrence of rip currents automatically by analyzing the pixel values of averaged images. Images for the analysis were created from video data recorded in March and April 2021 by a camera overlooking the study beach located on the west coast of Japan. The accuracy results of this method were 99 % for the validation dataset and 57 % for the verification dataset, respectively. When the wave height was 0.5 m and higher for the verification dataset, the accuracy was 75%. Therefore, it was considered that this method can detect the occurrence of rip currents when the wave height is 0.5 m and higher. As a result of applying this method to the 3-month image data recorded from October to December 2021, it was found that wave steepness was occurring lower under the conditions of rip currents. In conclusion, this method was able to automatically detect the rip currents from the images, and the conditions of waves when the rip currents that occurred could be investigated using this method.

Keywords: rip current; image analysis; average image; wave condition; Wakasawada Beach

INTRODUCTION

There are from 2,000 to 3,000 rescues every summer at bathing beaches in Japan. 54 % of drowning accidents were caused by rip currents (Ishikawa, T. et al., 2014), therefore rip currents are the main cause of drowning accidents in Japan. To analyze the rip current surveys, a method for visualizing rip currents with average images can be used. It is a method for visualizing currents by averaging consecutive images of the coast into a single image (Lippmann and Holman, 1989). The breaker zone is shown in the lighter-shaded area, and the current area is shown as the darker-shaded area (Figure 1). However, in case of the investigation over a long period, such as several months, it is necessary to confirm the occurrence of rip currents through thousands of averaged images by human eyes. In this study, we suggest a new method for detecting the occurrence of rip currents automatically by analyzing the pixel values of averaged images.

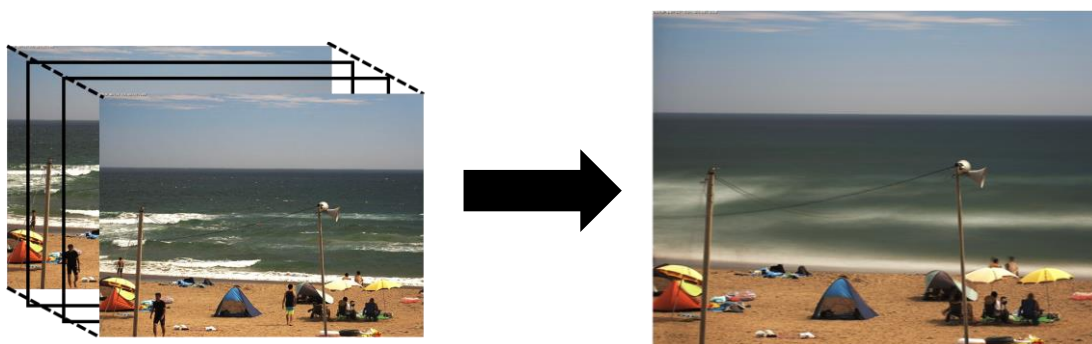


Figure 1. Example of average images.

METHODS

Method of Create an Average Image

The following steps are used to create an average image. First, prepare n consecutive images to be averaged. Note that the images must be consecutive to perform averaging. Second, obtain the pixel value of each pixel in the first image. Each pixel stores three values called pixel values as shown in Figure 2. Pixel values represent red, green, and blue, respectively, which have a maximum of 255 and a minimum of 0. (Figure 3). If the number of vertical pixels in the image is h , the number of horizontal pixels is w , the red pixel value is r , the green pixel value is g , and the blue pixel value is b , then an image is given by:

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$$I = \begin{bmatrix} (r_{11}, g_{11}, b_{11}) & \cdots & (r_{1w}, g_{1w}, b_{1w}) \\ \vdots & \ddots & \vdots \\ (r_{h1}, g_{h1}, b_{h1}) & \cdots & (r_{hw}, g_{hw}, b_{hw}) \end{bmatrix} \quad (1)$$

At last, an averaged image is calculated by:

$$I_{ave} = \frac{\sum_{k=1}^n I_k}{n} \quad (2)$$



Figure 2. Example of the pixel value.

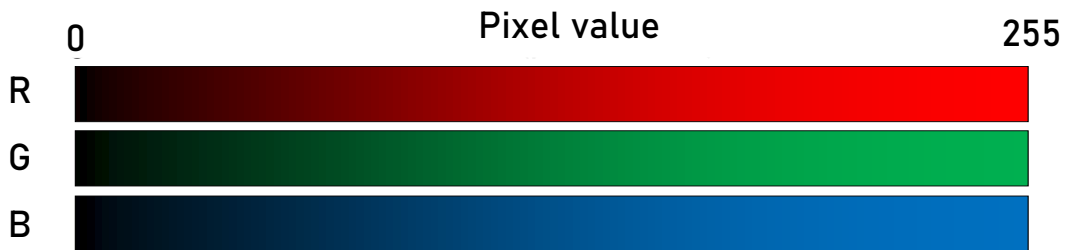


Figure 3. Explanation of the pixel value.

Introduction of Study Beach

The study beach is Wakasawada beach which is located on the west coast of Japan (Figure 4). Figure 5 shows an overhead view of the study beach. This beach has an approximately 1 km shoreline. This beach is surrounded by Wada harbor, Haseki island, therefore the wave direction from the North is dominated. The camera was installed and took approximately 3 frames per second, and the shooting range was 60 degrees. Figure 6 shows an example of image shooting from this camera. As a result of the color dye survey near the shoreline in the study area, a rip current was observed on the 24th of February 2021 as shown in Figure 7. Figure 8 shows wave conditions in 2021, and $H_{1/3} = 1.3$ m, $T_{1/3} = 8$ s at the time of the color dye survey. $H_{1/3} = 0.8$ m was the average, and the maximum was $H_{1/3} = 6.8$ m occurring on January 7th.

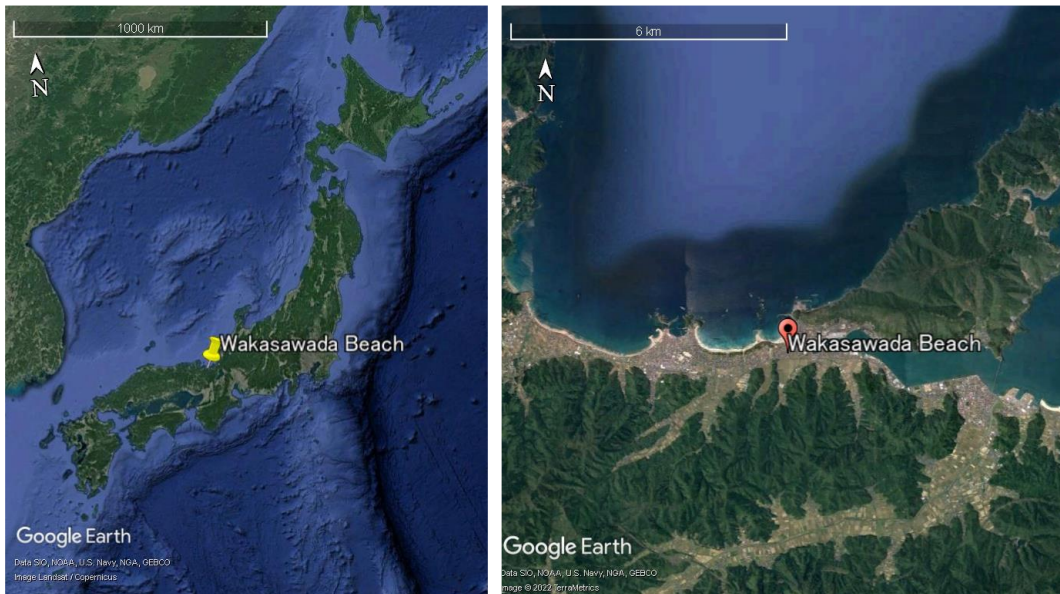


Figure 4. Location of study beach

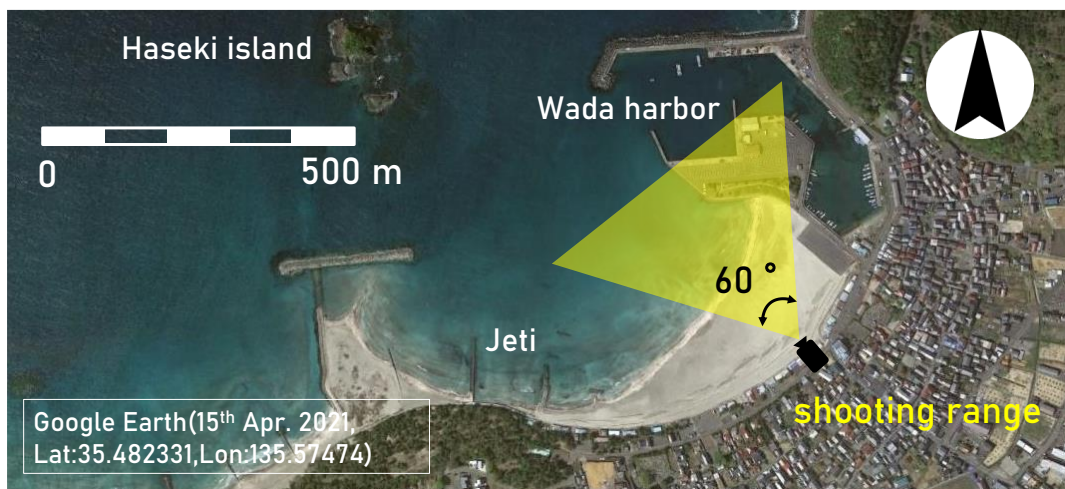


Figure 5. Overhead view of study beach.



Figure 6. Example of image shooting from this camera.

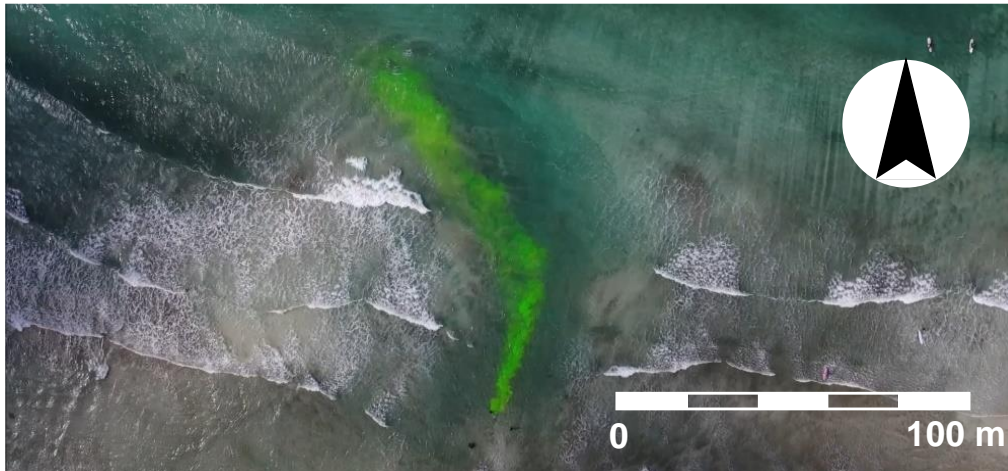


Figure 7. Results of the color dye survey on 24th February 2021

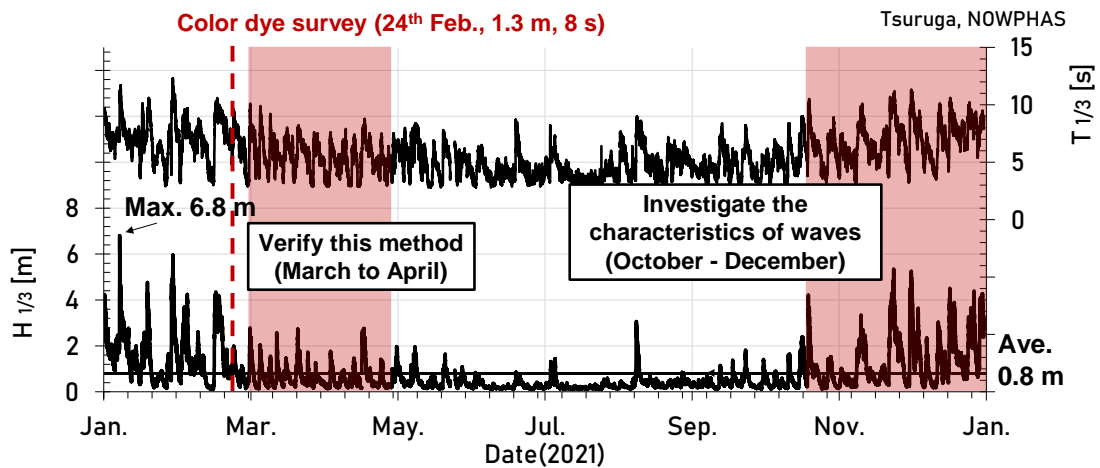


Figure 8. Example of image shooting from this camera.

Prepare Dataset

To verify this method, 2-month image data from March to April was used. This method was applied to 3-month image data, from October to December (Figure 8). Figure 9 shows the outline of preparing datasets. To verify this method, the analysis dataset, validation dataset and verification dataset were created. At first, the video data of rip currents was visually verified by three experienced lifesavers over the six days of the study period (March to April). They selected a dataset of 26 hours of video data with rip currents, and 30 hours without rip currents, respectively. Therefore, the total number of images with and without rip currents was approximately 2.9 M and 3.2 M respectively. An average image was made from approximately 720 consecutive images in a 4-minute video, as in our previous method (Shimada et al., 2020). Then, 395 averaged images as rip currents and 450 as no rip currents were created from the images. Figure 10 shows consecutive images and the averaged image in which an experienced lifesaver observed a rip current. There is a dark shaded area in the center of the image, and it was found that it has a good coincidence between the area where rip currents occurred and the dark shaded area. On the other hand, Figure 11 shows an example of an averaged image without rip currents. There was no dark shaded area in the entire area. Next, averaged images were split 8 to 2 for analysis and validation. As a result, the analysis dataset had 676 images, and the validation dataset had 169. To verify the generality of this method, the verification dataset was created which had 910 new averaged images taken in April.

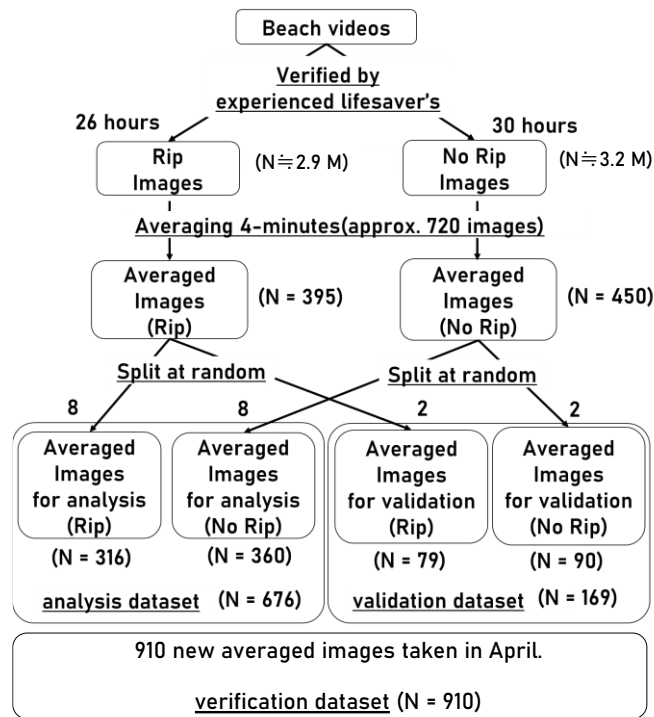


Figure 9. Outline of preparing datasets.

(a) A beach image at 10:36, 19th April, 2021



(b) A beach image in 10:38, 19th April, 2021



(c) A beach image at 10:40, 19th April, 2021



(d) Averaged image created by images from 10:36 to 10:40



Figure 10. Consecutive images and the averaged image when an experienced lifesaver observed a rip current



Figure 11. Example of an averaged image without rip currents

Set the area of the rip current and the wave breaker zone

Figure 12 shows a mean of the pixel values. 0 appears dark, whereas 255 appears light. Therefore, in the rip current area, the mean pixel value appears to be 0, whereas, in the wave breaker zone, it appears to be 255. An area-A was defined as the rip current area and an area-B as the wave breaker zone (Figure 13). It was defined that if there was a difference between the area-A and the area-B mean pixel values, a rip current occurred. To investigate the tendency where rip currents occurred, we created the averaged image from images when the rip current occurred in the analysis dataset (Figure 14). In Figure 14, an experienced lifesaver defined the rip current area and the wave breaker zone (Figure 15). The area A was defined as the 10×10 pixel box located in the rip current area, which minimized the mean pixel value. On the other hand, the area B was defined as the box located in the wave breaker zone, which maximized the mean pixel value. The score was defined as:

$$\text{score} = (\text{mean pixel value of Area B}) - (\text{mean pixel value of Area A}) \quad (3)$$

In case of the score is calculated high, rip currents are visualized clearly.

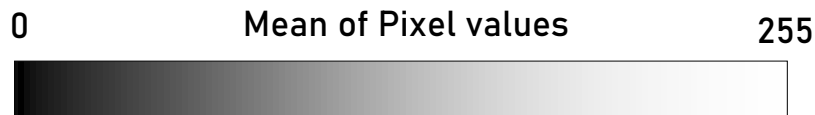


Figure 12. Mean of the pixel values

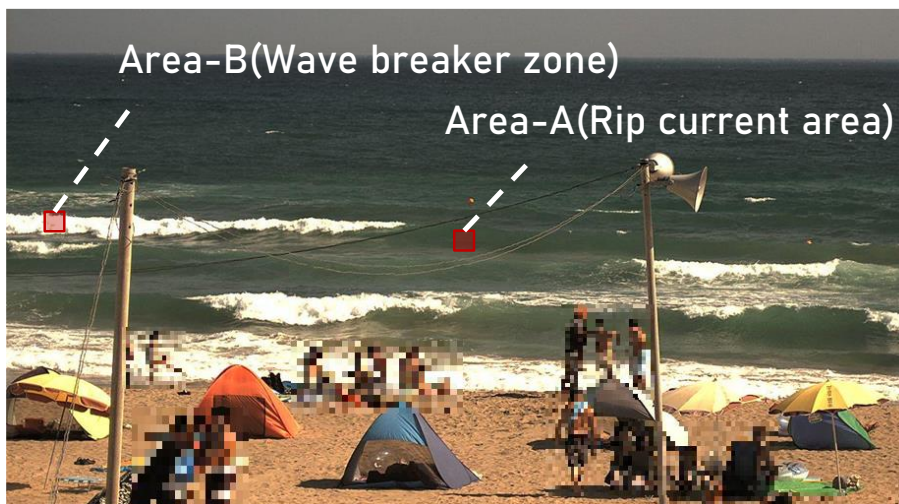


Figure 13. Examples of the area-A and the area-B

Calculate a Threshold Score for Detecting Rip Currents

The score was calculated for each image in the analysis dataset to set the threshold. Figure 14 shows the results of the scores of the analysis dataset. The red plots show that a rip was determined by 3 experienced lifesavers, whereas the blue plots show there was no rip determined. Figure 15 shows an average image on the date of the maximum score, and the rip current was observed in the center of the image.

According to the results of scores of the analysis dataset, rip currents occurrence was classified by a certain threshold score. The optimized threshold was calculated by:

$$Threshold = Median(score(Maximum(Accuracy))) \tag{4.1}$$

The accuracy was calculated by:

$$Accuracy = \frac{True\ Positive + True\ Negative}{True\ Positive + False\ Positive + True\ Negative + False\ Negative} \tag{4.2}$$

Positive and Negative mean average images where experienced lifesavers determined rip current occurrence and non-occurrence, respectively. True Positive means the number of positive examples classified correctly. True Negative means the number of negative examples classified correctly. False Positive means the number of actual negative examples classified as positive. False Negative means the number of actual positive examples classified as negative.

As a result, it was found that the optimized threshold was 4.7 with 98% classification accuracy.

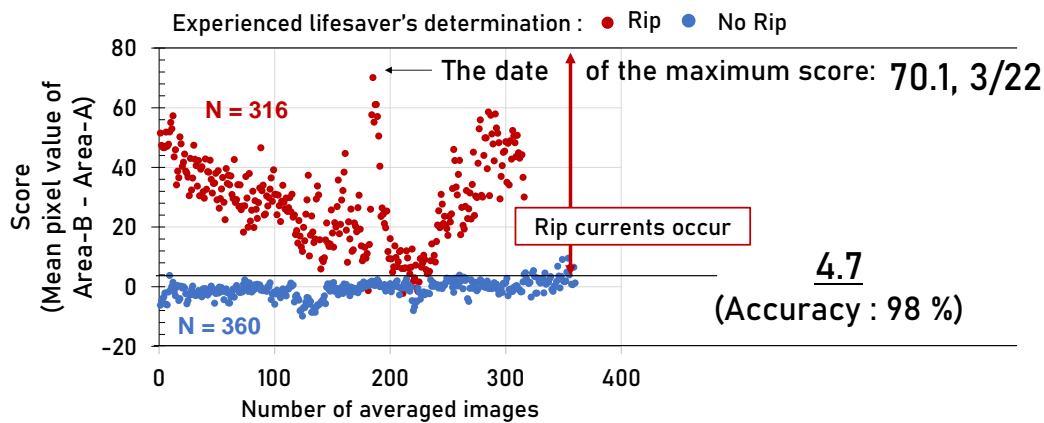


Figure 14. Results of scores of analysis dataset (N=616)

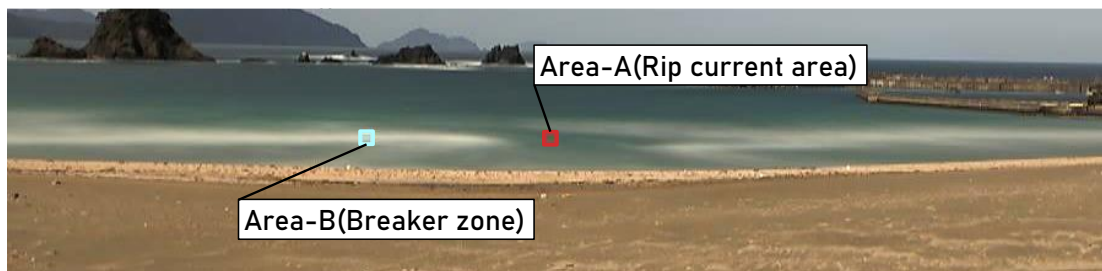


Figure 15. Average image on the date of the maximum score (22nd March 2022)

RESULTS

Validation and Verification

To validate the method, we applied the optimized threshold value to the entire 169 validation image dataset. Figure 16 shows the results of scores of the validation dataset, and it found that the accuracy was 99 % for the validation dataset. To verify the generality of this method, we applied the optimized threshold to the verification dataset that had 910 new averaged images taken in April. Figure 17 shows the result, it found that the verification dataset had an accuracy of 57% which was lower than the validation dataset. It was considered that wave conditions affected the result of accuracy.

Therefore, we investigated the accuracy sorted by wave heights. Figure 18 shows the results of accuracy sorted by wave height. The red bar shows correct, the blue bar shows incorrect, and the line graph shows the accuracy. As a result, when the wave height was 0.5 m and higher, the accuracy was 75%. According to those results, we suggest that this method can detect the occurrence of rip currents under conditions in which the wave height was 0.5 m and higher.

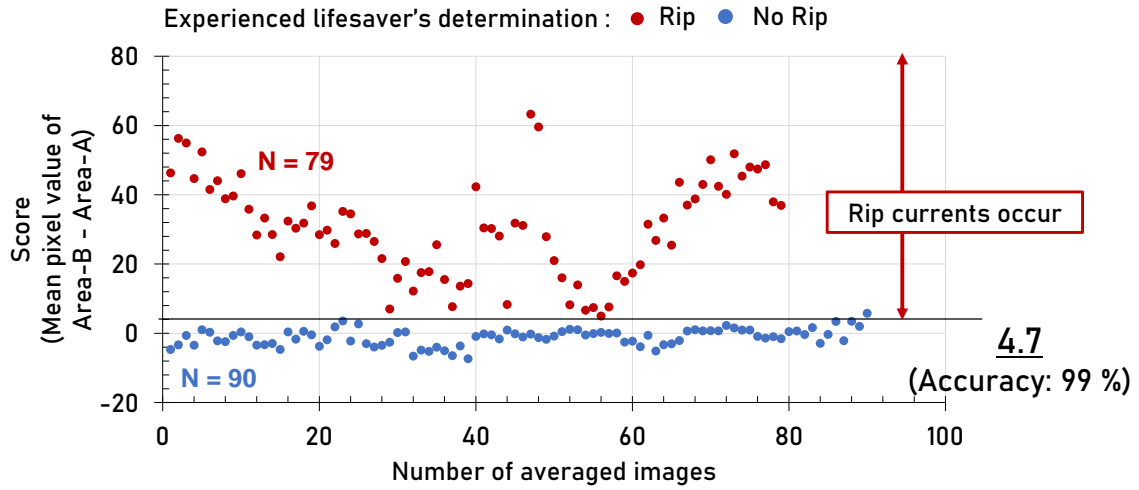


Figure 16. Results of scores of validation dataset (N=169)

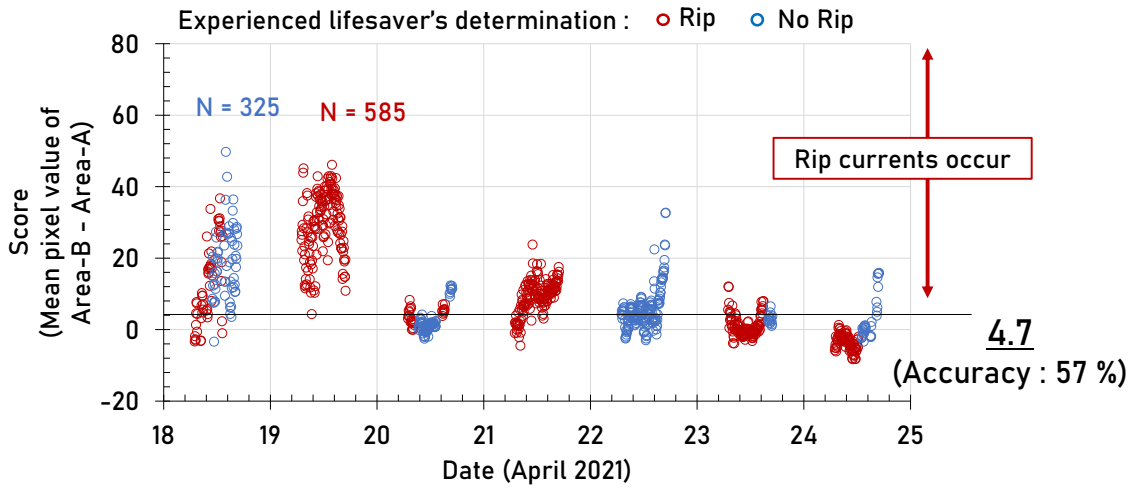


Figure 17. Results of scores of verification dataset (N=910)

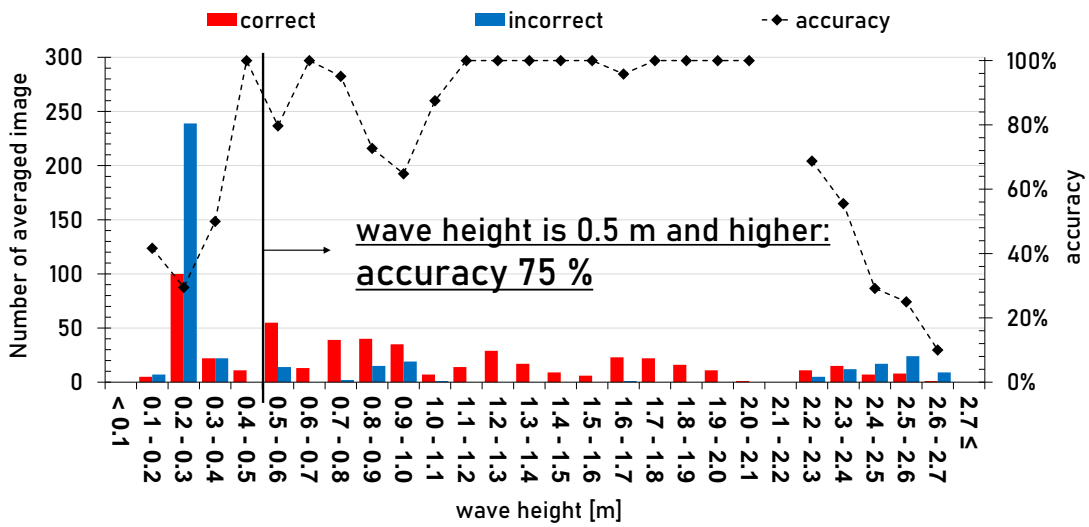


Figure 18. Results of accuracy sorted by wave height

Apply This Method to 3-month Data

In order to investigate the characteristics of wave conditions when rip currents occur at the study beach, we applied this method to 3-month image data from October 1st to December 31st, 2021. The average wave height from October to December was 1.18 m, and the average in the entire period was 0.83 m (Figure 8). The number of averaged images when wave heights were 0.5 m or higher was 5,879 in 13,800 of the totals. Figure 19 shows the results of applying this method to a 3-month image dataset. The red shows that rip was obtained, whereas the blue shows that rip was not obtained. As a result, 1,722 images were verified as rip currents, and 4,157 images did not verify as rip currents, respectively. The date of the maximum score was 19th December, and Figure 20 shows an average image at that time. The rip current was observed in the center of the image.

Figure 21 shows the box plot of wave height with and without rip currents. The mean wave heights were both 1.5 m, so there were not any characteristics in wave height when rip currents occurred. As a reason of this cause was the variation of seasonal conditions between spring when this method was verified and winter when this method was applied. On the other hand, Figure 22 shows the box plot of wave steepness with and without rip currents. The mean wave steepness was 0.007 with rip currents and 0.017 without rip currents. The energy mean waves were $H_E=1.8$ m, $T_E=7.4$ s, wave direction= 309° in rip currents, and $H_E=1.9$ m, $T_E=7.3$ s, wave direction= 312° without rip current shown in Table 1.

According to those results, it was found that wave steepness was occurring lower under the conditions of rip currents.

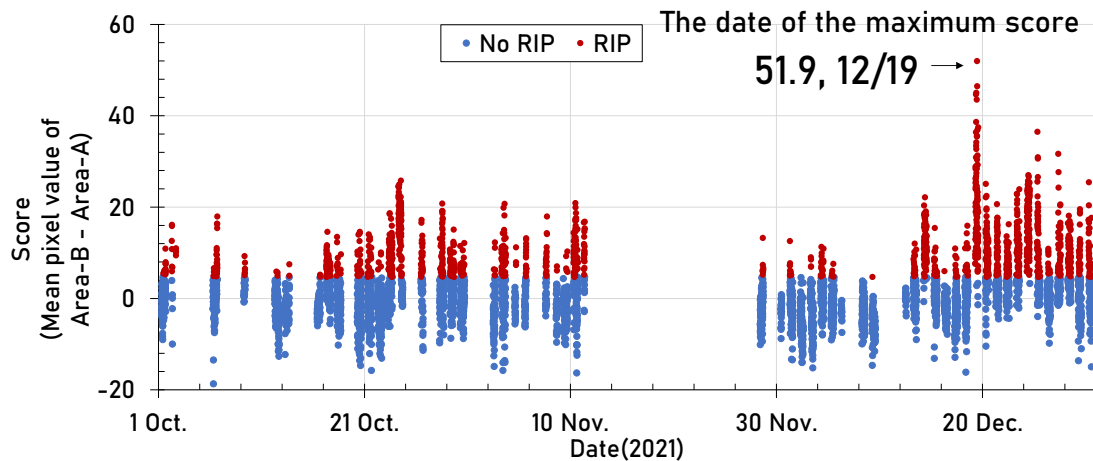


Figure 19. Results of scores of a 3-month image dataset

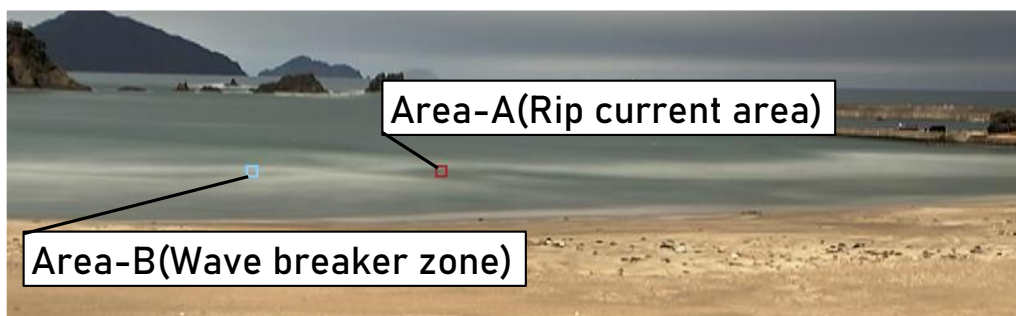


Figure 20. Average image on the date of the maximum score in the 3-month dataset (19th December)

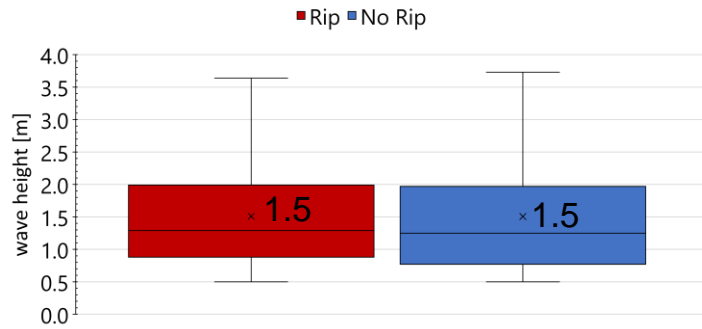


Figure 21. Box plots of wave height with and without rip currents conditions

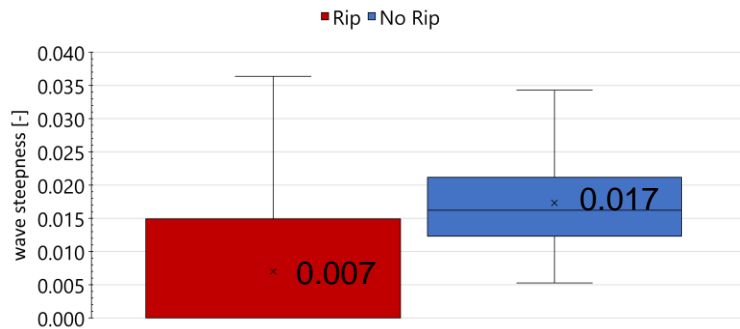


Figure 22. Box plots of wave steepness with and without rip currents conditions

	Rip (N=1722)	No Rip (N=4157)
Mean of wave heights [m]	1.5 m	1.5 m
Mean of wave steepness [-]	0.007	0.017
Energy mean waves [m]	1.8 m	1.9 m
Energy mean periods [s]	7.4 s	7.3 s
Wave directions [deg]	309 deg	312 deg

CONCLUSIONS

In this study, we suggested a new method for detecting the occurrence of rip currents automatically by analyzing the pixel values of averaged images. Images for the analysis were created from video data recorded in March and April 2021 by a camera overlooking the study beach located on the west coast of Japan. The accuracy results of this method were 99 % for the validation dataset and 57 % for the verification dataset, respectively. When the wave height was 0.5 m and higher for the verification dataset, the accuracy was 75%. Therefore, it was considered that this method can detect the occurrence of rip currents when the wave height is 0.5 m and higher. As a result of applying this method to the 3-month image data recorded from October to December 2021, it was found that wave steepness was occurring lower under the conditions of rip currents. In conclusion, this method was able to automatically detect the rip currents from the images, and the conditions of waves when the rip currents that occurred could be investigated using this method.

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