ANALYSIS OF RIP CURRENT GENERATION USING AI-BASED DETECTION DATA

Toshinori Ishikawa[1], Ryo Shimada[1] and Tsutomu Komine[2]

The occurrence of drowning accidents on beaches is mainly caused by rip currents. In this study, we created the AI model that can detect flash rip currents that occur intermittently in open areas. As a result of creating the AI model under various conditions, it was possible to detect the rip currents at each location with high accuracy at the stage of making the AI model. At the final point of the model's evolution, the accuracy, the precision and the recall rates of the rip current detection were 88 %, 17 % and 100 %, respectively. As a result of investigating the relationship between rip current detection results by the AI model and wave conditions, the characteristics of rip current generation on the study beach were able to be elucidated.

Keywords: rip current; flash rip; fixed rip; AI; Water safety; drowning prevention

INTRODUCTION

There are from 2,000 to 3,000 rescues including those of unconscious people every year on the beaches of Japan. Also, the occurrence of drowning accidents is mainly caused by the rip current, it accounts for 48% of drowning accidents (Ishikawa et al. 2014). Additionally, in Australia, the United States and the United Kingdom, more than 50 % of rescue accidents are caused by rip currents (Brighton et al., 2013). In order to reduce the rip current accidents, beach-goers need to recognize rip currents, then they have to avoid them using risk assessment. However, it is the difficulty of risk recognition and judgement under the momentary change in natural phenomenon for beach-goers. Especially, when almost all beach-goers understand the risk in the case of high wave conditions due to easy visual understanding, whereas they cannot understand rip currents the same way. On the other hand, the number of lifesavers is small at around one lifesaver compared to the thousands of beach-goers. In addition, swimming areas along the shore are limited, beach-goers sometimes enter unpatrolled areas. Therefore, we developed a new technology that can automatically detect the rip currents with the Artificial Intelligence, and notify beach-goers and lifesavers using the Internet of Things in 2019 (Ishikawa et al. 2021). In this system, the web cameras on the beach take photos of the surface image of a shooting range by three different cameras. Also, AI analyzes the image data in real time. At the time of occurrence of rip current, AI automatically informs it to the digital signage and beach-goer's smart phone. It is effective for the risk awareness of the beach-gores. Furthermore, if the beach-gores and swimmers enter the rip current area, AI informs it to lifeguard's wearable device. Then, Lifeguards can take early action. In addition, the drone can automatically fly to the location with a single motion. Therefore, AI has 2 primary functions which are the detection of rip currents and the detection of human entrance, as shown in Fig. 1.

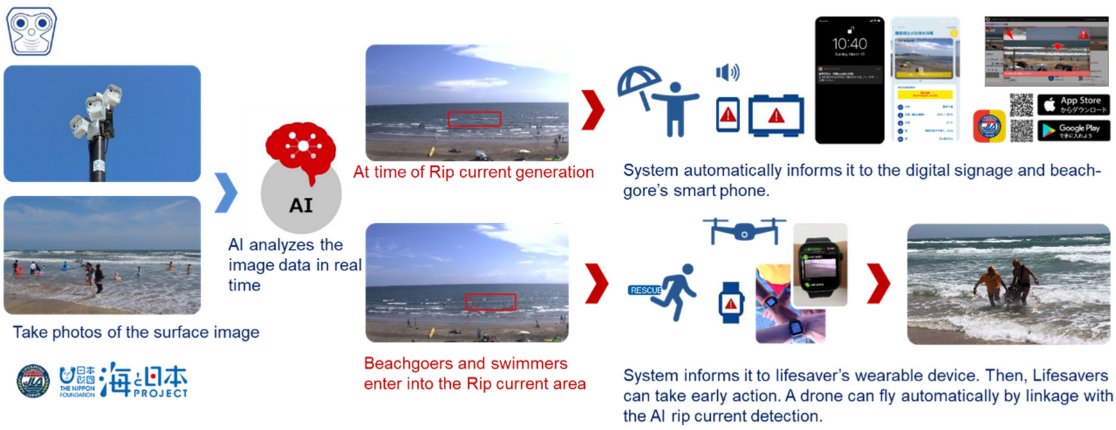

Figure 1. Overview of the new system.

---

[1] Research and Development Initiative, Chuo University, 1-13-27 Kasuga, Bunkyo, Tokyo 112-8551, Japan
[2] Faculty of Science and Engineering, Chuo University, 1-13-27 Kasuga, Bunkyo, Tokyo 112-8551, Japan

The developed AI model can detect two types of rip currents with distinct characteristics: a flash rip current that occurs intermittently in open areas, and a fixed rip current that occurs along structures such as jetty. This model utilizes three images of different shooting ranges (Ishikawa et al. 2021, 2023). Actually, the developed system has been operated on 5 beaches by 2023. In case of the 1st and 4th beaches, the rip current accidents reduced to 6% and 48 % respectively after the system operation. Also, on the other three beaches, the number of accidents has been reduced to zero, as shown in Fig. 2. On the other hand, rip currents generate suddenly and intermittently depending on the waves and topographical conditions. In this study, we investigated the characteristics of rip current generation in an open area using rip current detection data by the AI model as a new analysis method.

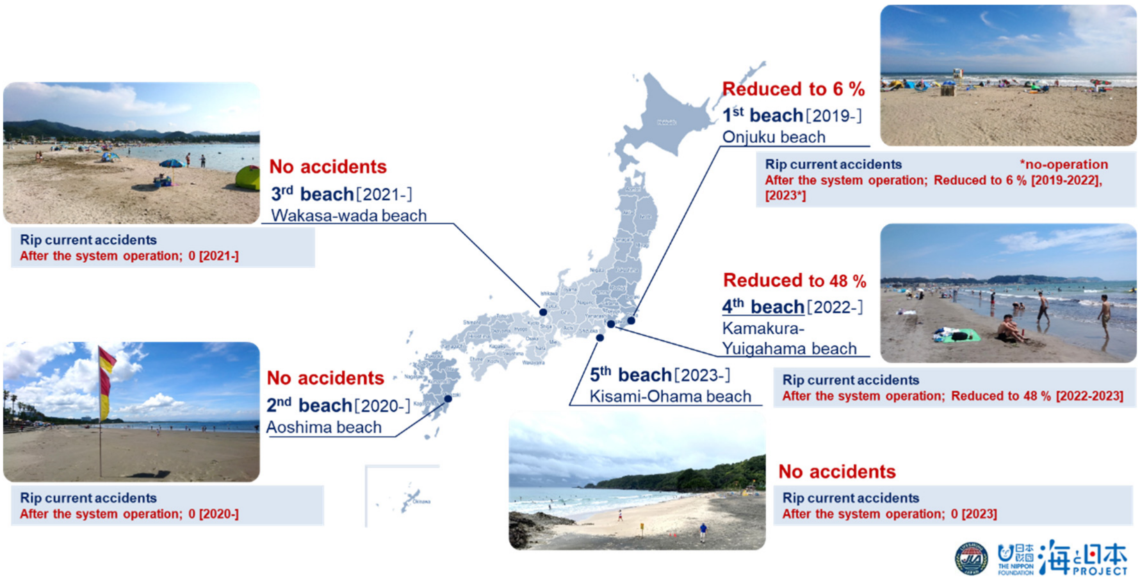

Figure 2. Beaches of the new system operation using AI.

SUMMARY OF STUDY BEACH

The study beach is a pocket beach with a total length of about 2.2 km located on the east coast of Japan (Figure 3). This beach is mainly composed of fine and medium-sized sand with a gentle seabed slope of 1/70. Rip currents are likely to occur around the river mouth. Also, rip currents occur suddenly and intermittently depending on the waves and topographical conditions within the 800 m long swimming area. In fact, there have been drowning accidents caused by rip currents, it accounts for 57 % of drowning accidents in recent average. Then we installed three web cameras on the beach so that rip currents in an open area would be within the shooting range of the fixed-point camera, as shown in Fig. 4.

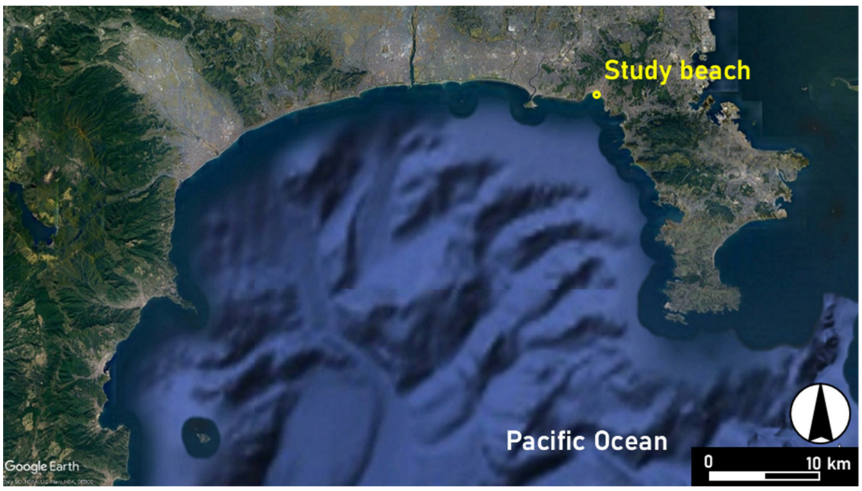

Figure 3. Location of study beach.

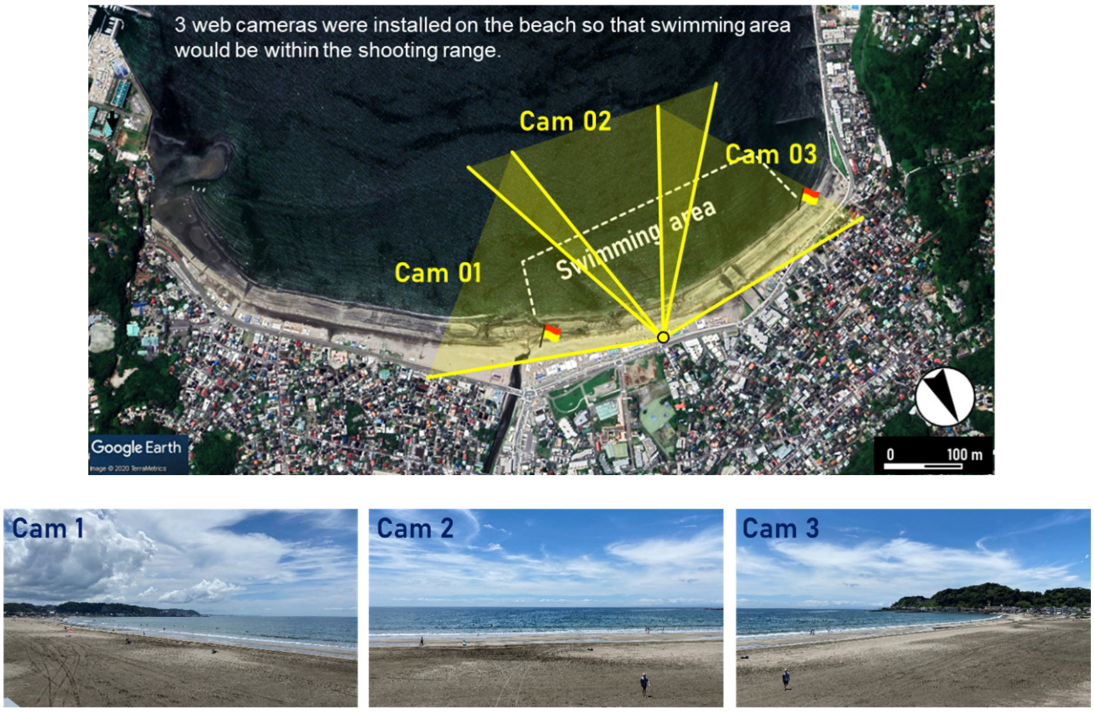

Figure 4. Images of shooting areas by 3 web cameras.

CREATION OF AI MODEL

AI learning Method

We created the AI model that can detect flash rip currents using the surface image data of cams from November to December 2021. For AI deep learning, 85 annotation videos of rip currents, and 163 videos without rip current were prepared. Each video was 20 minutes long. Next, we made 588,746 training and test samples with a different scale, random horizontal flip, hue, saturation, and brightness. These training samples with and without rip currents were split 8:2 for train samples and validation samples. Similar to existing AI models (Ishikawa et al. 2021, 2023), we applied the method of differences of three consecutive images as the feature extraction method for the rip current detection. Also, because three frames of image data are acquired per second, AI repeats the analysis at intervals of about one second. For AI learning, the Tiny YOLO (Redmon and Farhadi 2017) was used as the AI object detector algorithm for rip current detection. Figure 5 shows AI learning method and composition of data.

Model Evaluation

The AI model was evaluated by Accuracy, Precision, Recall and F-Measure values (Table 1). Precision is the percentage of rip currents that are actually detected as rip currents, and Recall is the percentage of correct detection of actual rip currents as rip currents. Also, True Positive (TP) means the number of a case in which the result of rip current occurrence by AI is correct, False Positive (FP) means the number of a case in which it is not correct. In addition, False Negative(FN) means a number of a case in which the result of rip current non-occurrence by AI is correct, True Negative(TN) means the number of a case in which it is not correct. Figure 6 shows a comparison example of the rip current detection area by AI and the annotation area, a blue area of detection by AI coincides well with a red area annotated by experienced lifesavers. According to these results, AI detected areas coincide well with annotated areas. As a result of creating the AI model under various conditions, it was possible to detect the rip currents at each location with high accuracy at the stage of making the AI model. Table 2 has the verification results of the created AI model at the final point of the model's evolution, Accuracy, Precision and Recall rates of the rip current detection were 88 %, 17 % and 100 %, respectively. Although the Precision had low values. On the other hand, Recall of all cams were 100 %, which means that the rip current that actually occurred was not overlooked. If Recall is emphasized to prevent drowning accidents, the reliability of the model can be evaluated as high.

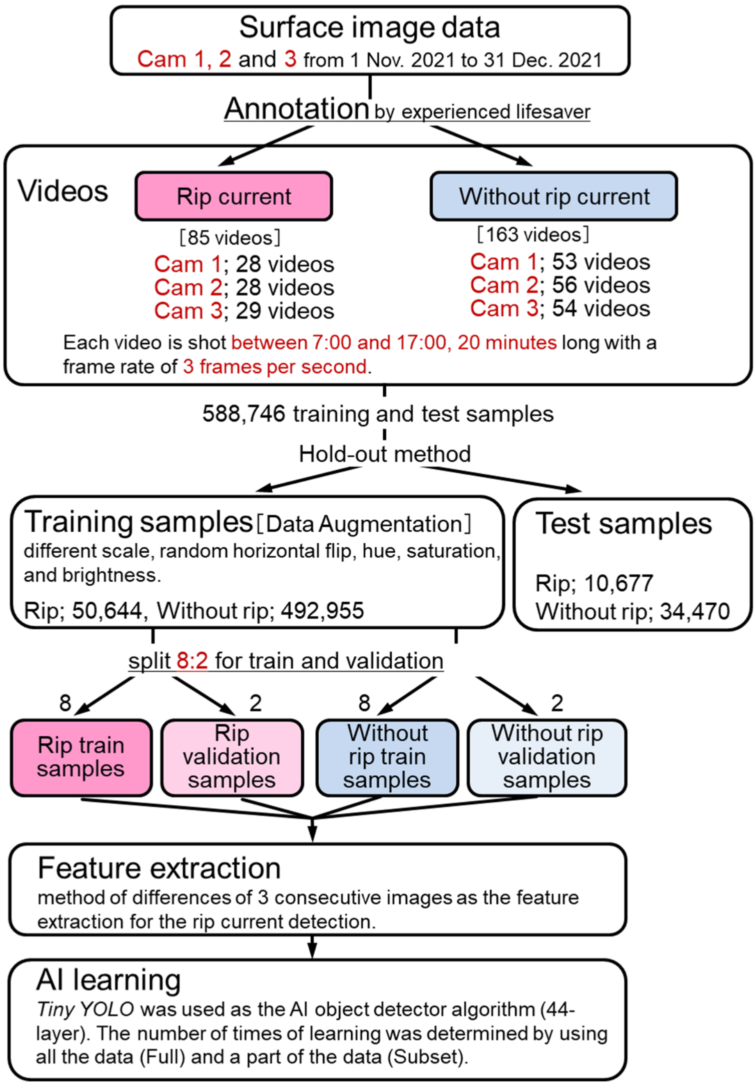

Figure 5 AI learning method and composition of data.

Table 1. AI model evaluation method.

Accuracy	Percentage of correctly detected rip currents and without rip currents. (TP+TN) / (TP+FP+FN+TN)
Precision	Percentage of correctly detected rip currents. TP / (TP+FP)
Recall	Percentage of correct detections for all test rip current data. TP / (TP+FN)
F measure	Harmonic Mean of Precision and Recall. (2×Precision×Recall) / (Precision+ Recall)

Table 2. Verification results of created AI model.

data	Accuracy	Precision	Recall	F-Measure
All	0.88	0.17	1.00	0.29
Cam 1	0.88	0.13	1.00	0.23
Cam 3	0.86	0.18	1.00	0.31
Cam 4	0.90	0.20	1.00	0.33

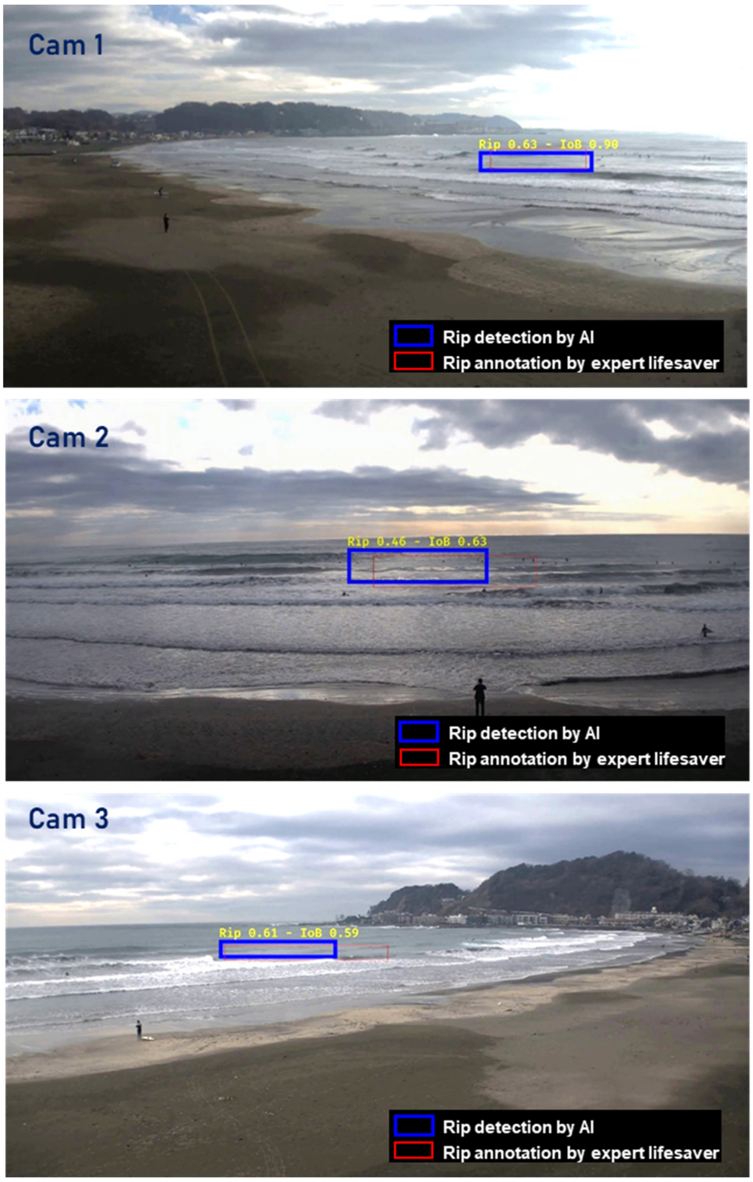

Figure 6. Comparison of the rip current detection by AI and the annotation area.

CHARACTERISTICS OF RIP CURRENT GENERATION

The created AI model was actually operated on the study beach during the summer season in 2022. Figure 7 shows number of rip current detections every hour by AI for Cams 1, 2 and 3 from July and August in 2022. The total number of rip currents detected by AI every second from 6:00 to 19:00 every day in the summer of July and August was 131,280 times for Cam 1. Similarly, Cam2 and 3 were 46,818 times and 76,672 times, respectively. In order to confirm the accuracy of the AI, images were randomly extracted and visually confirmed, and image analysis was used to investigate whether rip currents occurred (Shimada et al. 2023). As a result, there was good correspondence between the rip detections by AI and the image analysis results, indicating that the created AI model was able to appropriately detect rip currents that occurred intermittently in open areas. Figure 8 shows the wave conditions during the study period at a point 17 km west of the study beach. Although there were days when typhoons hit causing high waves, the wave conditions were mostly wave heights of 1.5 m or less in this period. As a result of investigating the relation between wave conditions and the number of rip currents detected each day during this period, it was considered that the higher the wave height and energy flux, except for stormy wave conditions caused by typhoons, a large number of rip currents generated in the shooting area of Cam 1, as shown in Fig. 9.

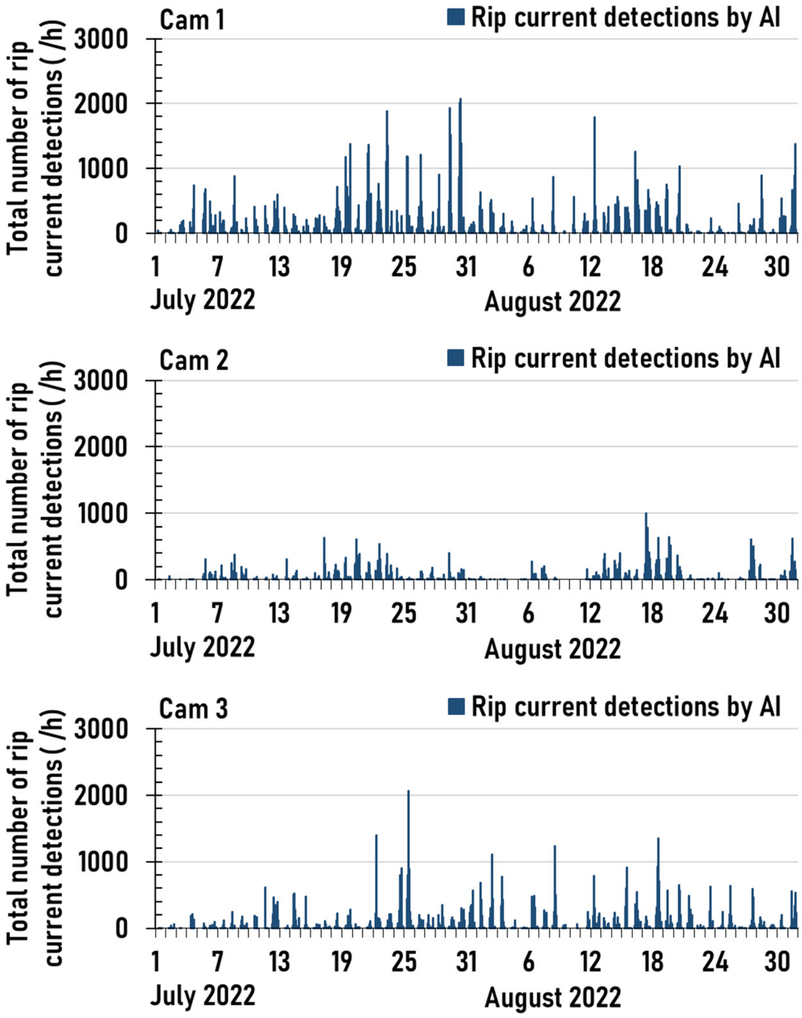

Figure 7. Number of rip current detections every hour by AI for Cams 1, 2 and 3 from July and August in 2022.

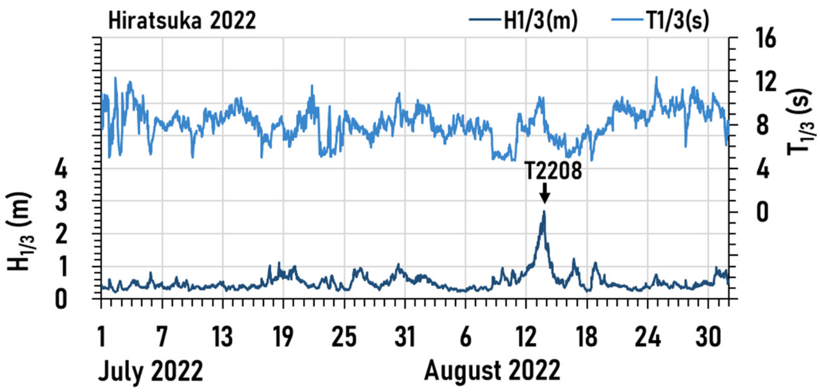

Figure 8. Wave conditions during the verification period for rip current detection by AI.

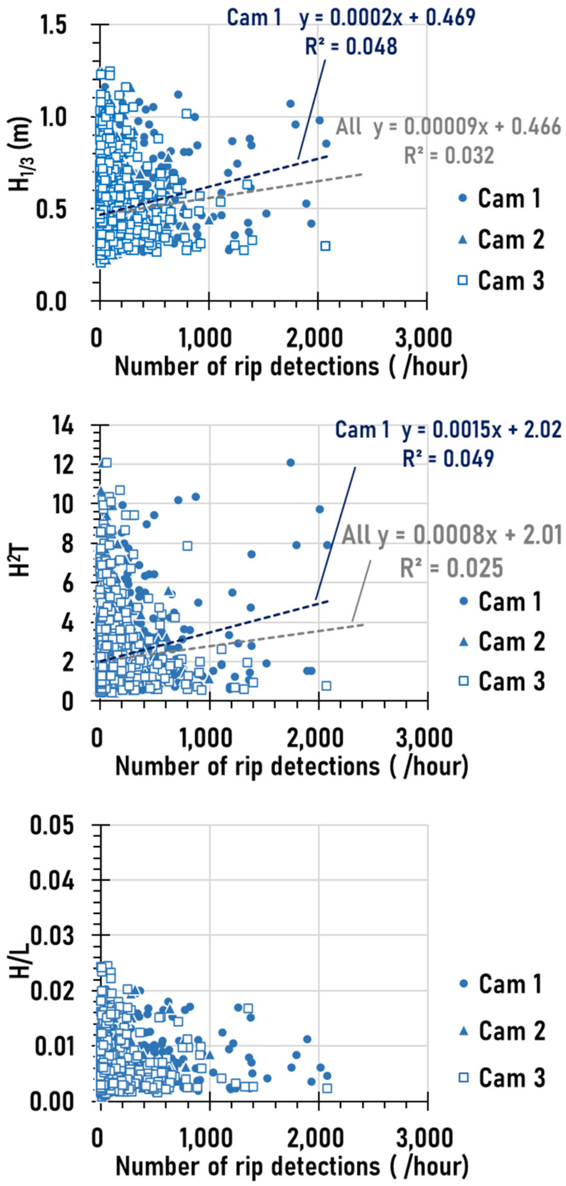

Figure 9. Relationship between the number of rip current detections per hour and wave conditions [wave height, wave energy flux and wave steepness] in the shooting range of each camera, except for stormy waves caused by typhoons.

Figure 10 shows the frequency distribution of rip current detection by wave direction which located 7 km offshore from the study beach. The number of detected rip currents was large when the wave direction was 195° for the shoreline direction angle of 180° of the study beach. This direction is 15° west of the 180° shoreline angle of the swimming area. The AI repeats the analysis at intervals of about one second, so if rip currents occur continuously, rip currents are detected up to 3,600 times per hour.

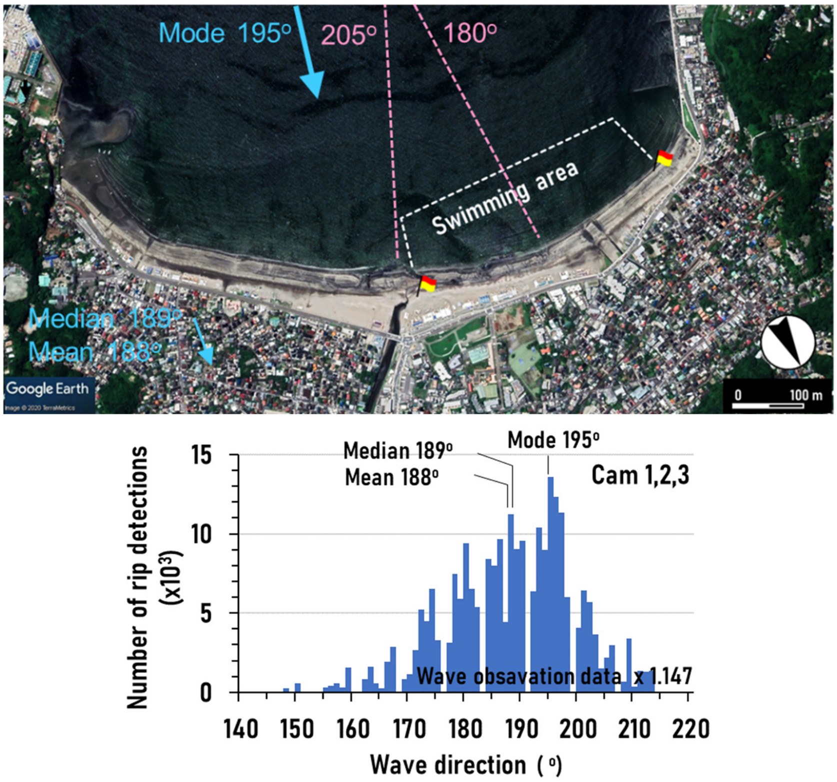

Figure 10. Frequency distribution of rip current detection by wave direction which located 7 km offshore from the study beach.

Figure 11 shows Aggregated values by number of rip current detections per hour during the study period. The number of rip current detections was less than 360 times per hour in most cases. It was thought that many flash rip currents were detected. Figure 12 show the corresponding wave conditions. The number of detected rip currents was 10 % or less per hour in most cases. When the number of rip current detections is less than 360 times, the wave height, wave steepness, and wave energy flux are smaller than in cases of a large number of rip current detections. It was considered that flash rip currents occur on the study beach even under calm wave conditions.

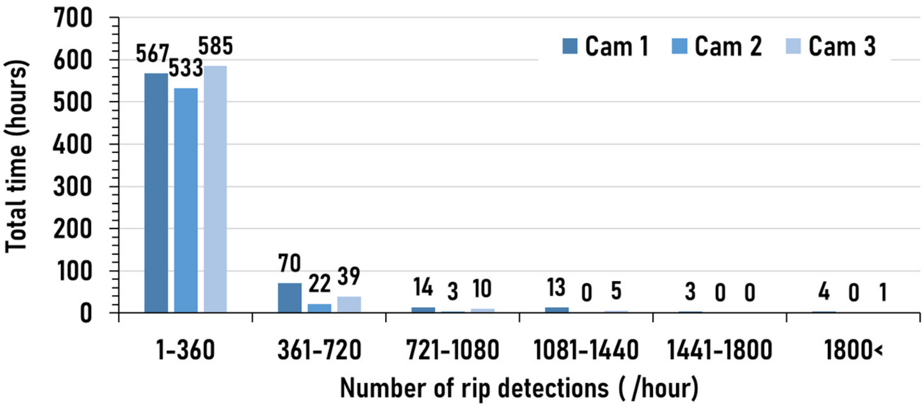

Figure 11. Aggregated values by number of rip current detections per hour.

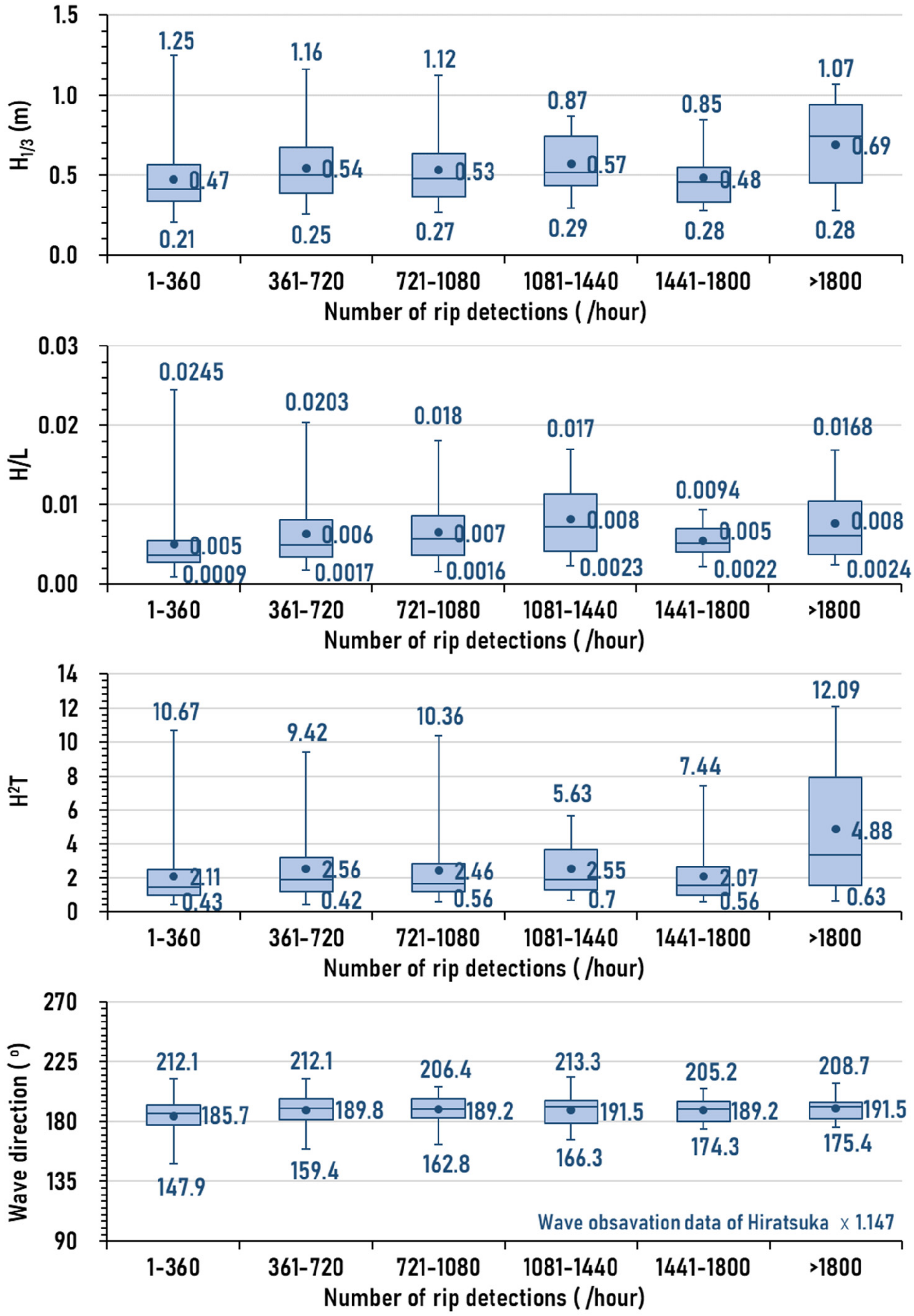

Figure 12. Wave height, Wave steepness, Wave energy flux and Wave direction by number of rip currents detected per hour.

Daily changes in location of rip current were observed during this period. Rip currents were generated in the center of the image in the shooting area in the case of Cam 1. This implies that rip currents are almost fixed around the river mouth, as shown in Fig. 13. On the other hand, in the case of Cam 2, locations of rip current changed toward the west, as shown in Fig. 14. Also, Figure 15 shows a result of Cam 3, locations of rip current slightly changed toward the west as well as that in the case of Cam 2. In the shooting areas by Cams 2 and 3, it was considered that the location of the flash rip changes depending on wave and topographical conditions.

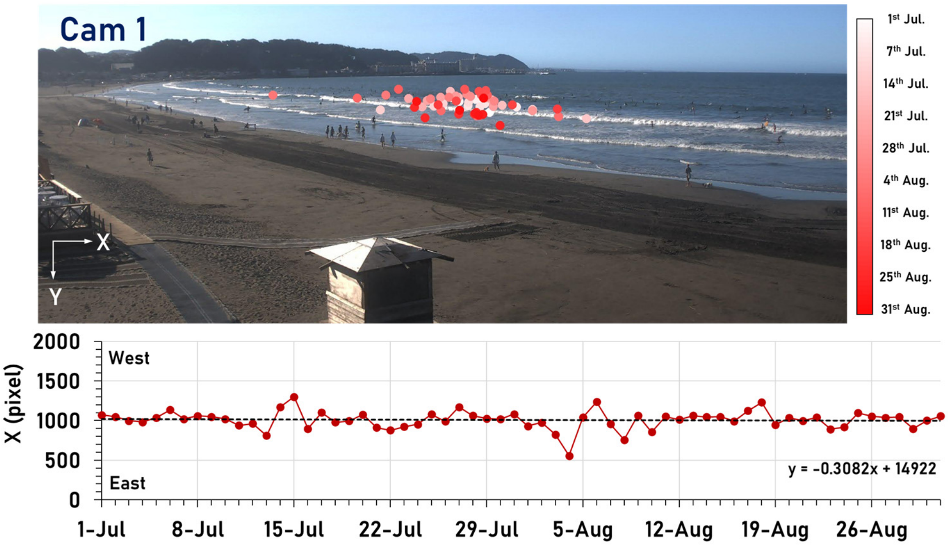

Figure 13. Daily changes in location of rip current in the shooting range of camera 1.

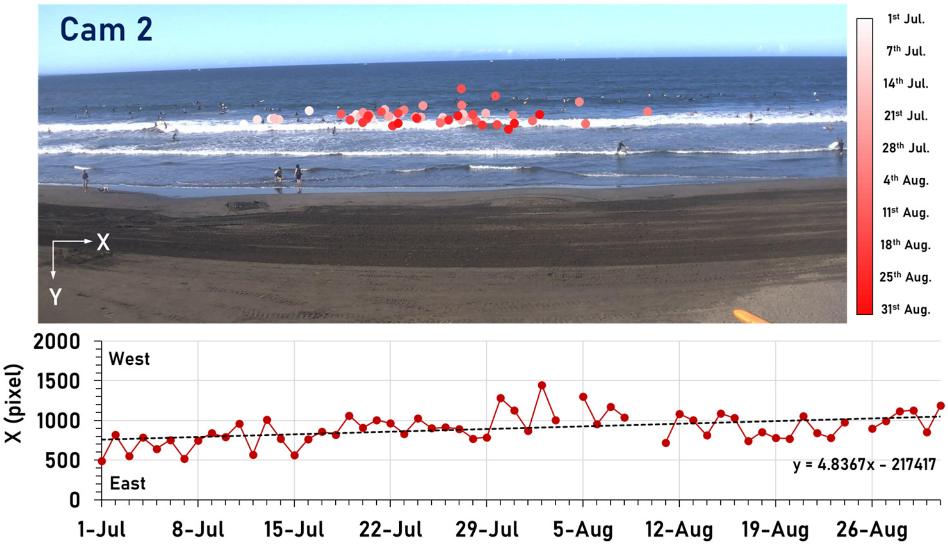

Figure 14. Daily changes in location of rip current in the shooting range of camera 2.

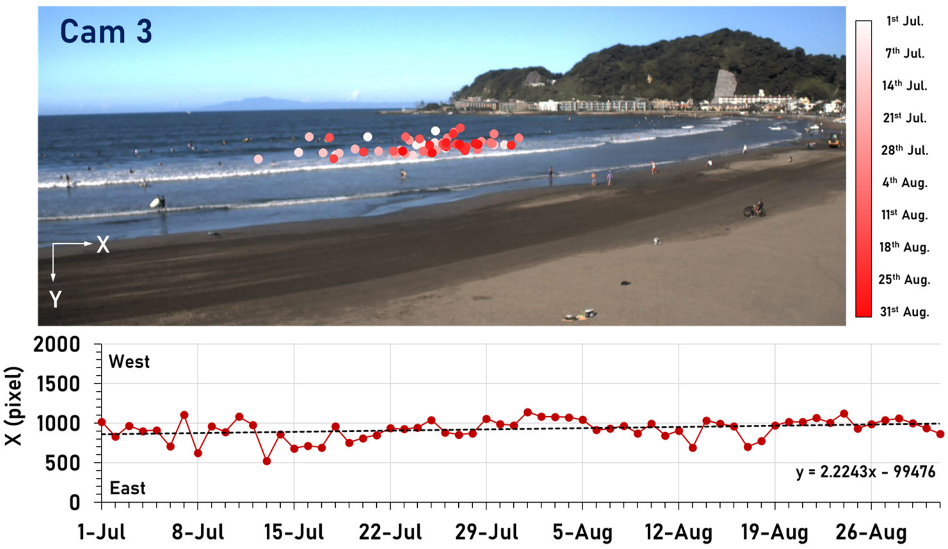

Figure 15. Daily changes in location of rip current in the shooting range of camera 3.

CONCLUSIONS

In this study, we created the AI model that can detect flash rip currents that occur intermittently in open areas. As a result of creating the AI model under various conditions, the accuracy, the precision and the recall rates of the rip current detection were 88 %, 17 % and 100 %, respectively at the final point. As a result of investigating the relationship between rip current detection results by the AI model and wave conditions, the characteristics of rip current generation on the study beach were able to be elucidated as follows. Except for stormy wave conditions caused by typhoons, the number of detected rip currents tended in the center of the pocket beach to increase with the wave height and wave energy flux. The number of rip currents detected was high when the wave direction was 15°to the west of the 180°shoreline direction of the swimming area, and 10°eastward to the 205°shoreline direction near the center of pocket beach. The number of detected rip currents was in most cases less than 360 times, or less than 10% per hour. In these cases, because the wave height and the wave energy flux were relatively small, it was considered that flash rip currents occur on the study beach even under calm wave conditions. In addition, the location of rip current around the river mouth was almost fixed.

ACKNOWLEDGEMENTS

This study was funded by the Nippon Foundation and the Japan Lifesaving Association.

REFERENCES

Brighton, B., Sherker, S., Brander, R., Thompson, M., & Bradstreet, A. 2013. “Rip current related drowning deaths and rescues in Australia 2004-2011.” Natural. Hazards and Earth System Sciences, 13, 1069-1075.

Ishikawa, T., Komine, T., Aoki, S. and Okabe, T. 2014. Characteristics of Rip Current Drowning on the Shores of Japan, *Journal of Coastal Research*, Special Issue 72, 44-49.

Ishikawa, T., Shimada, R., Sawagashira, R. and Komine, T. 2021. Proposal and Verification of Rip Current Detection using AI, *Coastal Dynamics 2021 Conference proceedings*. https://repository.tudelft.nl/islandora/object/uuid%3A8859f64c-2204-455d-a9a7-dfdacc4c2117

Ishikawa, T., Shimada, R., and Komine, T. (2023): Rip Current Detection in an Open Area and Along Jetty using AI, Coastal Engineering Proceedings, No. 37, papers.7.

Redmon, J. and Farhadi, A. 2017. “Yolo9000: Better, faster, stronger.” In Computer Vision and Pattern Recognition (CVPR), *IEEE Conference*, 6517-6525.

Shimada, R., Ishikawa, T., and Komine, T. (2023): Study of Methods for Detecting Occurrence of Rip Current using Image Analysis. Coastal Engineering Proceedings, No. 37, papers.13.