

FLOOD AND COASTAL SEDIMENT SUPPLY OF THE RIVER TENRYU, JAPAN, ANALYZED BY X-BAND RADAR OBSERVATION AND XBEACH COMPUTATION

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INTRODUCTION

The River Tenryu, Japan, flows to the Enshu Coast, facing the Pacific Ocean. The Enshu Coast suffers from long-lasting erosion, and authorities plan to enhance sediment supply from the catchment to mitigate the erosion. In this context, we conduct a coupled study of X-band radar observation and Xbeach computation.

We captured coastal and riverine processes in 2021 before and after the flood with the X-band radar. We analyzed wave propagations on the river mouth terrace from the radar observation and determined wave propagation speeds to estimate the depth distribution before and after the flood. During the flood, we simultaneously evaluated the flow velocity distributions in the river channel and the erosive processes. Then, we do Xbeach computation to reproduce and quantify riverine and coastal processes to understand and quantify the flood event comprehensively, especially for the amount of sediment supply from the river to the ocean.

SITE AND RADAR OBSERVATION

Figure 1 shows the area of interest: River Tenryu and the position of the X-band radar with images captured during the flood. The river flows from north to south and joins the ocean. A lateral sand bar exists at the river mouth, which erodes after the flood.

X-band radar is an imaging radar that helps us understand the morphology and hydrodynamics by capturing spatial distributions and temporal variation of floating objects on the water surface, water lines of the river channel and coastlines, flow motions, and wave propagation in the shallow area. Fig. 1(b) is a raw radar image, and we see floating objects in the river channel and waves traveling from south to north in the ocean. Fig. 1(c) is a time-averaged radar image. The bright streaks in the river channel represent the mean path of the floating objects.

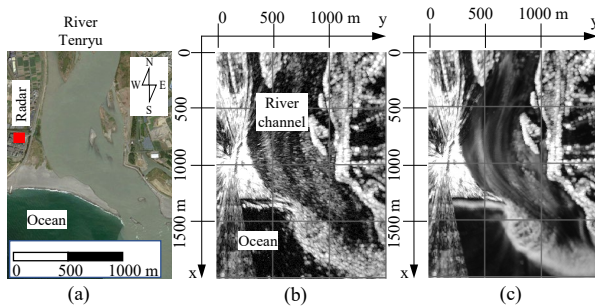


Figure 1 River Tenryu. (a) Satellite image, (b) Raw radar image captured during the flood, and (c) time-averaged radar image.

FLOOD AND WAVES

In August 2021, there was a large flood with discharge exceeding 4,000 m³/s (Fig.2). We analyzed the flow and wave field before, during, and after the flood.

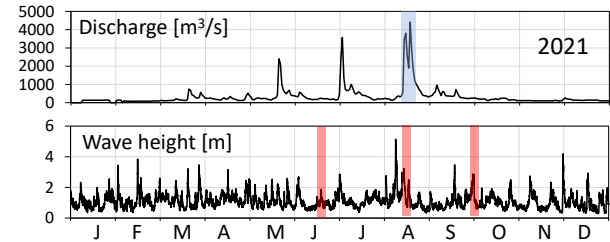


Figure 2 Variation of discharge and wave height. The blue strip in the upper panel denotes the flood, and the red strips in the lower panel are the periods for wave field analyses.

X-BAND RADAR OBSERVATION: FLOOD

The radar images during the flood show that bright portions migrate downstream along the flow. These bright portions may be drifting woods and garbage, which we frequently observe after the floods on flood plains. Unfortunately, we could not confirm this during the flood.

We analyze the motion of these bright portions by image analysis and try to estimate the surface flow pattern during the flood by Particle Image Velocimetry (PIV). Fig. 3 shows a snapshot of the surface velocity vectors and transverse distribution along a cross-section. In the middle of the section, the velocity exceeds 3 m/s. We confirmed that the flow velocities varied following the discharge curve and the local water level gradient.

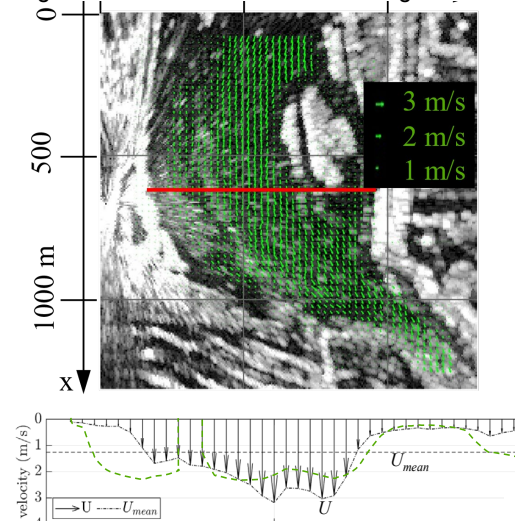


Figure 3 Velocities during the flood. The upper panel shows the velocity vectors, and the lower panel shows the transverse velocity distribution along the red line.

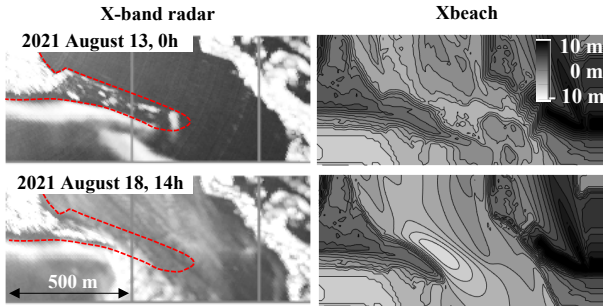


Figure 4 Erosion of the lateral river sand bar: X-band radar observation vs Xbeach computation.

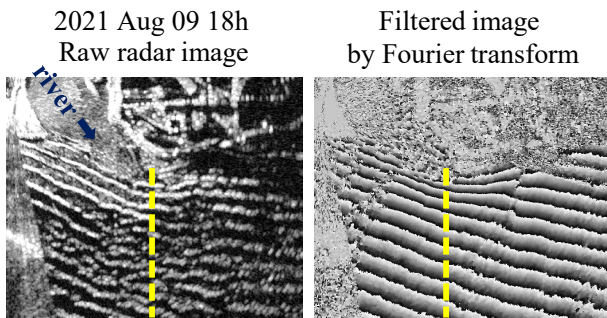


Figure 5 Wave crests observed with the X-band radar and iso-phases extracted from the Fourier transform mouth. (a) Raw radar images, (b) Phase diagram.

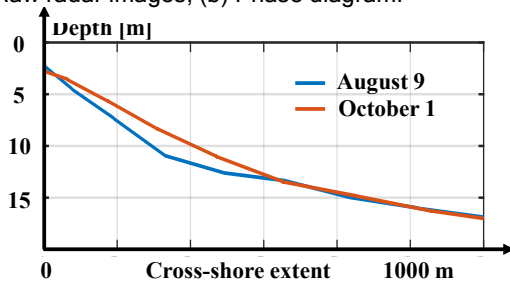


Figure 6 Sea depth variation along the cross-shore transect shown in Fig. 5: at and after the flood.

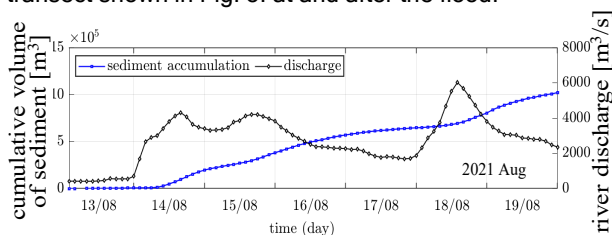


Figure 7 Variation of the cumulative volume of sediment discharged by the flood to the ocean section.

X-BAND RADAR OBSERVATION: MORPHOLOGY

Figure 4 shows the erosion process of the lateral sand bar at the river mouth. The erosion is caused mainly by the river flow, which shortens the lateral sand bar.

X-BAND RADAR OBSERVATION: WAVES

One of our interests is to know the amount of sediment discharged by the flood into the ocean. For this purpose, we analyzed the wave field and estimated the wavelength

distribution near the river mouth for depth inversion.

We applied the Fourier transform to the sequence of radar images. If we choose a proper frequency, we can extract the wave field's phase distribution to determine the local wavelengths, as shown in Fig. 5. We see refracting waves approaching the river mouth, especially in the filtered image. Next, we inverted the depths using the linear dispersion relationship from the phase diagram. We did this for the periods before, during, and after the flood and confirmed that the flood delivered a certain amount of sediment to the ocean, as shown in Fig. 6. Sediment reached a depth of 12 m.

XBEACH COMPUTATION: SEDIMENT DISCHARGE

To enhance and quantify the findings of the radar observation, we reproduced the flood event with the Xbeach. The main interest is to know the sediment processes in the river channel and the ocean during the event. The computation domain is the river channel and open sea close to the river mouth. We changed the discharge, wave, and tide conditions during the one-week computation. The numerical results were validated with the results of radar observation: flow speed in the river channel and changes in overall morphology. We confirmed that the Xbeach reproduces the sand bar erosion pretty well during the flood, as shown in Fig. 4.

The variation of the cumulative volume of sediment on the ocean side is shown in Fig. 7. We set a section on the ocean side, including the river mouth, and estimated the depth changes. Similar to sand bar erosion, the deposition of sediments accelerates when the river flow increases. The amount of sediment discharged by the flood is estimated at 1 million m^3 , which is larger than the long-term yearly sediment discharge (in the order of 0.3 million m^3) estimated by other studies.

CONCLUSION

We did a coupled study of a flood at the River Tenryu: X-band radar observation and Xbeach computation.

From the radar observation, we estimated the following: (1) Flood velocity in the river channel, (2) Overall morphology changes before and after the flood, and (3) Depth changes in the ocean near the river mouth. We confirmed that the flood discharged a certain amount of sediment into the ocean.

We reproduced these processes with the Xbaeach and quantified the sediment motion. The bed level close to the river mouth lowered stepwise with the changing gradient of the local water level. The flood discharged sediments of approximately 1 million m^3 into the ocean.

REFERENCES

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