

# LONG-TERM OBSERVATIONS OF INTERACTIONS AMONG WAVES, SAND, AND GRAVEL USING A LIDAR-CAMERA FUSION SYSTEM

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## INTRODUCTION

A target site of this study, Namiita Coast in Japan (Figure 1), originally had beautiful sandy beach. However, the sandy beach disappeared by a tsunami and land subsidence by Great East Japan earthquake in 2011. Nourishment using gravel and sand was conducted to promote the beach recovery, and the sandy beach has recovered to some extent as planned. However, a new problem has arisen due to the nourished gravel. The gravel was originally covered by fine sand, but today gravels under the fine sand repeatedly appear on top of sand surface, which makes tourists reluctant to enjoy bathing on the beach and deteriorates the landscape.

To monitor such beach process, a new fusion system of a 3D lidar and a camera has been developed, which enables us to grasp changes in beach elevation and its surface composition with high spatiotemporal resolution. We conducted a two-month observation employing the system during summer in 2023, and the morpho-hydrodynamics on the coast was analyzed.

## FUSION SYSTEM OF LIDAR AND CAMERA

In the present system, a single PC synchronizes a 3D lidar and a camera (Fig. 1(b)) and triggers their 10-min recordings of point data by the lidar and a video by camera every hour. The system was installed on a seaside terrace of a hotel along the beach at about 11 m height from mean water level. In this study, datasets over two months during the summer from July 18 to September 21 in 2023 were analyzed. A surface elevation at each location was computed by spatial interpolation of point data by the lidar. RGB values at the time and the location were picked up from the corresponding video frame.

## RESULTS

Spectral wave heights measured by a wave pressure sensor installed on this coast at a depth of about 3 m and timestacks of cross-shore/alongshore bottom profiles and surface colors are shown in Fig. 2. Owing to the closed bay, wave heights were relatively small and the maximum spectral wave height during the two months was about 1.1 m even though several typhoons/low pressure systems passed close to the coast. The timestack image on a cross-shore transect demonstrates that sandy beach was largely eroded during relatively high wave events ( $> 0.5$  m in wave heights, e.g., Jul. 21, Aug. 11-18, 28, Sep. 5-7), while beach recovery initiated after the events (Jul. 22-Aug. 8, Aug. 28-Sep. 4, Sep. 8-21). The timestack image on an alongshore transect (Fig. 2 (c)) gives us further insights. Contour lines are not parallel to the y-axis as a whole, suggesting that the beach evolution proceeded northward (y-ward positive) or southward (negative). The directions seemed to correspond to recovery and erosion processes, respectively. The beach recovery advanced

northward and beach erosion seemed to proceed southward during the forementioned high wave events.

Appearance and disappearance of gravel on the beach can be confirmed in Fig. 2(b,c) around Aug 22-28 as appeared in black surface color  $(x, y)=(23 \text{ m}, 10 \text{ m})$ . On the cross-shore transect, gravel appeared on August 22 after a high-wave event and bottom elevation increased at the point, i.e., which suggests that the reason why the gravel appeared is not because sand covering the gravel was swept away but because the gravel was transported by nearshore waves and currents. The gravel disappeared within a few hours on Aug 28 during the erosion phase. Southward movement of gravel could be confirmed from the timestack image, which agrees well with the directionality of beach erosion suggested before.

The rapid disappearance of gravel on Aug. 28 during a high wave event can be further discussed by the 10-min dataset in detail. Fig. 3(b) shows the net topography change from 10:55 (Fig. 1(a)) to 11:05 (Fig. 3(a)) when collapse of the accumulated gravel at  $(x, y) = (22 \text{ m}, 6 \text{ m})$  was confirmed. The bed was eroded on the north side ( $y > 10 \text{ m}$ ) and was accumulated on the south side ( $y < 10 \text{ m}$ ) in the upper part of the swash zone ( $25 \text{ m} < x < 35 \text{ m}$ ), which agrees with the forementioned trend in the erosion phase. In the area within  $2 \text{ m} < y < 7 \text{ m}$  and  $22 \text{ m} < x < 26 \text{ m}$ , the bed level was locally lowered (eroded) where gravel locally covered the bed surface. On the seaside of the gravel, on the other hand, the bed was elevated. The process can be analyzed further in a timestack image on a cross-shore transect crossing the gravel mound ( $y = 6.7 \text{ m}$ , Fig. 4). A high runup that reached the top of the gravel mound at  $t = 130 \text{ s}$  collapsed it and transported the gravel shoreward as appeared in seaward spread of the black pixels in the timestack image, which resulted in a decrease in bottom elevation around  $x = 23 \text{ m}$  and an increase at  $x = 25 \text{ m}$ . The seaward migrated gravel seemed to be further transported by swash motions, and then the next large wave runup at  $t = 490 \text{ s}$  eroded the gravel, and accumulation on the seaside ( $22 \text{ m} < x < 24 \text{ m}$ ) and erosion on the land side ( $22 \text{ m} < x < 24 \text{ m}$ ) became apparent again. It is expected that such continuous migration of gravel by swash derives disappearance of gravel on this beach.

## CONCLUSION

A new fusion system employing a 3D lidar and an optical camera was applied to monitor morpho-hydrodynamics on Namiita Coast, whose beach is composed of fine sand and gravel. The system captured different alongshore directionalities of beach evolution in erosion/recovery phases. Furthermore, the southward and seaward migrations of gravel resulted in the disappearance of the gravel. Further monitoring employing this system is expected to elucidate the whole process on this beach.

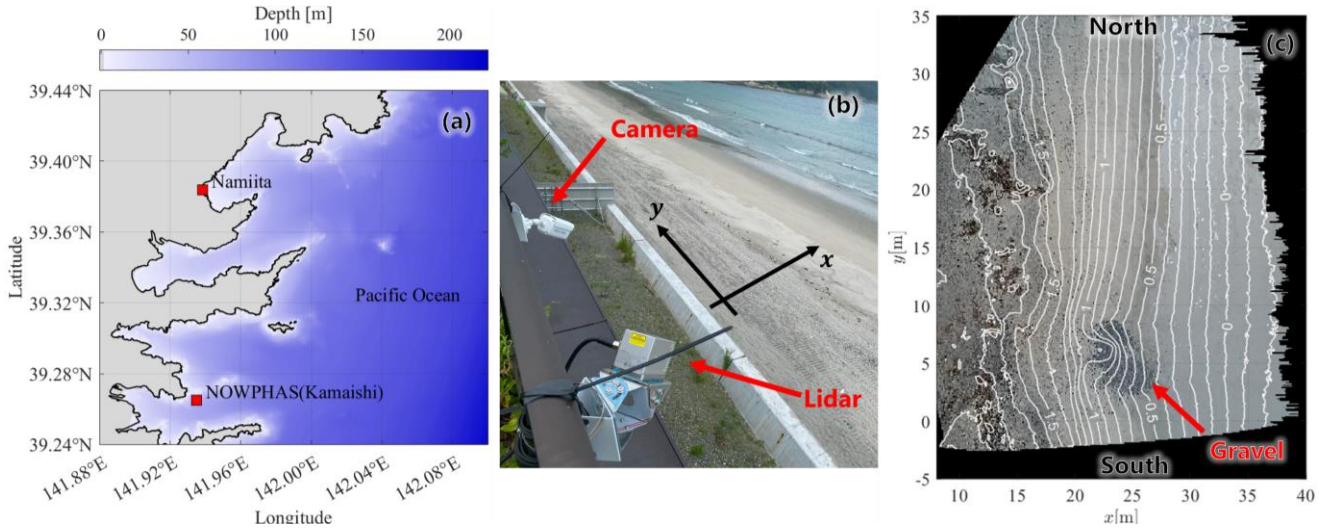


Figure 1 - (a) Locations of Namiita Coast. (b) Setting of a fusion system. (c) Beach surface elevation and color obtained by the fusion system at 10:55 on Aug. 28. Gravel accumulated at  $(x, y) = (22 \text{ m}, 6 \text{ m})$ .

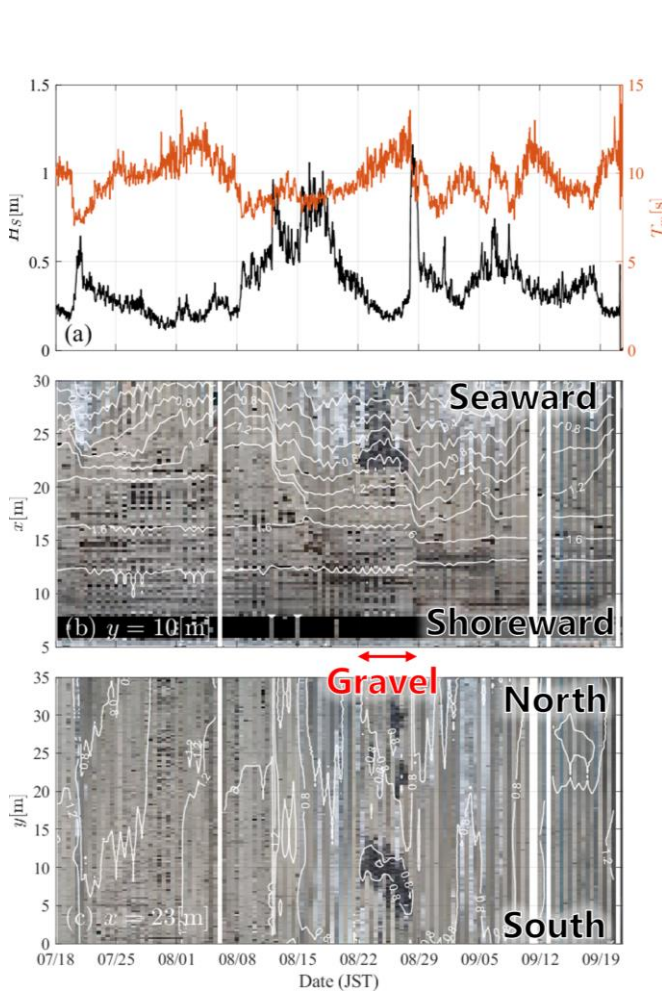


Figure 2 - (a) Observed wave data. (b) Time series of bottom elevation and surface colors on a cross-shore transect ( $y = 10 \text{ m}$ ). (c) Same with (b), but on an alongshore transect ( $x = 23 \text{ m}$ ).

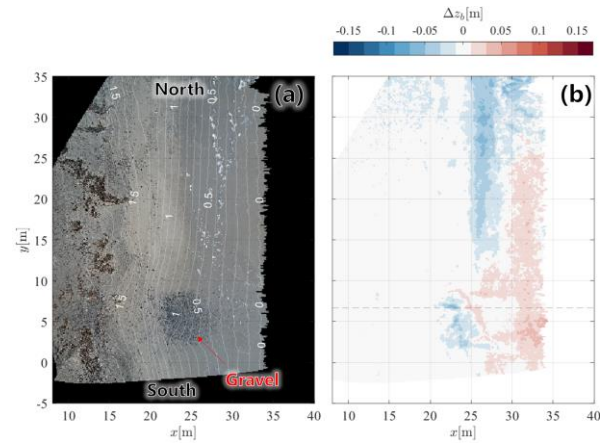


Figure 3 - (a) Beach surface elevation and color at 11:05 on Aug. 28. (b) Net change of beach elevation during 10 minutes from 10:55 on Aug. 28 shown in Fig 1(a).

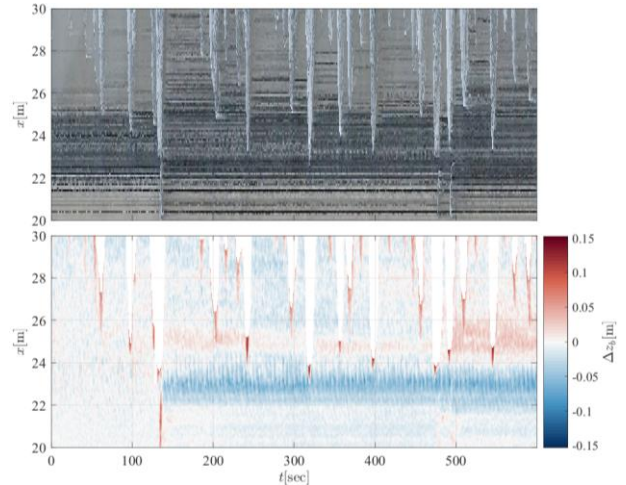


Figure 4 - (Upper) Timestack image and (Lower) Net bottom profile change from the first one minute on a cross-shore transect ( $y = 6.7 \text{ m}$ ). 10:55-11:05 on Aug. 28