Wave-induced current at Anmok Beach, Korea

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Abstract. Currents were measured at two stations on Anmok Beach, and were reproduced by a numerical model system CST3D-WA. Anmok area is known as wave-dominated coast, and the mean tidal range small. Field data with strong wave-induced current are rare, especially at shallow water depth. Measured currents were strong during three periods. The largest instantaneous current speed at a station during a period was 46 cm/s. CST3D-WA system simulated wave-induced current for the three periods, and compared with measurements. The deviation of the incident peak wave direction from the normal direction to the shoreline strongly affects the wave-induced current speed and direction. When the deviation angle crosses the normal direction, the wave-induced alongshore current direction changes between SE and NW. CST3D-WA is thought to have successfully reproduced the wave-induced current fields on this beach.

1. Introduction

When an artificial structure is to be constructed on a coast, we had better predict the environmental impact caused by the new structure as accurately as possible. If the new structure is planned at shallow water depth, we may need to predict shoreline change around the structure as well. Especially if the purpose of the new structure includes protection of shoreline and onshore zone, the prediction of sediment transport and the consequent morphological change is vital during design stage.

Sediment transport rate has often been described as a function of the bed shear stress, given characteristics of bed material, while the bed shear stress depends on information of waves current and water depth as well. Accurate flow information is the key to accurate prediction of morphological change. Flow information can be prepared from numerical modelling, and should be calibrated with measurements. Measuring meaningful wave-induced current has been hindered by various difficulties at field. In most cases currents include both tidal and wave-induced currents. The wave-induced current develops at high waves, and boats cannot approach both onshore and very shallow depths. Equipments cannot endure wild breaking waves. Thus field data on the wave-induced current are rare, especially at shallow depths.

Anmok Beach is situated on the east coast of Korea, see figure 1. Its shoreline is almost straight, and its normal direction is NE. At the SE end of the beach Kangneung Harbour of about 500 m × 500 m is situated . Another straight Namhangjin Beach runs at the south-east end of the harbour. Anmok beach bed material is mostly sand, and its size is between 180 μm and 560 μm. Crossshore bed slope is around 1/50 up to 30 m depth. Waves of 3 m or bigger height attack the beach, and wave-induced current develops at zone shallower than 10 m . Wave directions are normally from NE, but

they deviate from NE during specific typhoons or strong northerly wind period in winter.

(a) Korea (South)   (b) Anmok Beach
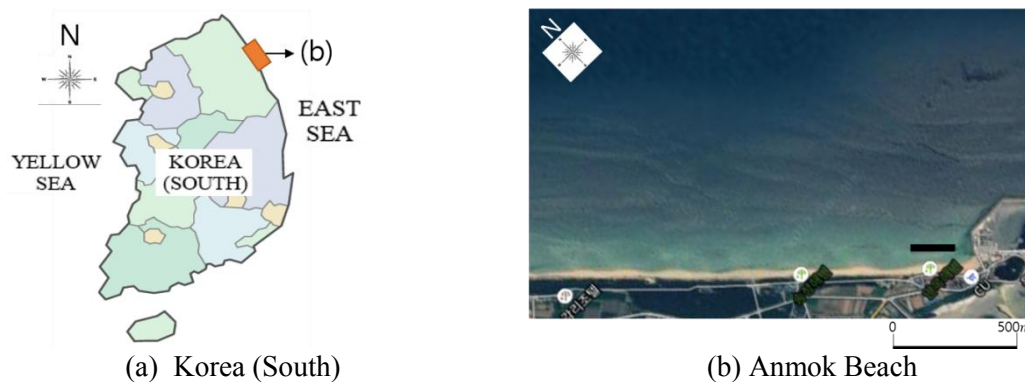
Figure 1. Map of Anmok Beach.

Mean tidal range at Anmok Beach is about 14 cm, and the maximum tidal current speeds during mean tidal range in both directions reach up to 10 cm/s at offshore, but are weak near the shoreline. A submerged breakwater was constructed near Kangneung Harbour late 2014 as in figure 1 to protect erosion of beach and the background road. It is important to evaluate its function at this time for prediction of long term future morphological evolution. KIOST [1] has measured the near-coast current at Anmok Beach since early 2015 up to the present. Currents and suspended sediment concentration were measured for a month each time from 12 February-14 February 2015, 27 February-01 March 2015, and 29 August-31 August 2016. Waves were measured continously, and morphology was measured intermittently depending on meteorologic events.

A numerical modelling system CST3D-WA has been developed by Kookmin University with support from Ministry of Ocean and Fisheries, Korea [2-8]. CST3D-WA includes wave, current, sediment transport, and morphological change modules. Existing phase-average wave model SWAN computes wave fields for given boundary conditions [9-11]. Then, wave-induced flow-driving force field is computed from the wave field by making use of Longuet-Higgins and Stewart's [12] radiation stresses and a spreading method of Kim [13]. Flow field is computed for given tidal water level boundary conditions with either additional wave-induced driving force or not depending on situation. Sediment transport is computed with options of suspended load, bed load, or both. CST3D-WA can handle shoreline retreat or advance due to sediment transport around mean water level by adopting the "beachface controlling method" [14].

2. Measurements and reproduction of wave-induced currents at Anmok Beach

Table 1. Details of field measurement at Anmok Beach.

St	Period	X (UTM)	Y (UTM)	Depth(m)	Equipment
W1	2015. 02.12~Date	495269.76	4181915.52	18.26	AWAC
V3	2015.02.12~2015.03.01, 2015.12.08~2015.01.16, 2016.08.25~2016.09.23	494674.25	4181499.83	2.47	Vector 1EA, OBS 1EA
S2	2015.02.12~2015.03.01, 2015.12.08~2015.01.16, 2016.08.25~2016.09.23	494890.07	4181616.19	4.01	ADCP-1200 1EA, Vector 1EA OBS 1EA

Waves and currents were measured at three stations, see figure 2 and table 1. During the third survey period typhoon LIONROCK arrived at the beach, and the biggest significant wave height at the time

was 4.01 m, the peak wave period was 11.5 s, and the peak wave direction was about 65.0 ° clockwise from N. Measured current including wave-induced current developed in the alongshore SE direction, and reached 23 cm/s at St. V3 behind the submerged breakwater due to structure-driven breaking and diffraction.
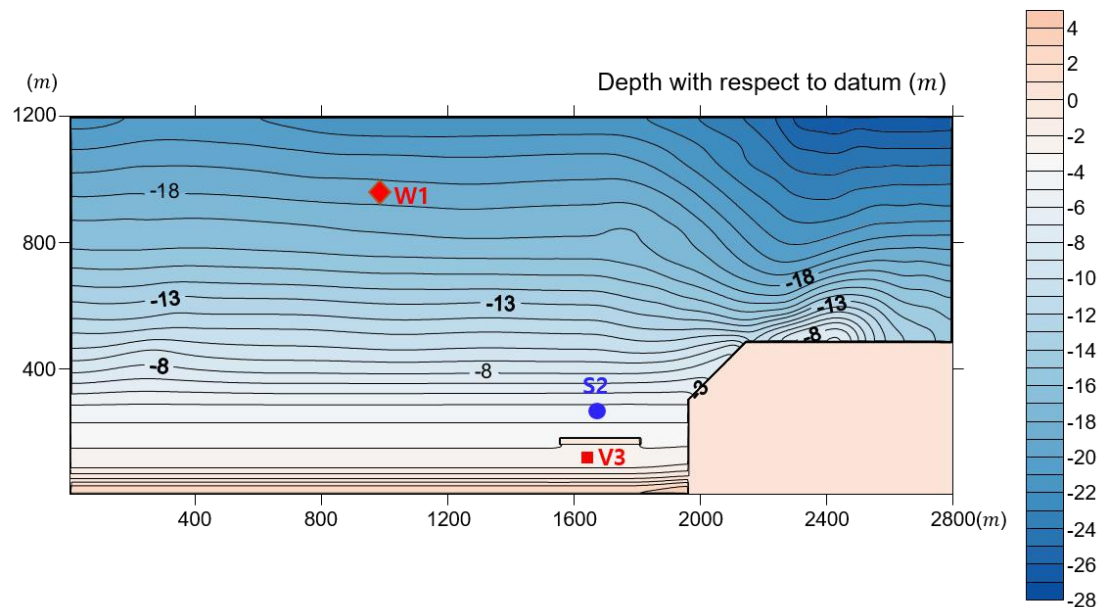
Figure 2. Depth of Anmok Beach.

Several different sources drive coastal currents, e.g. tidal current, wave-induced current, wind-induced current, and density current. Measured current speeds show high correlation with the significant wave height. First, we examine the significance of the tidal contribution to the coastal current at the two stations of this beach.

Simulated residual tidal current field for mean tidal range by CST3D-WA is shown in figure 3, where two circulation cells develop at both sides of Kangneung Harbour. The current speed of the circulation is about 5 cm/s, which is considered small compared to the wave-induced current during typhoons. We try to simulate the wave-induced current separately from the tidal current, considering them negligible during high wave periods.
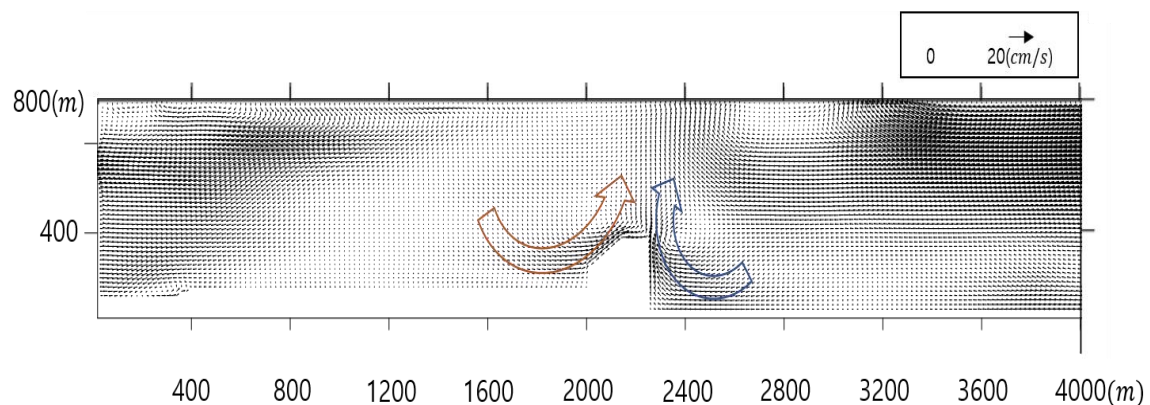
**Figure 3.** Computed residual mean tidal current field at Anmok and Namhangjin Beaches.

Computed time-series of wave-induced current based on the measured significant wave height, peak wave period, and peak wave direction with the measured current for three terms at the two station are shown in figures 4, 6 and 8, respectively; while the instantaneous wave-induced current fields at four specific instants are shown in figures 5, 7, 9, and 10. Both figures 4 and 6 show south-east alongshore current developed by waves coming from the north, while figure 8 shows transition of the alongshore current direction from north-west to south-east, which reflects well the change of wave direction coming from south-east to north-east. Figures 5, 7, 9, and 10 show local circulations behind the submerged breakwater, which are added to the ambient alongshore current field. Simulated vortices seem stronger than measured ones, see St. V3 measurements in figure 8. Further analysis could explain this deviation between measurements and computation results.
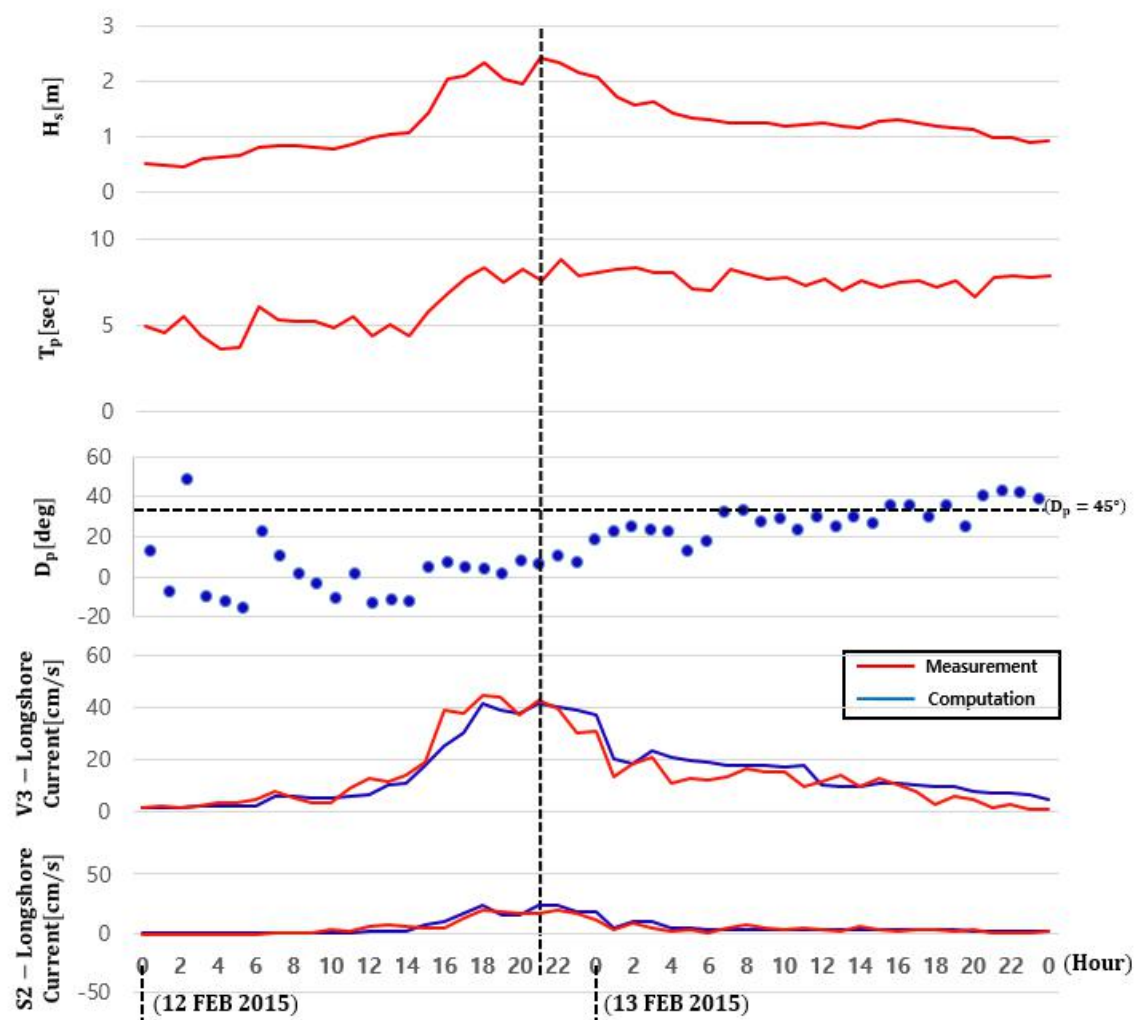
Figure 4. Computed time-series of wave-induced current at two stations from 12 February 2015 to 14 February 2015.
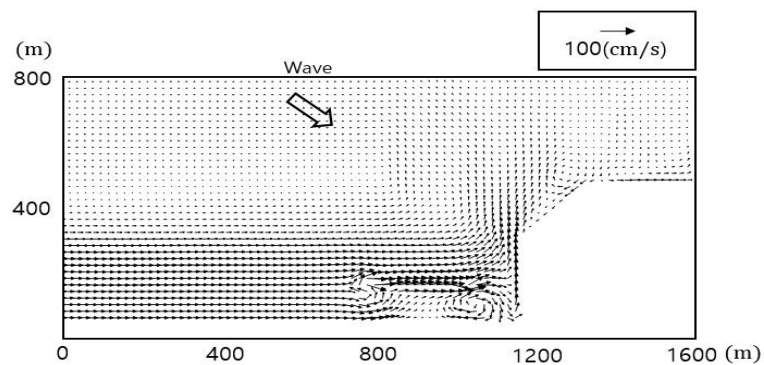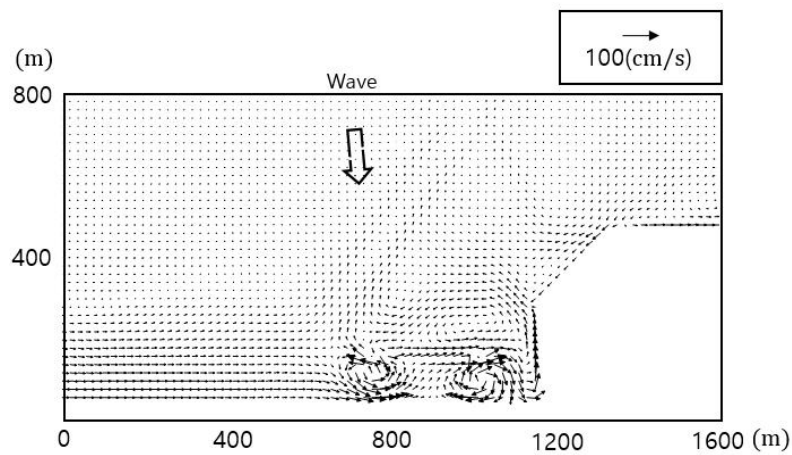
Figure 5. Computed wave-induced current field at Anmok at 21 O'clock, 12 February 2015.
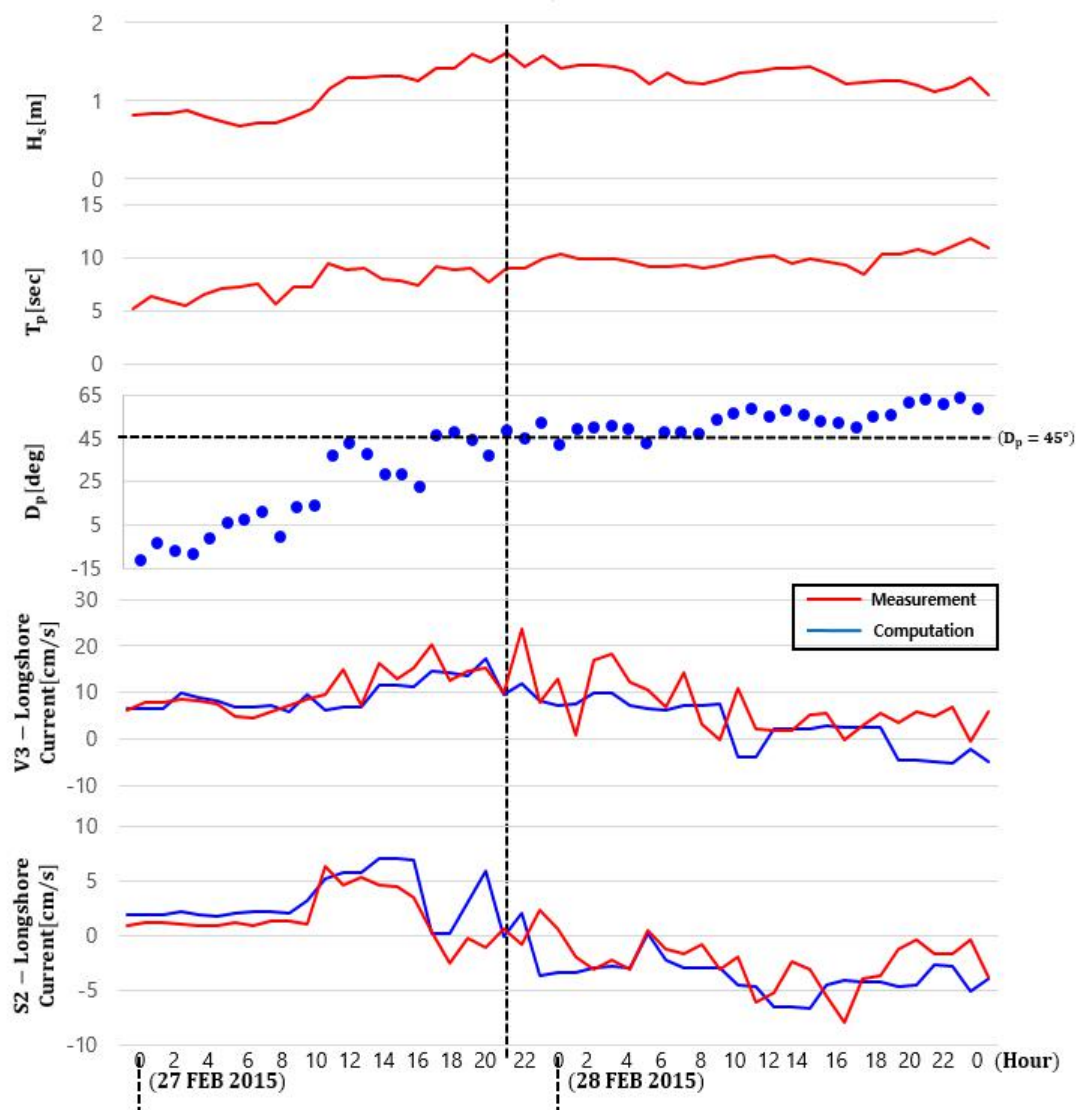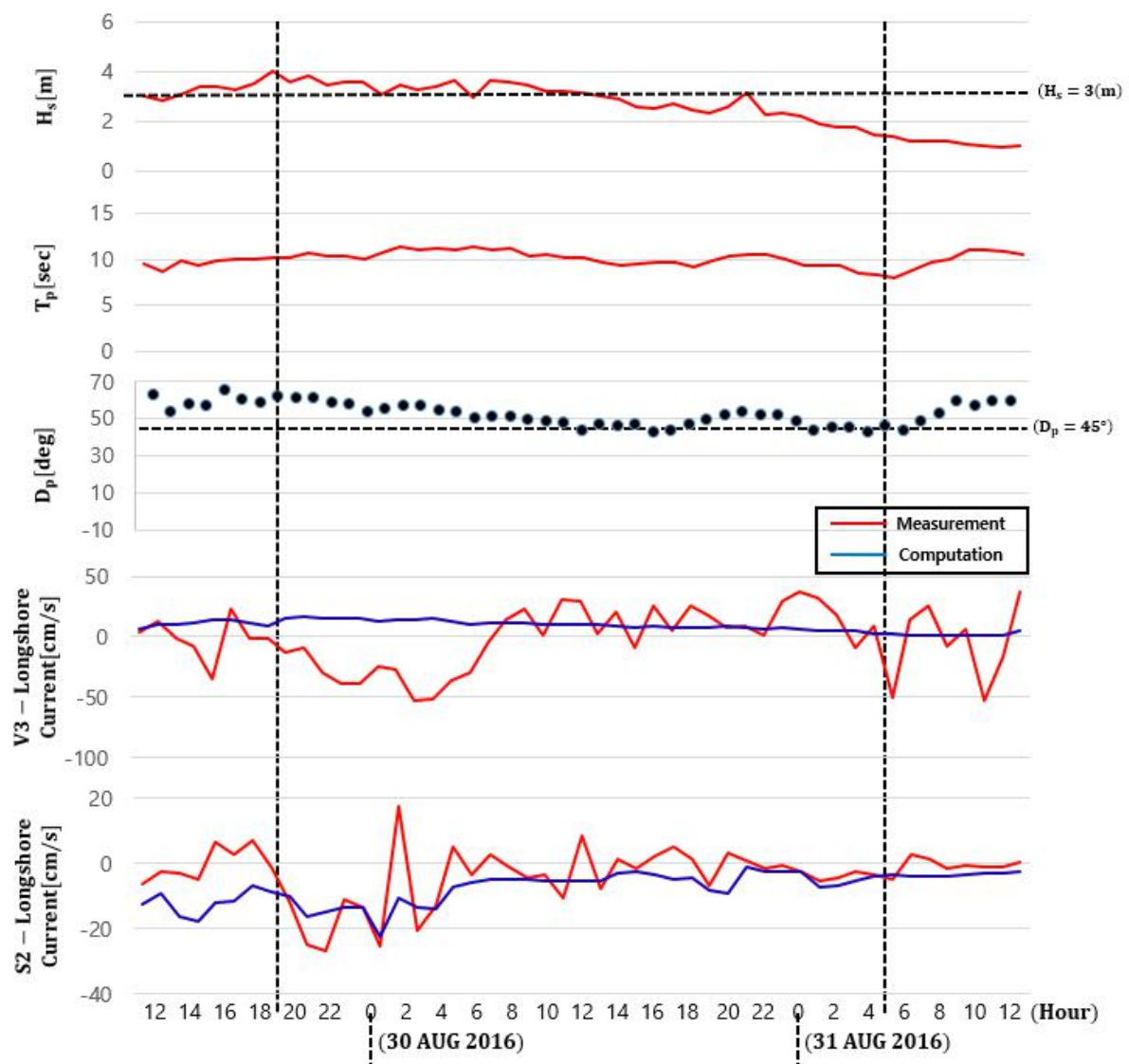

Figure 6. Computed time-series of wave-induced current at two stations from 27 February 2015 to 01 March 2015.
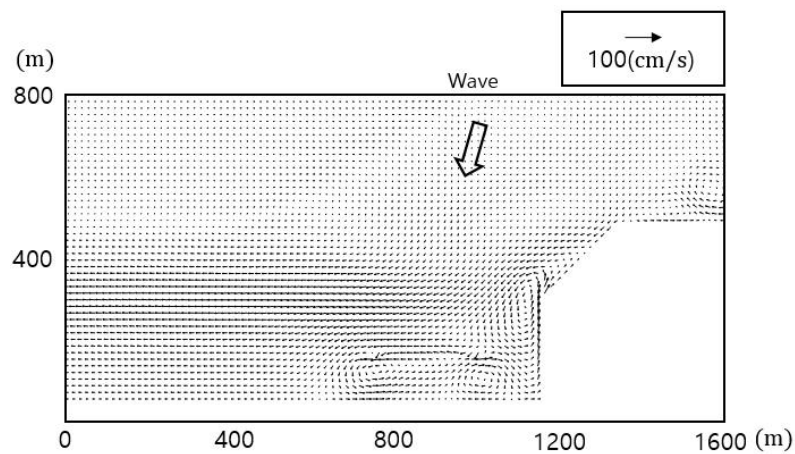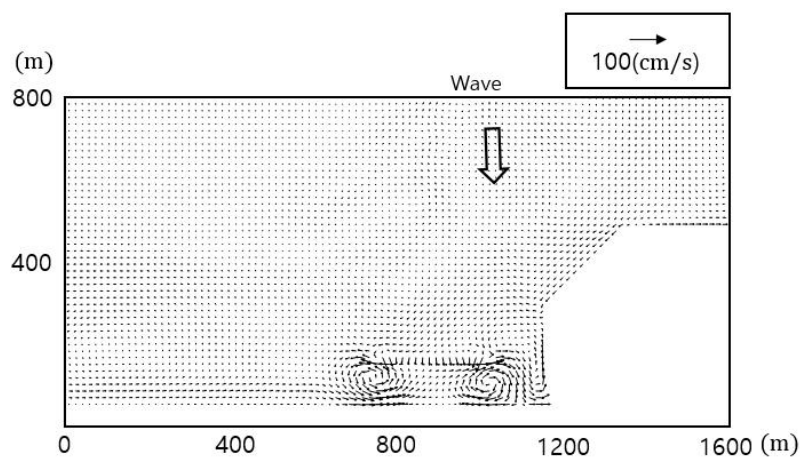
Figure 7. Computed wave-induced current field at Anmok at 21 O'clock, 27 February 2015.

Figure 8. Computed time-series of wave-induced current at two stations from 29 August 2016 to 31 August 2016.

Figure 9. Computed wave-induced current field at Anmok at 19 O'clock, 29 August 2016.

Figure 10. Computed wave-induced current field at Anmok at 05 O'clock, 31 August 2016.

Overall CST3D-WA is believed to have reproduced the wave-induced current fields from the direction and the order of magnitude point of view.

3. Conclusions

KIOST obtained valuable near-coast current data despite various difficulties like deployment of equipment at very shallow water depth, where waves break during typhoons.

CST3D-WA simulated the wave-induced current for three terms when waves were high, and explains correlation between the incident wave direction and the alongshore current direction. The model system also reproduced the current speed reasonably well. It is thought that the CST3D-WA could be applied for simulation of morphological change at the site with high reliability.

Acknowledgments

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