Effect of swells on the development of wind waves in the real ocean

*Kosei Komatsu[1,2], Hirotaka Omatsu[1,2], Kiyoshi Tanaka[2]

1. GSFS, Univ. Tokyo, 2. AORI, Univ. Tokyo

Wave-wave interaction plays main roles on the inter-scale exchange of several physical quantities such as energy and momentum. However, it is inherently accompanied by strong nonlinearity especially at the boundary of an open system, therefore it is difficult to understand accurately the realty of the wave-wave interaction occurring on the air-sea interface. Surface gravity wave induced by wind is one of the most energetic and influential phenomena that occur continuously at the sea surface, and it is classified conventionally into wind wave and swell. Wind waves are short waves with a typical period of a few to 7 seconds, which are developing under the energy input from the local wind. Swells, on the other hand, are longer waves with a typical period of ten to several tens of seconds that have propagated away from their generation region without receiving active energy input from the local wind. The interaction between wind waves and swells has not been understood completely still now, although the both waves compose the surface roughness that determines the drag coefficient while intermingling in the real oceans.
Interestingly, the wave-tank experiments of the past pointed out that swells suppressed the development of wind waves in the case of wind blowing in the same direction as the propagation of the swells, and inversely that swells promoted the development of wind waves in the case of wind blowing oppositely to the swell propagation. In contrast, theoretical studies presented that swells suppressed the wind wave development, regardless of whether wind blew in the same direction as the swells or not. This inconsistency between the previous experimental and theoretical studies has not still been solved, and moreover, it should be emphasized that these effects of swells on the development of wind waves have not been verified in the real oceans.
This study is the first to verify quantitatively the effects of swells on the development of wind waves in the real ocean. For this purpose, we analyzed 2D wave-energy spectra and wind velocity observed simultaneously and continuously by a buoy equipped with a GPS wave sensor and an ultrasonic anemometer, which had been moored over a four-year period in Otsuchi Bay on the Sanriku ria coast, Japan. Otsuchi Bay presents similar situations as the experimental conditions set up for a wind-wave tank with a plunger, because wind waves generated by local wind inside the bay are always coexistent with near-monochromatic swells which are originated from the offshore regions and propagate into the bay through the narrow bay mouth. The analysis revealed that the effects of swells on the development of wind waves were consistent with the conclusions of not the previous experimental studies but the theoretical studies. Energy of wind waves calculated from their spectral components was suppressed under the influence of swells in both the fair and opposite wind cases, comparing with that in the case when the influence of swells was inferred to be minimum from their smallest wave steepness. However, as for the opposite wind case, the energy of wind waves dispersed so widely that it indicated the probability of the wind-wave energy enhancement depending on the situation; the longer fetch leaded to the more remarkable enhancement. The discrepancy between this study and the previous experiments might be attributed to much smaller energy of swells simulated by monochromatic regular waves generated by a plunger in the wind-wave tank, in comparison with real swells in Otsuchi Bay. Moreover, wind waves in the wave-tank were under the local equilibrium between wind and wind waves, on the other hand wind waves in Otsuchi Bay were far from the local equilibrium. Detailed processes of the interaction between wind waves and swells have not been completely clarified still now. Spatial-temporal variation of the wind-wave energy needs to be analyzed for approaching the interaction processes in the future studies.

Keywords: wind-generated surface waves, interaction between swells and wind waves, Otsuchi Bay

