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Measurement of momentum flux across the air-water interface in high-speed wind-wave tank

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Since typhoons wreak catastrophic damages to a local society, it is of great importance to predict the development and decay mechanisms of typhoons accurately. To get reliable predictions, momentum transfer across the air-sea interface should first be estimated accurately. However, in the high wind-speed region with intensive wave breaking, there remains much uncertainty in the trend of drag coefficient and roughness length (z_0), and the momentum transfer mechanism has not been clarified. The purpose of this study is therefore to precisely estimate the momentum flux across the breaking air-water interface under strong wind conditions, and to investigate the momentum transfer mechanism.

A high-speed wind-wave tank with 15 m long was used. Wind waves were driven in the water tank at wind speeds of U_{10} = 7 - 67 m/s. A laser Doppler anemometry (LDA) was used to measure the wind-velocity fluctuations. The wind-velocity under breaking wind-wave conditions was measured using a phase Doppler anemometry instead of the LDA. The air friction velocity ($u*$) was directry measured by an eddy-correration method, and the roughness length (z_0) were estimated using the logarithmic law of the wind profile. The water level fluctuation was also measured by a resistance type wave height meter.

The results show that z_0 monotonically increases with $u*$ in the normal wind-speed region, whereas z_0 approaches to a constant value in the high wind-speed region. In previous field and laboratory experiments, the trends of z_0 under high wind-speed conditions are controversial among three groups (increase, decrease, and constant with $u*$). The values of momentum flux across the air-sea interface, in whole previous studies, were indirectly estimated by a wind profile method or a momentum budget method. Thus, the precision of these previous data seems to be lower than the present data based on the direct measurements of the Reynolds stress. This supports that the z_0 has a constant value under high wind-speed condition. In additon, we derived a new relationship between wind wave shape and z_0 applicable in the whole wind speed region, and we expect that the present finding will be useful to improve predictions of typhoons.

Keywords: wind-wave, drag coefficient, roughness length