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Atmosphere-Ocean-Wave coupled model performing 4DDA with a tropical cyclone bogussing scheme to calculate storm surges in an inner bay

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Typhoon MELOR attacked Ise Bay in Japan on October 2009, creating one of the largest storm tides on record—-a storm tide of 2.6 m—-observed at Mikawa Port, located at the eastern inner part of Ise Bay. The storm surge disaster set 100 or more containers adrift in the container yard. Such storm surge disasters in inner bays are predicted to increase and intensify because of global warming. Therefore, a numerical model that can reproduce storm surge in inner bays correctly is necessary to elucidate the spatial distribution of the maximum tidal level and thereby enable effective countermeasures against storm surges.

Correct evaluation of sea surface winds affected by complicated coastlines and landforms surrounding the inner bay must be done to produce highly accurate calculations of storm surge in inner bays. Usual simulations for storm surges have used parametric typhoon models, such as those presented by Schloemer et al., or meteorological models with a tropical cyclone bogussing scheme to calculate the sea surface winds. However, the former parametric typhoon models are inadequate for physical evaluation of the roughness effects of complicated coastlines and landforms and three-dimensional effects of the meteorological field on the sea surface winds. The latter meteorological models typically suffer from the following problem. The track and structure of the typhoon can not be reproduced correctly as time progresses because the tropical cyclone bogussing scheme is applied only to the initial field of the meteorological models and cannot control the track. We therefore cannot calculate sea surface winds accurately as long as those models are used.

We constructed a meteorological model, MM5, to perform four-dimensional data assimilation (4DDA) with the tropical cyclone bogussing scheme to solve the problem described above. An atmosphere–ocean–wave coupled model using a coastal ocean current model CCM and a wave model SWAN together with MM5 performing the 4DDA with the bogussing scheme were developed to calculate the storm surge in the inner bay accurately. They were used to regenerate the storm surge caused by Typhoon MELOR (2009) in Ise Bay. Moreover, comparisons of calculated values and observed ones were conducted for storm tides, wind speeds, and wind directions.

The calculated and observed results agreed well at all locations in Ise Bay. Particularly, the computational error of the coupled model for the storm tide at Mikawa Port, where a storm tide of 2.6 m had been observed, was only 0.05 m. In contrast, the conventional parametric typhoon model had computational error engendering underestimation of 0.8 m. A usual meteorological model without 4DDA with the bogussing scheme suffered from a computational error engendering underestimation of 1.1 m.

Results show that the coupled model performing 4DDA with the bogussing scheme enabled highly accurate calculation of the storm surge in the inner bay despite influences by its complicated coastline and landforms.