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Importance of air-sea interaction on wind waves, storm surge and hurricane simulations

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It was reported from field observations that wind stress coefficient levels off and even decreases when the wind speed exceeds 30-40 m/s. We propose a wave boundary layer model (WBLM) based on the momentum and energy conservation equations. Taking into account the physical details of the air-sea interaction process as well as the energy dissipation due to the presence of sea spray, this model successfully predicts the decreasing tendency of wind stress coefficient.

Then WBLM is embedded in the current-wave coupled model FVCOM-SWAVE to simulate surface waves and storm surge under the forcing of hurricane Katrina. Numerical results based on WBLM agree well with the observed data of NDBC buoys and tide gauges. Sensitivity analysis of different wind stress evaluation methods also shows that large anomalies of significant wave height and surge elevation are captured along the passage of hurricane core. The differences of the local wave height are up to 13 m, which is in accordance with the general knowledge that the ocean dynamic processes under storm conditions are very sensitive to the amount of momentum exchange at the air-sea interface.

In the final part of the research, the reduced wind stress coefficient is tested in the numerical forecast of hurricane Katrina. A parabolic formula fitted to WBLM is employed in the atmosphere-ocean coupled model COAWST. Considering the joint effects of ocean cooling and reduced wind drag, the intensity metrics – the minimum sea level pressure and the maximum 10 m wind speed – are in good inconsistency with the best track result. Those methods, which predict the wind stress coefficient that increase or saturate in extreme wind condition, underestimate the hurricane intensity.

As a whole, we unify the evaluation methods of wind stress in different numerical models and yield reasonable results. Although it is too early to conclude that WBLM is totally applicable or the drag coefficient does decrease for high wind speed, our current research is considered to be a significant step for the application of air-sea interaction on the ocean and atmosphere modelling.