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Wind waves in tropical cyclones: satellite altimeter observations and modeling

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Results of investigation of wind-wave generation by tropical cyclones using satellite altimeter data are presented. Tropical cyclones are generally relatively small rapidly moving low pressure systems that are capable of generating severe wave conditions. Translation of a tropical cyclone leads to a prolonged period of time surface waves in the right sector remain under high wind forcing conditions. This effect has been termed extended fetch, trapped fetch or group velocity quasi-resonance. A tropical cyclone wave field is thus likely more asymmetrical than the corresponding wind field: wind waves in the tropical cyclone right sector are more developed with larger heights than waves in the left one.

A dataset of satellite altimeter intersections of the Western Pacific tropical cyclones was created for 2010-2013. Data from four missions were considered, i.e. Jason-1, Jason-2, CryoSat-2, SARAL/AltiKa. Measurements in the rear-left and front-right sectors of tropical cyclones were examined for the presence of significant wave asymmetry. An analytical model is then derived to efficiently describe the wave energy distribution in a moving tropical cyclone. The model essentially builds on a generalization of the self-similar wave growth model and the assumption of a strongly dominant single spectral mode in a given quadrant of the storm. The model provides a criterion to anticipate wave enhancement with the generation of trapped abnormal waves. If forced during a sufficient timescale interval, also defined from this generalized self-similar wave growth model, waves can be trapped and large amplification of the wave energy will occur in the front-right storm quadrant. Remarkably, the group velocity and corresponding wavelength of outrunning wave systems will become wind speed independent and solely relate to the translating velocity. The resulting significant wave height also only weakly depends on wind speed, and more strongly on the translation velocity.

Satellite altimeter measurements, together with TC intensities estimates, are used to assess the proposed formulations. Compared to satellite altimeter measurements, the proposed analytical solutions for the wave energy distribution are in convincing agreement. For almost symmetrical wind field, the model quantitatively reproduces measured profiles of the wave energy with significant asymmetry between the wave-containment front-right quadrant and the rear-left quadrant where wave energy is remarkably damped. Though the differences between parametric model-wind and altimeter-wind profiles are noticeable, the energy ratios between the front-right and the rear-left quadrants are similar for both wind sources. As analytically developed, the wave enhancement criterion can provide a rapid evaluation to document the general characteristics of each storm, especially the expected wave field asymmetry.