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Nonlinear generation of infra-gravity waves from deep to shallow water

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Infra-gravity (IG) waves are commonly defined as sea surface gravity waves whose frequency is lower than that of the wind sea (0.05 Hz) and higher than that of the tides and internal waves (0.005 Hz). They are important for various aspects in oceanography and marine engineering such as: estimations of sediment transport and harbor resonances, altimetry measurements, the breaking of the ice sheet in the Pacific and Earth's hum. Their primary known generation mechanism is the nonlinear shoaling of the wave field. Therefore, the focus of most previous related works was limited to coastal areas. Yet, details of the generation, and specifically their directional properties, are still not fully understood. Results of recent field measurements confirmed the existence of IG wave climate in deeper waters. A common assumption is that the origin of deep water IG waves is the reflection from coastlines (leaky waves), however not every occurrence can be explained in this manner. Here, we present a new triad interaction mechanisms for IG wave generation in deep water and analyze the 2D properties of IG wave generation from deep water to the shoaling region.

For steady homogeneous deep water wave fields, three wave interactions only produce steady non-resonant interactions. However, for evolving seas waves are able to resonate with changes of the wave field in time and space to yield mean energy transfer to the IG frequency range. The considered effects include simple growth of the wave field, effects of gustiness, and whitecapping. A new model for IG wave generation is constructed, which takes these effects into account. It is used to evaluate several storm events, where data obtained from archived reanalysis is used. Model results are compared to measurements of deep water pressure gauges with a good capability of describing the directional properties of the IG frequency range.

We also investigate generation of the IG waves during the shoaling of the wind sea. It is observed that the generated IG waves can have directional properties very different from that of the wind sea. Also, it is observed that energy transfer coefficients are much higher for energy transfer from the IG frequency range to the wind sea range, compared to vice-versa. This means that the IG wave are more linearly dependent (rather than quadratically) to the wind sea energy, which is confirmed in a large number of observations.

The presented work can set the basis for future formulation of an IG wave source term for extending wave forecasting models to the IG frequency range.