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UNSTRUCTURED SWAN MODELLING OF FREE INFRAGRAVITY WAVES OVER THE SOUTHERN NORTH SEA

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1 INTRODUCTION

Infragravity (IG) waves are relatively long waves with typical periods of several tens of seconds to several minutes. The energy at the IG band plays an important role in nearshore areas. For example, IG waves can significantly contribute to dune erosion and sediment transport (e.g., Roelvink *et al.*, 2009), and may excite harbor oscillations (e.g., Bowers, 1977). Furthermore, IG waves may result in destructive inundation events (e.g., Roeber and Bricker, 2015). These documentations of IG waves' impacts emphasise the necessity to account for IG contributions as part of coastal hazard assessments, especially under storm conditions.

Detailed assessments of coastal hazard and erosion due to waves usually rely on large scale wave-circulation models (e.g., coupling of SWAN and Delft3D), which provides the boundary conditions for small scale wave models (e.g., XBeach, SWASH). The latter resolve wave runup and overtopping, and include contributions due to the IG band. The imposed incoming IG spectra along small scale model boundaries typically consist of the bound wave components which are estimated using second-order Stokes theory (e.g., Hasselmann, 1962) based on local sea-swell wave information. However, incoming IG waves may also include freely propagating components. These free IG waves are usually ignored along incoming model boundaries, although they may explain significant part of the incoming IG energy (e.g. Reniers *et al.*, 2021), and thus, they may significantly contribute to wave inundation and erosion.

Recently, Ardhuin *et al.*, (2014) proposed an efficient approach for the estimation of free IG wave radiation using a parameterization based on sea-swell information. This approach has been implemented in the spectral wave model SWAN by Rijnsdorp *et al.*, (2021), and thus, it is now available for operational use. Based on observations over the southern part of the North Sea, Rijnsdorp *et al.*, (2021) examined the performance of this spectral modelling approach. Good agreement was found between modelled and measured significant wave heights, indicating the suitability of this approach to describe free IG wave variability over the North Sea. However, the verification study considered by Rijnsdorp *et al.*, (2021) was restricted to relatively long IG periods (due to unavailability of measurements at shorter IG periods) and also limited to bulk wave parameters (i.e., the significant wave height). Therefore, increasing the reliability of this modelling approach requires extending this validation study.

The present study generalizes both the validation of this new modelling approach and its underlying parametrization, focusing on IG modelling over the southern part of the North Sea. Figure 1 provides an overview of the considered domain, the source lines along which free IG waves are being generated and also presents a set of locations for which measurements of IG data are available. As implied by Figure 1, one of the steps considered here is the generalization of this modelling approach to unstructured grids. This provides the flexibility to refine nearshore model resolution and properly represent complex coastlines while maintaining cost-effective offshore coarse resolution in a single computational grid. By itself, such a possibility reduces modelling complexity compared to the nested modelling approach. Moreover, the unstructured approach also avoids potential errors which may cause due to the nesting process and the introduction of internal boundaries and allows a built-in smooth exchange of information between coarser and finer computational regions.

The extension of model validation is achieved using collection of recent measurements (e.g., Rutten *et al.*, 2024), allowing model validation over the spectral domain and over the full IG frequency band. Moreover, these new measurement collections allow model validation for both deeper water offshore-sites and shallower nearshore-sites (see measurement locations in Figure 1). Furthermore, insights gained by the new measurement collections allow to optimize modelling performance. Specifically, three optimization measures are considered. The first is the improvement of the assumed frequency and directional distributions of the free IG spectra along the source lines. The second is to try to extract the bottom friction coefficient to adequately account for wave dissipation due bottom friction. Finally, the third measure aims to distinguish between the different coast lines surrounding the North Sea basin. This is performed by defining a specific division of shoreline segments along which the source lines are implemented (see Figure 1). Each source line is then characterized by a "coast specific value" of the calibration parameter which tunes the parameterization of the free IG generation based on the sea-swell wave information. This allows to take into account (roughly) the effect of the seabed characteristics (e.g., slope, material) on the generation of the radiated IG waves. The different parameter values are selected such that modelling errors are minimized with respect to the measurement observations. Ultimately, the predictive capabilities of the generalized model will be studied using an independent set of free IG wave observations over the southern part of the North Sea.

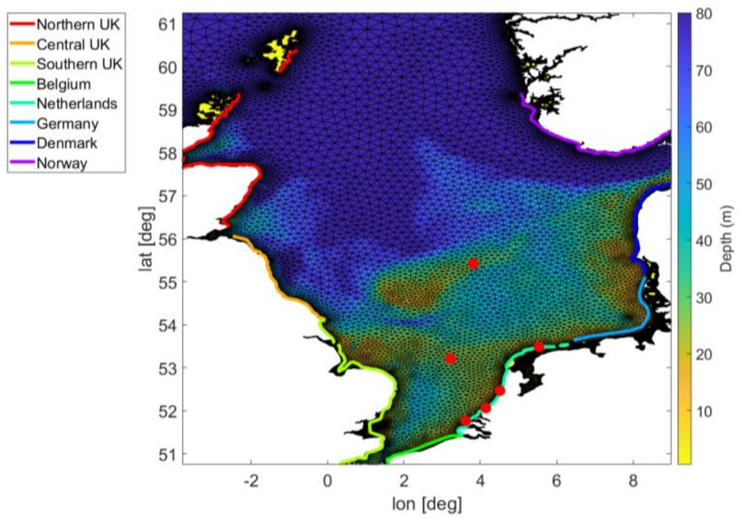

Figure 1. The North Sea domain over which free IG wave variability is considered. Spectra of free IG are generated along the source lines which are indicated by the colored line segments along the North Sea coasts. The red dots plotted over the southern part of the North Sea indicate measurement locations for which free IG observations are available.

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