MODELING INFRAGRAVITY WAVES WITH SWAN

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INTRODUCTION

Infragravity (IG) waves play an important role in the coastal zone affecting wave runup, overtopping, dune erosion and shipping. They originate from the sea-swell wave groups that force them either as bound IG waves or as free IG waves due to the breakpoint variation. The bound IG waves that are released within the surfzone (partly) reflect and are either refractively trapped or leaky where the latter can travel large distances and arrive at remote shorelines (Ardhuin et al., 2014, Rijnsdorp et al., 2021). As such the incident IG wave field at a particular coast consists of wave-group-forced (WGF) IG waves combining the bound and released IG waves (Herbers and Burton, 1997), and free infragravity (FIG) waves consisting of locally trapped and remote IG waves. To assess the potential impact of overtopping as well as dune erosion during extreme storm conditions sophisticated process models like XBeach (Roelvink et al., 2007) and SWASH (Zijlema et al., 2011) are often used. In addition to the sea-swell conditions and tide and surge levels these models require a boundary condition for the incident IG waves. Typically, this boundary condition is defined by the bound IG waves only using the equilibrium theory of Hasselmann (1962). This approach may lead to a significant over estimation in the presence of a sloping beach, but also an underestimation in the presence of incident FIG waves. Here we use an extended version of SWAN (Booij et al., 1999) to predict the total incident IG wave field during storm conditions that subsequently can be used as a boundary condition for these more detailed overtopping and dune erosion models. To verify the modeling approach, detailed comparisons with recently acquired observations at the Sand Engine of the directional free and forced IG wave field (Rutten et al., 2023) are used.

MODELING APPROACH

To predict the contributions of the FIG waves originating both from remote coasts and local trapping we use the spectral wave model SWAN at the regional scale of the North Sea augmented with the FIG source function of Ardhuin et al. (2014). To increase the resolution in the coastal zone to enable comparisons with the nearshore observations an unstructured grid version of the SWAN-FIG model of Rijnsdorp et al. (2021) has been created (see Figure 1). This is complemented with a SWAN-SB (SurfBeat) model (Reniers and Zijlema, 2022) to predict the WGF IG waves at the location of the observations. The combined SWAN-FIG and SWAN-SB output has been compared with the observations of Rutten et al. (2023).

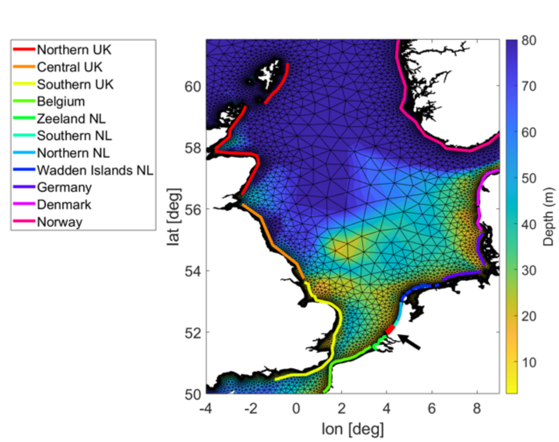

Figure 1 - Unstructured SWAN-FIG model of the North Sea domain with different source lines indicated on the left. SWAN-SB model domain (red rectangle) denoted by the arrow.

RESULTS

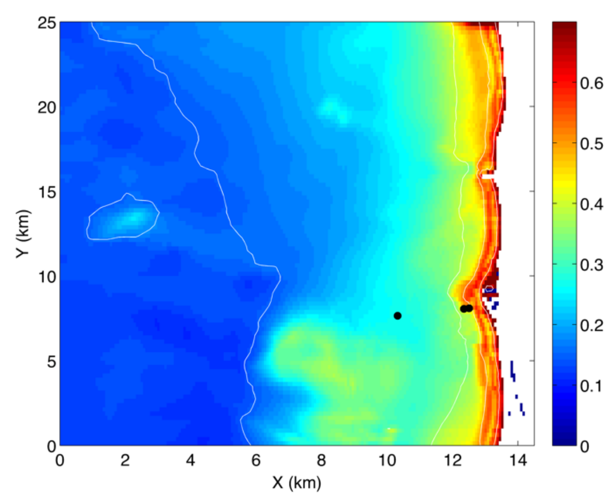

Figure 2 - SWAN-SB prediction of WGF IG significant wave height during storm conditions on January 31st 2022 (color scale in (m)).Instrument locations offshore of the sand engine for model-data comparisons indicated by the black dots.

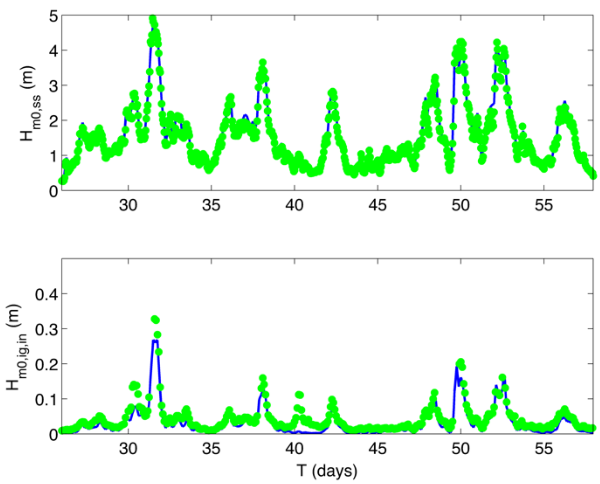

Figure 3 – SWAN-SB predictions (blue lines) of significant Sea-Swell wave height (upper panel) and incoming WGF IG significant wave height (lower panel) at the offshore sensor location (see Figure 2 for location) compared with observations (green dots). The time starts on January 1st 2022.

These observations span a period of five months during which multiple storms occurred at depths of 14, 8.5 and 6.5 m with respect to MSL (see Figure 2 and accompanying abstract of Tissier). Predictions of the significant sea-swell wave height at the offshore frame compare well with the observations. However, the total observed incident IG wave height is underestimated by the SWAN-SB predictions (see lower panel of Figure 3) and can be explained by the missing contribution of the incident FIG waves due to remote sources and local refractive trapping, for which the SWAN-FIG predictions will be used. In addition to the integral parameters the frequency-directional IG spectra will be compared to the observations, where the novel analyses method of (Matsuba et al., 2022) has been used, to elucidate the role of free, bound and released incident IG waves during storm conditions and different depths.

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