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FIELD OBSERVATIONS OF THE INFLUENCE OF INFRAGRAVITY WAVES ON WAVE OVERTOPPING AT A DIKE ON A SHALLOW FORESHORE

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1 INTRODUCTION

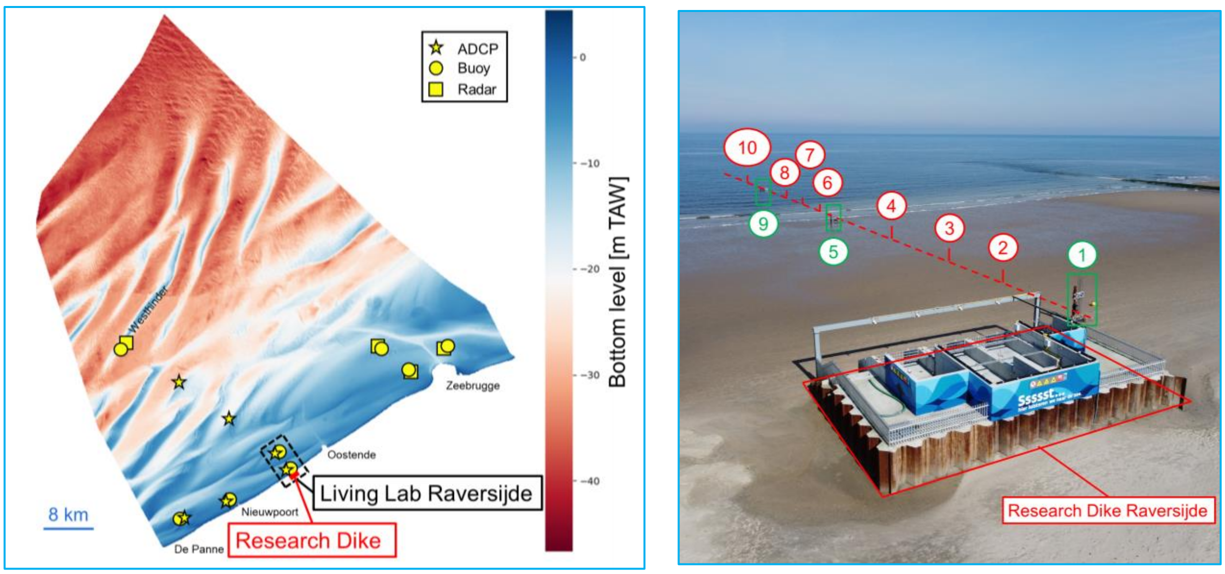
Infragravity (IG) waves are low-frequency waves (0.0033 Hz < f < 0.05 Hz) that exist: (i) being bound to the wave groups of high-frequency sea-swell (SS) waves (0.05 Hz < f < 1 Hz), (ii) generated by the moving breakpoint due to the groupiness of the SS waves (Bertin et al., 2018), and (iii) as free IG waves released from the SS wave groups and reflected from neighbouring coasts (Rijnsdorp et al., 2021). Offshore in deeper water ($h/H_{m0,o}$ > 4, with h the water depth and $H_{m0,o}$ the offshore significant wave height), IG waves become most apparent during storm conditions, but are still rather limited in wave height (order of a couple of cm). However, at the toe of coastal structures with a shallow foreshore depth ($1 < h_t/H_{m0,o} < 4$, with h_t the water depth at the toe), the energy of IG waves becomes more significant relative to the SS wave frequency band of the wave spectrum (Hofland et al., 2017), becomes equally important for very shallow foreshores ($0.3 < h_t/H_{m0,o} < 1$), and even dominates SS wave energy for extremely shallow foreshore depths ($h_t/H_{m0,o} < 0.3$). IG wave growth on mildly sloped shallow foreshores is a result of IG wave shoaling and SS wave energy transfer to IG waves via nonlinear wave-wave interactions (Bertin et al., 2018), and the relative growth of IG to SS wave energy is further aided by SS wave breaking.

Coastal urban areas along the Belgian coast (and in other low-lying countries worldwide) rely on a hybrid beach-dike coastal defense system for protection against flooding. During design storm conditions, the nourished beach erodes to a very to extremely shallow foreshore in front of a low-crested impermeable sea dike. Wave overtopping at this type of structure has been shown to be affected by IG waves, based on physical (Altomare et al., 2016) and numerical modelling (Lashley et al., 2021) for shallow to extremely shallow foreshores. However, field observations of the influence of IG waves on wave overtopping have been scarce (van Gent and Giarusso, 2003) and the influence of free IG waves has not been investigated yet. Indeed, the amount of IG wave energy that is expected to arrive at the coastline, not only depends on IG waves naturally bound to the SS wave groups, but also on free IG waves generated offshore or locally reflected from the coast (edge waves). The Belgian continental shelf is characterized by the prevalence of offshore sandbanks (see Figure 1a), which might be an additional source of free IG waves, due to ss wave breaking on the shallow crest of those banks. These free IG waves are location specific and their existence can only be determined by field observations. Knowledge of the offshore boundary conditions with detailed IG wave information is indispensable for the correct prediction and modelling of surf zone hydrodynamics and beach morphodynamics (Fiedler et al., 2019), and the consequent wave overtopping on the dike. Simultaneous measurements of IG waves, offshore and on the beach-dike system during storm conditions together with wave overtopping has not been done before, as it is complex and needs a specific setup with high precision measurement equipment. In-situ measurements provide an invaluable dataset (i.e., no model nor scale effects) and are essential for validating safety assessment and design methodologies of coastal defense systems.

This paper presents the field setup for observations of IG waves offshore and nearshore at Living Lab Raversijde (LLR) with the Research Dike Raversijde (RDR) (presented by Gruwez et al. (2024), also at Coastlab24) measuring the wave-structure interactions (overtopping, impact,…), and presents the results of IG wave influence on wave overtopping, including free IG waves. Finally, a first evaluation of existing empirical formulas with the field measurements is done.

2 FIELD MEASUREMENT SETUP, METHODS AND RESULTS

Free IG waves can be obtained from total IG wave measurements by removing the calculated bound IG waves. The bound IG wave spectrum can be determined theoretically from the equilibrium theory based on an SS directional wave spectrum and a surface elevation measurement (e.g., radar, pressure), or directly from bi-spectral analysis of the pressure signal (Herbers et al., 1994). Directional bound and free IG wave spectra can be reconstructed using PUV measurements (pressure P and perpendicular horizontal velocities U and V, e.g., ADCP) in intermediate depths (Matsuba et al., 2022). Offshore waves are therefore measured by a collocated radar and directional wave buoy or an ADCP (see Figure 1a), from Westhinder towards LLR to investigate free IG wave generation at the sandbanks, and along the coast from De Panne to Zeebrugge to investigate the alongshore variation of (free) IG wave energy. Nearshore, the intertidal measurements at the LLR site (Ostend, Belgium) are used and extended with additional pressure sensors, to allow the decomposition of IG waves into the incident and reflected components based on PUV and array methods (Bertin et al., 2018). The overtopping is measured simultaneously at the RDR. At the conference, the field setup and results will be presented in more detail, based on storms measured during winters ’22-’23 and ’23-‘24.



(a) **(b)**

Figure 1. Field setup of IG and SS wave and overtopping observations, (a) offshore wave measurement locations on the bathymetry of the Belgian Continental Shelf, (b) RDR and cross-shore intertidal measurements at 10 locations (along the dashed red line): 3 PUV (green) and 7 P (red).

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