Project Summary B2 - Wave propagation over foreshores
The influence of infragravity waves on overtopping at coastal structures with shallow foreshores

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Project Summary

B2 - Wave propagation over foreshores

The influence of infragravity waves on overtopping at coastal structures with shallow foreshores

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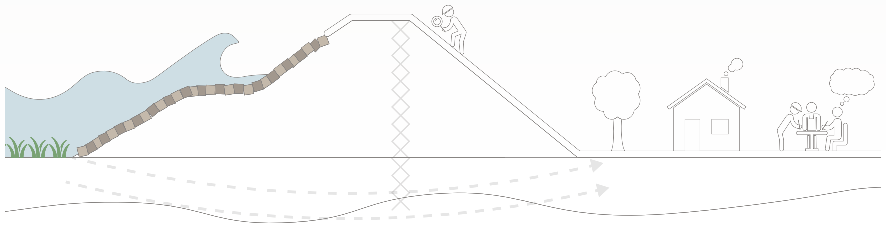

Promotors

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Outcome

This project developed new empirical methods to estimate the relative magnitude or significance of infragravity waves and the mean overtopping discharge at coastal defences with shallow foreshores. For wave overtopping, two methods were proposed: the first augments the traditional approach where phase-averaged numerical modelling is first used to estimate wave parameters at the toe, followed by an empirical estimate of the wave overtopping. The second approach is fully empirical and uses deep-water wave parameters as input and directly account for infragravity waves. These approaches were then assembled into a probabilistic framework capable of quantifying the impact of infragravity waves on safety along the Dutch Wadden Sea coast.

Figure 1: Dike partially covered by asphalt and partially by grass, fronted by a shallow, mildly-sloping mudflat along the Dutch Wadden Sea coast. Photo by Jaap van Duin.

Motivation and practical challenge

To incorporate nature-based measures, such as the effect of salt marshes and mudflats, in the design and assessment of sea dikes, we must fully understand their impact on waves and the likelihood of flooding during extreme storms. While the influence of such shallow environments on short-period wind waves (periods less than 25 seconds) is well understood and accounted for, what happens to longer-period infragravity waves (periods of minutes) is still not fully understood. During extreme storms, these waves typically propagate, reaching up to coastal dikes. Despite their importance for flood safety and coastal dynamics, the current approaches neglect or only indirectly consider the IG waves in the analysis. In the Netherlands, this challenge presents itself in the Wadden Sea, which is quite shallow for kilometres and experiences waves generated locally and in the North Sea. The improved understanding of these waves propagating over the foreshores is also useful for building with nature in other coastal areas such as the Caribbean Islands where I am from.

Figure 2: Recent field campaign to measure waves and currents during the yearly winter storms in the same location. Photos by Pieter van der Gaag.

Research Challenge

The research seeks to answer: under what conditions are these infragravity waves significant at the structure toe, and given that they are significant, what is their impact on flood safety?

Innovative components

The following methods were applied and validated as much as possible with field measurement campaigns to answer the above questions:

- **Numerical modelling:** while field measurements and physical model tests are often difficult and expensive to implement, numerical models may be used to understand better the interaction between waves and the foreshore in a timely and cost-effective manner. This research applied state-of-the-art numerical modelling tools such as SWAN, SWASH, XBeach and OpenFOAM to estimate the nearshore wave heights and the volumes of waves overtopping the dike.
- **Empirical modelling:** Using existing physical model tests and new numerical data, the relationship between the foreshore, nearshore waves and the volume of water that may overtop the dike were captured in simple empirical relations. These relations may then guide coastal advisors towards more accurate dike designs and flood risk assessments. Thereby, they can estimate the influence of infragravity waves that are often enhanced due to shallow waters according to: (1) the magnitude of the offshore waves; (2) the foreshore characteristics such as the slope and vegetation coverage; and (3) the slope of the dike.

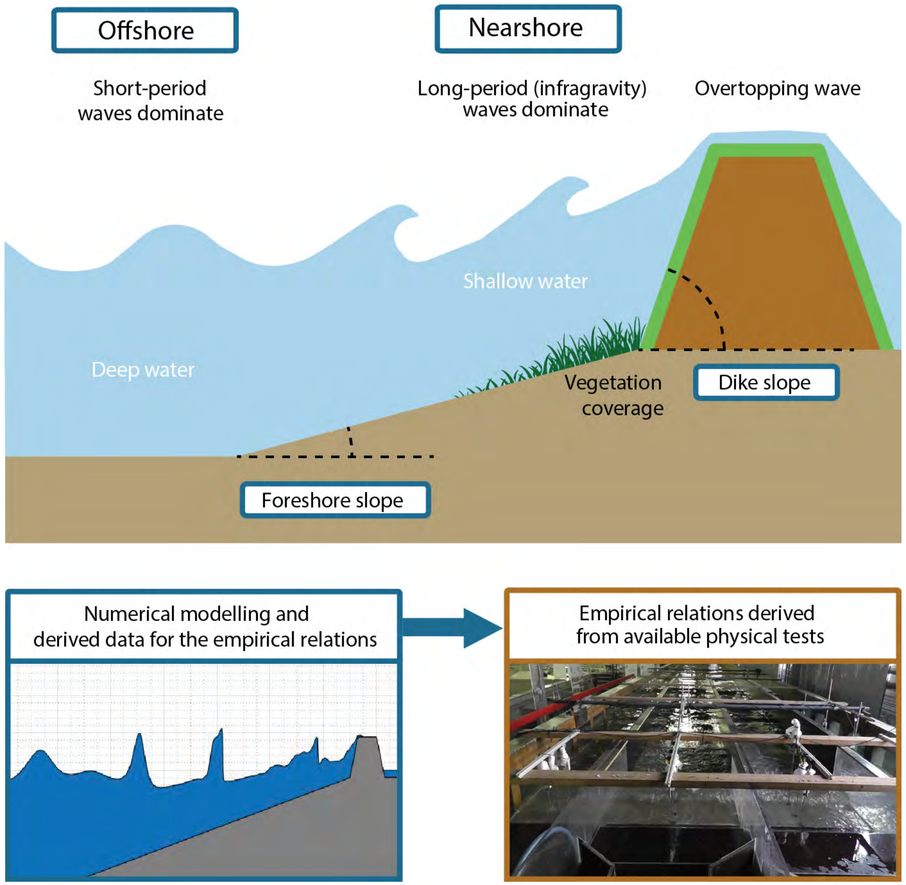

Figure 3: Components of the research to estimate the influence of nearshore waves according to the offshore and dike characteristics for more accurate dike designs and flood risk assessments. Based on schemes from Christopher Lashley. Physical model tests photo by: Corrado Altomare and Tomohiro Suzuki (Flanders Hydraulics Research, Belgium).

Relevant for whom and where?

The improved understanding of wave propagation over shallow foreshores is useful for coastal engineers, researchers, ecologists and flood risk advisors.

Progress and practical application

Findings indicate that infragravity waves become significant at locations exposed to high offshore swell with shallow, mildly sloping foreshores and reduced vegetated cover. Additionally, the numerical model comparison highlighted that more computationally-demanding models do not guarantee improved accuracy in predicting nearshore wave parameters or overtopping discharge.

The influence of infragravity waves in the nearshore is further significant for shallower water depths, milder foreshore slopes, reduced vegetated cover, and milder dike slopes. Moreover, with empirical adjustments, phase-averaged models like SWAN —which on their own do not model infragravity waves— can be used to estimate infragravity waves. For further details about each finding, see the **project outputs** on the next page.

Recommendations for practice

- Even when the infragravity wave height at the structure is minor, their influence on the wave period — and, by relation, wave overtopping — can be significant.
- The influence of infragravity waves is highly dependent on local bathymetric and forcing conditions. It is recommended that a quick check for the expected magnitude of the infragravity waves always is carried out using the tools developed here.
- It is important to assess not only wave attenuation but also the evolution of the mean wave period over the foreshore.

The research components are applied into a case study located in the north of the Netherlands.

Photo by Beatriz Marin-Diaz.

Key project outputs

Lashley, C.H., Jonkman, S.N., Van der Meer, J.W., Bricker, D.J. & Vuik, V. (2021). The Influence of Infragravity Waves on the Safety of Coastal Defences: A Case Study of the Dutch Wadden Sea
Doi: 10.5194/nhess-2021-211

Lashley, C.H., Van der Meer, J.W., Bricker, D.J. & Altomare, C. (2021). Formulating Wave Overtopping at Vertical and Sloping Structures with Shallow Foreshores Using Deep-Water Wave Characteristics.
Doi: 10.1061/(ASCE)WW.1943-5460.0000675

Lashley, C.H., Bricker, D.J., Van der Meer, J.W., Altomare, C. & Suzuki, T. (2021). Relative Magnitude of Infragravity Waves at Coastal Dikes with Shallow Foreshores: A Prediction Tool.
Doi: 10.1061/(ASCE)WW.1943-5460.0000576