REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE: Netherlands

Principal Investigator1: Paulina Kindermann (p.e.kindermann@tudelft.nl)

Affiliation: Delft University of Technology

Address: Stevinweg 1
2628 CN Delft
The Netherlands

Other researchers: Henk van den Brink (henk.van.den.brink@knmi.nl)
José A. A. Antolínez (j.a.a.antolinez@tudelft.nl)
Jacco Groeneweg (jacco.groeneweg@deltares.nl)

Project Title: Wave modelling for the North Sea from SEAS5 wind fields using the HurryWave model

Starting year: 2026
(A project can have a duration of up to 3 years, agreed at the beginning of the project.)

Would you accept support for 1 year only, if necessary? YES

Computer resources required for 2026-2028:

	2026	2027	2028
High Performance Computing Facility (SBU)	85M		
Accumulated data storage (total archive volume)(GB)	100 TB	100 TB	

Project description

Introduction

Coastal flood defences in the Netherlands must be designed to withstand hydraulic boundary conditions that are exceeded only once every 10,000 years. These hydraulic boundary conditions result from the combined effects of astronomical tides, wind-driven surges, and waves. As both surges and waves are primarily caused by wind over the North Sea, a detailed understanding of extreme wind conditions is essential for determining reliable flood defence design.

Traditionally, design conditions have been derived through statistical extrapolation of observational records. However, this method has several limitations: (1) the observational records are relatively short (~100 years), requiring extrapolation over two orders of magnitude; (2) it yields only a single extreme value, offering no insight into the meteorological conditions that cause such events; (3) it neglects interactions between the various physical processes such as surges, tides, waves, and resonance effects; and (4) it provides information only at specific observation sites, necessitating spatial interpolation for other locations.

To overcome these limitations, recent efforts have focused on using long-term climate and weather model output to derive design conditions. A major advancement has been the use of ECMWF's SEAS5 seasonal ensemble forecast, which provides almost 10,000 years of synthetic wind and stress fields. KNMI has used these fields to drive the WAQUA-DCSMv5 surge model (with 8 km resolution), resulting in a large, consistent dataset of wind and sea level conditions. This dataset has already been applied for extreme value analysis and has led to the development of updated hydraulic boundary conditions for sea level and wind speed along the Dutch coast (van der Valk & van den Brink, 2024). With this wind–surge dataset now established, the logical next step is to extend the analysis to include wave conditions, providing a physically consistent set of hydraulic boundary conditions.

Scientific goal

The objective of this project is to provide a wave hindcast based using the SEAS5-WAQUA DSCMv5 dataset as input, which results in approximately 9,000 years of wave conditions. Using this dataset, we aim to improve our understanding of the natural variability in wave conditions during extreme storm events. This extensive synthetic dataset enables investigation of a broader range of extreme scenarios than observational records allow. The scientific goals are threefold:

(1) To analyze meteorological characteristics – such as depression size, storm duration, wind direction, etc. - that cause the most severe (offshore) wave conditions in the Dutch North Sea.
(2) To investigate statistical properties of extreme wave conditions;
    a. Exceedance probabilities / return periods of wave height and period
    b. Spatial correlation and correlation with extreme surges
(3) To compare extremes of observational wave data with the modelled data.

Methodology

In this study, we are going to apply HurryWave, a newly developed wave model by Deltares, which offers significantly faster runtimes than traditional models such as SWAN (van der Lugt et al., 2024). This makes it particularly well-suited for the large-scale, long-term simulations required in this project. In comparison to the WAM model (which is used to generate waves within SEAS5) HurryWave has a finer spatial resolution, which makes it possible to nest other models for near-shore waves. To ensure reliable model performance, we are currently conducting a series of validation and sensitivity analyses. These analyses assess the model's response to variations in model settings, such as boundary conditions, grid resolution, and physical parameterizations, by comparing the model output from ERA5 wind fields against available observational wave data. The outcome of this validation phase will be a set of optimized model settings that ensure both computational efficiency and consistency with observations. These settings will be applied in this project to simulate off-shore wave conditions over the North Sea using the wind stress fields from the ECMWF SEAS5 seasonal forecast. By using SEAS5, we ensure that the resulting wave dataset is aligned with the wind and surge dataset previously generated and analyzed by KNMI.

For consistency, we adopt the same spatial domain and bathymetry used in the WAQUA-DCSMv5 model, as illustrated in Figure 1.

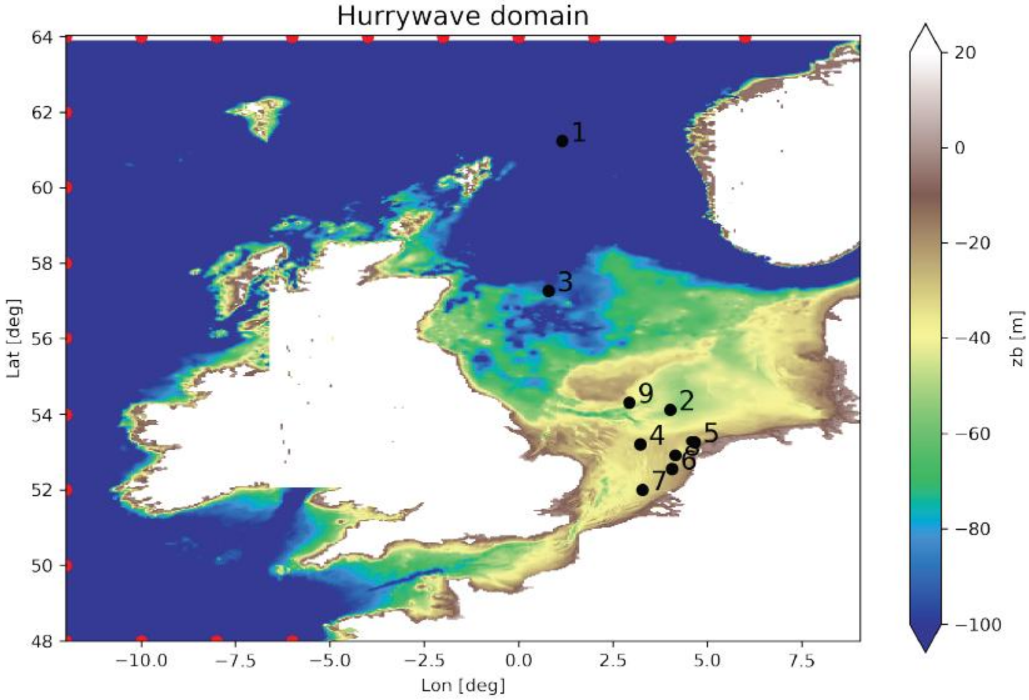

Figure 1: The WAQUA-DCSMv5 model domain and bathymetry (van der Lugt, 2024)

Justification of resources

In ECMWF, SBUs are computed as follows:

SBU = P*N*T
P = 0.00474 (is a fixed proportionality factor);
N = number of (physical) cores allocated to a job;
T = elapsed time (real time in seconds) recorded for a job.

- 1 year of simulation runs 31 hours on 16 CPU --> N = 16
- Therefore: N = 16, T = 31*3600
- We have to run 10,000 years of simulation in total
- So: SBU=0.00474*16*31*3600*10,000 = **84,640,000 SBU**

Regarding the storage, we estimate that each simulation will create an output of 1,2 GB. If we add the 800MB of SEAS5, it will be 10 GB per simulation. For 10,000 years this adds up to approximately 100 TB. Since the model scales very well on GPU, we would like to request using the vGPU recources.

Application

The resulting wave dataset provides a long-term record of offshore wave conditions in the North Sea, which can be directly applied in coastal flood defence design. In the Netherlands, where infrastructure must be resilient to extreme events with return periods of up to 100,000 years, this dataset enables a more robust derivation of hydraulic boundary conditions by incorporating a much broader range of extreme scenarios than previously possible using observations alone. The integration of wind, surge, and wave data ensures that complex interactions between physical drivers are consistently represented.

Beyond applications for the Dutch coast, the spatial extent of the dataset also covers the coastal waters of other countries (Belgium, the United Kingdom, and Denmark). This makes it a valuable resource for applications to coastal research and infrastructure design in other North Sea-bordering countries.

References

de Valk, C.F. & van den Brink, H.W. (2023). Update van de statistiek van extreme zeewaterstand en wind op basis van meetgegevens en modelsimulaties. De Bilt, Technical report TR-406

van der Lugt, M., van Asselt, K., van Ormondt, M., van Dongeren A. (2024). HurryWave - an instationary wave model on ocean scales. Validation report. Deltares.