

# EMI R&D PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

**Reporting year** 2026

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

**Computer Project Account:** spnlkind

**Principal Investigator(s):** P.E.Kindermann

**Affiliation:** Delft University of Technology

**Name of ECMWF scientist(s) collaborating to the project (if applicable)** /

**Start date of the project:** 01-01-2026

**Expected end date:** 31-12-2026

**Computer resources allocated/used for the current year and the previous one (if applicable)**

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
<b>High Performance Computing Facility</b>	(units)	-	-	SBU: 60,000,000 GBU-A: 1,000,000	SBU: 75,182 GBU-A: 121,607
<b>Data storage capacity</b>	(Gbytes)	-	-	HPCPERM: 1TB HOME: 10GB PERM: 500GB	HPCPERM: 780GB HOME: 6GB PERM: 17.6GB

### **Summary of project objectives** (10 lines max)

- Generate a wave dataset for the full SEAS5-WAQUA ensemble using HurryWave, providing approximately 9,000 synthetic years of offshore wave conditions for the North Sea (currently being completed on Snellius)
- Characterise statistical dependencies between meteorological drivers, storm surges, tides, and waves using the combined SEAS5-WAQUA-HurryWave dataset
- Develop a machine learning model to forecast extreme storm surges and waves directly from meteorological characteristics, trained on this large synthetic dataset

### **Summary of problems encountered** (10 lines max)

Prior to project approval, preparatory activities including wave modelling and validation had already been initiated in 2025 using Snellius (Dutch national HPC). By the time the ECMWF resources became available, the wave modelling was further along than expected and all data and model configurations were already in place on Snellius, making it most efficient to continue that work there. The ECMWF resources are therefore being used for the next step of the project: developing the machine learning model for storm surge forecasting, with waves to follow once the HurryWave-SEAS5 dataset is complete (as indicated in the slightly adapted project objectives). This shift brought a greater need for GPU resources than originally anticipated, which was resolved by reallocating part of the existing SBU budget.

### **Summary of plans for the continuation of the project** (10 lines max)

- Further develop the storm surge forecasting model by incorporating physical relationships into the model architecture (e.g. wind stress-surge coupling) and testing additional architectures such as Graph Neural Networks (GNNs) and Fourier Neural Operators
- Extend predictions from point locations to full spatial fields
- Once the HurryWave-SEAS5 wave dataset is complete, analyse statistical dependencies between meteorological characteristics, storm surges, tides, and wave conditions using the combined dataset
- Integrate wave conditions into the machine learning framework to enable joint forecasting of surges and waves

(The last two steps may not be fully achieved by the end of this year.)

### **List of publications/reports from the project with complete references**

No publications yet.

### **Summary of results**

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

Regarding wave modelling, preliminary runs and comparisons against observations have confirmed that HurryWave produces sufficiently accurate results at locations with water depths greater than 15 metres. This validation work was initiated by an MSc student in 2025 using Snellius resources, and has since then been continued and extended. We are currently executing the large-scale HurryWave simulations driven by SEAS5-WAQUA wind and sea level fields on Snellius. Once complete, this will provide approximately 9,000 synthetic years of wave conditions in the current climate, a

dataset well-suited for analysing dependencies between meteorological drivers, storm surges, tides, and waves, as well as for training machine learning models.

In parallel, work on the machine learning model has begun using the ECMWF special project resources. The SEAS5-WAQUA dataset has been analysed to identify and select periods of storm activity for model training. Several model architectures have been explored, including regression models, CNNs, and CNN-LSTM networks. We started building up the architecture from simple (predicting one scalar max. daily skew surge at one location) to complex (spatio-temporal fields of storm surge). The most recent step is that we have started to include physical relationships into the model architecture. The model is currently able to predict storm surges at Dutch coastal locations with an  $R^2$  of 0.9 and an RMSE of approximately 15–20 cm, which is a very promising result for this stage of development.