# Developing coastal wave forecasting to better support maritime traffic and offshore industry

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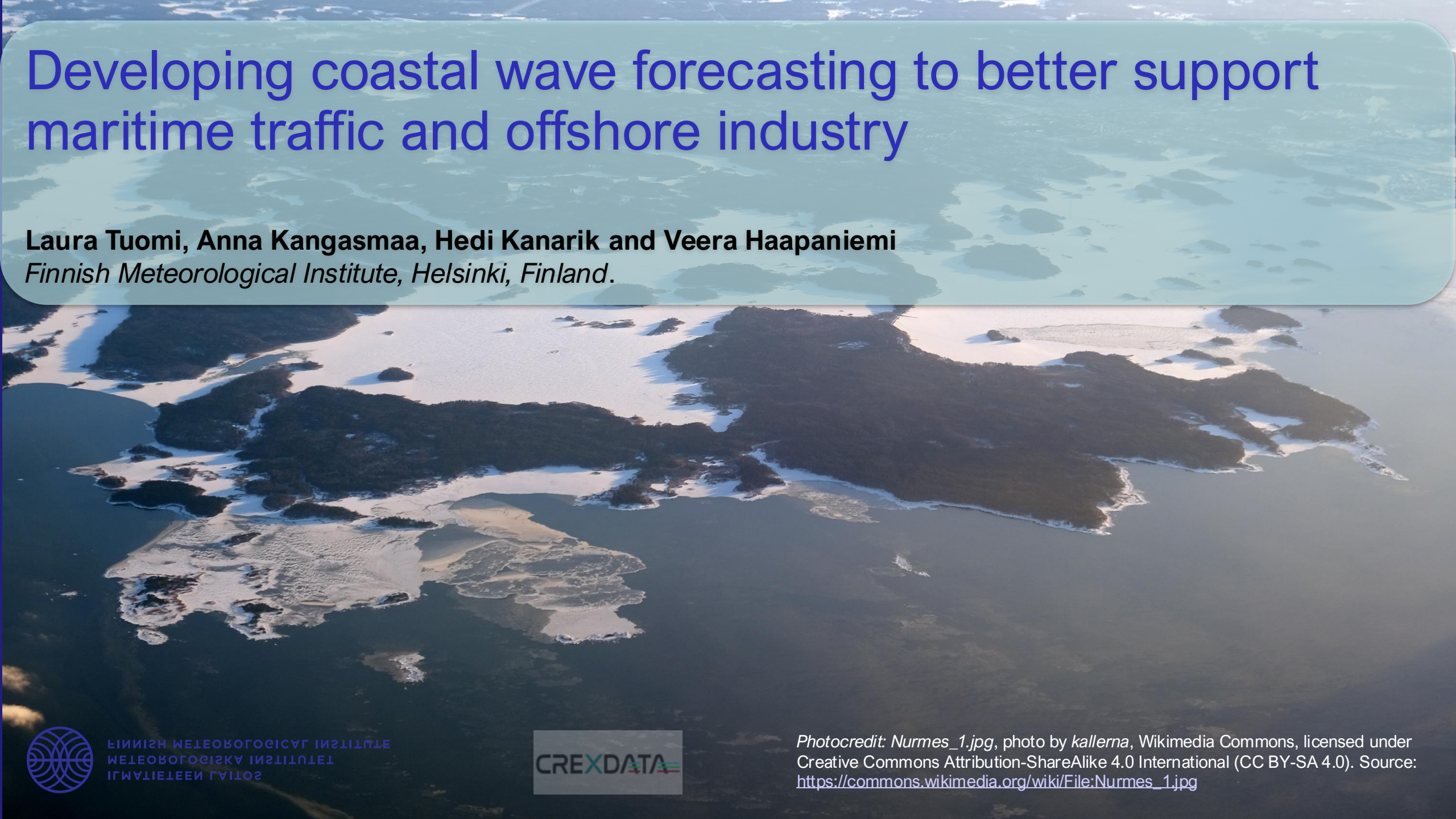


# Improving coastal oceanographic services for the Baltic Sea

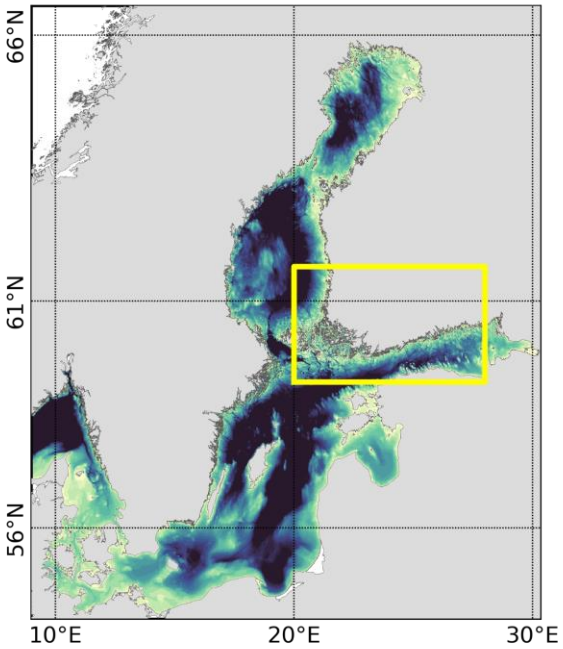
Complex bathymetry, irregular shorelines, and dense archipelagos present challenges for wave forecasting

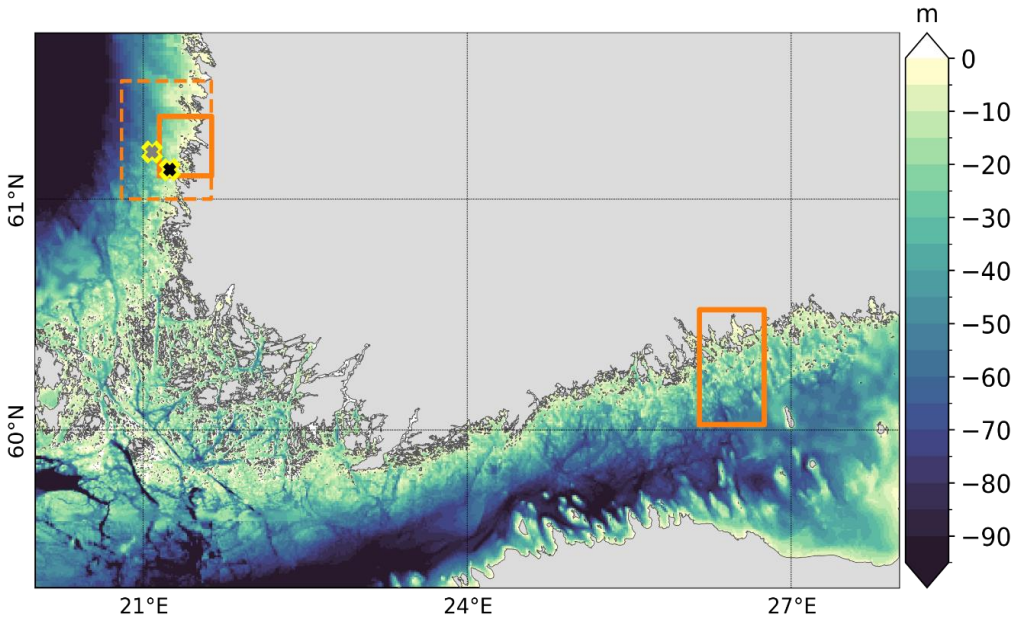
Need for more accuracy and higher resolution in near-coastal areas for piloting, planning and maintenance of windfarms and aquaculture sites

Presenting two approaches:

New **on demand forecasting services for piloting** and **tailored statistics**

Ongoing developments on two coastal sites, Bothnian Sea, Gulf of Finland, to improve accuracy and produce training data for machine learning applications

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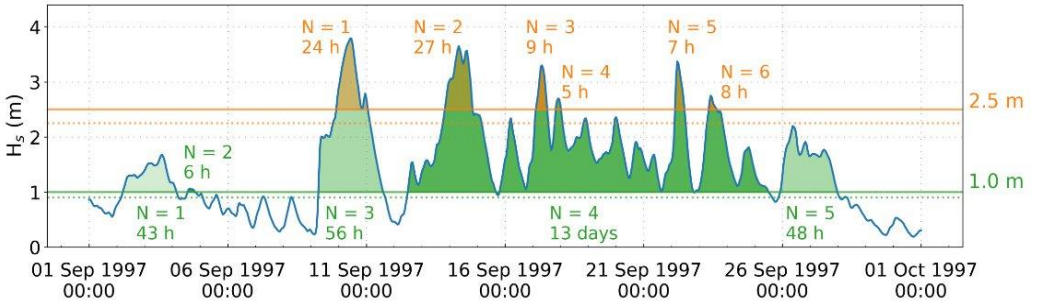
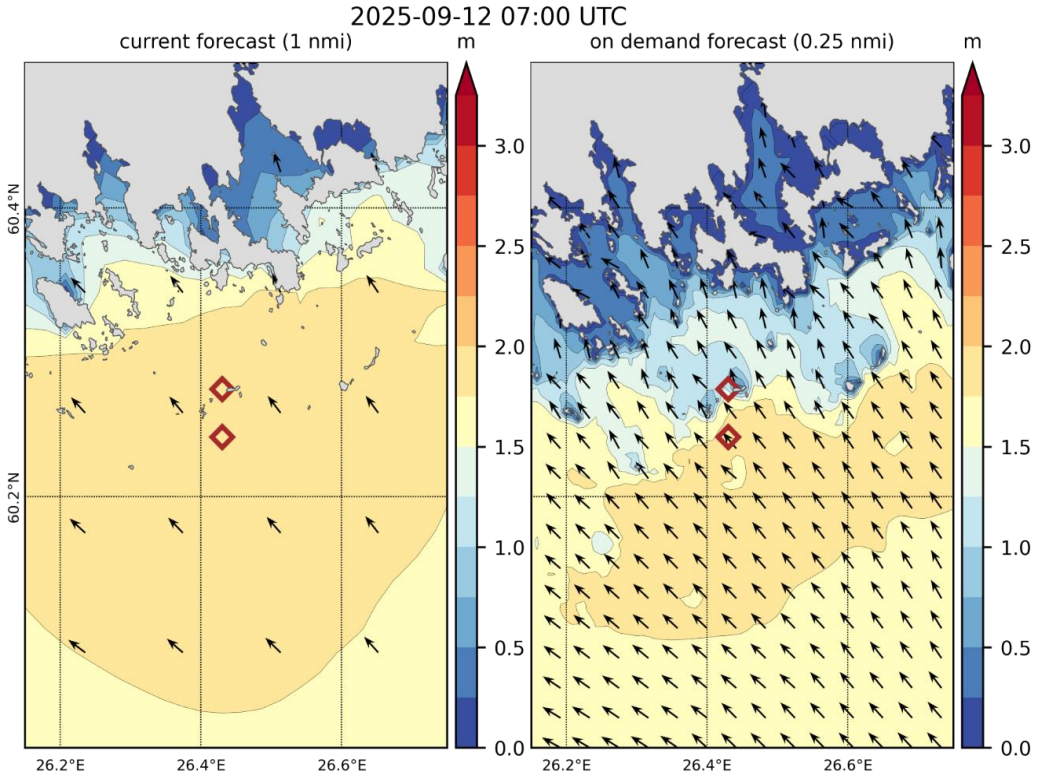
# Event-based approach

Due to the complex coastline, **harbors are not accessible to cargo** ships **without piloting**. Piloting includes risks for pilots is typically paused in high sea states. Finnish pilots have defined **2.2 m SWH** as one of the thresholds for their activities.

When the coarse resolution wave forecast indicates that the threshold will be exceeded within the next two days, the **on-demand 0.25 nmi resolution coastal forecast is activated**.



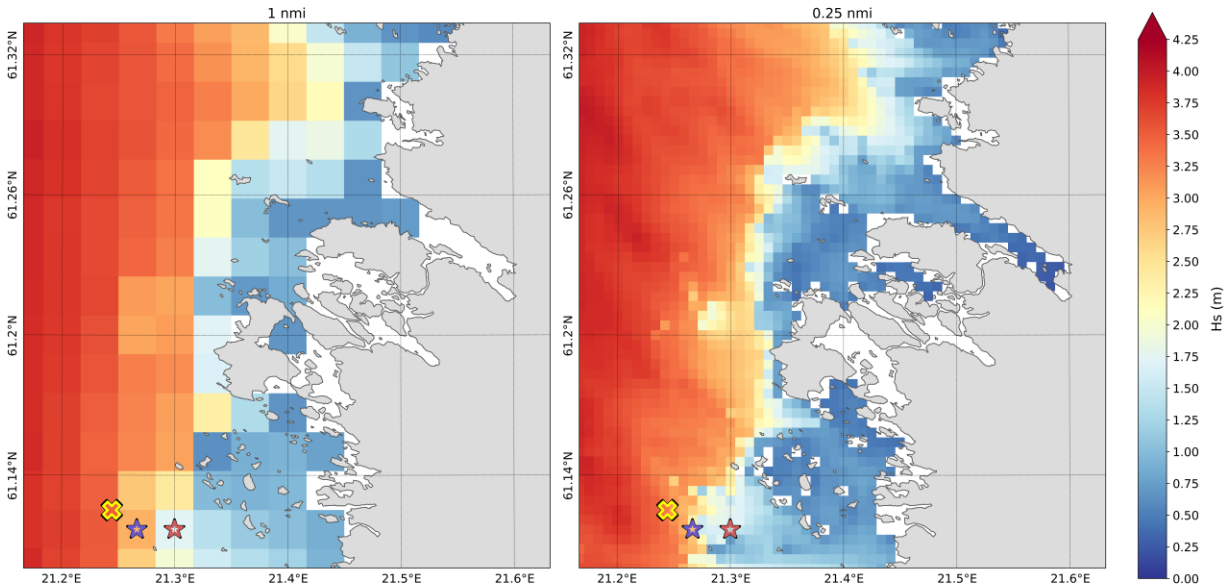



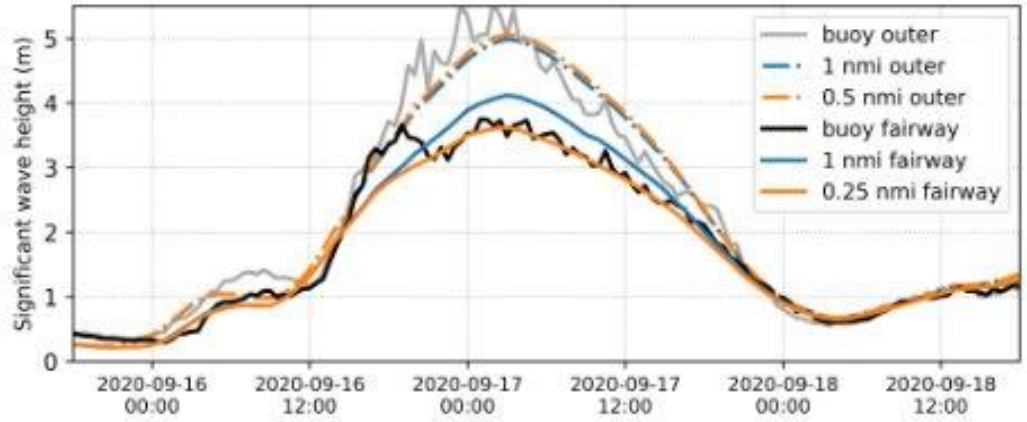
# New high resolution coastal statistics

Nested setup with 1 nmi, 0.5, 0.25 and 0.1 nmi grids for WAVEWATCH III®

As the coarse resolution grid uses obstruction grids to account for the unresolved islands, it is fairly well able to describe the wave conditions also close to the coast

Largest differences between the grids are seen in the transition zone from the deeper to shallower areas and around shoals that are not captured by the coarse grid



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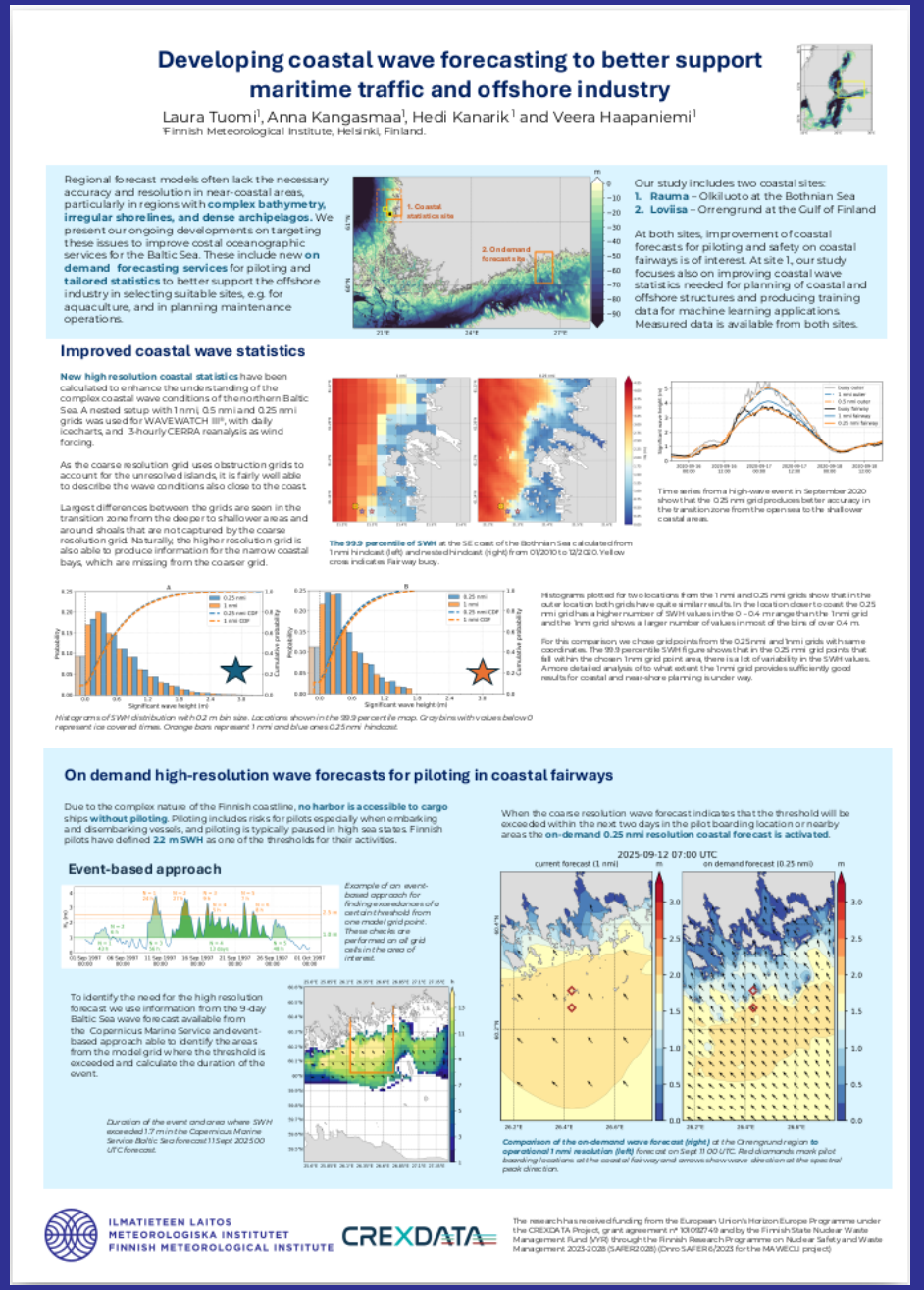

## Developing coastal wave forecasting to better support maritime traffic and offshore industry

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Regional forecast models often lack the necessary accuracy and resolution in near-coastal areas, particularly in regions with **complex bathymetry, irregular shorelines, and dense archipelagos.** We present our ongoing developments on targeting these issues to improve costal oceanographic services for the Baltic Sea. These include new **on demand forecasting services** for piloting and **tailored statistics** to better support the offshore industry in selecting suitable sites, e.g. for aquaculture, and in planning maintenance operations.

Our study includes two coastal sites:
1. **Rauma** – Olkiluoto at the Bothnian Sea
2. **Loviisa** – Orrengrund at the Gulf of Finland

At both sites, improvement of coastal forecasts for piloting and safety on coastal fairways is of interest. At site 1, our study focuses also on improving coastal wave statistics needed for planning of coastal and offshore structures and producing training data for machine learning applications. Measured data is available from both sites.

### Improved coastal wave statistics

**New high resolution coastal statistics** have been calculated to enhance the understanding of the complex coastal wave conditions of the northern Baltic Sea. A nested setup with 1 nmi, 0.5 nmi and 0.25 nmi grids was used for WAVEWATCH III®, with daily icecharts, and 3-hourly CERRA reanalysis as wind forcing.

As the coarse resolution grid uses obstruction grids to account for the unresolved islands, it is fairly well able to describe the wave conditions also close to the coast.

Largest differences between the grids are seen in the transition zone from the deeper to shallower areas and around shoals that are not captured by the coarse resolution grid. Naturally, the higher resolution grid is also able to produce information for the narrow coastal bays, which are missing from the coarser grid.

**The 99.9 percentile of SWH** at the SE coast of the Bothnian Sea calculated from 1 nmi hindcast (left) and nested hindcast (right) from 01/2010 to 12/2020. Yellow cross indicates Fairway buoy.

Time series from a high-wave event in September 2020 show that the 0.25 nmi grid produces better accuracy in the transition zone from the open sea to the shallower coastal areas.

Histograms plotted for two locations from the 1 nmi and 0.25 nmi grids show that in the outer location both grids have quite similar results. In the location closer to coast the 0.25 nmi grid has a higher number of SWH values in the 0 – 0.4 m range than the 1nmi grid and the 1nmi grid shows a larger number of values in most of the bins of over 0.4 m.

For this comparison we chose grid points from the 0.25 nmi and 1nmi grids with same coordinates. The 99.9 percentile SWH figure shows that in the 0.25 nmi grid points that fall within the chosen 1nmi grid point area, there is a lot of variability in the SWH values. A more detailed analysis of to what extent the 1nmi grid provides sufficiently good results for coastal and near-shore planning is under way.

*Histograms of SWH distribution with 0.2 m bin size. Locations shown in the 99.9 percentile map. Gray bins with values below 0 represent ice covered times. Orange bars represent 1 nmi and blue ones 0.25 nmi hindcast.*

### On demand high-resolution wave forecasts for piloting in coastal fairways

Due to the complex nature of the Finnish coastline, **no harbor is accessible to cargo ships without piloting.** Piloting includes risks for pilots especially when embarking and disembarking vessels, and piloting is typically paused in high sea states. Finnish pilots have defined **2.2 m SWH** as one of the thresholds for their activities.

When the coarse resolution wave forecast indicates that the threshold will be exceeded within the next two days in the pilot boarding location or nearby areas the **on-demand 0.25 nmi resolution coastal forecast is activated.**

#### Event-based approach

*Example of an event-based approach for finding exceedances of a certain threshold from one model grid point. These checks are performed on all grid cells in the area of interest.*

To identify the need for the high resolution forecast we use information from the 9-day Baltic Sea wave forecast available from the Copernicus Marine Service and event-based approach able to identify the areas from the model grid where the threshold is exceeded and calculate the duration of the event.

*Duration of the event and area where SWH exceeded 1.7 m in the Copernicus Marine Service Baltic Sea forecast 11 Sept 2021 00 UTC forecast.*

2025-09-12 07:00 UTC
current forecast (1 nmi) | on demand forecast (0.25 nmi)

***Comparison of the on-demand wave forecast (right) at the Orrengrund region to operational 1 nmi resolution (left) forecast on Sept 11 00 UTC. Red diamonds mark pilot boarding locations at the coastal fairway and arrows show wave direction at the spectral peak direction.***

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