Enhanced modelling tools for mitigation of marine pollution hazards

Laura Tuomi[1], Veera Haapaniemi[1], Antti Westerlund[1], Aleksi Nummelin[1], Jani Häkkinen[2], Kari Lehtonen[2], Elina Miettunen[1,2], Kai Myrberg[2]

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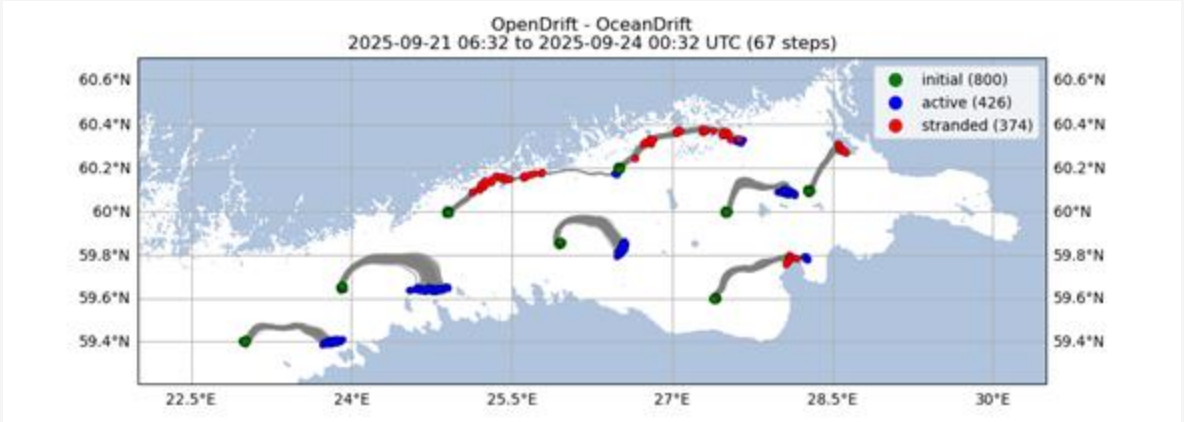
Developing coastal forecasting and impact assesment tools

CoWup – Coastal Waters Under Pressure – safeguarding a healthy Gulf of FInland in changing geopolitical and environmental landscape

- Identify, analyse and quantify **risks to the marine environment** in the Gulf of Finland, especially in the **current geopolitical context**.
- methods and **models to assess the impact** of risks on the marine environment, including the associated uncertainties

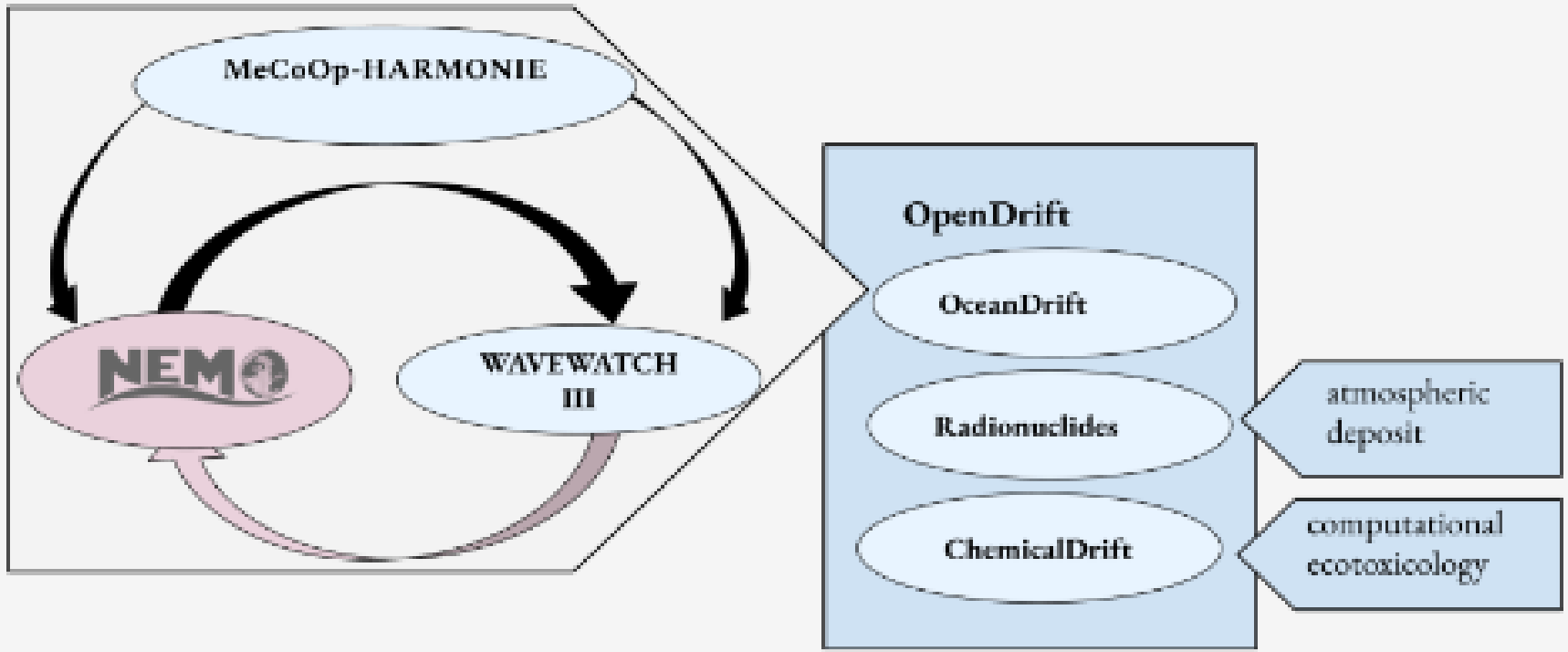
DRIFTERI

development of drift forecasts for the Gulf of Finland



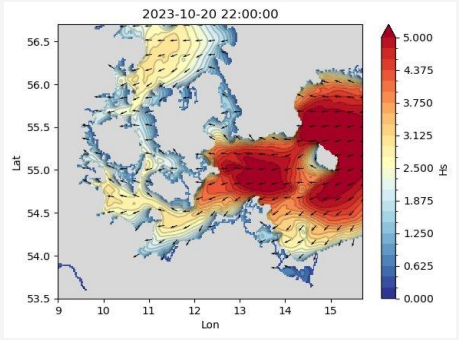
Towards capabilities to simulate drift and fate of harmful substances

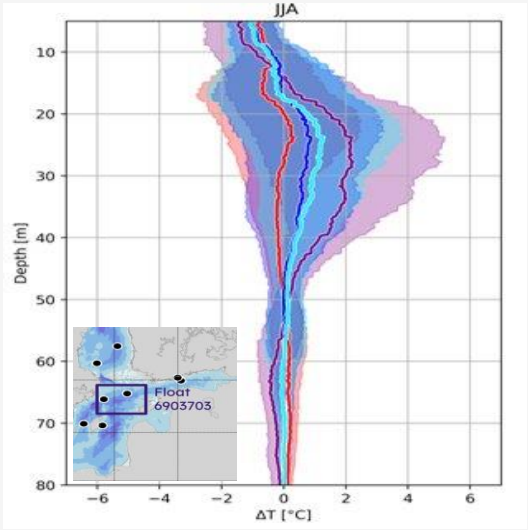
- Development of OpenDrift to forecast **drift and fate of harmful substances** with specific focus on
  - Developing modelling systems able to solve the **wave, current and sea level dynamics** in the Gulf of finland
  - Understanding **toxicity of mixtures** using **computational ecotoxicology**

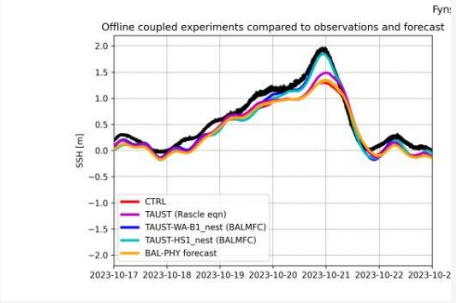


Improving coastal modelling capabilities

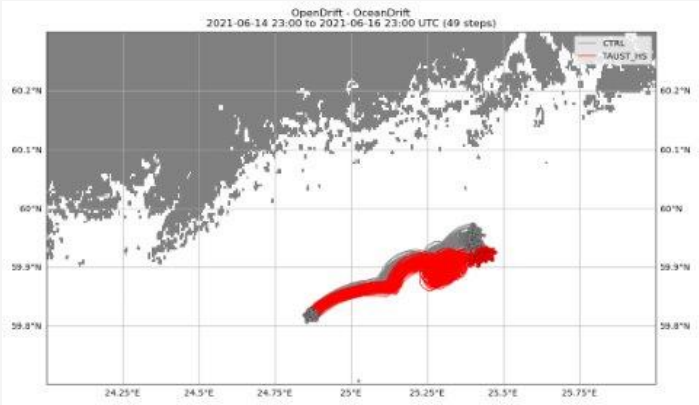
Enhanching **model coupling** to better solve **mixing** and forecast **storm surges.**

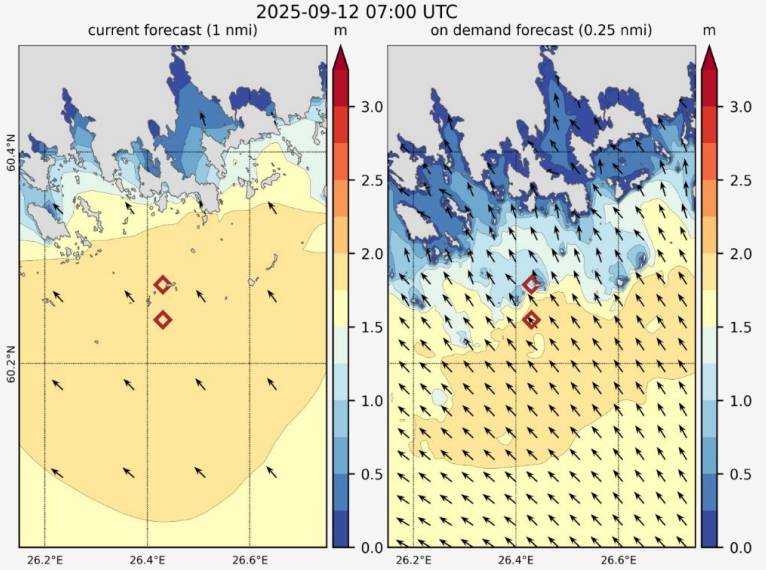






Coupled high-resolution system to better solve waves, currents and sea level in this complex coastal area

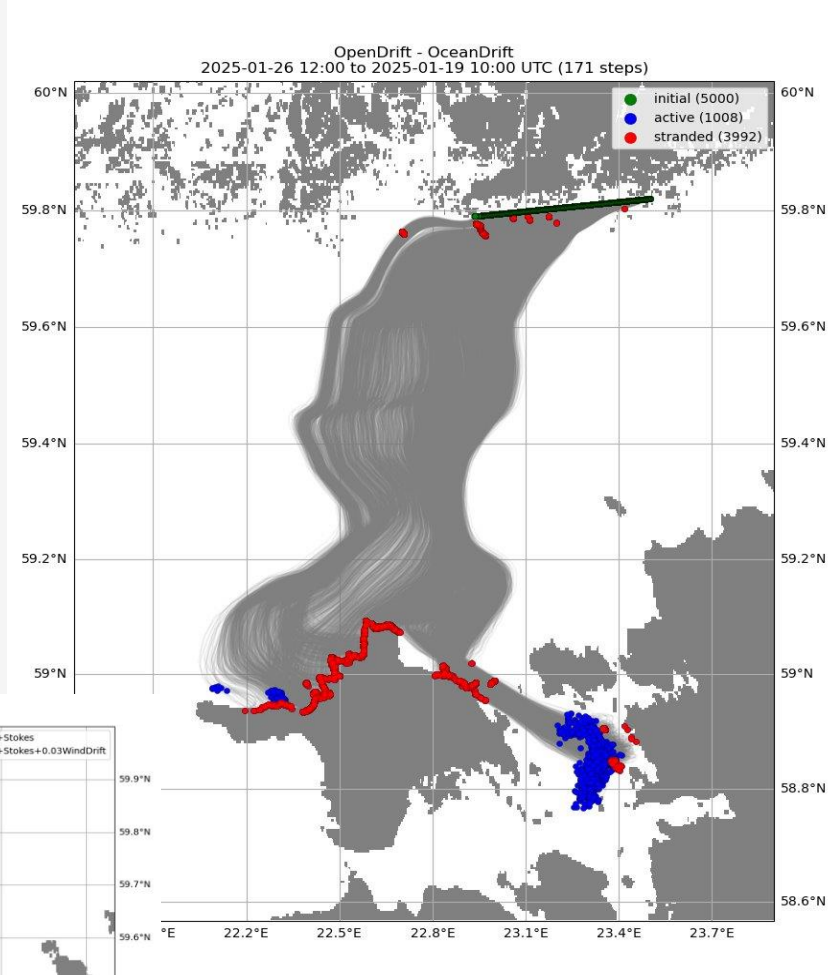


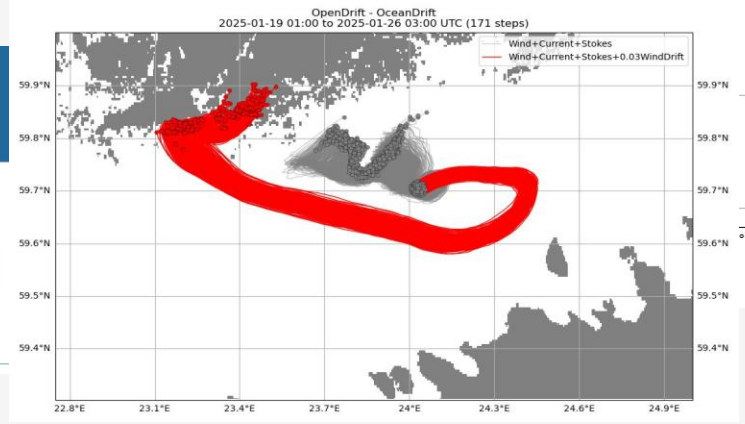


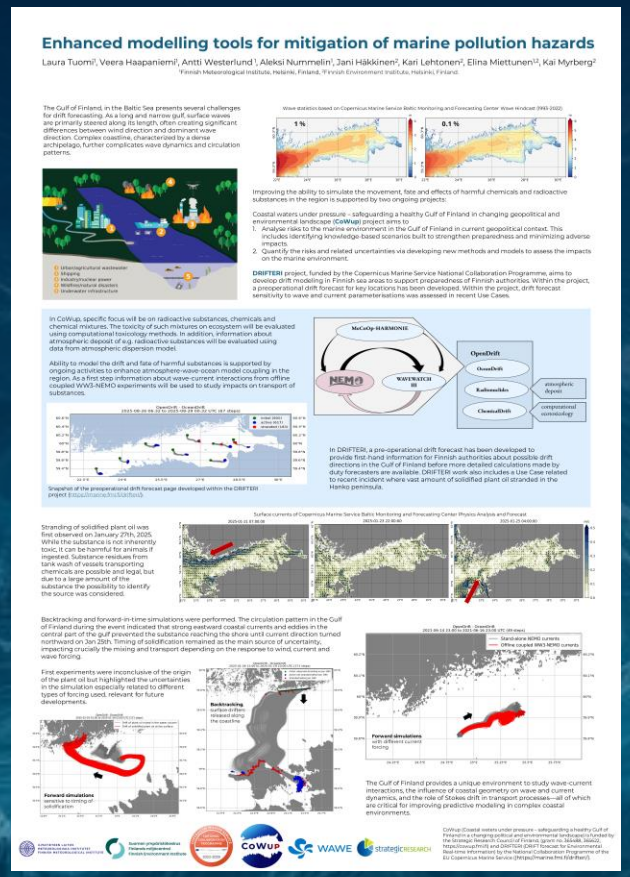
Also see poster **PA04** about **coastal wave forecasting**

Use Case: Solidified plant oil stranding in Hanko

- On 27th of January 2025, **clumps of a white substance, of unknown origin**, were observed on a 25 km stretch of coastline along the Hanko Peninsula, Gulf of Finland.
- **Backtracking simulations** of the origin was requested by the authorities
- Use Case available in the Copernicus Marine Service: https://marine.copernicus.eu/services/use-cases/drift-modelling-investigate-stranding-vegetable-oil-hanko-peninsula-gulf-finland







Enhanced modelling tools for mitigation of marine pollution hazards

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The Gulf of Finland, in the Baltic Sea presents several challenges for drift forecasting. As a long and narrow gulf, surface waves are primarily steered along its length, often creating significant differences between wind direction and dominant wave direction. Complex coastline, characterized by a dense archipelago, further complicates wave dynamics and circulation patterns.

Wave statistics based on Copernicus Marine Service Baltic Monitoring and Forecasting Center Wave Hindcast (1993-2022)

Improving the ability to simulate the movement, fate and effects of harmful chemicals and radioactive substances in the region is supported by two ongoing projects:

Coastal waters under pressure – safeguarding a healthy Gulf of Finland in changing geopolitical and environmental landscape (**CoWup**) project aims to

1. Analyse risks to the marine environment in the Gulf of Finland in current geopolitical context. This includes identifying knowledge-based scenarios built to strengthen preparedness and minimizing adverse impacts.
2. Quantify the risks and related uncertainties via developing new methods and models to assess the impacts on the marine environment.

DRIFTER project, funded by the Copernicus Marine Service National Collaboration Programme, aims to develop drift modeling in Finnish sea areas to support preparedness of Finnish authorities. Within the project, a preoperational drift forecast for key locations has been developed. Within the project, drift forecast sensitivity to wave and current parameterisations was assessed in recent Use Cases.

In CoWup, specific focus will be on radioactive substances, chemicals and chemical mixtures. The toxicity of such mixtures on ecosystem will be evaluated using computational toxicology methods. In addition, information about atmospheric deposit of e.g. radioactive substances will be evaluated using data from atmospheric dispersion model.

Ability to model the drift and fate of harmful substances is supported by ongoing activities to enhance atmosphere-wave-ocean model coupling in the region. As a first step information about wave-current interactions from offline coupled WW3-NEMO experiments will be used to study impacts on transport of substances.

MeCoOp-HARMONIE
NEMO
WAVEWATCH III
OpenDrift
OceanDrift
RadionuclidesDrift
ChemicalDrift
atmospheric deposit
computational ecotoxicology

Snapshot of the preoperational drift forecast page developed within the DRIFTER project (https://research.fmi.fi/drifter/).

In DRIFTER, a pre-operational drift forecast has been developed to provide first-hand information for Finnish authorities about possible drift directions in the Gulf of Finland before more detailed calculations made by duty forecasters are available. DRIFTER work also includes a Use Case related to recent incident where vast amount of solidified plant oil stranded in the Hanko peninsula.

Stranding of solidified plant oil was first observed on January 27th, 2025. While the substance is not inherently toxic, it can be harmful for animals if ingested. Substance residues from tank wash of vessels transporting chemicals are possible and legal, but due to a large amount of the substance the possibility to identify the source was considered.

Surface currents of Copernicus Marine Service Baltic Monitoring and Forecasting Center Physics Analysis and Forecast

Backtracking and forward-in-time simulations were performed. The circulation pattern in the Gulf of Finland during the event indicated that strong eastward coastal currents and eddies in the central part of the gulf prevented the substance reaching the shore until current direction turned northward on Jan 25th. Timing of solidification remained as the main source of uncertainty, impacting crucially the mixing and transport depending on the response to wind, current and wave forcing.

First experiments were inconclusive of the origin of the plant oil but highlighted the uncertainties in the simulation especially related to different types of forcing used, relevant for future developments.

Backtracking surface drifters released along the coastline

Forward simulations sensitive to timing of solidification

Forward simulations with different current forcing

Standalone NEMO currents
Offline coupled WW3-NEMO currents

The Gulf of Finland provides a unique environment to study wave-current interactions, the influence of coastal geometry on wave and current dynamics, and the role of Stokes drift in transport processes—all of which are critical for improving predictive modeling in complex coastal environments.

CoWup (Coastal waters under pressure – safeguarding a healthy Gulf of Finland in a changing political and environmental landscape) is funded by the Strategic Research Council (SRC) (https://www.aka.fi/en/strategic-research/) and DRIFTER (DRIFT forecast for Environmental Real-time information) by the National Collaboration Programme of the EU Copernicus Marine Service (https://marine.fmi.fi/drifter/).

CoWup

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NATIONAL COLLABORATION PROGRAMME
PROGRAMME OF THE EUROPEAN UNION
Copernicus
implemented by MERCATOR OCEAN INTERNATIONAL
2022-2028

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