Circulation and transport dynamics in the Archipelago Sea

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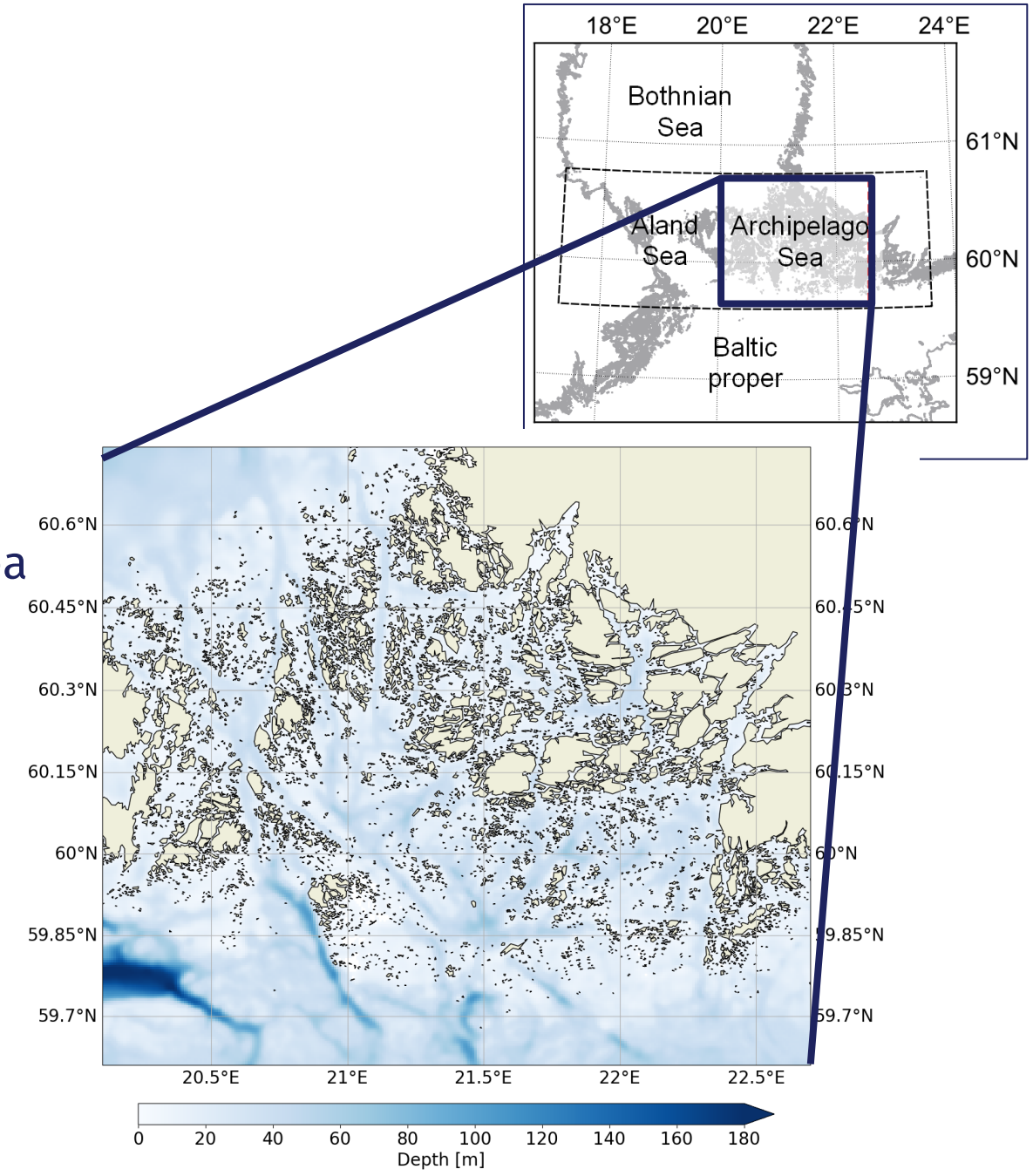
VESIENSUOJELUN TEHOSTAMIS-OHJELMA

The Archipelago Sea

- A shallow coastal area with thousands of islands and complex bottom topography
- Transition zone between
  - the inner coastal areas and the open sea
  - the Baltic Proper and the Bothnian Sea
- Understanding the dynamics with the surrounding basins is important for the protection and management
- Earlier studies on circulation and transport have been based on short measurements time series or coarse-resolution models
- High resolution is needed to describe the archipelago and depth variations in sufficient detail



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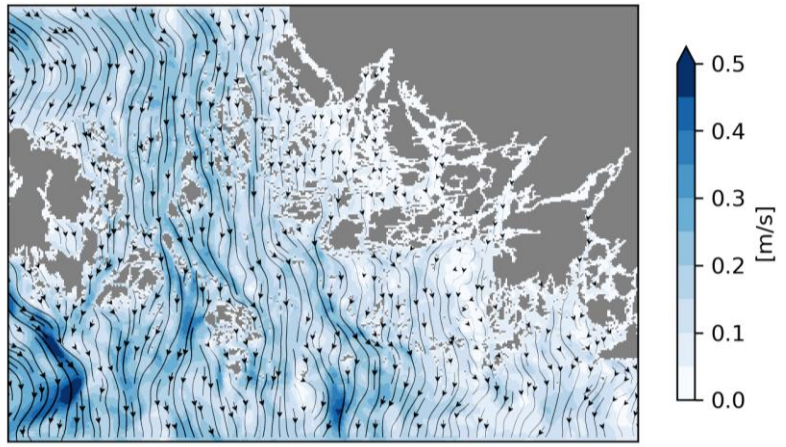
What is a 3D circulation model?

- Simulates temperature, salinity, sea level elevation and currents in a 3D grid
- Input data:
  - Bottom topography in the computing grid
  - Initial values for temperature and salinity
  - Meteorological forcing (e.g., temperature, pressure, wind, precipitation, humidity, clouds)
  - River run-off
  - Temperature, salinity, etc. at open boundaries
- Computationally heavy, requires high-performance computing

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} - fv = -\frac{1}{\rho_0}\frac{\partial p}{\partial x} + F_x^t + \frac{\partial}{\partial z}\left(\nu_T \frac{\partial u}{\partial z}\right) + \frac{\partial}{\partial x}\tau_{xx} + \frac{\partial}{\partial y}\tau_{xy}$$



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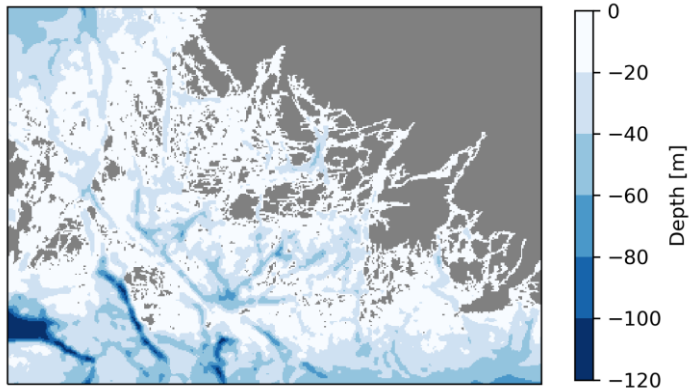
Two models used in the Archipelago Sea region

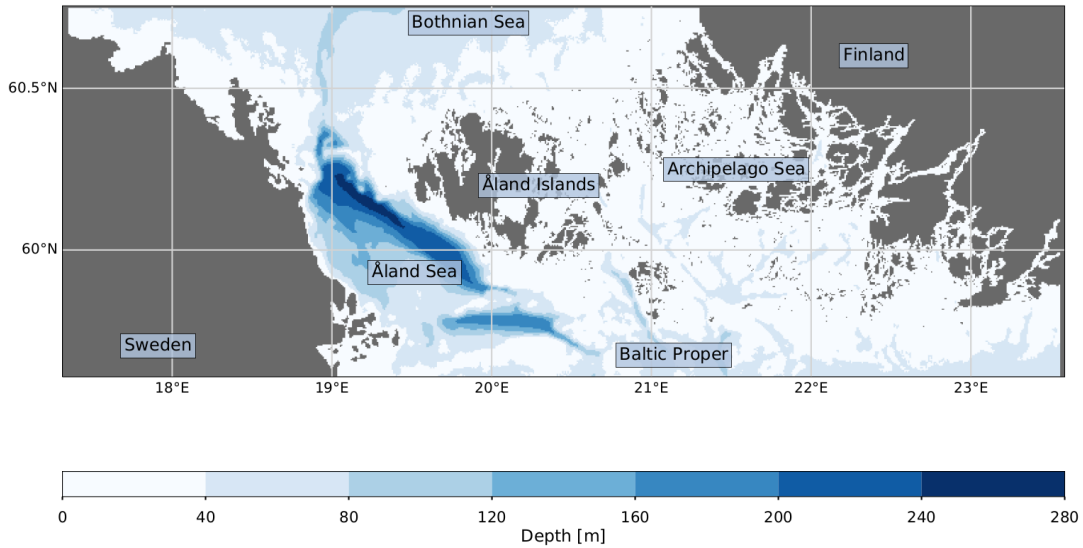
COHERENS setup:

- Tuomi et al. 2018
- 0.25 NM (460 m) horizontal resolution
- 40 vertical levels, sigma-coordinates
- Bathymetry: nautical charts and VELMU depth model (Syke)
- Met. forcing: HIRLAM weather prediction model (FMI)
- Open boundaries: 2 NM Baltic Sea COHERENS setup (Syke)
- River run-off: VEMALA catchment model (Syke)
- Output used in coastal nutrient load model FICOS (Syke)



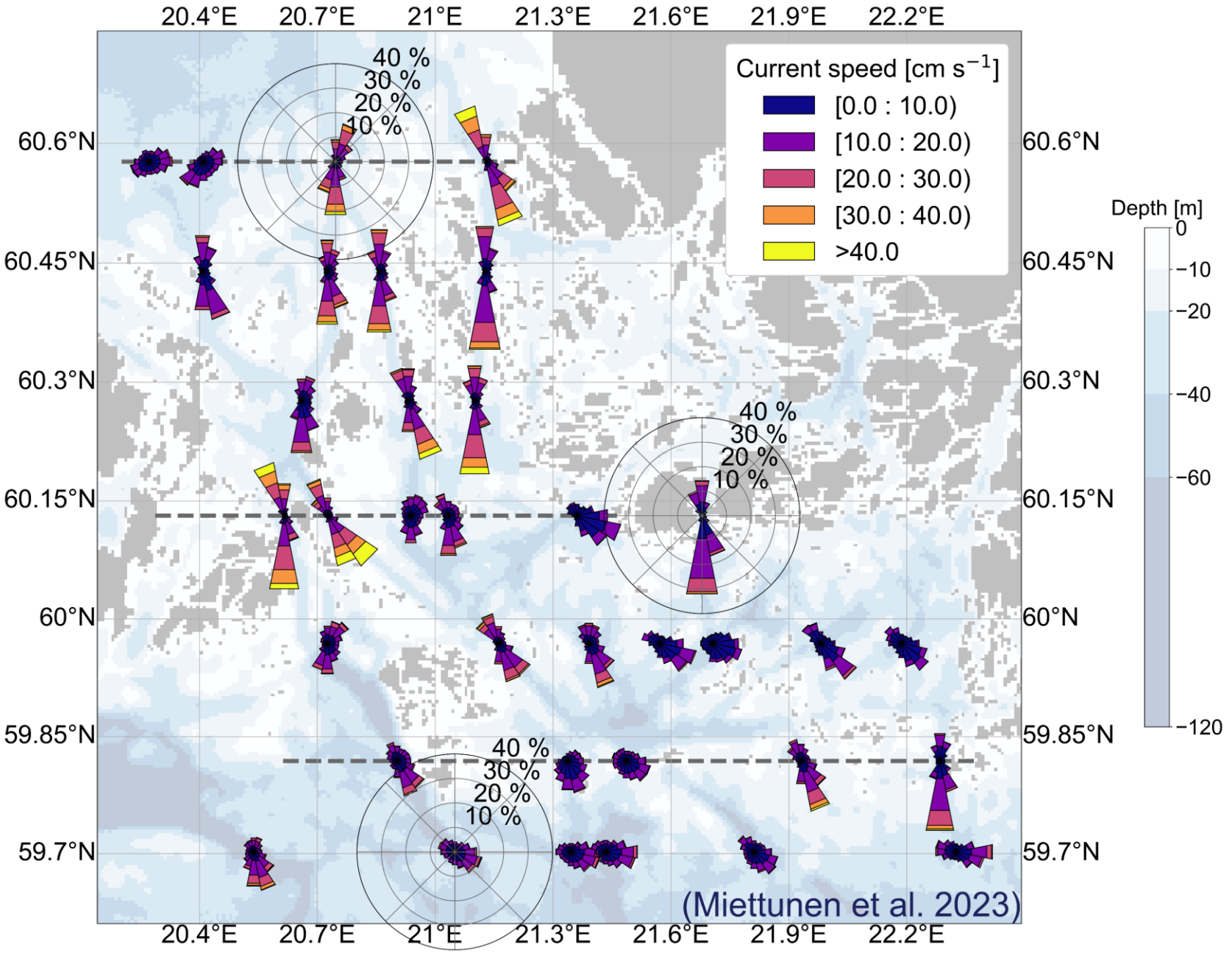
NEMO setup, developed in BlueAdapt:

- Westerlund et al. 2022
- 0.25 NM (460 m) horizontal resolution
- Up to 1 m vertical resolution, up to 200 vertical levels
- Bathymetry: VELMU and BSBD
- Met. forcing: ERA5 reanalysis (ECMWF)
- Open boundaries: 2 NM Baltic Sea reanalysis (CMEMS)
- River run-off: VEMALA (Syke)



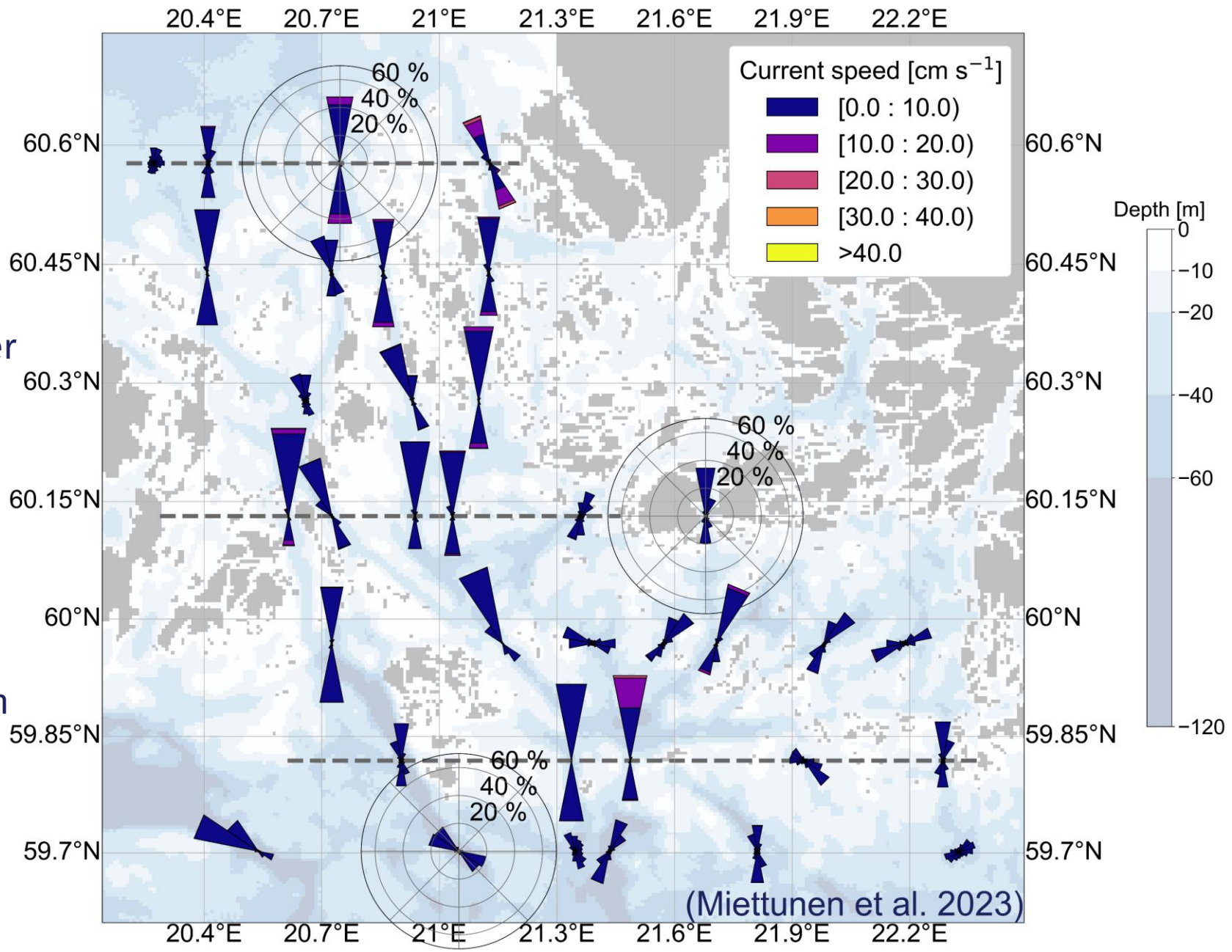
Surface layer currents in 2013–2017

- Upmost 5 m layer, direction to
- Currents steered by bathymetry and islands
- Currents strongly aligned in narrow straits
- Wider directional distribution in more open areas
- Southward and south-eastward currents dominate during the simulation period



Bottom layer currents in 2013–2017

- Bottommost 5 m (in areas deeper than 25 m), direction to
- Currents more strongly aligned than in the surface layer
- Northward currents dominate in the southern and central parts
- Southward and northward currents almost equally common in the northern part



Net transport in the surface layer is mainly southward

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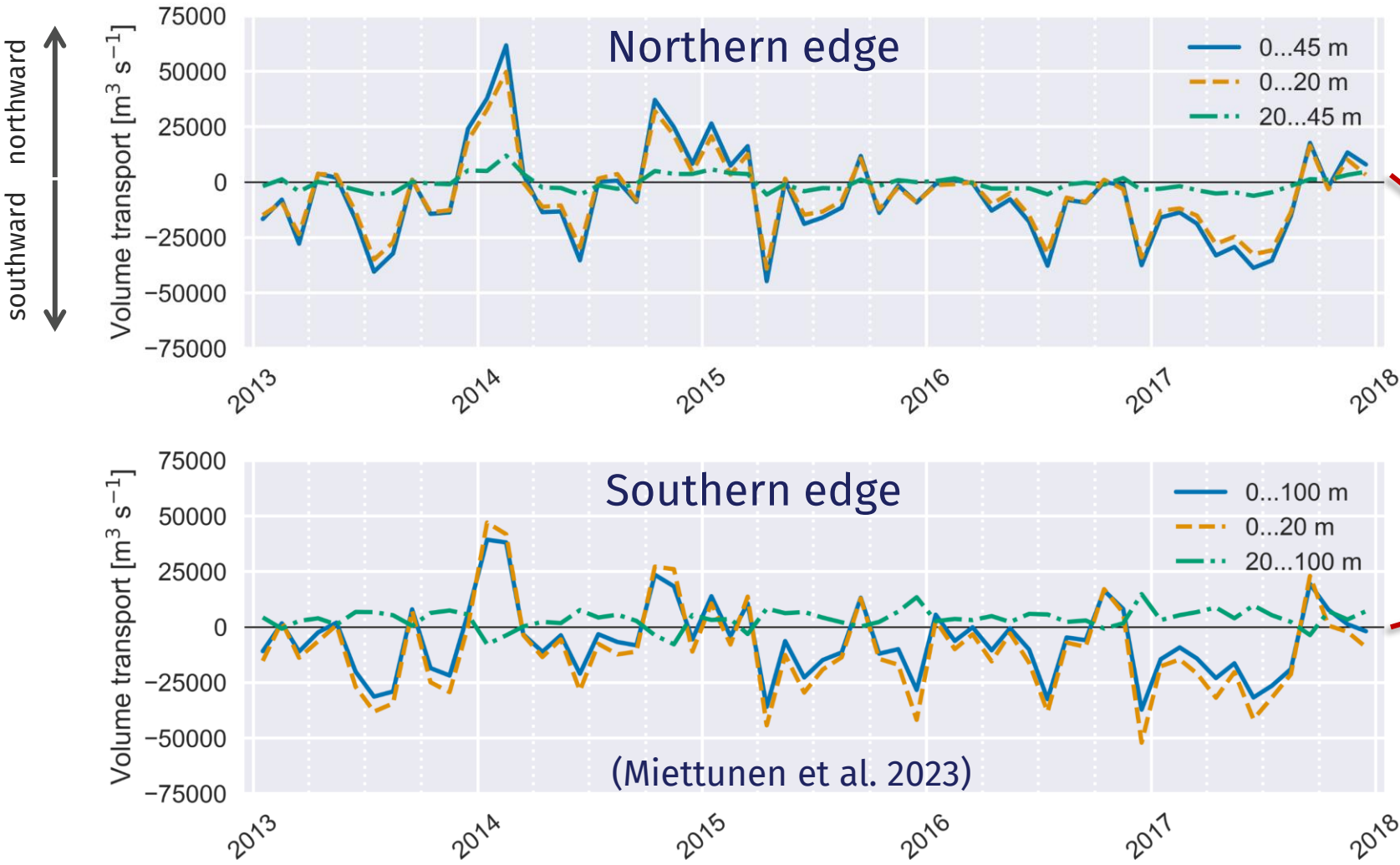
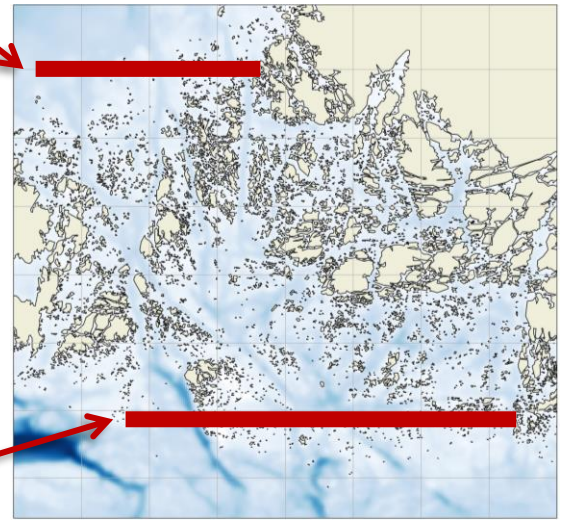


Whole water column
Surface layer (0–20 m)
Lower layer (below 20m)



Middle archipelago is more sheltered from transport from south than from north

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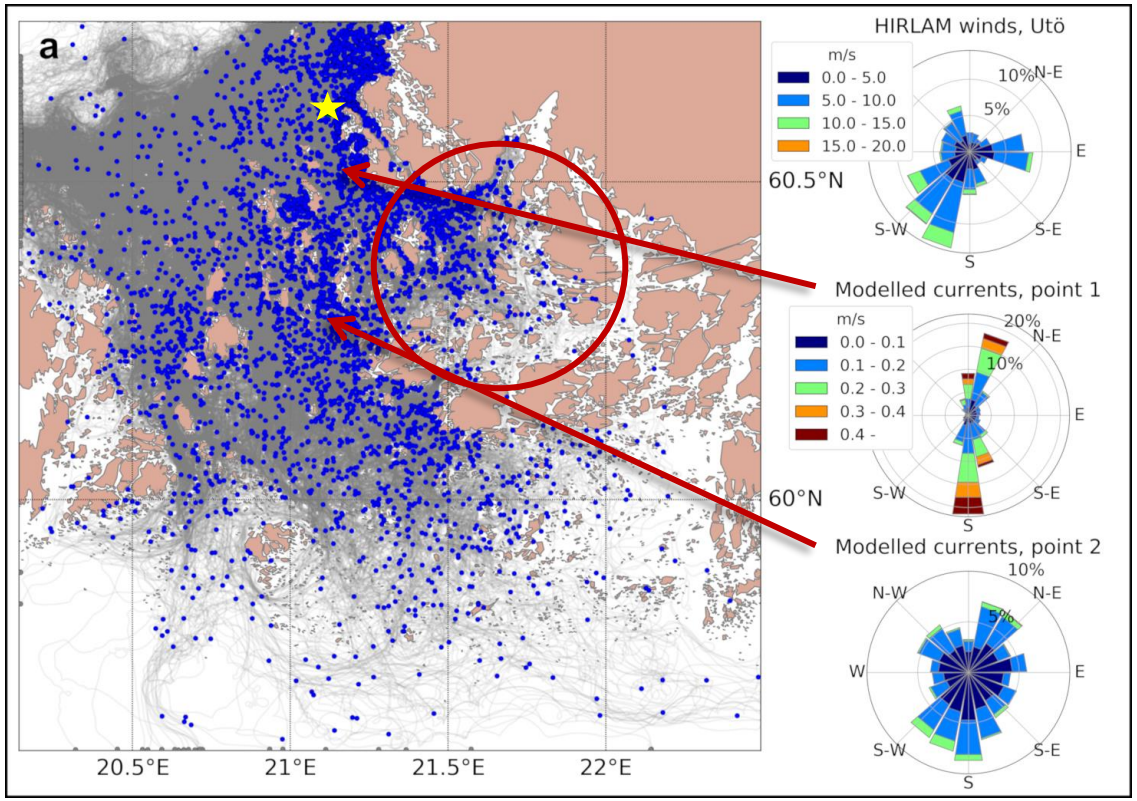
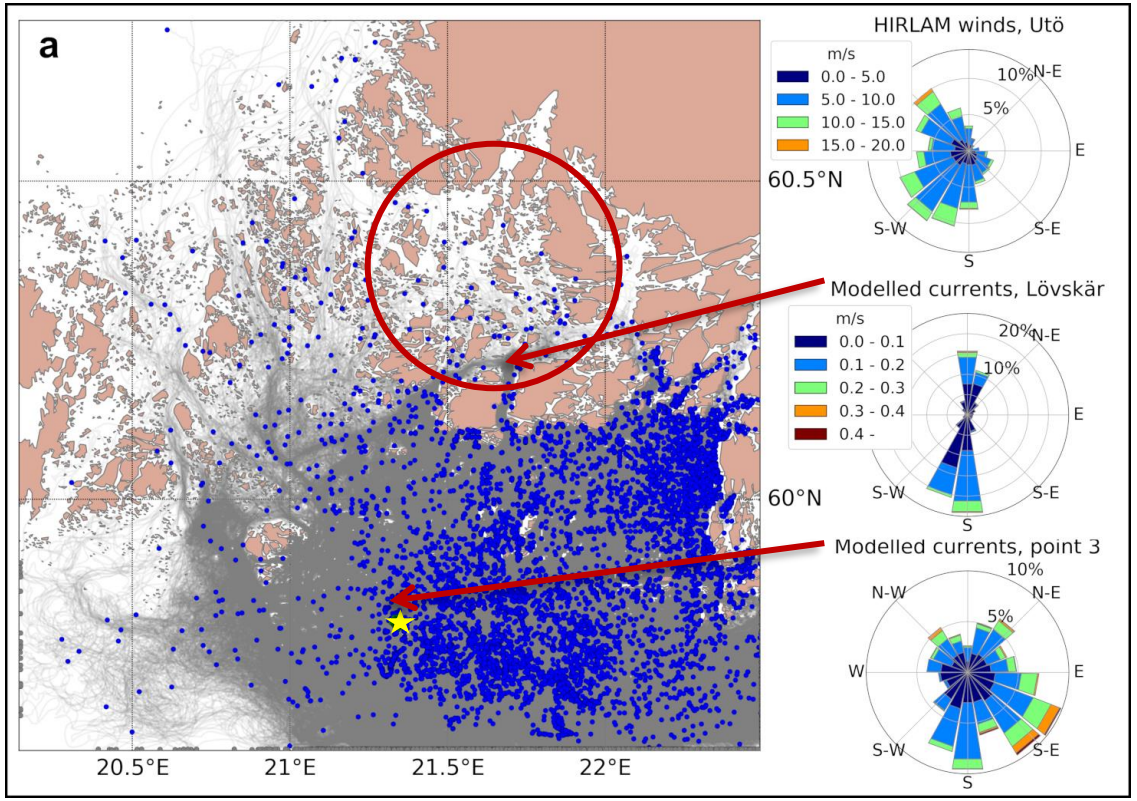
Transport of passive tracers from a point source (yellow star) in the surface layer during 3-month periods

Wind roses: direction from, Current roses: direction to

From north, April–June 2013



From south, April–June 2015



(Miettunen et al. 2020)

Summary

High-resolution circulation modelling has increased our understanding on the dynamics of the Archipelago Sea

- Currents in the area cannot be described well with averages
- The net transport in the surface layer is southward
- The net transport lower layer (below seasonal thermocline):
  - southward in the northern part of the area
  - northward in the central and southern parts of the area
- Middle archipelago is relatively sheltered and transport from outer archipelago is sensitive to prevailing wind conditions

References

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