SeaHeat: Assessing Baltic Sea potential and risks for thermal energy source

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Motivation

- Need for heating: e.g. in Finland, heating accounts for nearly 30% of the total energy demand, and the district heating is largely produced with fossil fuels and biomass.
- Marine Heat Pumps take advantage of the renewable sea heat with low emissions. This can be combined with heat reserves.

Challenge

The potential for marine sea heat is still largely unmapped. For an area to be suitable for this, it needs to have stable, sufficiently warm (≈>3 °C) water mass, with volume to sustain extraction.

What is needed:

- Data through models and mesurements to create climatology, for current and future situations, with seasonal changes.
- Means to determine the risk of intake affecting the immediate area.
- Means to determine the risk of outlet changing the surrounding conditions.
- To have meaningful impact on society, all results must be available in easy to use way.

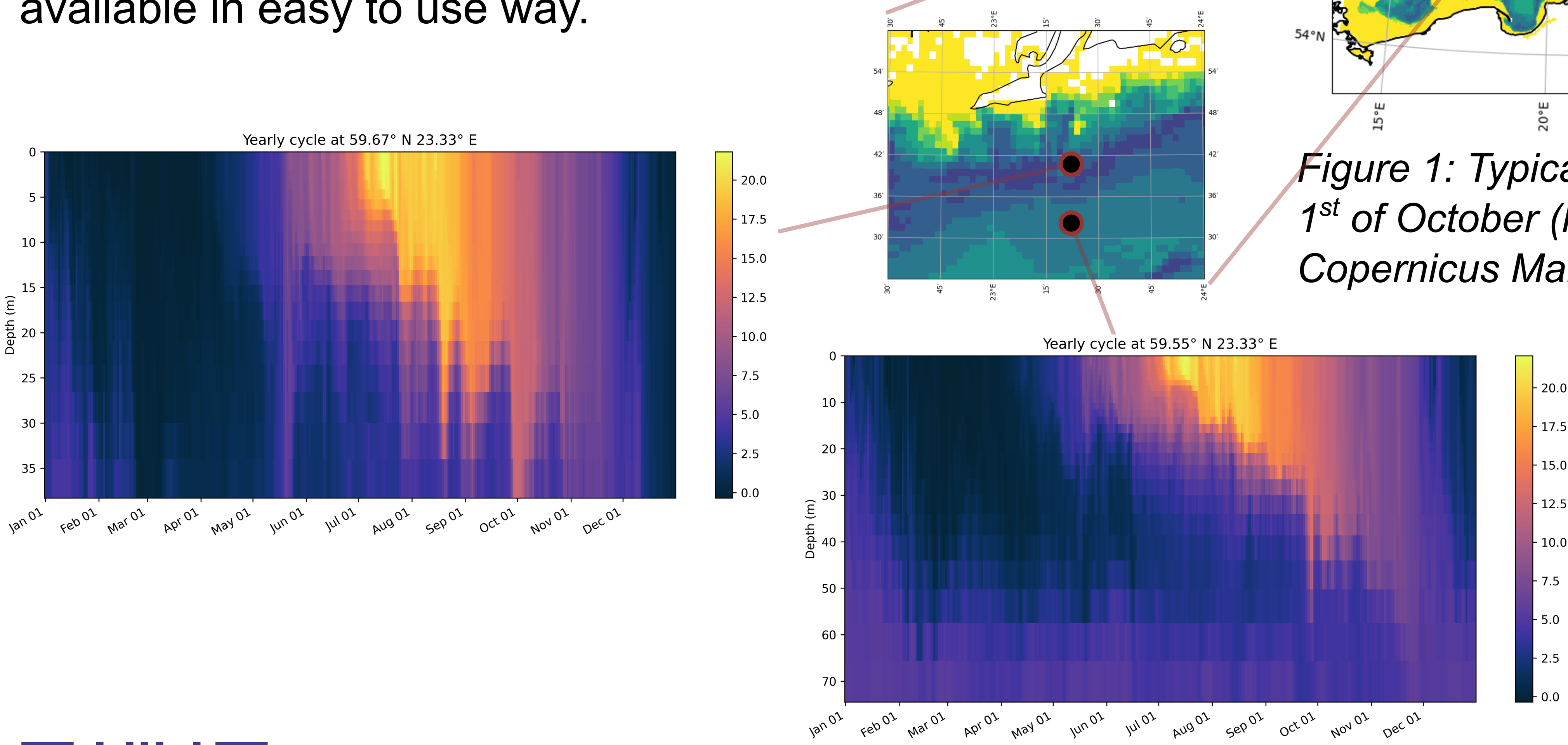

Figure 2: Example of yearly cycle in two points near Hanko. Lower has rather stable bottom layer protected by halocline, upper one is gets mixed to the bottom.

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Baltic Sea

The Baltic Sea presents an unique environment for thermal energy usage through heat pumps. Its distinct characteristics like complex bathymetry, strong vertical stratification dominated by salinity and relatively shallow depth, create a setting where, despite cold winters, the water beneath the halocline can remain relatively warm. During winter, with water temperatures typically under 5 °C, the water flows required for large power plants would be around 60 m^3/s, which is comparable to a small river.

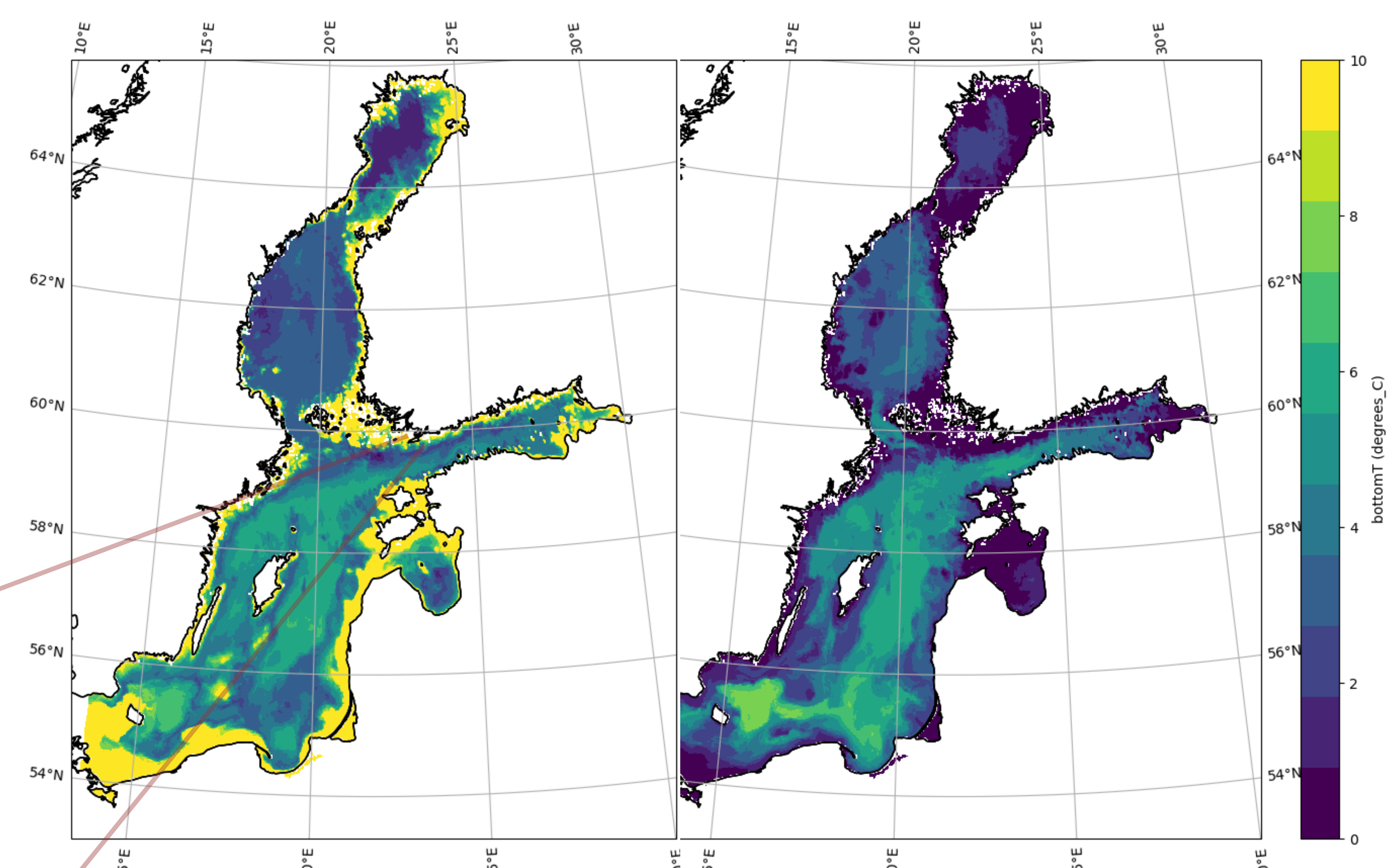

Figure 1: Typical sea bottom temperature (SBT) on the Baltic Sea, in 1st of October (left) and 1st of March (right). Data is derived from Copernicus Marine Servises (CMS) reanalysis from 1993-2021

Next steps

- Analysis of future scenarios
- Develop describing measure for area resilience to artificial outlet of water.
- Analysis of the watermasses and connectivity
- Easy to use software for viewing the results

Data Used

Suitable watermasses are identified using the Copernicus Marine Services reanalysis dataset. The one nautical mile resolution gives an estimate of the large scale stability and distribution of water masses

As any larger sea heat powersystem is likely to have multi decadal lifetime, it is needed to also estimate the future changes in the conditions. For this we use scenario simulations from recent times to up to year 2100.

In order to estimate uncertainty in climate developments we use two Representative Concentration Pathways: RCP4.5 (the intermediate) and RCP 8.5 (worst case) in the analysis.

Outlet Impact

The impact radius is estimated from the density difference of the inflow to the surrounding: if denser, it is assumed to form a bottom gravity current; otherwise, a buoyant surface plume. Next the velocity shear between the plume (front) and the ambient fluid is calculated, using interface diffusivity based on the bulk Richardson number (KPP model).

This allows us to compute the turbulent entrainment to the plume. We define the impact radius to be such that the volume flux due to the turbulent entrainment over a circle with that radius, is less than set value, for example, 0.1 °C when looking temperature, or 0.05 g/kg for salinity.

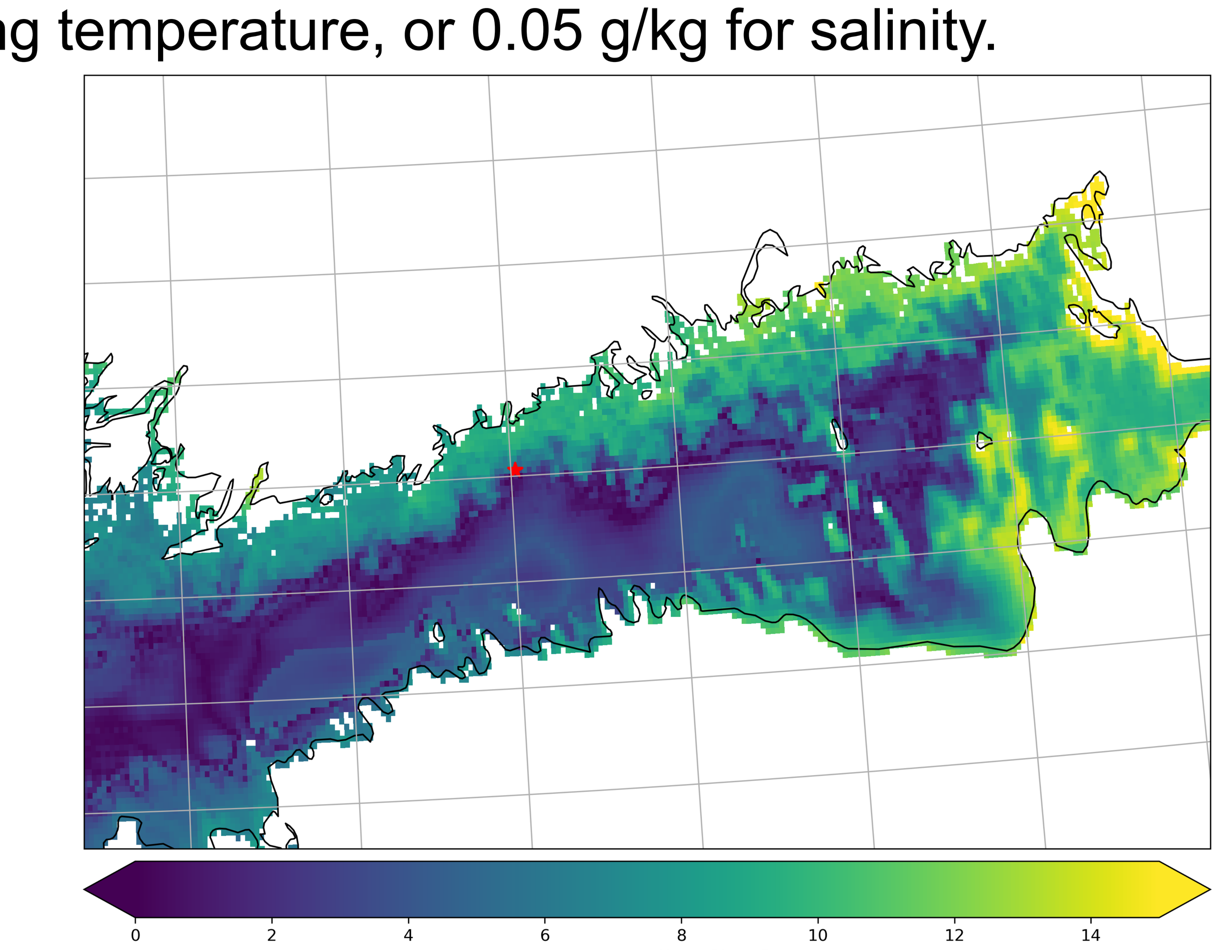

Figure 3: A red star indicates a point of reference. Color indicates the potential impact radius should water from the reference point be released at a given point. Here, the impact limit is set to 0.05 g/kg.