Using seawater thermal energy for district heating: an oceanographic point of view

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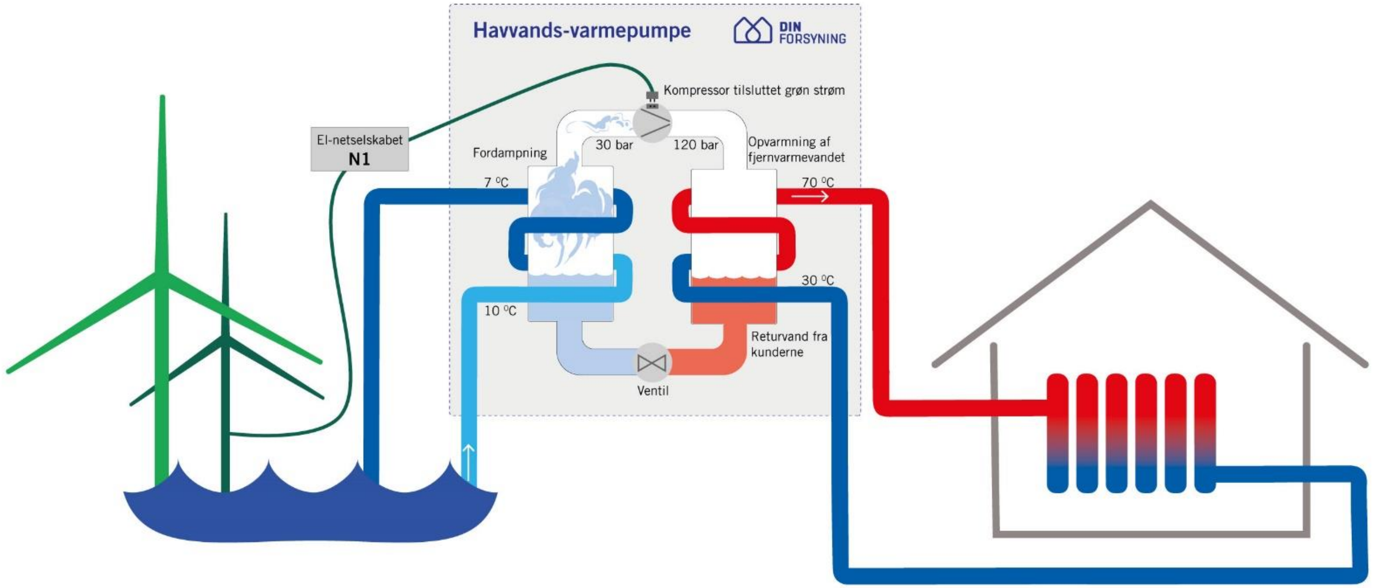
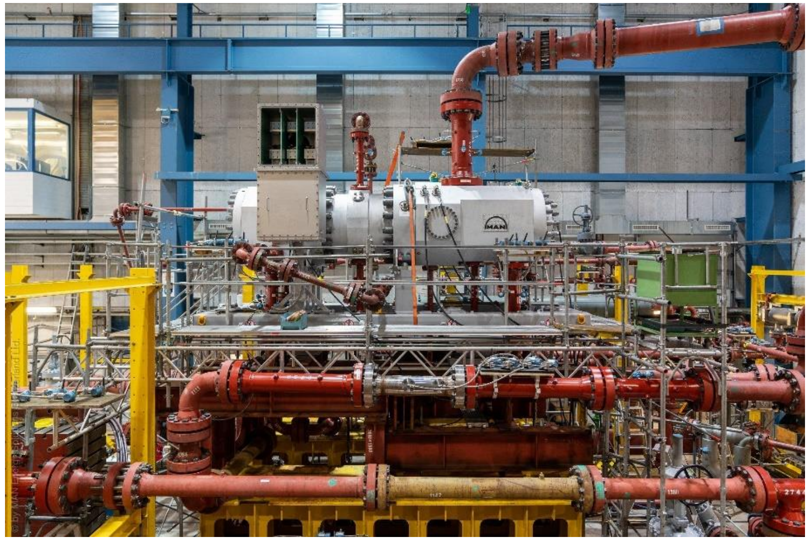
Basics of seawater heat pump (SWHP)



New seawater heat pumps in Esbjerg
North Sea side of Denmark



- temperature of input water is lowered due to evaporation of agent;
- evaporated agent is compressed and subsequently condensed,
  heat is released in secondary circuit

- heating is needed in cold season;
- due to icing risk temperature drop can be only a few degrees;
- **heating of medium district requires seawater volume flow comparable to small rivers** (thermodynamics)

Basics of oceanograpy *related to SWHP*

For seawater Intake location:
temperature should be warm enough = frequently above 3 - 4 °C to avoid freezing

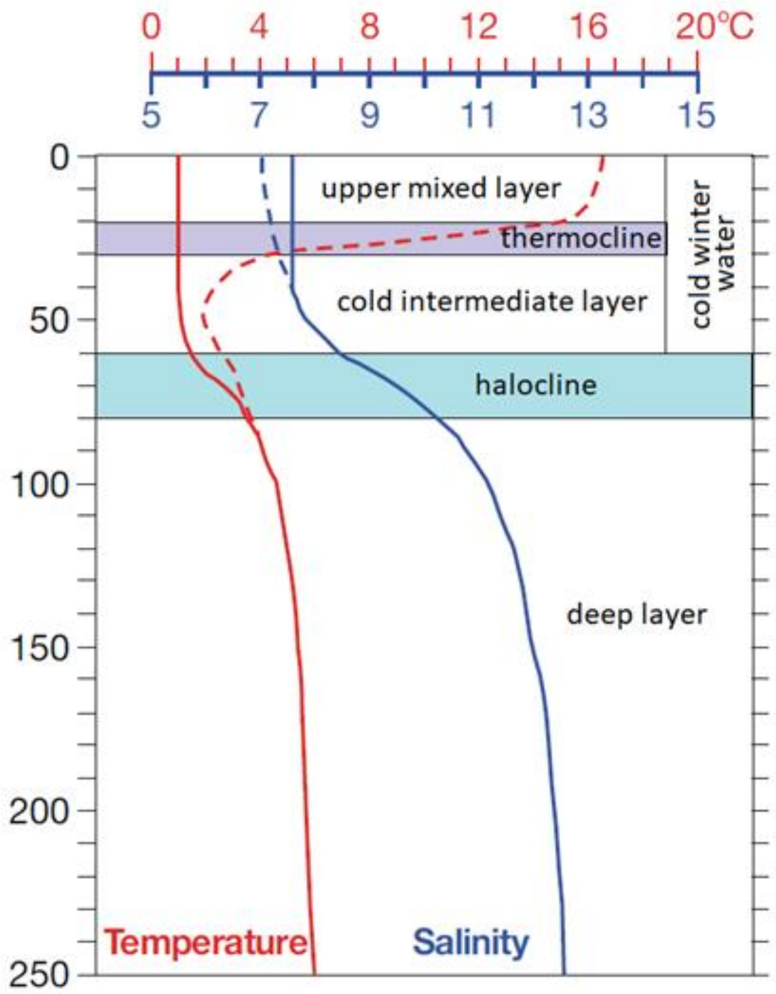
- **on perfect 4D gridded data set find thermally best locations**
- joint optimization with engineering, environmental and socio-economic aspects

Already a change by 1 - 2 °C matters a lot for SWHP

Besides well-studied physical processes from decadal changes to mesoscale eddies, there seem to be importance of local effects:

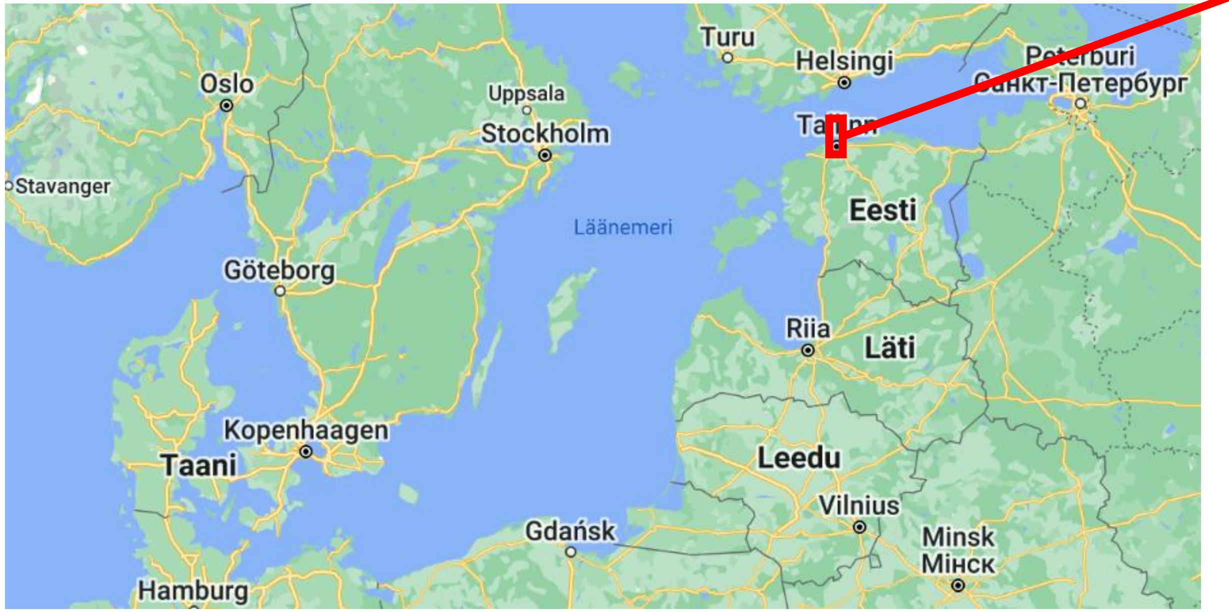
- differential heating on variable depth (cooling-driven thermal siphon)
- barotropic-to-baroclinic motions on sloping bottoms (including temperature response on seiche periods)
- differential mixing on rough/smooth bottoms
- water mass patchiness (T-S variations on isopycnals)

Stratification
has seasonal character
ohter variability scales also involved

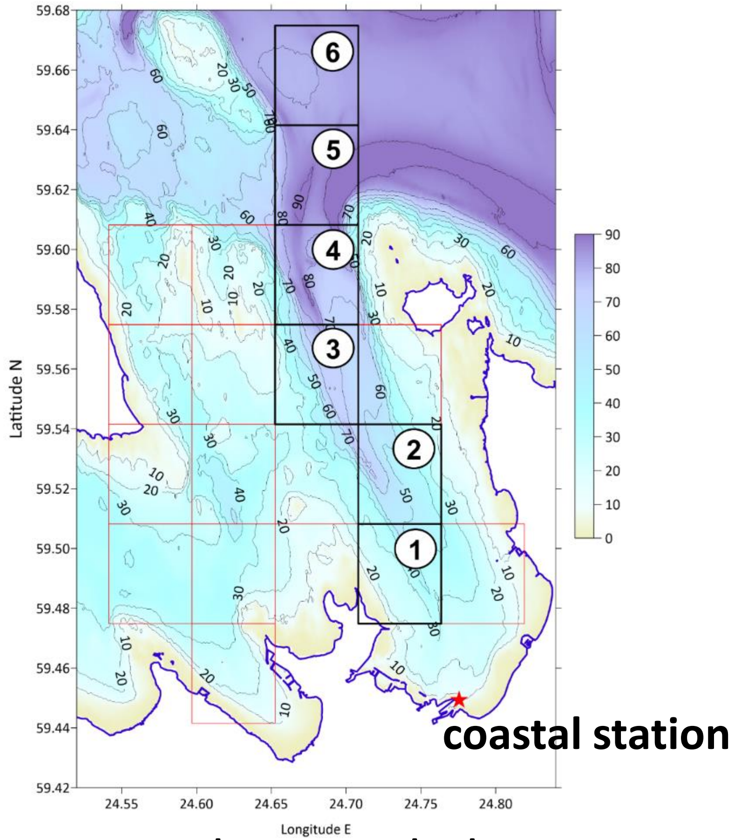


Pilot Study in Tallinn Bay

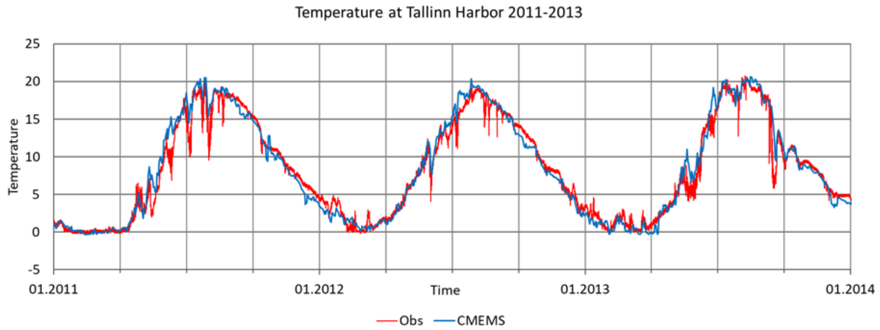
Copernicus Marine Service
Physical Reanalysis Product
Grid step 2 nautical miles (ca 4 km)
Vertical step starting from 3 m
Uses NEMO-Nordic
LSEIK data assimilation
Daily mean 3D data from 1993 - 2019



Topography and reanalysis grid

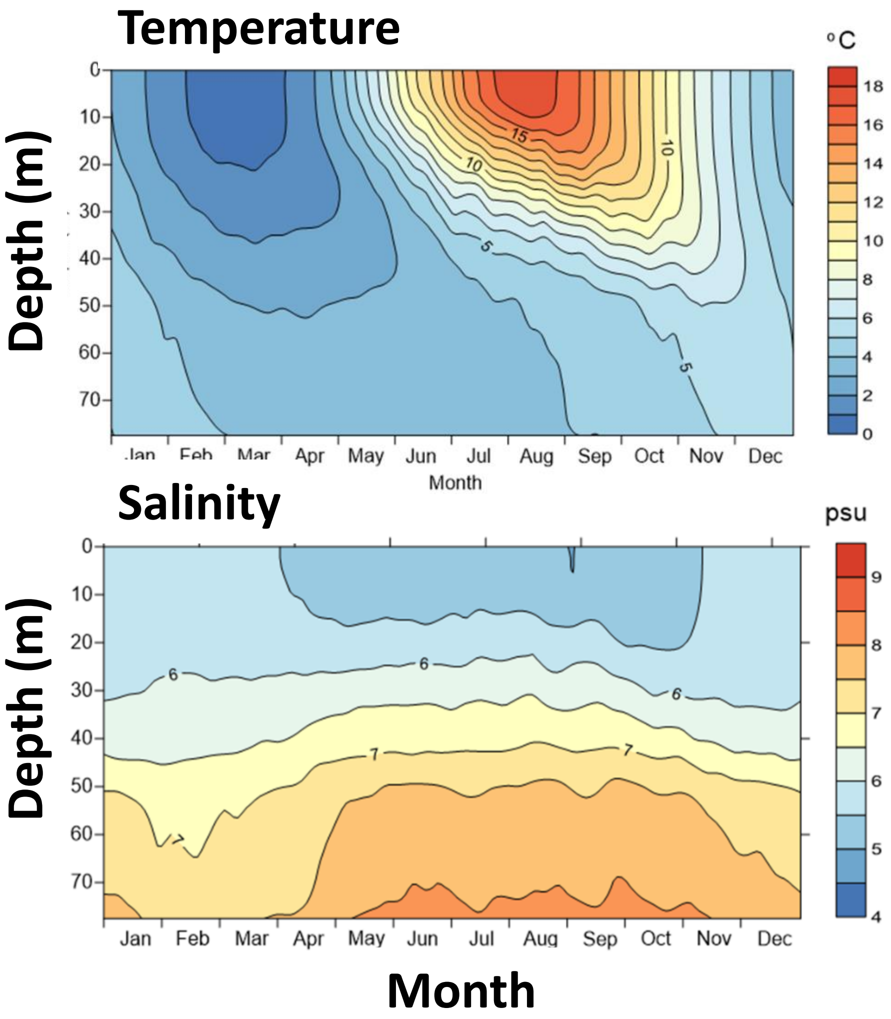


Validation with coastal observations

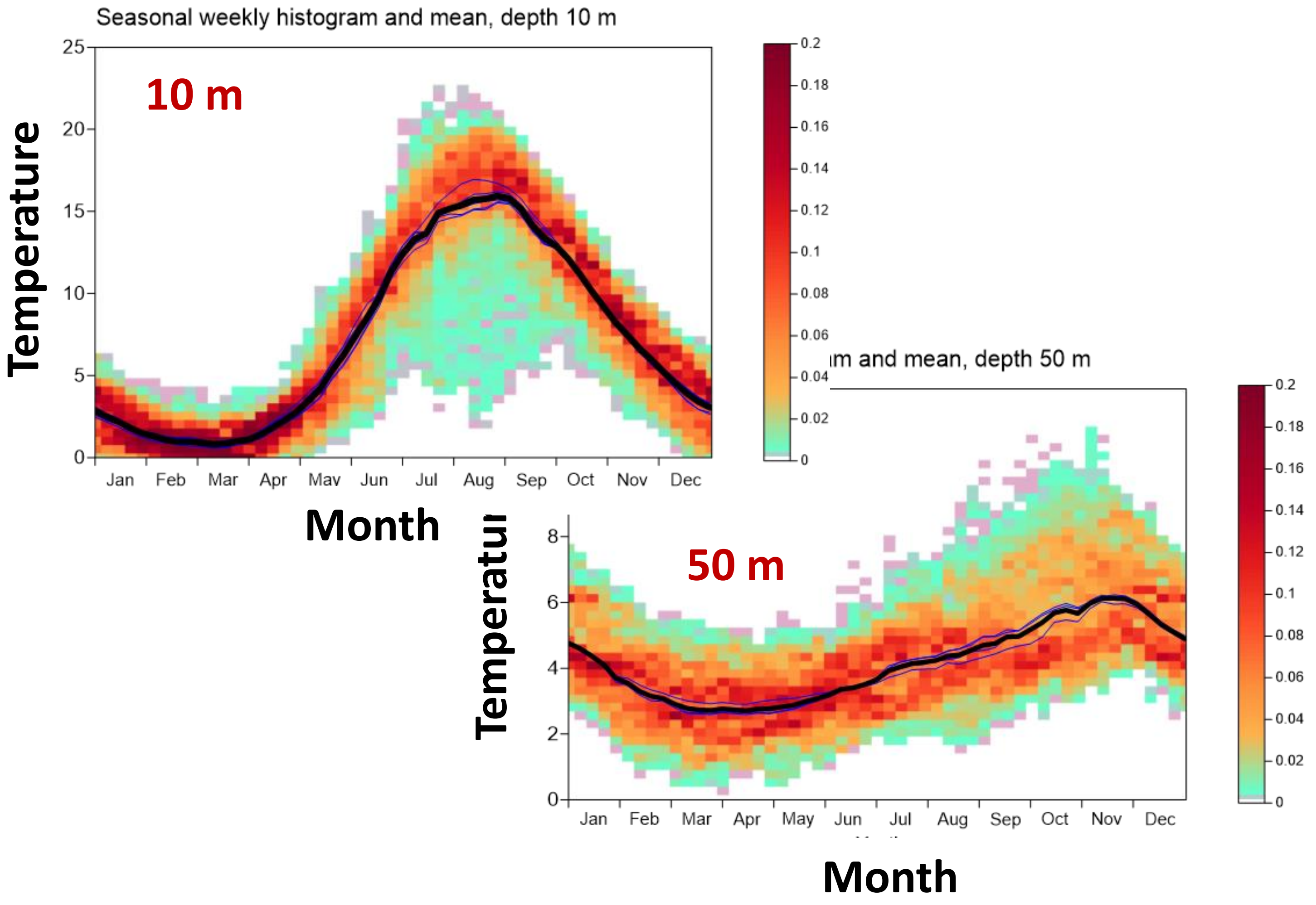


Seasonal course and variability

Mean seasonal cycles over 27 years



Weekly 2D frequency histograms over all model points in the bay distributions are **more complex than Gaussian**

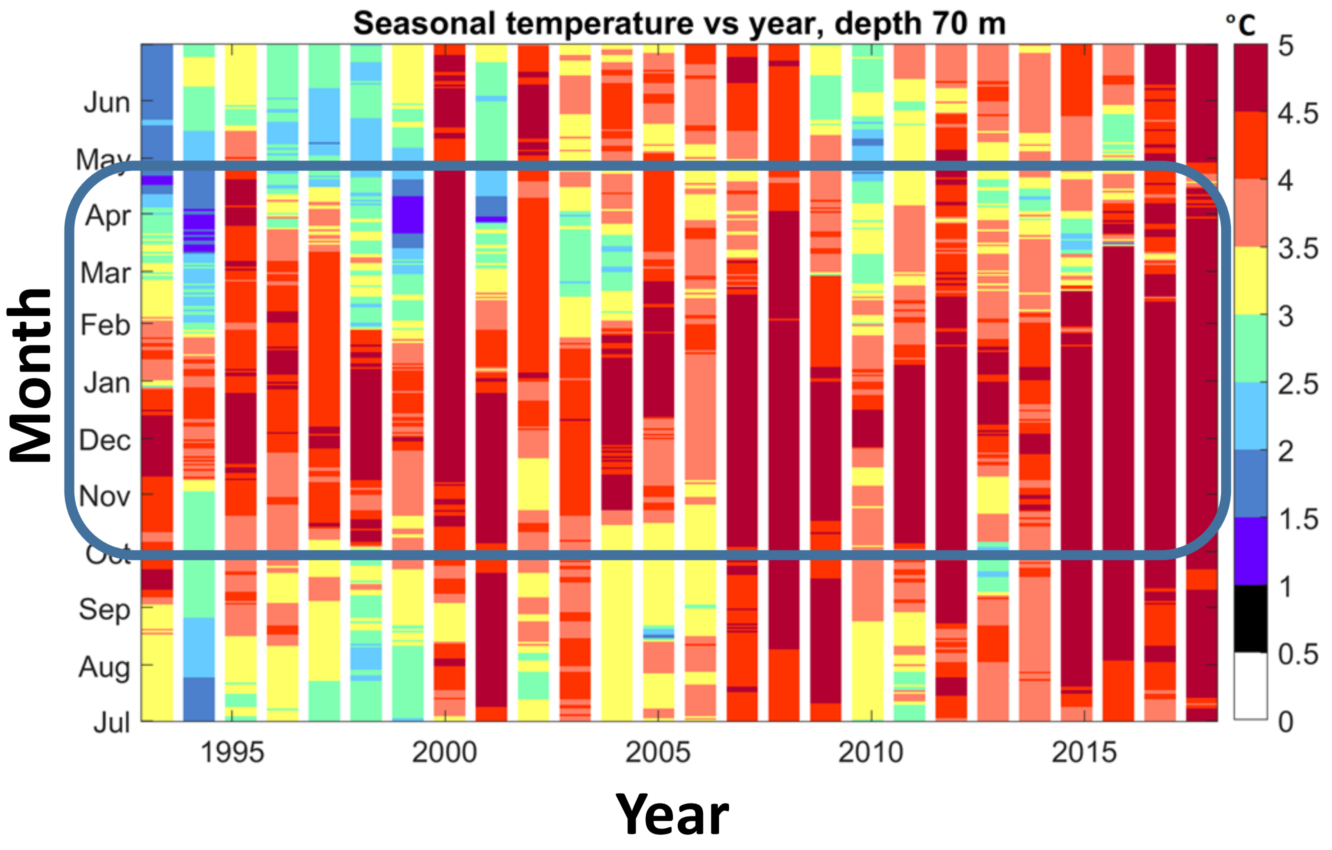


For the statistics of start and duration of seawater-based heating periods, **non-averaged initial data should be used**

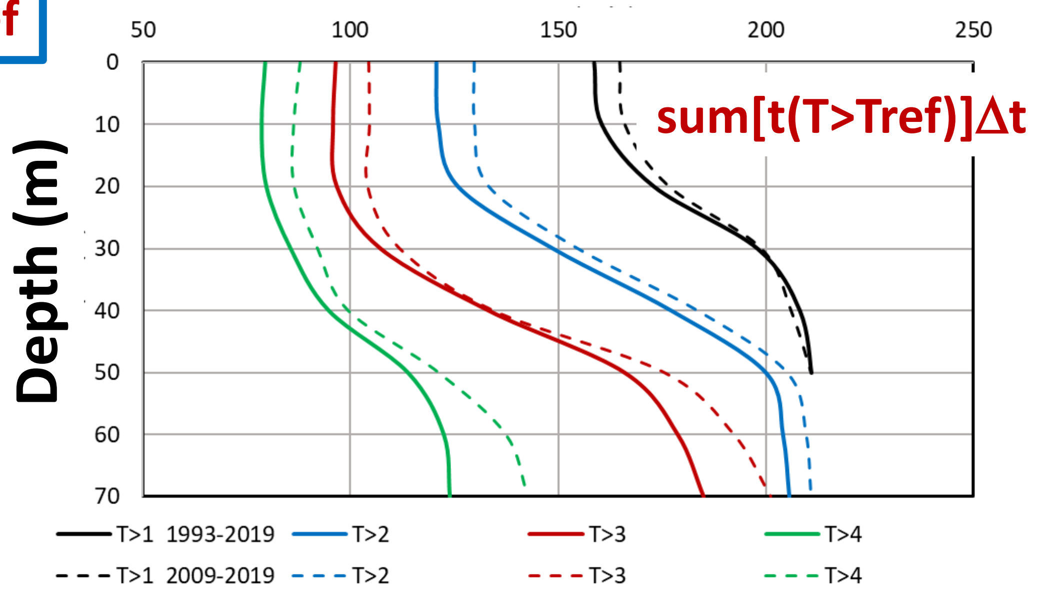
Seawater-based heating times

SWHP needs T>Tref

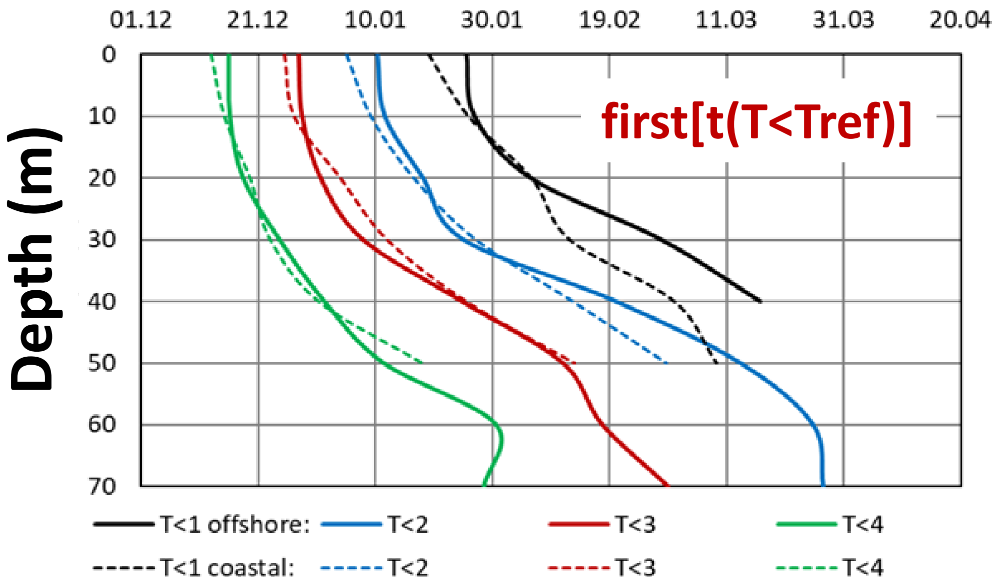
Initial temperature data 70 m
as color stripes for each year



Mean duration of seawater heating



Mean end date of seawater heating

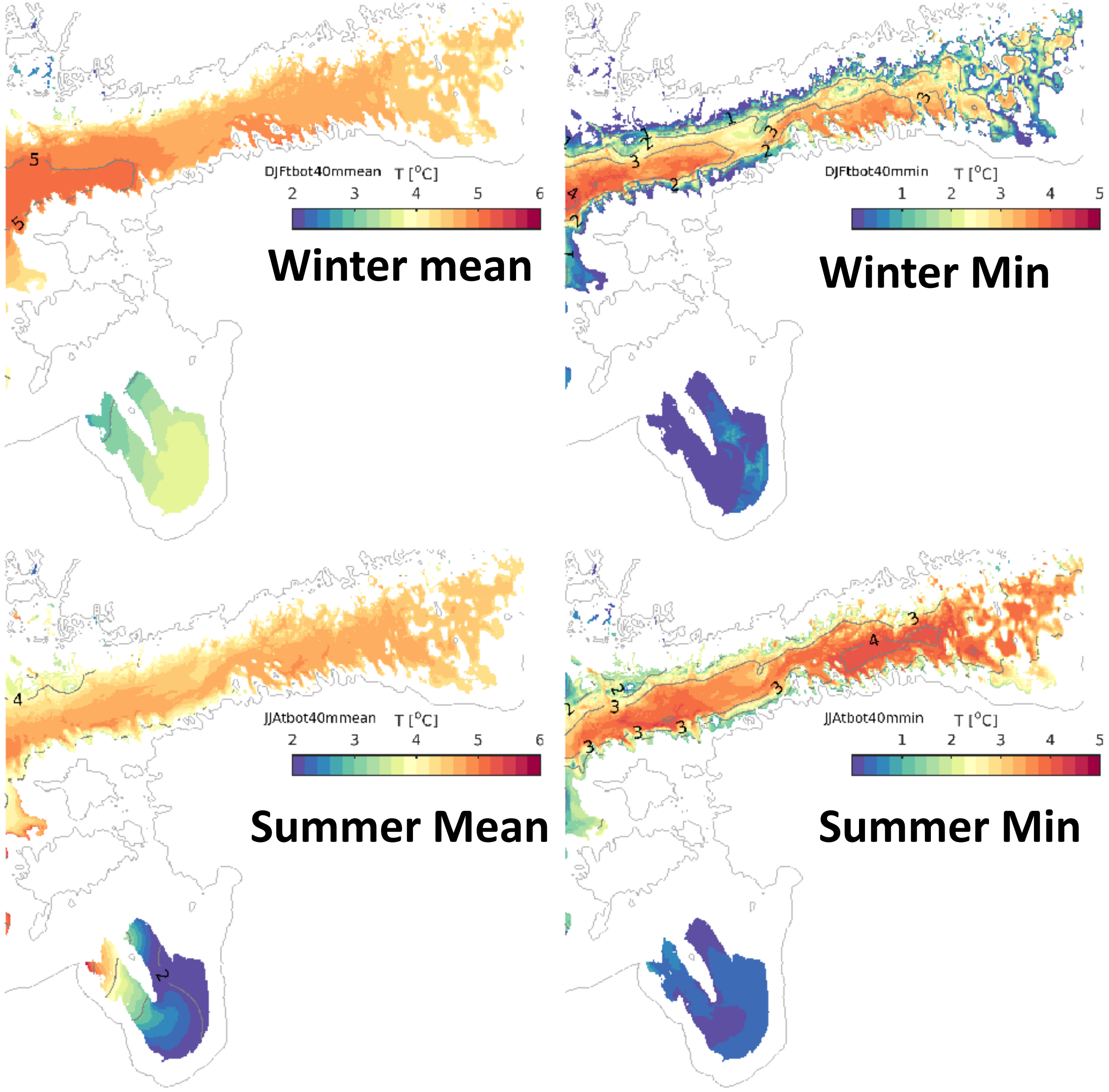


Deep-water (> 45 m) temperature maps

NEMO-Est subregionaal model
Grid step 0.5 nautical miles (ca 1 km)
Vertical step starting from 1 m
Uses NEMO-Nordic
open boundary from reanalysis
Daily mean hindcast data from 2005 - 2017

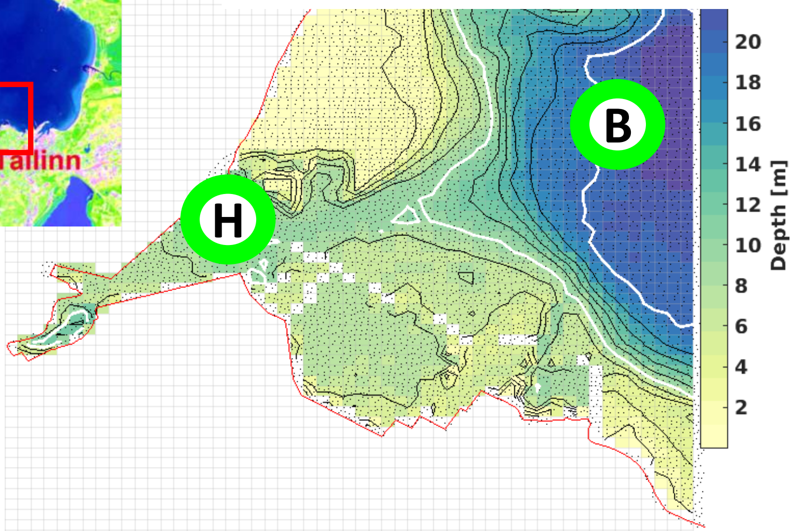
<u>Gulf of Finland</u>
Monthly mean temperature is 3.5 - 6 °C due to saline stratification.
Using of SWHP is favourable, but during winter a limited need for additional energy may come up

<u>Gulf of Riga</u>
Monthly mean temperature during winter is below 2 °C.
Using of SWHP is NOT favourable

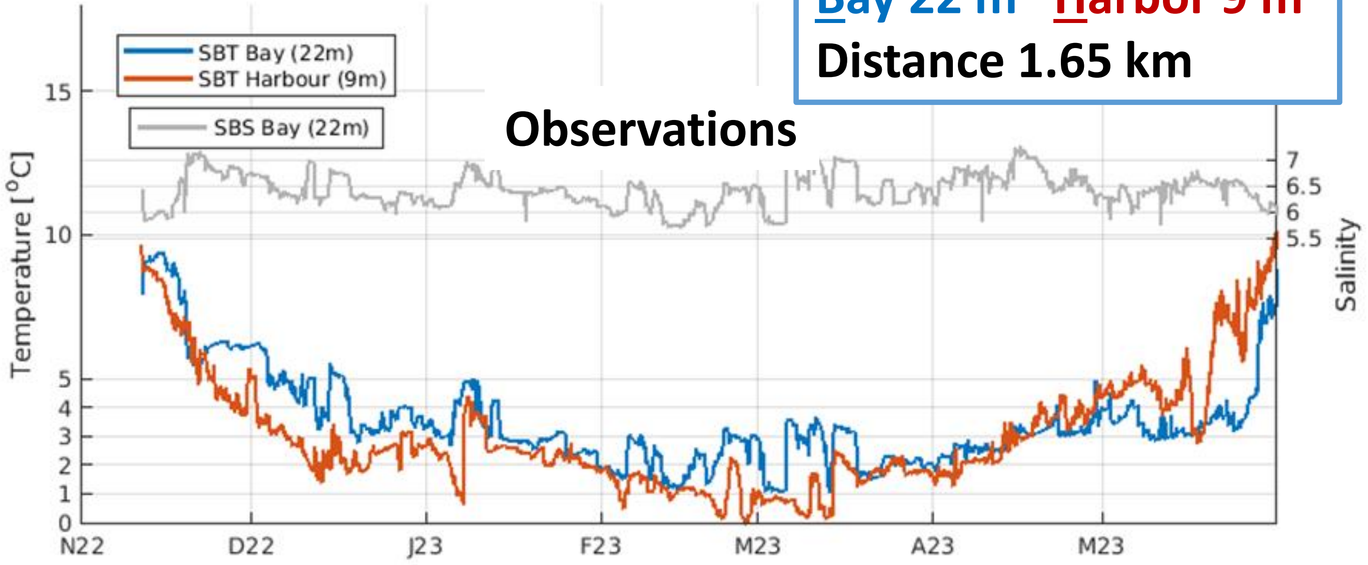


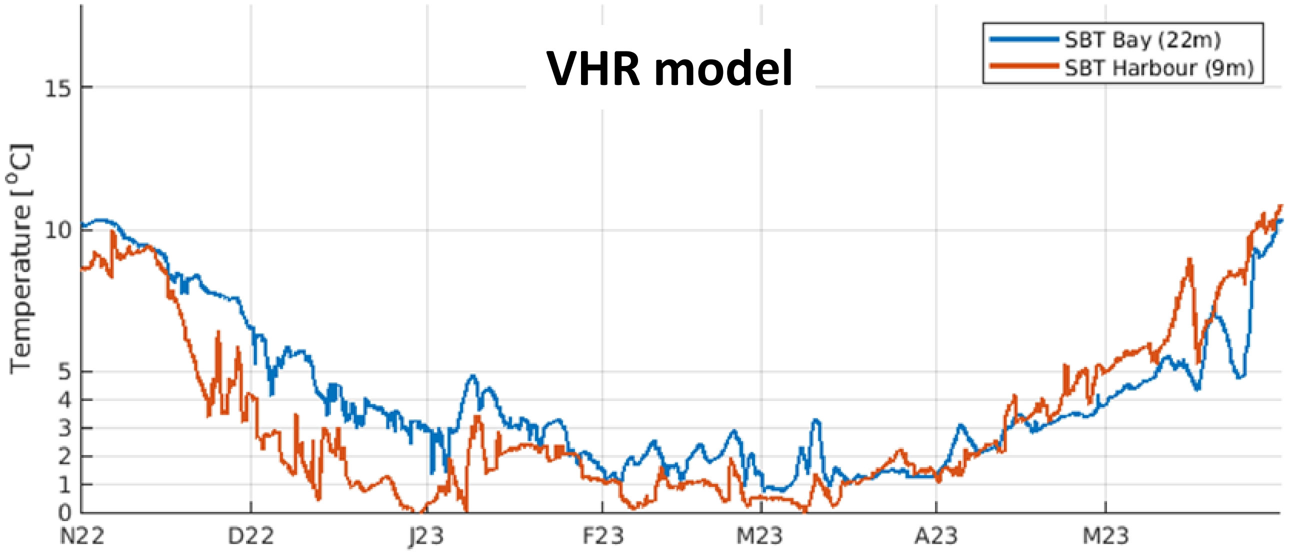
Near-bottom temperature dynamics in a small Hundipea/Paljassaare area

VHR model topography
GETM, grid step 50 m



Bay 22 m **Harbor 9 m**
Distance 1.65 km

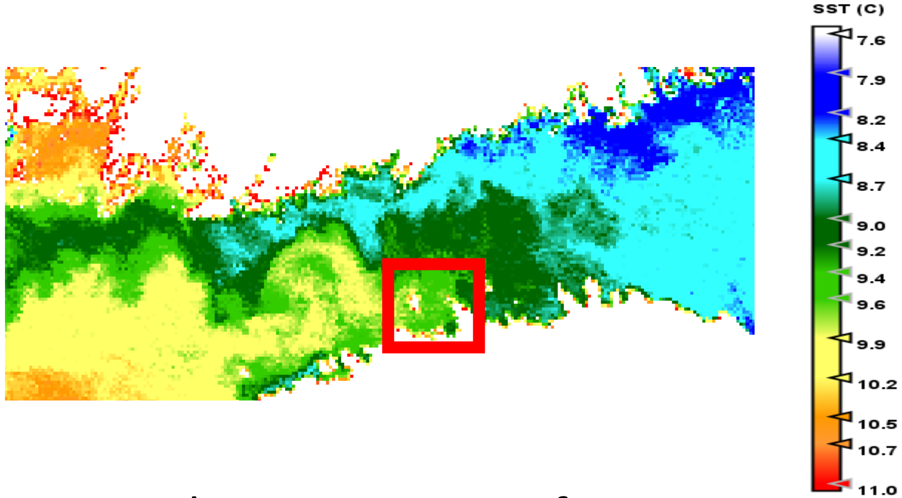




- **differential heating** - shallow coastal waters cool and heat faster than deeper waters
- **SWHP period** near coast (Harbor) **ends a few weeks earlier** than offshore (Bay)
- **well modelled** - seasonal course and weather-forced deviations, **poorly modelled** - phases of small-scale dynamics due to water mass patchiness

Fine scale temperature patterns from remote sensing

12.11.2022



Sentinel-3 SLSTR Sea surface temperature product on 12.11.2022 indicating upwelling in the Gulf of Finland.

Remarkable temperature and water mass variations as streaky, frontal, spiral and eddy structures occur on small scales

High resolution (10 m) SENTINEL-2 RGB view (red-B4, green-B3, blue-B2) on 12.11.2022 indicating different water masses in the coastal zone (Tallinn Bay and Hundipea)

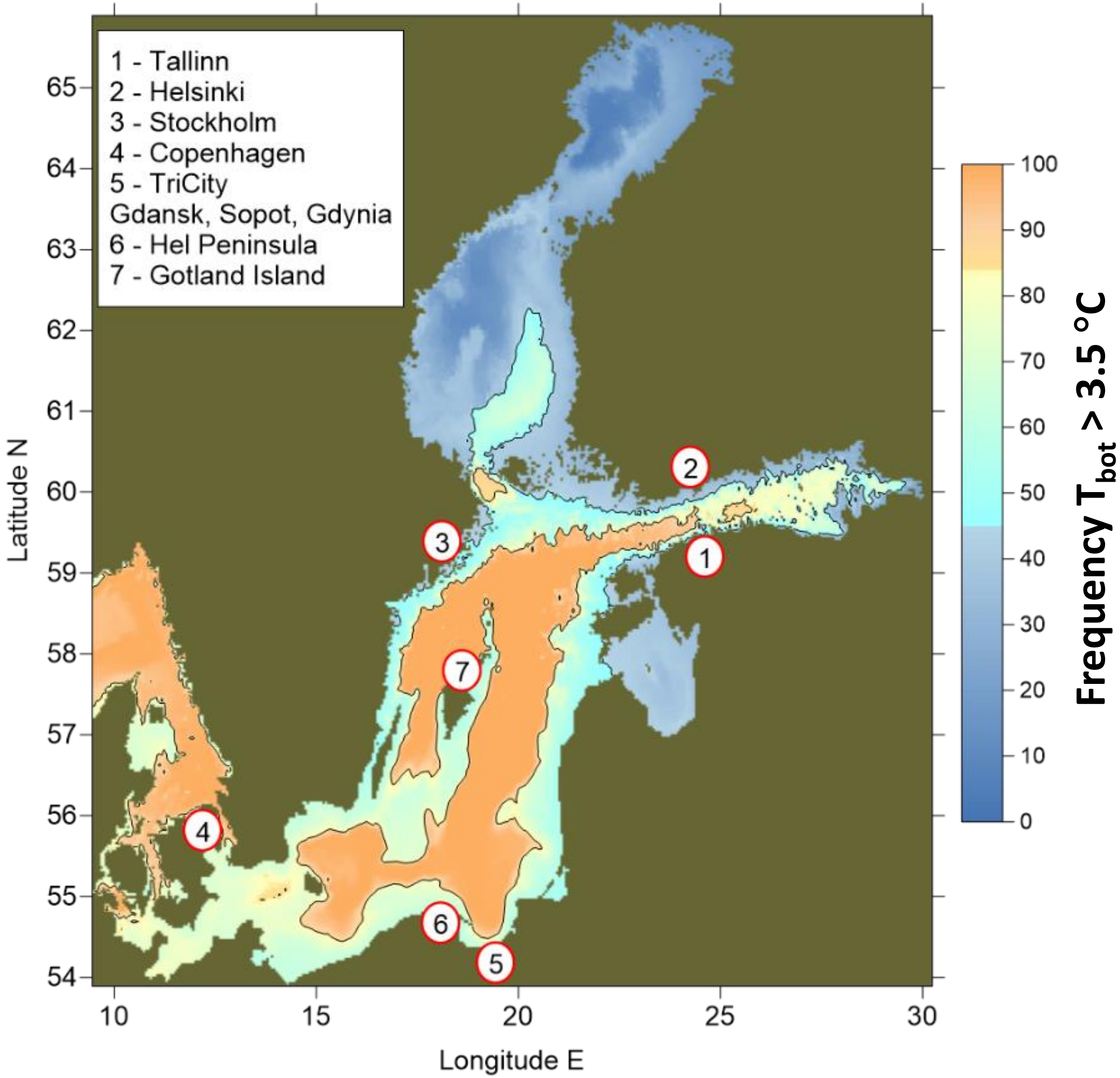
Frequency of extractable seawater heat occurrence over the Baltic Sea bottom

Based on Copernicus Marine Service Physical Reanalysis Product
Daily mean data from 1993 - 2021
Grid step 2 nautical miles (ca 4 km)

- **T_{bot} > 3.5 °C is considered reasonable limit**
- Frequency 85% is also considered reasonable

Favourable areas:

- Estonian coast of Gulf of Finland (Tallinn)
- TriCity of Poland
- West coast of Gotland
- Copenhagen, Kattegat



Coda

⇒ Deep seawater has low temperature, but it is relatively stable throughout the year and it is still warm enough that **heat can be extracted** from the water before cooling to the freezing temperature.

⇒ However, extracting the heat in large quantities (tens of MW) needed for town district scale, requires **costly solution**. The pumped **seawater volume may be rather large**. Therefore, with long pipelines, energy loss for pumping may become considerable.

⇒ Another **less costly solution**, pumping the seawater through short tubes from a coastal location, is limited in time for three late autumn months, because of the seasonal cycle of sea surface temperature.

⇒ Because of large volume flows, **environmental aspects should be carefully investigated and engineered**, especially the local effects in semienclosed sea areas.