# Dynamics of the deep layer in the Central and Eastern Baltic Sea

# Läänemere kesk- ja idaosa süvakihtide dünaamika

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# Outline

- Background- Baltic Sea and conventional monitoring

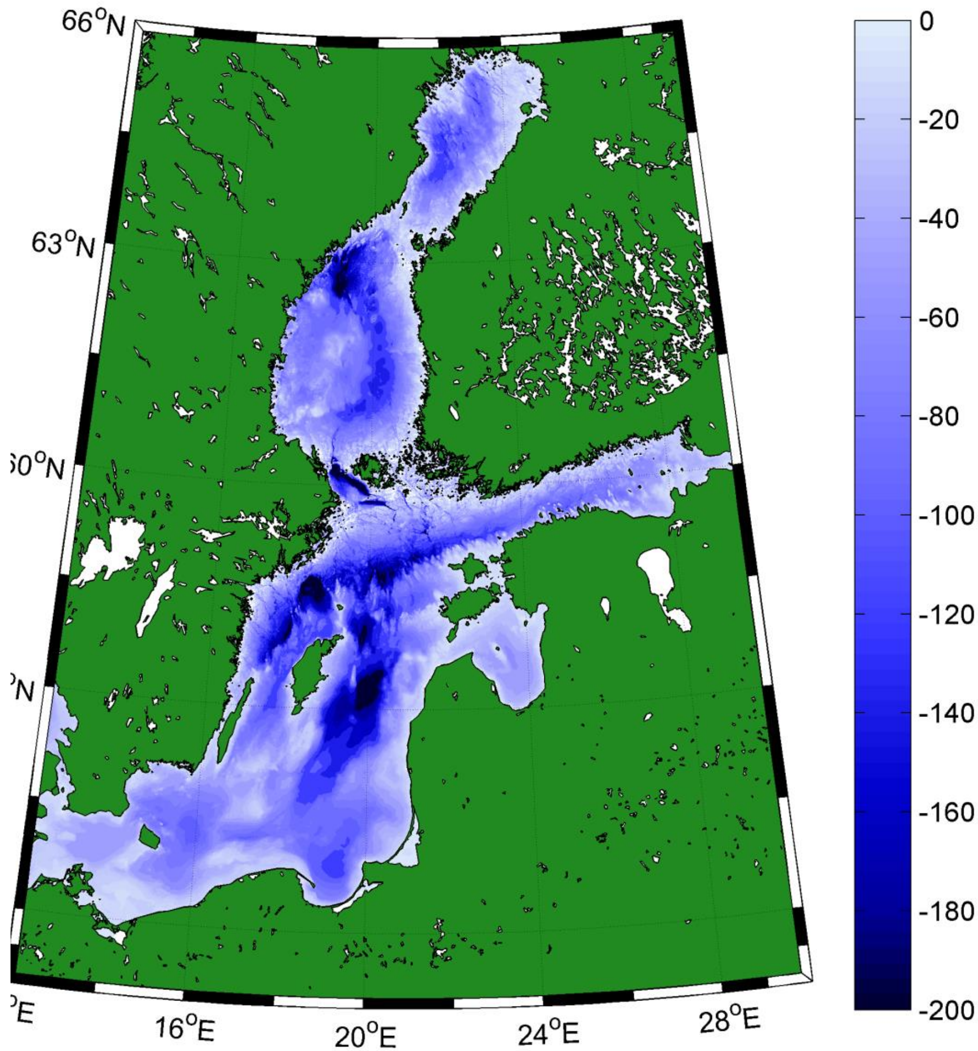
- Examples of the dynamics in the deep layer
  - Major Baltic Inflows and related effects in the Central and Eastern Baltic.
  - Changes in the near bottom layer in the Gulf of Finland.
  - Changes in the near bottom layer in the Gulf of Riga.

- How could we utilize autonomous platforms in monitoring and characterization of habitats?

- Characterisation of water column habitats by automous high-frequency observations – activity 2.1.1 in RITA (IMAGE) project.

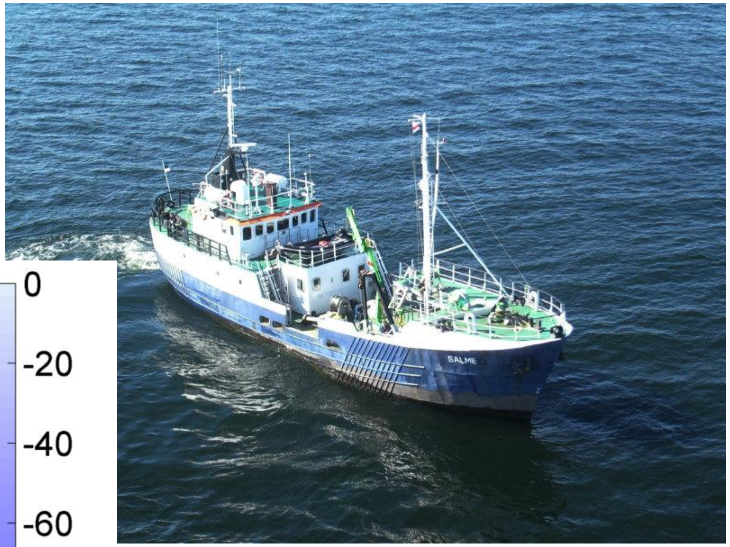
# Baltic Sea – importance of vertical structure and deep layers

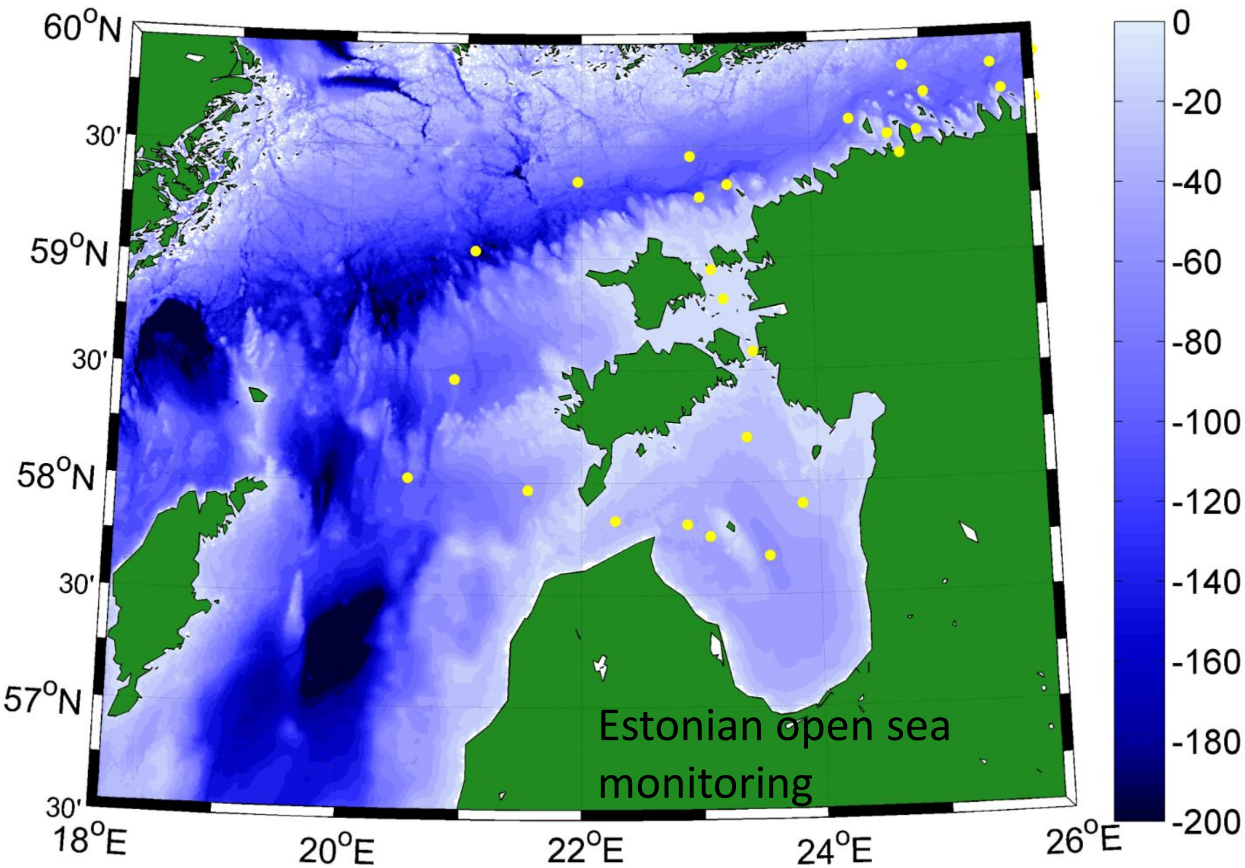
- Layered density structure and strong vertical gradients
- Impeded vertical mixing
- Layered current structure
- Layered biogeochemical fields
- Fluxes between water column and bottom sediments



# Conventional monitoring in open sea

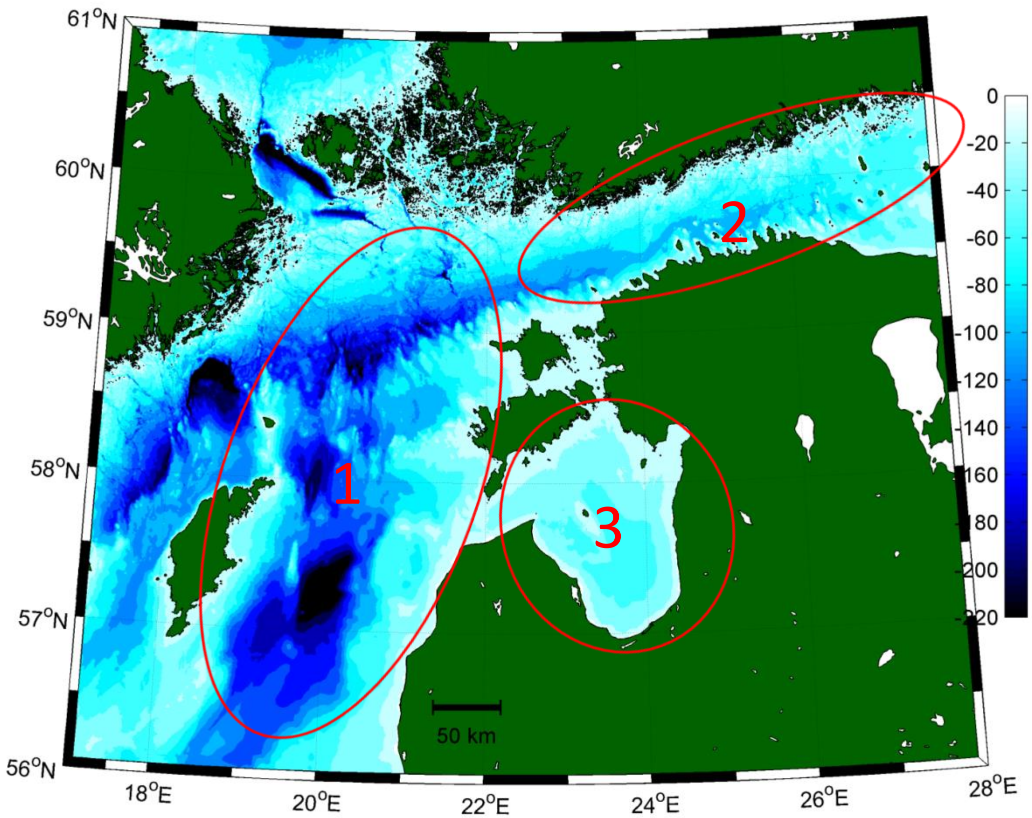
5-6 times a year in open sea stations






Is that enough to cover and capture spatiotemporal variability of processes?

# Open sea areas



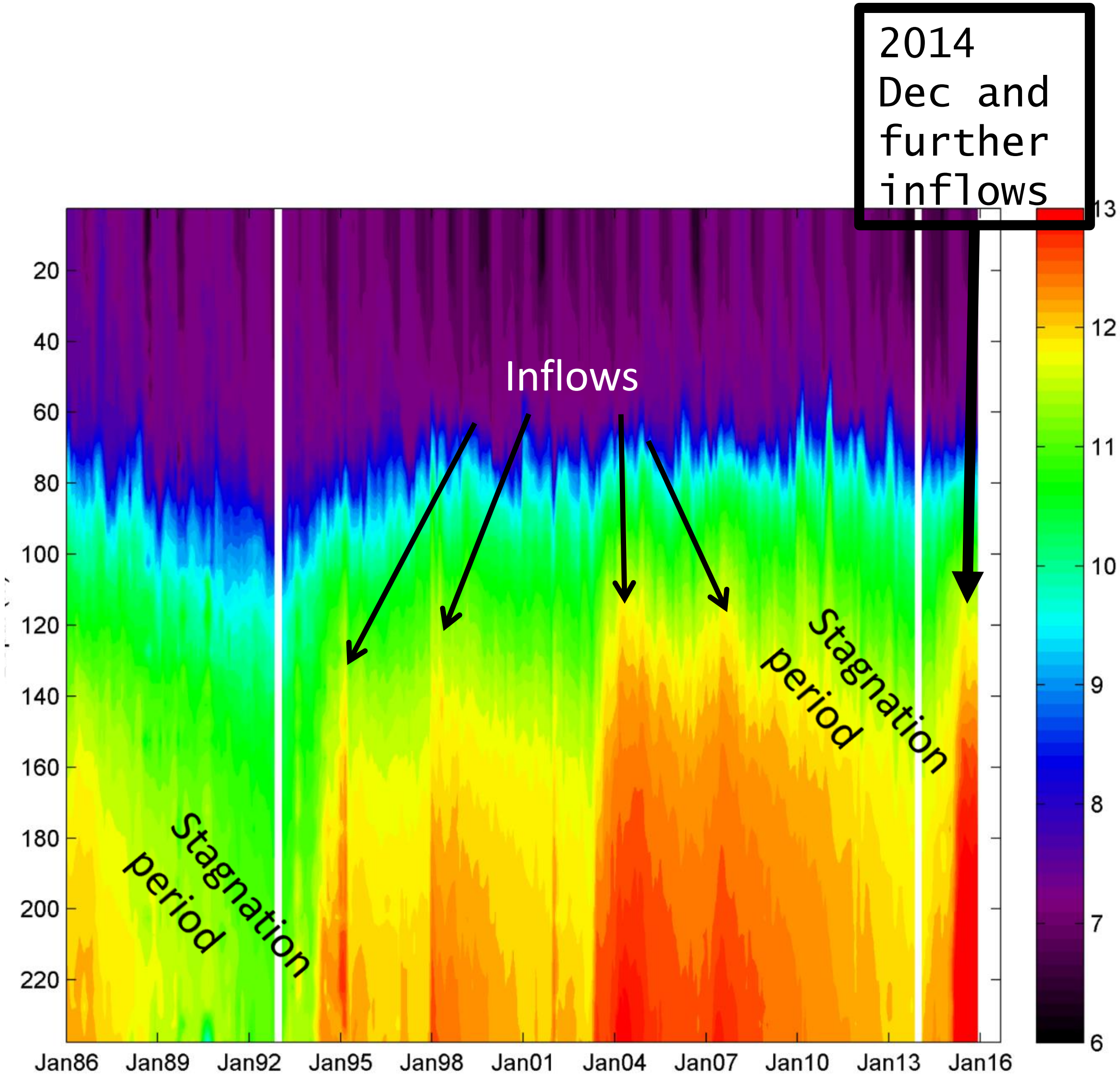

1. Baltic Proper- the central basin of the Baltic Sea, permanent halocline exists. Two pycnoclines in summer.

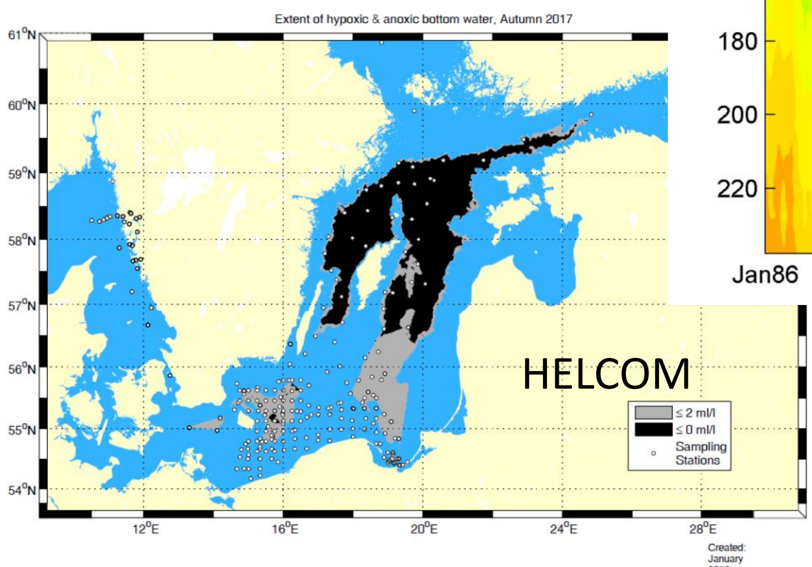
2. Gulf of Finland- well connected to the Northern Baltic Proper, quasi-permanent halocline exists. Two pycnoclines in summer.

3. Gulf of Riga- separated by sills from the rest of the Baltic, water column is mixed down to bottom during winters.

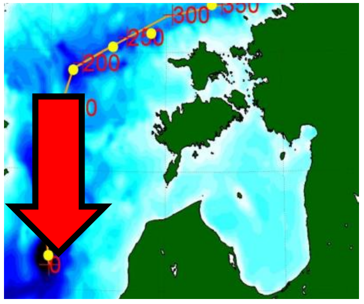
# Baltic Proper

- Anoxic and hypoxic bottoms are common.
- Only sporadic inflows from the North Sea can ventilate deep layers.
- High inflow activity 2014-2016.

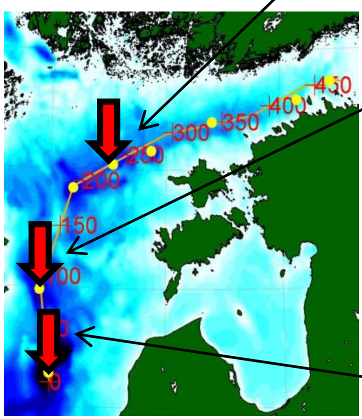


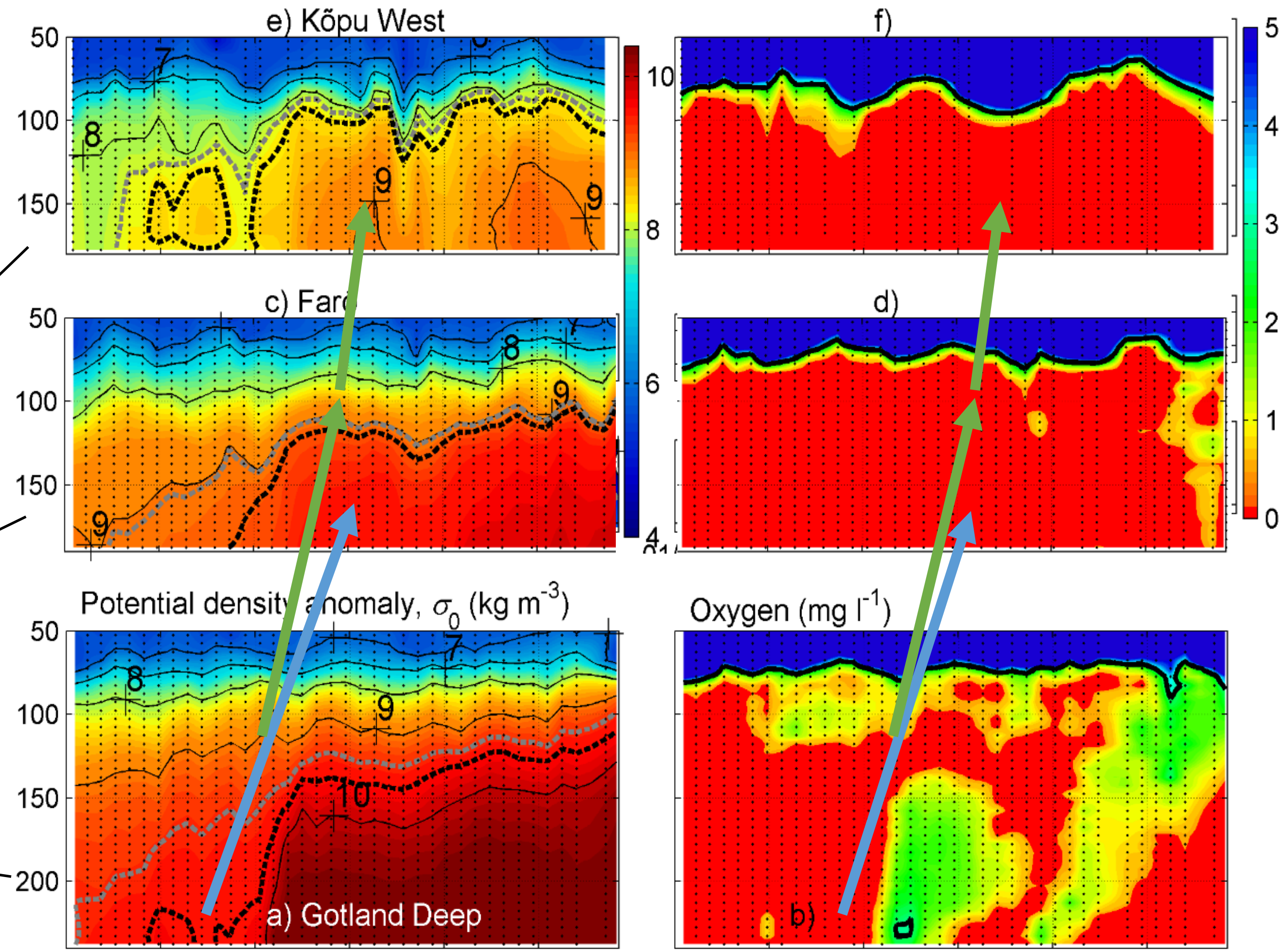




Salinity in the Gotland Deep 1986-2016



# Density and oxygen time-series, 2014-2016, 50-240 m




Fresh oxygen was consumed by 3-6 months in the near-bottom layer of the Gotland Deep

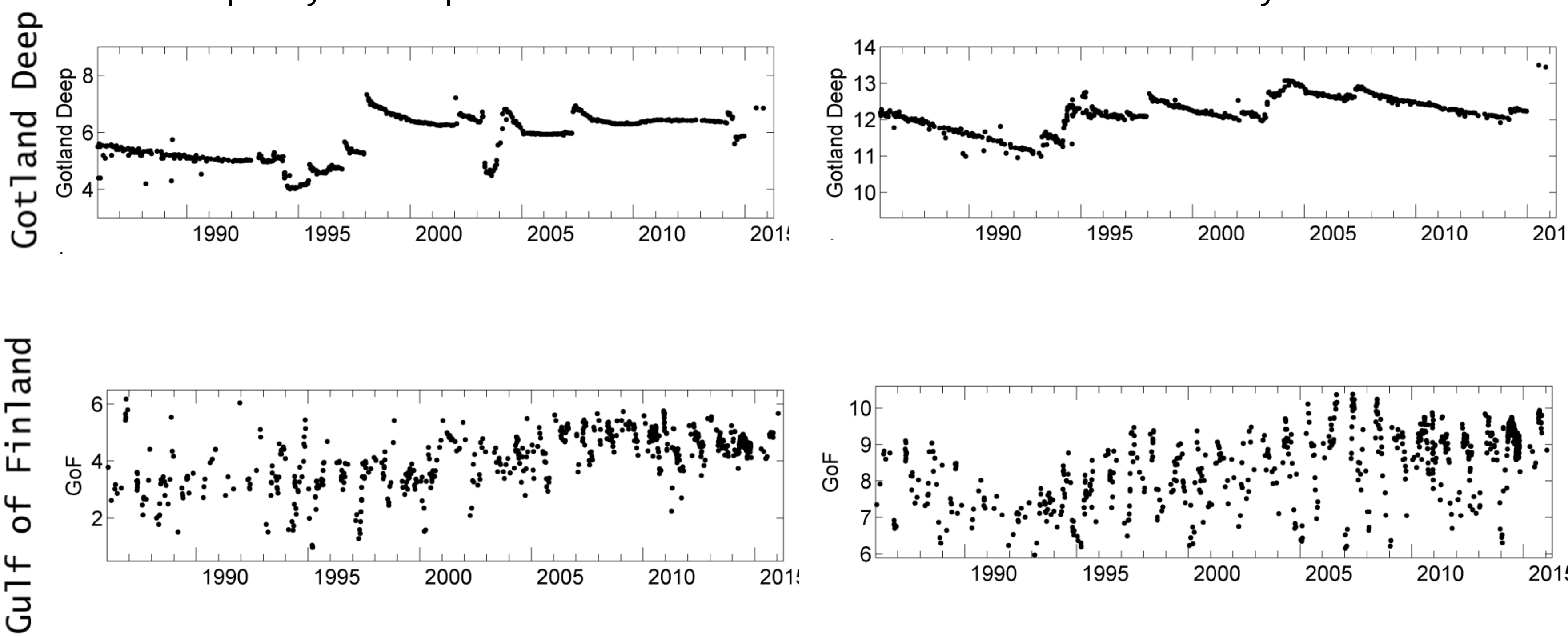
The old anoxic Gotland Deep water was pushed to Farö Deep

Sub-halocline mid-layer flow intensified after large inflow and that water occupied deep layer of the northern Baltic Proper

Liblik et al. 2018. Frontiers.

# Near bottom layer in the Central Baltic Proper vs. Gulf of Finland

Deep layer temperature …  … and salinity

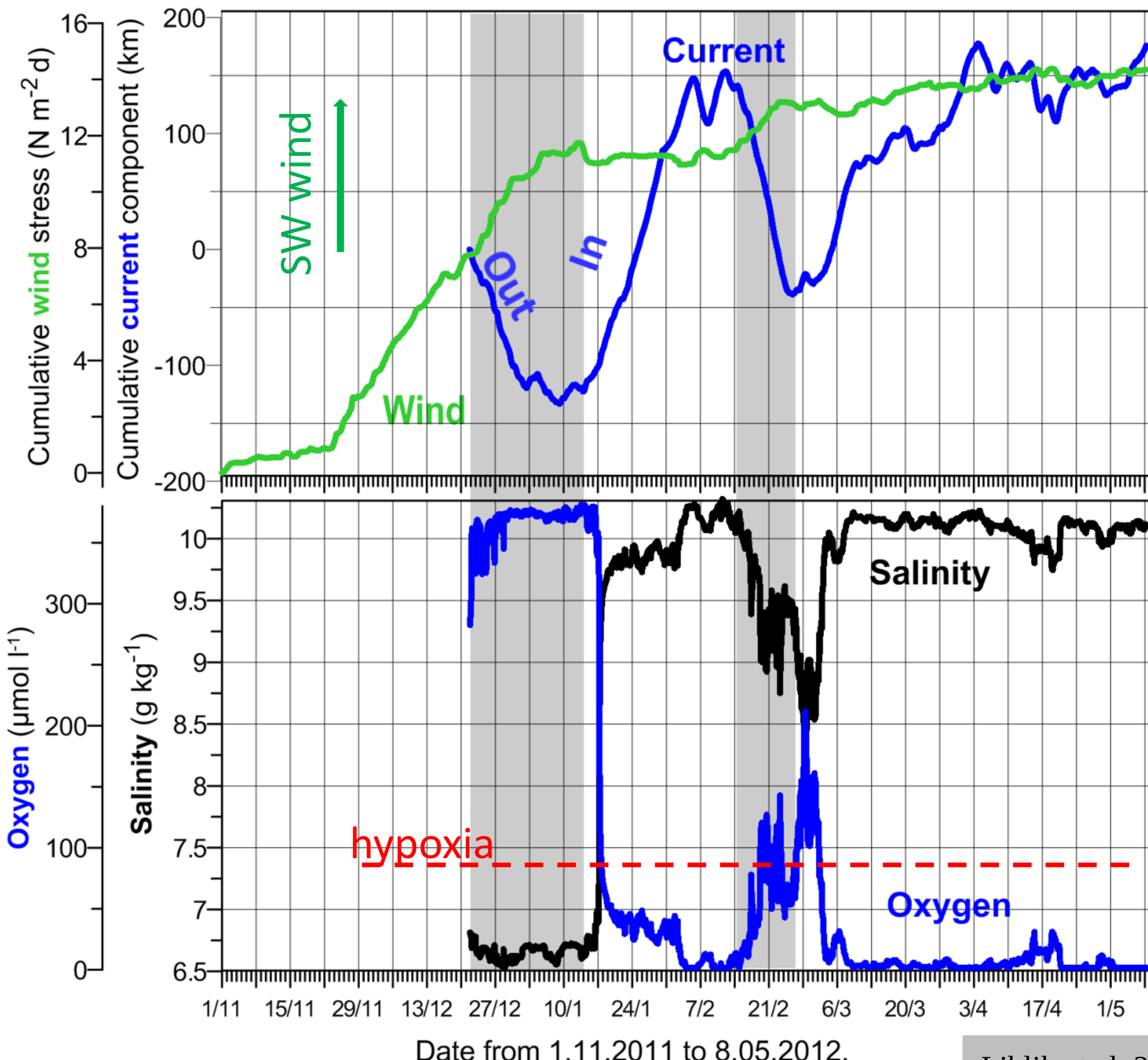


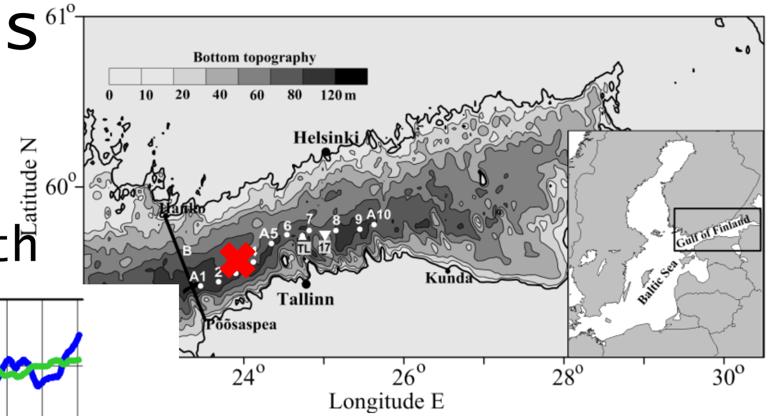

**Central Baltic Proper**: Long term changes are determined by rapid salt pulses, otherwise short-term variability is low.

**GoF**: Large amplitude of synoptic scale variability, but long-term changes can be seen on the background.

# Estuarine circulation and its reversals 2011/12 winter

Near-bottom time-series at 90 m depth




SW wind causes outflow, higher oxygen, lower salinity in the deep layer

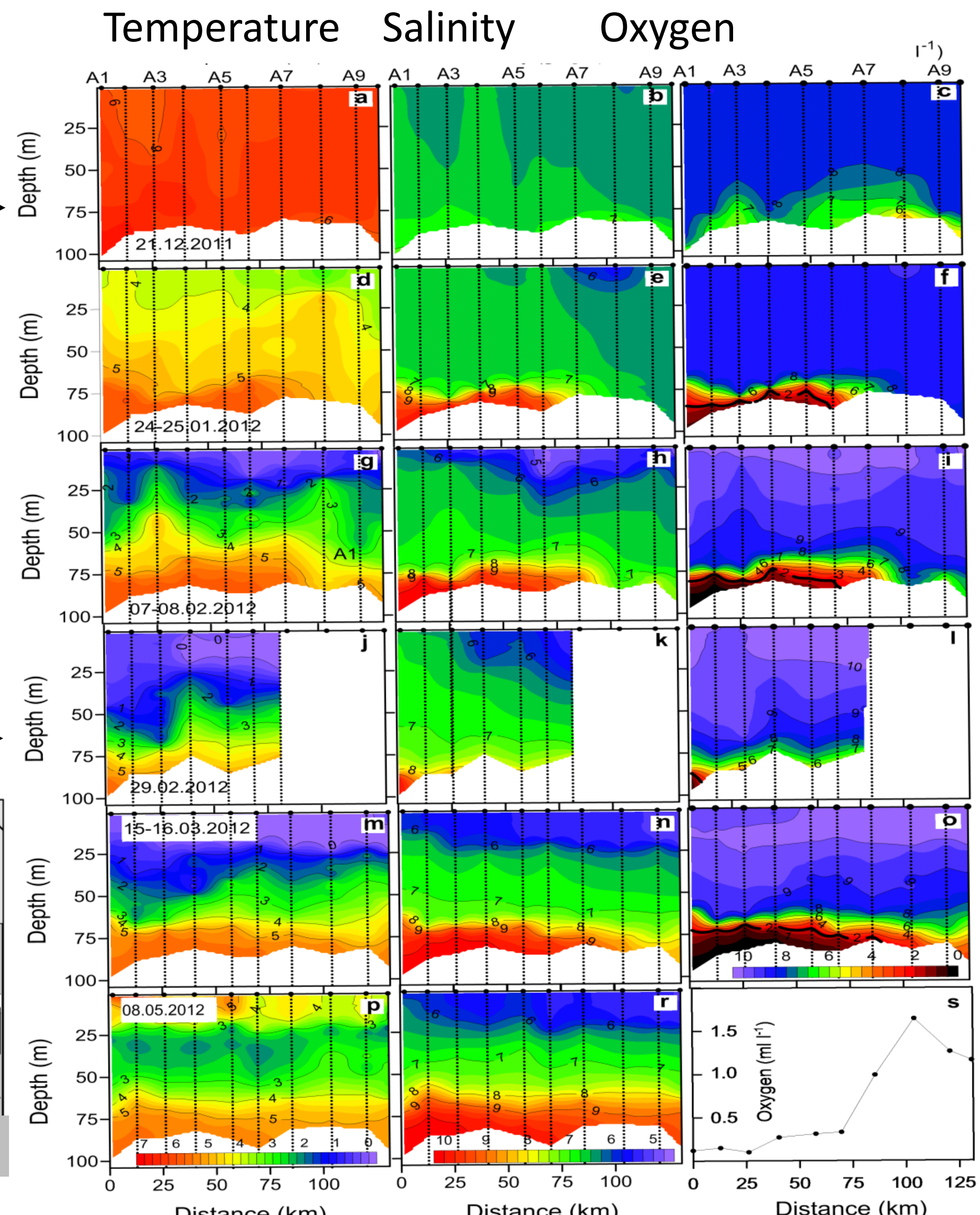
After relaxation of SW wind, hypoxic, saltier water re-establishes in deep layer

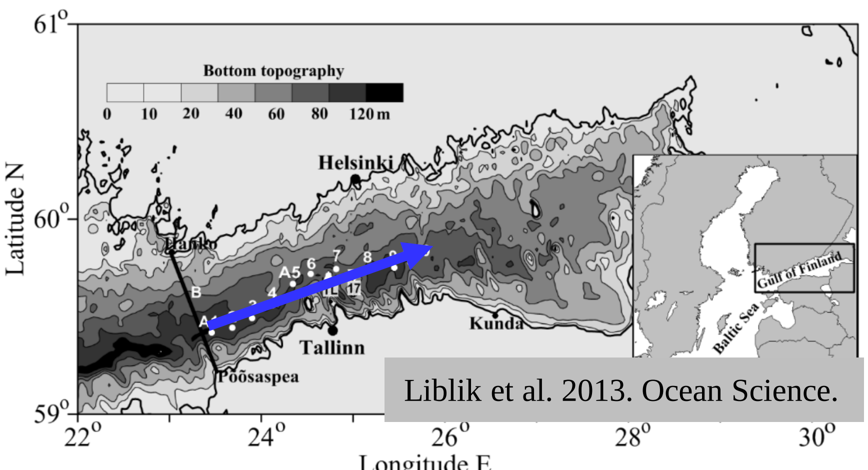
Liblik et al. 2013. Ocean Science.

# Estuarine circulation and its reversals 2011/12 winter

Major reversal event ->

Minor reversal event ->



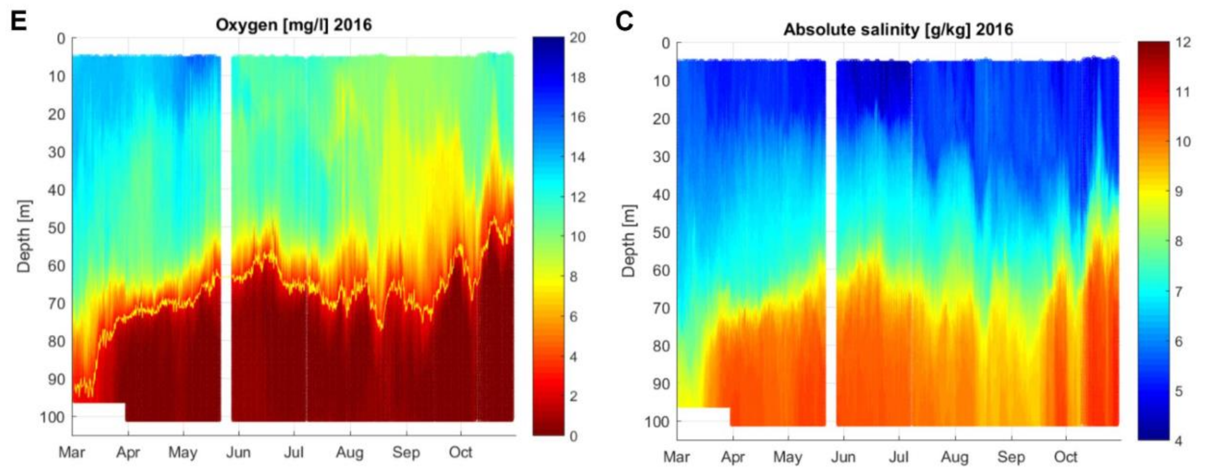



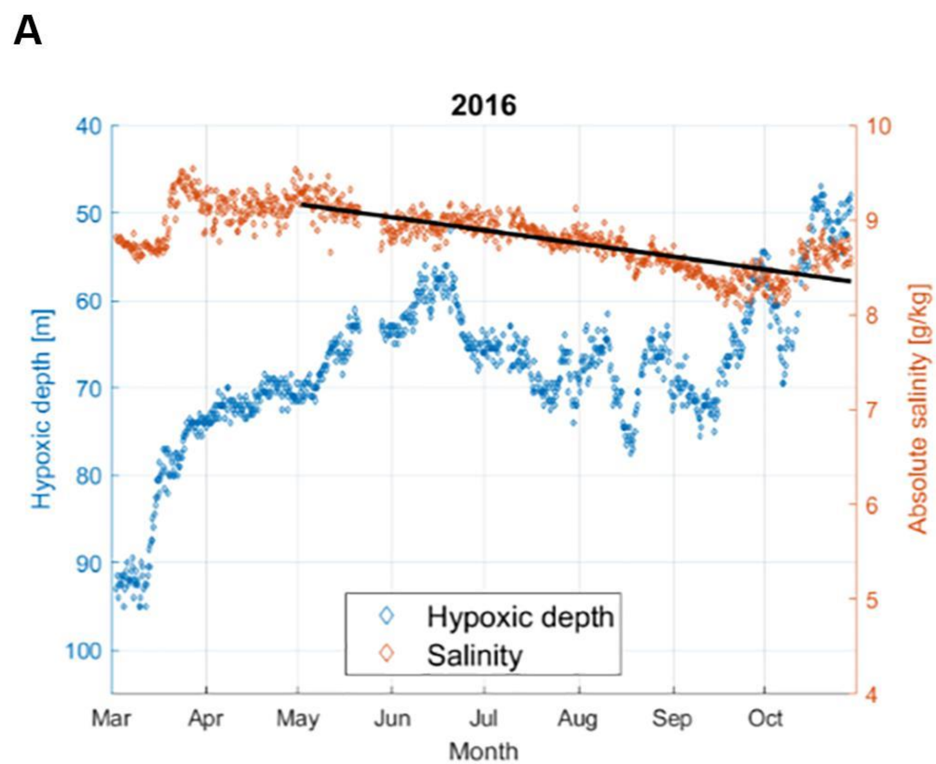

Liblik et al. 2013. Ocean Science.

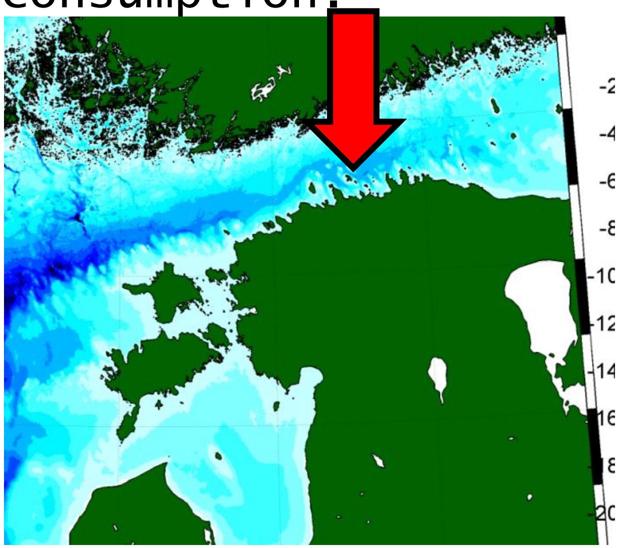
# Vertical profiling in the Gulf of Finland

Thickness of hypoxic layer in the GoF is linked to the halocline;

Import of hypoxic water from the Baltic Proper + local consumption.



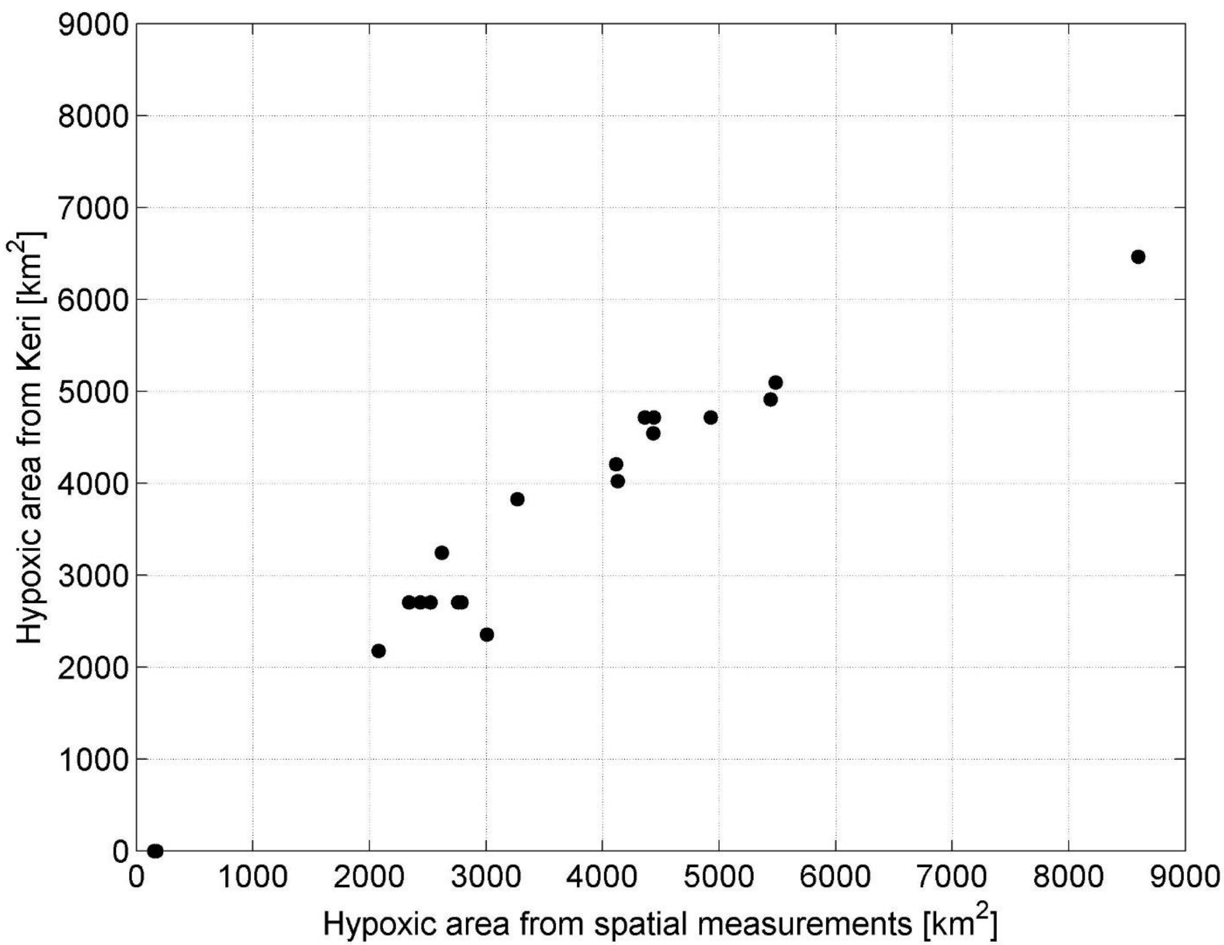



Stoicescu et al. 2019. Frontiers.

# Vertical profiling in the Gulf of Finland

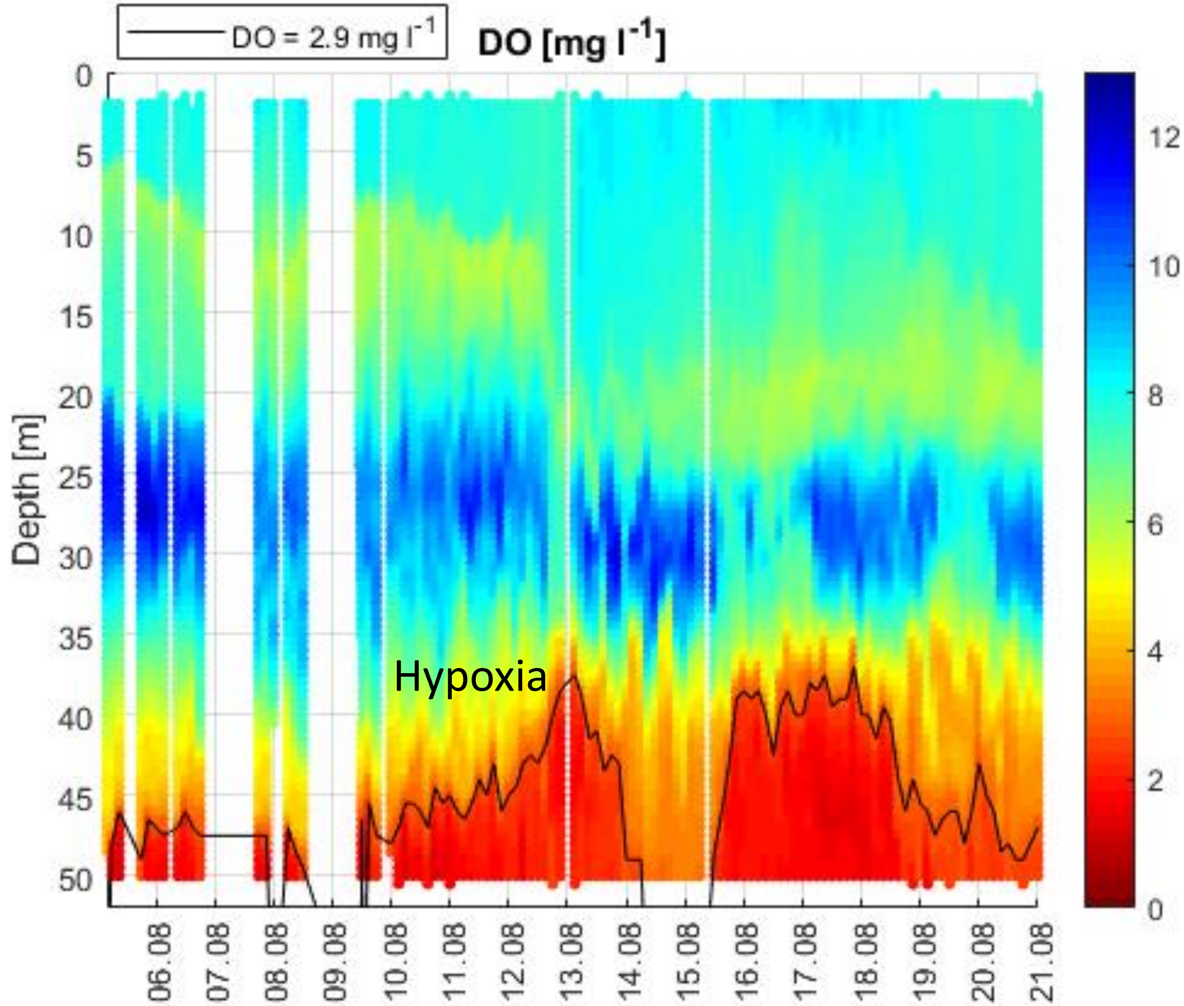
Vertical profiling at Keri quite well describes oxygen conditions in the whole Gulf.

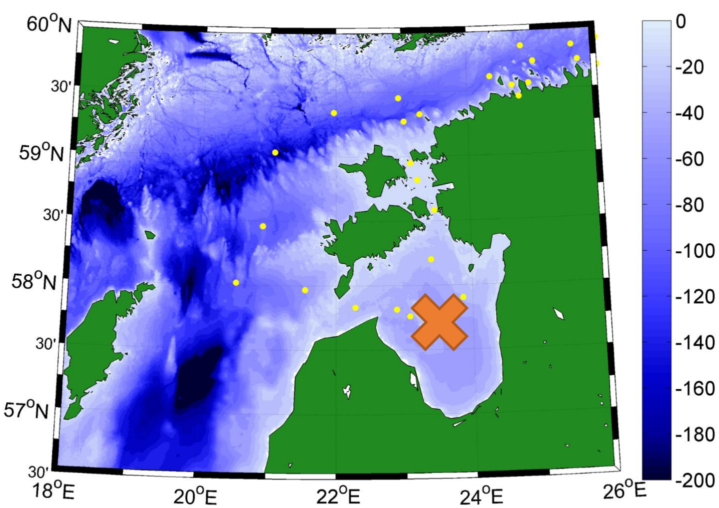
Vertical profiling allows to understand temporal changes between monitoring surveys



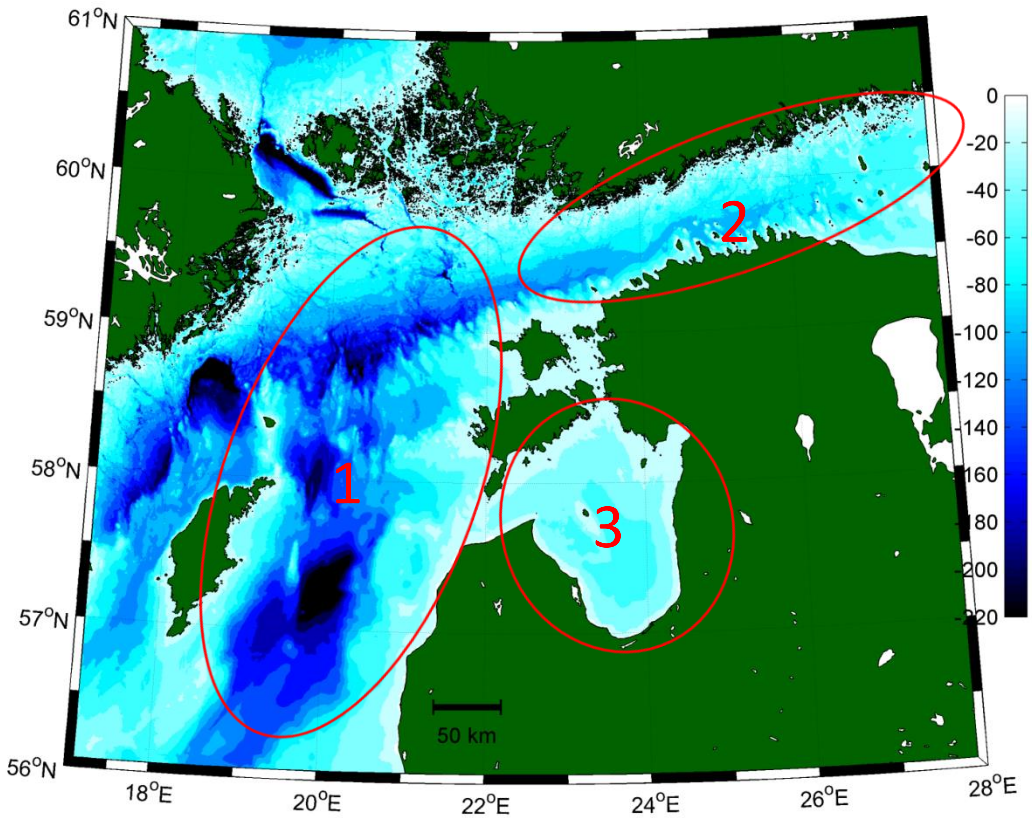
# Gulf of Riga

High-resolution profiling in the Gulf of Riga revealed synoptic scale variations in the hypoxic up to 37 m depth.



# Modern monitoring system should be able to capture signals in appropriate spatiotemporal scales



# Monitoring in Global Ocean

In-situ ship-borne:

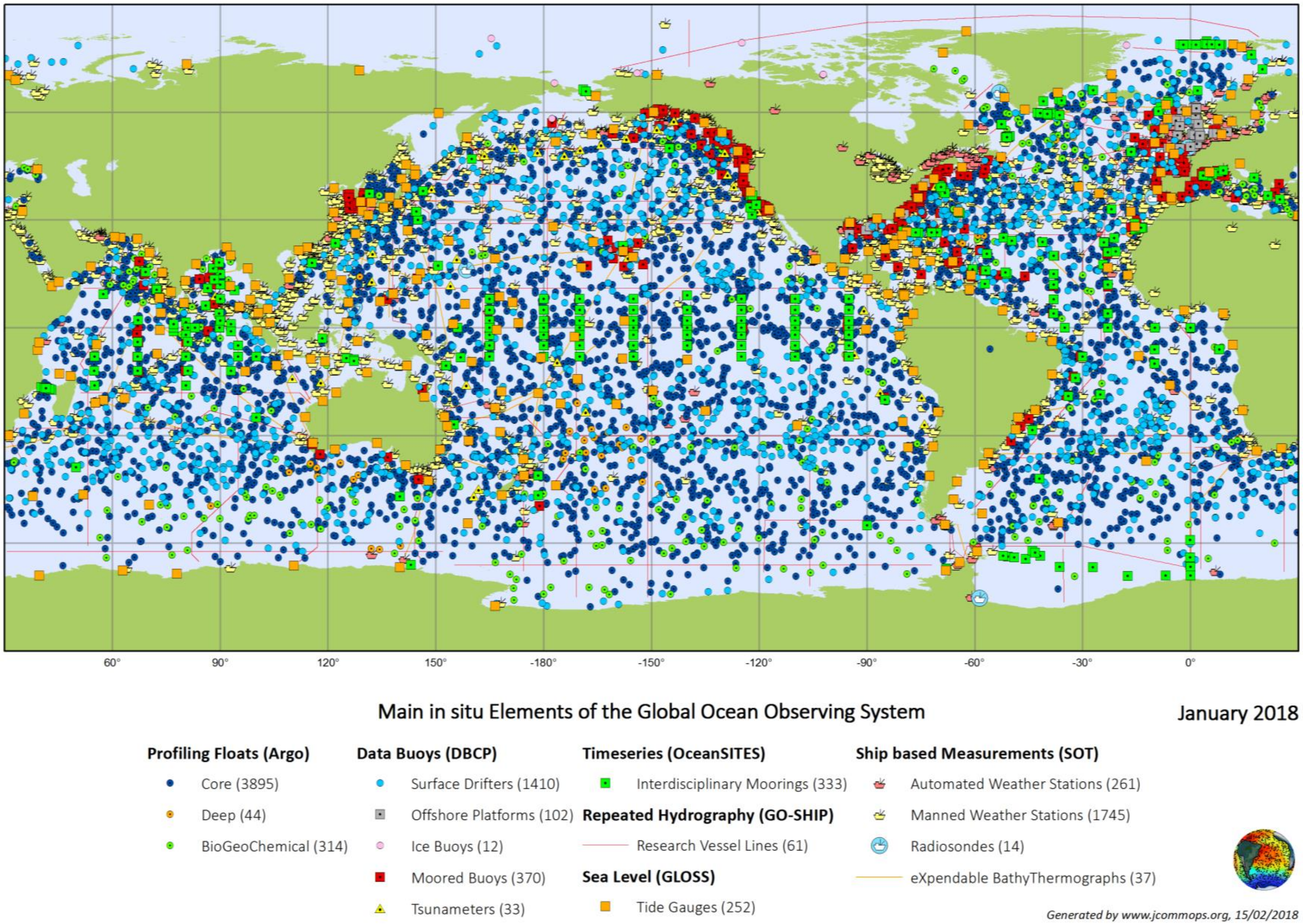
- GO-Ship programm + national programs

In-situ autonomous:

- Voluntary Observing Ship program and Ships of Opportunity Program;
- Argo float array
- Global surface drifter array
- Coastal stations
- Moorings

Remote sensing

# GOOS (Global Ocean Observing System) platforms.



# Autonomous monitoring in Global Ocean and Baltic Sea

## Global:

- Voluntary Observing Ship program and Ships of Opportunity Program;
- Argo float array
- Global surface drifter array
- Coastal stations
- Moorings
- Underwater gliders
- Remote sensing

## Baltic Sea:

Ferrybox measurements in the upper layer;

Few Argo floats in the Baltic, case studies only;

Case studies with drifters only;

Coastal stations network exists (sea level, temperature);

Few long-term moorings established;

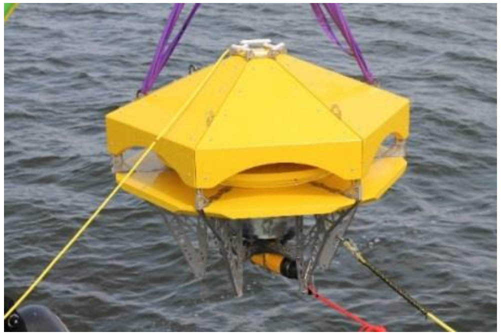
Scientific glider surveys only;

Remote sensing covers sea surface only, region specific algorithms needed;

# What autonomous platforms could complement sub-surface open sea monitoring in the Baltic Sea?

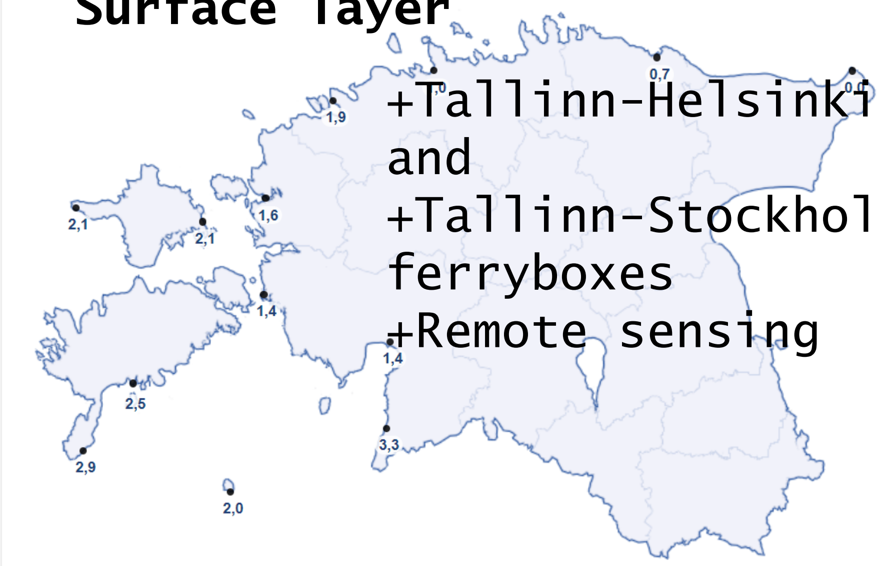
Baltic Sea:

- Ferrybox measurements
- Argo floats
- Drifters
- Coastal network
- Long-term moorings
- Gliders
- Remote sensing



# Sustainable autonomous measurements in Estonian waters

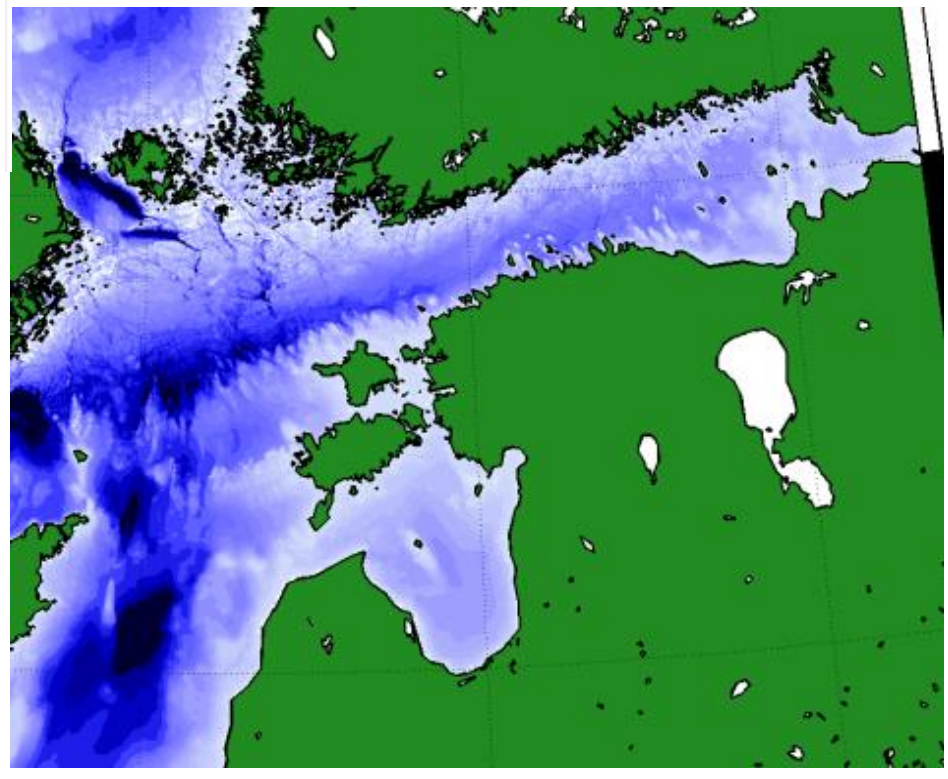
**Surface layer**




+Tallinn-Helsinki and +Tallinn-Stockholm ferryboxes

+Remote sensing

**Water column**



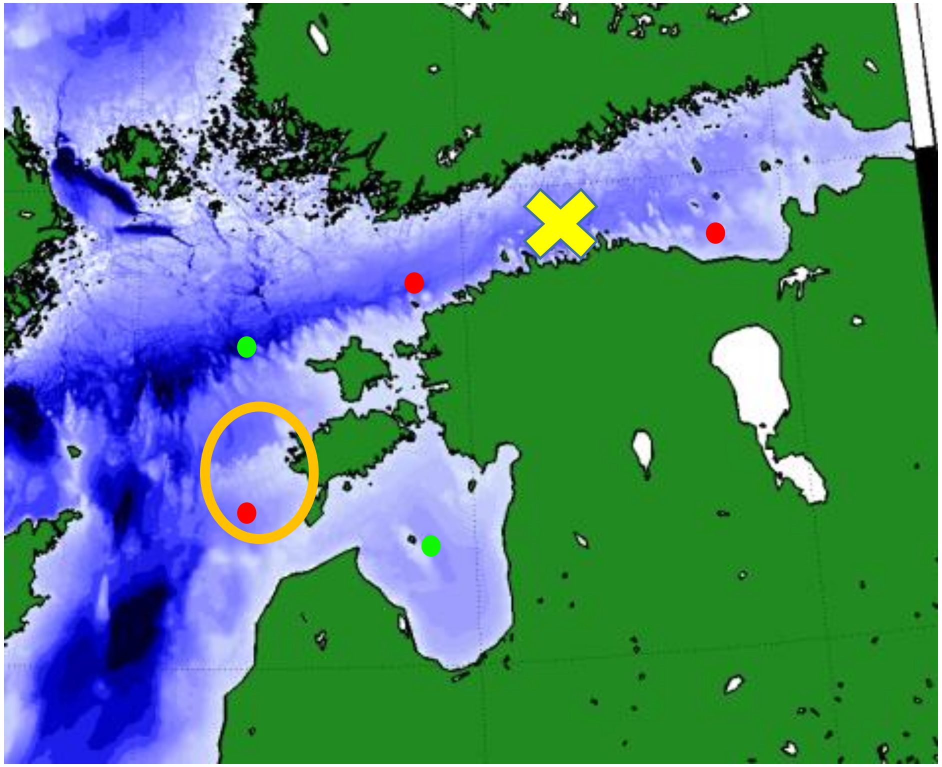
# Actions planned to improve monitoring

- Research vessel access must be maintained. New research vessel 2024.
- Profiling station at Keri Island is running since 2016. Project-based funding so far, sustainable funding mechanisms required.
- **Testing autonomous platforms for spatial characterisation of habitats.**
- Starting near bottom continuous point measurements in two locations in 2020.

- Applying funding (e.g. from Environmental Investment Centre, KIK) for starting point-measurements in another three locations.

- **Sensors from lab to sea**. Time-series of phosphates were measured in the near-bottom layer in the Gulf of Riga in 2019.

- International collaboration is needed. JERICO (Joint European Research Infrastructure for Coastal Observation) has been initiated by EC-funded projects. JERICO progress towards ESFRI is planned.



# RITA: Parameters and variability

**Selected key parameters related to the pelagic ecosystems from MSDF:**

**Vertical profiles of**

Temperature

Salinity

Oxygen

Nutrients

Currents

**Variability in various spatiotemporal scales might be important:**

- Long-term (decadal) changes related to the changes in freshwater discharges, inflow activity from the North Sea and atmospheric forcing.
- Inter-annual variability.
- Annual cycle / seasonality.
- Synoptic scale processes:
  - across boundary/coastal slope pycnocline variations (including up/downwellings)
  - along boundary advection
  - variability in vertical mixing
  - mesoscale eddies and fronts
- Submesoscale processes.

# RITA: Data

**Measurements**

**Validation**

**Model and remote sensing data**

- Available monitoring data (HELCOM database, Copernicus)

Arranged during the project:

- Ship-gathered profiles and samples
- Surface data by flow-through system
- Glider deployments
- Current profiling by moored ADCP

- Baltic Sea Physics reanalysis (003_011), 1993 to 2016
- Baltic Sea Biogeochemistry reanalysis, 4 km, 1993 to 2016
- Baltic Sea Physics analysis and forecast 31 May 2016 to present
- Baltic Sea Biogeochemistry analysis and forecast, 31 May 2016 to present
- Sea surface temperature analysis (various products)

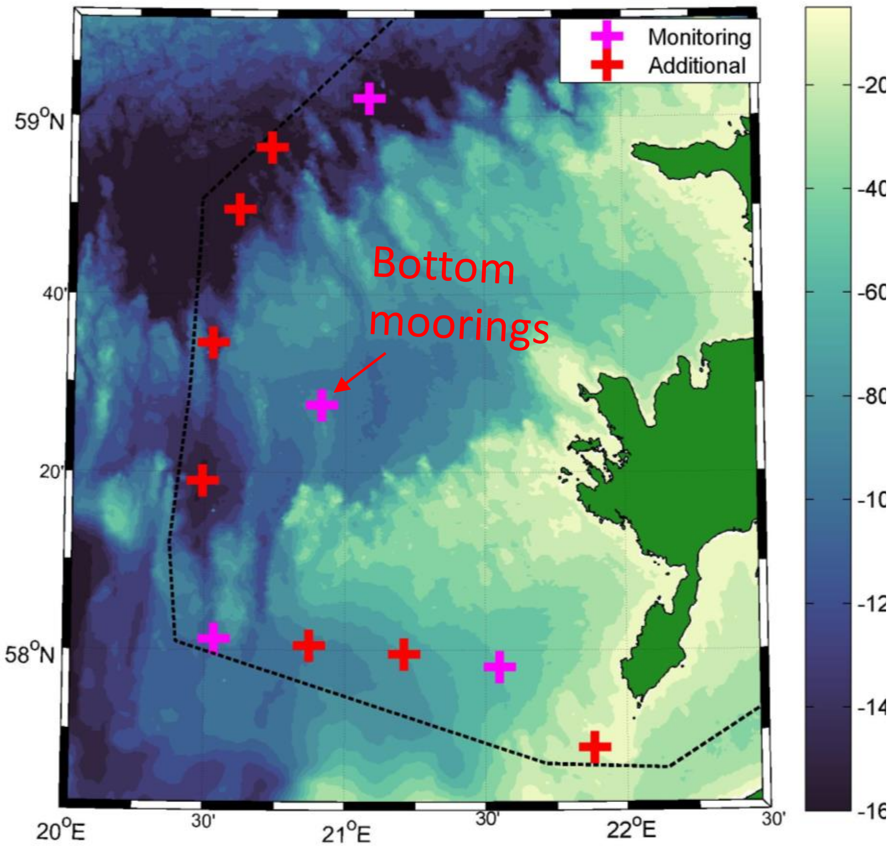
# Methods

- Variability in various scales will be described and understood.
- Model and remote sensing products will be validated and assessed. Uncertainties will be given. Empirical corrections of the model/remote sensing results will be suggested if possible.
- 3D time-series will be build from the combined data of measurements and the modelling/remote sensing products.
- Derived  key parameters will be estimated to characterize the pelagic habitats.
- Different monitoring strategies will be tested and suggestions for the monitoring program in future will be given.

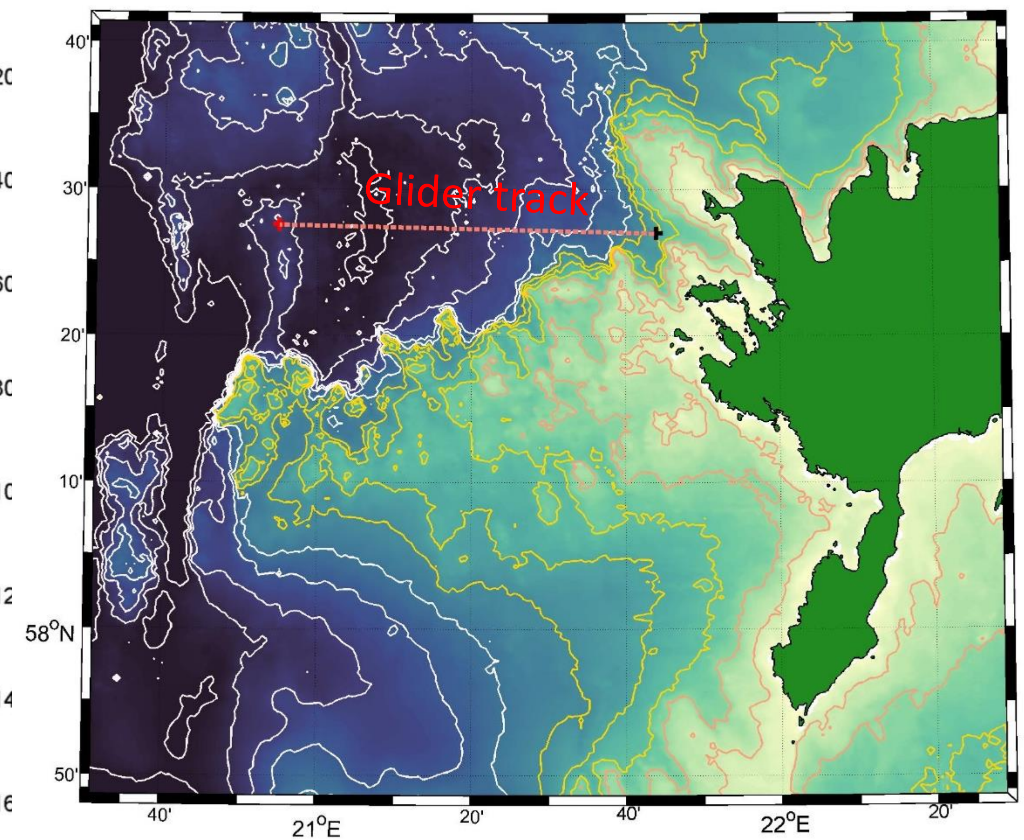
# Derived key parameters

- T/S/density/$O_2$/nutrients/currents in the upper mixed layer, intermediate layer, deep layer.
- Vertical gradients between the three layers.
- Meridional and zonal (coastal-offshore) gradients of the parameters.
- Thermocline/halocline depth and strength.
- Vertical profiles and vertically integrated Apparent Oxygen Utilization.
- Bottom areas and volumes of hypoxia.
- Nutrient pools.
- Circulation pattern.

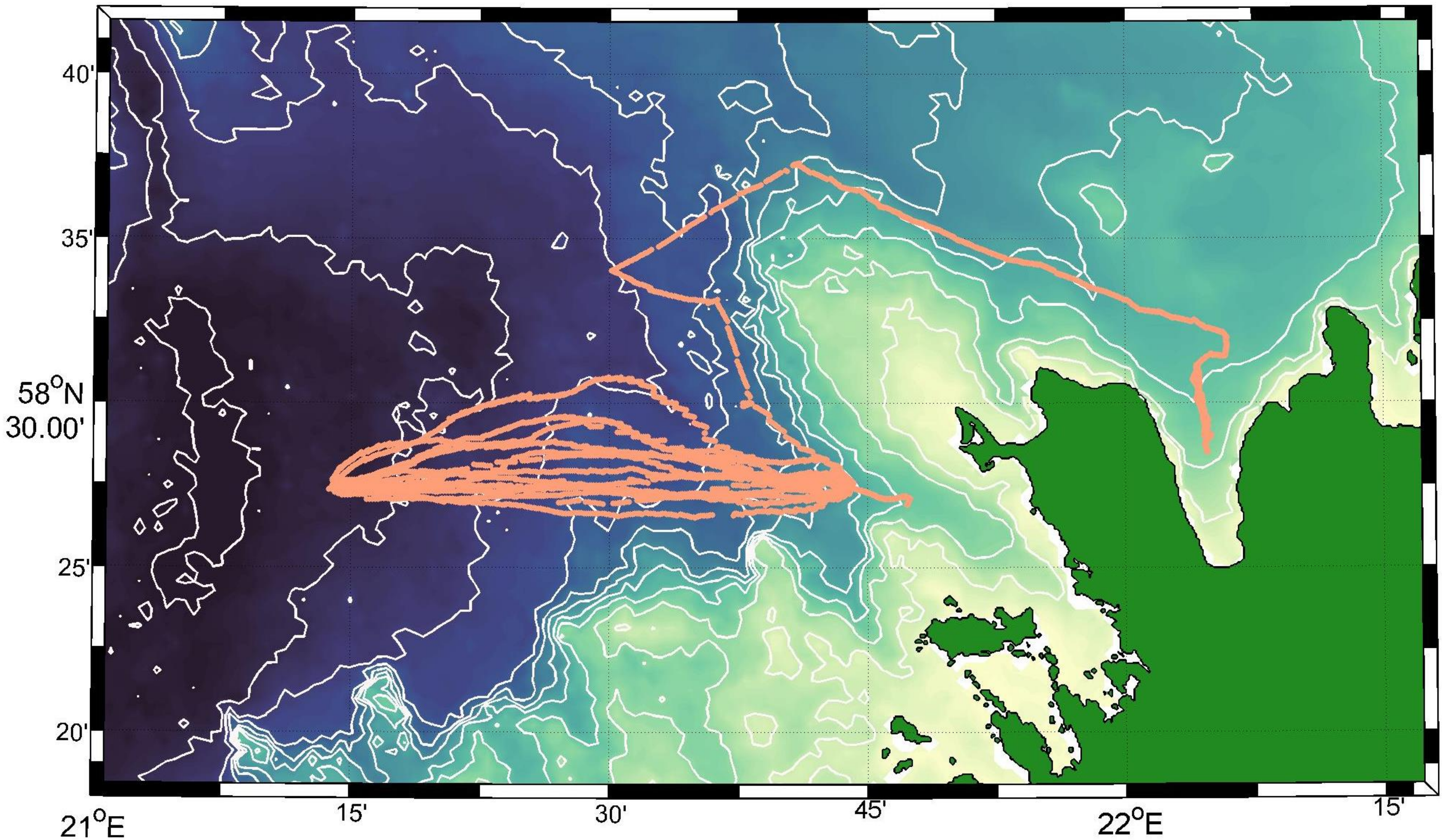
Extended monitoring




Glider surveys



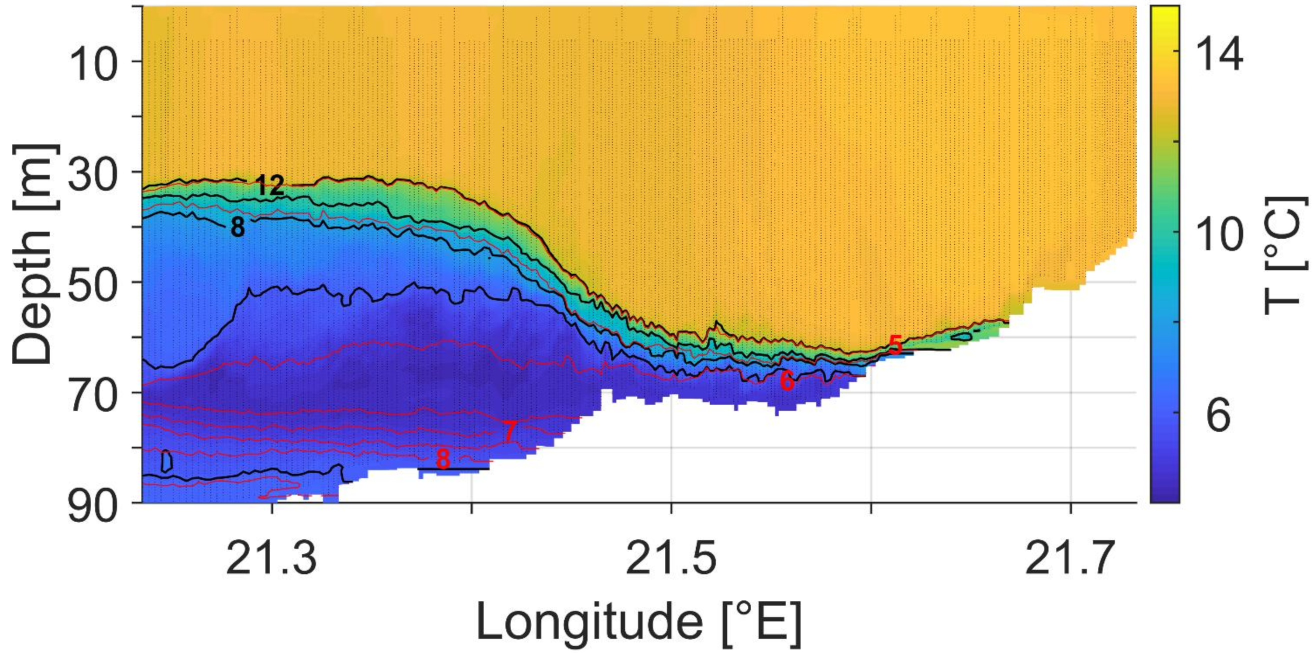
# Glider survey Sep-Oct



# Glider survey Sep-Oct 2019

Section was repeated 15 times during on month survey;

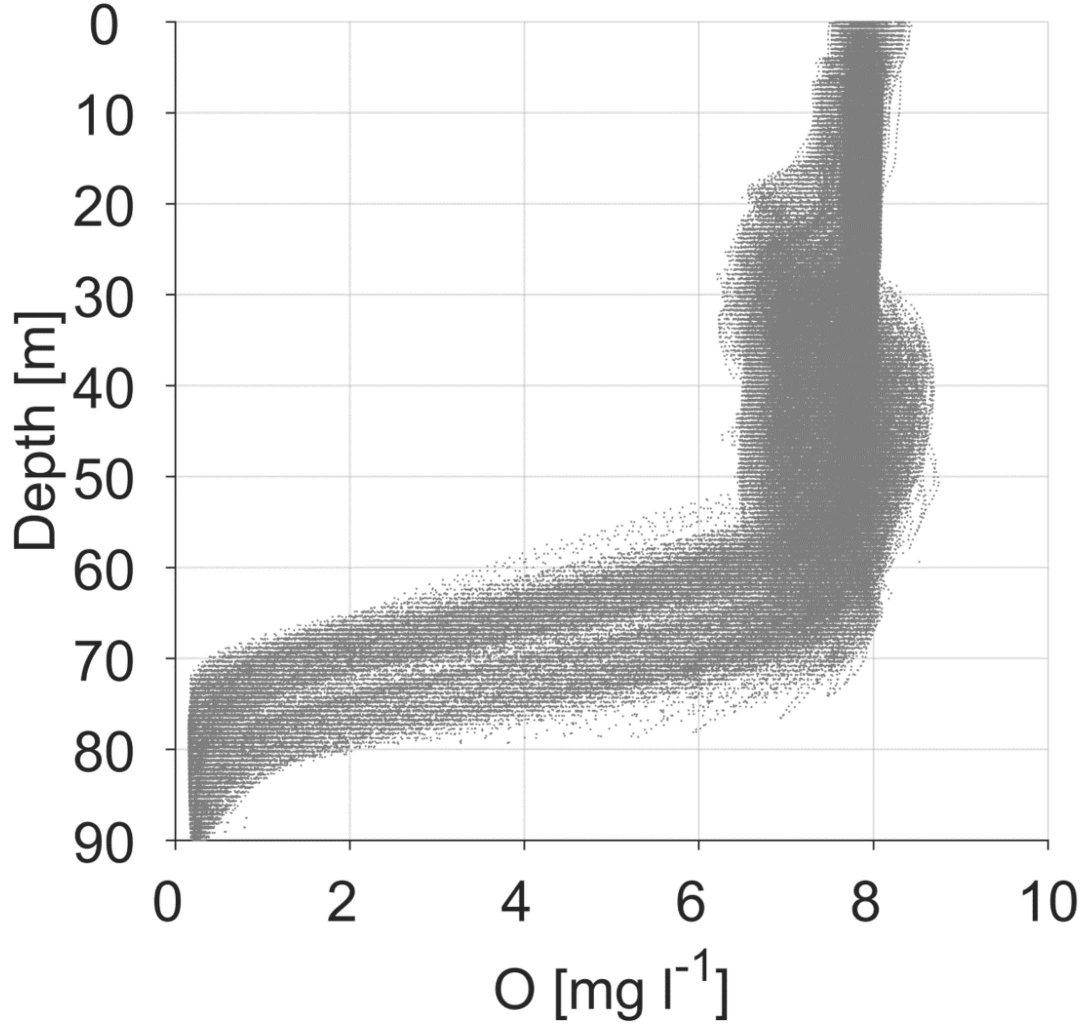
Example of temperature distribution at section.



# Glider survey Sep-Oct 2019

Oxygen profiles during survey

Hypoxia was observed at the depth of 63 to 78 m



# Thank you!

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