Continuous Ferrybox measurements create new knowledge on essential processes in the marine environment

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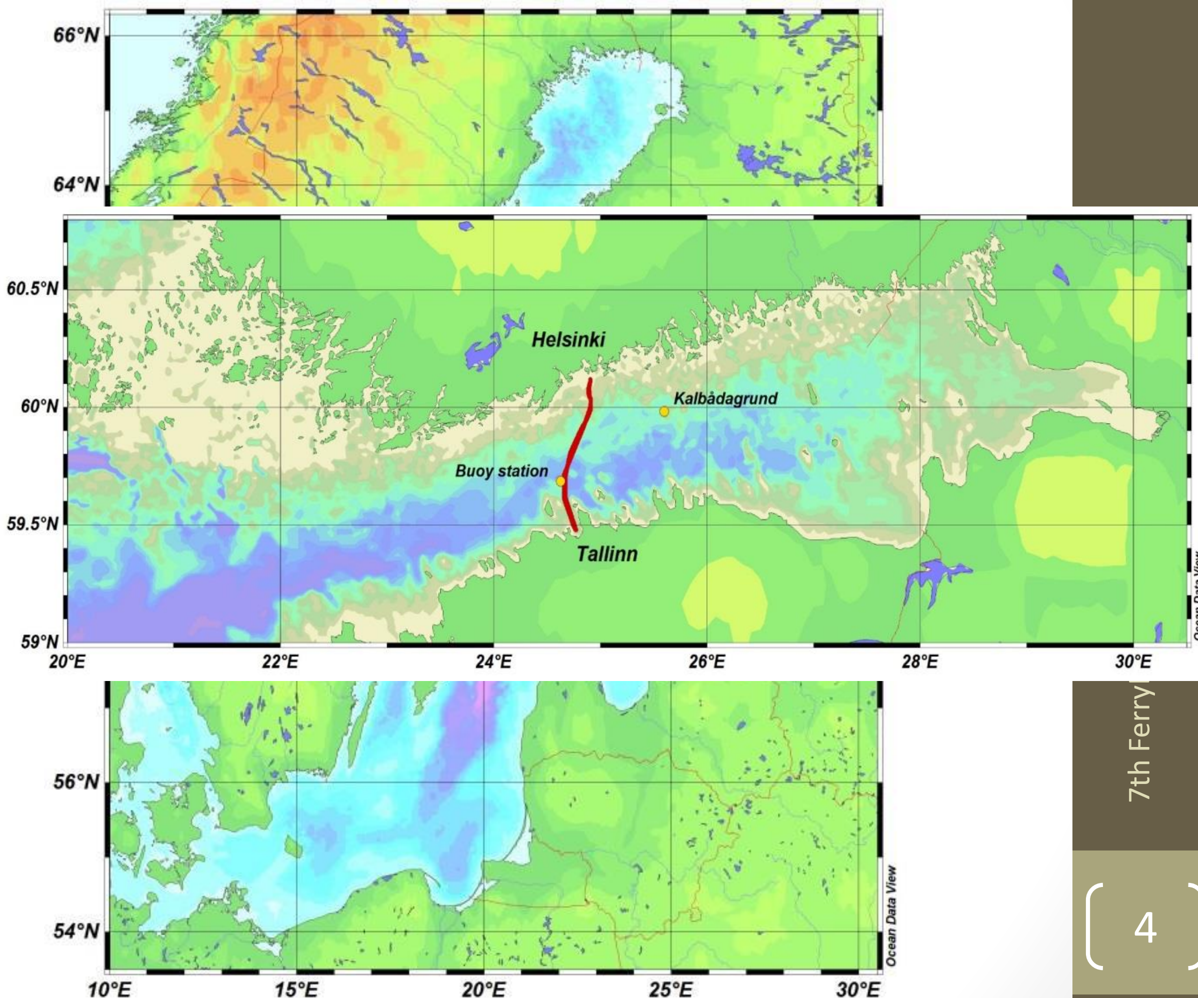
Background: Aim

- Collect continuos measurements between Tallinn – Helsinki
- Complement other oceanographic measurements – buoy station, CTD probing, satellite data etc

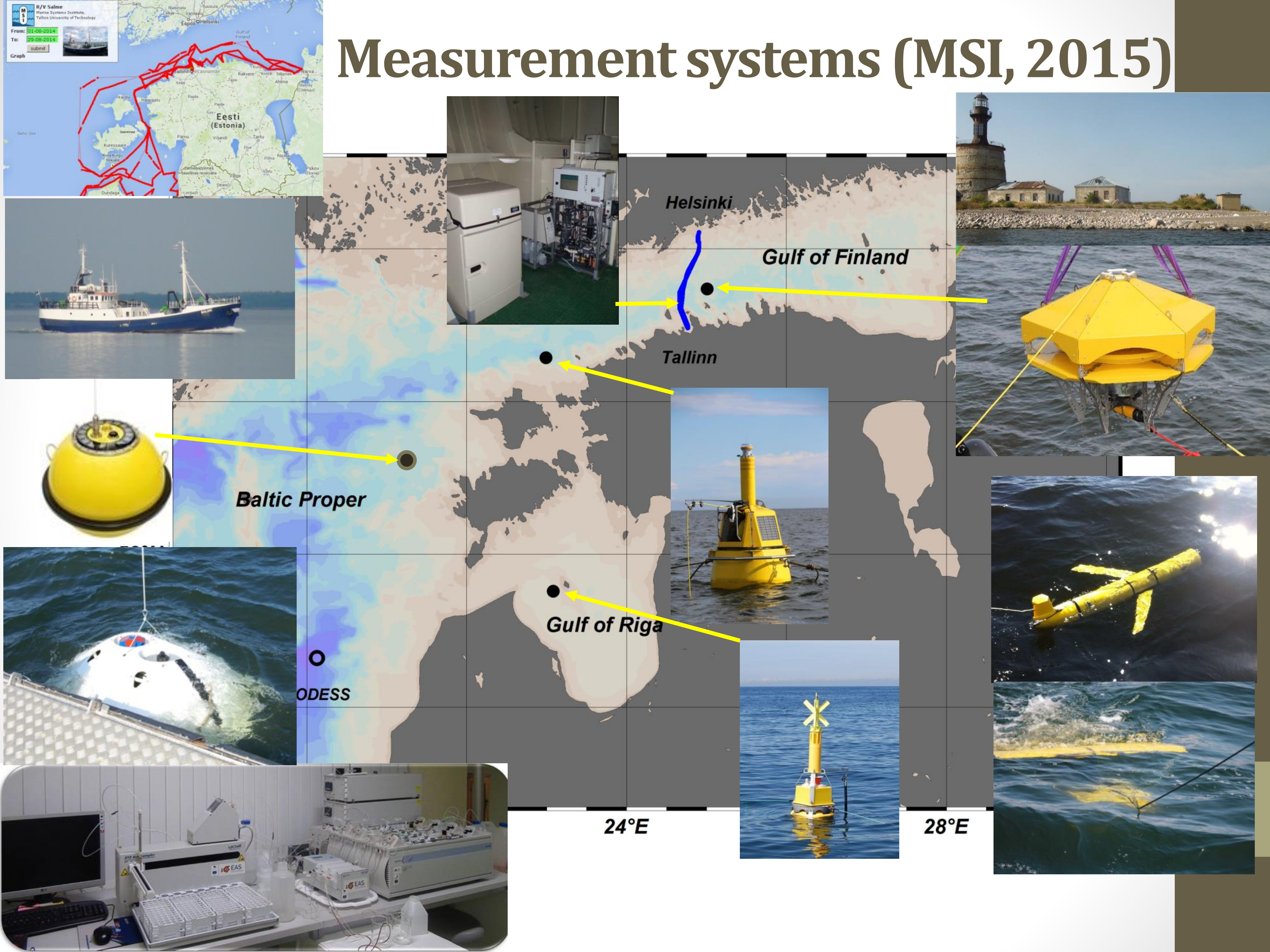
- (Sub)Mesoscale processes
  - Upwelling indexing
  - Upwelling Types

Background: Gulf of Finland

- The Gulf of Finland is a typical **deep/stratified** and **wide** (400km by 135 km) estuary with a major fresh water inflow in the eastern end and relatively open water exchange with the Baltic Proper through the gulf's western boundary.
- Vertical stratification is characterized by a quasi - permanent **halocline** at depths of 60-70 m, and a **seasonal thermocline**, which forms at the depths of 10-20 m in spring-summer
- **Residual circulation** consists of an outflow of gulf's waters in the northern part and an inflow of open Baltic Sea waters in the southern part of the gulf.
- Wind-driven circulation in the Gulf of Finland is highly variable and is characterized by intense **meso-scale features – eddies, upwelling/ downwelling, coastal and frontal jet currents**, which can cause significant advection and mixing of water masses and substances (e.g. nutrients and phytoplankton).



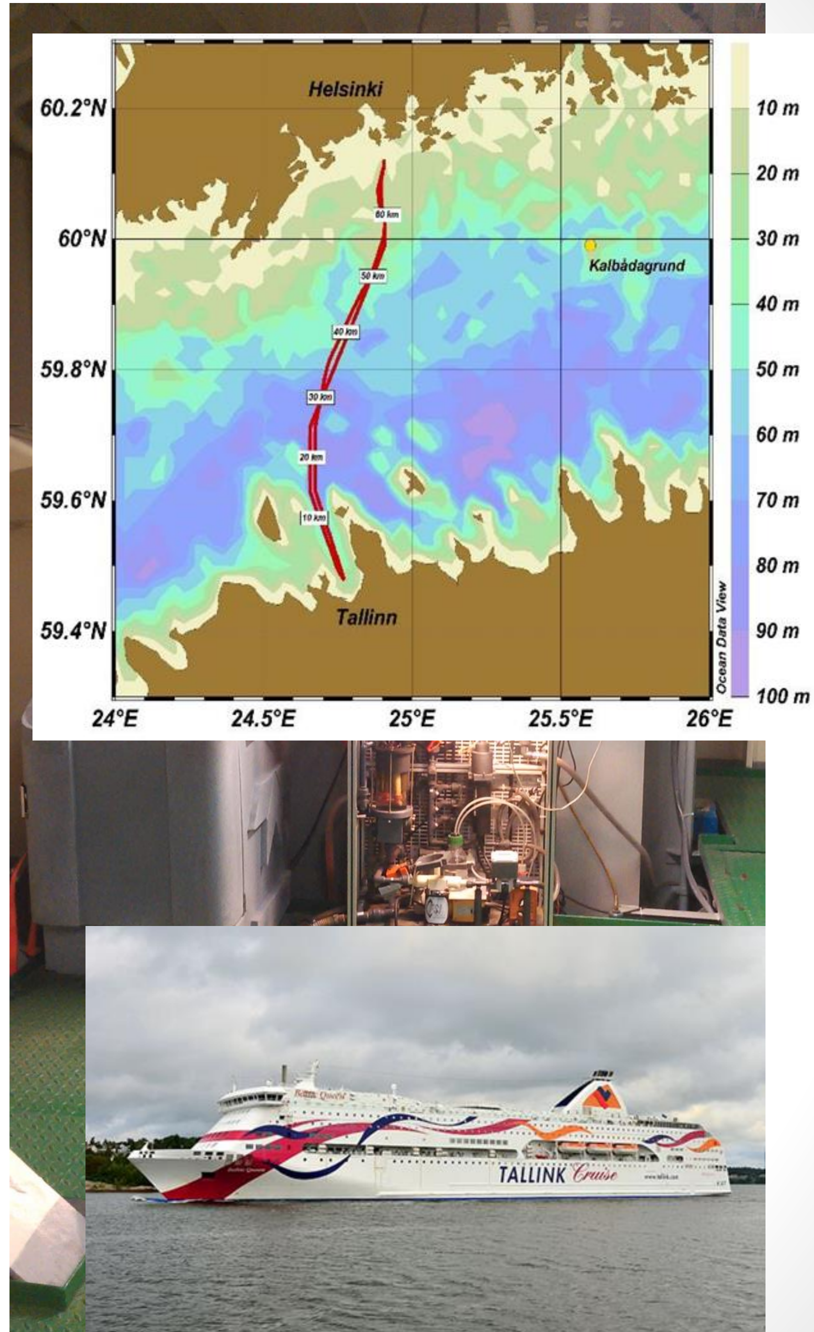
Measurement systems (MSI, 2015)



Ferrybox

- Since 2006 (*Galaxy, Baltic Princess, Silja Europa, Baltic Queen*)
- 4H-Jena FerryBox I
- FSI salinograph
- SCUFA
- PT100 temp. sensor
- ISCO 5800

- Data every 20 sec
- Acid cleaning every night
- 2x11 watersamples weekly/bi-weekly



Upwellings in GoF

- The Finnish coastal sea in the north-western GoF is one of the main upwelling areas in the Baltic Sea
- Mean upwelling area detected during 2000-2009 was 5642km2 (19% of the GoF surface area)
- Cross-share extent of upwelling area was 20-30km for northern coast and 7-20 km off the southern coast
- The intesity of upwelling events depends on the values of cumulative upwelling-favorable wind stress and strength of vertical stratification: 0.1 $\frac{N}{m^2}$ and 60h favorable wind
- Difference in topography, differing upwelling dynamics in opposite coasts

Data analysis

- 0.5 km step cell along transect – matrix with a constant spatial resolution
- cosine of the angle between the south-north direction and a perpendicular line to the shore – approximately 20 degrees
- Width of 20 km was selected on the basis of the analysis of all available temperature data from Tallinn-Helsinki ferry line in 2007-2013
- Upwelling index for both coasts: UI_S & UI_N

  - $UI_S = \sum_{\Delta T_i<0}^{i=1...40} |\Delta T_i|$ and $UI_N = \sum_{\Delta T_i<0}^{i=101...140} |\Delta T_i|$

    - ΔT temp deviation at 0.5 km cell i from the average temp of the crossing

Data analysis

- The cumulative upelling index (*CUI*)
- Obtained CUI values were divided by 40 to keep the meaning of CUI as the sum of average negative temperature deviations
- threshold value as 40 ℃, which corresponds e.g. to a 20-km wide upwelling with an average negative temperature deviation of 1 ℃

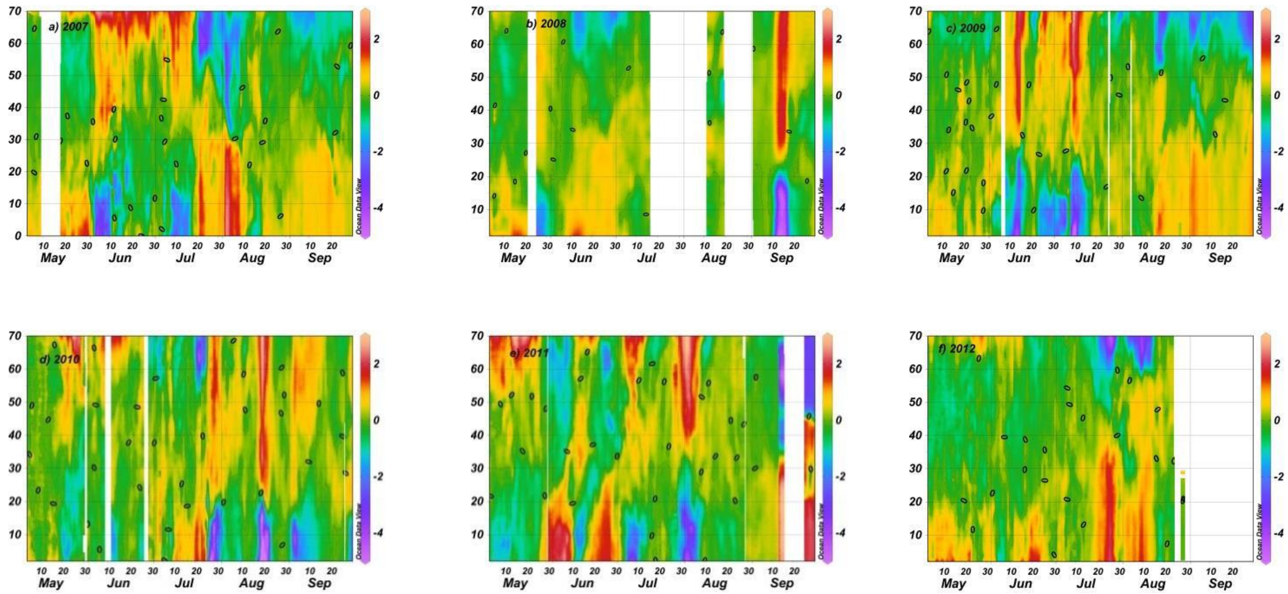
- Unit [°C day]

  - $CUI_S(n1 \ldots n2) = \sum_{j=n1}^{j=n2} \left(\frac{1}{40} UI_{Sj} \right)$
  - $CUI_N(n1 \ldots n2) = \sum_{j=n1}^{j=n2} \left(\frac{1}{40} UI_{Nj} \right)$

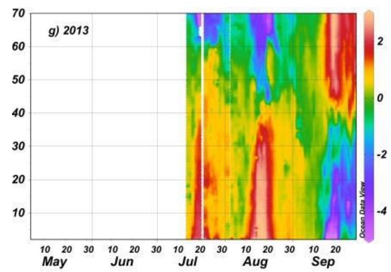
Wind data

- HIRLAM version of the Estonian Meteorological and Hydrological Institute
- Spatial resolution of 11 km
- Time interval of 3 h
- Location: Kalbådagrund
- 10 m height
- Wind direction turned by 20° counter-clockwise

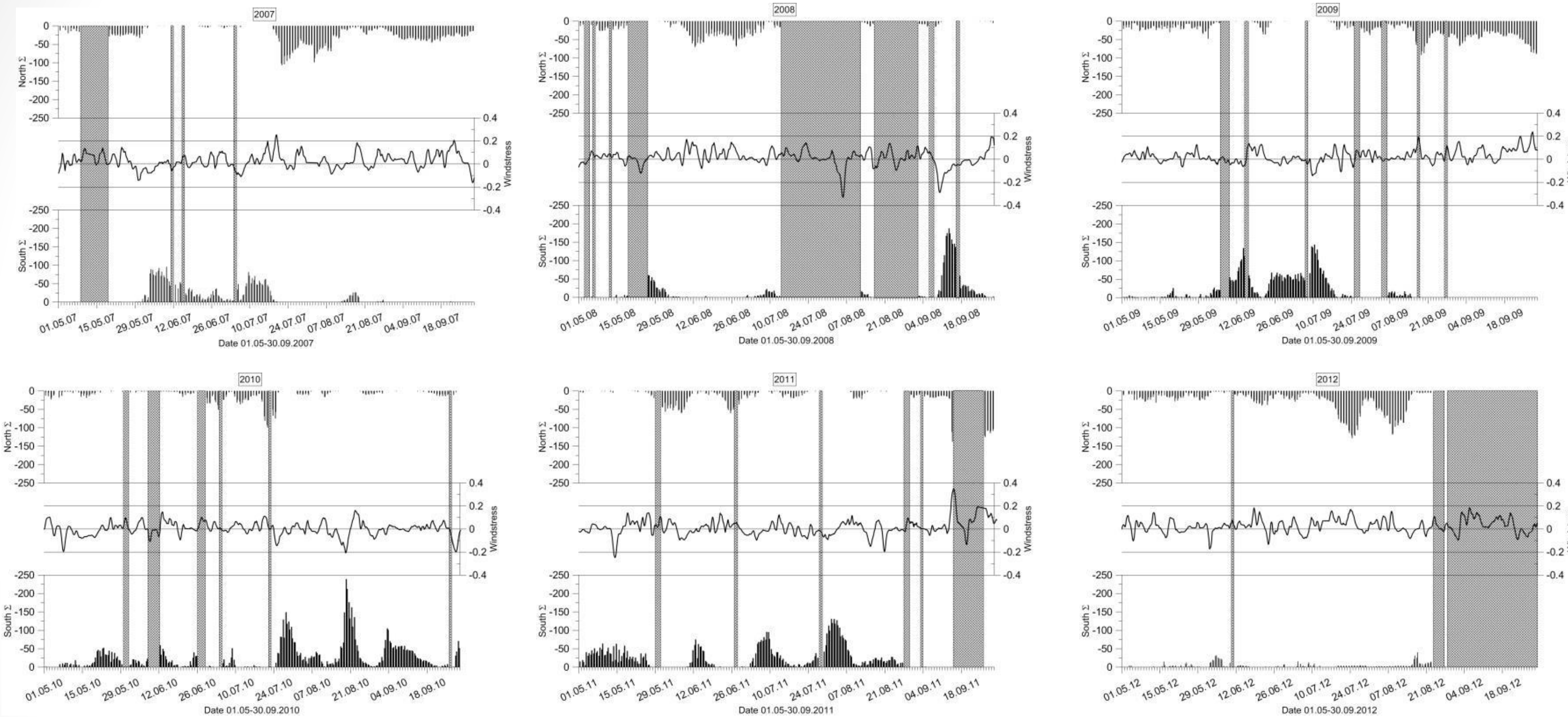
Results: Temperature data May-September 2007-2013



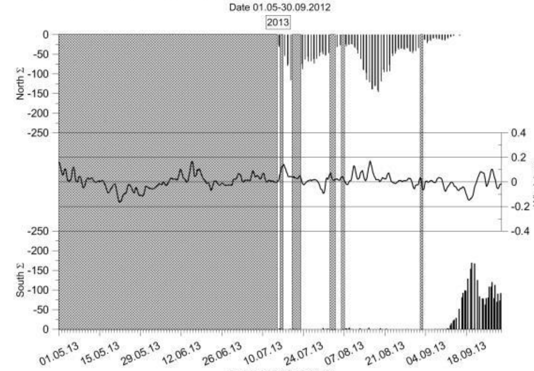
- **Temporal changes in spatial distributions of temperature deviations (in °C) from the daily transect mean value between Tallinn and Helsinki**



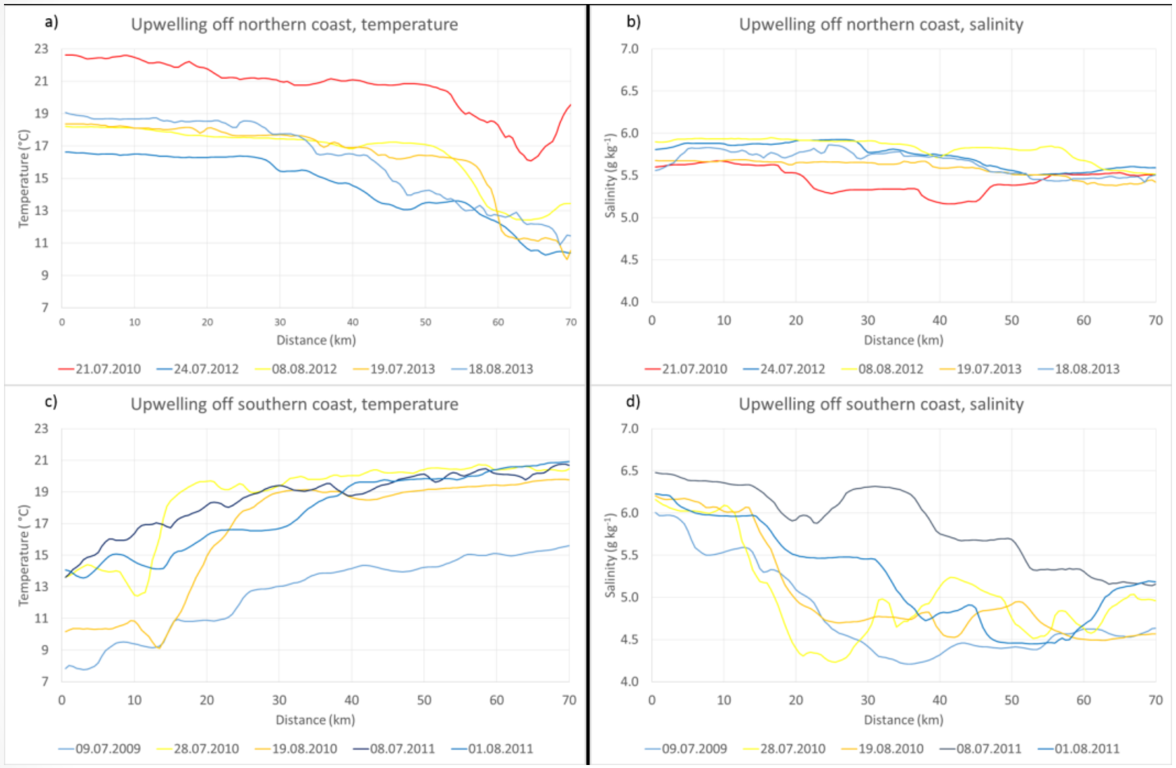
Results: *CUI* and wind data

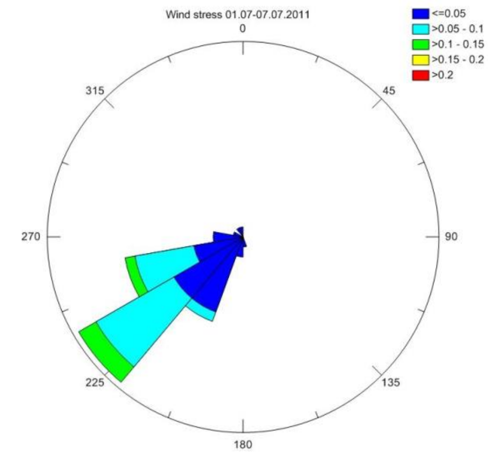


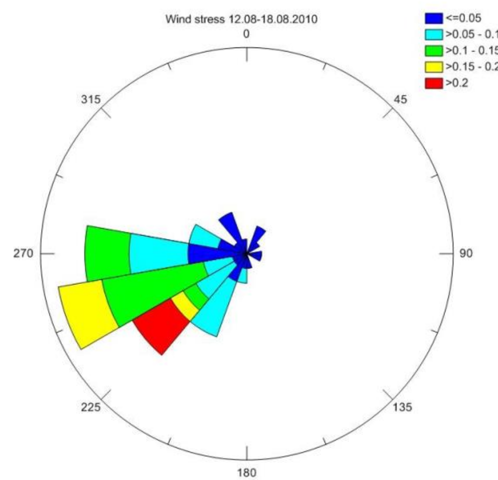
- **Temporal changes in upwelling index off the northern coast (upper columns; °C) and off the southern coast (lower columns, °C) and along-gulf wind stress (black curve in the middle; $\frac{N}{m^2}$)**
- **Maximum of upwelling index appears about 3 days after the wind stress peak**



Results: upwellings & wind stress



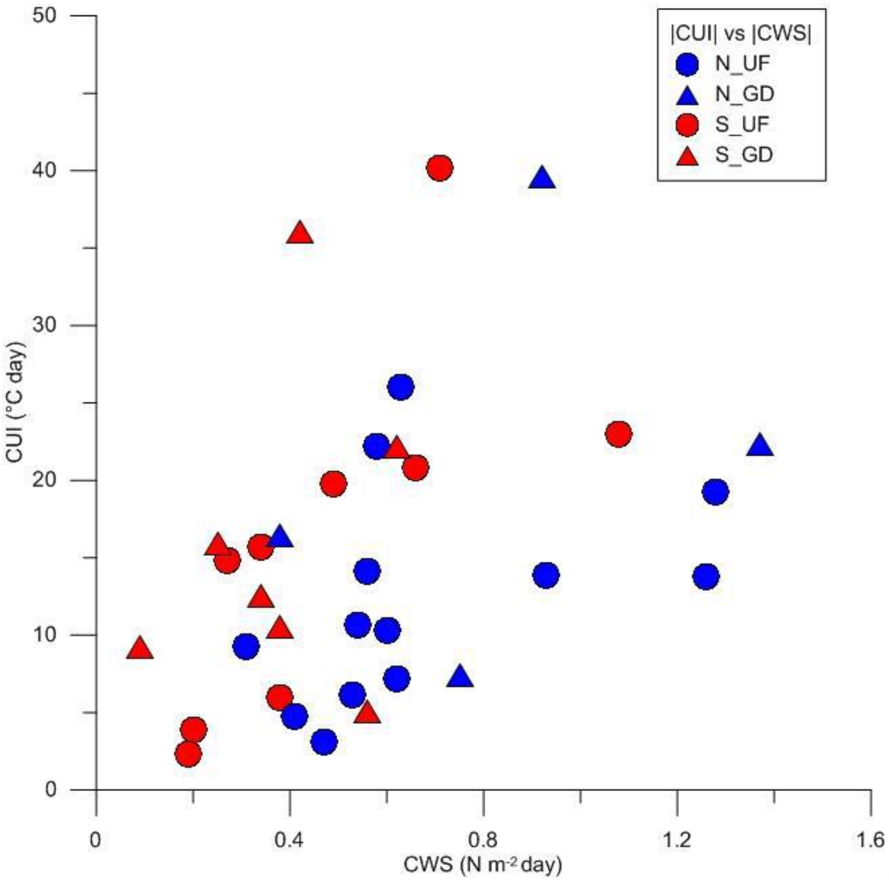




- Horizontal salinity gradient much stronger in case of upwelling events along the southern coast
- Stronger wind stress causes upwelling events with strong temperature front

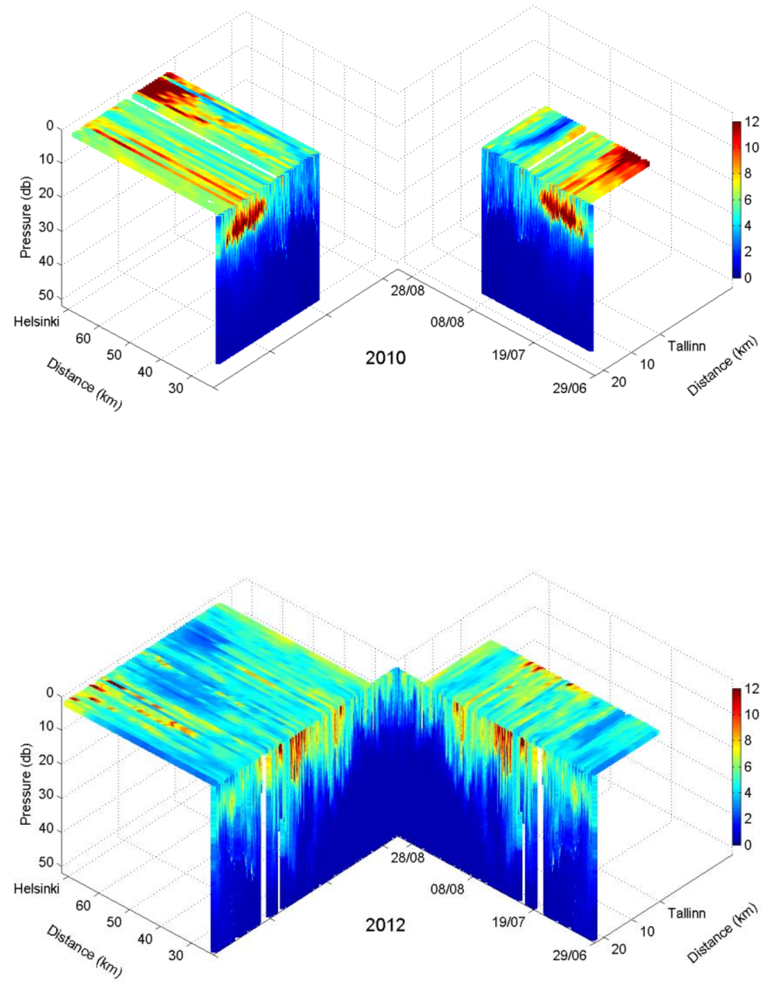
Results: different types of upwellings

- **The relationship between the cumulative upwelling index (CUI) and cumulative along-gulf wind stress (CWS) based on 33 detected upwelling events in May-September 2007-2013. Red symbols indicate the events off the southern coast and blue symbols the events off the northern coast; circles correspond to the events with pronounced upwelling front (N_UF and C_UF) and triangles the events with a gradual decrease in temperature towards the coast (N_GD and S_GD).**



Results: FB and buoy combined data

- Temporal changes in horizontal and vertical distribution of chlorophyll *a* (mg m-3) in the Gulf of Finland measured by the Ferrybox system between Tallinn and Helsinki and the autonomous buoy profiler at station AP5 from 29 June to 31 August in 2010 (a) and 2012 (b).



Conclusions

- Part of oceanographic monitoring system to observe environmental processes – continuous data from research area
- Reveling different physical processes – sub-mesoscale features and upwellings
  - 33 coastal upwelling events
  - 20 km wide coastal area (North and South of GoF)
  - Similar wind impulse
  - Two types of upwelling events were identified:
    - Strong temperature front
    - Gradual decrease of temperature from the open sea to the coastal area with maximum temperature deviation close to the shore

Thank you!