Six years of methane observations in the Baltic Sea:

inter-annual variability and process studies

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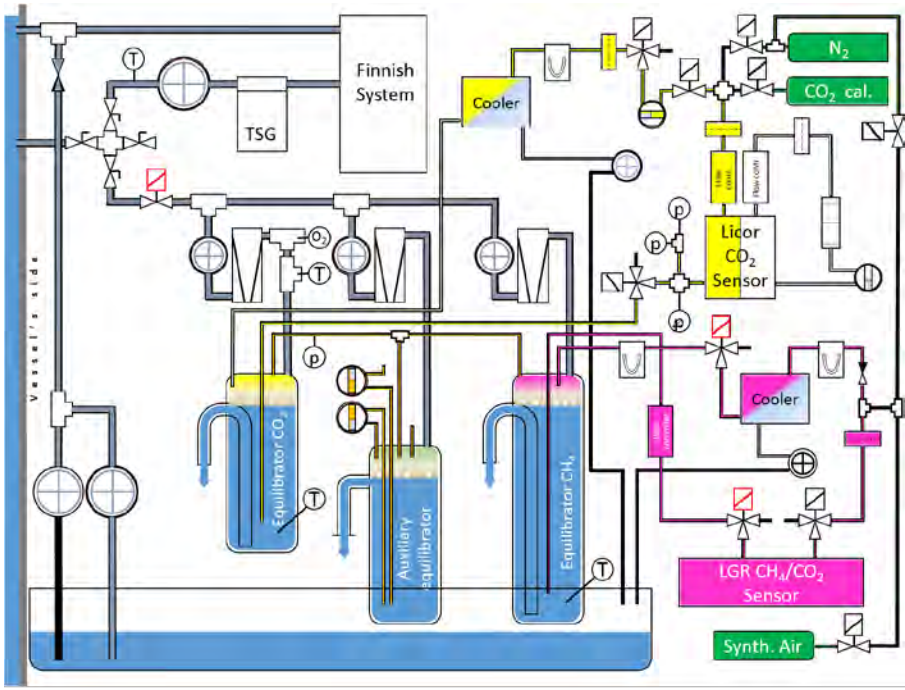
Outline

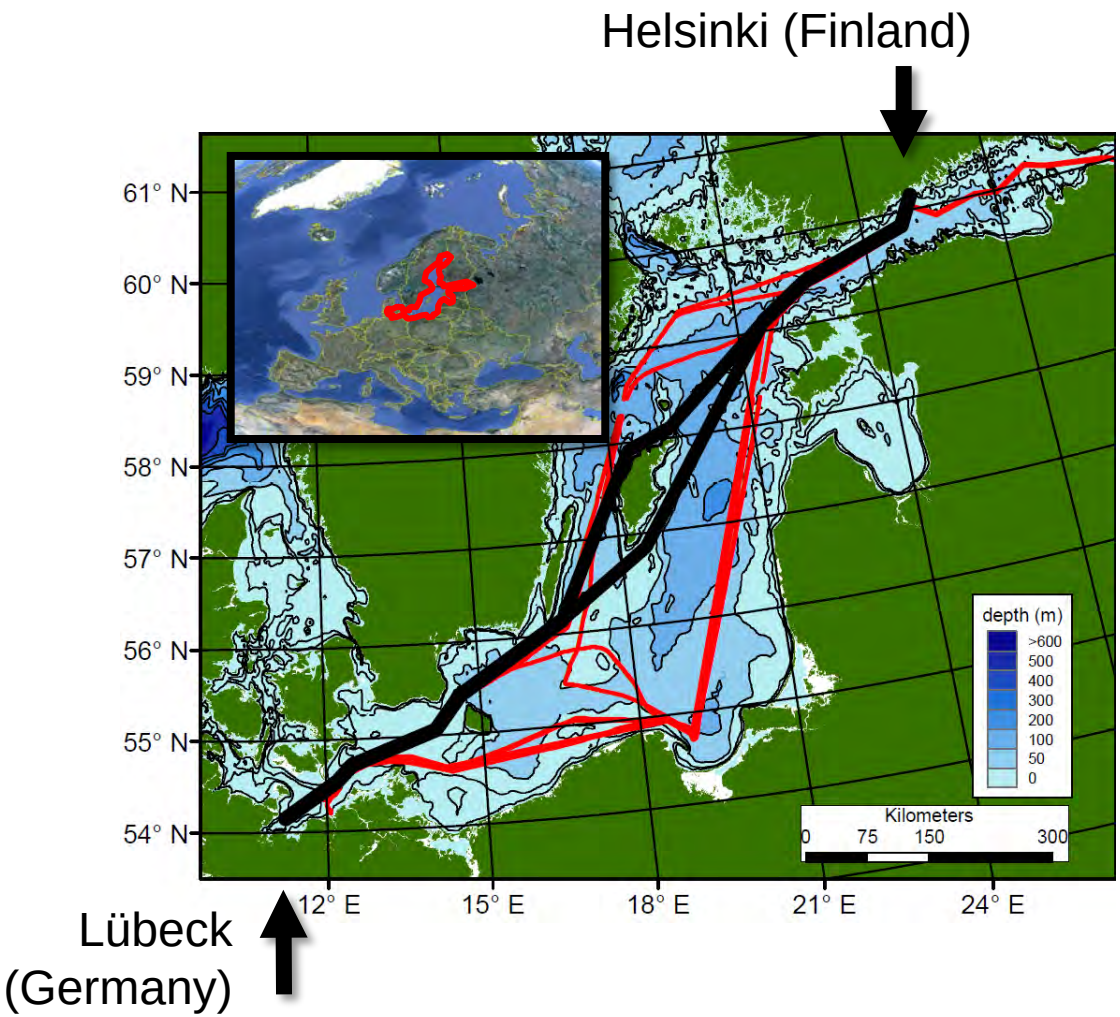
- Introduction
  - IOW's Ferrybox System
  - Why study methane in the Baltic Sea?
- Overview of the data set
- One example of using of inter-annual variability in process studies

IOW Ferrybox System

- Greenhouse gas measurements: **pCO_2** and **CH_4**
- Installed alongside preexisting Finnish Alg@line system (Real time algal monitoring in the Baltic Sea)

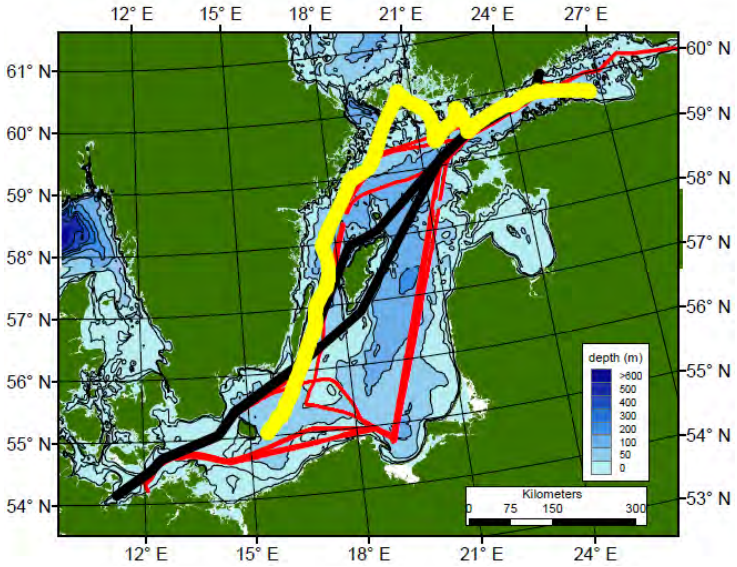


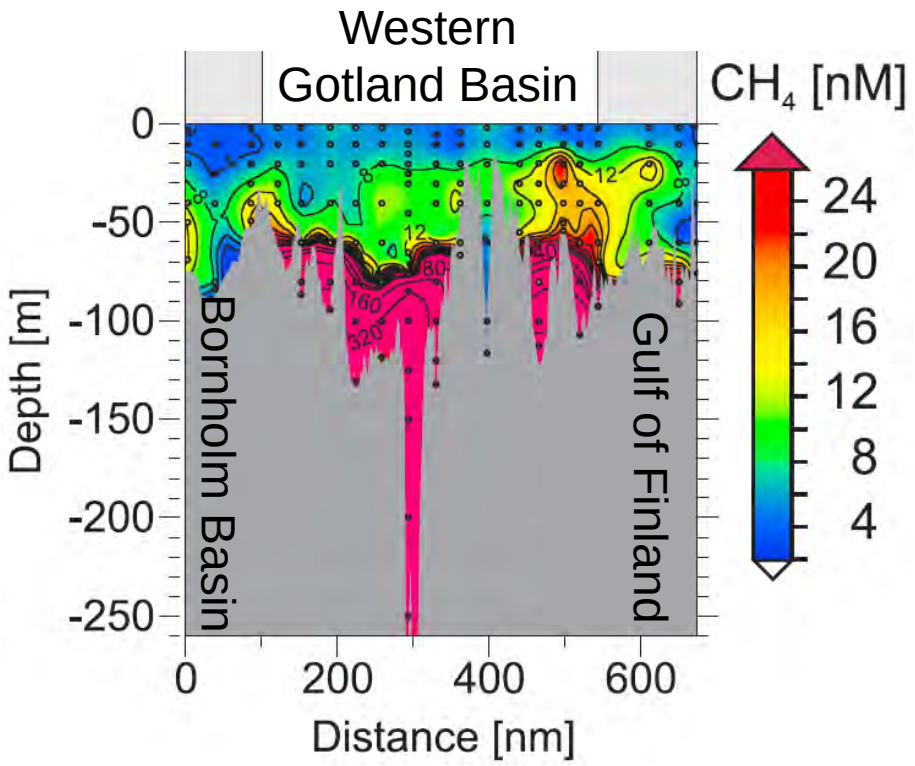
Spatial and temporal data coverage



- Good spatial coverage of the central Baltic Sea
- High repeat frequency: twice every three days
- 6 years of data =
  - 800 (valid) transects,
  - 728 along main routes

Methane in the Baltic Sea





Modified from Schmale et al., (2010) Distribution of methane in the water column of the Baltic Sea.

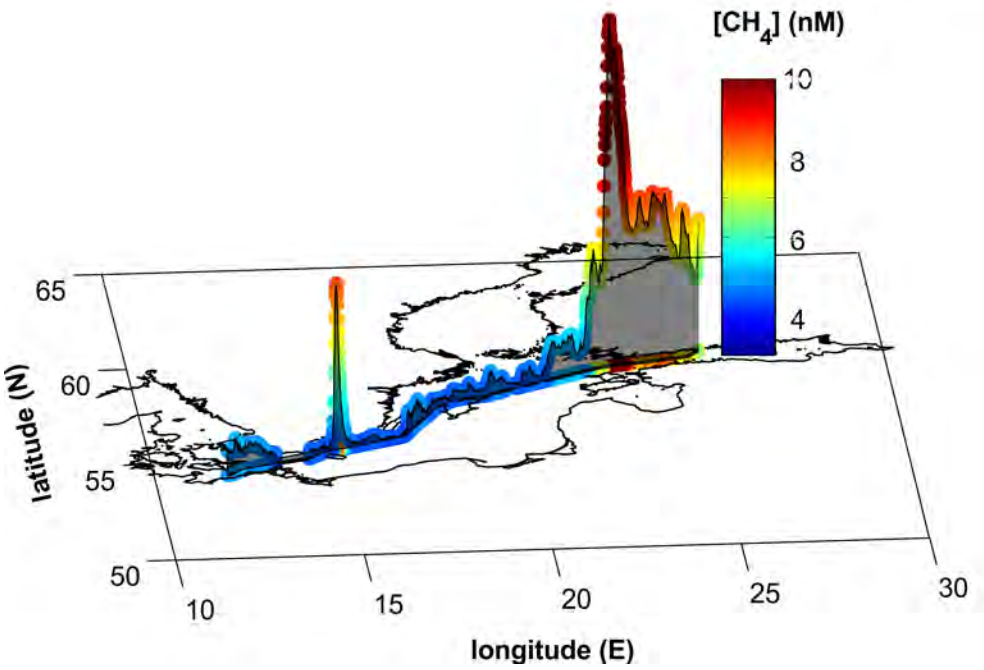
Why study Methane in the Baltic?

- Methane is an important greenhouse gas
- Shelf and marginal seas dominate the marine methane source to the atmosphere
- Strong influence of anthropogenic and climate stresses
- Supporting parameters are well constrained (e.g. long term monitoring, physical models, remote sensing)

DATA OVERVIEW

One transect:

February 1st to 2nd 2014



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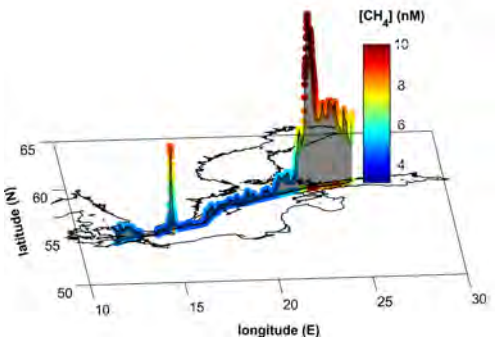

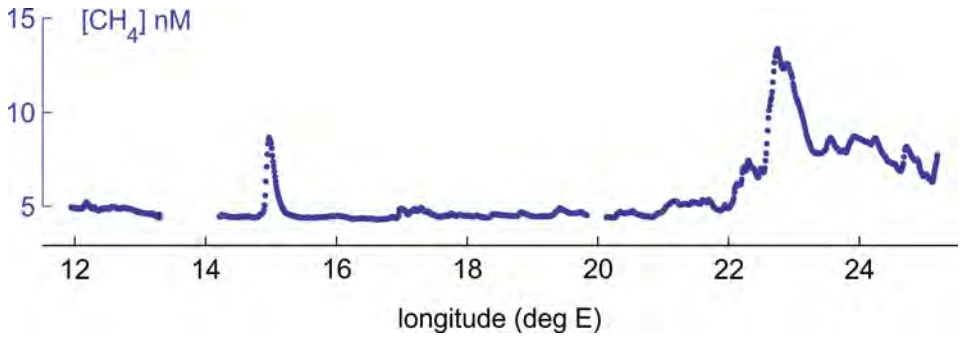

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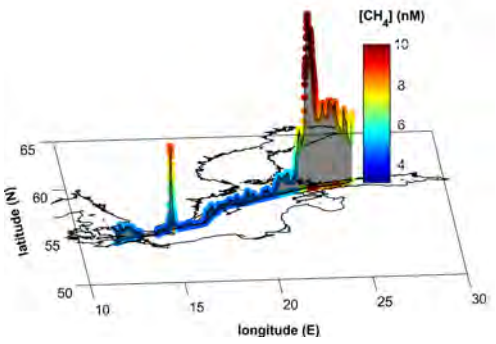
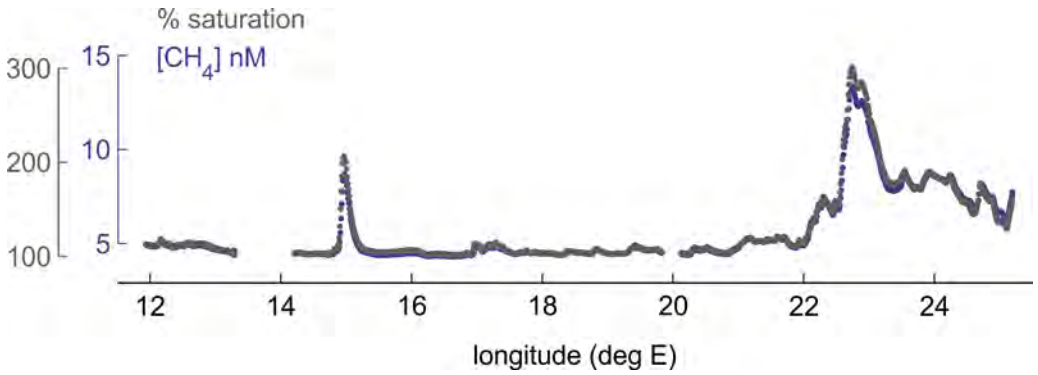
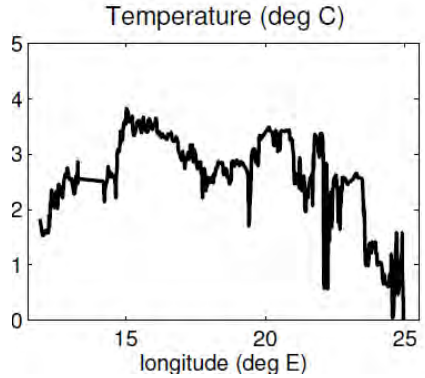
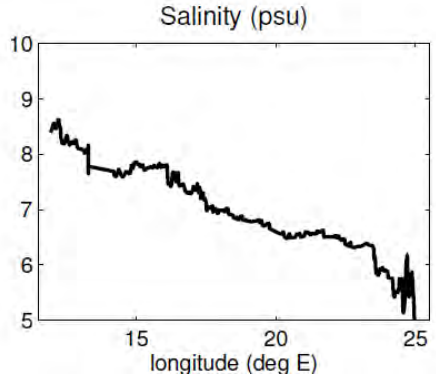




$$\% \text{ saturation} = \frac{C_{obs} - \mathbf{C_{equilibrium}}}{C_{equilibrium}} \cdot 100\ \%$$

$$C_{equilibrium} = \mathbf{C_{atmosphic}} \cdot \text{Solubility} \longleftarrow \propto \mathbf{T, S}$$





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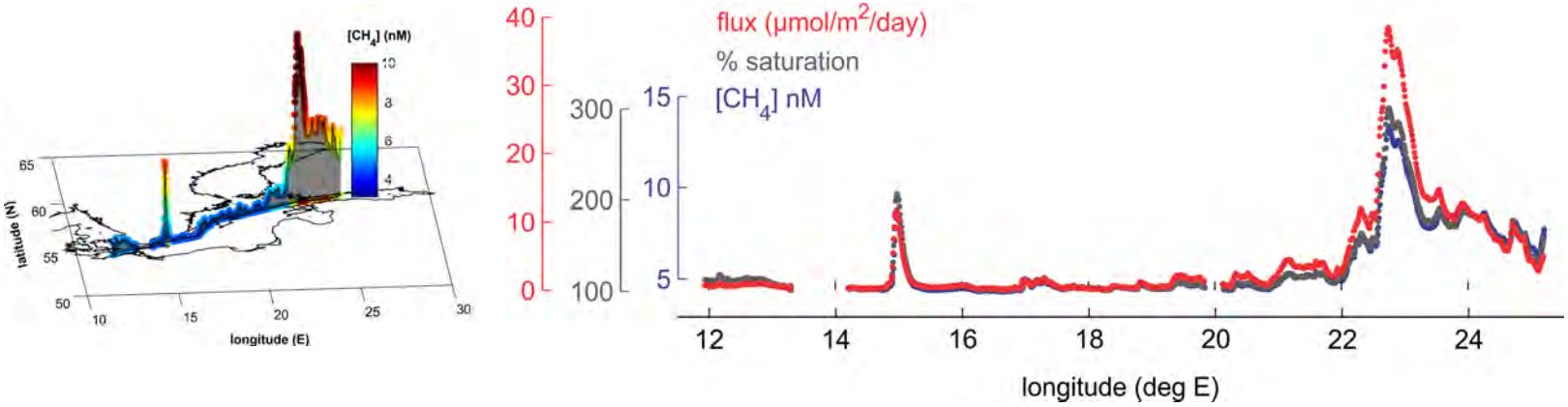
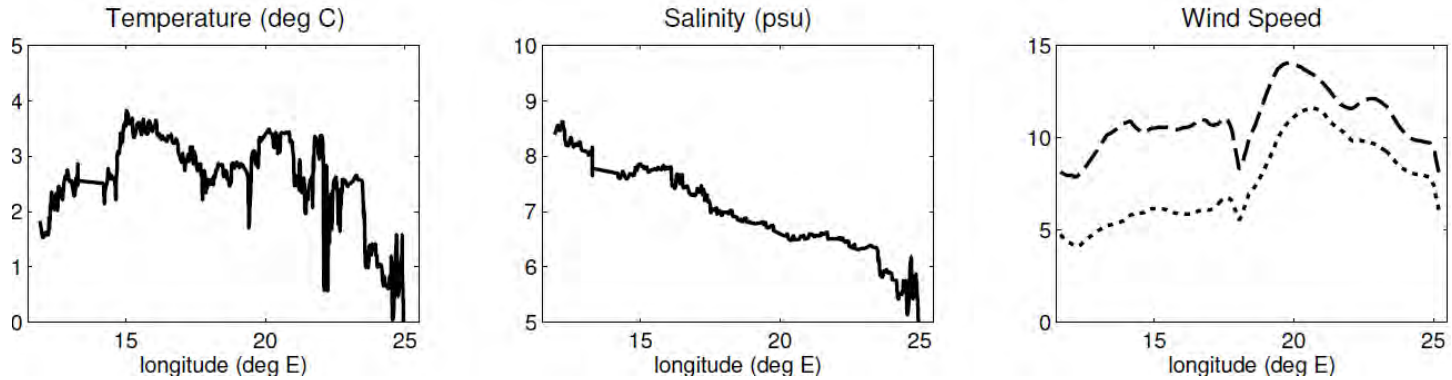


$$\text{sea} \rightarrow \text{air flux} = \left(C_{obs} - C_{equilibrium}\right) \cdot \textbf{exchange coefficient}$$

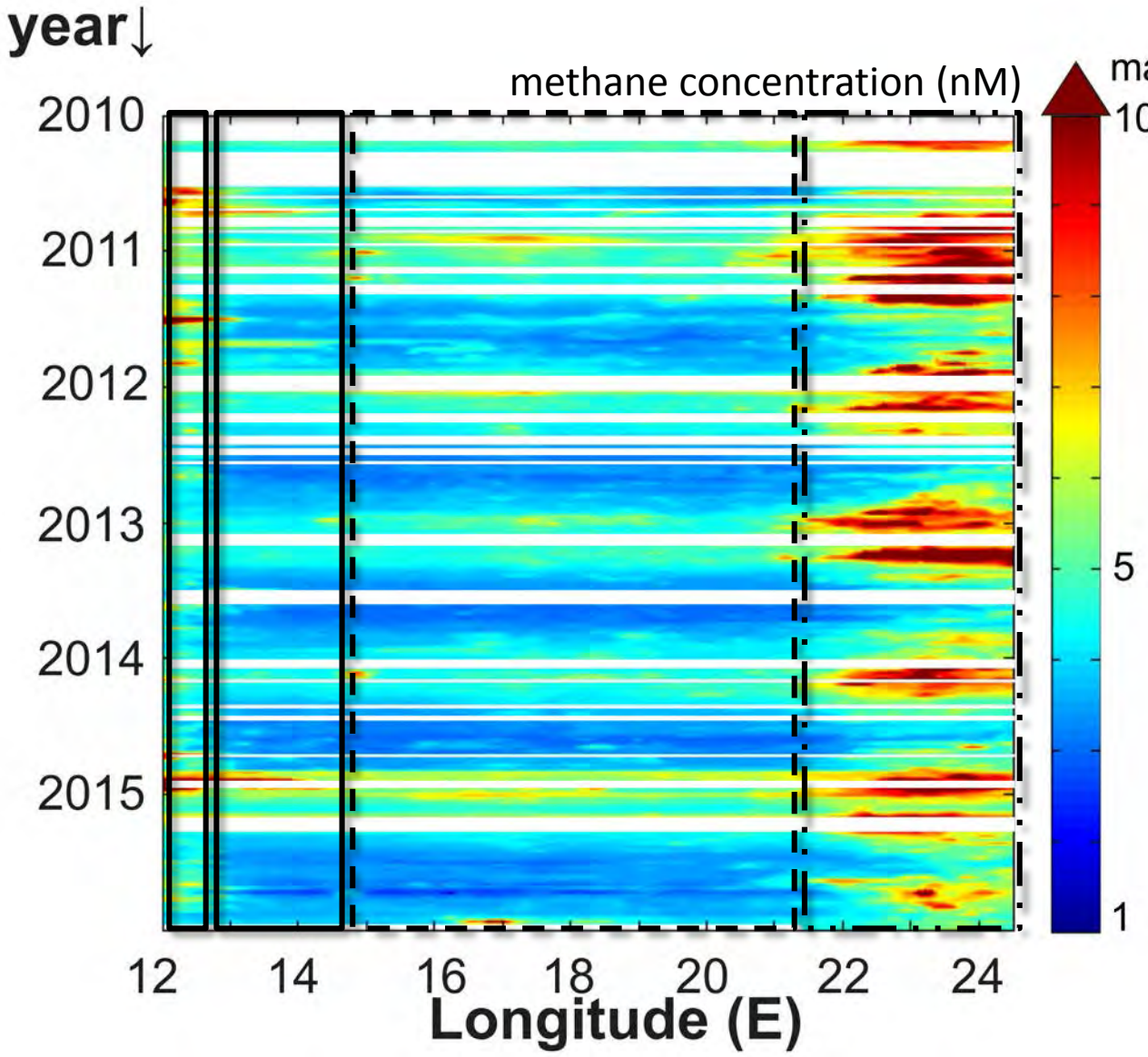
$$k = \left(\frac{\text{Schmidt number}}{660}\right)^{-0.5} \cdot (\text{wind speed})^2$$



Meteorological data curtesy of Ulf Gräwe, IOW

Wanninkhof et al., (2009) Advances in Quantifying Air-Sea Gas Exchange and Environmental Forcing.

All transects:



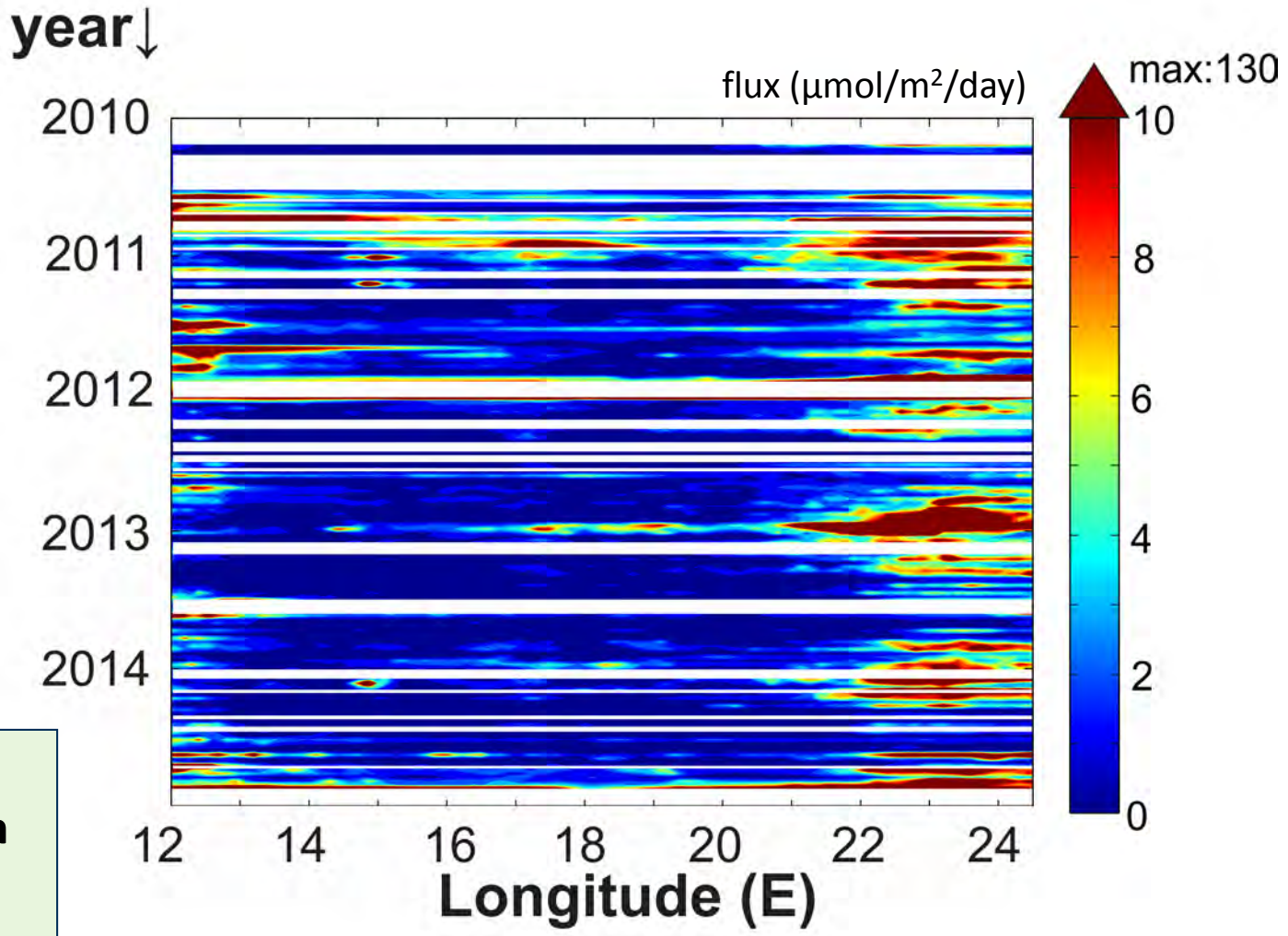
Western Basins: shallow water allows mixing down to sediment surface

Central Basins: generally low CH_4 except for upwelling events

Northern Baltic Proper and Gulf of Finland: Extremely wintertime high surface concentrations

Gülzow et al. (2013) One year of continuous measurements constraining methane emissions from the Baltic Sea to the atmosphere.

Flux to the atmosphere



Extremely variable in space and time

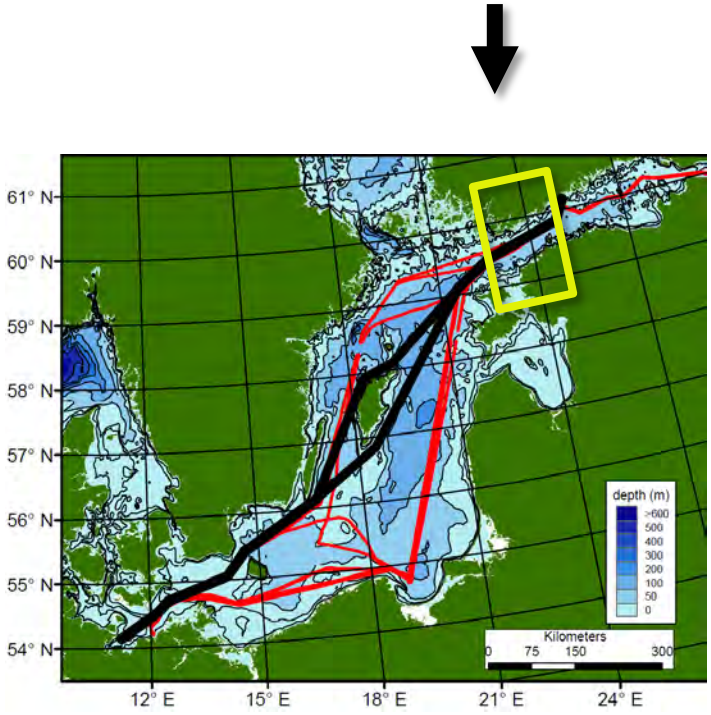
How to extrapollate off ferry-line?

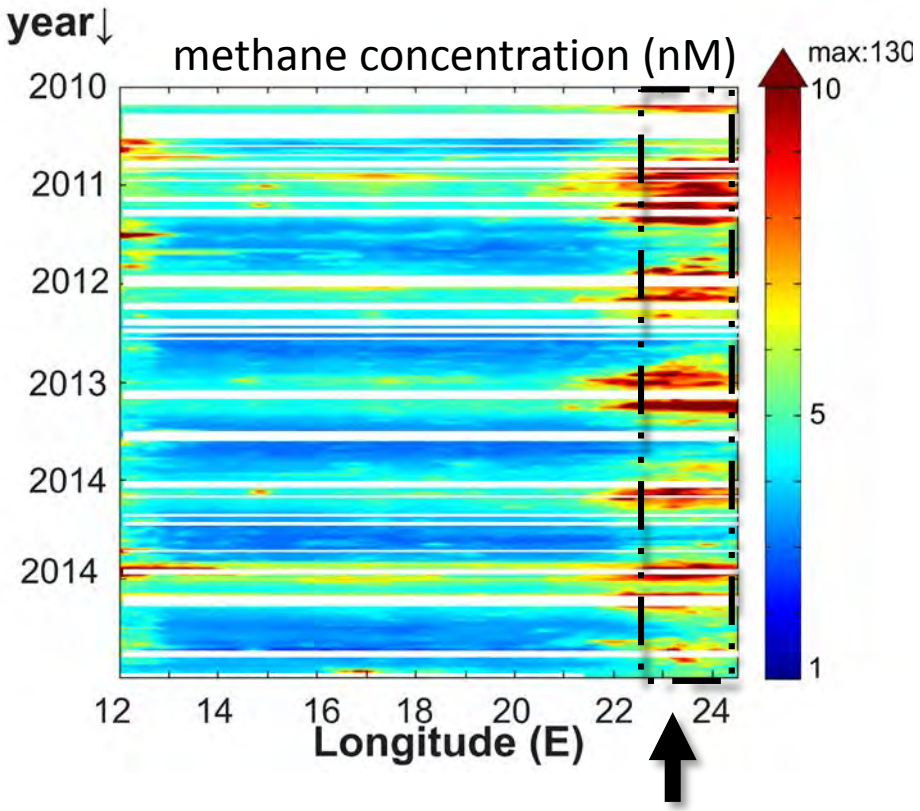
Requires process-based understanding of flux controls

EXAMPLE:

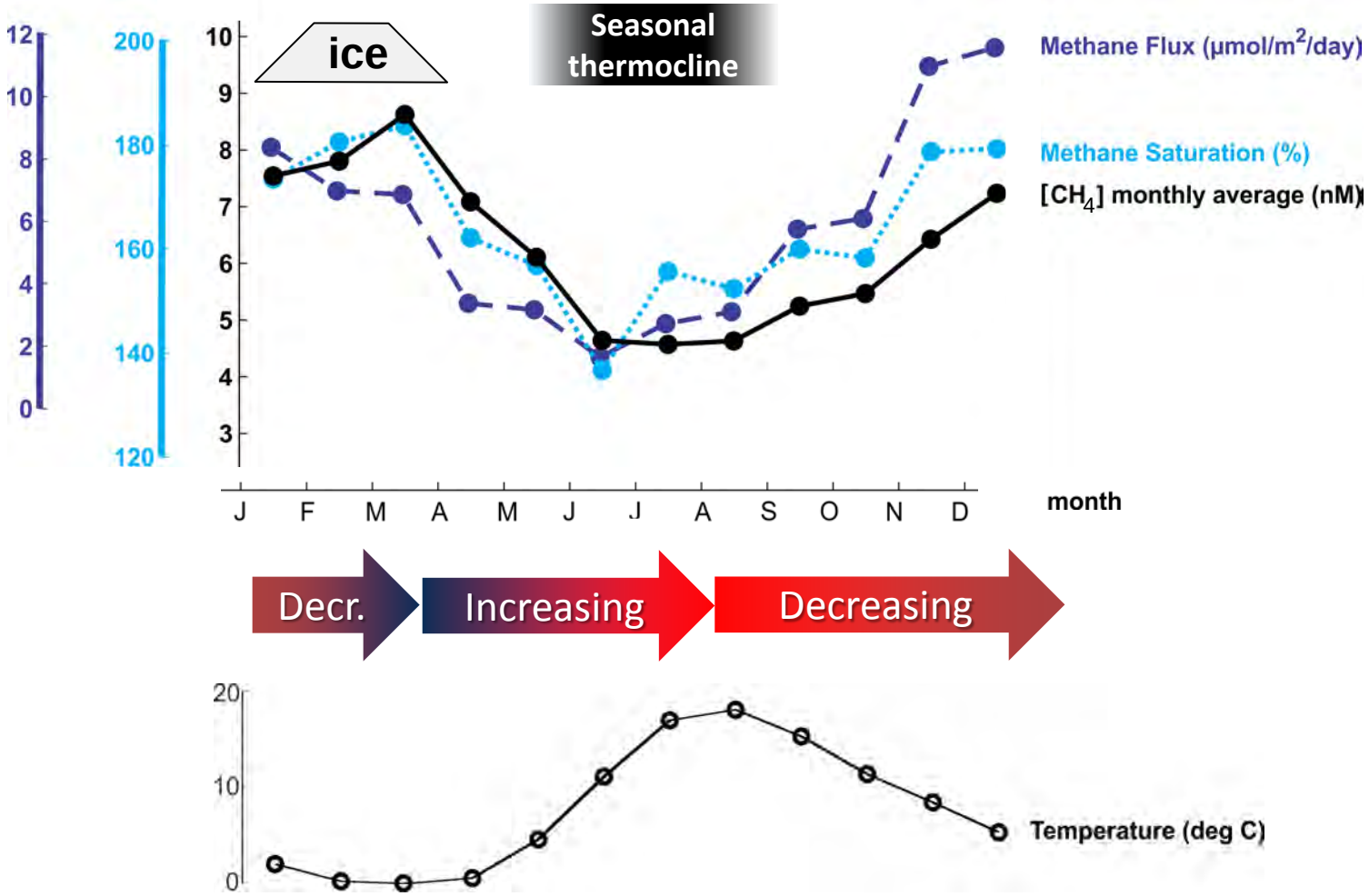
IDENTIFYING CONTROLS OF SURFACE CH_4 IN THE GULF OF FINLAND

Averaging in space and time…

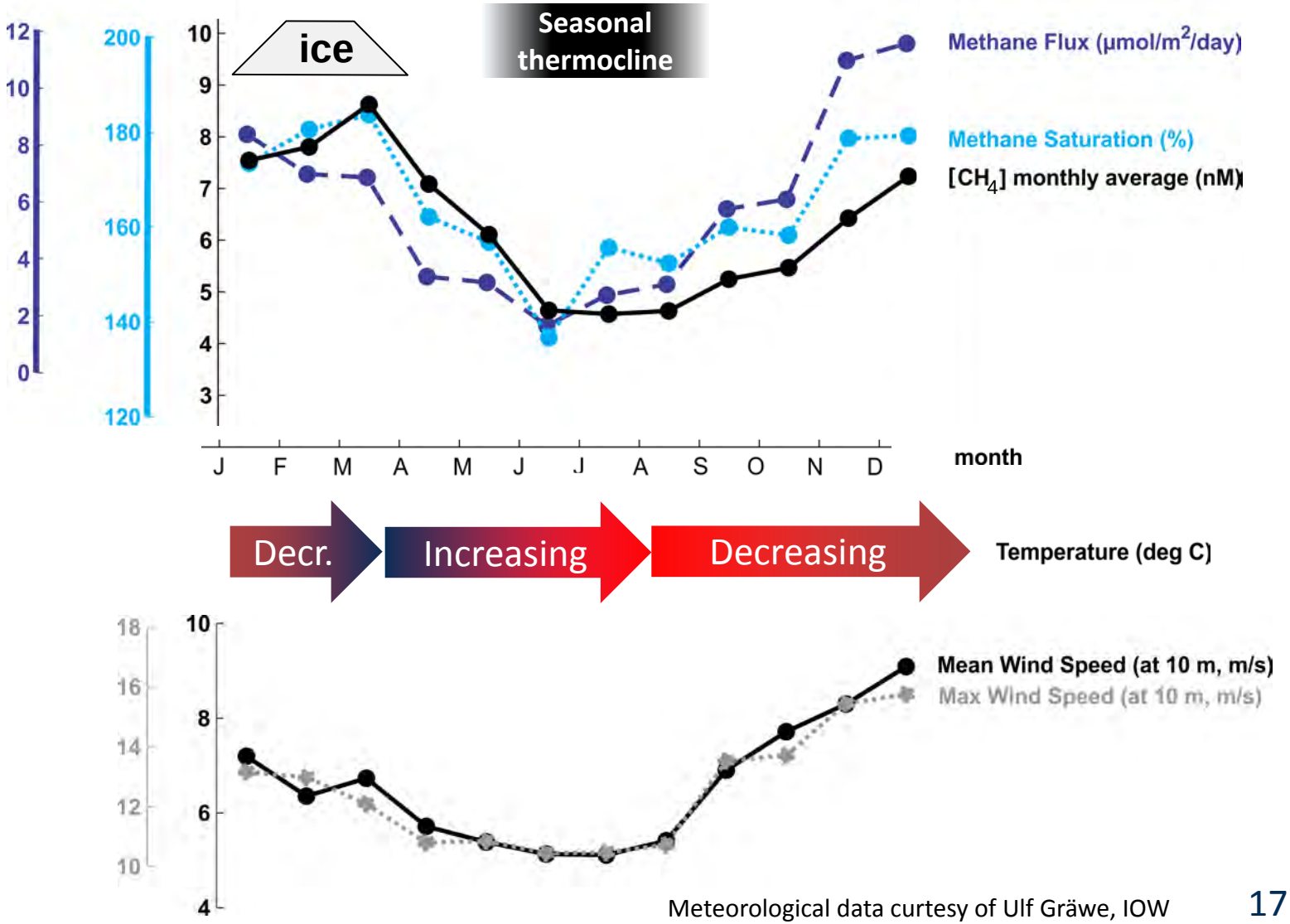




Seasonal patterns

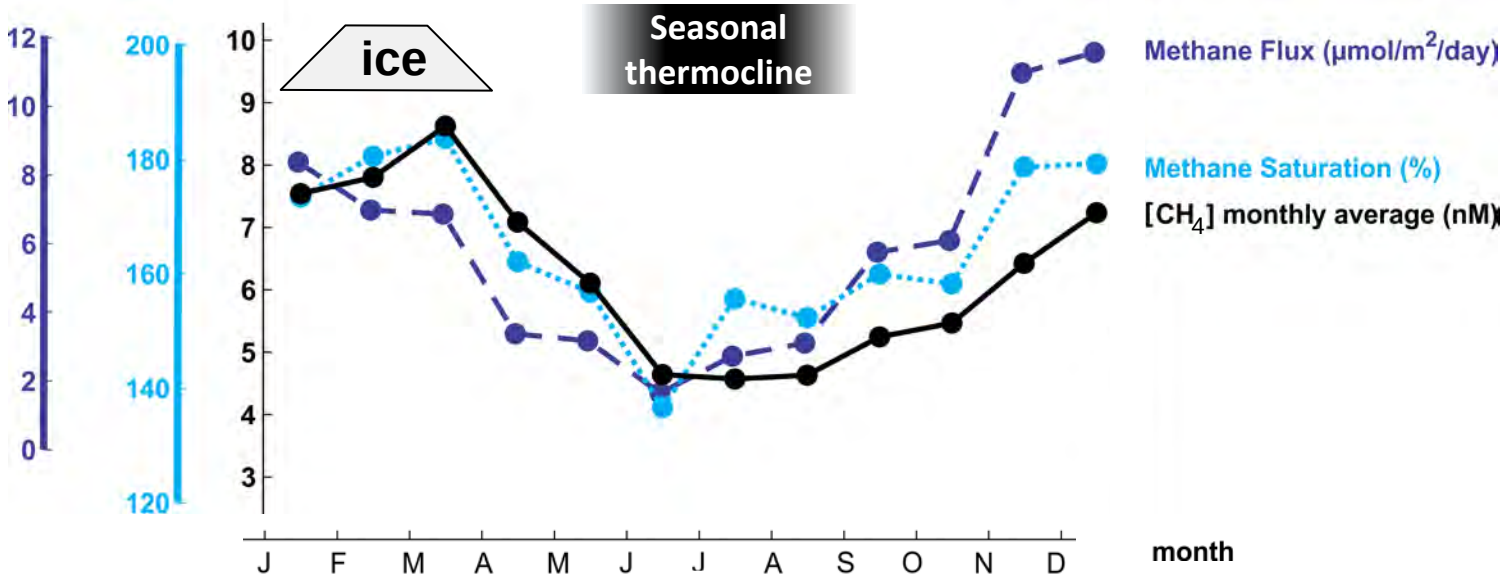


Seasonal patterns



Meteorological data curtesy of Ulf Gräwe, IOW

Seasonal patterns



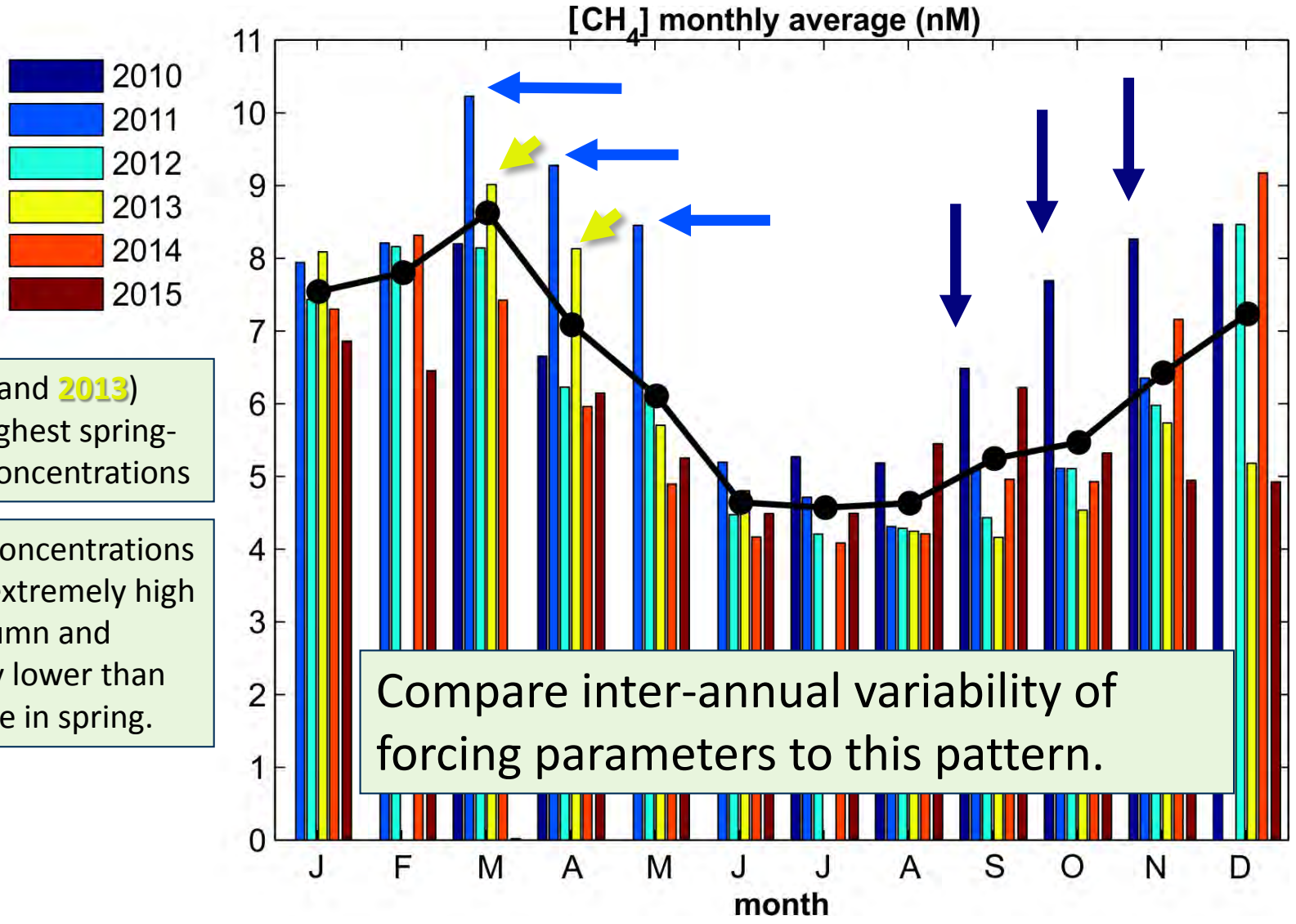
Seasonal cycles of temperature and wind drive **vertical stratification and mixing** and determine the seasonal cycle of surface methane concentrations

Why is this effect so pronounced in the Gulf of Finland?

Use inter-annual variability of forcing parameters to better constrain key processes

Meteorological data curtesy of Ulf Gräwe, IOW

Inter-annual variability

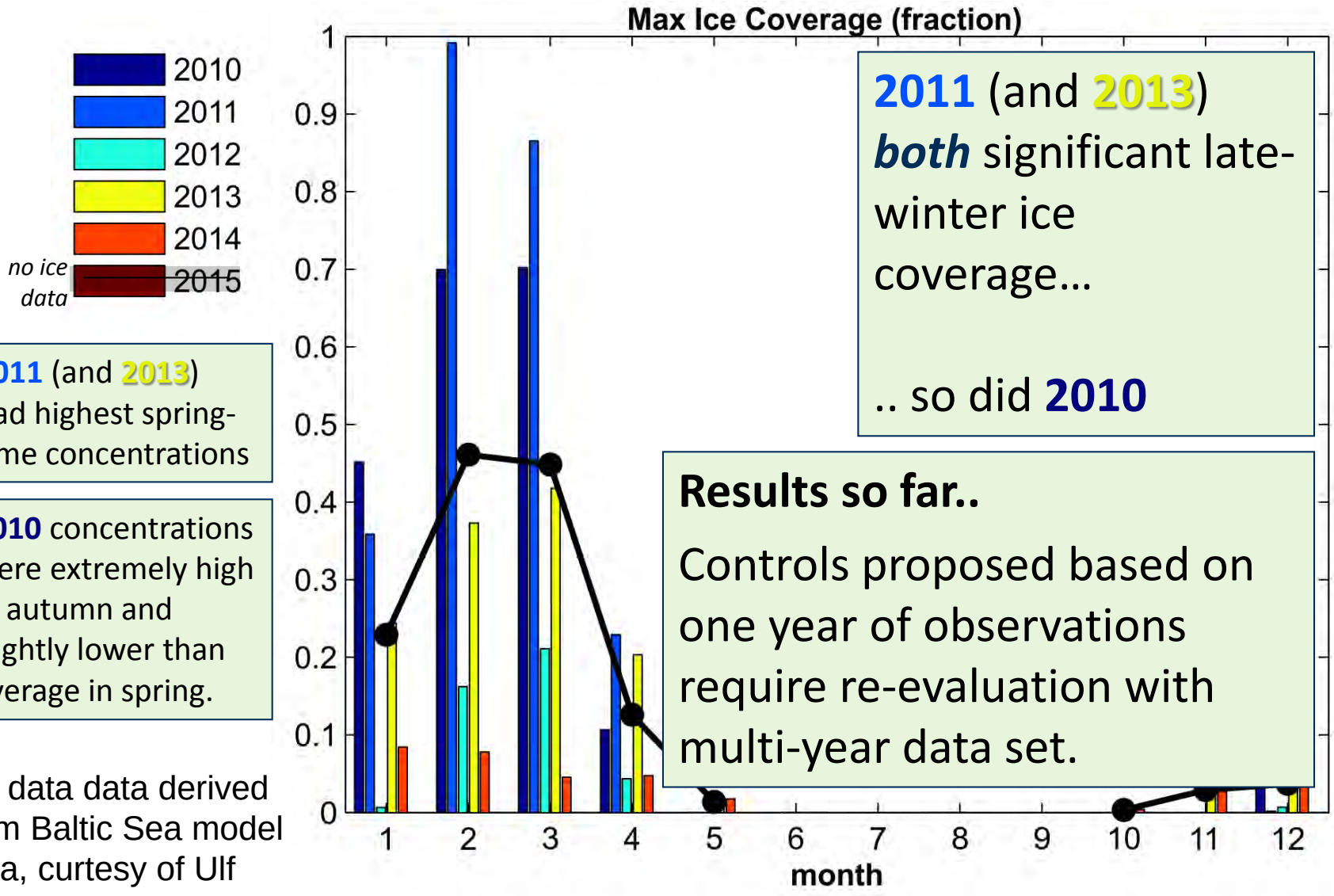


2011 (and **2013**) had highest spring-time concentrations

2010 concentrations were extremely high in autumn and slightly lower than average in spring.

Compare inter-annual variability of forcing parameters to this pattern.

Ice?



2011 (and **2013**) had highest spring-time concentrations

2010 concentrations were extremely high in autumn and slightly lower than average in spring.

2011 (and **2013**) ***both*** significant late-winter ice coverage…

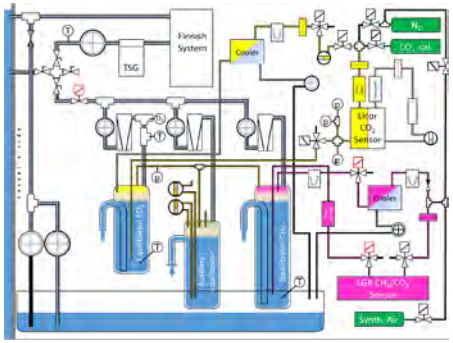
.. so did **2010**

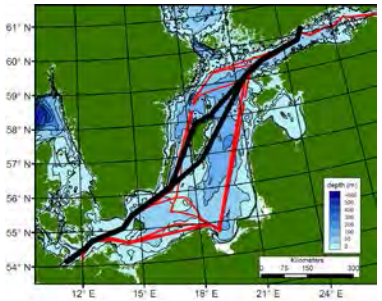
Results so far..

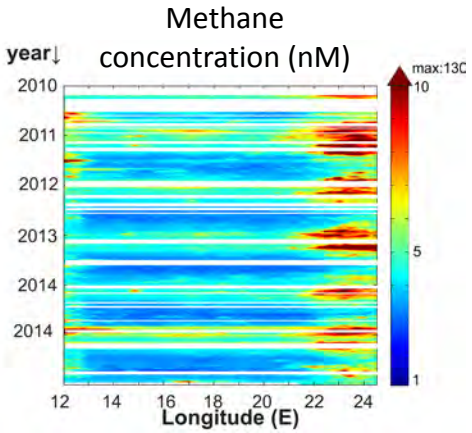
Controls proposed based on one year of observations require re-evaluation with multi-year data set.

Ice data data derived from Baltic Sea model data, curtesy of Ulf Gräwe (IOW)

Summary and Outlook







- IOW ferrybox system provides:
  - Good temporal and spatial sea surface concentration data
  - **Multi-year observations**
- Soon to be upgraded for additional parameters:
  - **pCO_2** (LI-COR)
  - **O_2** (PreSens)
  - **CH_4** and secondary **pCO_2** (Los Gatos Research)
  - **$\delta^{13}C$-CO_2** (PICARRO)
  - **N_2O** + **CO** (LGR)
  - **pH** (Bonus Pinbal project)
  - **Atmospheric concentrations** + **weather station**

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

Questions?

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... thanks for contributions from:

Ulf Gräwe

Wanda Gülzow

... thanks to coauthors:

Michael Glockzin

Bernd Sadkowiak

Bernd Schneider

Gregor Rehder

Reference for model data:
Gräwe, U., et al., Advantages of vertically adaptive coordinates in numerical models of stratified shelf seas. Ocean Model. 92, 56–68 (2015).

Title page image from: <http://www.naviearmatori.net/eng/foto-17971-4.html>