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: $p\text{CO}_2$ and $\text{CH}_4$
- 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

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)
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DATA OVERVIEW
One transect:

February 1\textsuperscript{st} to 2\textsuperscript{nd} 2014
One transect:

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One transect:

February 1\textsuperscript{st} to 2\textsuperscript{nd} 2014

\[
\text{% saturation} = \frac{C_{\text{obs}} - C_{\text{equilibrium}}}{C_{\text{equilibrium}}} \cdot 100 \%
\]

\[
C_{\text{equilibrium}} = C_{\text{atmospheric}} \cdot \text{Solubility} \propto T, S
\]
One transect:

February 1\textsuperscript{st} to 2\textsuperscript{nd} 2014

\[ \text{sea → air flux} = (C_{\text{obs}} - C_{\text{equilibrium}}) \cdot \text{exchange coefficient} \]

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

Meteorological data courtesy of Ulf Gräwe, IOW

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**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

Gülvzow 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 extrapolate off ferry-line?
Requires process-based understanding of flux controls
EXAMPLE:

IDENTIFYING CONTROLS OF SURFACE \text{CH}_4 \text{ IN THE GULF OF FINLAND}
Averaging in space and time...
Seasonal patterns

- Methane Flux (µmol/m²/day)
- Methane Saturation (%)
- [CH₄] monthly average (nM)

Temperature (deg C)

Decr. → Increasing → Decreasing

Ice → Seasonal thermocline
Seasonal patterns

Methane Flux (μmol/m²/day)
Methane Saturation (%)
[CH₄] monthly average (nM)

ice
Seasonal thermocline

Temperature (deg C)

Mean Wind Speed (at 10 m, m/s)
Max Wind Speed (at 10 m, m/s)

Meteorological data courtesy 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 courtesy of Ulf Gräwe, IOW
2010 concentrations were extremely high in autumn and slightly lower than average in spring.

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

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

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

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, courtesy of Ulf Gräwe (IOW)

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

2011 (and 2013) had highest spring-time concentrations

2010

2011

2012

2013

2014

2015

no ice

data

Max Ice Coverage (fraction)

month
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:
  - $\text{pCO}_2$ (LI-COR)
  - $\text{O}_2$ (PreSens)
  - $\text{CH}_4$ and secondary $\text{pCO}_2$ (Los Gatos Research)
  - $\delta^{13}\text{C}-\text{CO}_2$ (PICARRO)
  - $\text{N}_2\text{O} + \text{CO}$ (LGR)
  - pH (Bonus Pinbal project)
  - Atmospheric concentrations + weather station
Questions?

Reference for model data:

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