Spatio-temporal dynamics of pCO2 in the southern North Sea investigated by continuous FerryBox measurements

Wilhelm Petersen
Outline:

• FerryBoxes activities at HZG in the North Sea
• Measurements of pCO2 with FerryBox Systems
  • experiences with membrane based pCO2 sensors
  • example data of pCO2 and
• performance of pH sensors (glasselectrode vs. ISFET)
• Future plans for measuring the carbon cycle
• Summary
General Aims of FerryBox Activities at HZG

- provide basic measurements of oceanographic parameters (T, S, Turb, Chl-a, oxygen...)
- delivering data to European projects and activities (MyOcean, JERICO, EMODNet)
- application of physical parameters (T, S) in data assimilation schemes
- investigation of productivity along the transect from continuous oxygen data (+ wind fields)
- investigation of nutrient behaviour and algae dynamic along the transects
- investigation of the carbon cycle and the importance of different coastal areas as source or sink for atmospheric carbon (pCO2, pH, TA) (with newly developed instruments for continuous measurements of high precision pH and total alkalinity)
- optimization and validation of biogeochemical models with FerryBox data
FerryBox Routes operated by Helmholtz Zentrum Geesthacht (HZG)

currently not operated, waiting for coming back in autumn 2014
FerryBox Systems: Parameters

**Basic parameter:**
- water temperature
- salinity
- chlorophyll-a fluorescence
- turbidity
- dissolved oxygen
- pH (glass electrode)

**Additional parameter:**
- CDOM fluorescence (not all systems)
- algal groups (algal-online-analyser (bbe))
- nutrients (nitrate, nitrite, o-phosphate, silicate, ammonium)
  (devices from Systea (IT) only partly operated),
FerryBox Systems: Parameters (cont)

• **New developed sensors with focus on biogeochemistry:**
  - high precision pH & alkalinity (Steffen Aßmann, laboratory prototype, further development and test EU project NEXOS)
  - new nutrient analyzers based on SIA technique (Carsten Frank, laboratory prototype)
  - test of new nutrient analyzer from Systea (µLFA, see talk from Enrico)
  - PSICam (more reliable Chl-a & turbidity, algal groups)
    Jochen Wollschläger, EU project NEXOS
  - BioSensor (detection of algal species and HABs) Co-operation AWI (Katja Metfies, EU project EnviGuard)
Motivation:

Coastal Seas: Sinks and sources of CO2

Helmuth Thomas et al. Science 304, 1005 (2004);
Enhanced Open Ocean Storage of CO2 from Shelf Sea Pumping
Helmuth Thomas,* Yann Bozec, Khalid Elkalay, Hein J. W. de Baar

Seasonal field observations show that the North Sea, a Northern European shelf sea, is highly efficient in pumping carbon dioxide from the atmosphere to the North Atlantic Ocean. The bottom topography–controlled stratification separates production and respiration processes in the North Sea, causing a carbon dioxide increase in the subsurface layer that is ultimately exported to the North Atlantic Ocean. Globally extrapolated, the net uptake of carbon dioxide by coastal and marginal seas is about 20% of the world ocean’s uptake of anthropogenic carbon dioxide, thus enhancing substantially the open ocean carbon dioxide storage.
Annual cycles of $\Delta$CO2 for selected areas in the North Sea

Continuous pCO2, pH and A_T Measurements by underway System (e.g. FerryBoxes)

• Expected Results:
  → Spatially and seasonally resolved sources and sinks of CO2 along a certain transect
  → Alkalinity transport from Land into the North Sea
  → CO2 air-sea fluxes
  → ocean acidification
  → quantification of production rates
    → comparison of productivity with estimates derived from other variables (DO, Chl-a, winter nutrient stocks….)
  → phytoplankton dynamics (e.g. seasonality…)
Available pCO2 Measurements:

- Immingham – Cuxhaven: 2011 – 2012 (TorDania)

ProOceanus pCO2 sensor

Contros pCO2 sensor

not suitable for long-term unattend operation
Problems of long-term Stability: Zero Drift HydroC pCO2 Analyzer During two Years of Operation at FerryBox (Lysbris)

\[ Y = M_0 + M_1 \cdot x + \ldots + M_8 \cdot x^8 + M_9 \cdot x^9 \]

| \( M_0 \)  | 42.403 |
| \( M_1 \)  | -0.46372 |
| \( M_2 \)  | 0.0054316 |
| \( M_3 \)  | -1.2561e-5 |
| \( M_4 \)  | 1.2066e-8 |
| \( M_5 \)  | -4.3396e-12 |
| \( R \)    | 0.99921 |

Performance of pCO2 Sensor: Zero Drift Correction

Graphs showing the performance of the pCO2 sensor with and without zero drift correction. The top graph displays the corrected pCO2 values over time, while the bottom graph shows the difference of calculation in percentage.
First Results of pCO2 Measurements in the North Sea
pCO2 Dataset
weekly transects from Lysbris in 2013

<table>
<thead>
<tr>
<th>Month in 2014</th>
<th>Latitude (°N)</th>
<th>Longitude (°E)</th>
<th>pCO2 (µAtm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moss/Halden</td>
<td>Zeebrugge</td>
<td>Immingham</td>
</tr>
</tbody>
</table>

pCO2 (µAtm)
pCO2 in 2013: Transect Halden – Zeebrügge

Distance from Halden (km)

Time

1 Jan 1 Feb 1 Mrz 1 Apr 1 Mai 1 Jun 1 Jul 1 Aug 1 Sep

0 200 400 600 800 1000

pCO2 (μAtm)

500.0 462.6 395.3 328.0 260.6 193.3 126.0
pCO2 in 2014: North Sea (Immingham – Moss):
Transect Apr 2014
Imm- Moss

- Salinity
- pCO2
- pH
- Chl-a
- DO%