Looking beyond stratification: 
A model-based analysis of the biological drivers of oxygen depletion in the North Sea

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Introduction: Oxygen minimum zones (OMZ) in the German Bight

D. Topcu & U. Brockmann, Oxygen depletion in the North Sea, a case study for OSPAR OSPAR ICG-EUT Meeting, February 2014 Paris
ECOHAM4: \( \text{O}_2 \) module and coupling to C and N cycle

Müller (2008, BSH Report 43)
ECOHAM4: Model setup

- 3D physical-biogeochemical model (Lorkowski et al., 2012)
- 20 km x-y- / 5-1000 m z-resolution
- climatologic boundary conditions for temperature, salinity and biochemistry at open boundaries
- NCEP meteorological forcing
- 249 rivers, daily values (courtesy of van Leeuwen, Cefas/UK)
- physics from long-term simulation
- 2 years spin-up for biochemistry
Results – Part I: Model validation

MARNET ‘German Bight’ in 2002

Data source: BSH
Results – Part II: Minimum O$_2$ concentration & depletion period

minimum O$_2$ concentrations

depletion period
Results – Part II: stratification & depletion period

stratification period
(ΔT ≥ 0.05K)

depletion period

2002
2004

2002
2004
Results – Part III: $O_2$ dynamics at 56°n, 6°E

**bottom layer $O_2$ and T difference**

**2002**

- Days with $\Delta T \geq 0.05 K$: 215
- $O_2 < 6 \text{mg/l}$: 53

**2004**

- Days with $\Delta T \geq 0.05 K$: 180
- $O_2 < 6 \text{mg/l}$: 0

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**Legend:**
- $\Delta T$ sim
- Bottom $O_2$ sim
- $O_2$ threshold
- Stratified period
Results – Part III: Bottom layer O$_2$ fluxes during stratification

**Biological fluxes**
- st-o2o/10
- p1c-o2o
- p2c-o2o
- o2o-zic
- o2o-zec
- o2o-bac
- o2o-n4n
- phys-o2o

**Physical fluxes**
- st-o2o
- phys-o2o*10
- adv-o2o/10
- adh-o2o/10
- mix-o2o
- o2o-sed

2002
- O$_2$
- physics
- nitrification
- remineralisation

2004
- physics
- vertical transport
- vertical mixing
- benthic remin.
- horizontal trans.
Results – Part III: Major biological fluxes affecting bottom layer $O_2$

Mean loss per day

<table>
<thead>
<tr>
<th></th>
<th>DET</th>
<th>SOC</th>
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<tbody>
<tr>
<td>2002</td>
<td>-1.9</td>
<td>-9.6</td>
</tr>
<tr>
<td>2004</td>
<td>-1.1</td>
<td>-6.8</td>
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</table>

Mean $O_2$ flux per day

<table>
<thead>
<tr>
<th></th>
<th>BAC</th>
<th>SED</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>1.9</td>
<td>5.8</td>
</tr>
<tr>
<td>2004</td>
<td>2.0</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Fluxes in units of $mmol m^{-2} d^{-1}$
Conclusion

• ECOHAM provides information on the inter-annual variability of the OMZ with respect to:
  • spatial extent,
  • intensity,
  • and duration

• still problems with validation data with respect to:
  • quality,
  • and spatial and temporal coverage

• model analysis allows for description of O₂ dynamics related to:
  • stratification period → isolation of bottom water from sea surface
  • physical & biological processes → quantification of relevant processes in the bottom layer during stratified period

• analysis revealed the importance of processes in:
  • the water column between surface layers and bottom zone
  • the sediment
Outlook

• extend the simulation period to investigate interannual changes in the OMZ in the recent past

• improve validation by using more recent data sets (better quality)

• foster interpretation of data with analysis tool for more areas in the North Sea (in relation to available data sets)

• compare flux calculations with measurements (e.g. bacterial respiration, benthic remineralisation etc.)
Thank you very much for your attention.
Additional slides: Occurrence of OMZ (O₂ < 6 mg/l)
Additional slides: Vertical temperature distributions at 56°n, 6°E
Additional slides: Vertical O$_2$ distributions at 56°n, 6°E