Mechanistic modelling of organic carbon budget reworked by macrobenthos – case studies of the Baltic & North Sea

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Seafloor as sink of organic carbon

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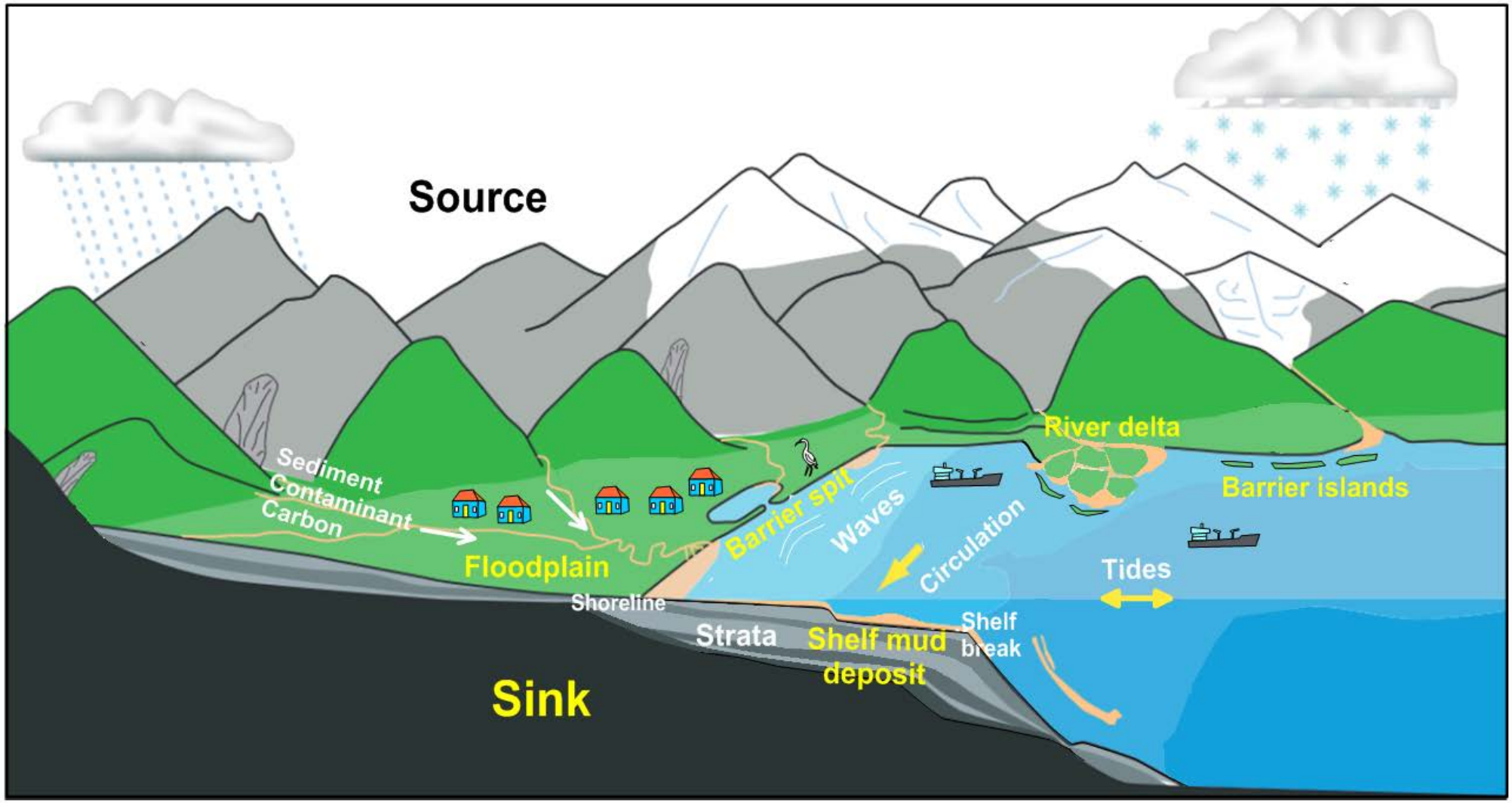
The source-to-sink transport of particulate matter



Modified from Walsh et al. (2004)

Seafloor as sink of organic carbon

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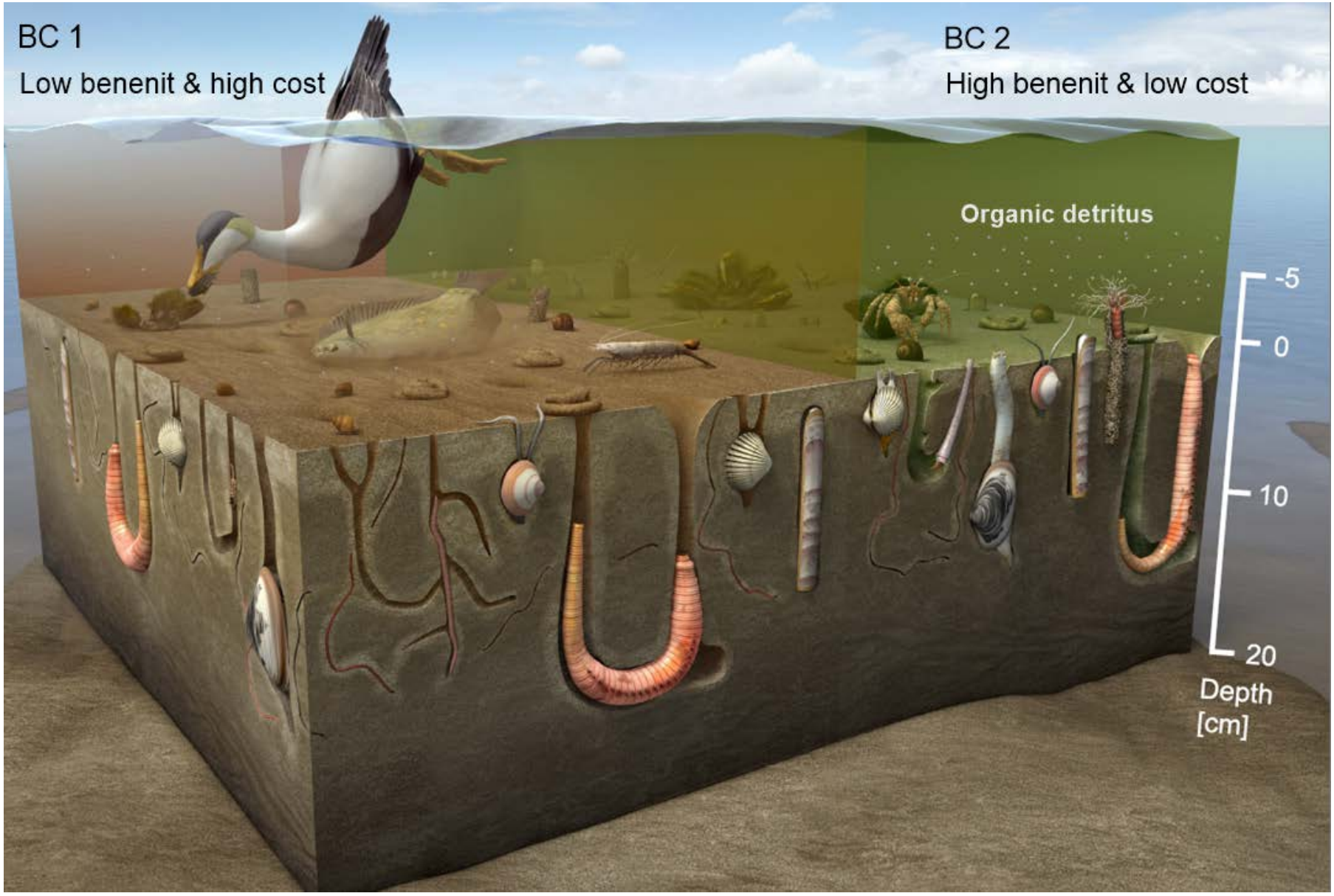

Carbon cycling at the sediment-water interface is strongly influenced by biotic-abiotic interactions

Seasonal cycle of benthic activity

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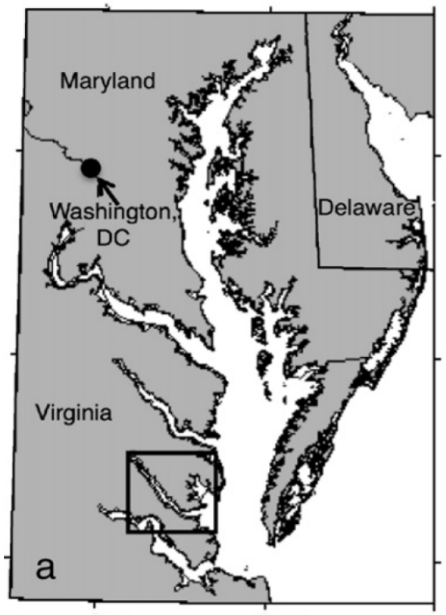
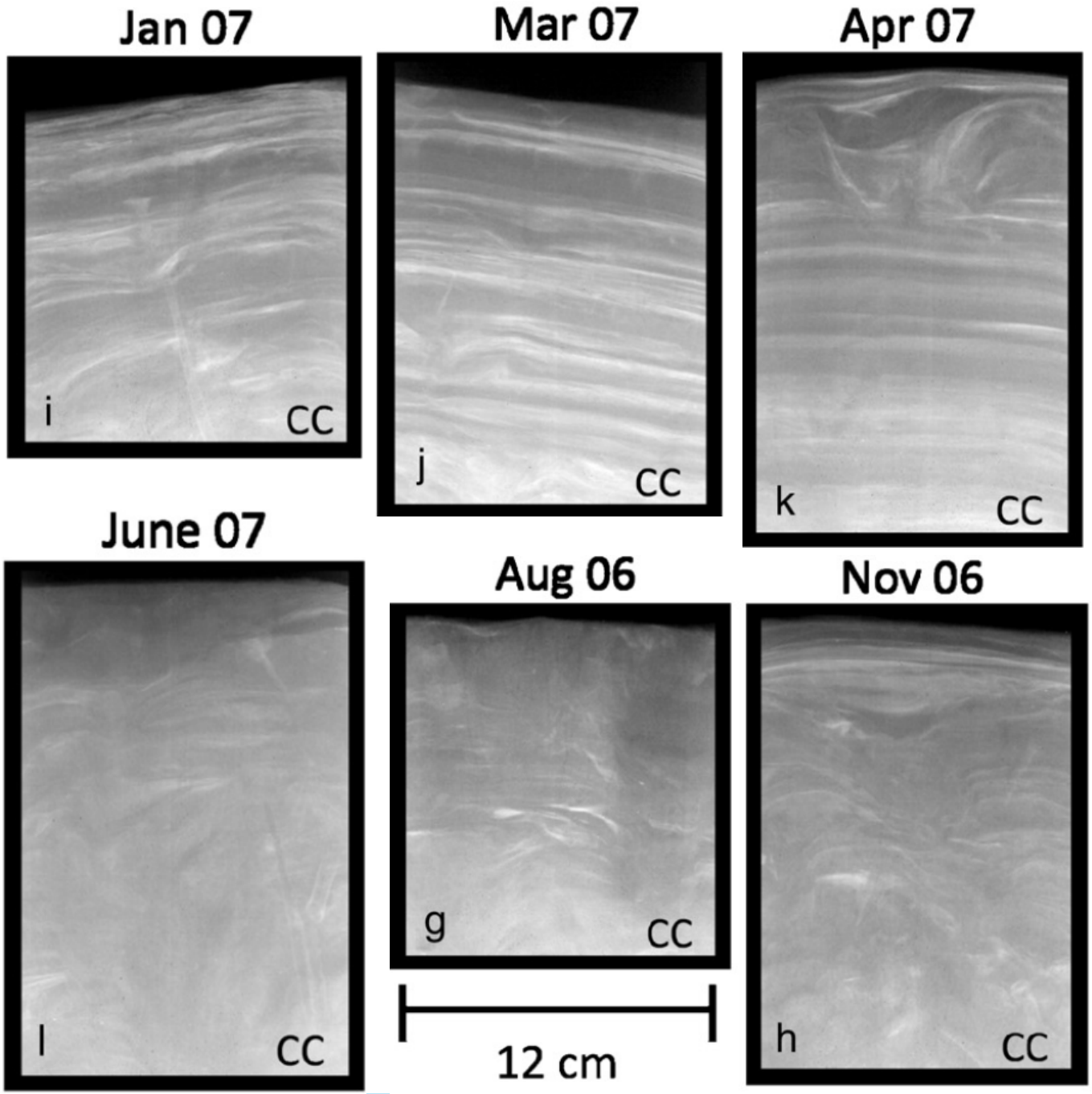


Dickhudt et al., 2009

Seasonal variation is prominent !



Field data

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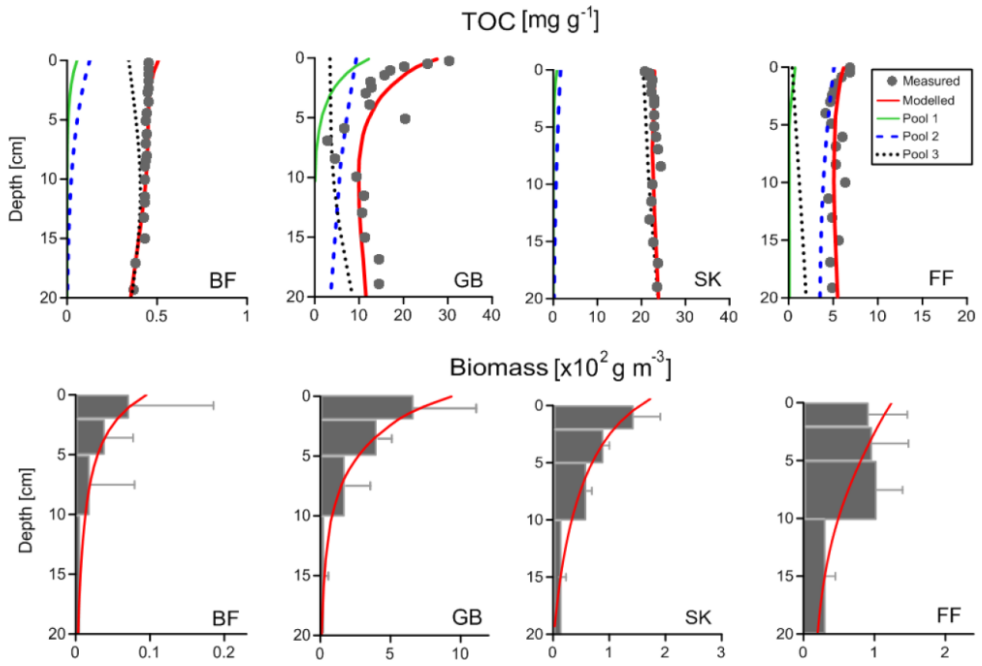
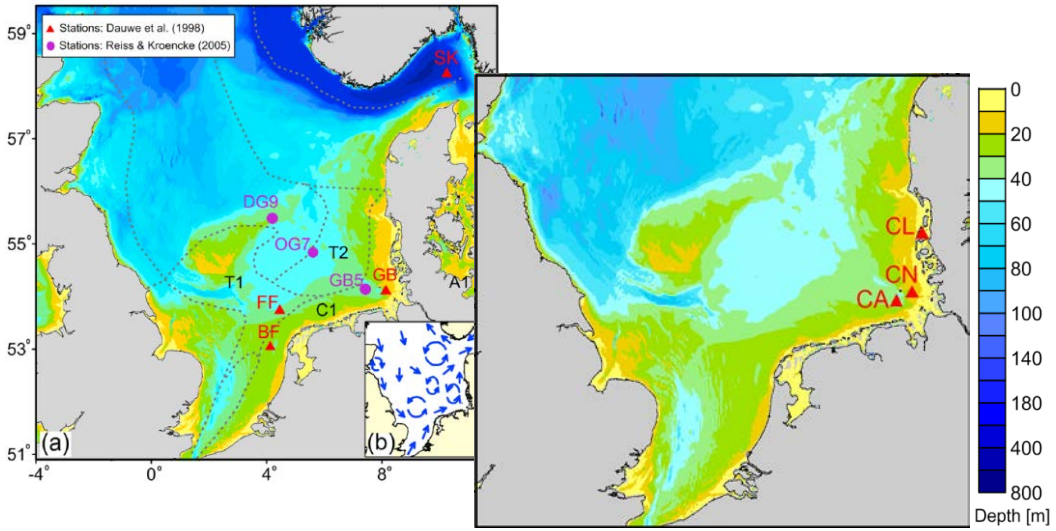
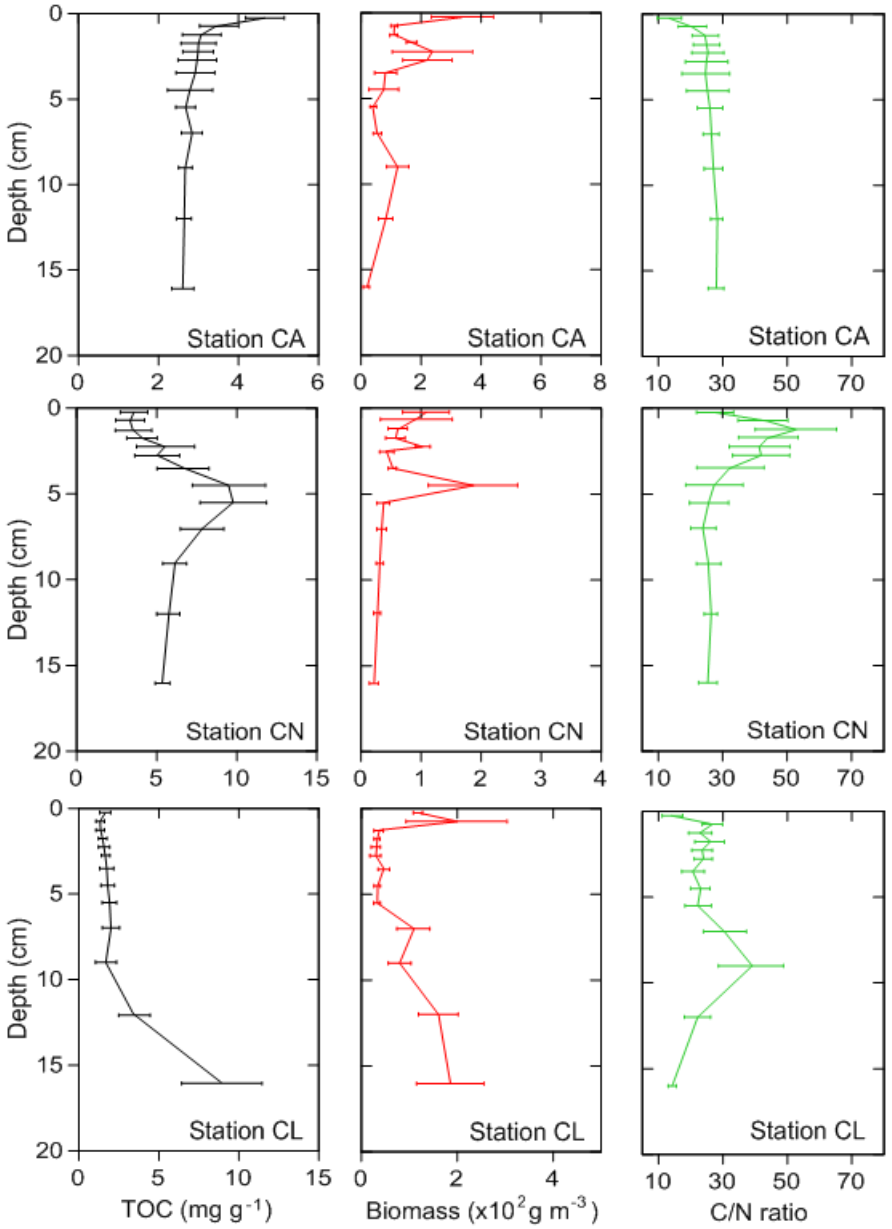


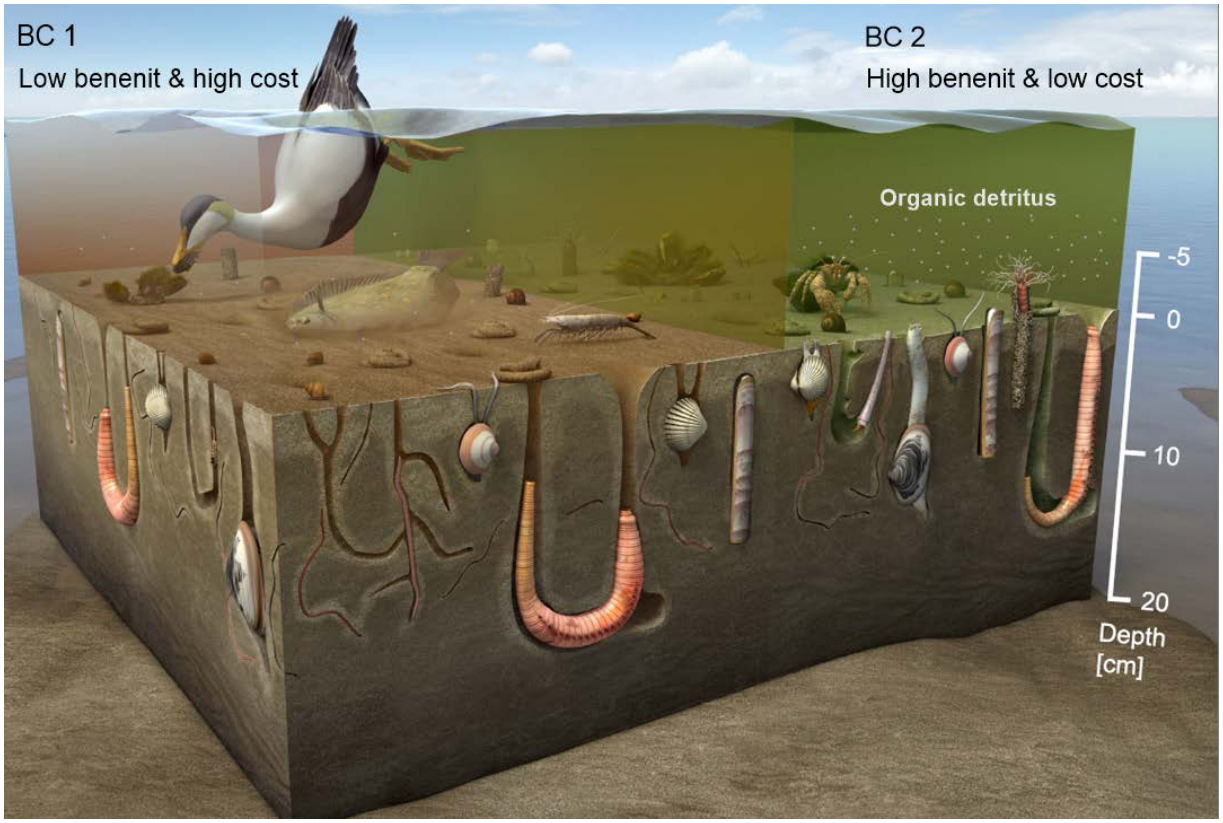




Both quantity and quality of food are of critical importance!

Zhang & Wirtz, 2017

A Macrobenthos-TOC model



Parallel ecological networks in ecosystems

- Consumer–resource interactions
- Interactions of organisms with abiotic (non-resource) conditions
- Spatial interactions (flux of energy, material and organisms)
- Non-trophic direct interactions among organisms
- Physical and chemical interactions
- External forcing of abiotic conditions

Olff et al., 2009

$$(1-p)\frac{\partial C_i}{\partial t} = -\frac{\partial w(1-p)C_i}{\partial z} + \frac{\partial}{\partial z}\left(K_v(1-p)\frac{\partial C_i}{\partial z}\right) - (1-p)\left(R_i + (1-\varepsilon_i)\gamma\frac{B}{\rho_s}\right)C_i$$

Zhang & Wirtz, 2017

Model calibration & validation

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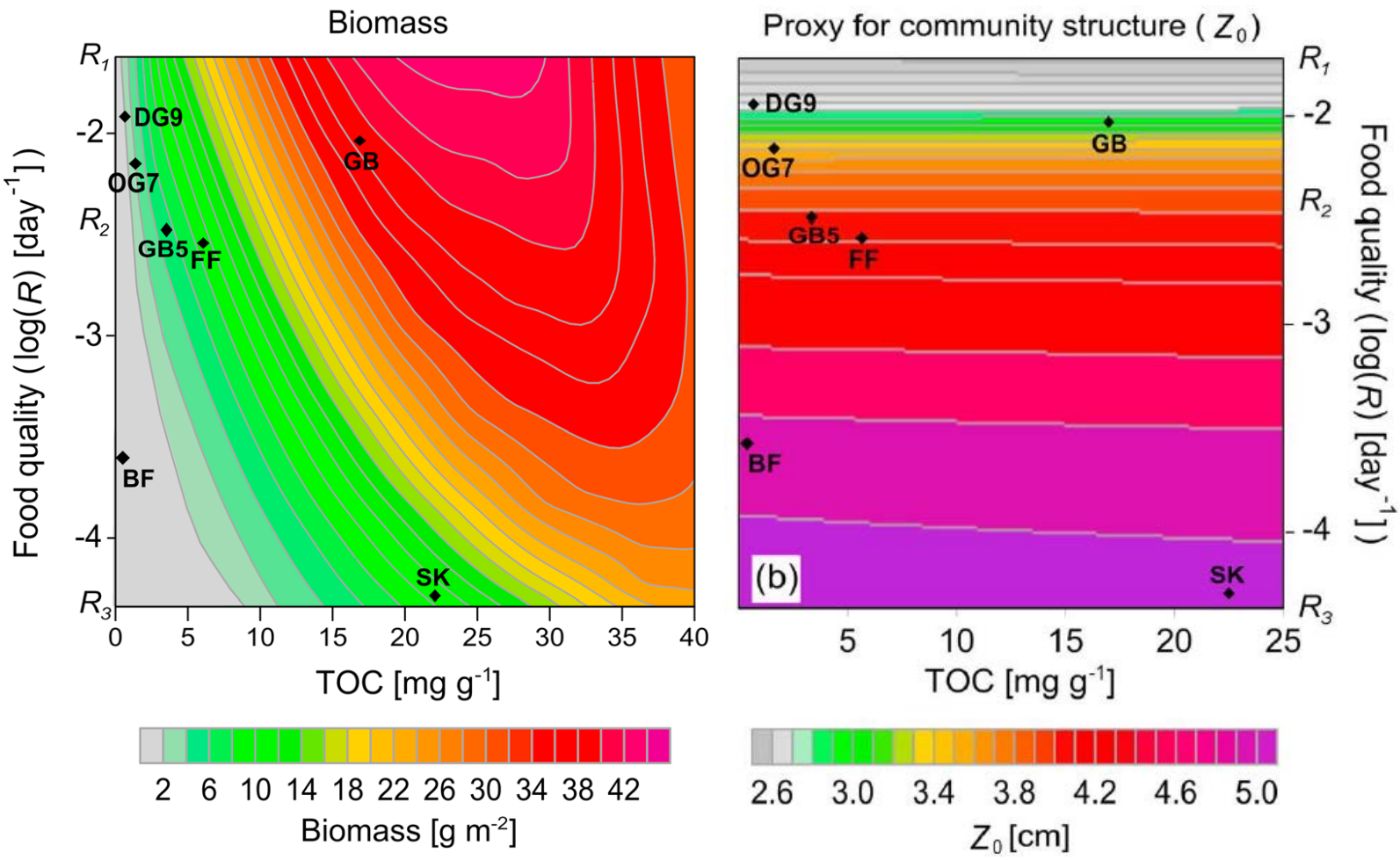
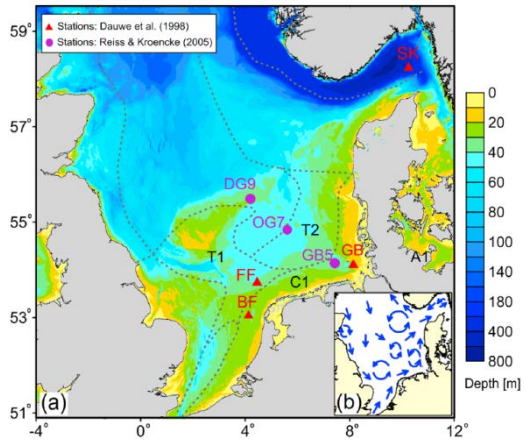
Diagram for benthic animals in relation to food resource





Zhang & Wirtz, 2017

Model application

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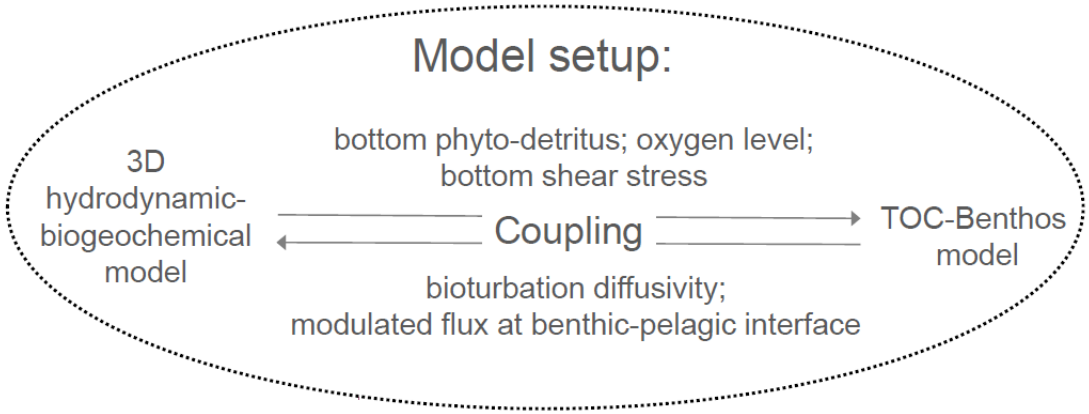
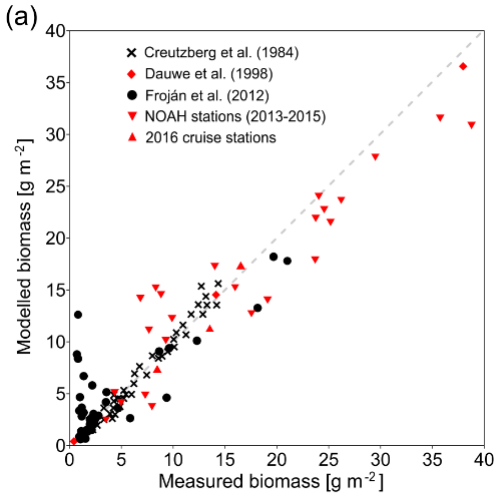
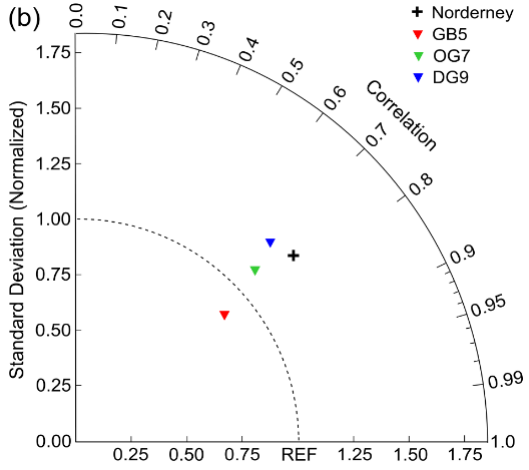
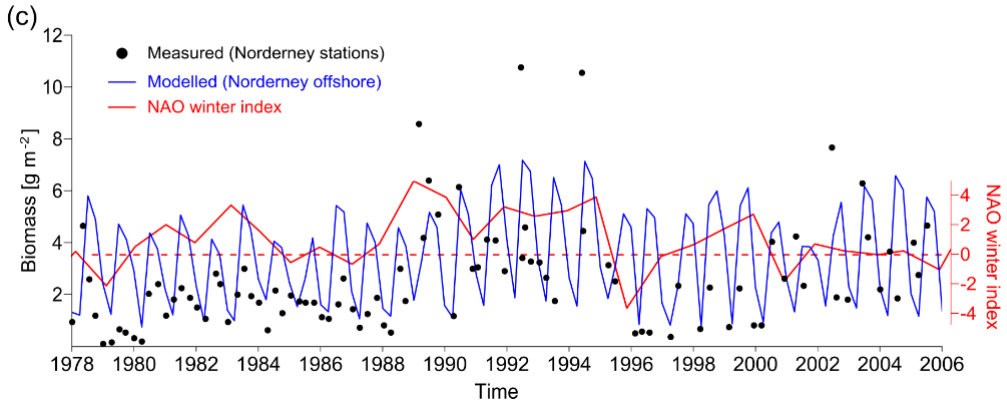
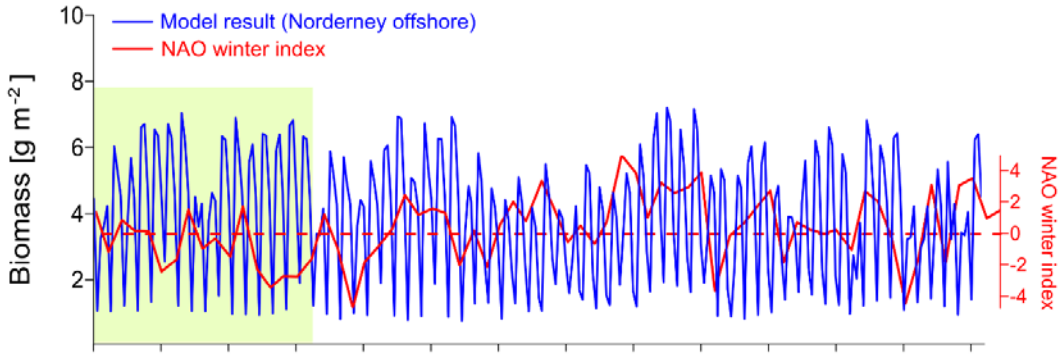


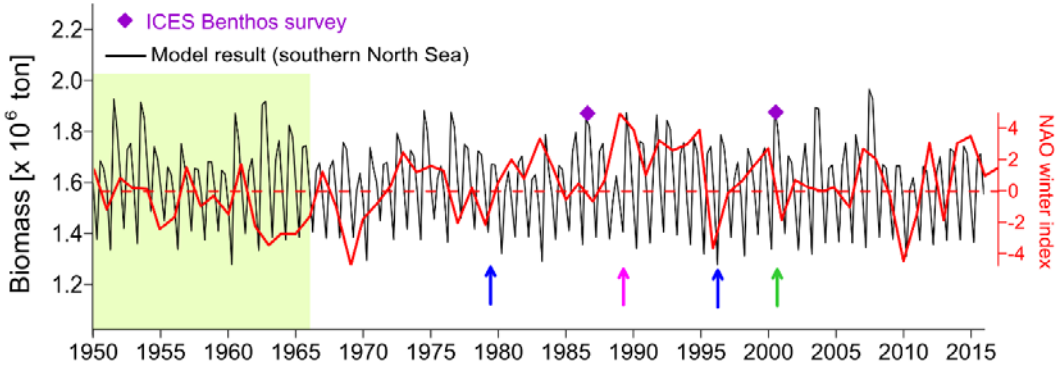






Zhang et al. (in prep)





Model application to North Sea

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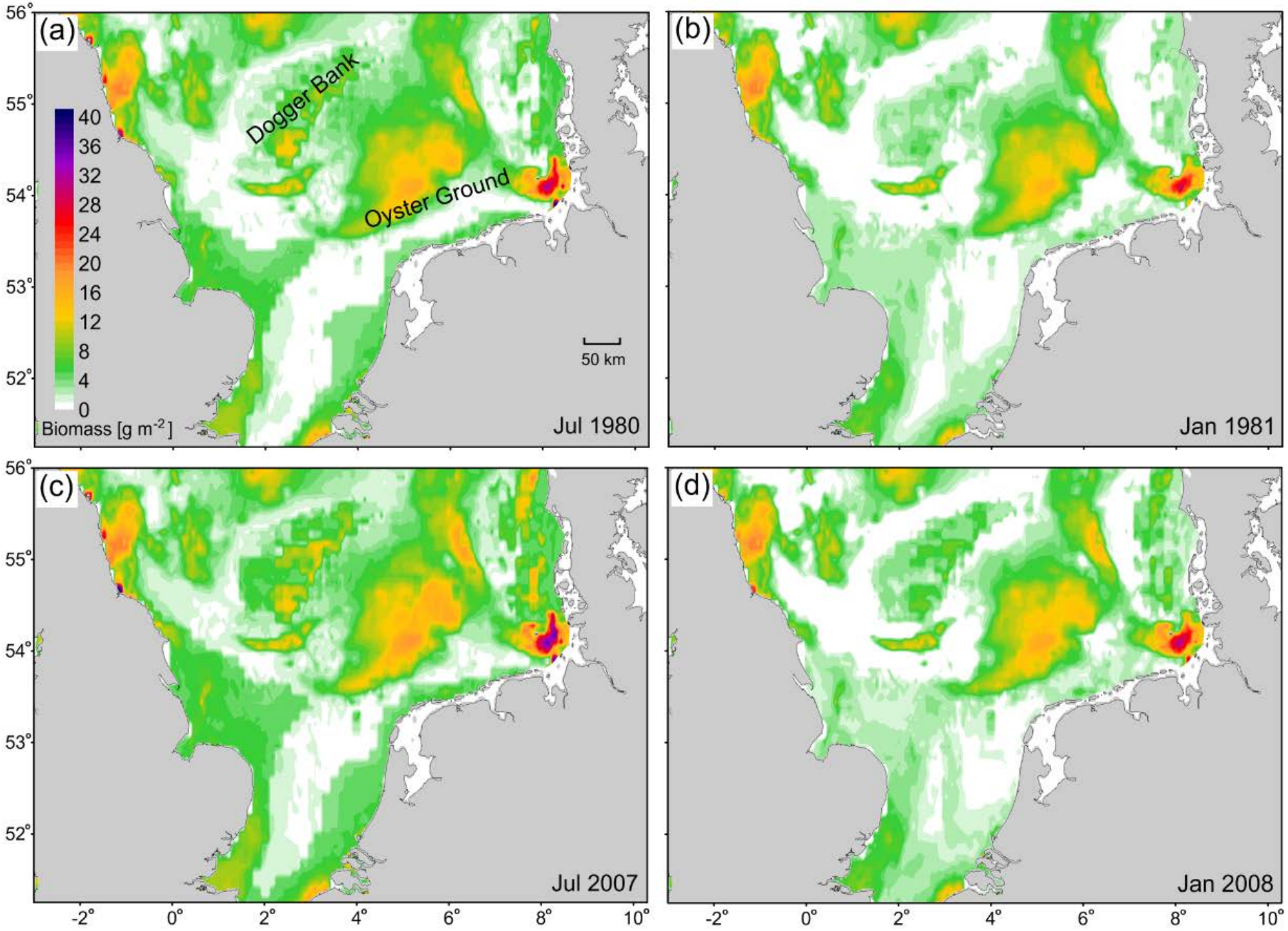

Model application to North Sea

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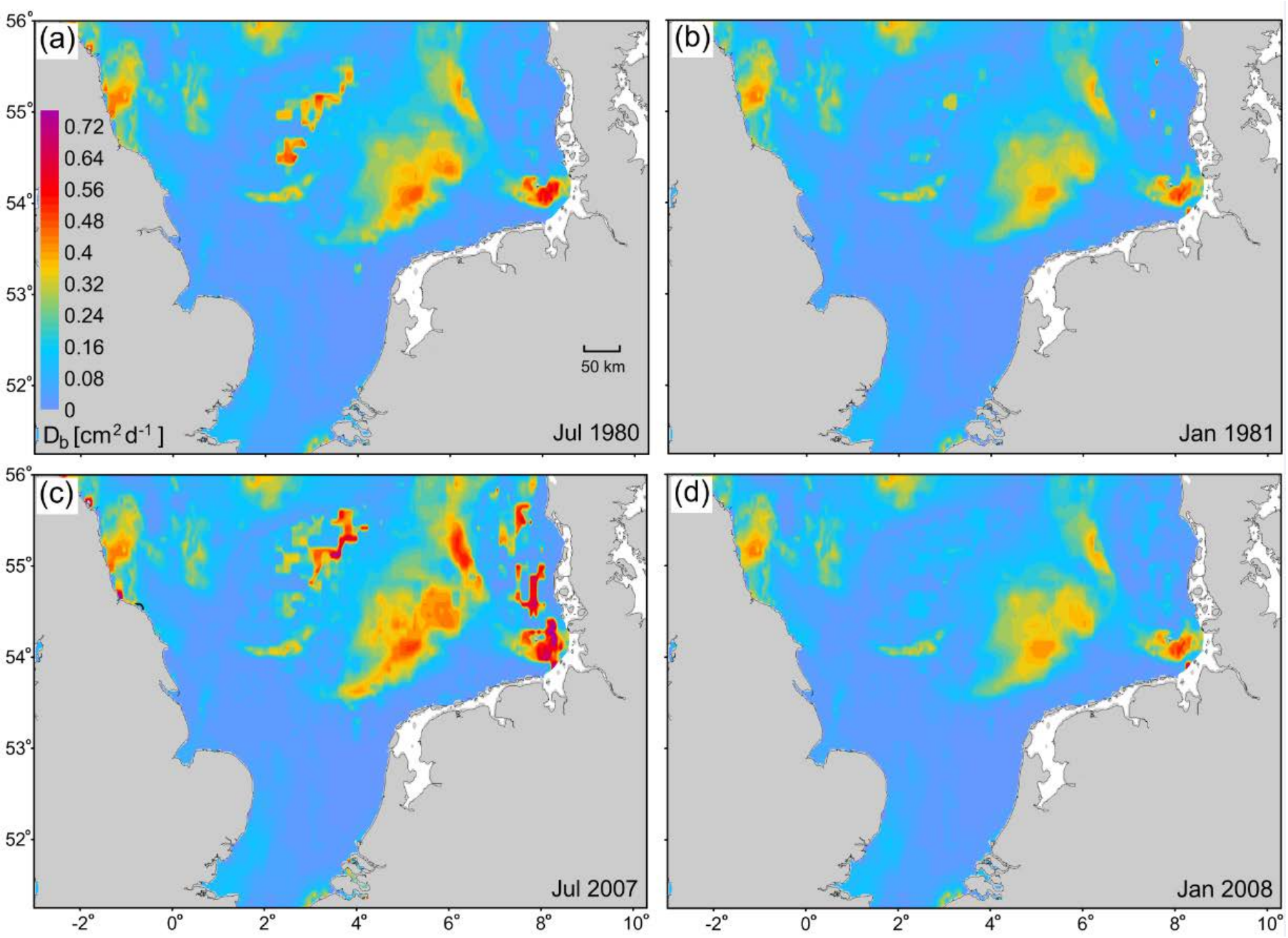

Model application to Baltic Sea

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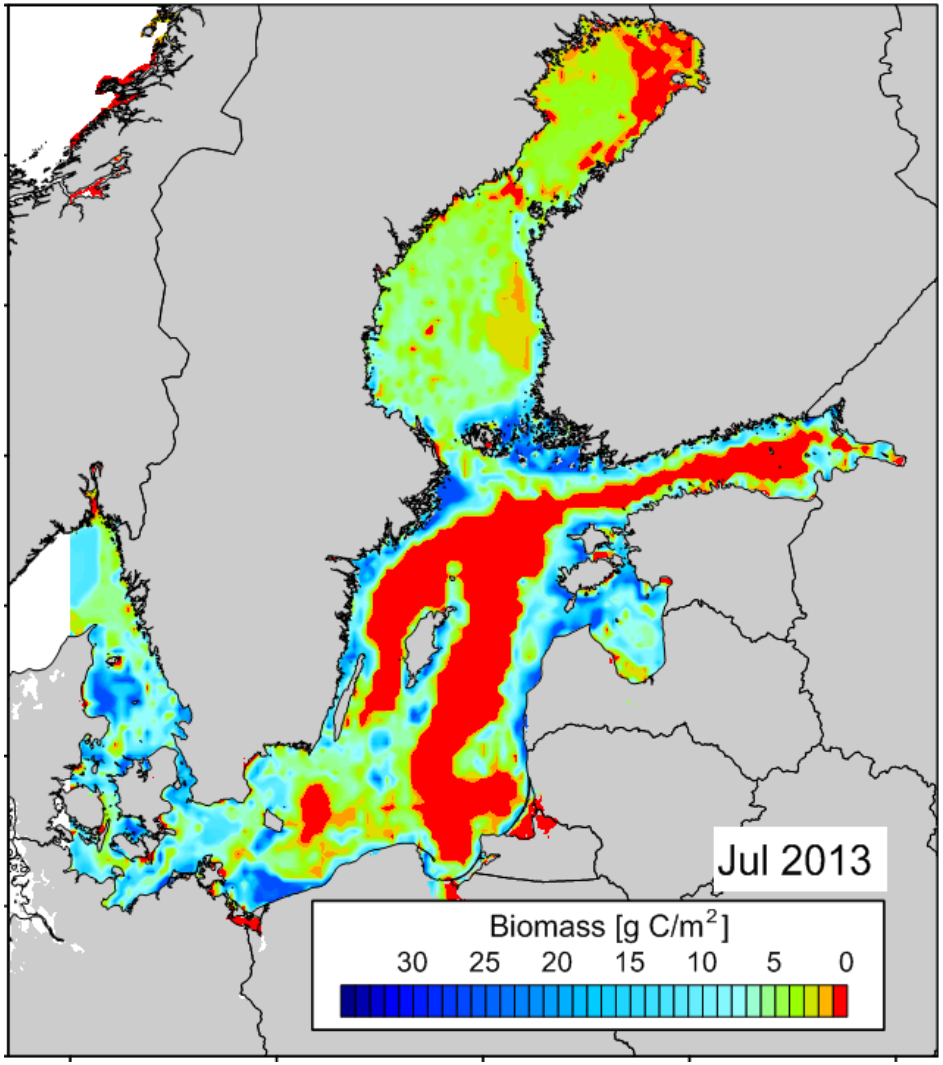
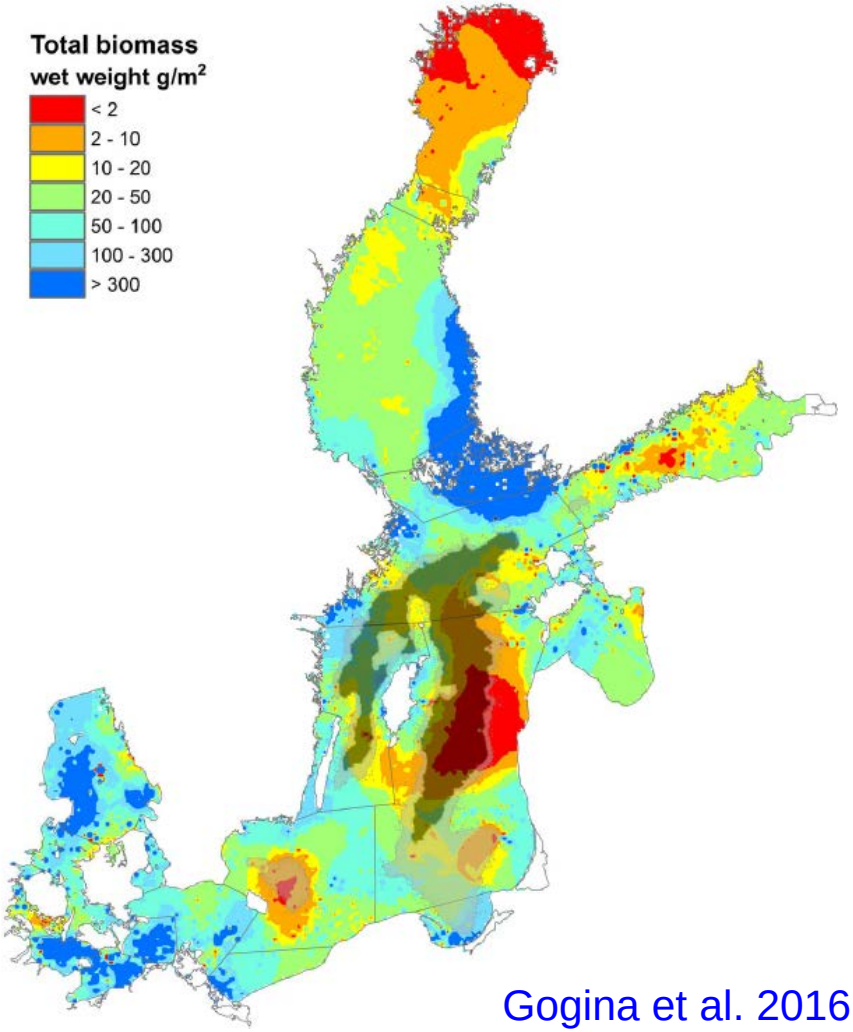
Simulation result



Measured biomass (wwt) 2000-2013



Gogina et al. 2016

Model application to Baltic Sea

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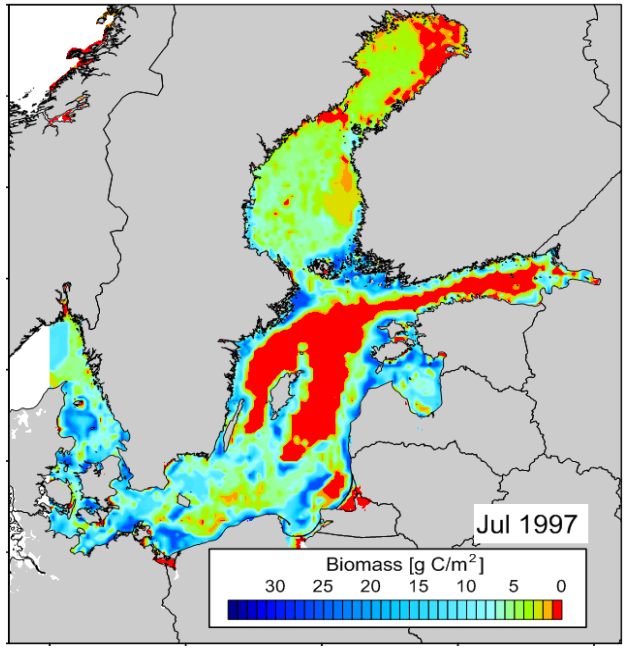

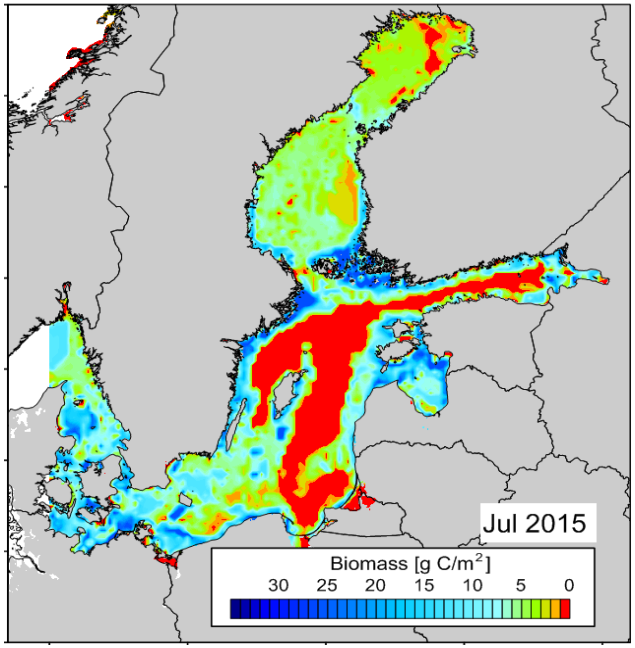

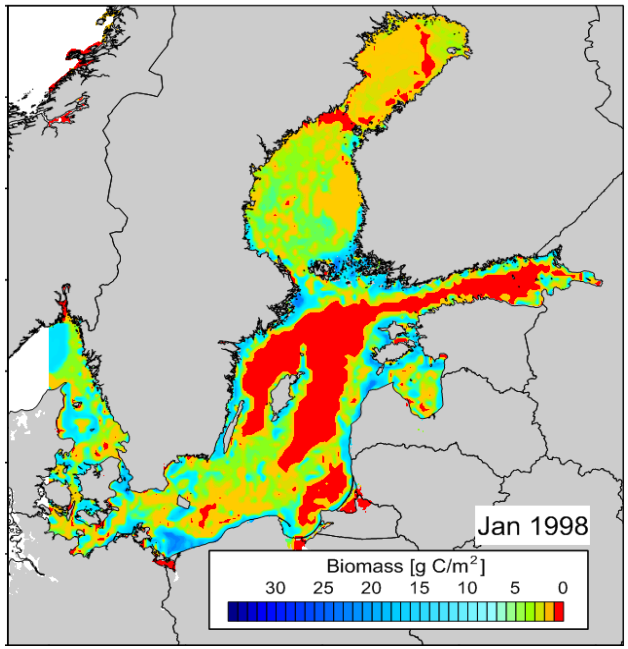

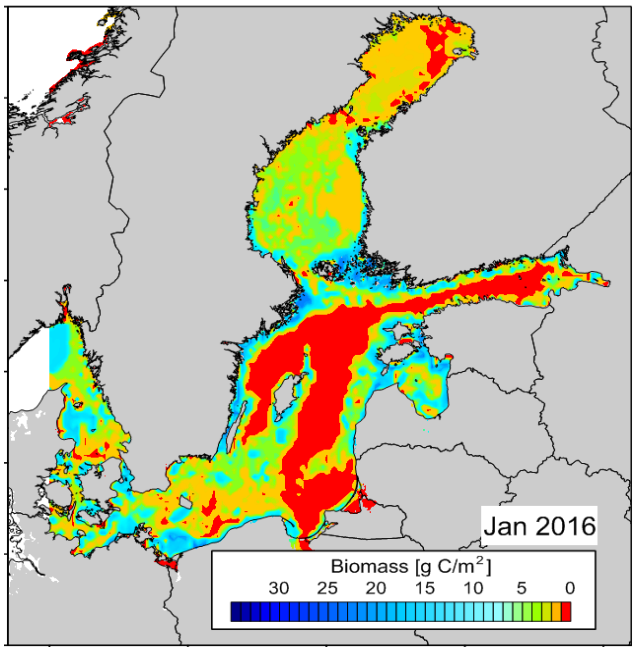

Model application to Baltic Sea

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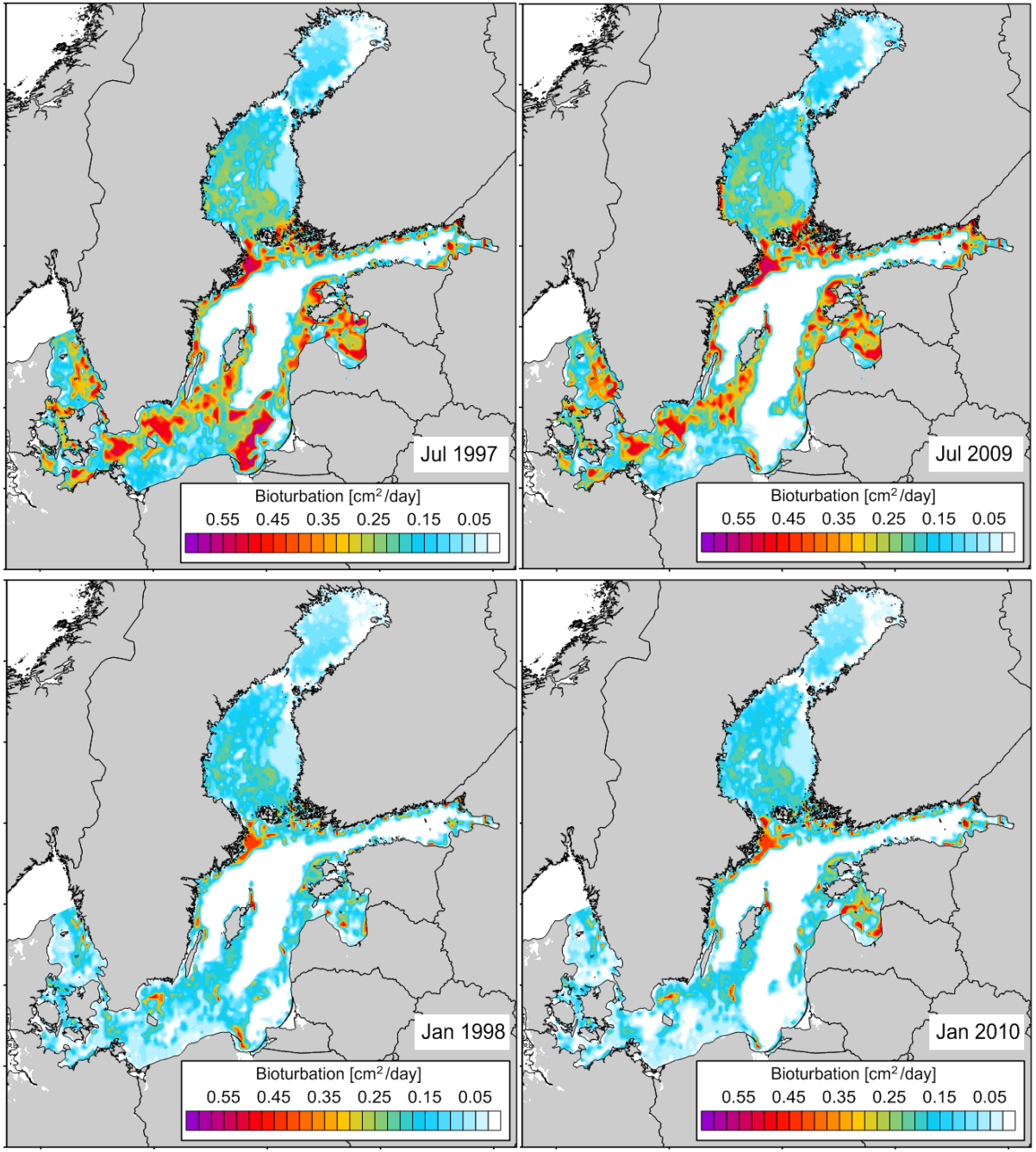

Summary – North Sea application

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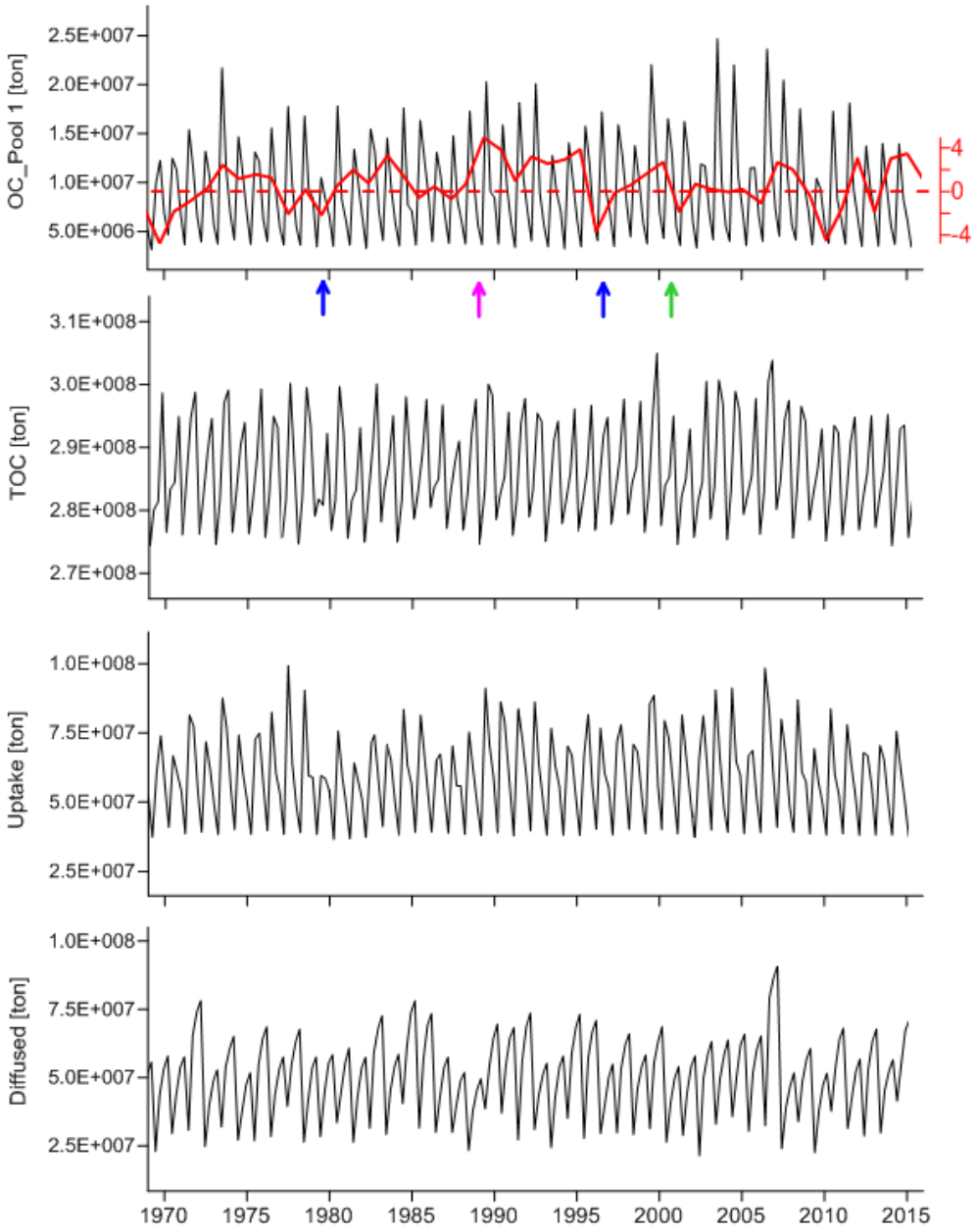
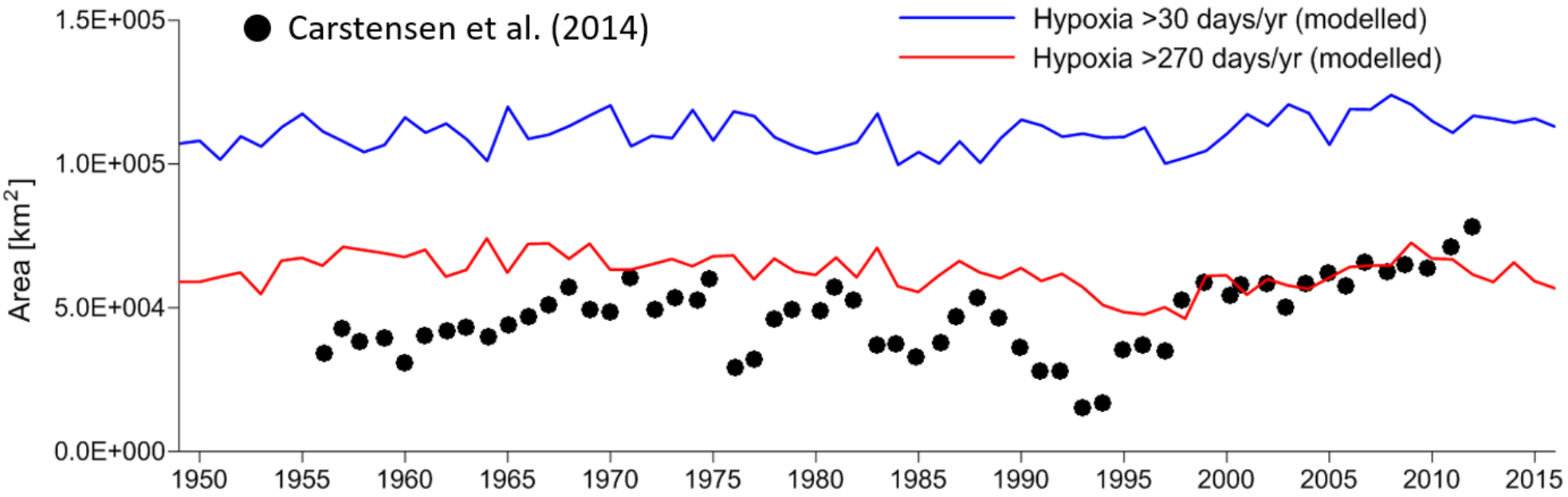


- Good agreement between field data and model results;
- Long-term (multi-year) variation of benthic biomass in shallow water (<20 m) is significantly influenced by climate drivers (e.g. NAO winter index);
- Macrobenthos in the regional scale (SNS) are more resilient to climate drivers, except for a prominent seasonal fluctuation;
- Macrobenthos annually reworked 30 – 50% of TOC in seafloor surface sediments;
- Macrobenthic uptake is larger than vertical transport in terms of reworked TOC budget at the interface;
- No net change in TOC budget in surface sediments.

Summary – Baltic Sea application



Summary – Baltic Sea application

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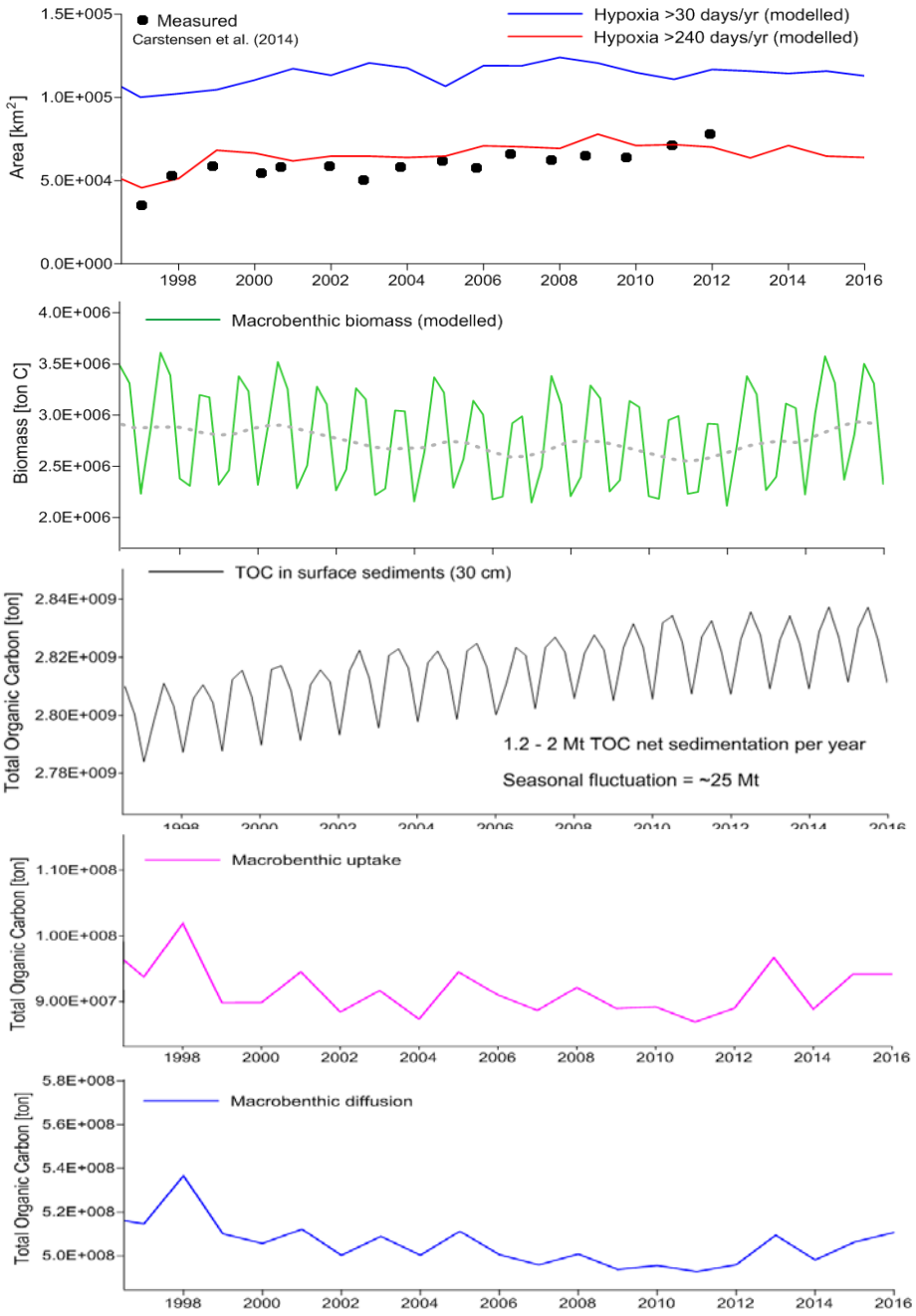

- Good agreement between field data and model results;
- Long-term (multi-year) variation of benthic biomass in shallow water (<20 m) is significantly influenced by climate drivers (e.g. NAO winter index);
- Macrobenthos in the regional scale (BS) are heavily affected by hypoxia;
- Macrobenthos annually reworked 15 – 25% of TOC in seafloor surface sediments;
- Macrobenthic uptake is subordinate compared to vertical transport in terms of reworked TOC budget;
- Net increase in TOC budget in surface sediments.