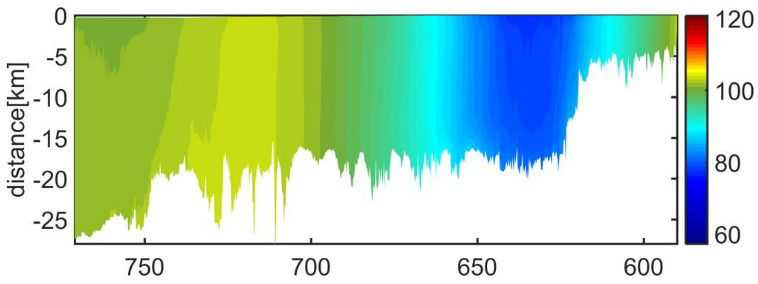
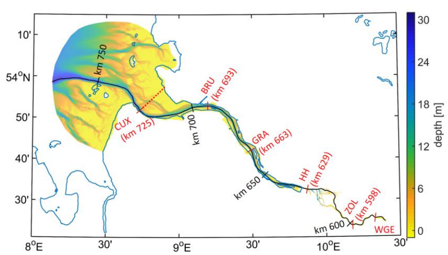
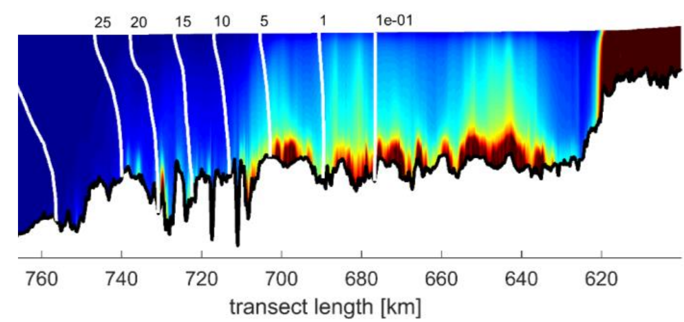
RESPONSE OF ELBE ESTUARY ECOSYSTEM TO CHANGED RIVERINE NITROGEN LOADS







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04.05.2020, EGU, Online Discussion

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MOTIVIATION

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- Eutrophication leads to increased production of biomass, sedimentation, oxygen depletion due to bacterial degradation, changes in species composition (Lenhart et al. 2007)
- OSPAR Convention recommended 50 % reduction of the inorganic nutrients (1985)
- Water Framework Directive: „Good ecological status of river, lakes, coastal and transitional waters by 2027“
- Estuaries: Difficult to discern between anthropogenic vs. natural stresses and to derive nutrient criteria (Poikane et al., 2019)
- Climate change and other long-term processes increase the uncertainity, specifically in hot spot areas like coastal seas, estuaries and artificial embayments
- Difficulty due to lack of knowledge about the ecological response to certain nutrient levels (Elliott and Quintino, 2007), which might lead to not optimal defintions of good ecological status and associated legal nutrient threshold

→ Need for understanding of the specific ecological system or type of system, the specific response to nutrient loading (increase, reduction)

ELBE SET-UP

Model area, coupling, forcing

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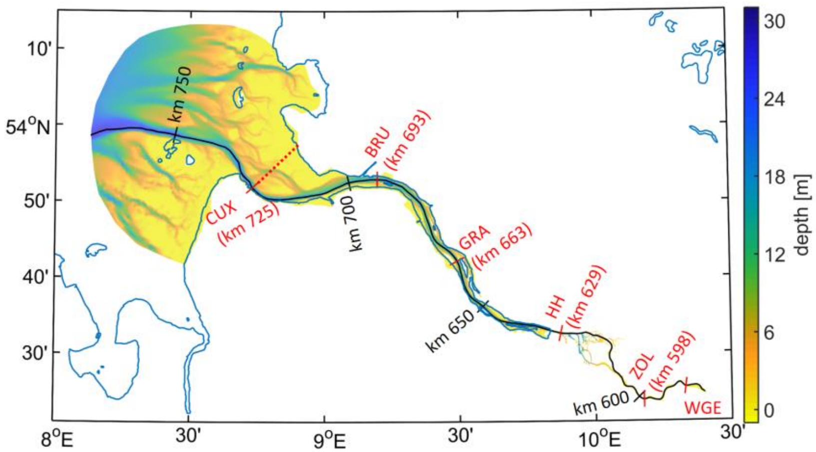
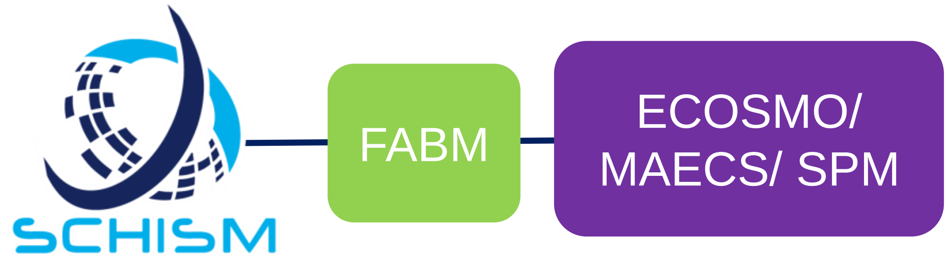


- SCHISM hydrodynamical core (Zhang et al. 2016)
- ~32k nodes in horizontal, LSC² hybrid coordinates with 2 – 21 layers
- Horizontal resolution between ~500m and ~ 35 m
- Time step 60 s
- O.B. Forcing: Physics 1-way nest into GB
- Biological model uses Redfield ratio (106:12:1, C:N:P)



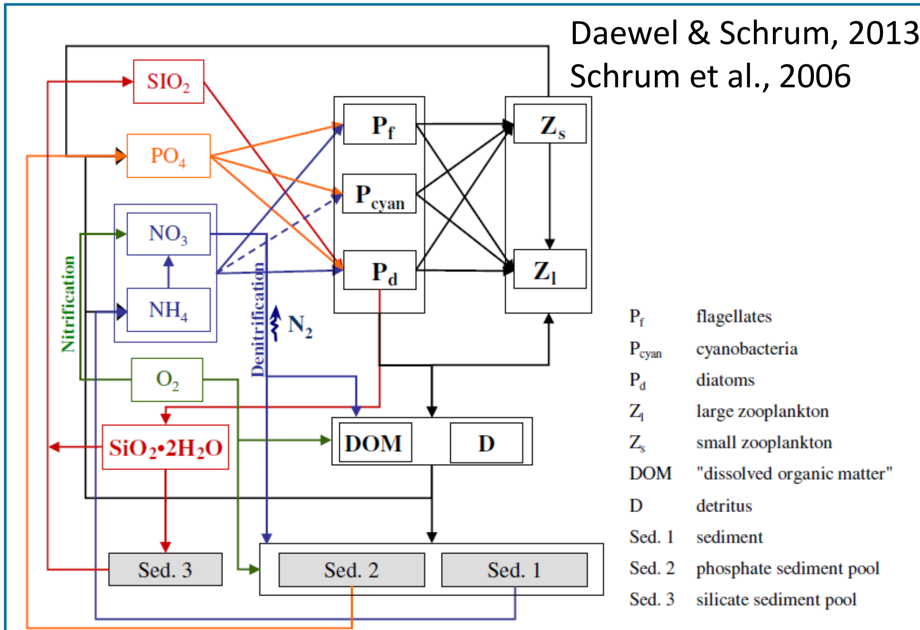


Fig. 2. Schematic diagram of biochemical interactions in ECOSMO II.

SCHISM-(FABM)-ECOSMO (R. Hofmeister, U. Daewel, C. Schrum)

HYDRODYNAMICAL FORCING MODEL

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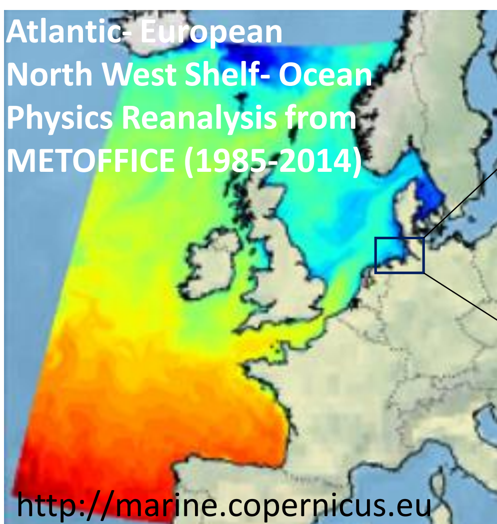
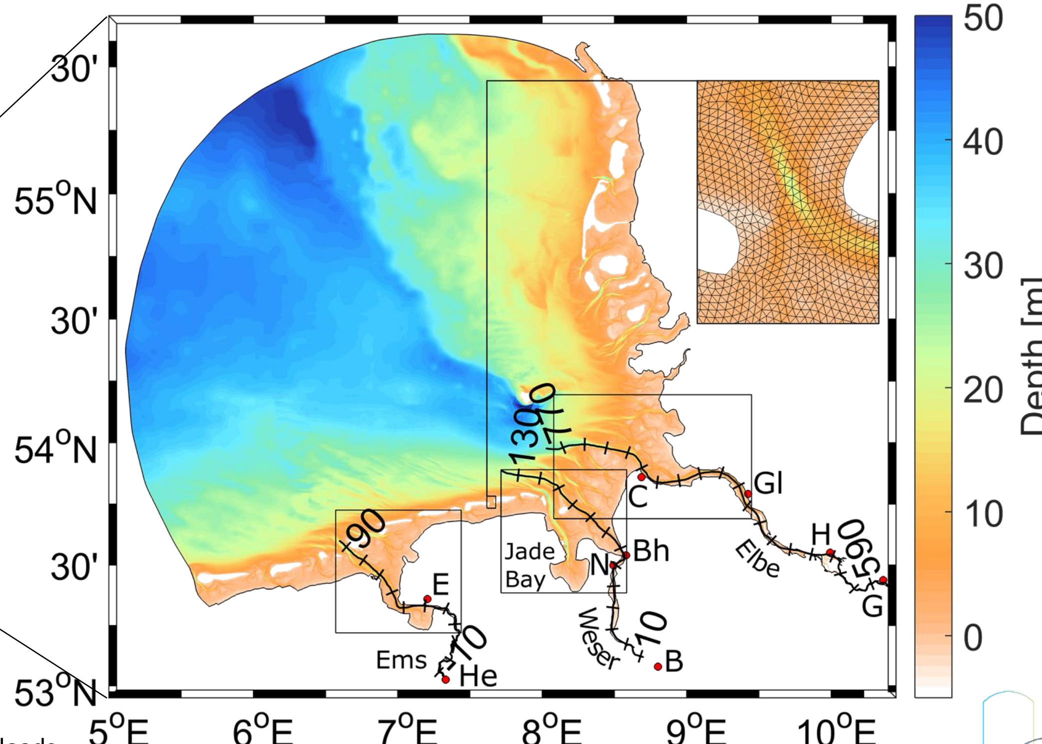
Set-up & Forcing (Stanev et al. 2019)

- Horizontal grid: ~0.5 Mio nodes (resolution: 50 m in channels, 400 m open ocean)
- Vertical grid: 21 Vertical Layers
- Time step: 120 s, Integration: 1 Jan 2012 to 31 December 2013
- Open boundaries: CMEMS reanalysis with SSH, currents, salt & temp.
- Rivers: WSV run-off data
- Atmospherical forcing: German Weather Service (DWD) Reanalysis (Cosmo-EU, 7 km)
- Sediment initialised with BSH surveys of sea bed composition (8 classes)





RIVER BOUNDARY

Forcing & scenario details

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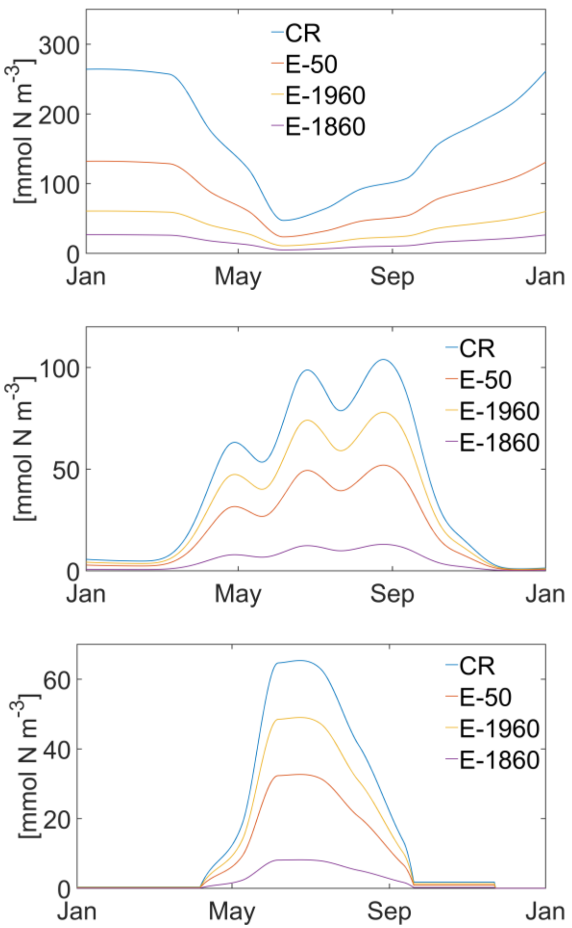

- River discharge, water temperature (observations) applied at tidal weir – 2012 observations used for all runs
- Observations of inorganic nutrient, oxygen concentrations at weir multiplied with discharge ($m^3\ s^{-1}$ * mmol m^{-3})
- Chl-a and biomass concentration specified at weir with C/Chl following Schöl et al.(2014)
- Labile organic nitrogen derived from observed total nitrogen minus inorganic nitrogen minus an estimated refractory part
- O.B. in North Sea relaxed to seasonal variability of North Sea observed inorganic nutrients, oxygen, organic N (ICES region IVb) forced onto the model in a sponge layer – no external forcing of plankton
- Nutrient reduction scenarios
    - 50 % reduction of DIN & organic inputs („E-50“)
    - ~80%-reduction of nitrate, ~40 %-reduction of organic nitrogen adapting estimated ratios of N-species in 1990s vs. 1960 („E-1960“) by Serna et al.(2010)
    - Pre-industrial scenario („E-1860“) adapting estimates of N-species by Serna et al.(2010)

OVERVIEW HINDCASTS 2012-2013

Surface variability: distance [km] over time

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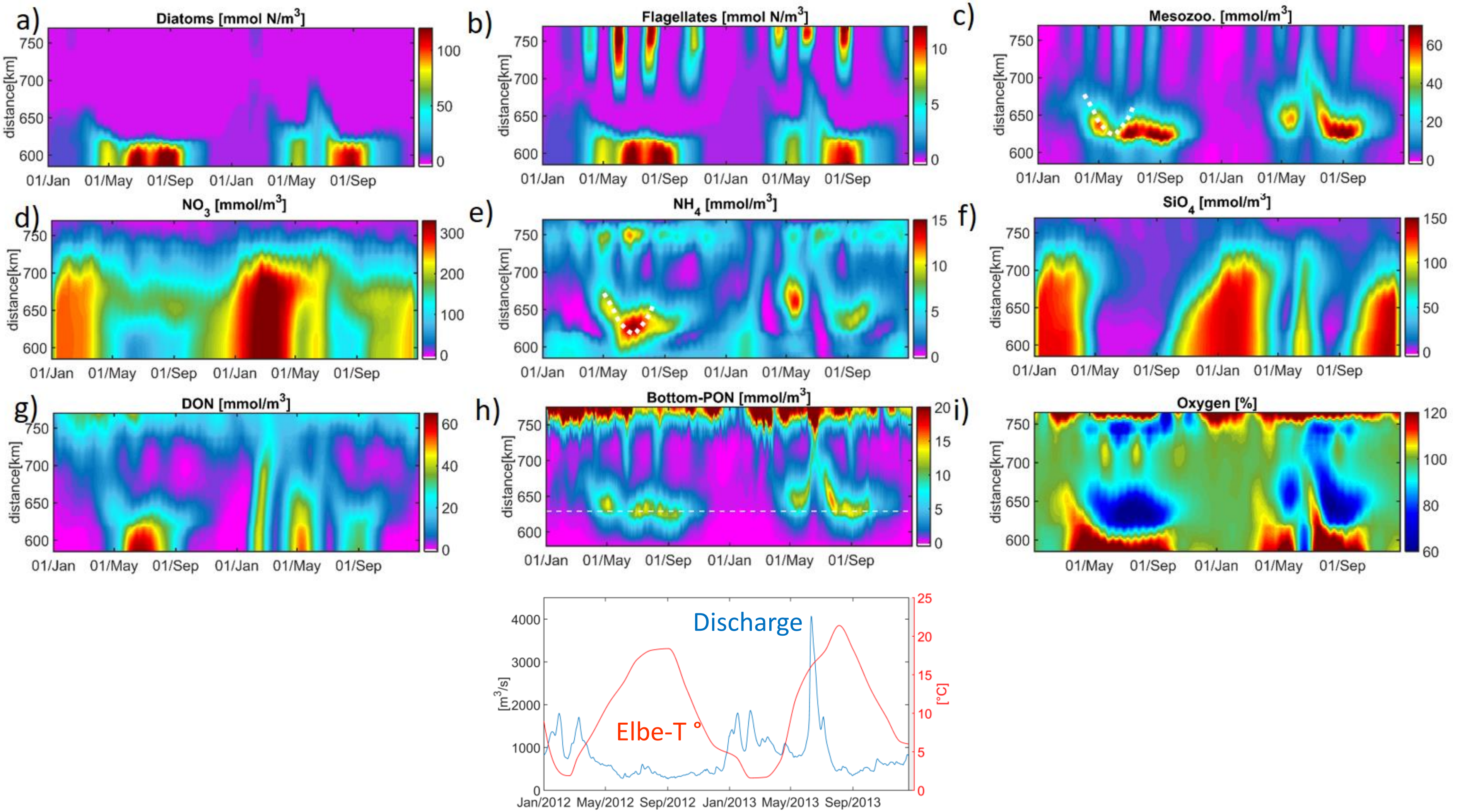

Response of Elbe estuary ecosystem to changed riverine nitrogen loads

HOTSPOTS OF HETEROTROPHIC TURNOVER

Summer situation harbor – sedimentation of organic material

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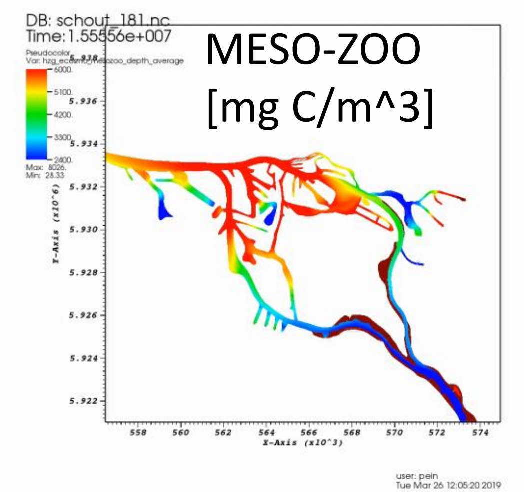

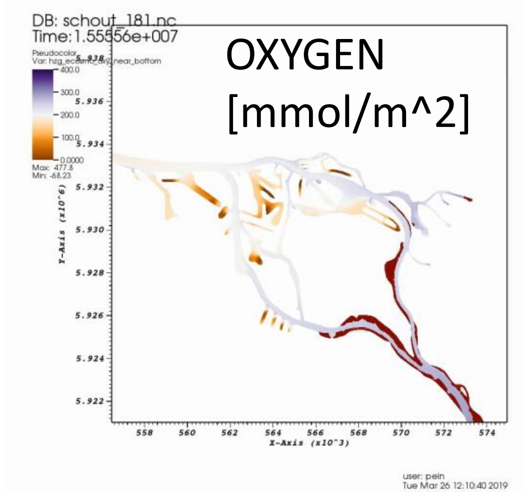

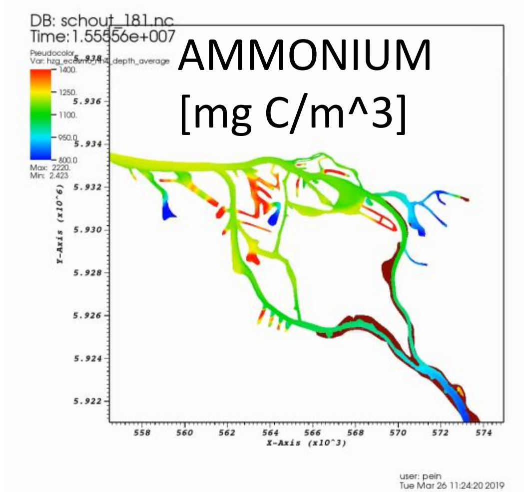

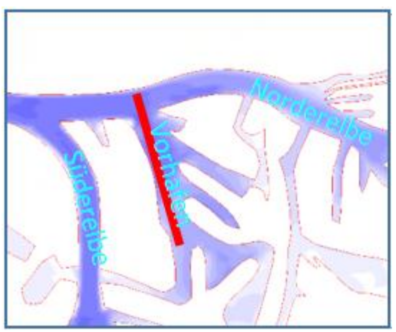

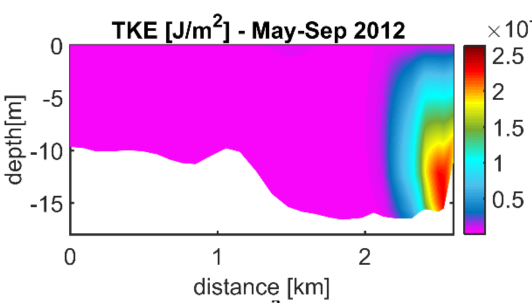

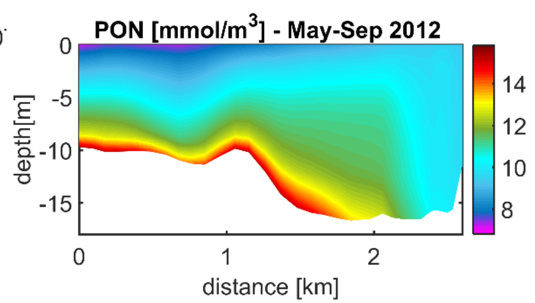

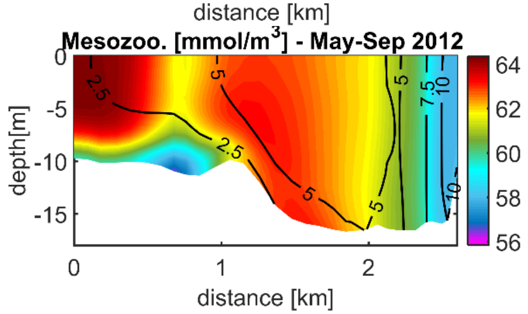

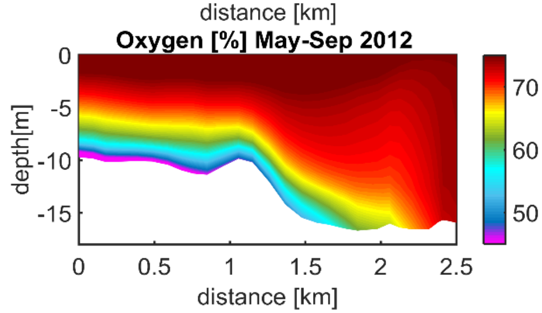

EFFECT OF NUTRIENT REDUCTION

Upper estuary – main channel downstream port of Hamburg

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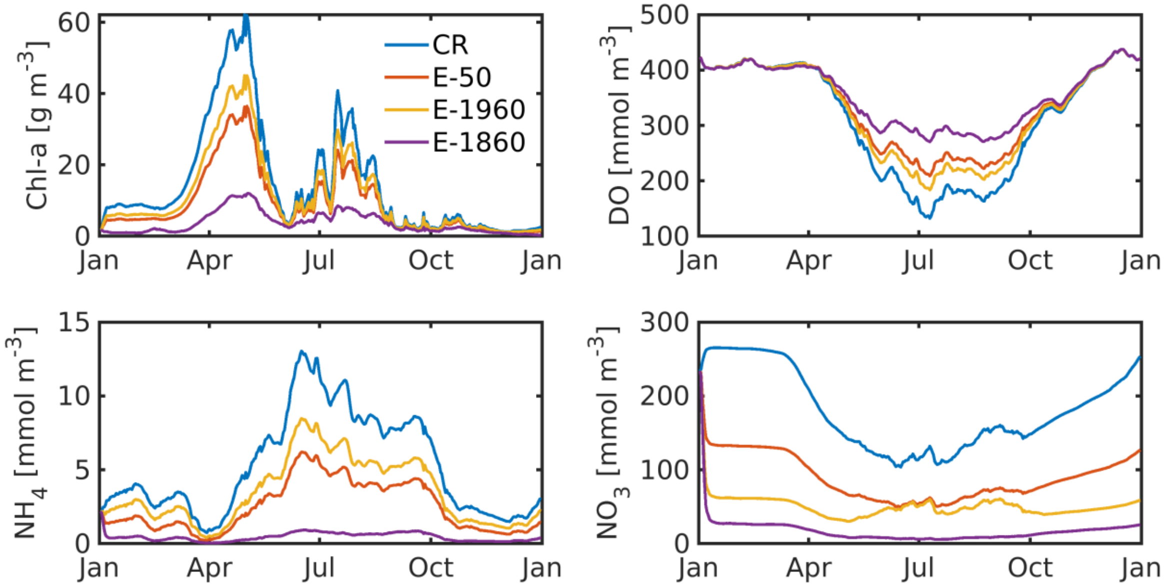
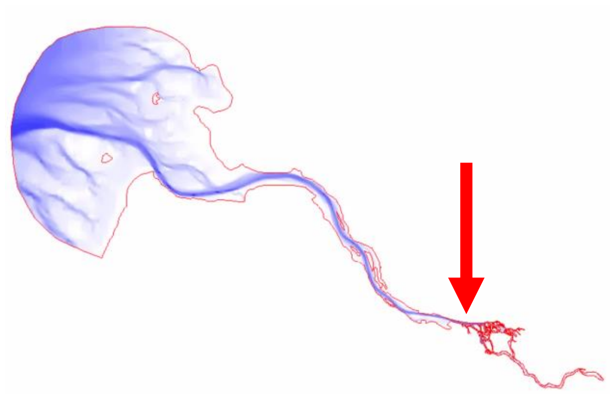


Good ecological status OSPAR:
DO conc. > 4-6 mg/l
(127-187 mmol/m³)
Hypoxia: 62.5 mmol/m³

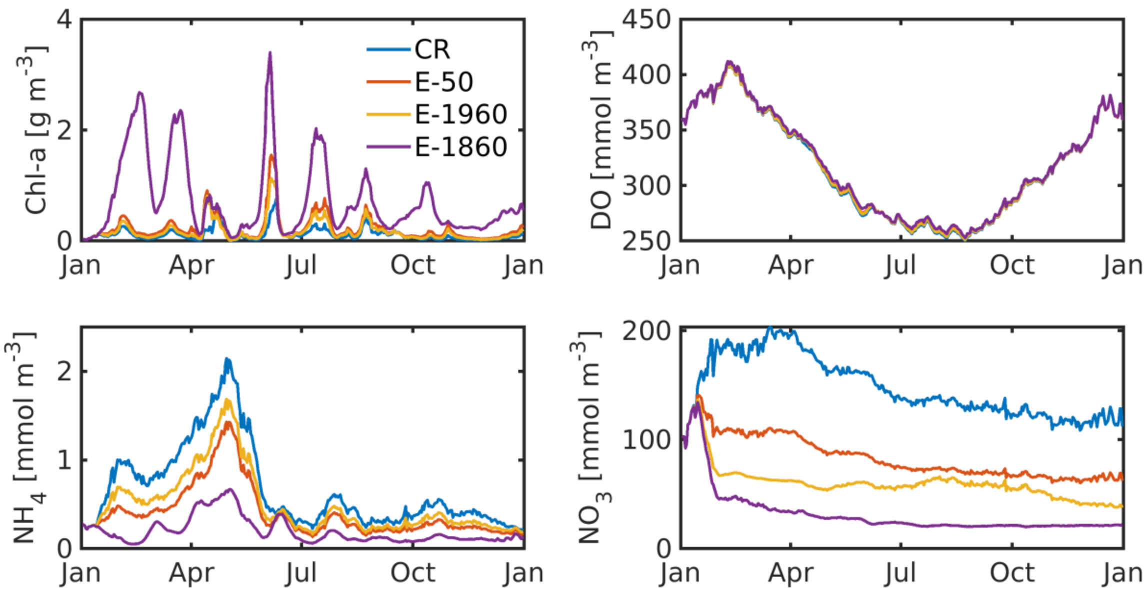


- Scenarios lead to reduced chlorophyll and nutrient levels
- Oxygen levels improve
- Nitrate reveals differentiated response: Although DIN reduction is higher in E-1960 (80% vs. 50 %), mid-summer levels equal the E-50

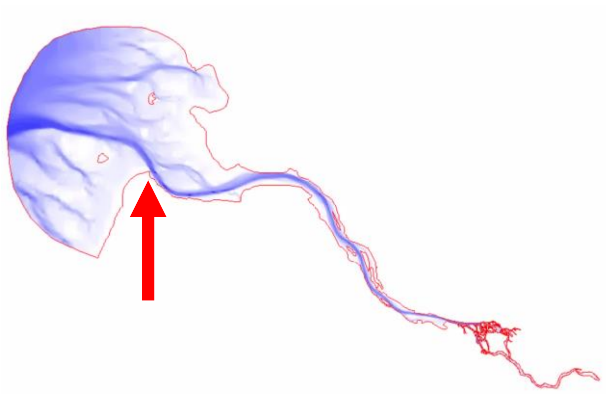
Response of Elbe estuary ecosystem to changed riverine nitrogen loads

EFFECT OF NUTRIENT REDUCTION

Lower estuary



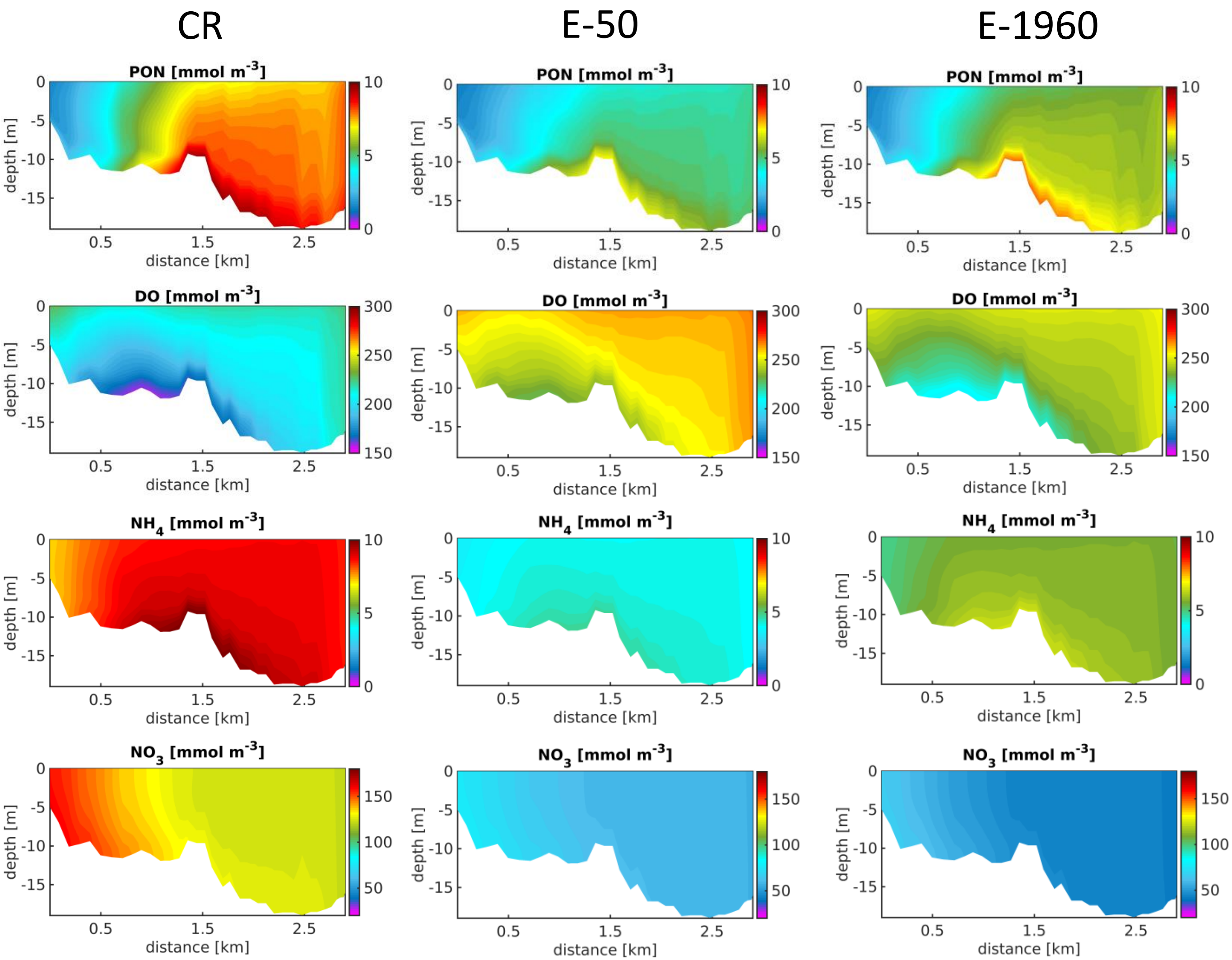
Increase of primary producers

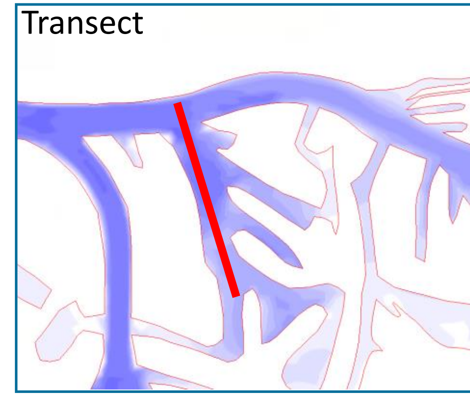


- Scenarios lead to reduced nutrient levels
- Oxygen levels almost not affected
- Chlorophyll levels increase slightly under „modest“ reduction scenarios, strong increase under the E-1860 scenario

→ Less zooplankton arriving from uptream region?

Nutrient reduction scenarios
Port basin mean summer conditions

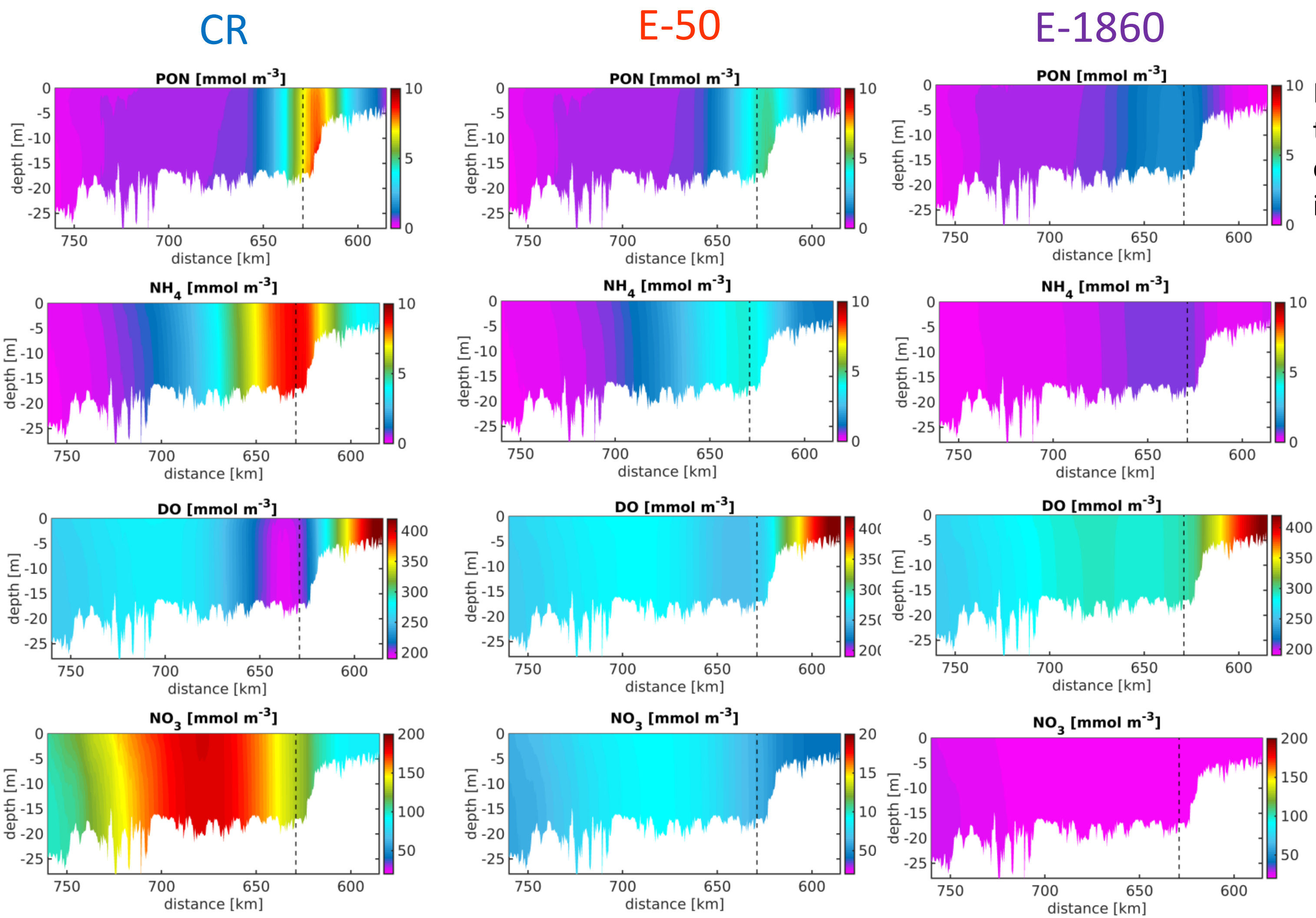




- 50/50% reduction of both DIN and TON vs. 80/35% reduction, respectively
- Reduced PON and increased oxygen levels in both cases
- Relatively higher reduction of organic nitrogen inputs more effectively mitigates oxygen depletion, reduces local ammonium and nitrate levels

IMPACT ON SUMMER CONDITIONS

Main channel



Distinct maximum turbidity zone largely ceases under pre-industrial scenario.

Nutrient, oxygen levels approach background levels under pre-industrial scenario.

WARMING SCENARIOS

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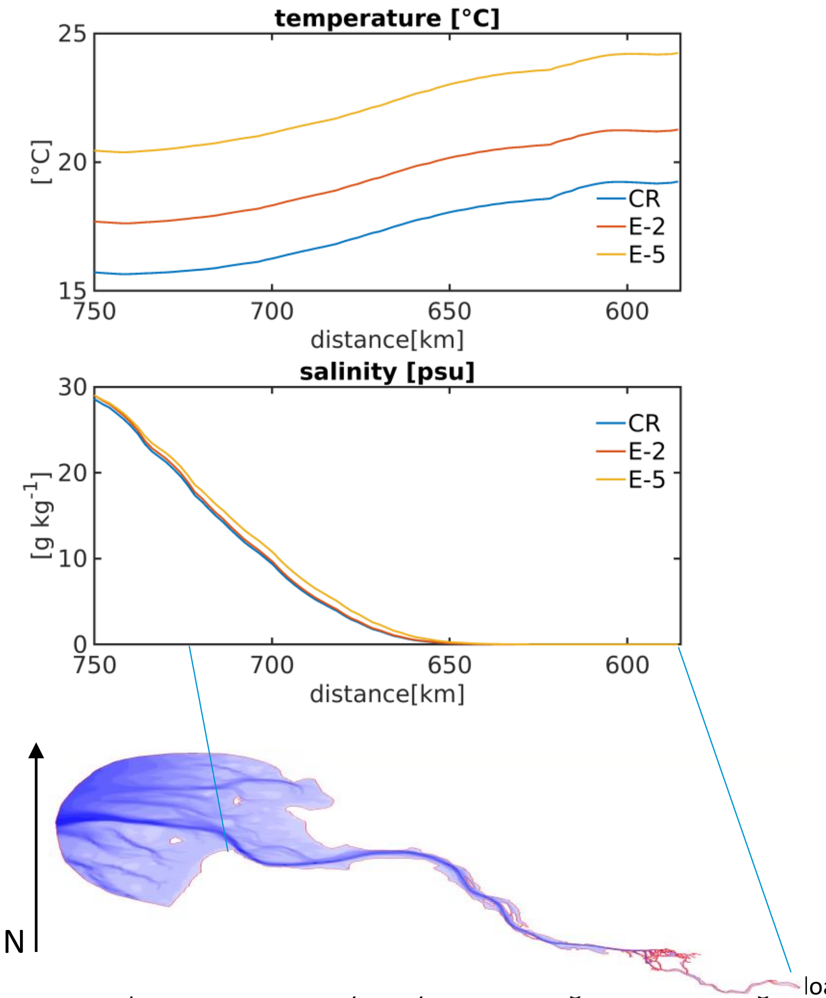
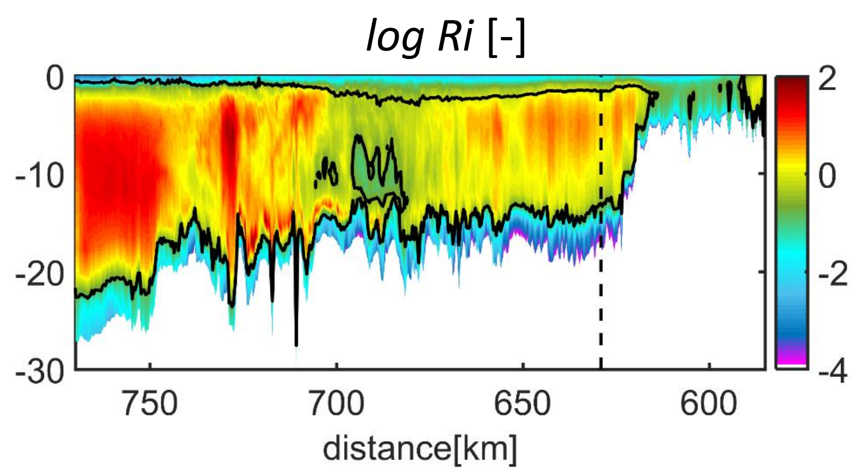
SST and SSS averaged along the main channel, May-September average



Set-up

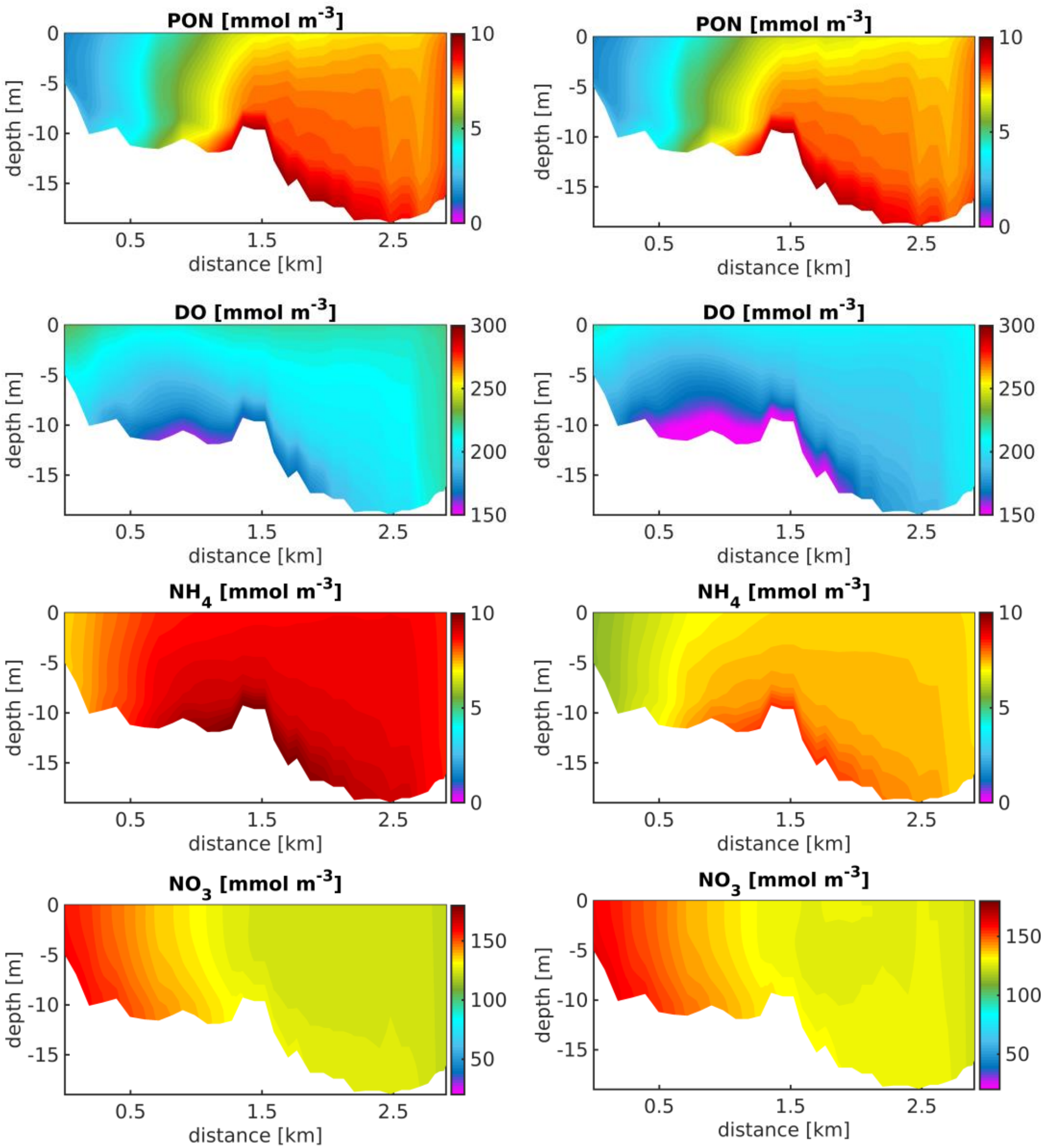
- Increase open ocean and river boundary conditions by 2°C and 5°C, („E-2“, „E-5“) respectively
- Increase air temperature & long-wave radiation
- Expectation: Increased stratification in oxygen minimum zone, increased reaction rates



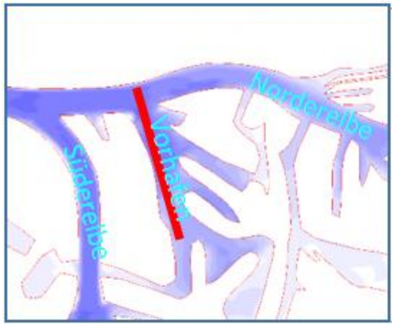
Warming scenario +2°C

Impact on average port basin summer conditions (May-September 2012)

CR E-2



Increased risk of hypoxia in the port area.



CONCLUSIONS

- Estuarine ecosystem reveals clear response to nutrient load reduction on seasonal time scale
- Applied reduction scenarios lead to increased oxygen levels, in particular in hot spot region of heterotrophic decay
- Under a pre-industrial scenario oxygen and nitrate levels approach background estuarine concentrations in minimum/maximum zones under present forcing conditions
- A simple warming scenario demonstrates increased risk of hypoxia in the port area
- Combining warming scenarios with nutrient reduction necessary to understand potential of reduction strategies to mitigate effects of climate change

Thank you for your attention!

Acknowledgments

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