Hypoxia in future climates: A model ensemble study for the Baltic Sea

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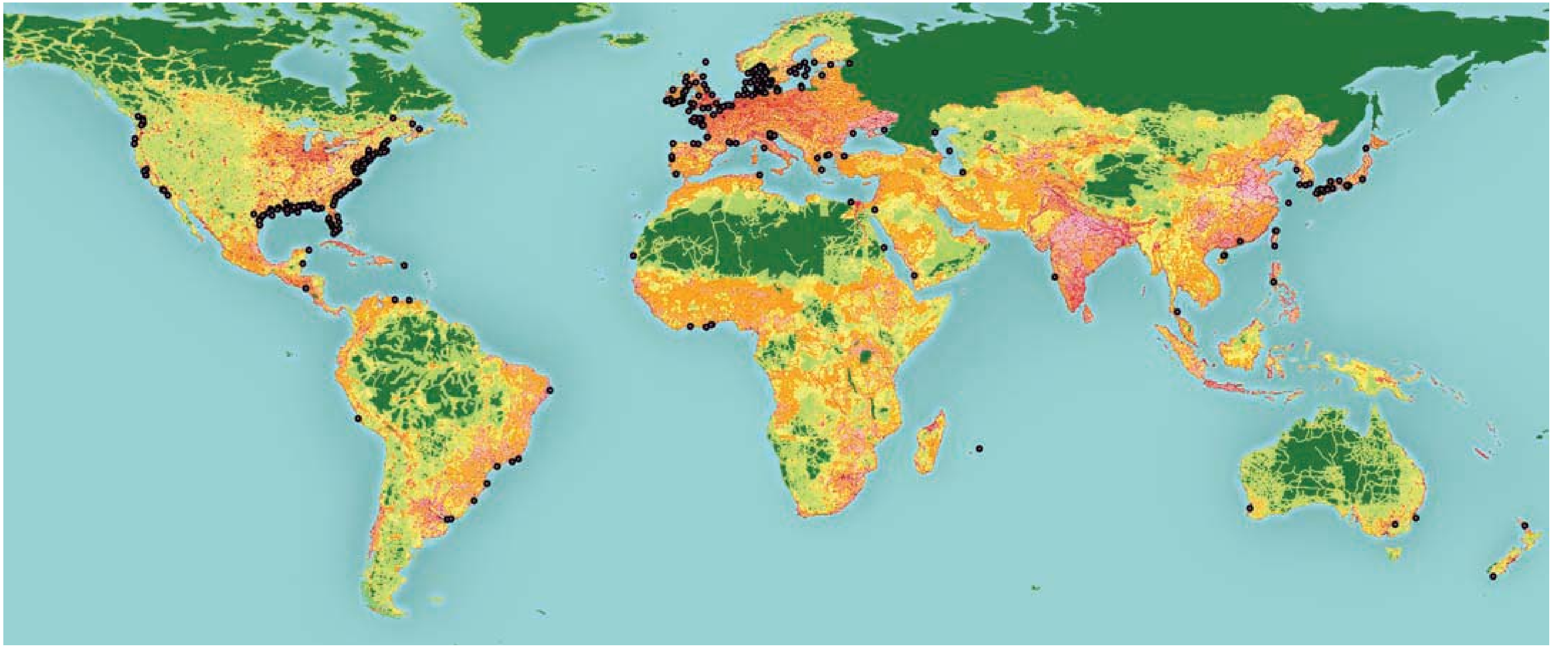
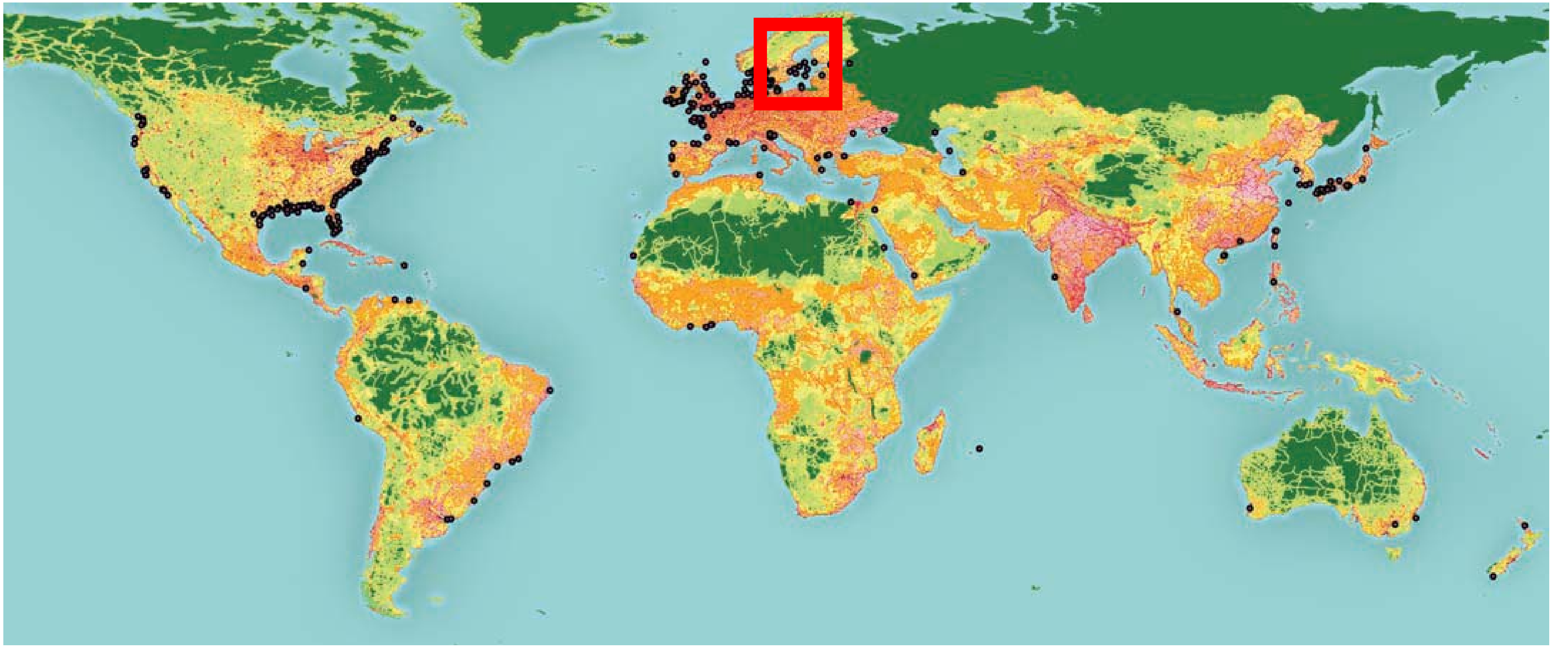


Eutrophication-associated dead coastal zones

(Source: Diaz and Rosenberg, 2008)



Eutrophication-associated dead coastal zones

(Source: Diaz and Rosenberg, 2008)

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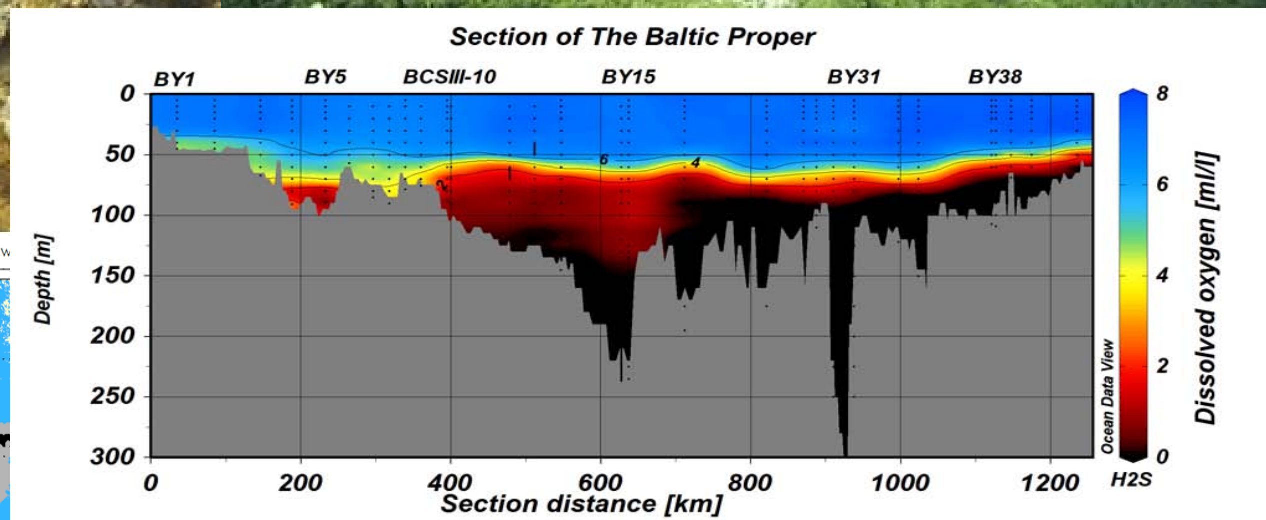
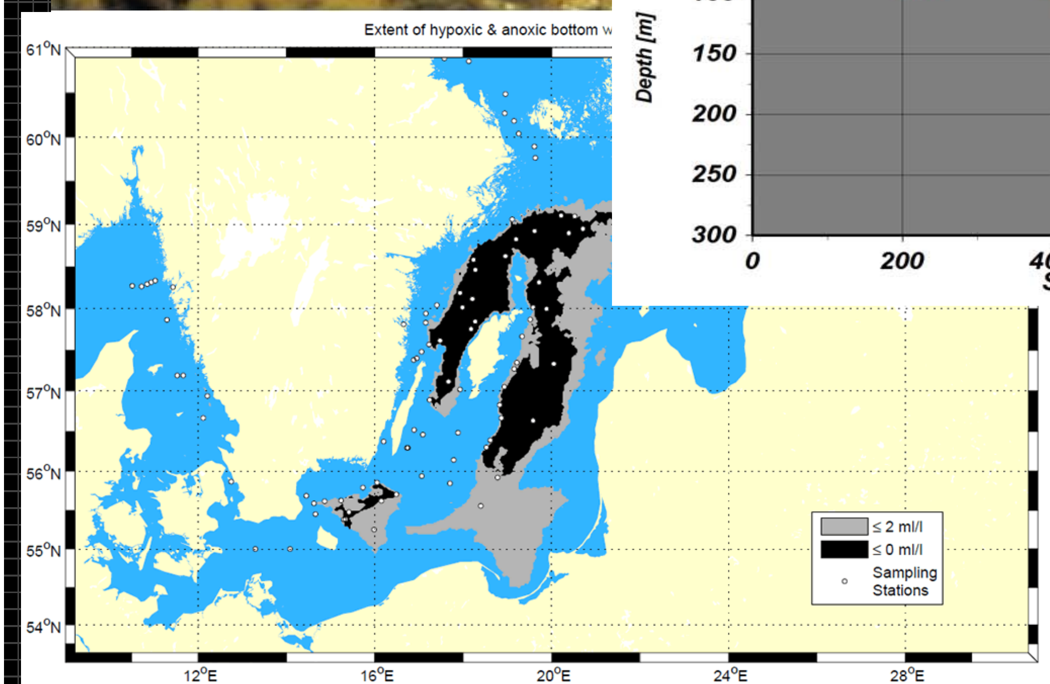
Baltic Sea - where are we now?

Large Cyanobacterial blooms

Baltic Sea - where are we now?





Hypoxia/anoxia

4 times as large today compared to 100 years ago

Baltic Sea - where are we now?

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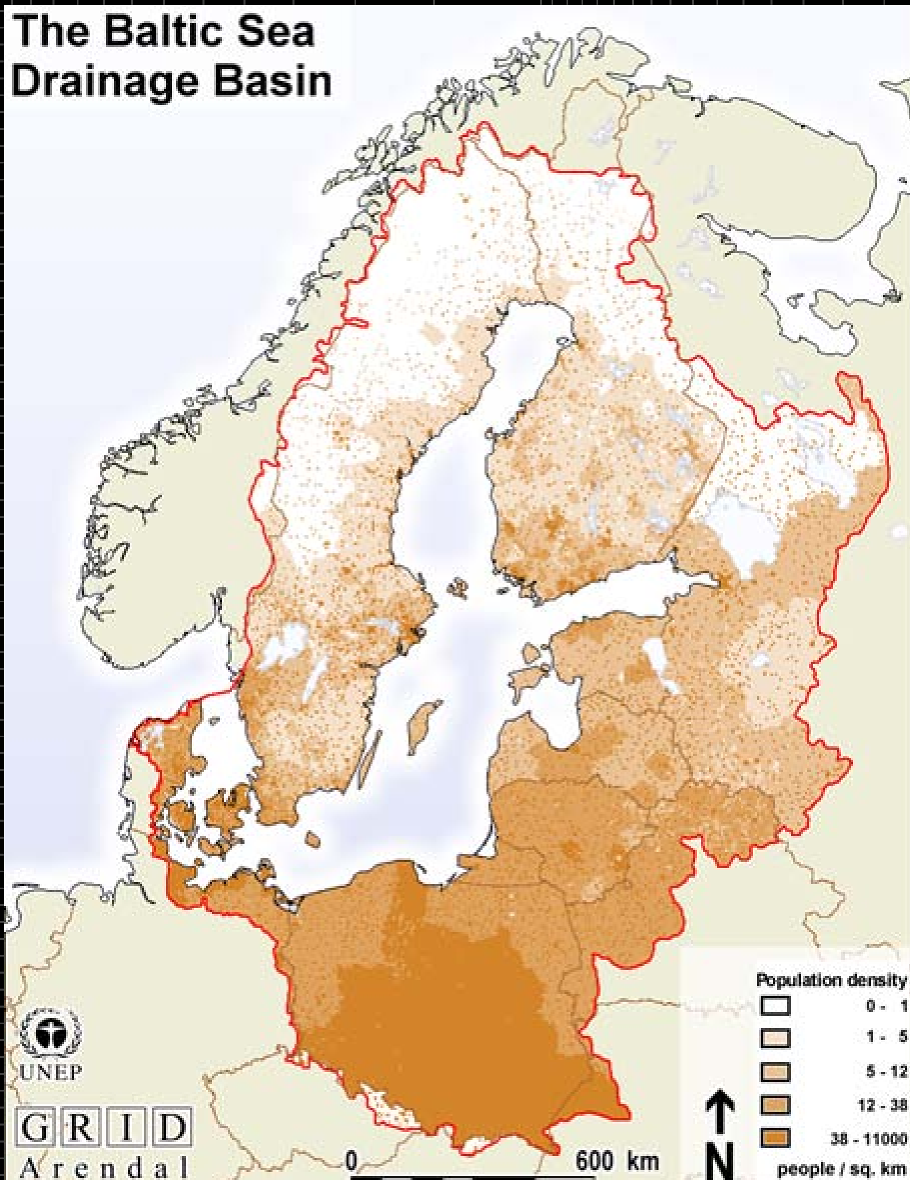
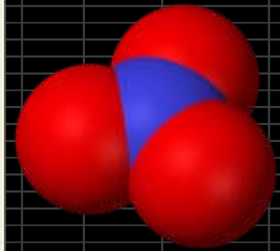
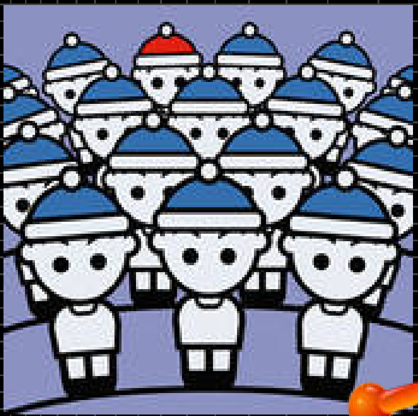


NO_3





PO_4

- Huge catchment area
- 85 million people
- Freshwater supply 15,000 m s^{-1}

Baltic Sea - how to approach the future?

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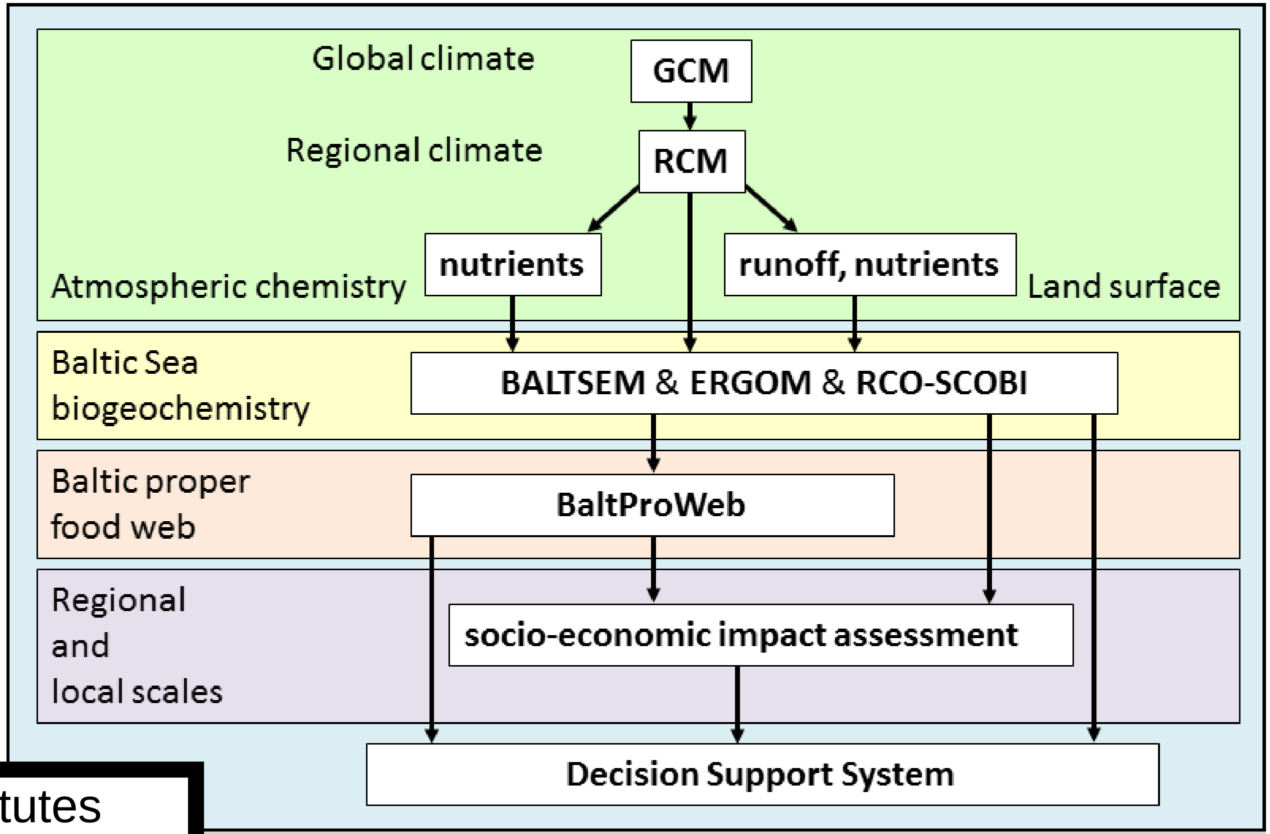
Advanced modeling tool for scenarios of the Baltic Sea ECOsystem to SUPPORT decision making

ECO SUPPORT



11 partner institutes
from 7 Baltic Sea
countries
2009-2011

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Baltic Sea - how to approach the future?

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IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO UNEP

Combined effects of climate change and nutrient loads

Ensemble modelling to quantify uncertainty

Decision support to policy makers

Baltic Sea: future projections

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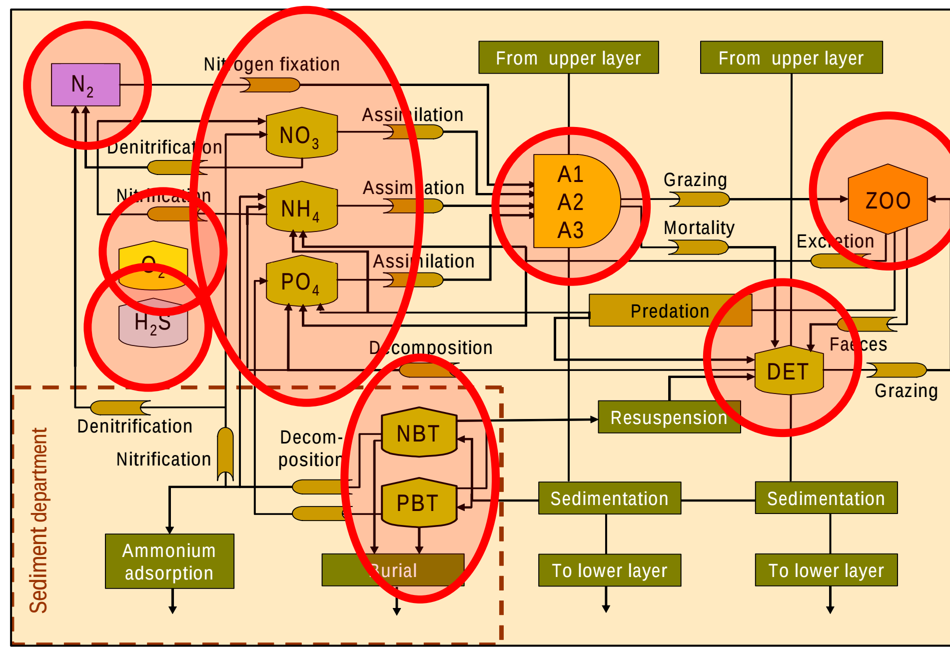
Baltic Nest Institute

- 4 climate projections 1961-2099
- 2 different global climate models
- A1B and A2 scenarios
- 2 realizations
- 1(2) regional climate model (RCAO, CLM)
- 1(2) hydrological models
- 3 Baltic Sea models (BALTSEM, ERGOM, RCO-SCOBI)
- 3(4) nutrient load scenarios: BSAP, (CLEG), REF, BAU
- Total: 38(58) scenario simulations

RCO – SCOBI High resolution (2nm) 3-D model for biogeochemical climate- and process studies in the Baltic Sea

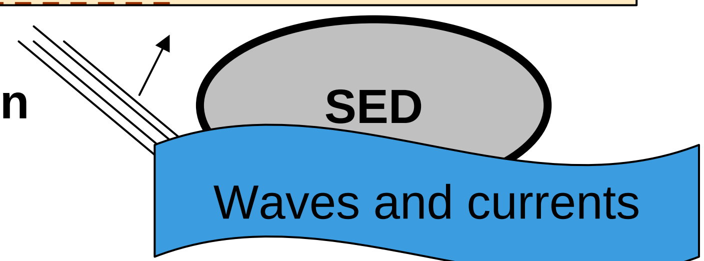
The model handle dynamics of nitrogen, oxygen and phosphorus for example including:

- **inorganic nutrients**
- **nitrogen fixation**
- **particulate organic matter**
- **sediment**
- **oxygen**
- **hydrogen sulphide**
- **resuspension**



Resuspension

of sediments



Model evaluation 1970-2005

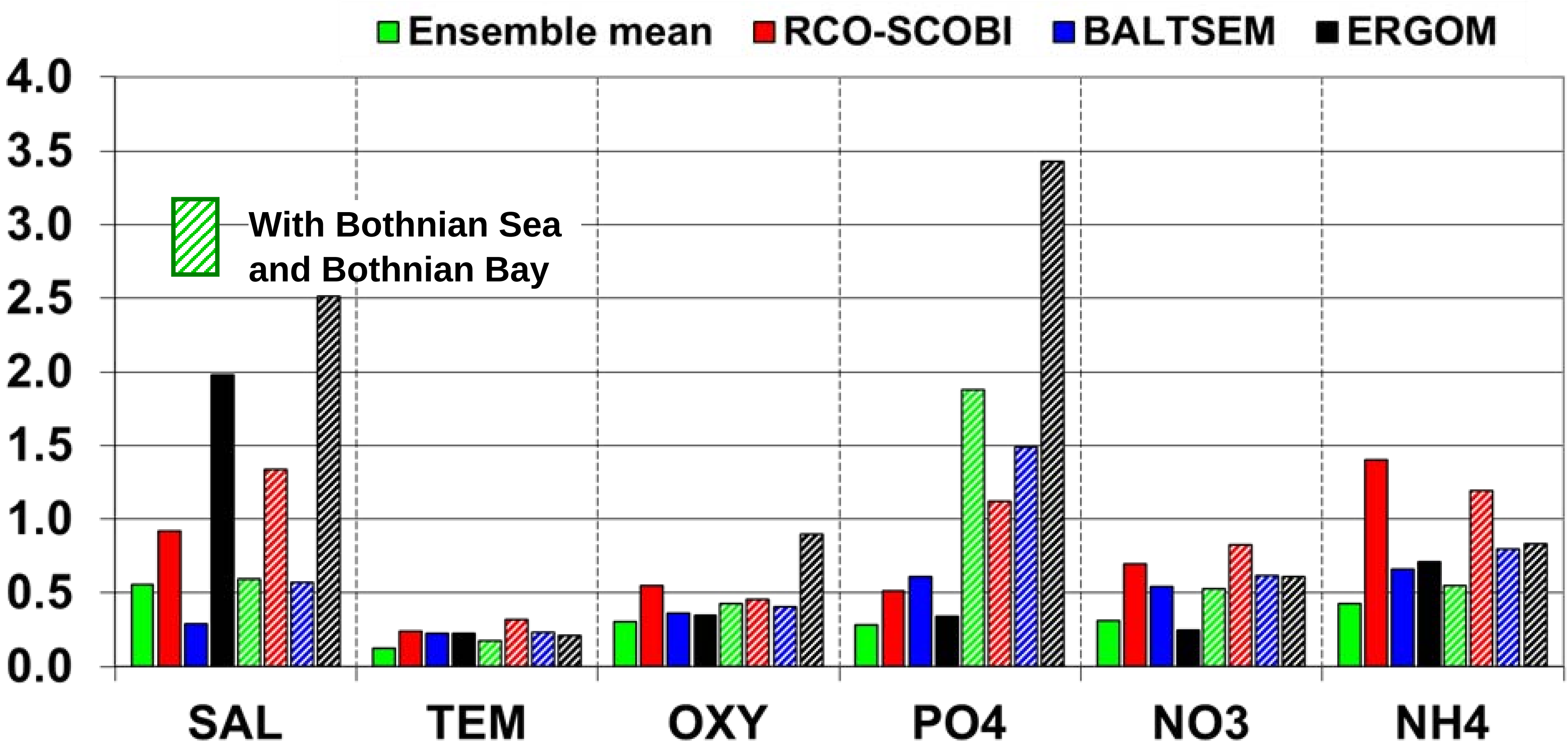
- **Coupled physical-biogeochemical models**

1. RCO-SCOBI	(3D, 2nm)	SMHI	Sweden
2. BALTSEM	(1D, 13 basins)	BNI	Sweden
3. ERGOM	(3D, 3nm)	IOW	Germany

- **Atmospheric forcing 1961-2006 (ERA40-RCA)**
  - High sensitivity of the Baltic Sea to the atmospheric forcing.

- **Validation data 1970-2005**
  - Baltic Environmental Database (BED).

Mean of cost function values from all stations



(Source: Eilola et al., 2011)

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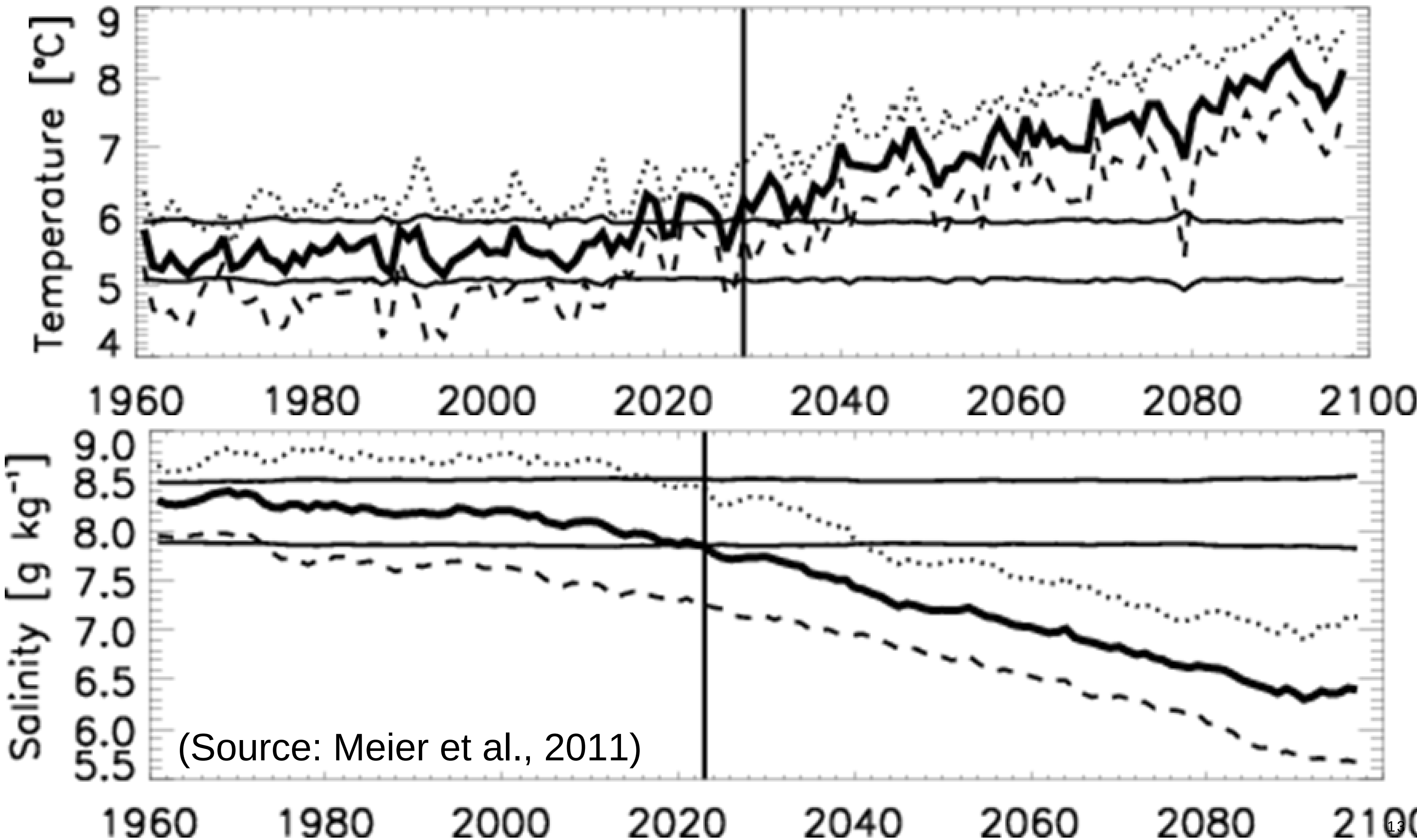
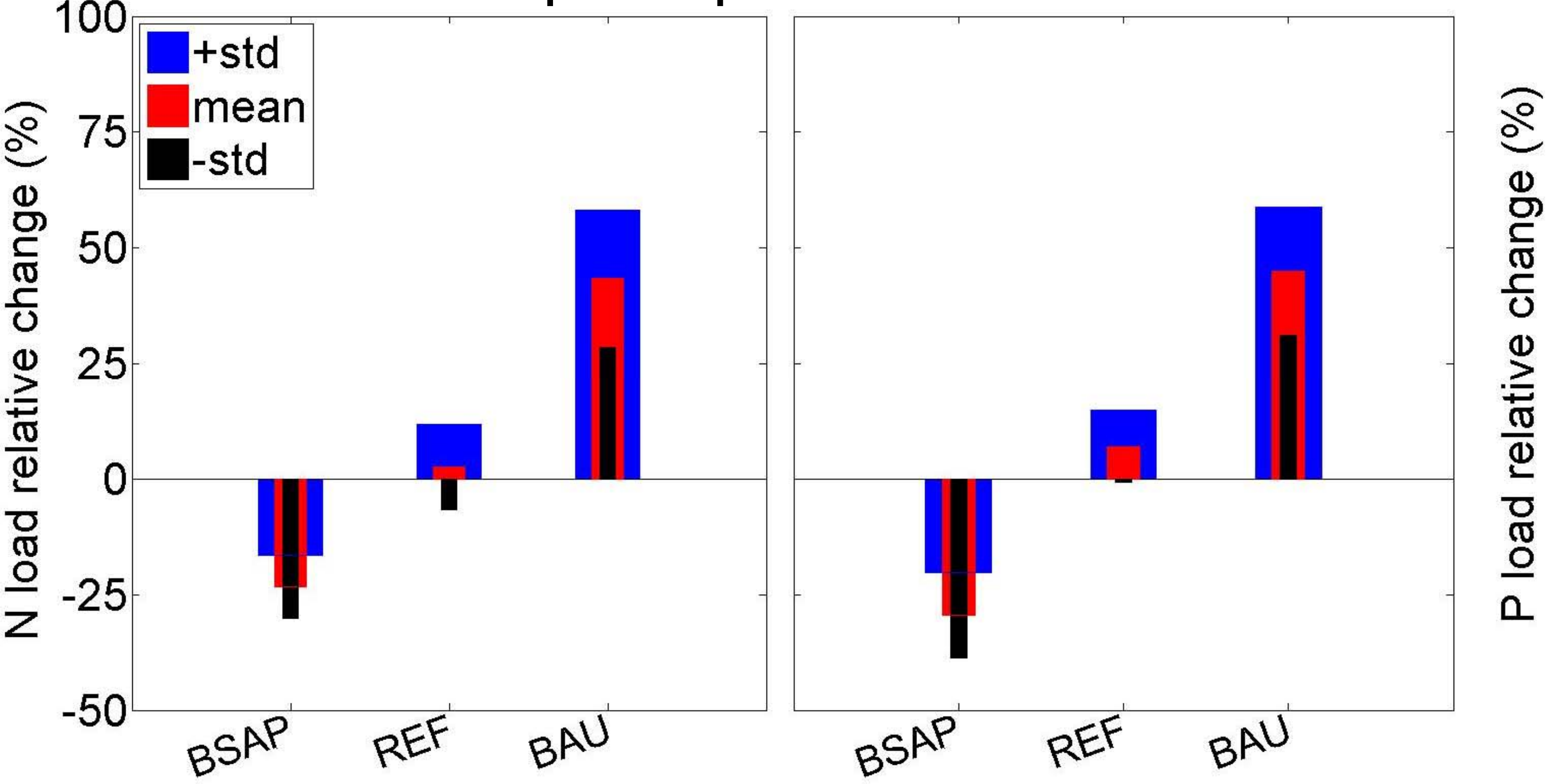
Ensemble mean volume averaged temperature and salinity



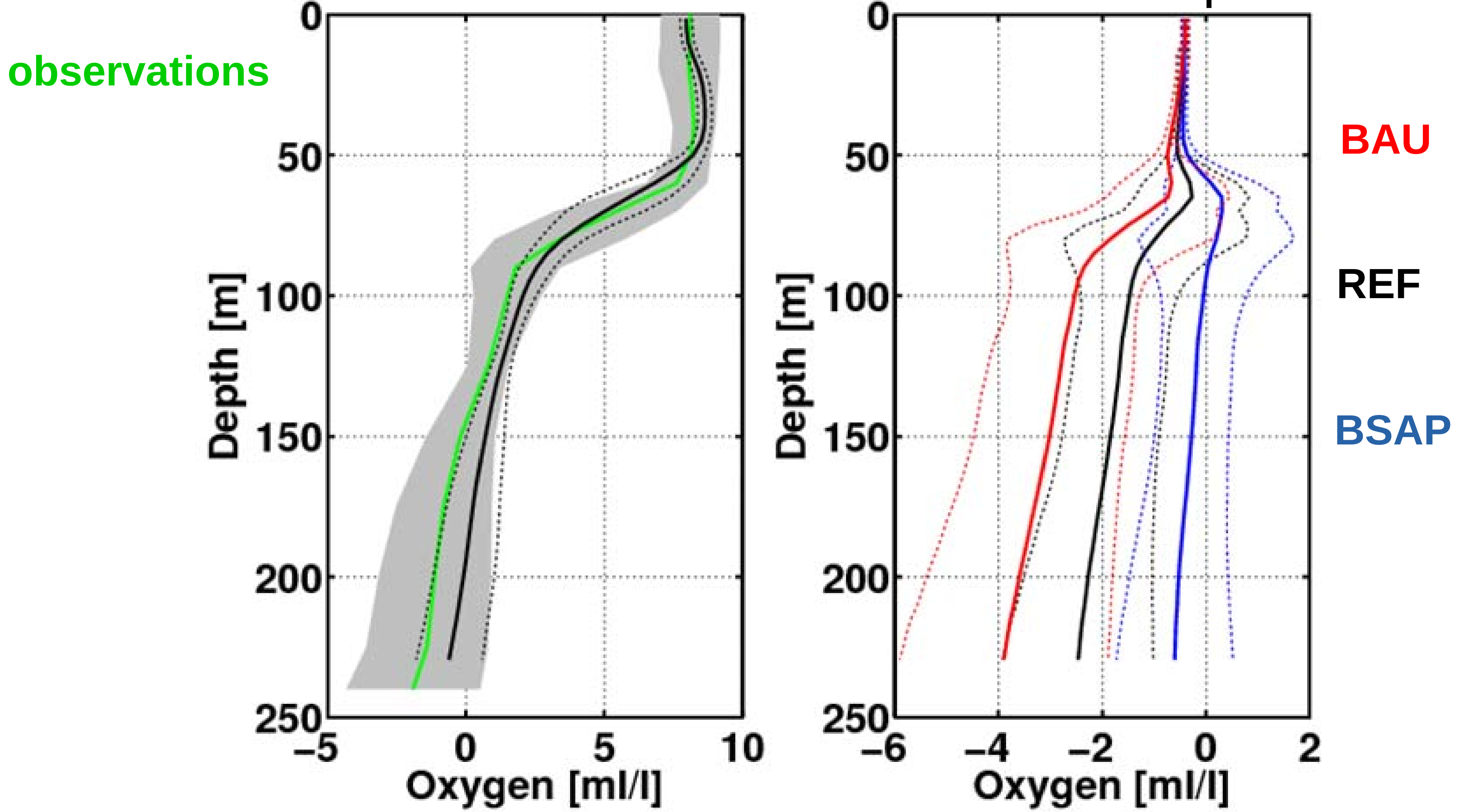
(Source: Meier et al., 2011)

Ensemble average changes of the annual mean biologically available total nitrogen and phosphorus loads



(Source: Meier et al., 2011)

Ensemble average vertical profiles and changes between 2069–2098 and 1978–2007 in oxygen concentration at Gotland Deep



(Source: Meier et al., 2011)

Ensemble average changes between 2069–2098 and 1978–2007 of summer bottom oxygen concentration and the signal-to-noise ratio

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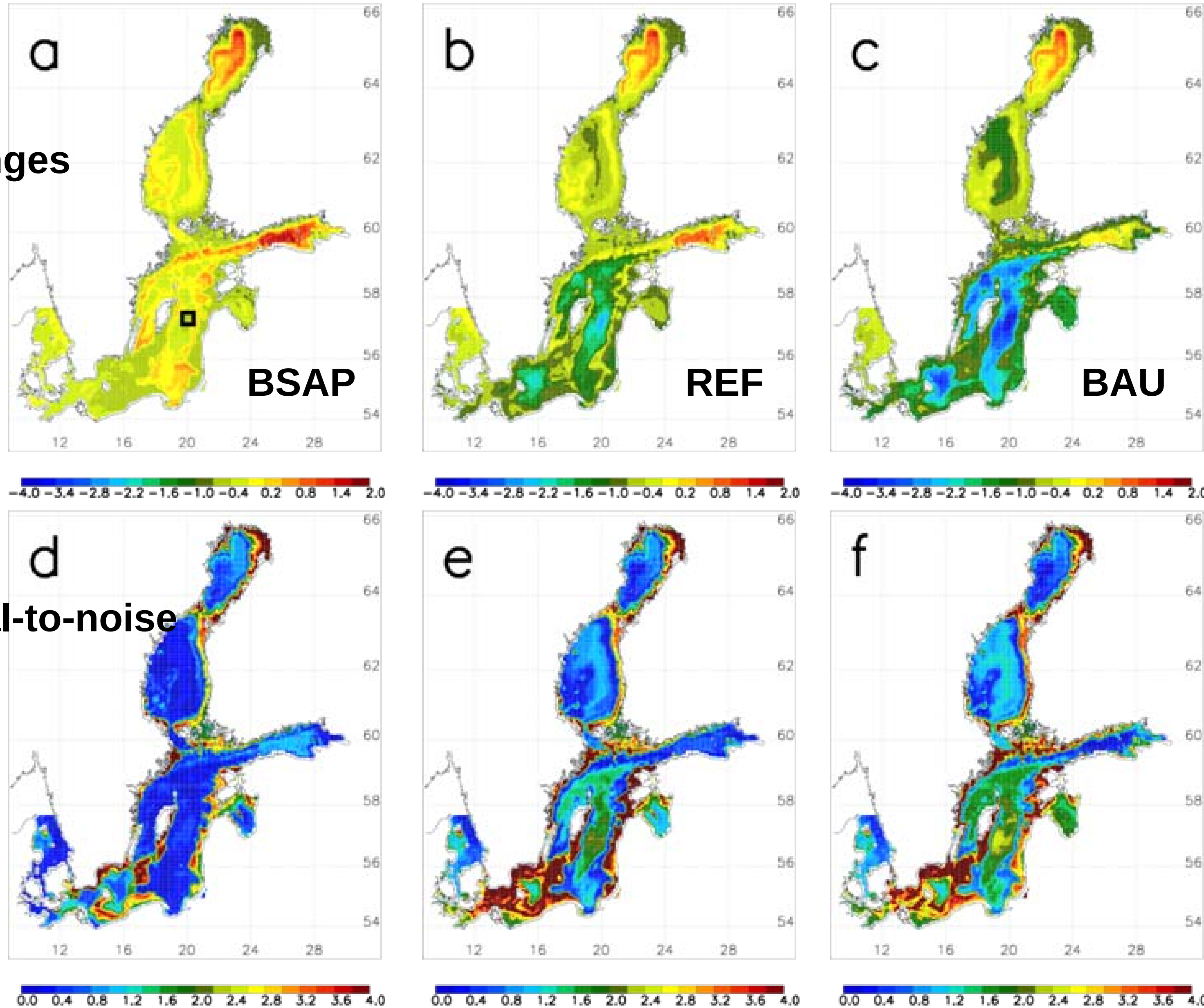
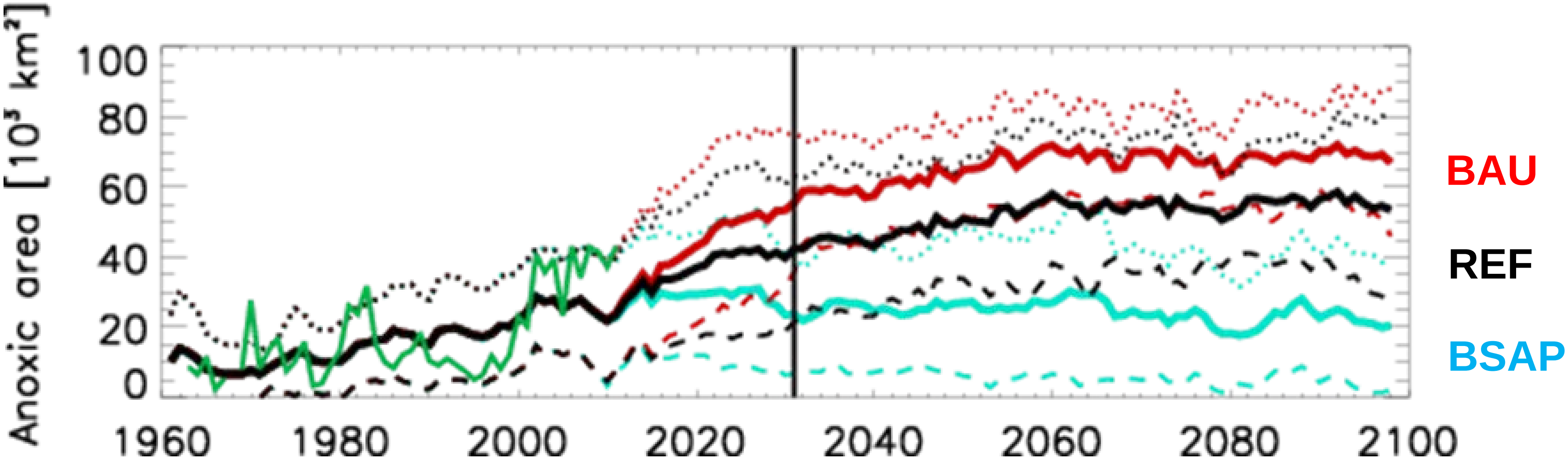


(Source: Meier et al., 2011)

Volume averaged anoxic areas



observations

(Source: Meier et al., 2011)

BAU **REF** **BSAP**

Primary production

Nitrogen fixation

Phosphorus release from the sediments

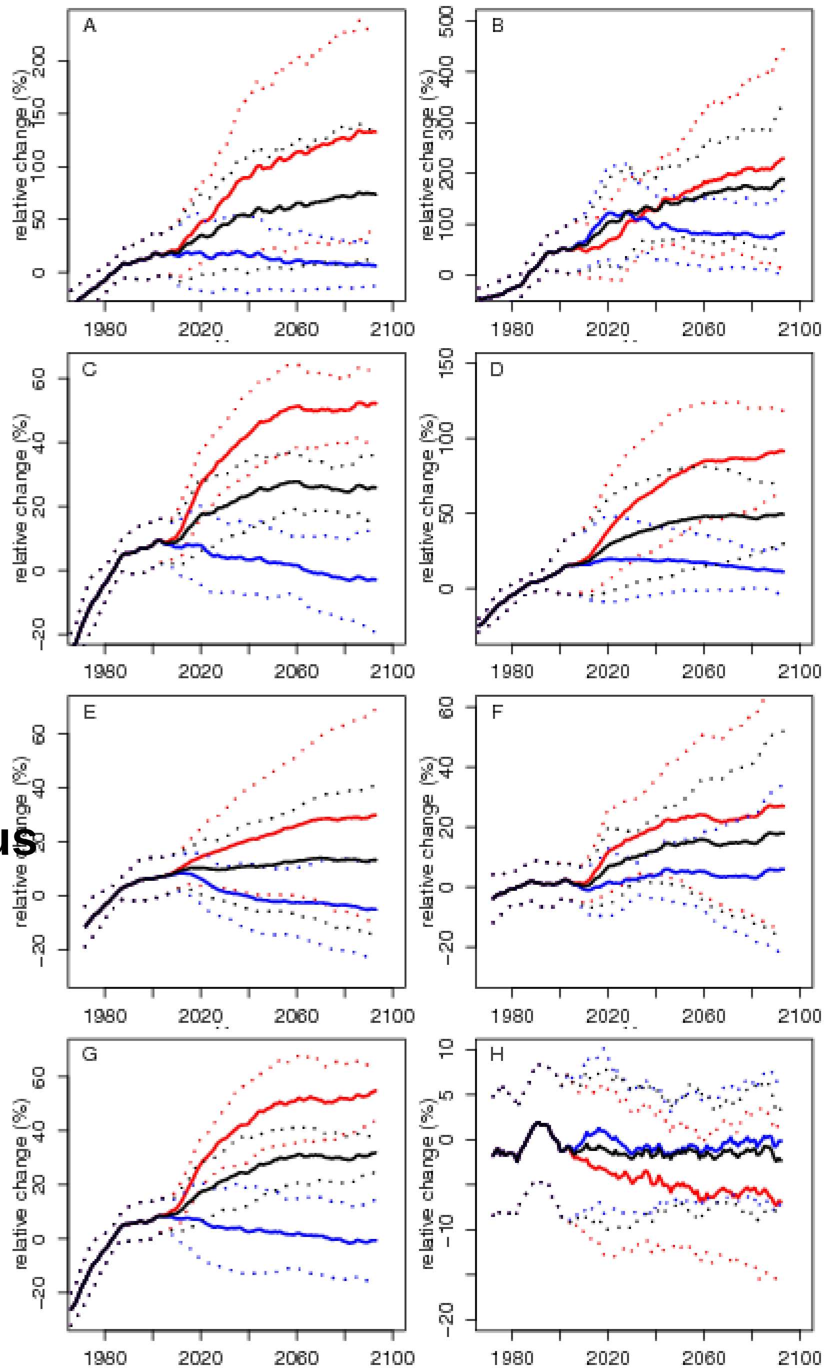
Nitrogen release from the sediments

Sediment phosphorus pool

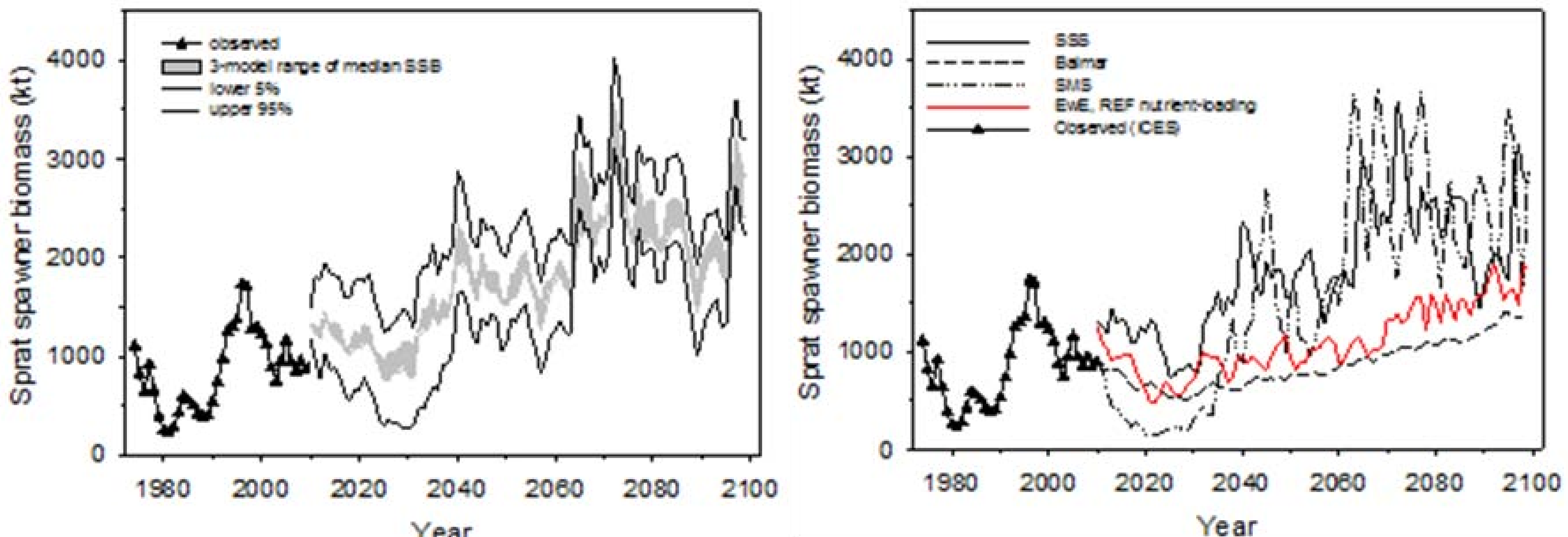
Ratio between release and phosphorus sediment pool

Denitrification

Ratio between denitrification and nitrogen supply



Projections of higher trophic levels (sprat)

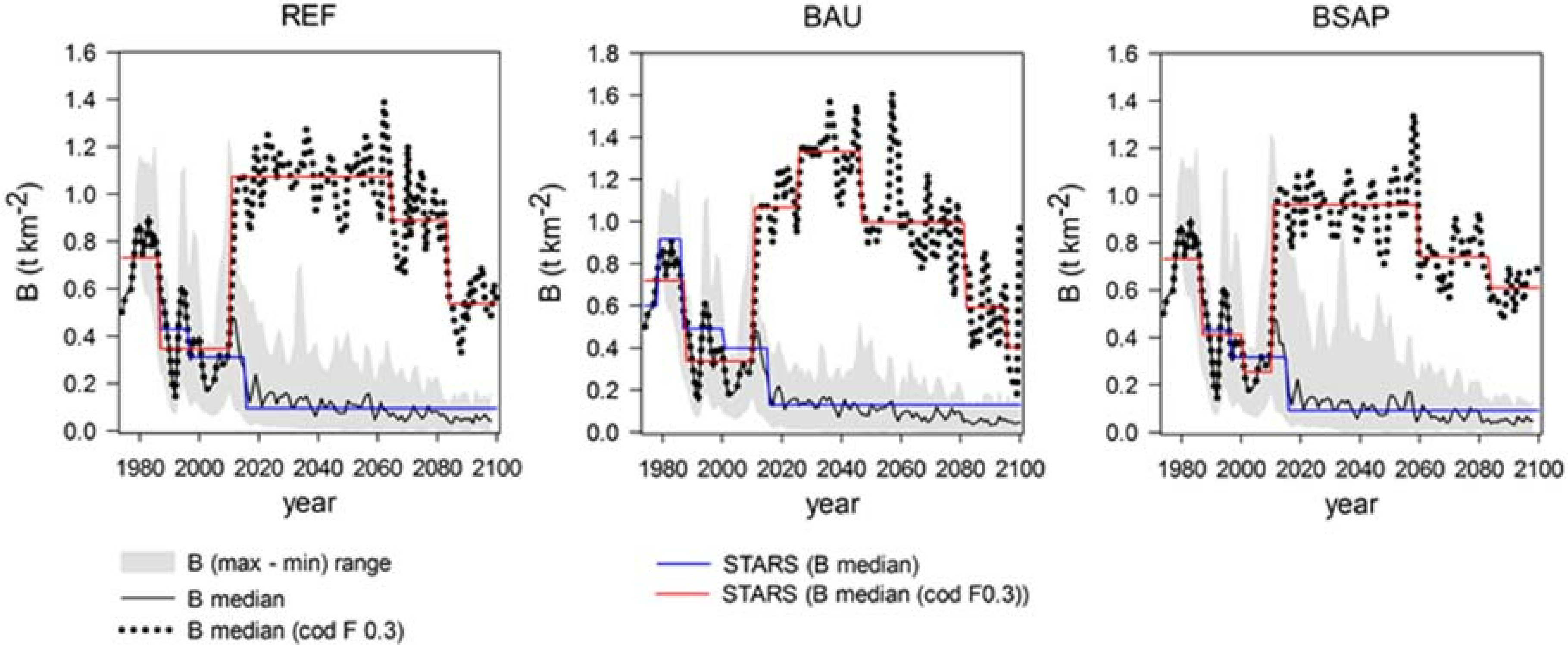


(Source: MacKenzie et al., accepted)

Projected spawner biomass of sprat in the Baltic Sea assuming a temperature – driven spawner-recruit relationship with temperatures estimated from three different climate-oceanographic models. Fishing mortality of sprat was at a currently defined sustainability level and natural mortality was assumed equal to the mean level during 2008-2010.

Different population and food web models. All projections use the A1B emission scenario, ECHAM5 climate forcing and the RCO-SCOBI oceanographic-biogeochemical model.

Projections of higher trophic levels (cod)



(Source: Niiranen et al., in preparation)

Projected spawner biomass of cod in the Baltic Sea as simulated using BaltProWeb coupled to three biogeochemical models assuming three nutrient loading scenarios as well as two cod fishery scenarios ("Business-as-Usual" and "cod recovery plan" (F03)).

Reconstruction of the past since 1850

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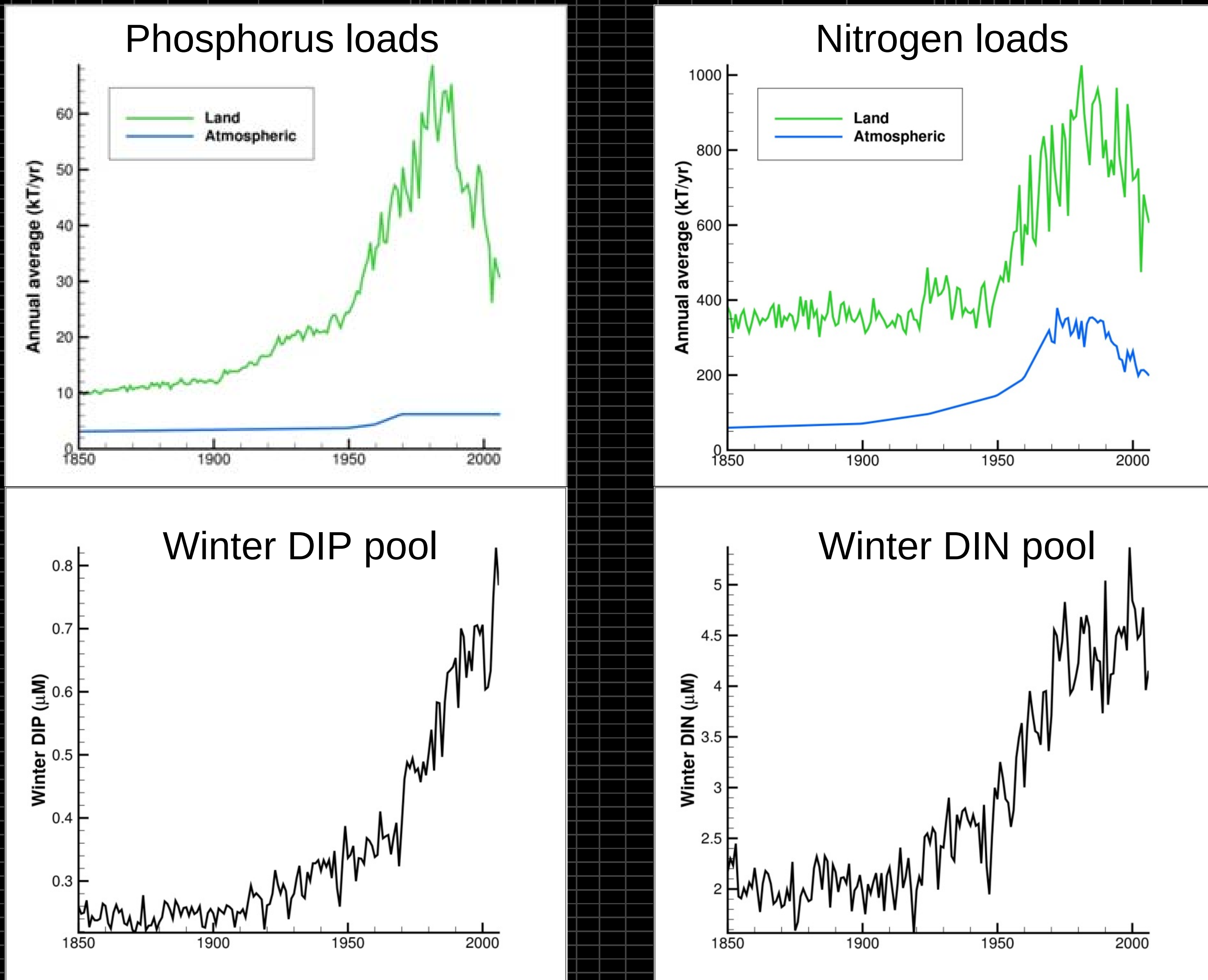

(Source: Gustafsson et al., accepted)

Reconstruction of the past since 1850

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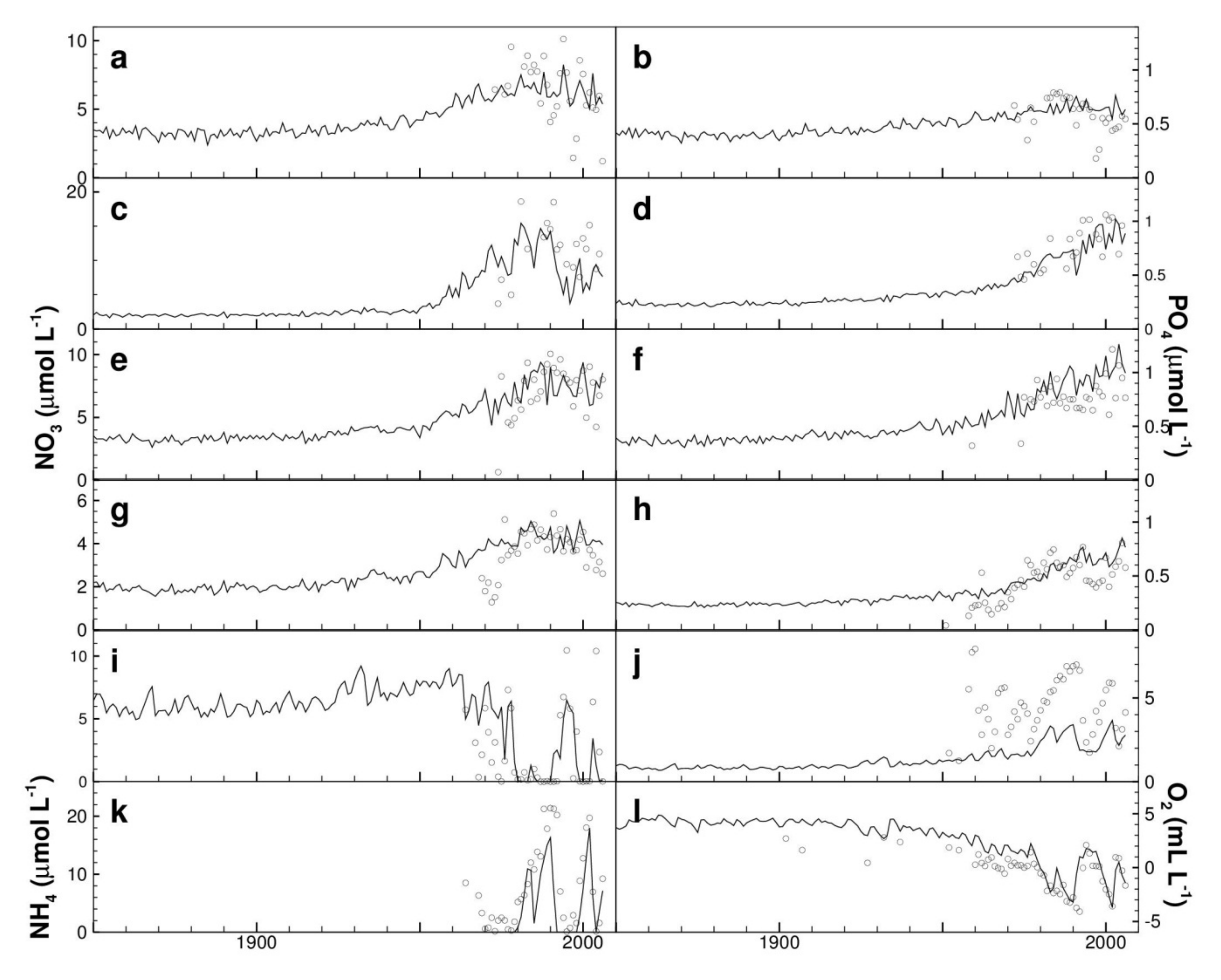

Southern Kattegat 0m

Gulf of Riga 0 m

Gulf of Finland 0 m

Gotland Sea 0 m

Gotland Sea 200 m

Gotland Sea 200 m

(Source: Gustafsson et al., accepted)

Winter average surface nitrate and phosphate concentrations in southern Kattegat (a, b), Gulf of Riga (c, d), Gulf of Finland (e, f), and Gotland Sea (g, h). Annual average nitrate (i), phosphate (j), ammonia (k) and oxygen (l) concentrations at 200 m depth in Gotland Sea.

Conclusions

- **State-of-the-art biogeochemical models are capable to simulate past climate variations and eutrophication since 1850.**

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- **State-of-the-art biogeochemical models are capable to simulate past climate variations and eutrophication since 1850.**
- **The biogeochemical models show good quality in the Baltic proper but fail in the northern Baltic Sea.**

Conclusions

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- **In future climate, increased loads and temperature dependent rates of biogeochemical processes may result in an overall intensification of internal nutrient cycling, including substantial increases in both primary production of organic matter and oxygen consumption for its mineralization.**

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Conclusions

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- In future climate, increased loads and temperature dependent rates of biogeochemical processes may result in an overall intensification of internal nutrient cycling, including substantial increases in both primary production of organic matter and oxygen consumption for its mineralization.
- Without drastic nutrient load abatements hypoxic and anoxic areas are projected to increase.

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Conclusions

- **Uncertainties of the projections are dominated by unknown nutrient loads, biases of the GCMs and biases of the biogeochemical models. For instance, we found largely differing sensitivities of the models to changing nutrient loads.**

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- **The uncertainty due to incompletely understood ecological processes within the fish population models is in general larger than the uncertainty due to differences among the three oceanographic-biogeochemical models that force the fish models.**

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Conclusions

- **All food web and fish population models indicate that the level of cod fishery is important in determining the cod stock size also in the future although the climate impact is substantial.**


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