Scenarios of the Baltic Sea ecosystem calculated with a regional climate model

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HELCOM Ministerial Meeting
15 November 2007, Krakow, Poland

HELCOM makes history with ambitious plan to restore the Baltic

HELCOM Baltic Sea Action Plan

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Baltic Sea Action Plan

	Phosphorus (tonnes)	Nitrogen (tonnes)
Denmark	16	17,210
Estonia	220	900
Finland	150	1,200
Germany	240	5,620
Latvia	300	2,560
Lithuania	880	11,750
Poland	8,760	62,400
Russia	2,500	6,970
Sweden	290	20,780
Transboundary Common pool	1,660	3,780

Nutrient load reductions:

15 000 t phosphorus and 133 000 t nitrogen

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Baltic Sea Action Plan

Country	Phosphorus (%)	Nitrogen (%)
Denmark	0.04	2.3
Estonia	0.6	0.1
Finland	0.4	0.2
Germany	0.7	0.8
Latvia	0.8	0.3
Lithuania	2.4	1.6
Poland	24.1	8.5
Russia	6.9	0.9
Sweden	0.8	2.8
Common pool	4.6	0.5
Total	41.3	18.1

Open question:

- **Do the calculated nutrient load reductions have the same effect in future climate?**

- **Note: the residence time of the total phosphorus pool amounts to about 60 years**

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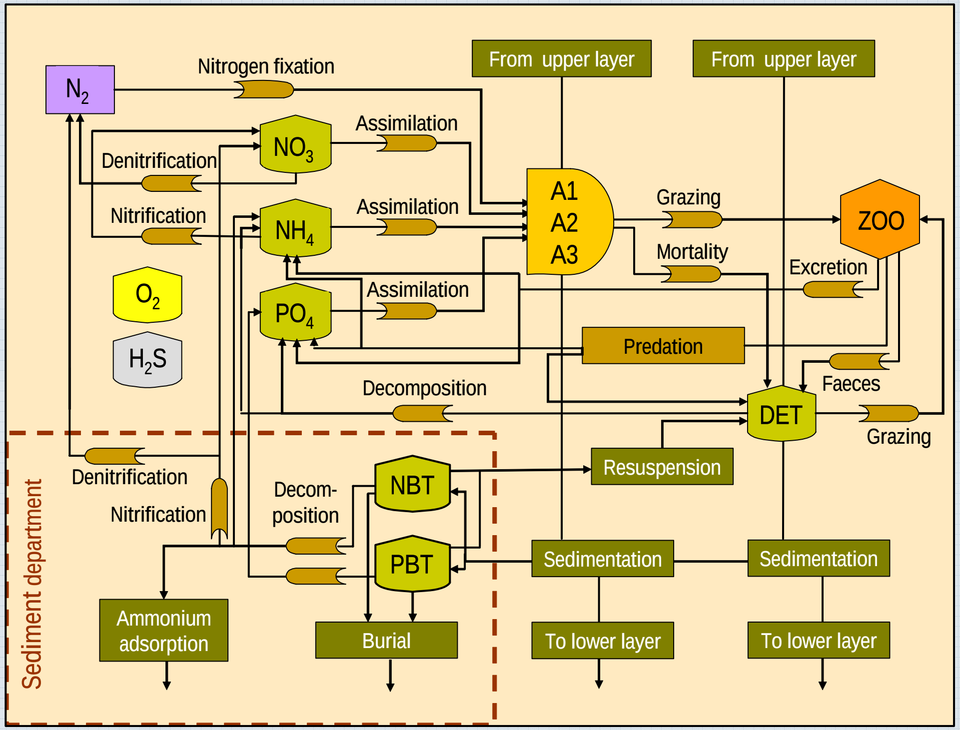
RCO-SCOBI

High-resolution 3-D coupled physical-biogeochemical model for climate and process studies



Pelagic variables:

- ***nitrate*** ***(NO3)***
- ***ammonium*** ***(NH4)***
- ***phosphate*** ***(PO4)***
- ***autotrophs*** ***(A1,A2,A3)***

(diatoms, flagellates, cyanobacteria)

- ***zooplankton*** ***(ZOO)***
- ***detritus*** ***(DET)***
- ***oxygen*** ***(O2)***
- ***Hydrogen sulfide*** ***(H2S) is included as negative oxygen.***

- **The sediment contains nutrients in the form of benthic nitrogen (NBT) and phosphorus (PBT).**
- **Aggregated process descriptions for oxygen dependent nutrient regeneration, denitrification and adsorption of ammonium to sediment particles as well as re-suspension and permanent burial of organic matter.**

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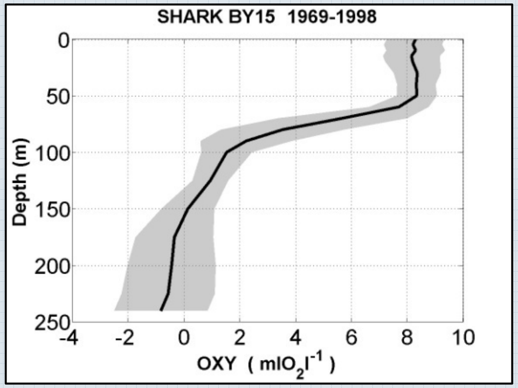
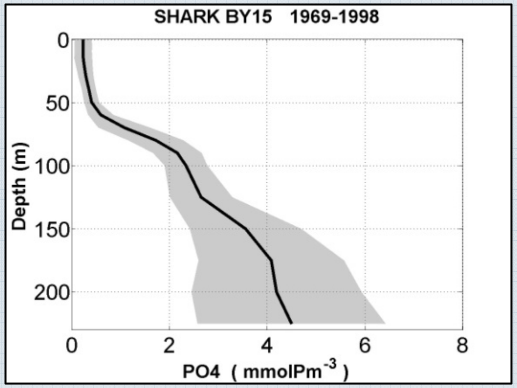
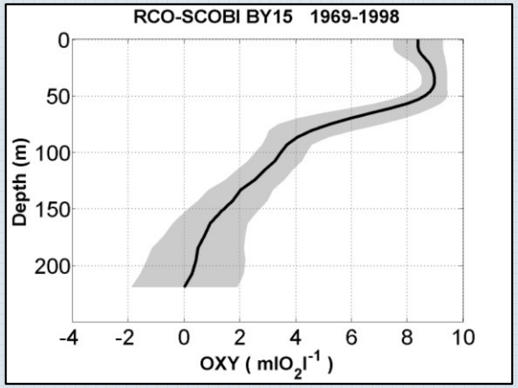
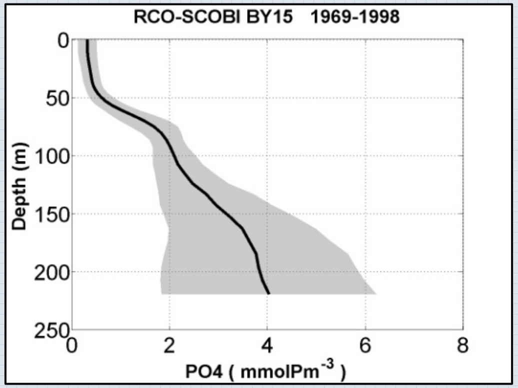
Long period experiment

Forcing and model set-up of the 100 years model run

- **RCO 6 nm run on the period 1902-1998 with reconstructed atmospheric forcing and river discharge data.**
- **Nutrient loading from land (rivers and coastal runoff) is based on climatological mean concentrations from the period 1970-1993.**
- **Point sources are based on HELCOM estimates from the 1990s.**
- **Atmospheric nitrogen deposition is based on HELCOM estimates from the 1980s and 1990s.**

30-year mean and standard deviation 1969-1998

Gotland Deep

	Oxygen	PO4
Observations		
RCO-SCOBI		

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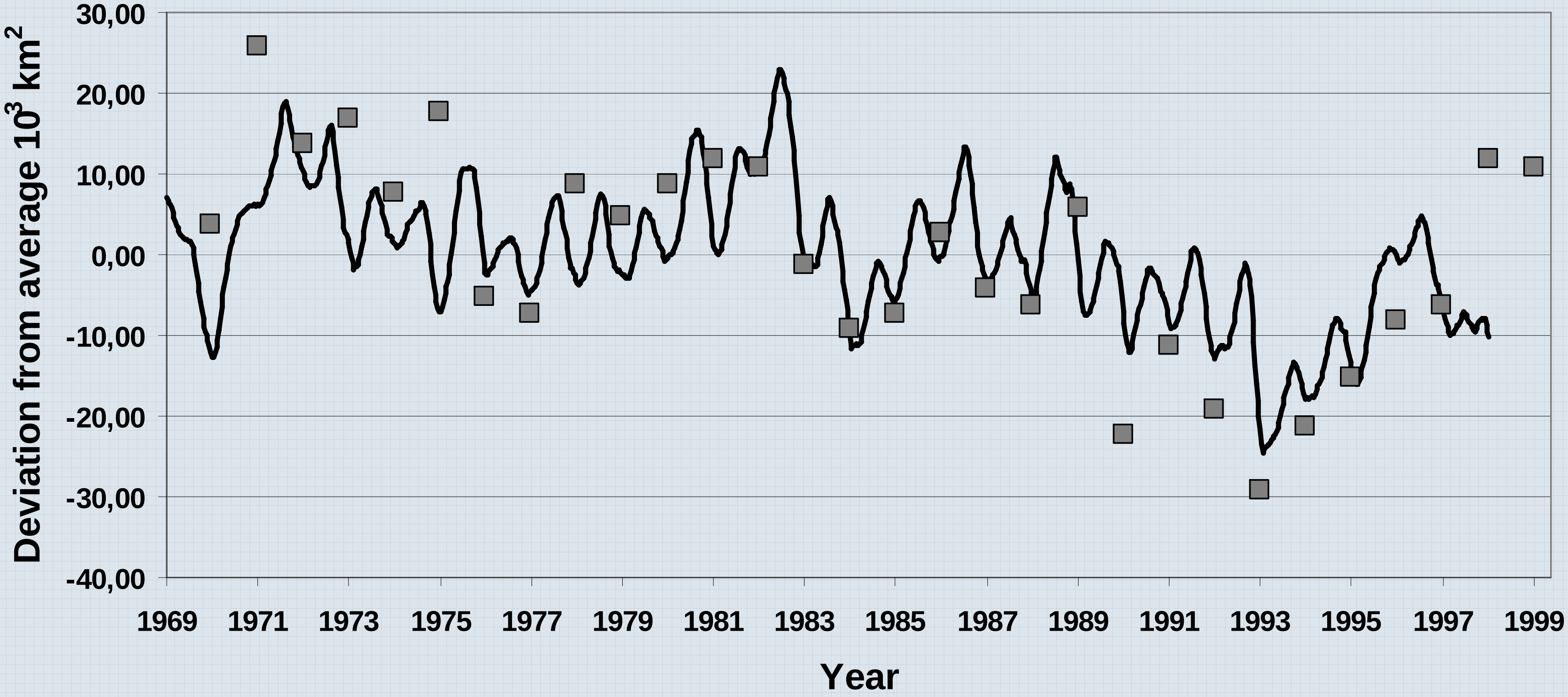
Anomalies of hypoxic area



Black lines show model results (3-month running mean) and grey squares show results (average January-March) from Table 1 in Conley et al. (2002). The simulated anomalies are calculated relative to the mean values of 1969-1998.

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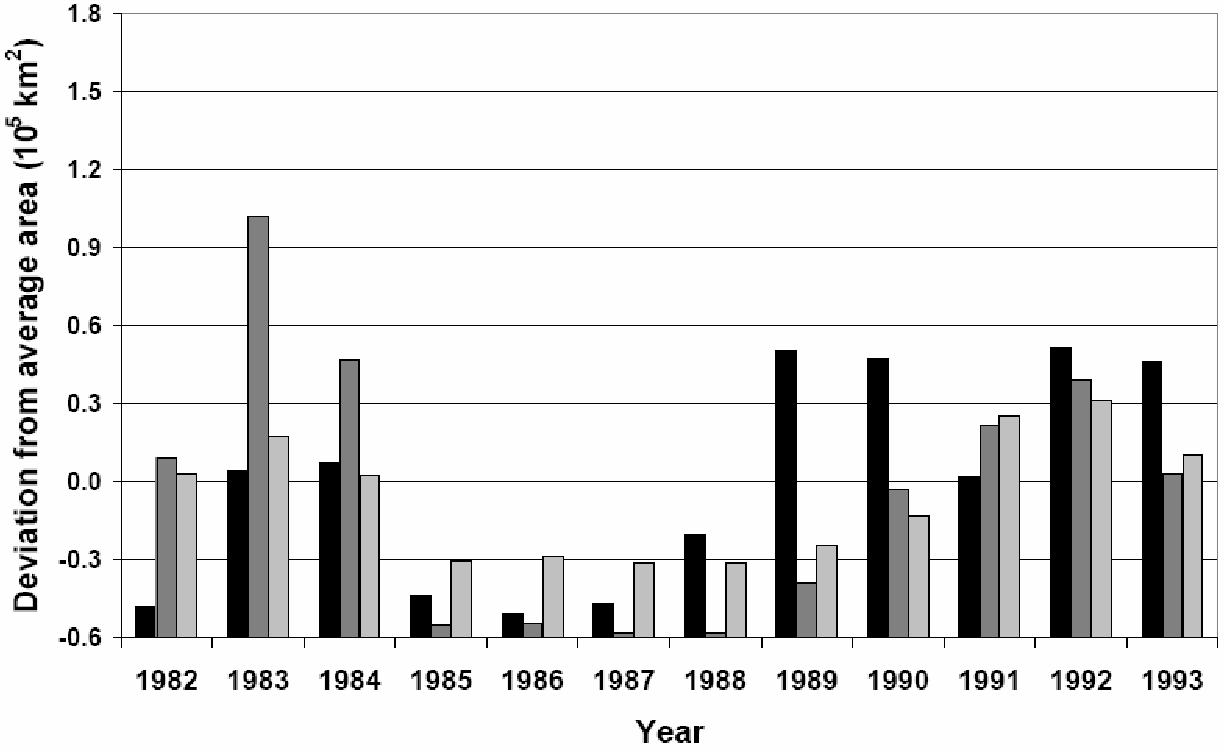
Maximum surface area covered by cyanobacteria 1982-1994 in the Baltic proper



Annual anomalies of the modeled maximum surface area (10^5 km^2) covered by cyanobacteria 1982-1994 in the Baltic proper (black bar). The corresponding anomalies of annual cumulative surface area covered by cyanobacteria blooms estimated from satellite images and the area corrected for unequal number of available images (see Kahru, 1997) are shown by grey and dark grey bars, respectively. The anomalies are calculated relative to the mean values of 1982-1994.

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To estimate uncertainties an ensemble of 20 simulations has been performed:

- **three nutrient load scenarios:**

  1) best case combining improved sewage treatment, P-free detergents and best possible agricultural practices (BC): P -21 000 t, N -150 000 t

  2) Baltic Sea Action Plan (BSAP): P -15 000 t, N -133 000 t

  3) Business as usual in agriculture (BAU): P +16 000 t, N +340 000 t

- **four climate scenarios using RCAO forced with two emission scenarios (A2, B2) and two GCMs:**

  1) ECHAM4/A2: SST +3.7ºC, SSS -3.2 psu, increased mixing

  2) ECHAM4/B2: SST +2.9ºC, SSS -3.0 psu, increased mixing

  3) HADAM3H/A2: SST +3.2ºC

  4) HADAM3H/B2: SST +2.1ºC

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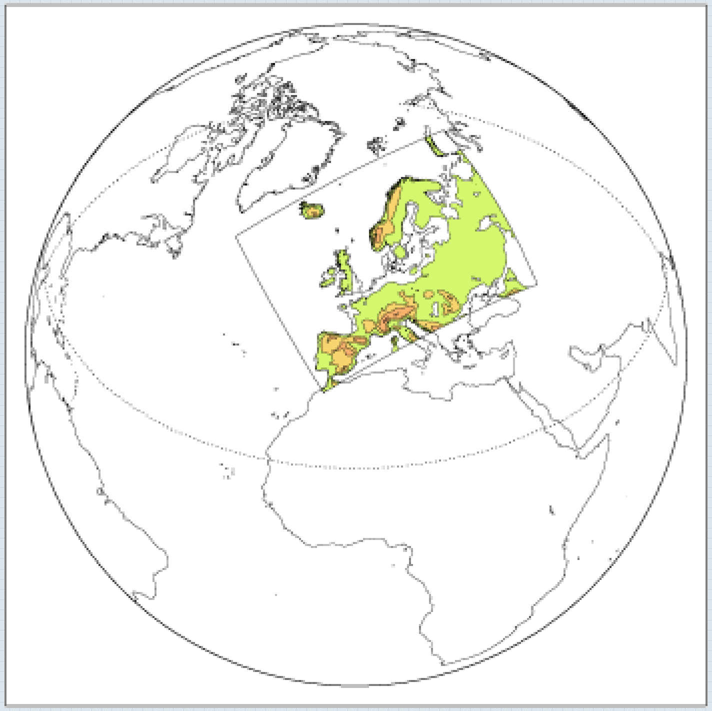
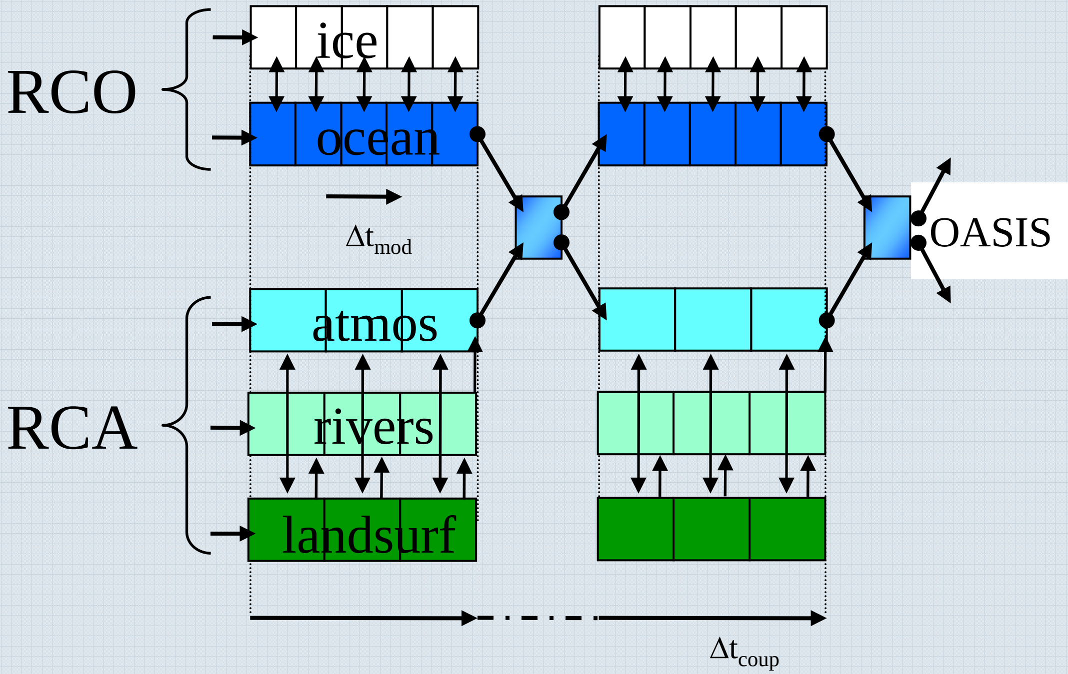
The **coupled** system RCAO

RCA: 44 km, 30 min
RCO: 11 km, 10 min
Coupling timestep: 3 h



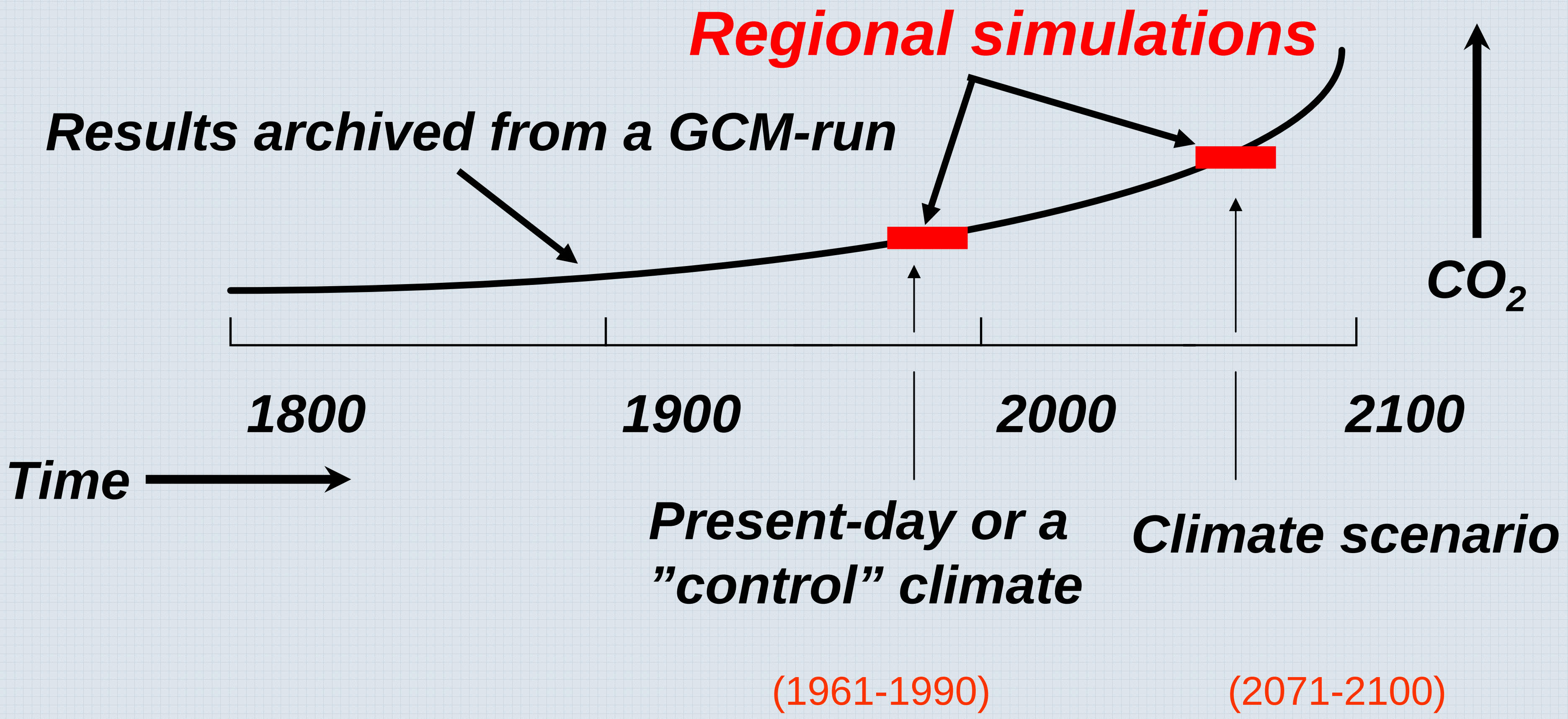
Model domain, covering most of Europe and parts of the North Atlantic Ocean and Nordic Seas. Only the Baltic Sea is interactively coupled.



The coupling scheme of RCAO.
Atmosphere and ocean/ice run in parallel.

Döscher et al. (2002)

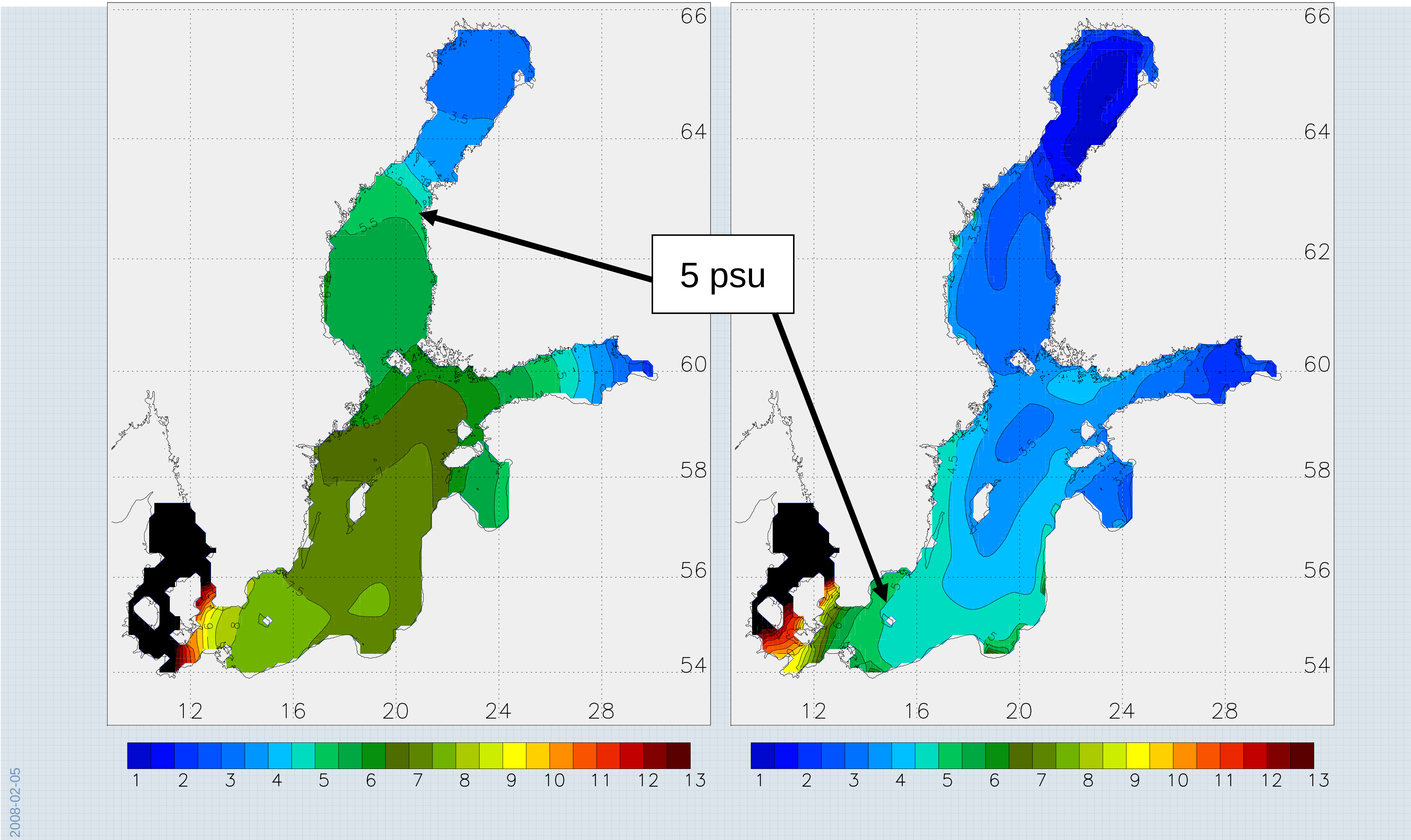
Regionalization is done for ”time-slices” from GCMs



Sea surface salinity

Present climate

Projection with the largest change
RCAO-ECHAM4/A2



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Sea surface temperature: annual +1.9 … +3.9°C

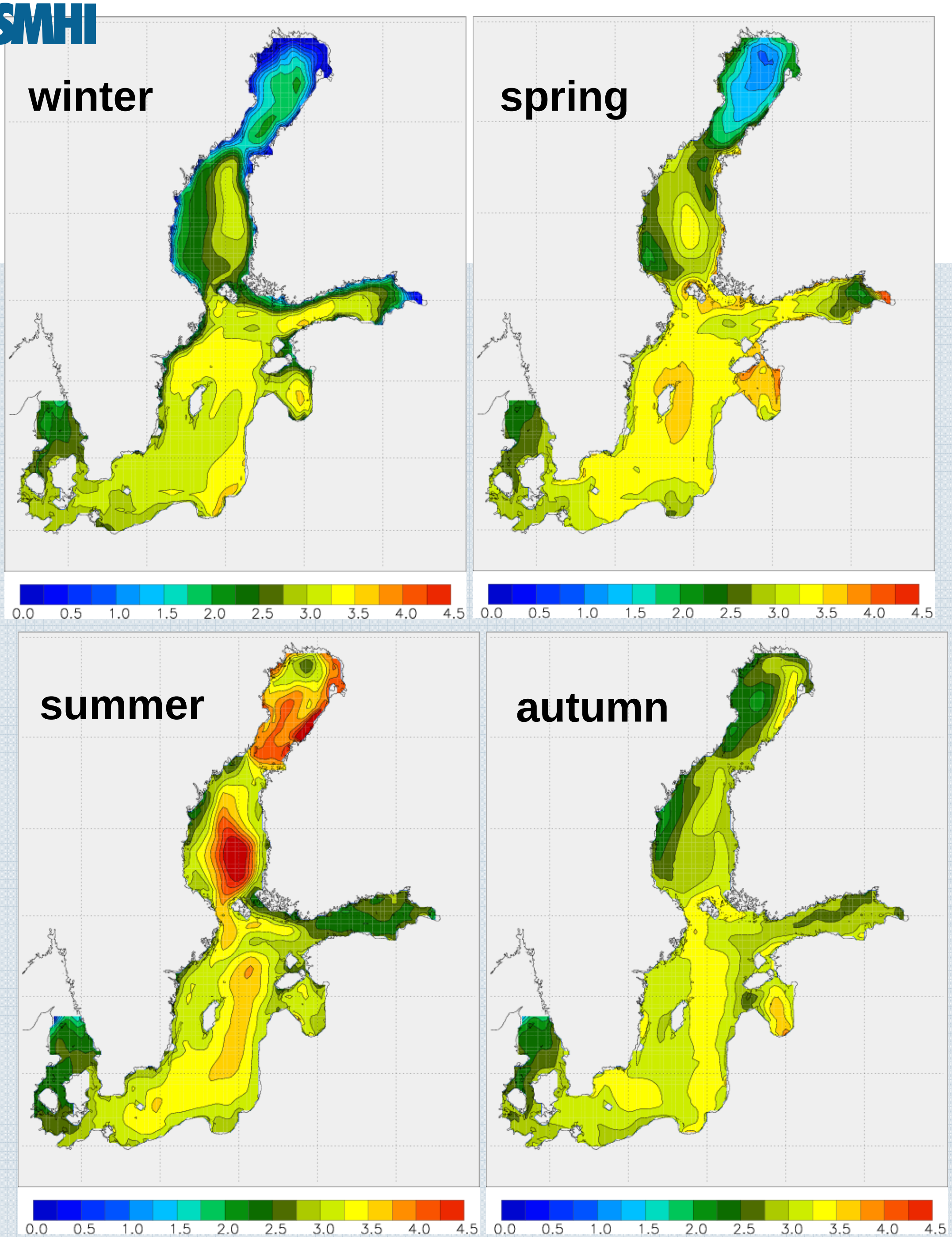
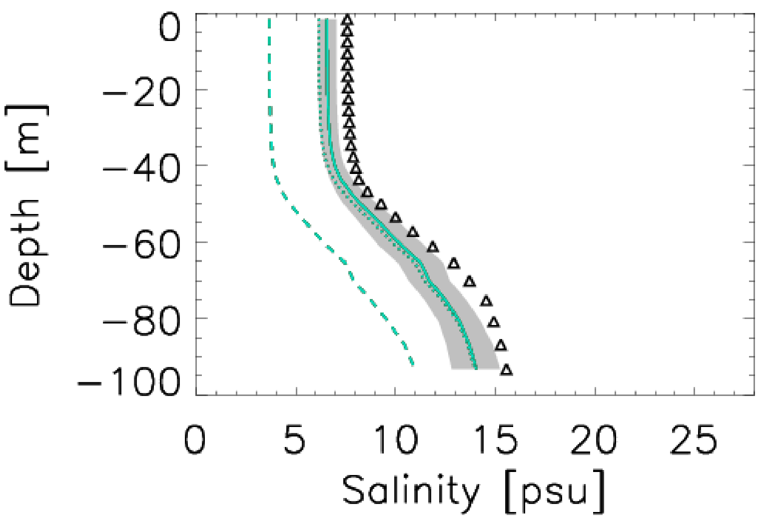
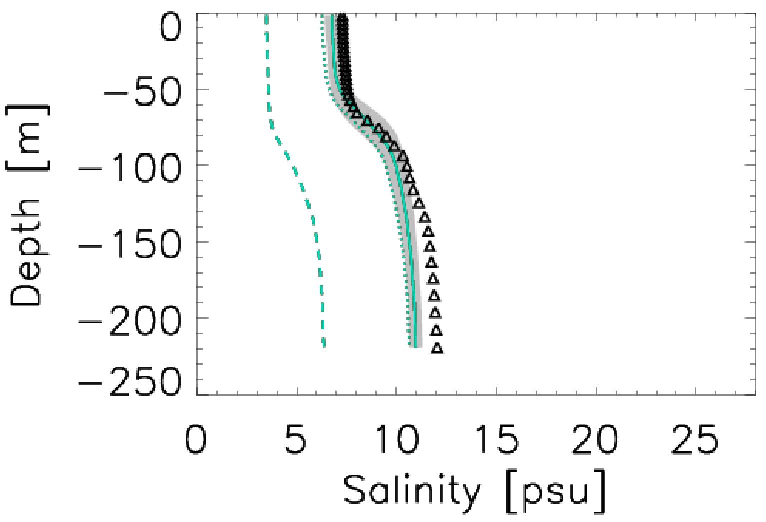


Figure 5. Seasonal mean SST differences between the ensemble average scenario and simulated present climate (in °C): DJF (upper left), MAM (upper right), JJA (lower left), and SON (lower right). The figure is taken from Meier (2006, Fig.13) with kind permission of Springer Science and Business Media.

Scenario simulations: Median, first and third quartiles at Bornholm Deep and Gotland Deep

- **Reference simulation (black) and nutrient load scenarios BC, BSAP, BAU in present climate (solid lines)**
- **ECHAM4/A2 (2071-2100) (dashed lines)**
- **HADAM3H/A2 (2071-2100) (dotted lines)**





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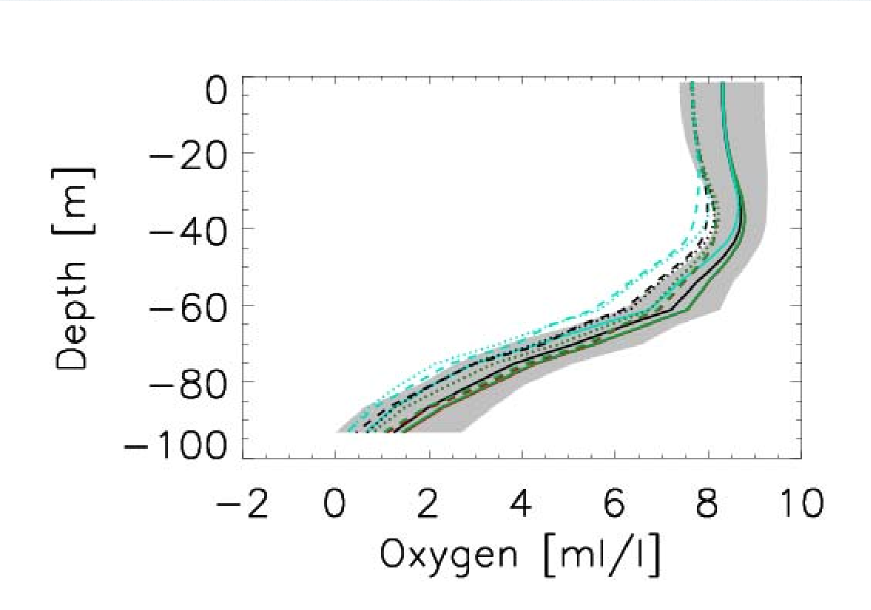

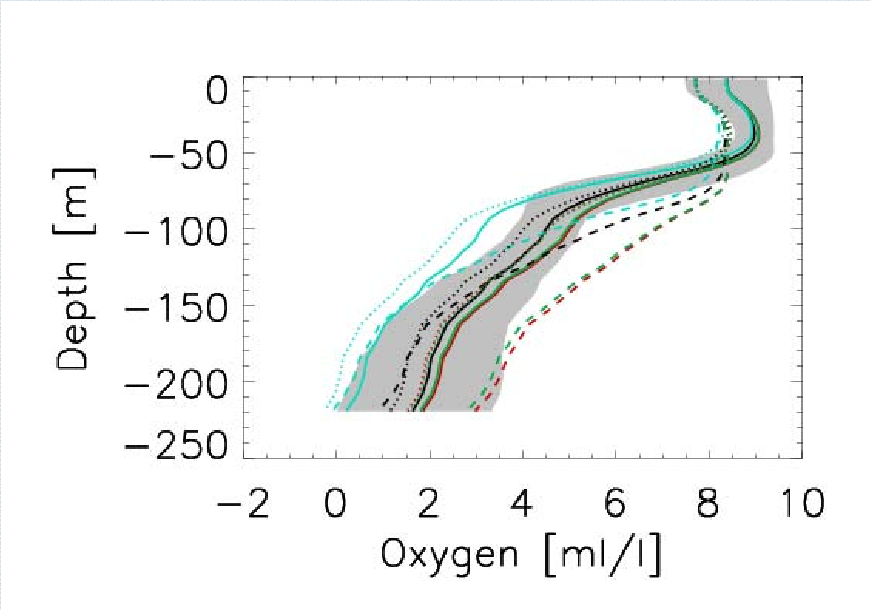

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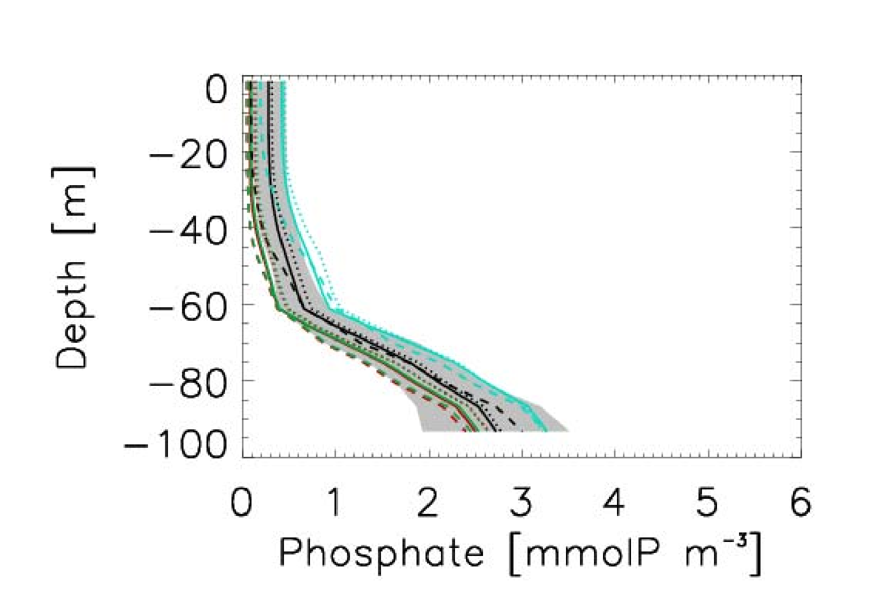

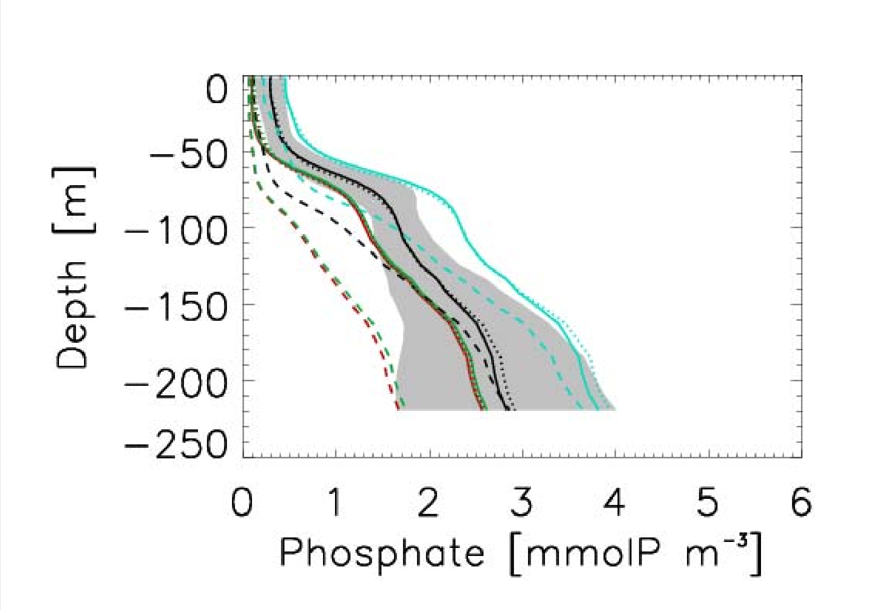

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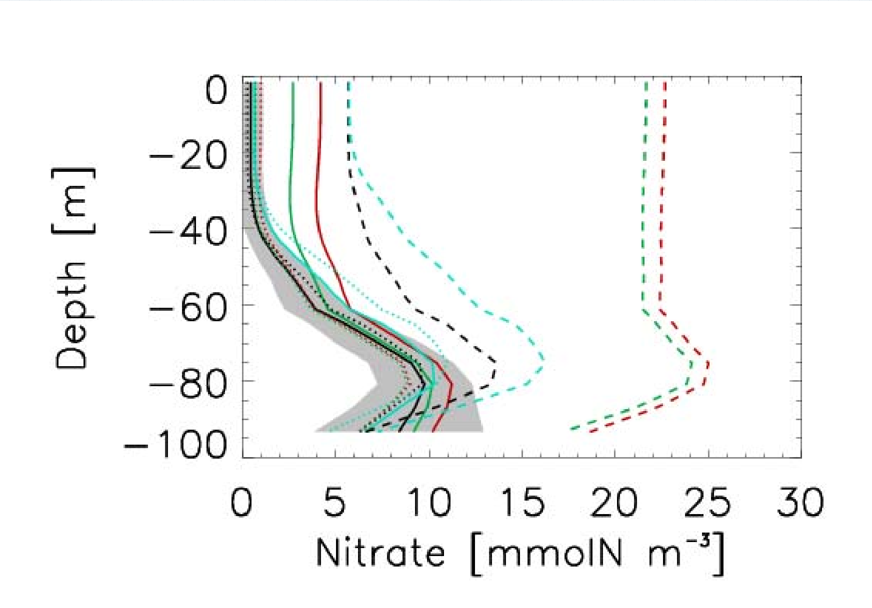
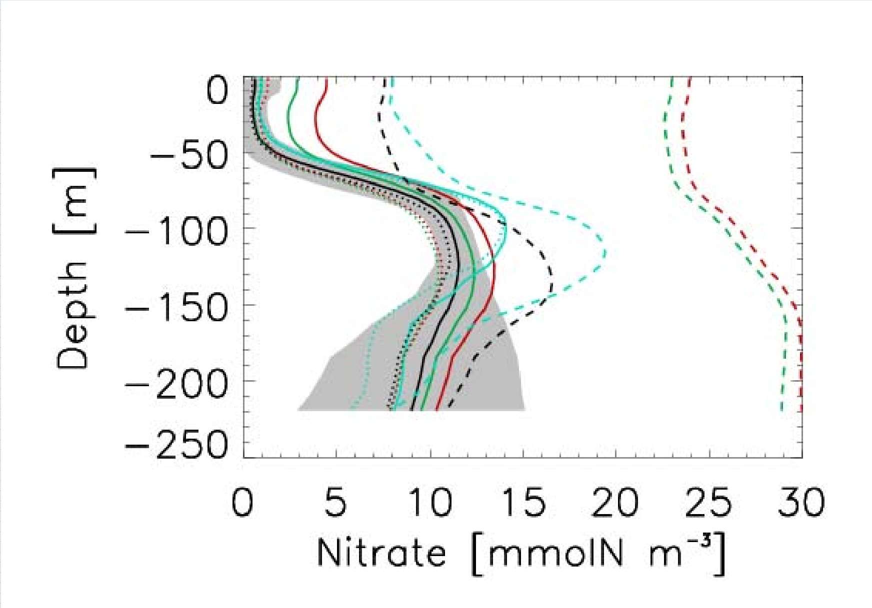
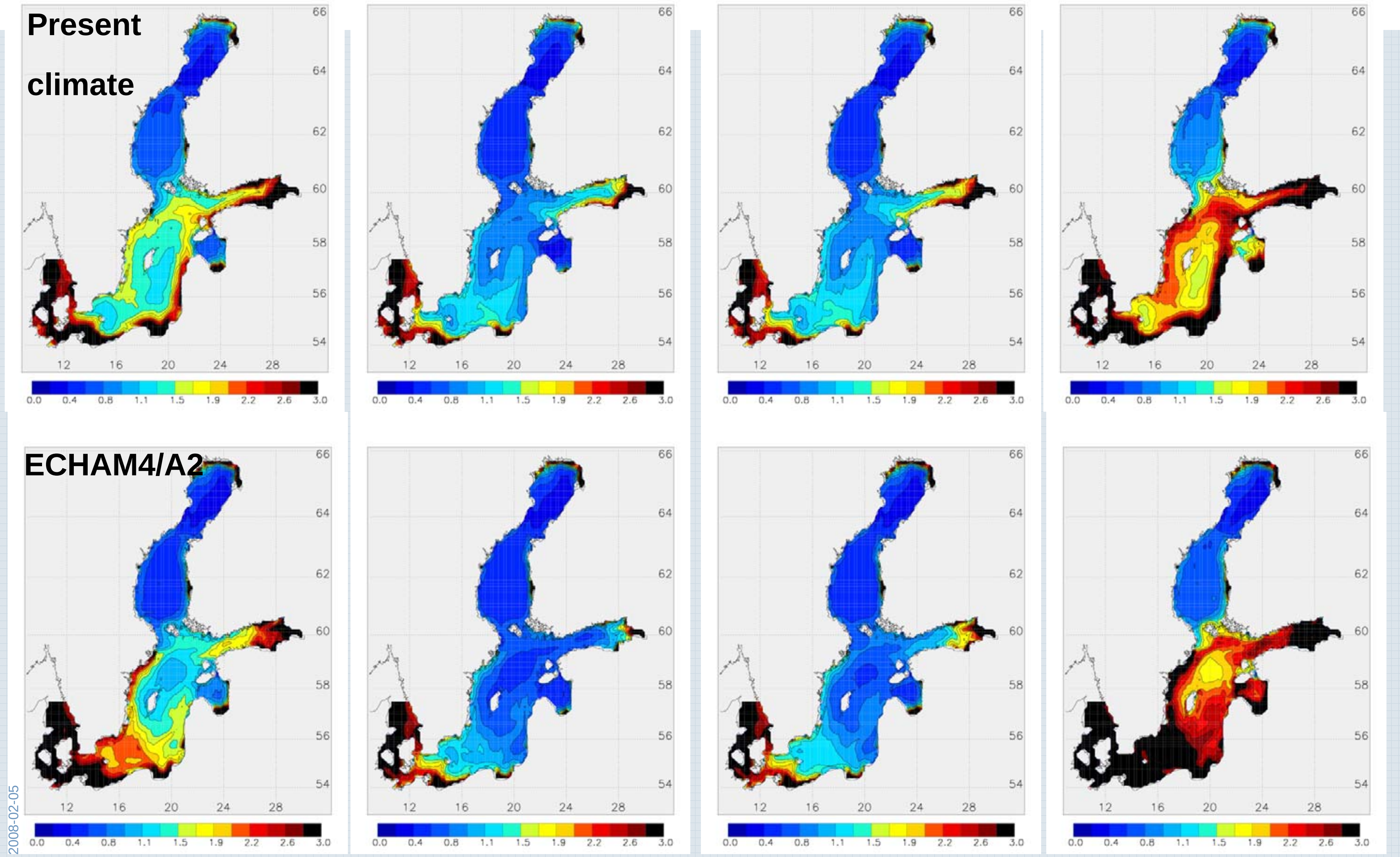




Annual mean phytoplankton concentration [mgChl/m^3] (0-10m)

Reference (1969-1998) | **Best case** | **BSAP** | **Business as usual**



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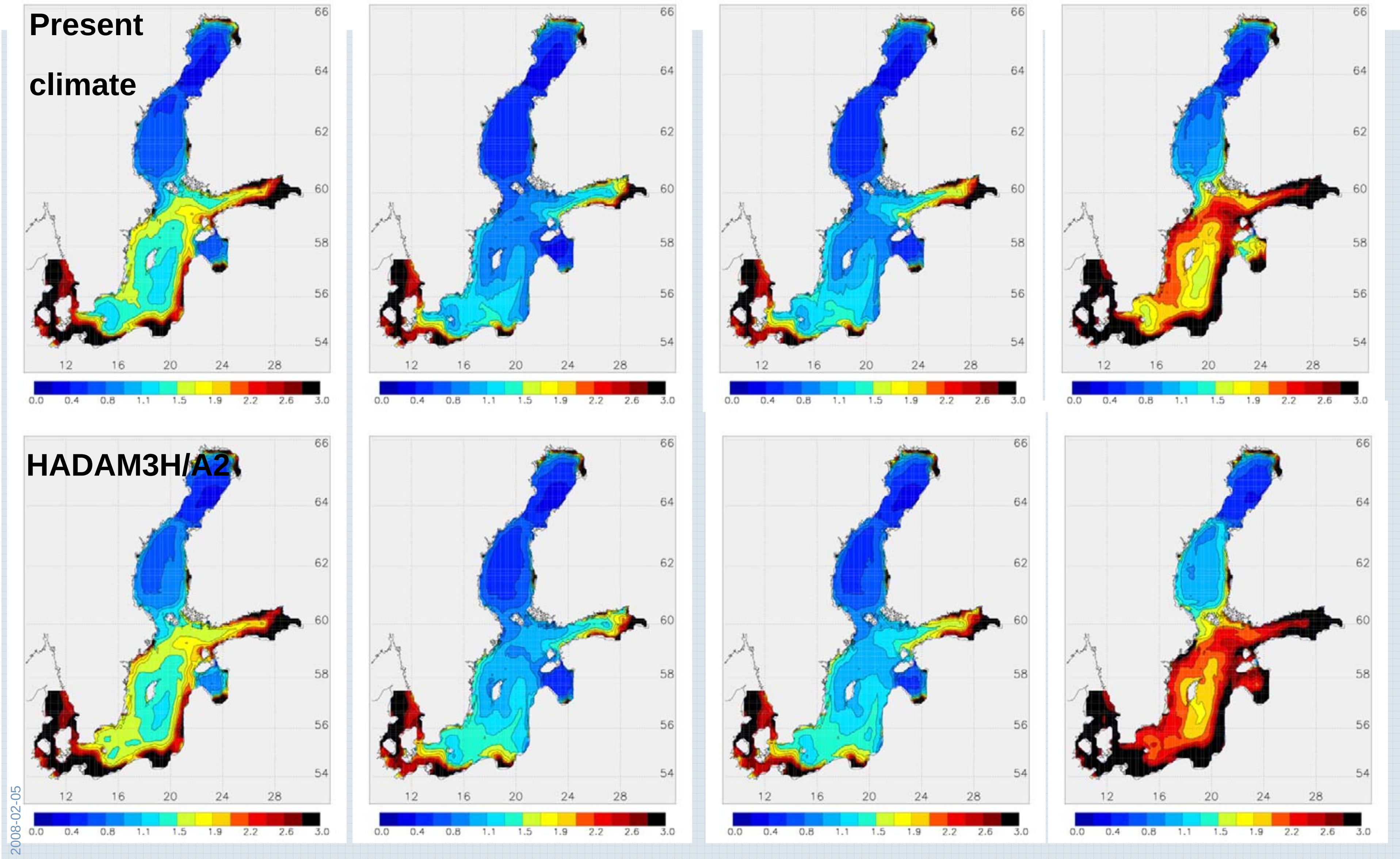

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Summary of the scenario simulations

•Nutrient load reduction scenarios need to take changing climate into account because the impact of changing physical conditions on the marine ecosystem is significant (competing forcings)

•The efficiency of the implementation of the BSAP might differ in future climate

•The sensitivity of the response to climate change depends on key processes that are not well understood

•The response is highly non-linear (low nutrient loads = disagreement, high nutrient loads = agreement)

Added value of RCMs

- To calculate the impact of climate change dynamical downscaling with coupled atmosphere-ocean RCMs is necessary
- To perform scenarios and cause-and-effect studies of the marine ecosystem coupled physical-biogeochemical models are needed (due to the importance of physical processes)
- Due to the long timescales involved transient simulations are needed (plus high-resolution = RCM)