Regional climate models and the coupling with marine biogeochemical models

Cyanobacteria bloom 2005

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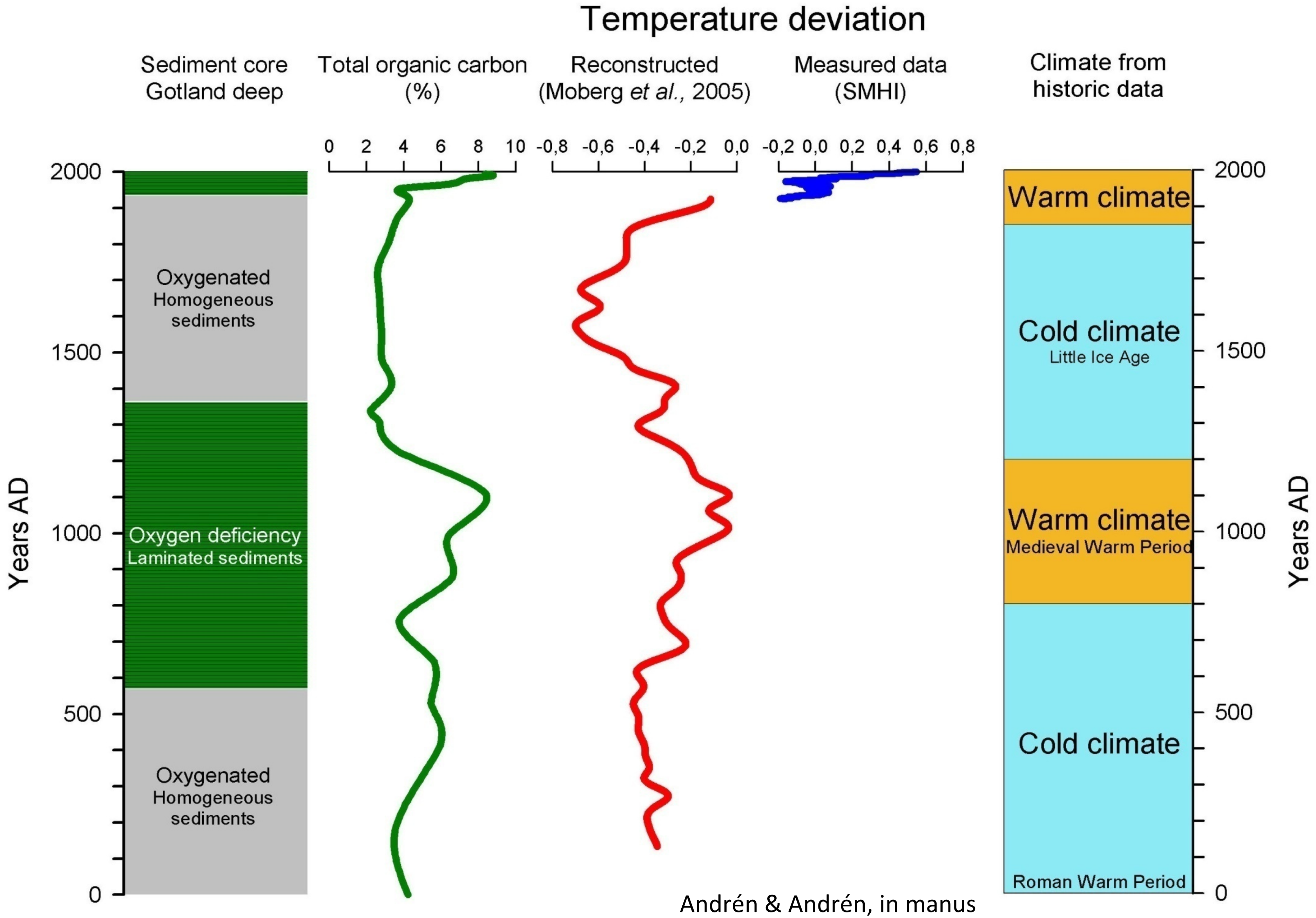
Threats for the Baltic Sea:

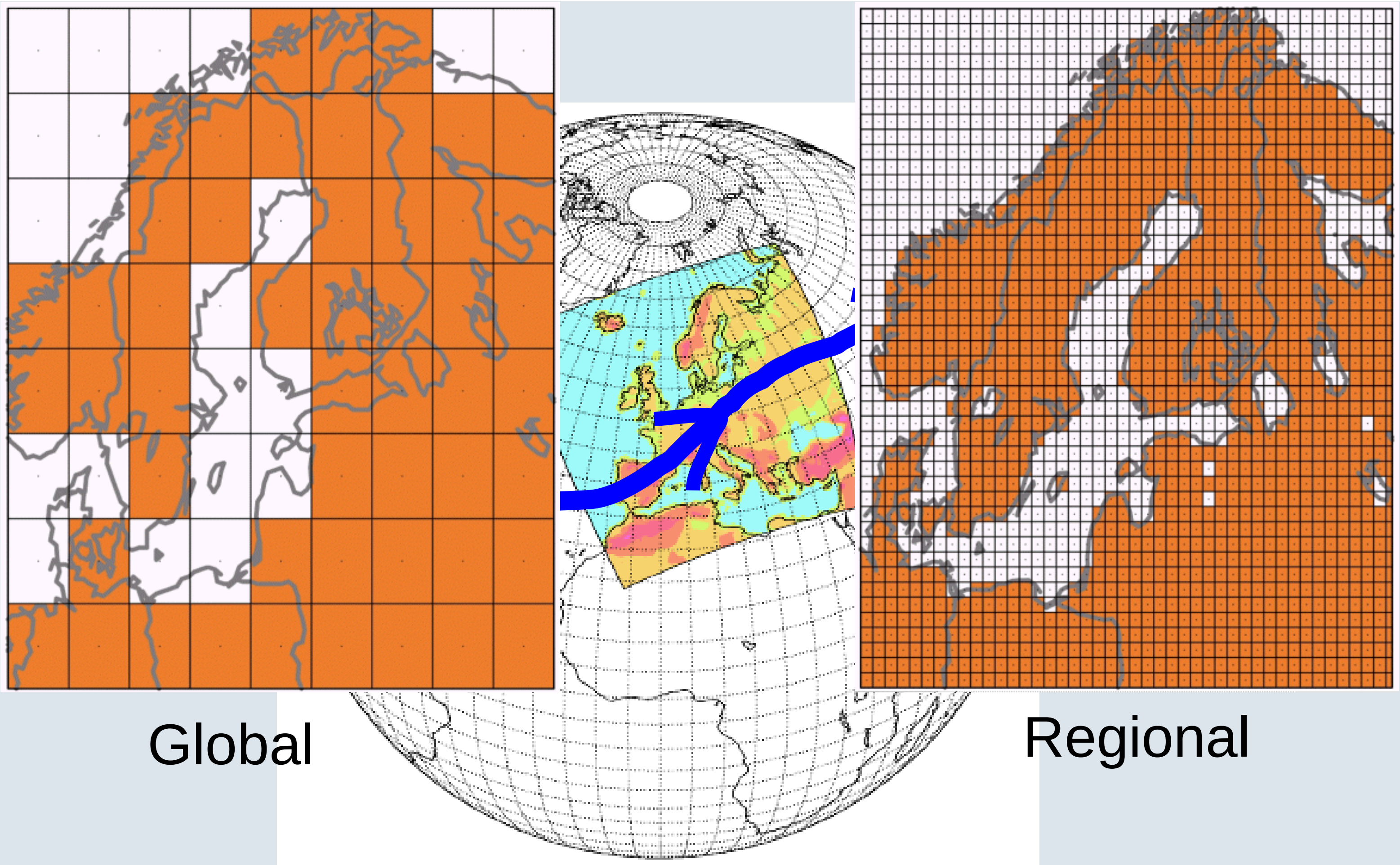
1. Eutrophication (increase in nutrients typically nitrogen or phosphorus)
2. Overfishing
3. Invasive species
4. Organic environmental poisons
5. Climate change
6. Oil discharges

SMHI The open Baltic Sea during the last 2000 years



Andrén & Andrén, in manus

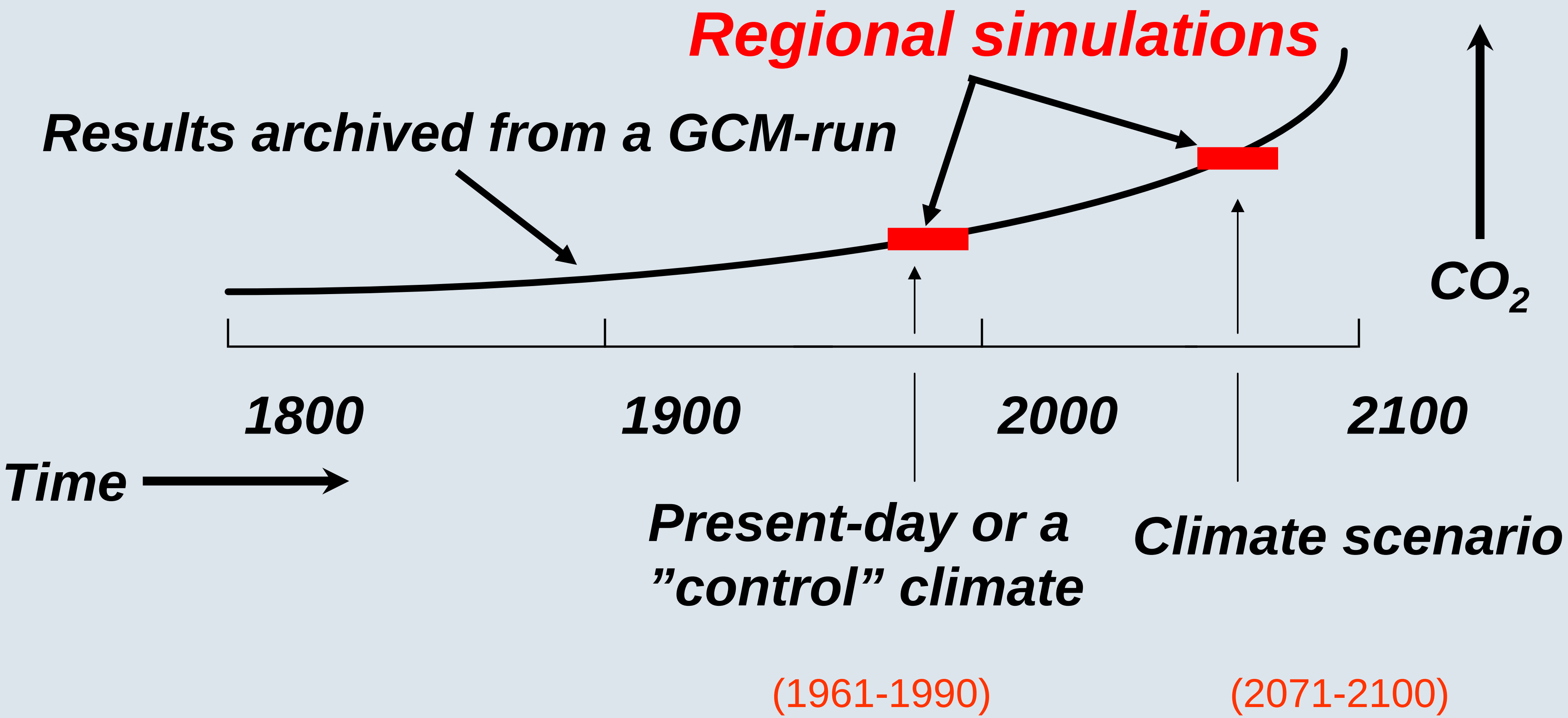
Regional climate modeling at SMHI



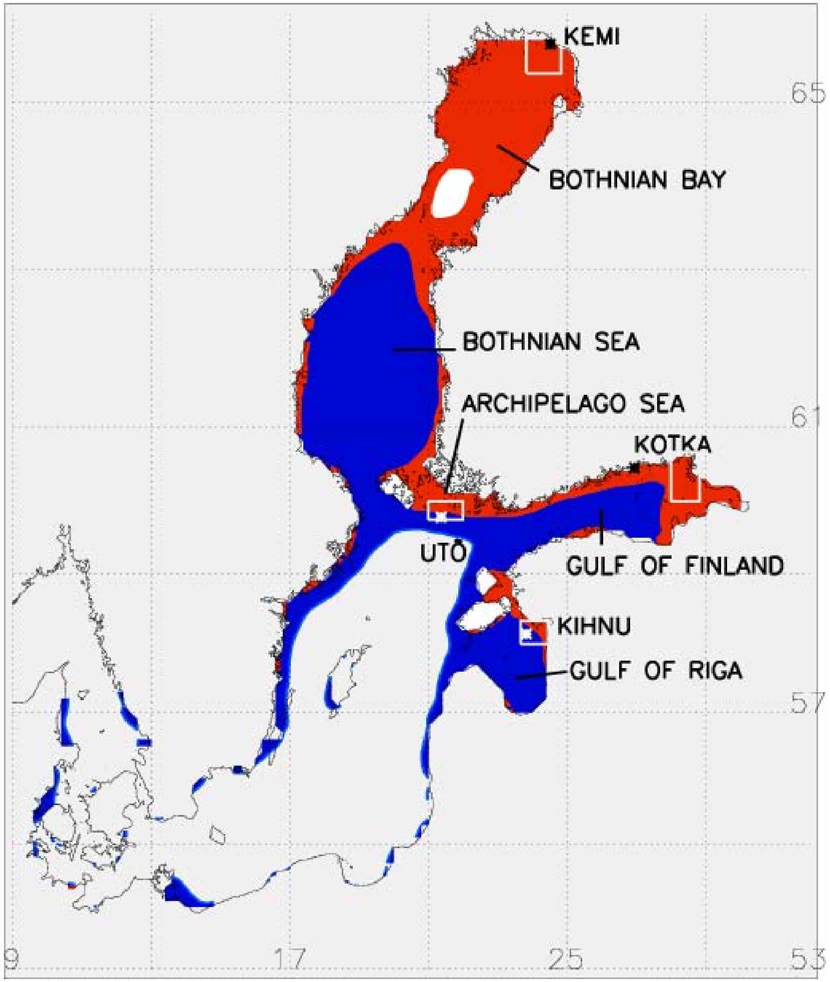
Dynamical downscaling

- Add regional details (land-sea mask)
- Consistent scenarios using coupled models are needed

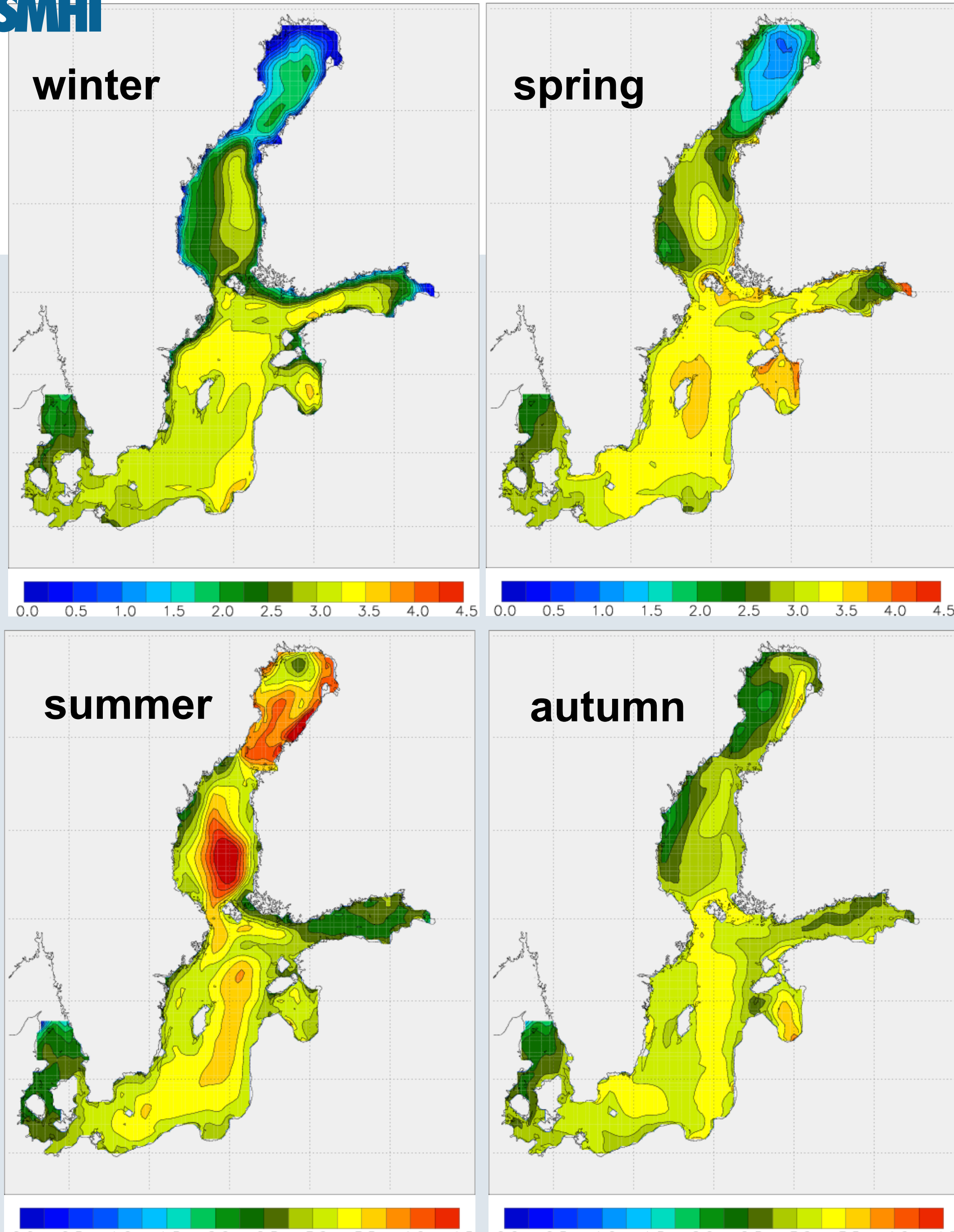
Regionalization is done for ”time-slices” from GCMs



Mean maximum ice cover in control (blue) and scenario (red)



(Meier et al., 2004)



Annual mean sea surface temperature change: + 2-4°C

Figure: 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) (Meier, 2006).

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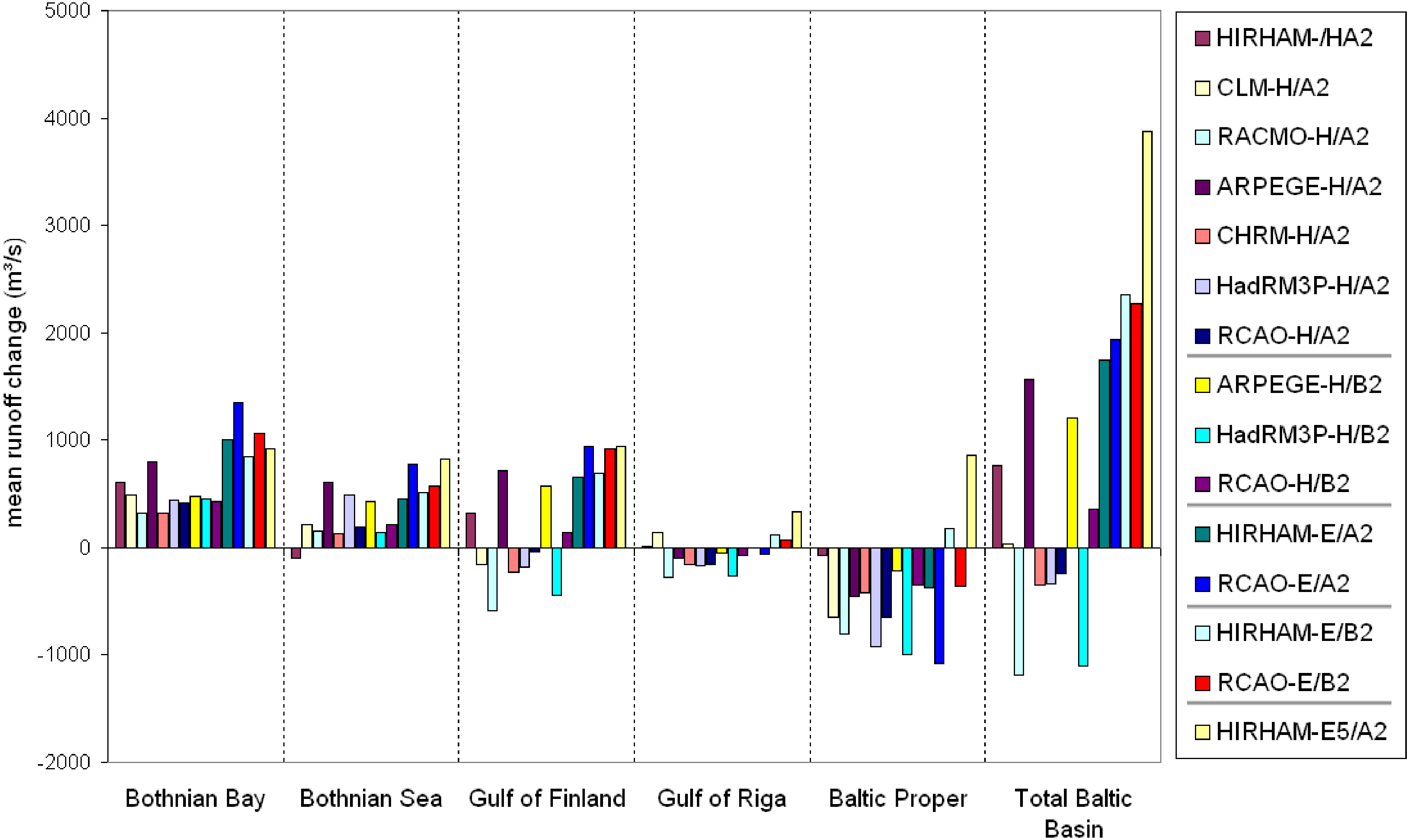
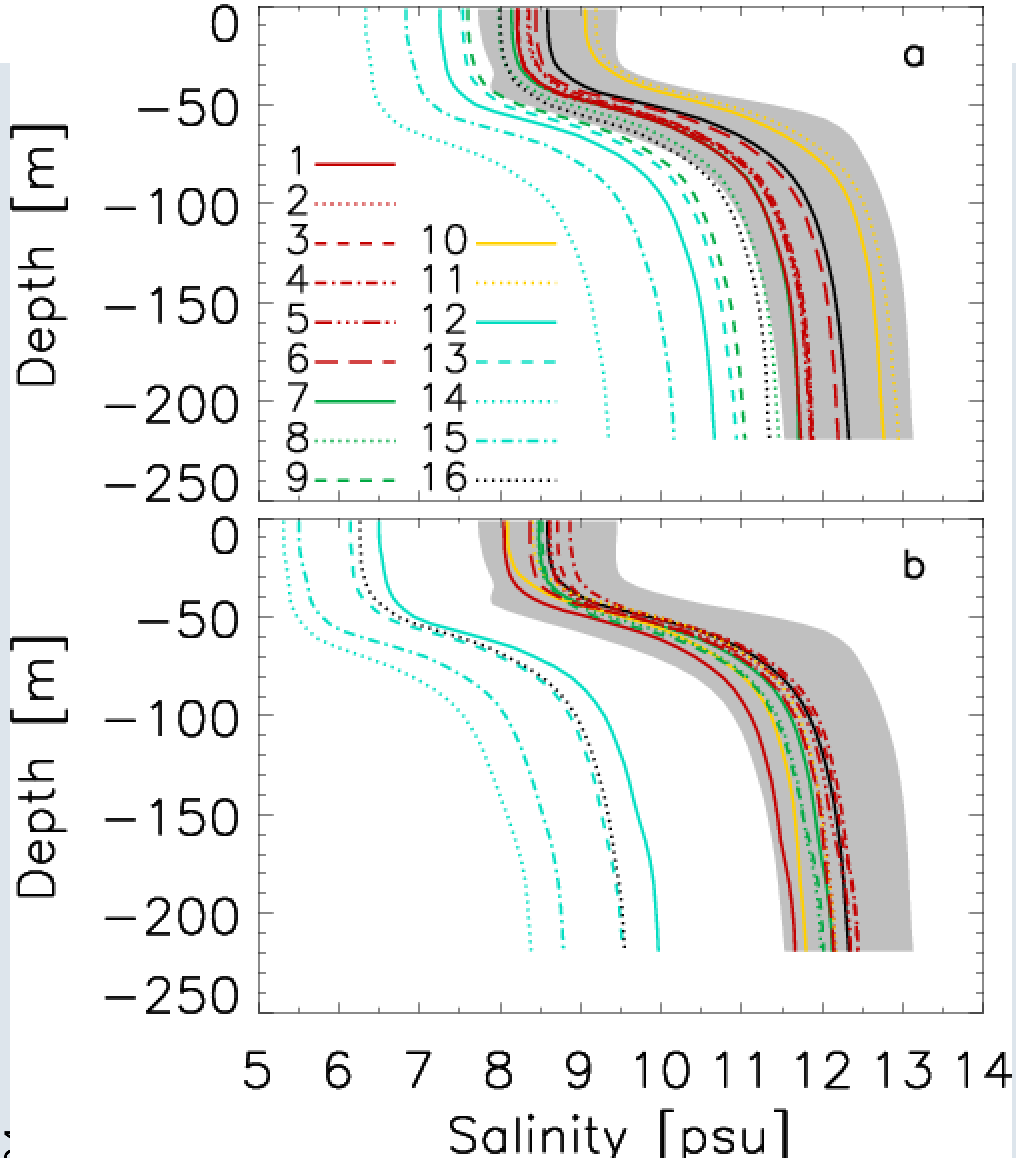
Mean Annual Change in Runoff



(Source: Phil Graham, SMHI)

Salinity at Gotland Deep

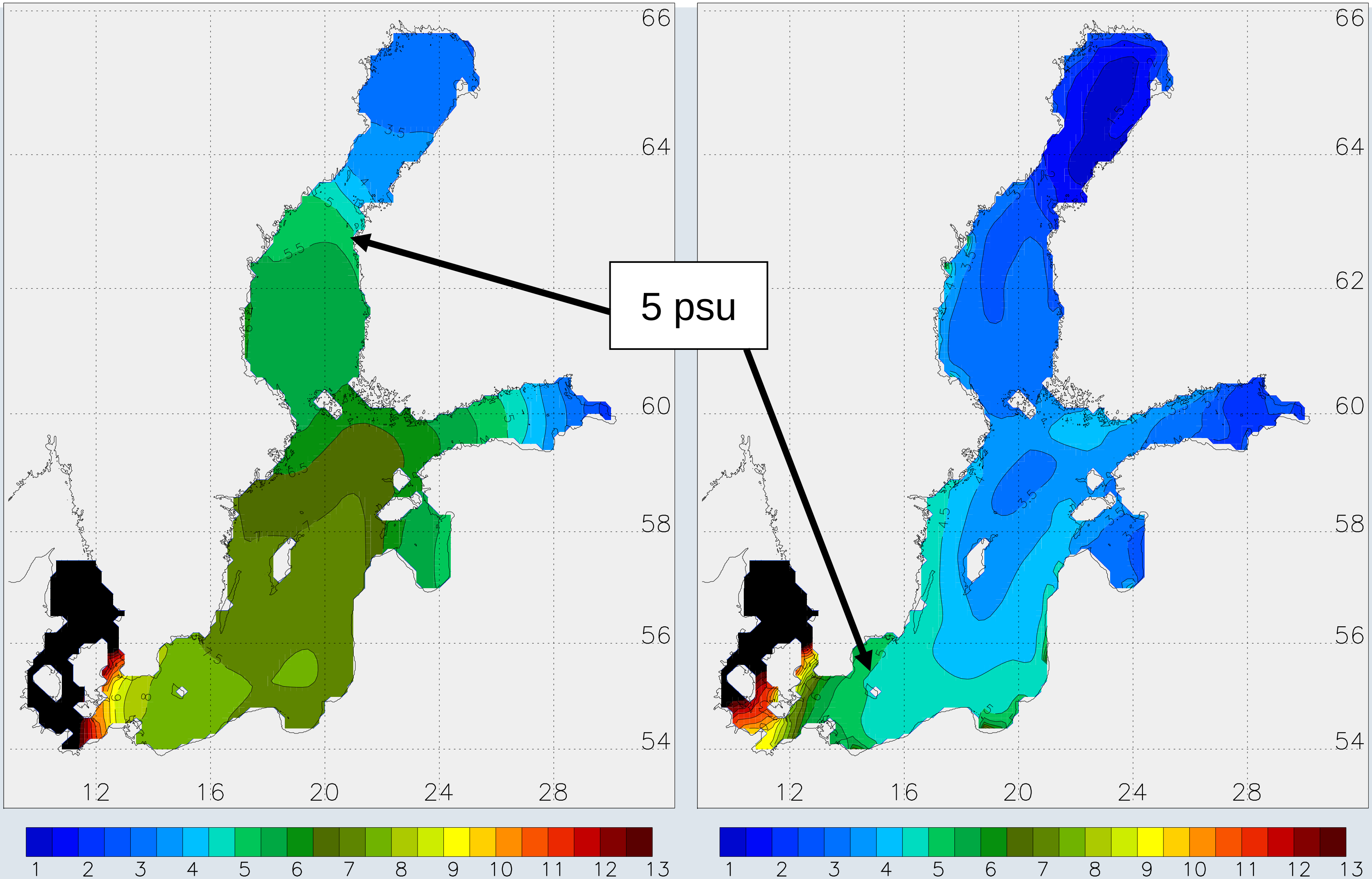


Median profiles of salinity at monitoring station BY15 for present climate 1961-1990 (black solid line, shaded areas indicate the +/- 2 standard deviation band calculated from two-daily values for 1903-1998) and in projections for 2071-2100 (colored lines). In (a) only effects from wind changes are considered whereas in (b) projections based upon wind and freshwater inflow changes are shown. Numbers in the legend correspond to different scenario runs (Meier et al. 2006).

Sea surface salinity

Present climate

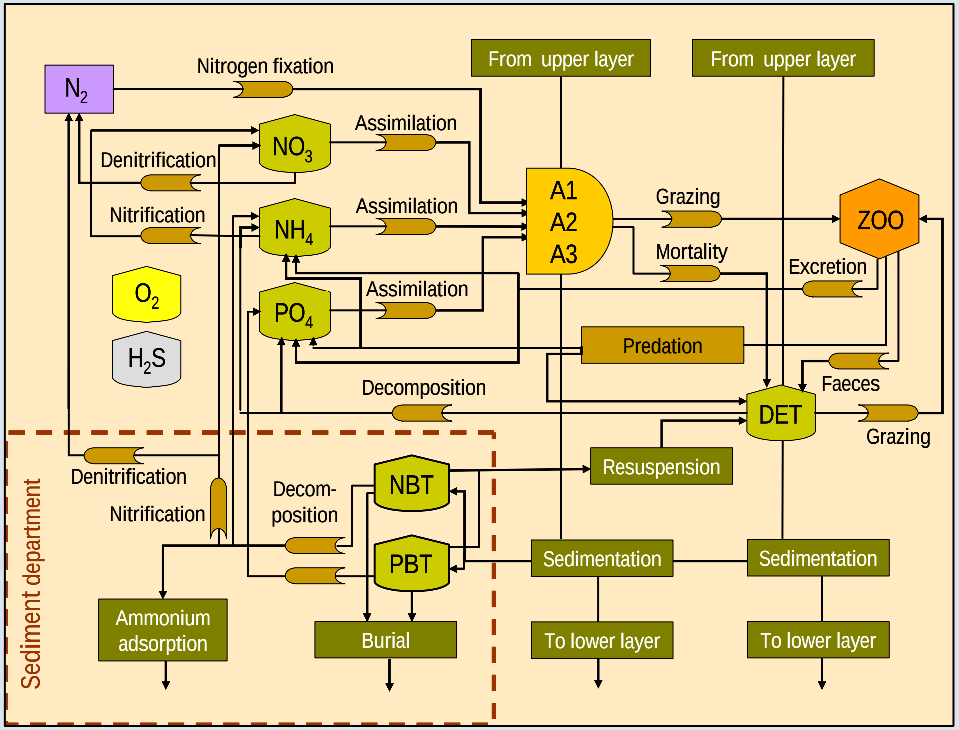
Projection with the largest change
RCAO-ECHAM4/A2



Coupling with a biogeochemical model

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.**

Long period experiment

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

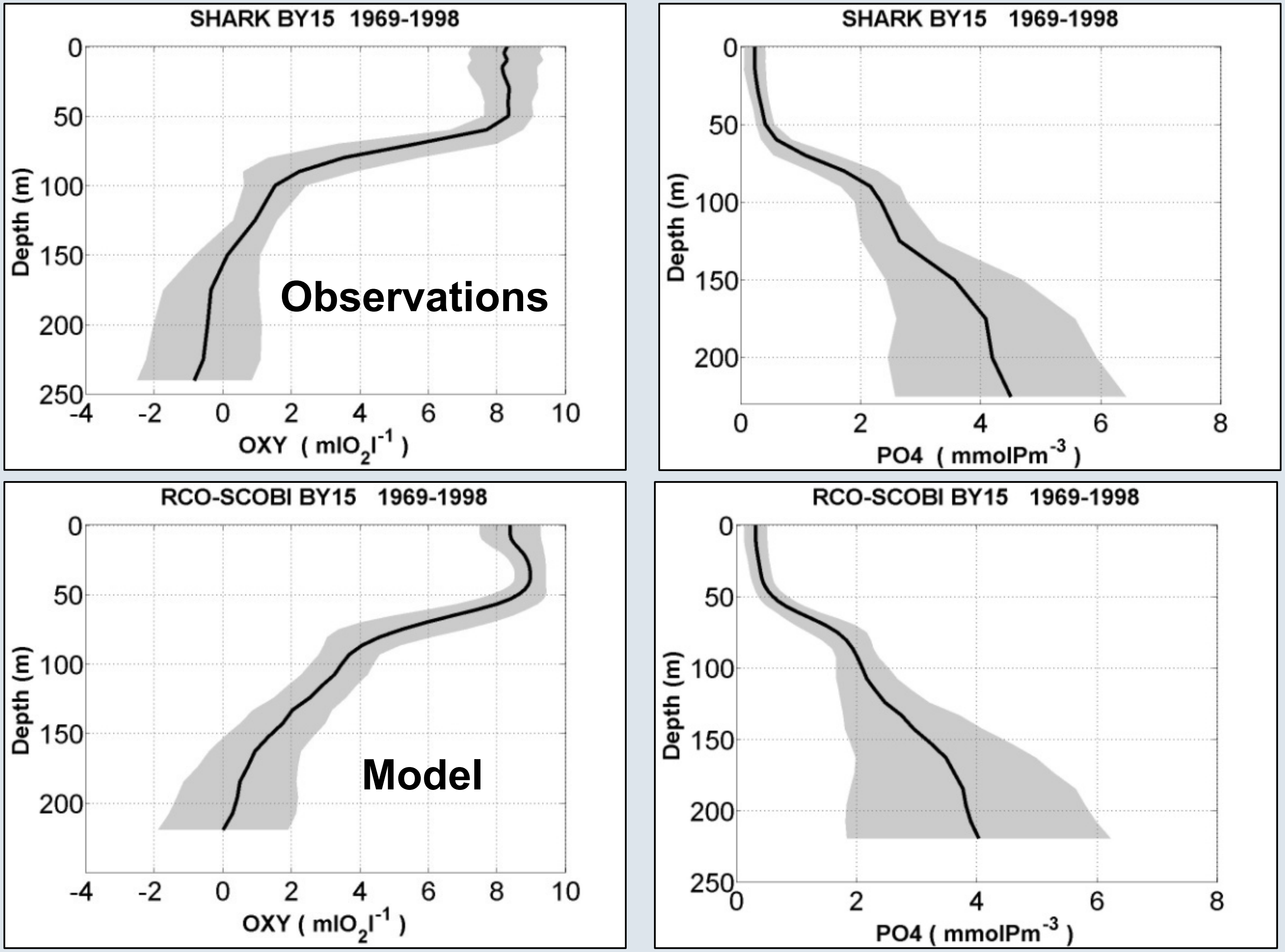
- RCO 6 N.m. run on the period 1902-1998 with reconstructed atmospheric forcing and river discharge data.

- 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) at Gotland Deep



Run 30

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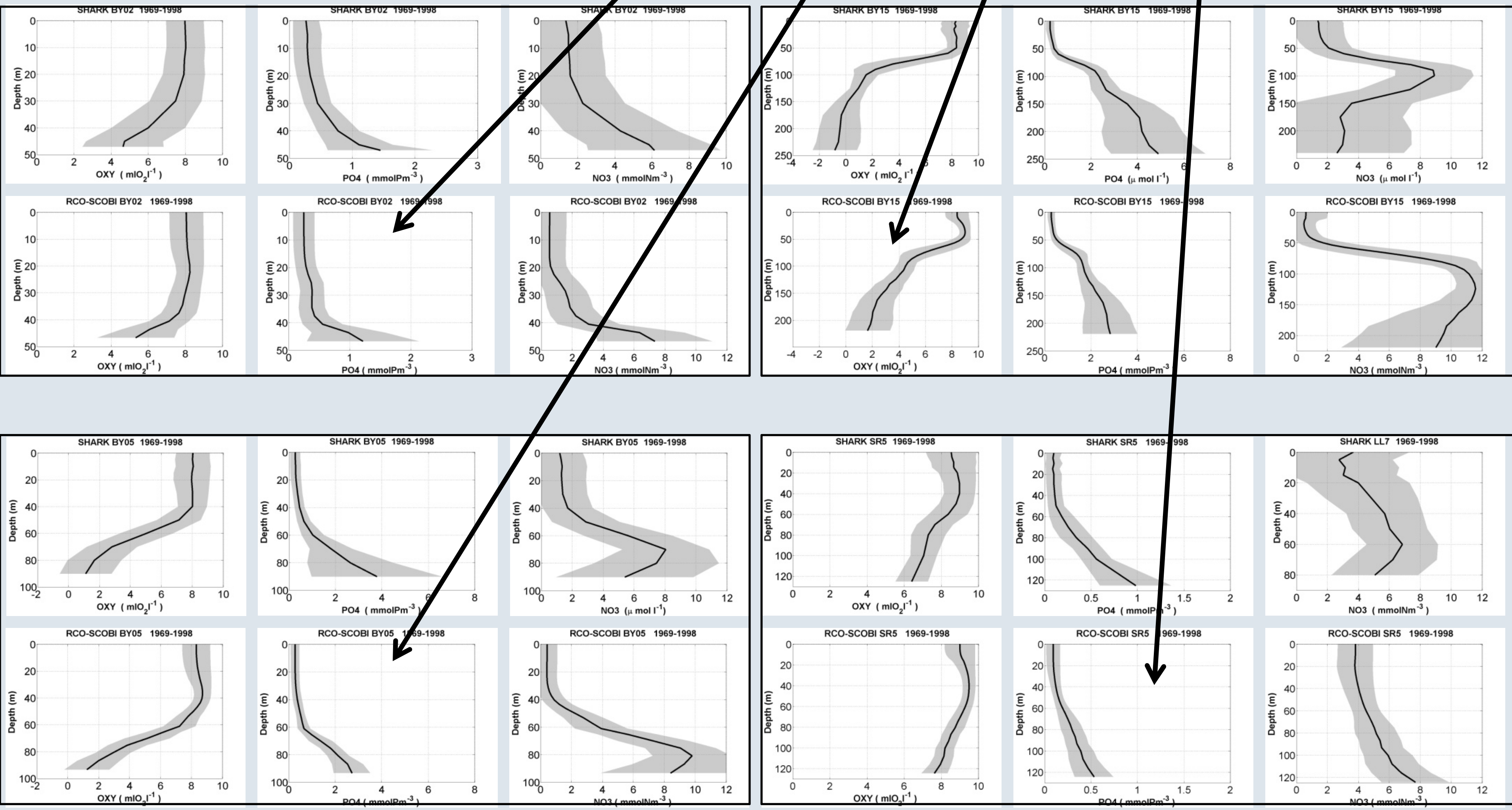
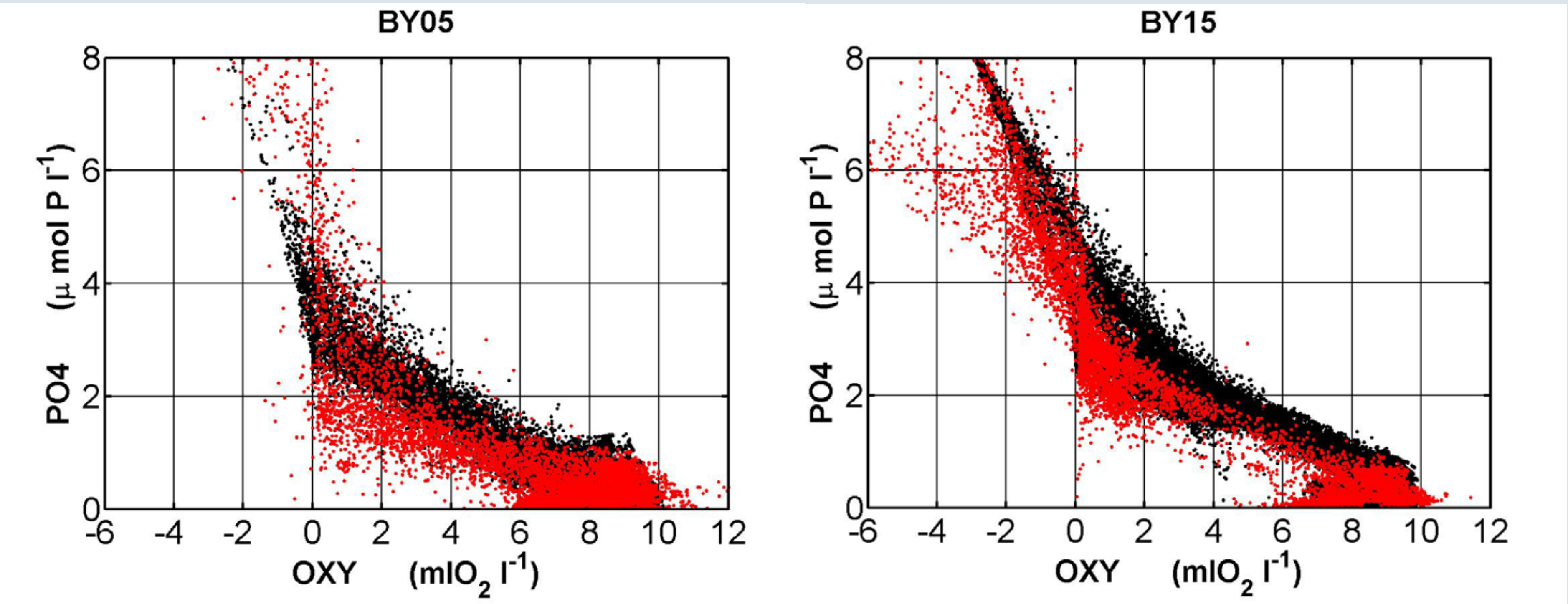
Oxygen, phoshate, nitrate at monitoring stations BY2, BY5, BY15, SR5



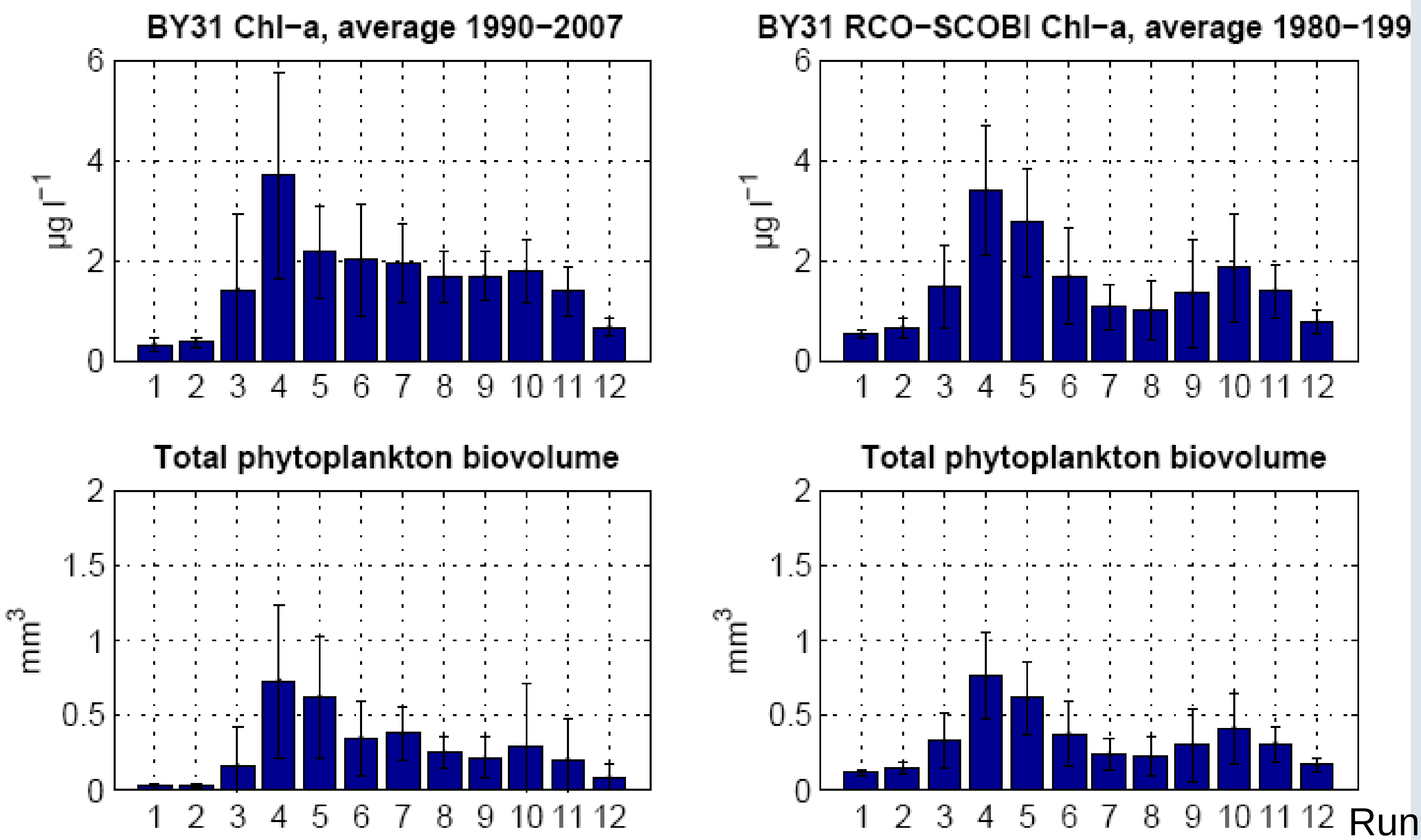
Run 45

Phosphate [µmol P/l] versus oxygen concentrations [ml O2/ l] at Bornholm Deep (BY5) and Gotland Deep (BY15) during 1969-1998: model results (black dots) and red dots (observations).



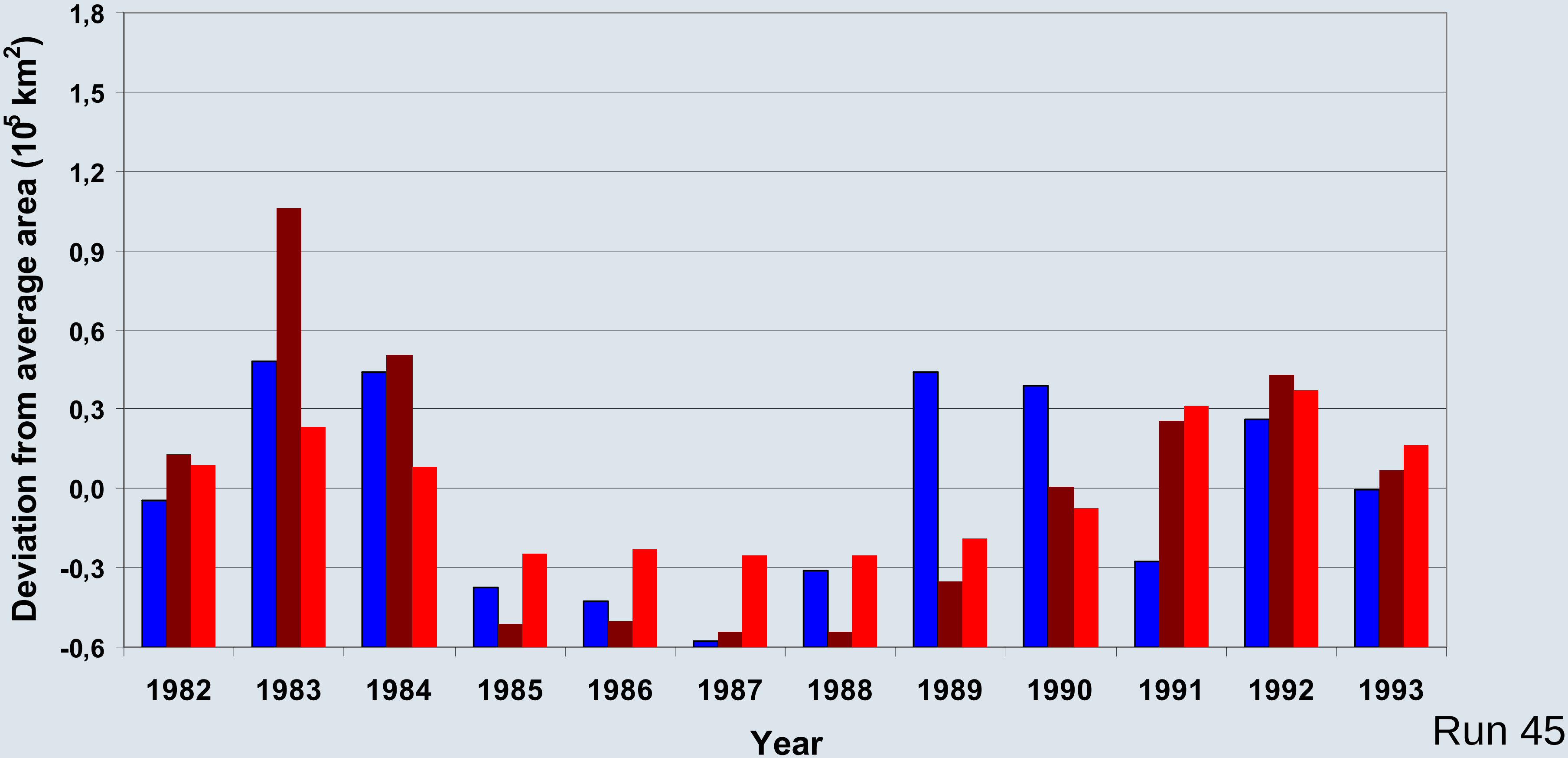
Run 30

Monthly mean of observations (1990-2007) and model data (1980-1998) at Landsort Deep



Run 45

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



Model results (blue), cumulative surface area estimated from satellite images (red) and the area corrected for unequal number of available images (brown; Kahru, 1997)

Scenario simulations

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Scenario simulations of the marine ecosystem

- Important to assess uncertainties due

  natural variability,

  model biases from GCMs and RCMs,

  greenhouse gas emission scenarios,

  land use and sewage treatment scenarios,

  biogeochemical processes)

- To get robust information ensemble simulations

  should be performed

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

Four climate scenarios 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

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

Three nutrient load scenarios (Nest Institute, Stockholm University):

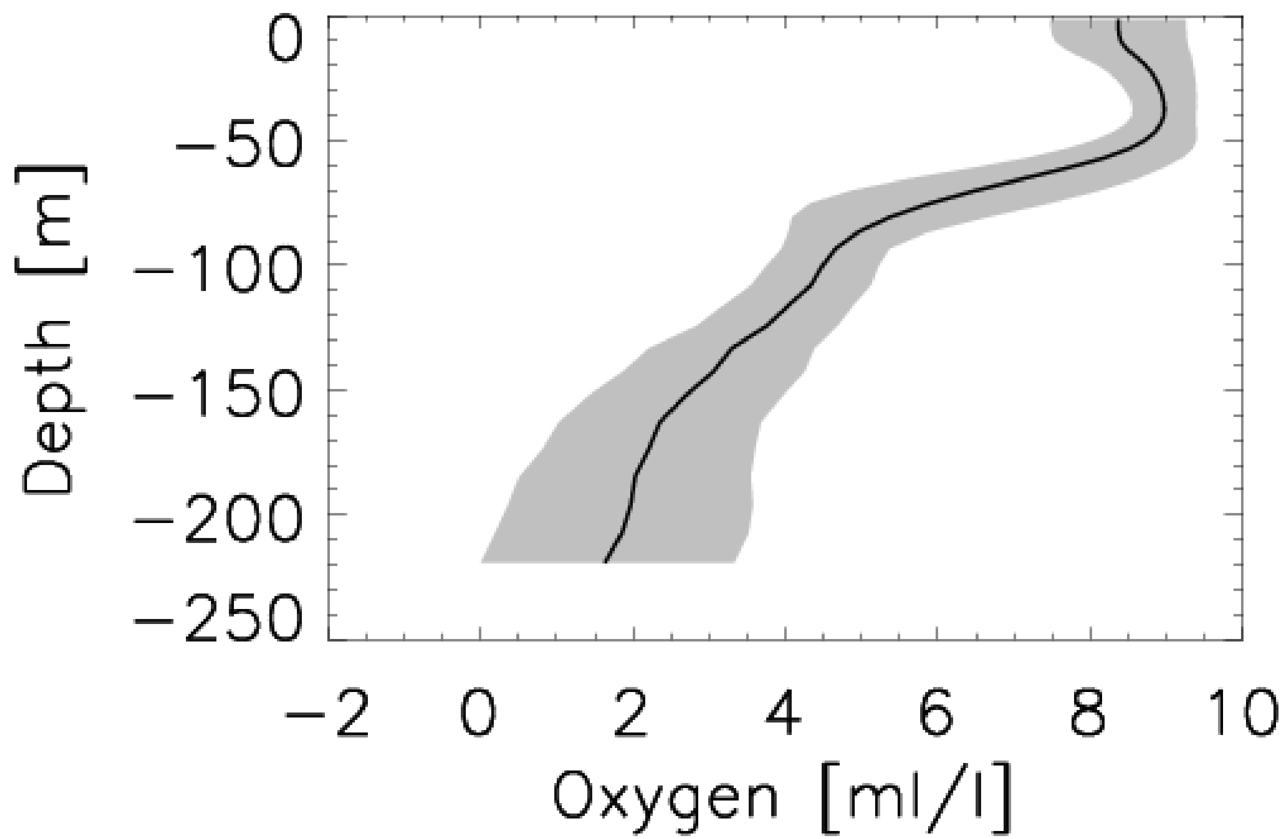
1) best case combining improved sewage treatment, P-free detergents and best possible agricultural practices (BC): P -21 000 t, N -150 000 t

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

Mean oxygen profile at Gotland Deep

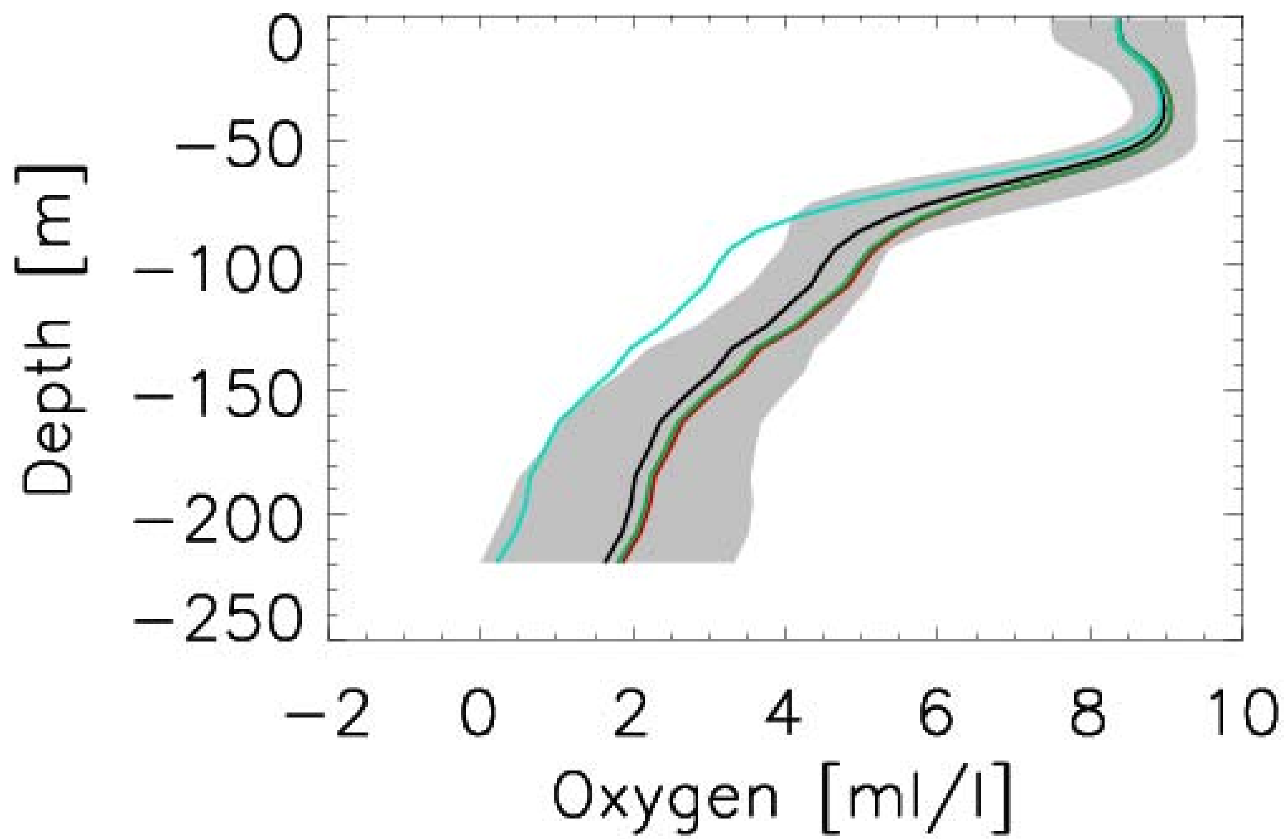
- **Reference simulation (black)**



Run 45

Mean oxygen profile at Gotland Deep

- **Reference simulation (black) and nutrient load scenarios BC, BSAP, BAU in present climate (solid lines)**



Run 45

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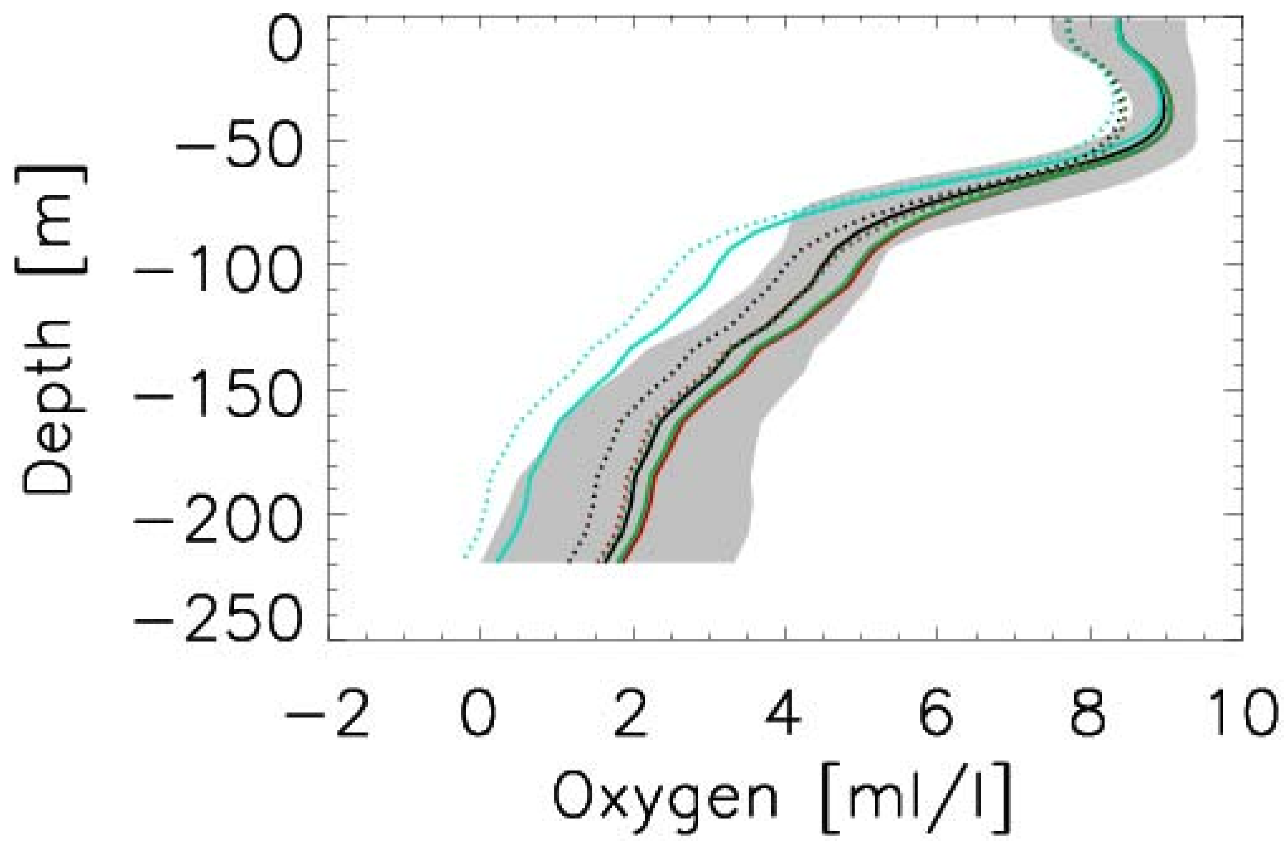
Mean oxygen profile at Gotland Deep

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



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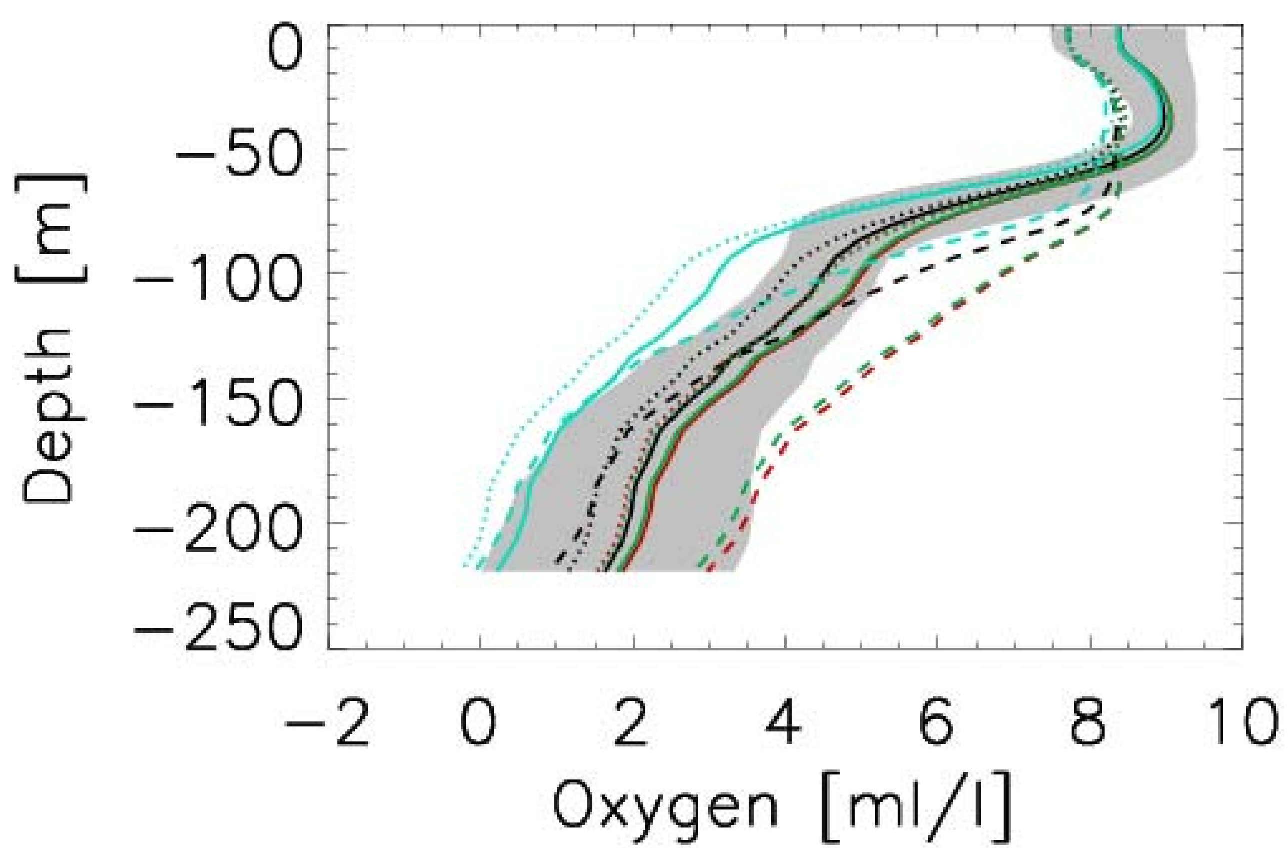
Mean oxygen profile at Gotland Deep

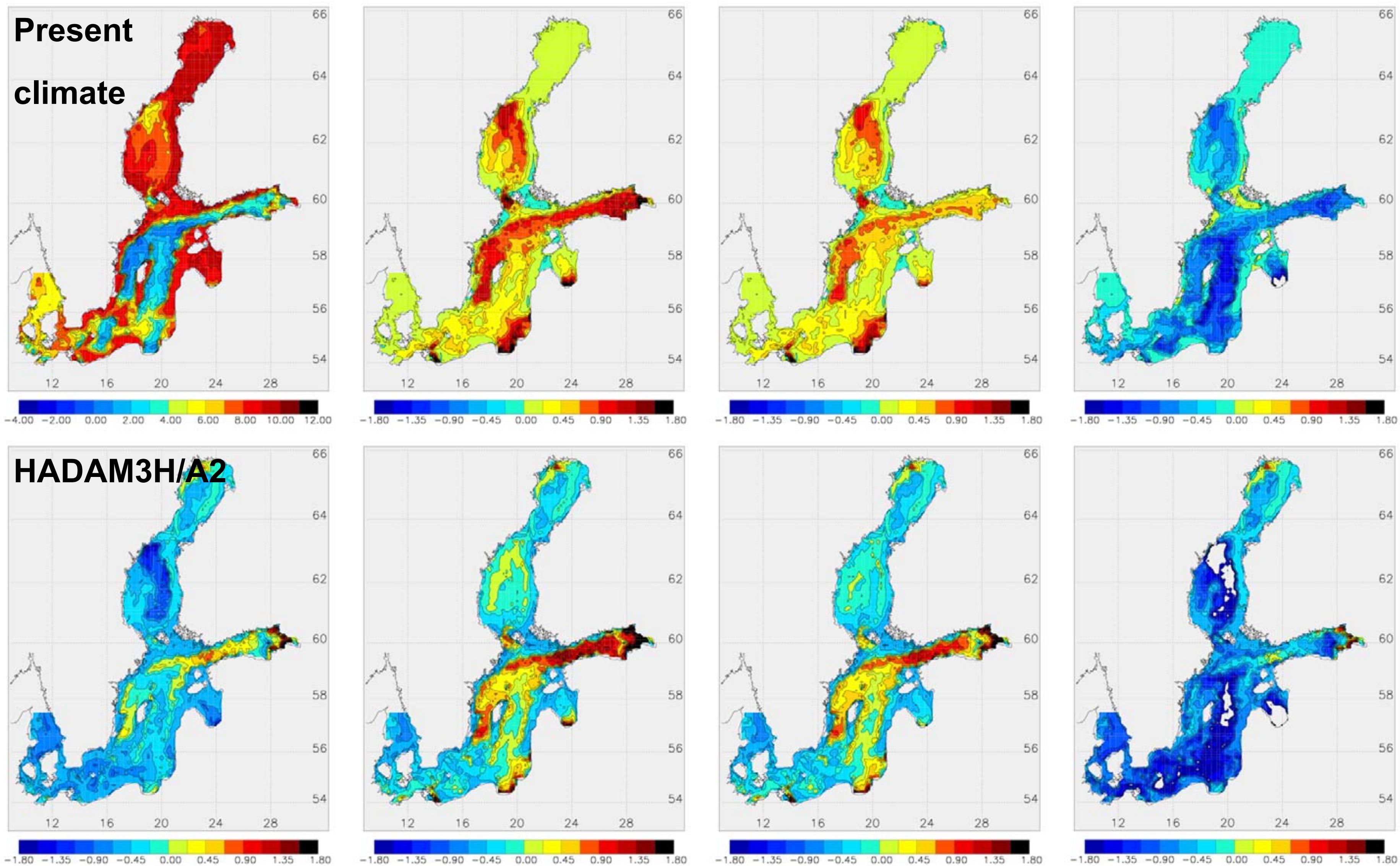
- Reference simulation (black) and nutrient load scenarios BC, BSAP, BAU in present climate (solid lines)
- HADAM3H/A2 (2071-2100) (dotted lines)
- ECHAM4/A2 (2071-2100) (dashed lines)



Run 45

Annual mean bottom oxygen concentration and changes [ml/l]

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



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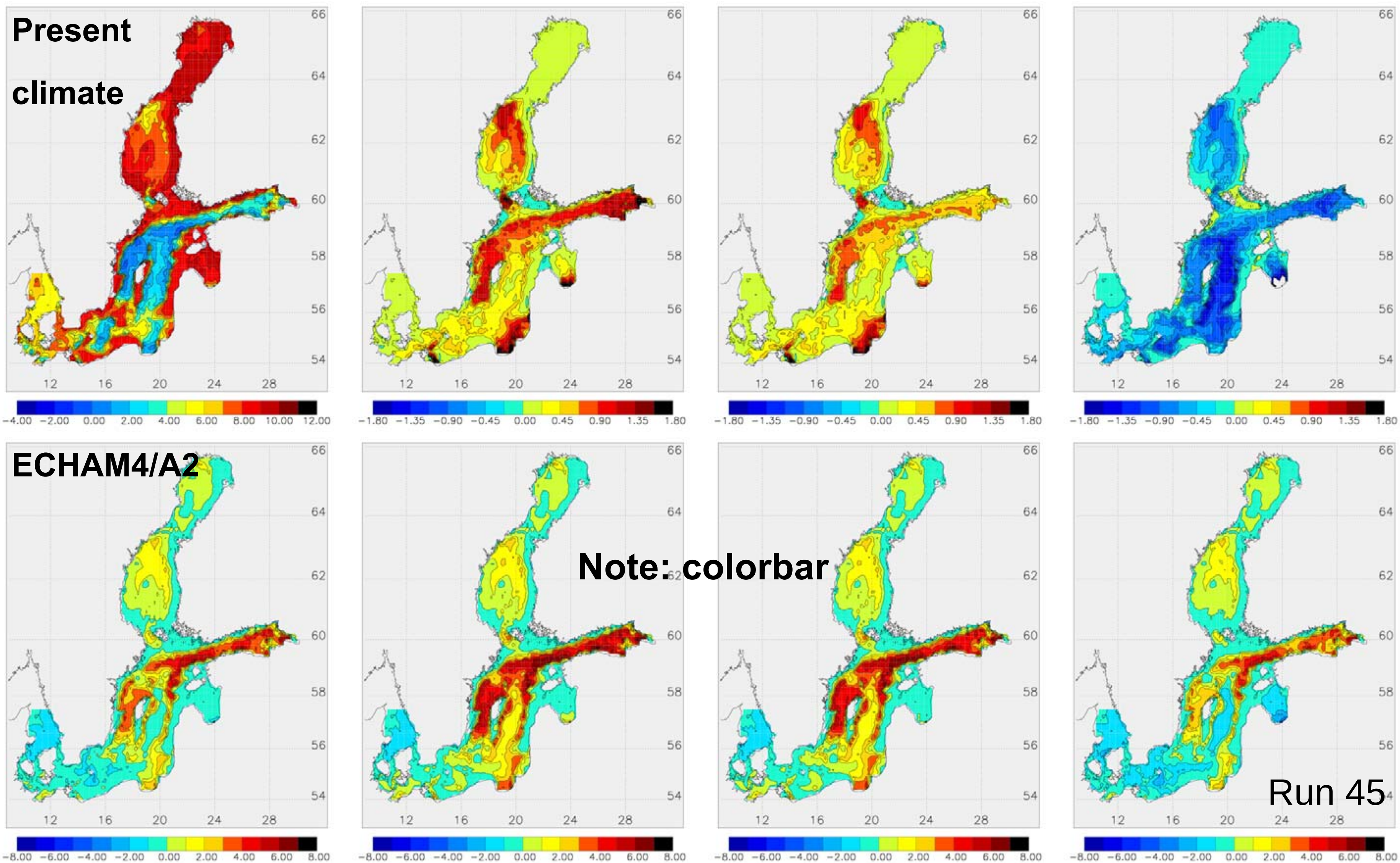

Annual mean phytoplankton concentration [mgChl/m^3] (0-10m)

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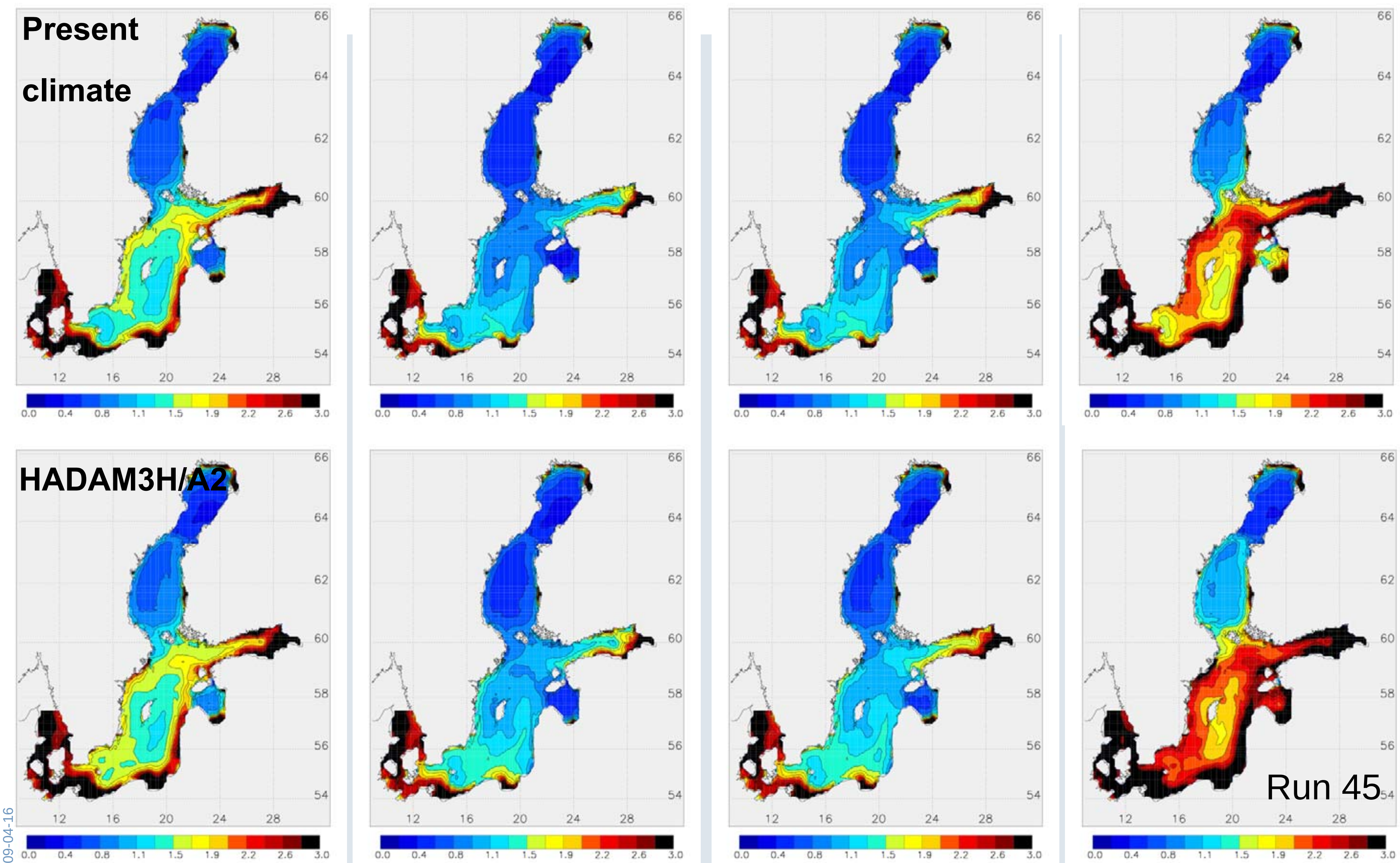

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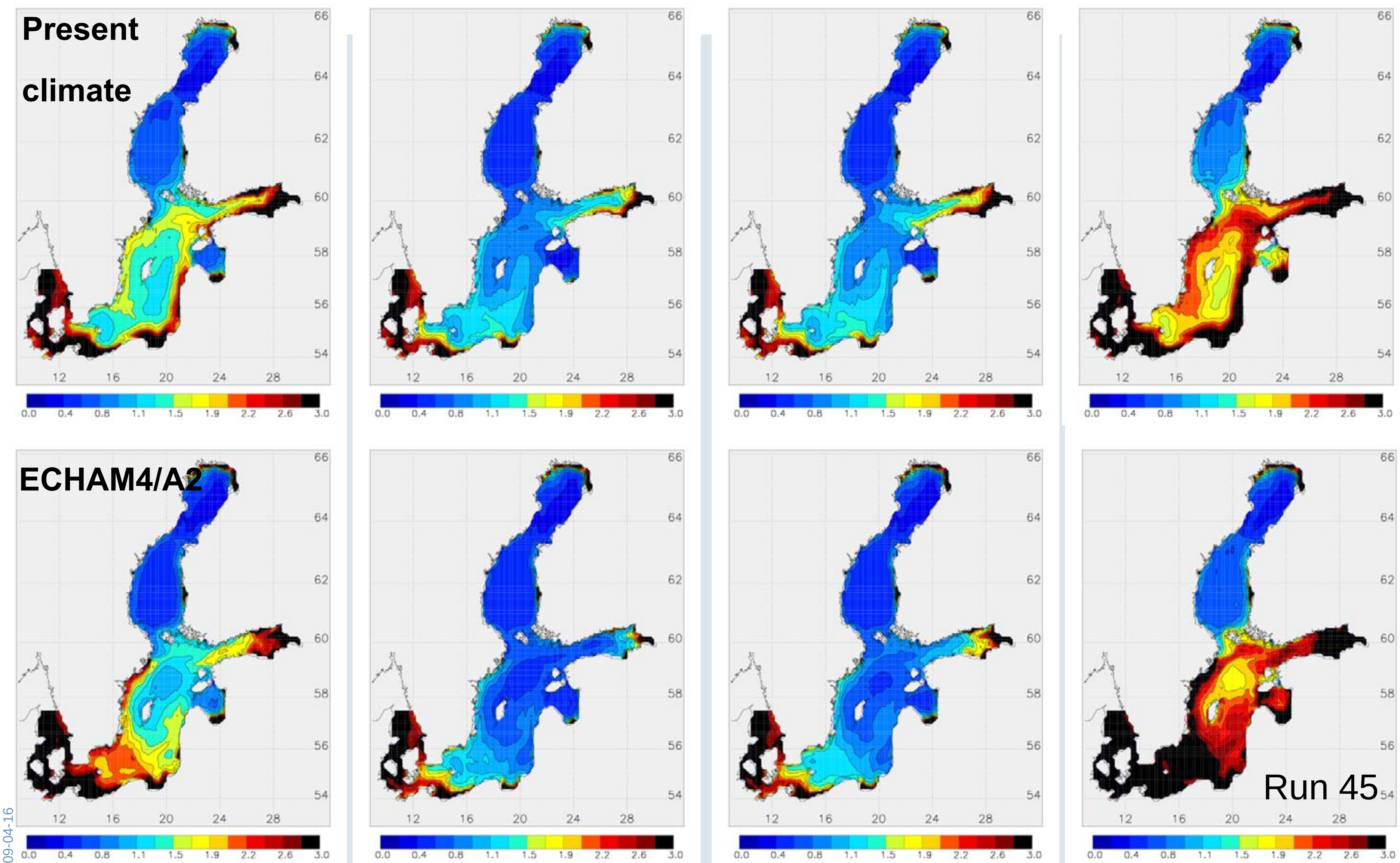

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Summary 1

•Projections of future climate suggest that water temperature may increase and ice cover may decrease

•In addition salinity may (or may not) decrease with reduced stability and deeper halocline (uncertainty caused by GCMs)

•The sensitivity of the highly non-linear biogeochemical response to climate change depends on key processes (e.g. in the sediments) that are not well understood (uncertainty caused by biogeochemical models)

•Oxygen concentrations of the surface layer may decrease

•In the southwestern Baltic phytoplankton concentrations may increase and there is a risk that cyanobacteria blooms become more intense

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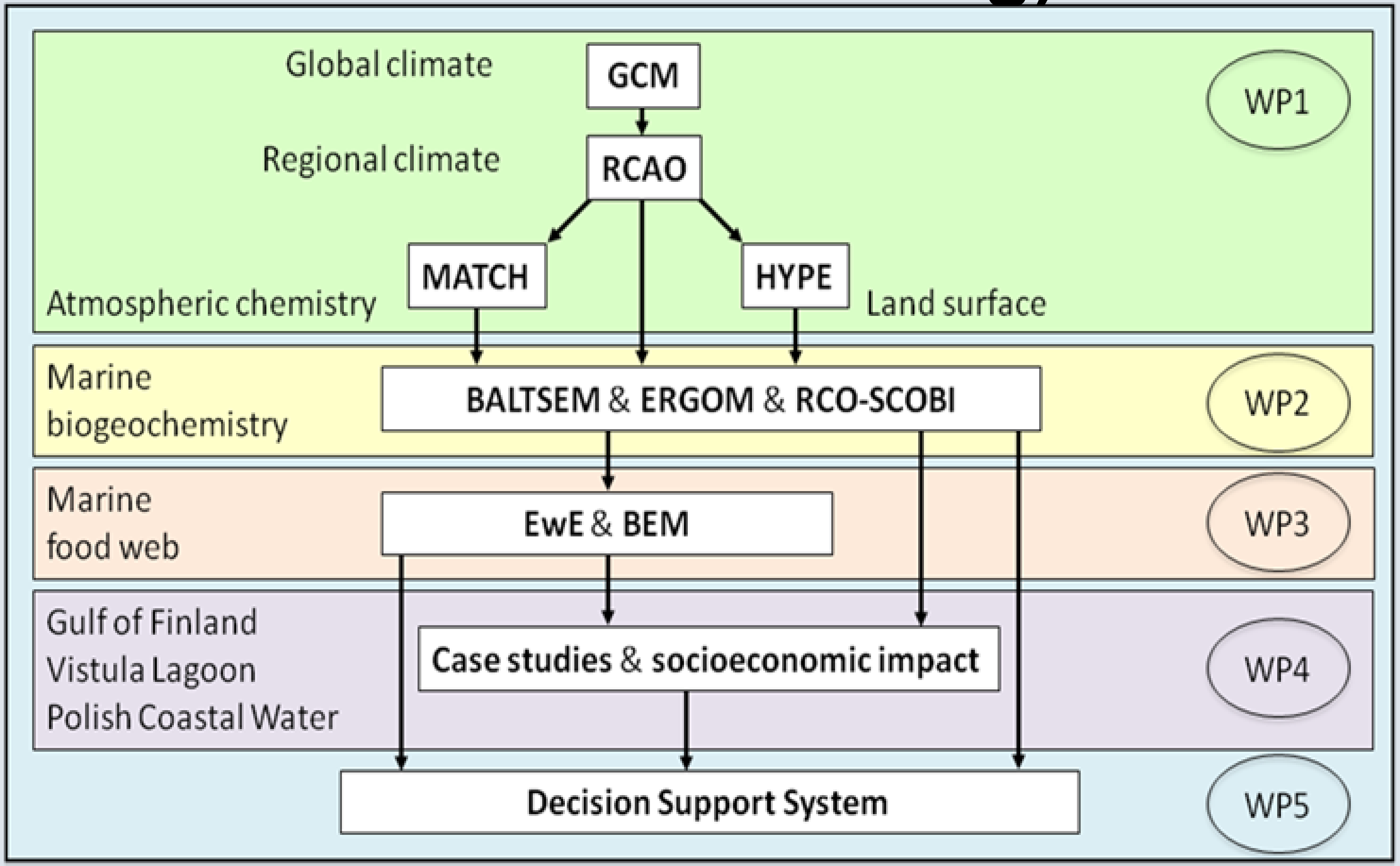
Summary 2

•Future nutrient loads are uncertain due to unkown agricultural practices, sewage treatment, etc.

•The efficiency of the implementation of the BSAP may differ in future climate. However the BSAP will likely reduce the phytoplankton concentrations also in future climate (robust result)

•The ”business as usual in agricultural practices” scenario in future climate may have larger impacts on the marine environment with increased phytoplankton concentrations than in present climate (robust result even when the bottom oxygen concentrations increase regionally)

Model hierarchy in ECOSUPPORT (Advanced modeling tool for scenarios of the Baltic Sea ECOsystem to SUPPORT decision making)



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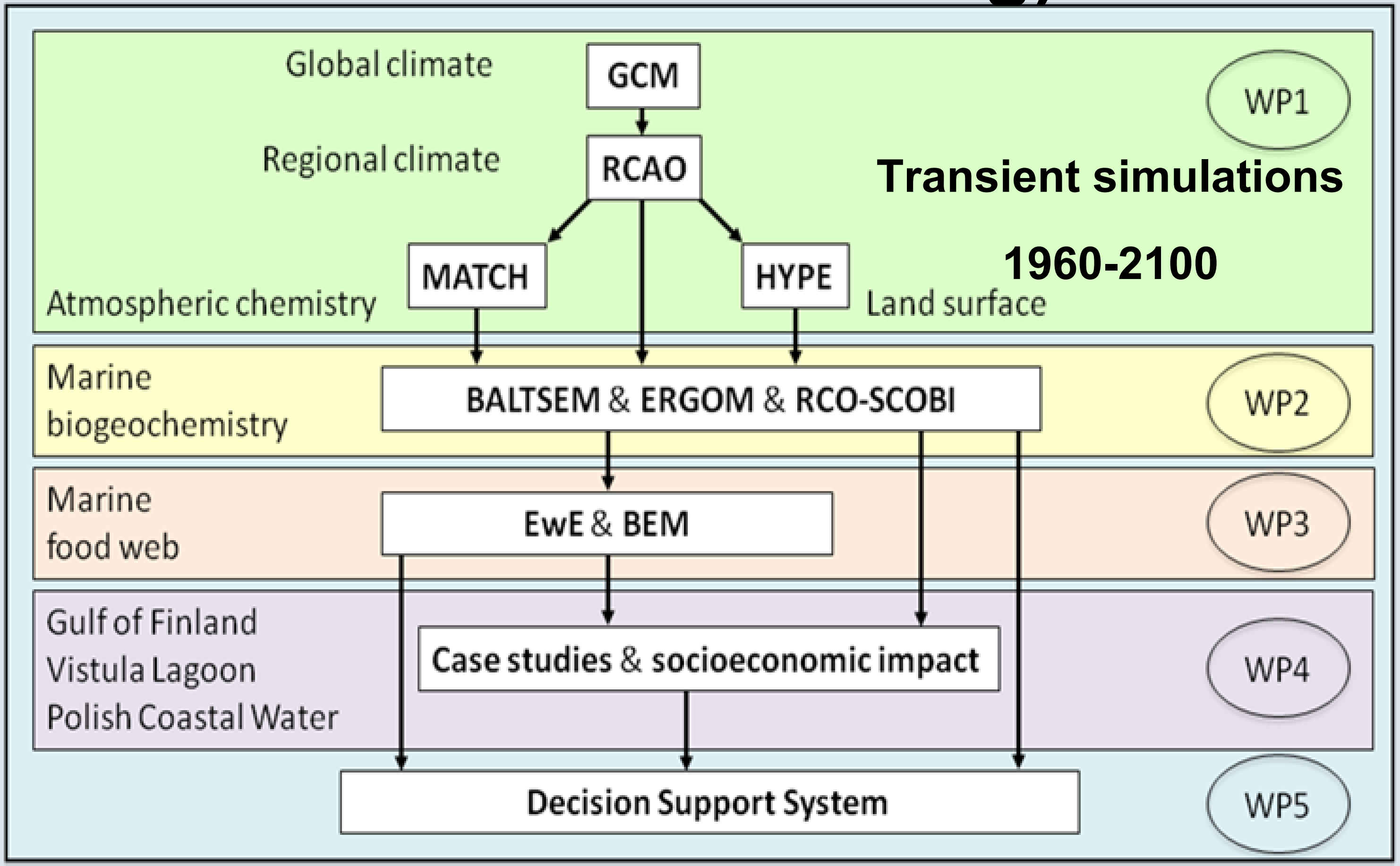

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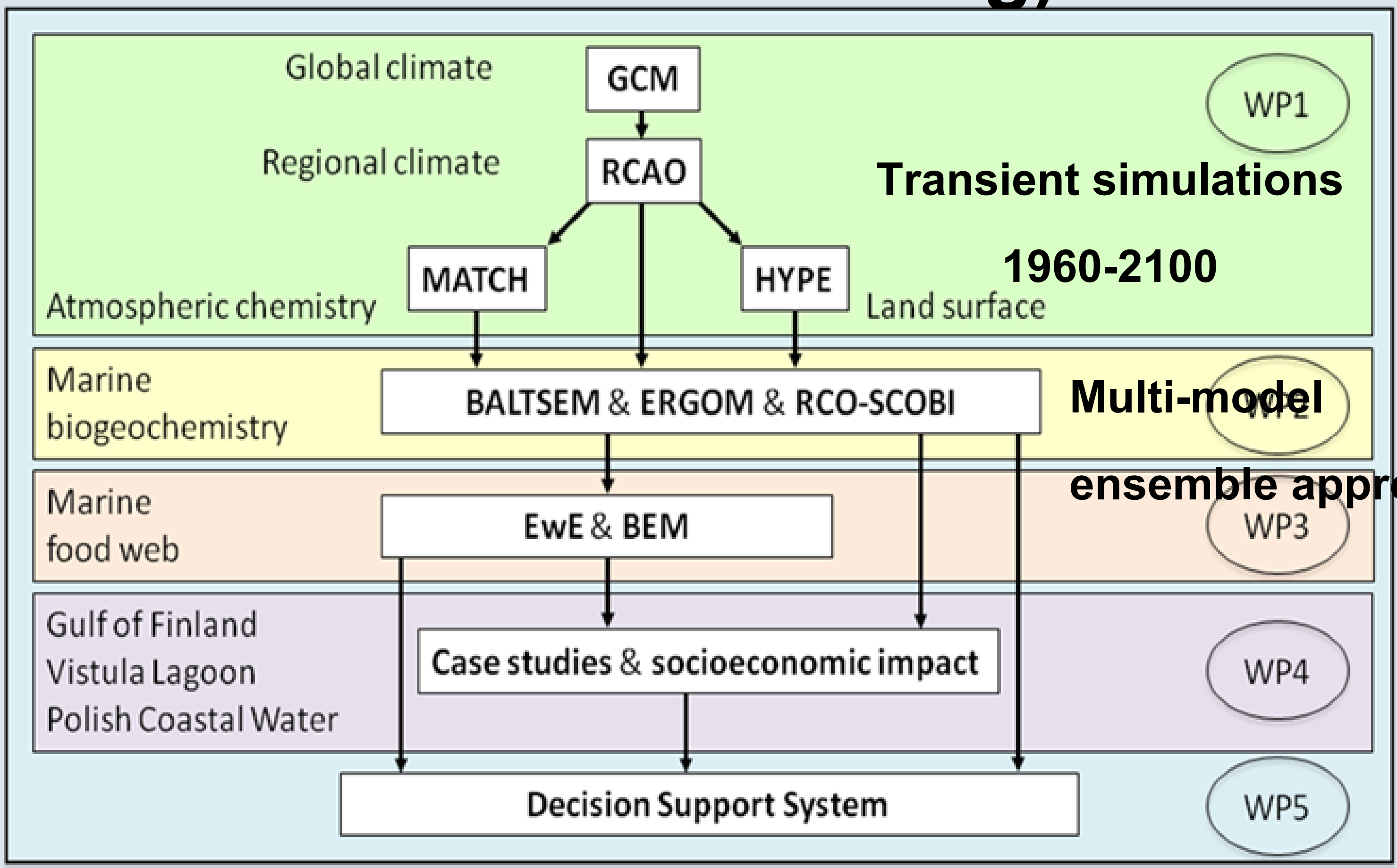

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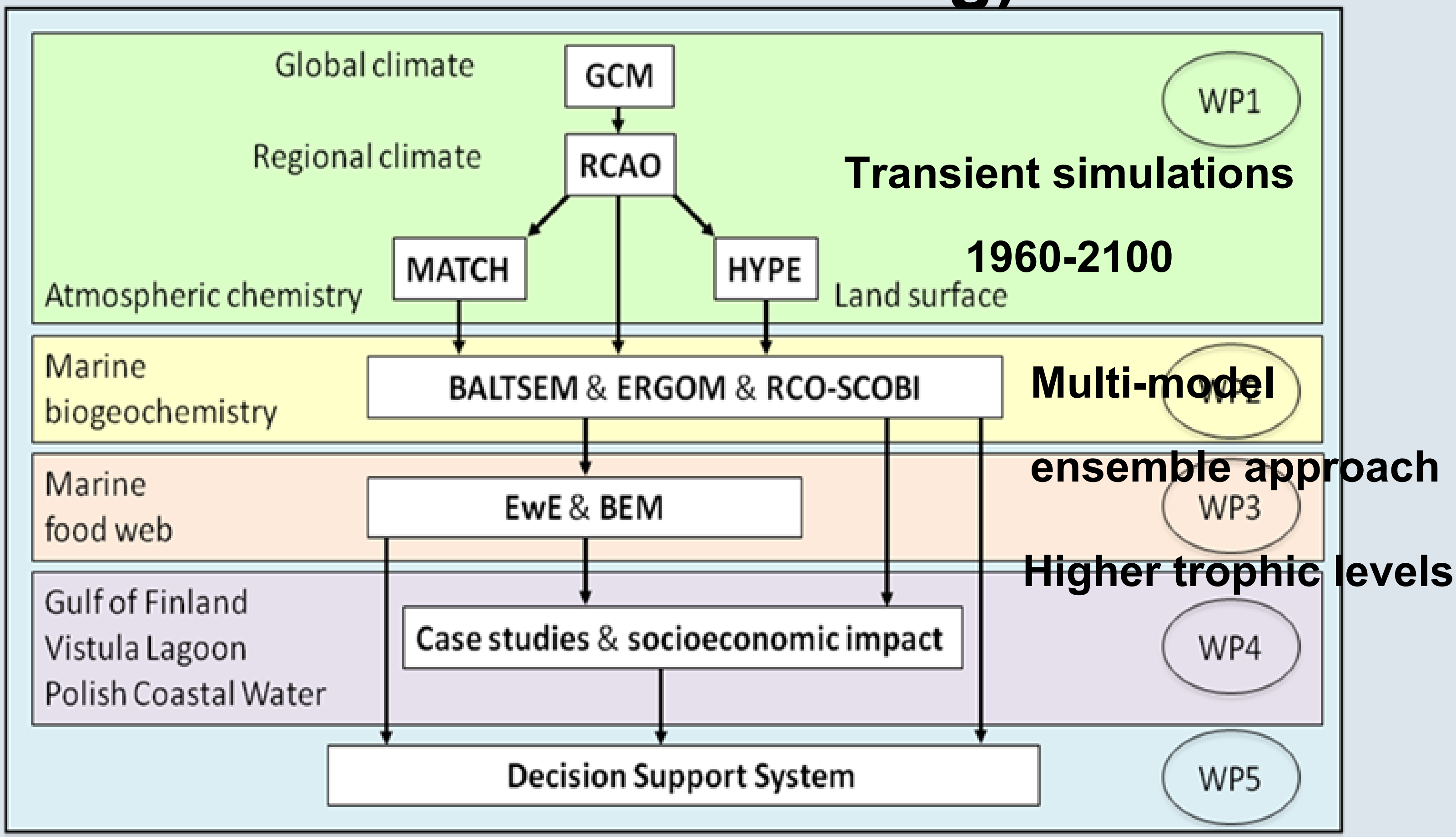

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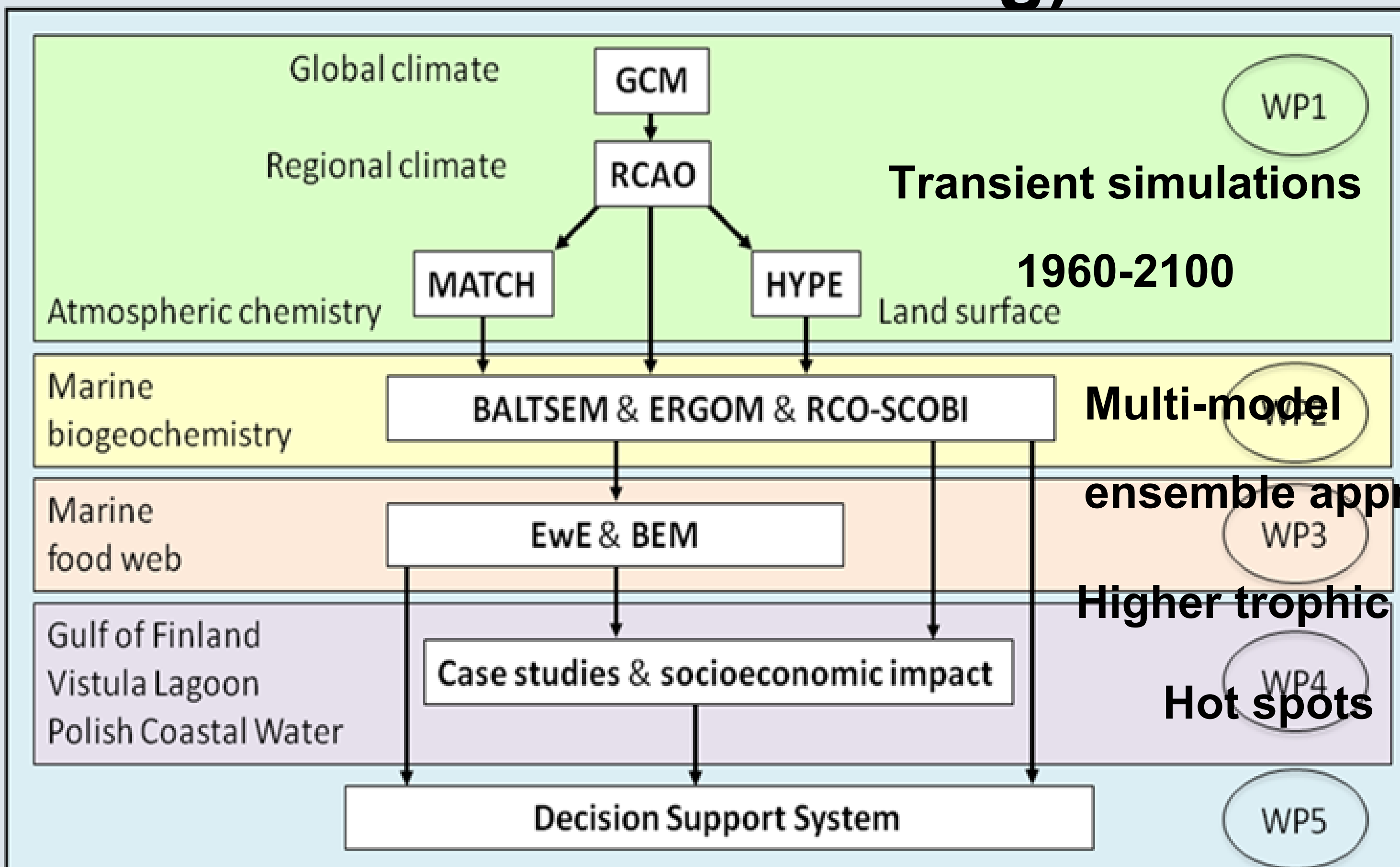

Transient simulations

1960-2100

Multi-model

ensemble approach

Higher trophic levels

Hot spots

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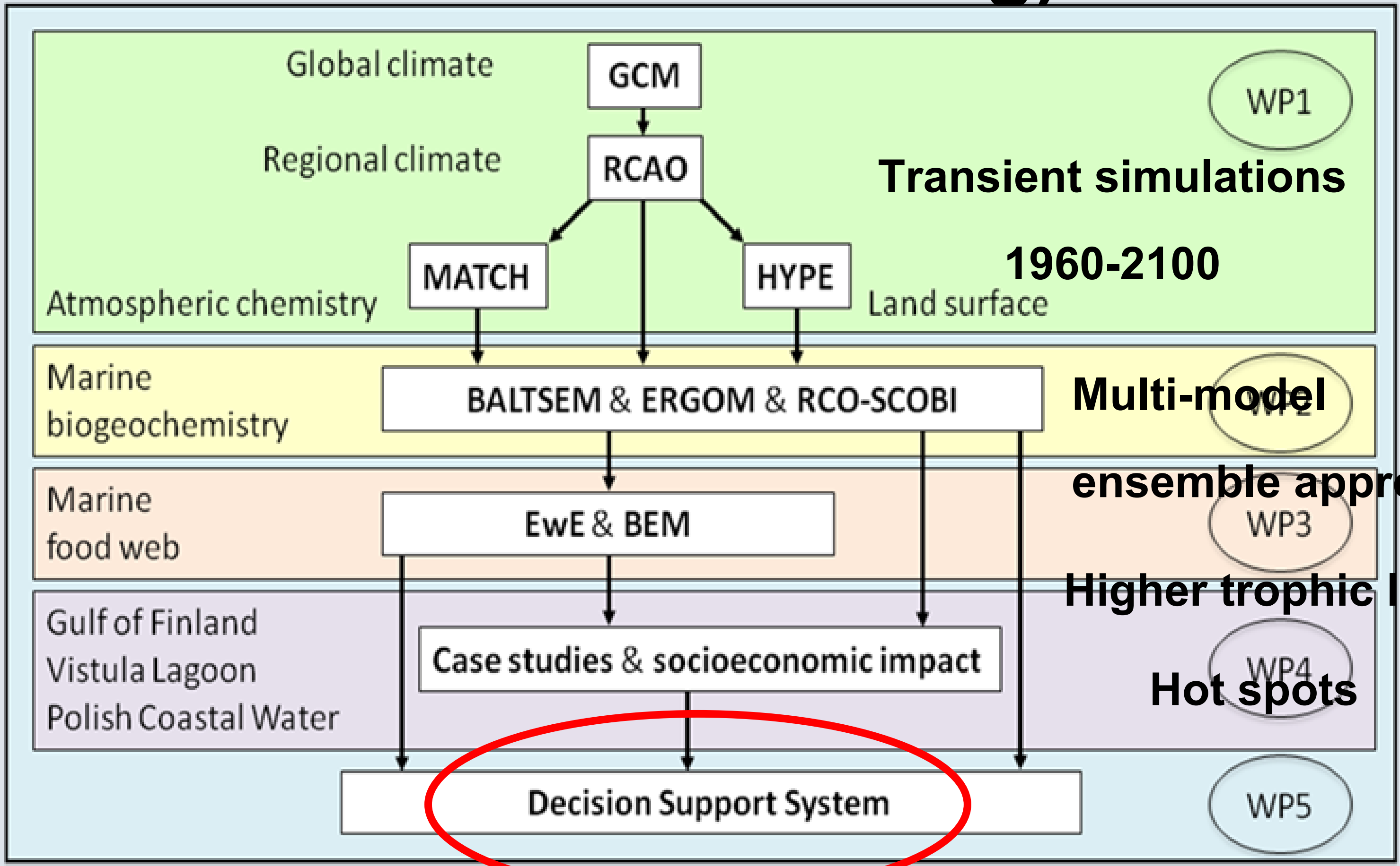

Transient simulations

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Thank you

for your attention!

Cyanobacteria bloom 2008