Lecture

”Baltic Sea climate modelling”

SMHI, Norrköping

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Overview:

1. Introduction
2. Decadal climate variability
3. Regional climate models and dynamical downscaling
4. Projections of Baltic Sea climate at the end of the 21st century - physics
5. Projections of future biogeochemical cycles

References:

- Leppäranta, M. and K. Myrberg, 2009: Physical Oceanography of the Baltic Sea, Springer, 378 pp

- ftp://ftp.smhi.se/busers/guestacc/markus/lecture_climate_modelling_school_amber_SMHI_20101013.pdf

References:

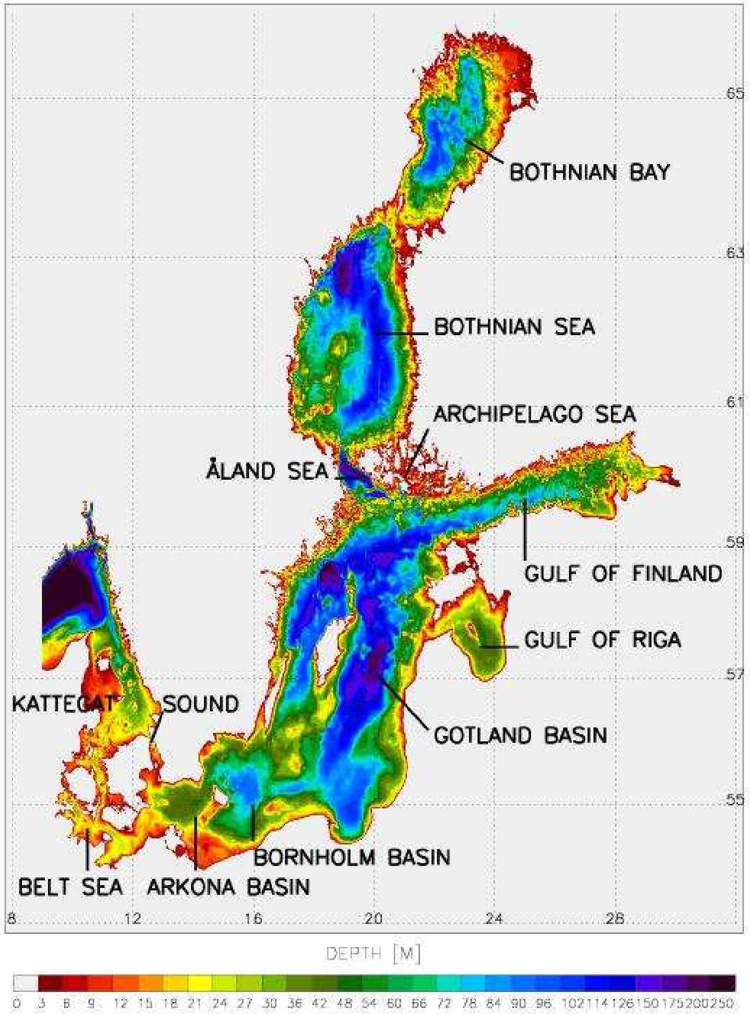
- The BACC Author Team: Assessment of Climate Change for the Baltic Sea Basin, Series: Regional Climate Studies, Springer, 2008, 474 p.

Links:

www.ipcc.ch

1. Introduction

The circulation of the Baltic Sea is determined by :



- the interactions between atmosphere-ice-ocean
- the water exchange through the Danish straits,
- the bottom topography, (mean depth 52 m, max depth 459 m)
- the river runoff.

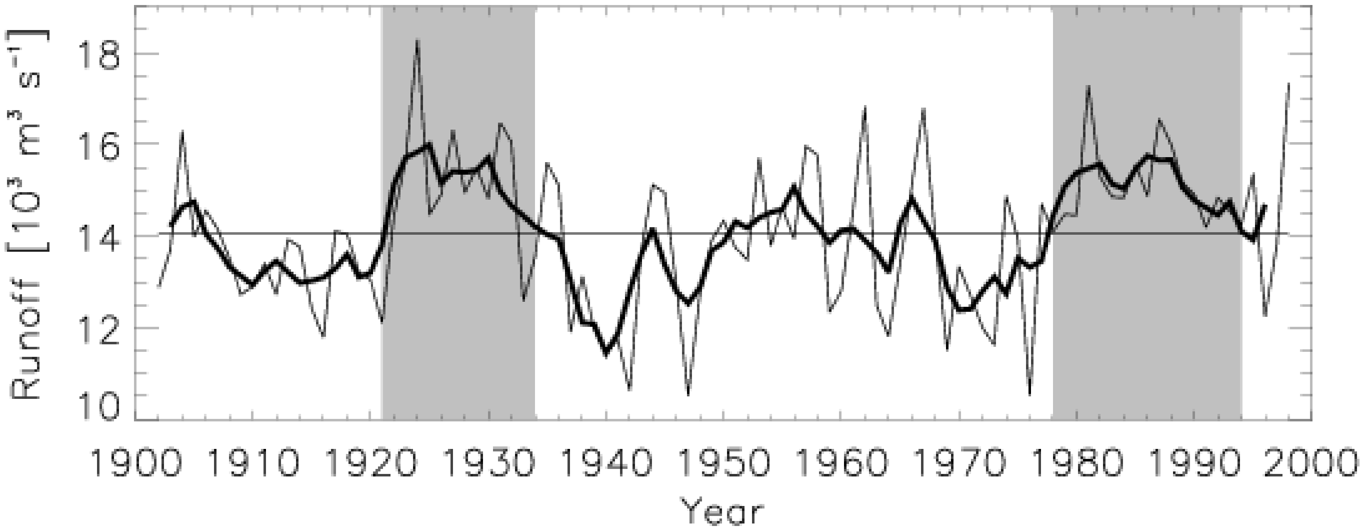
Baltic Sea catchment area

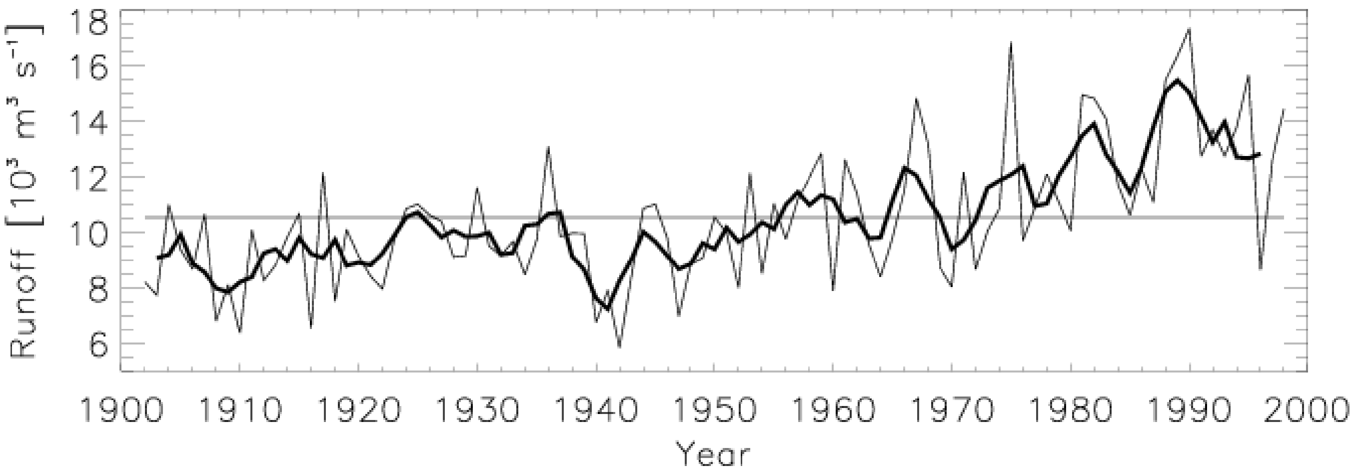
with Kattegat (without Skagerrak):
1 729 000 km^2 =
4 times Baltic Sea surface

Baltic surface (without Kattegat) = 398 470 km^2

Baltic volume (without Kattegat) = 21 500 km^3

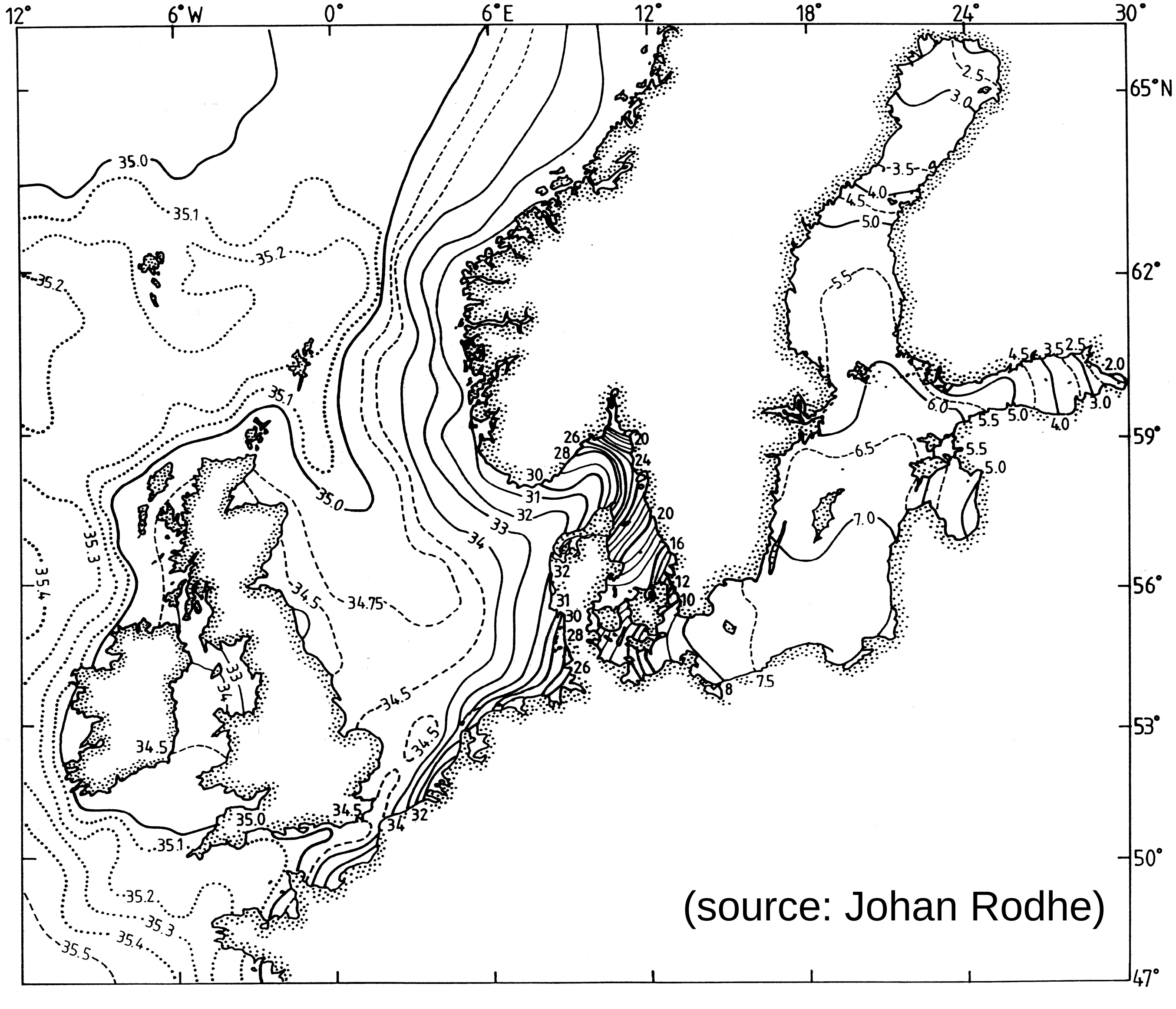
Annual and winter (JFM) mean runoff





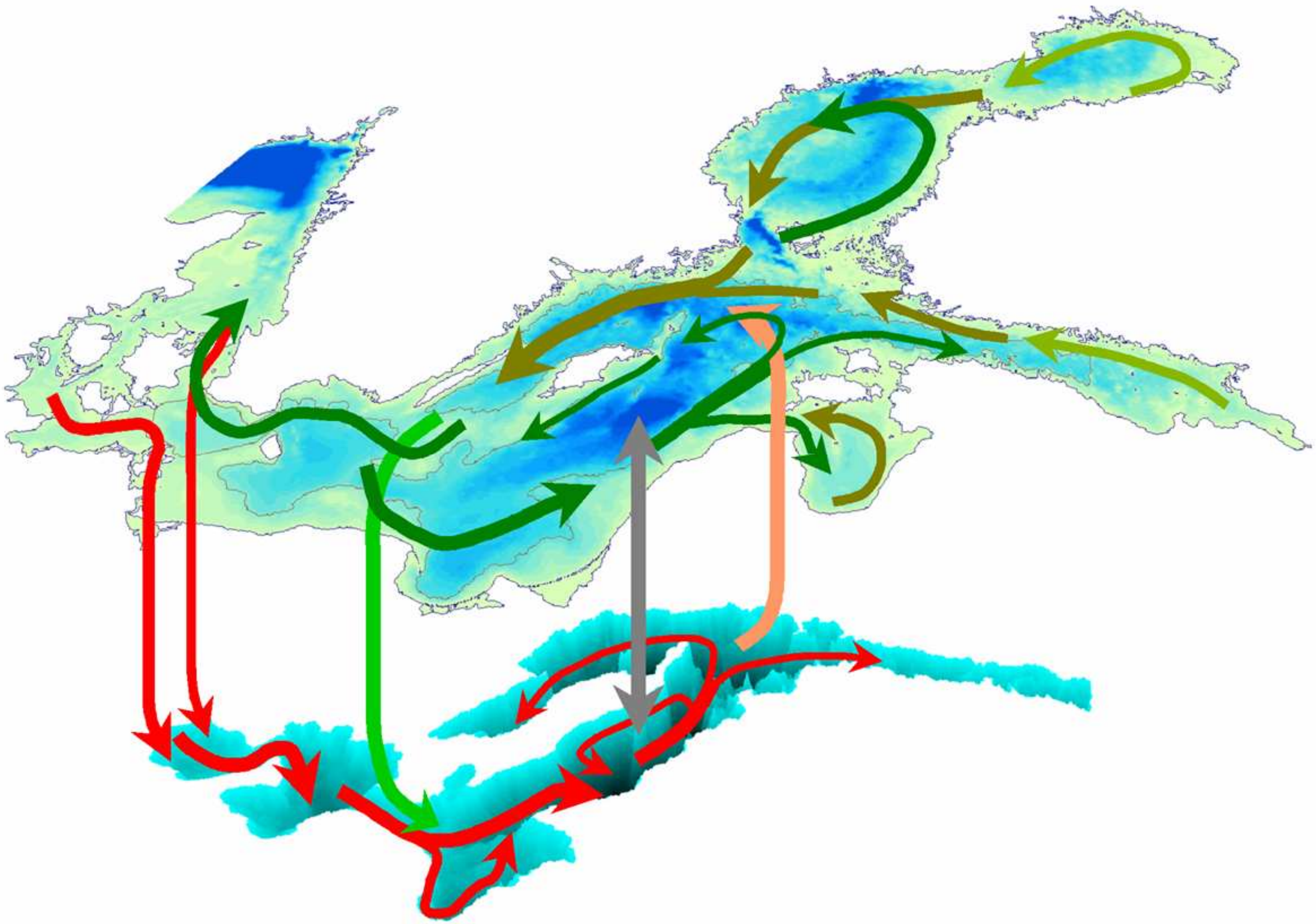
(Meier and Kauker, 2003a) (thick line: 4-year running mean runoff)

Sea surface salinity

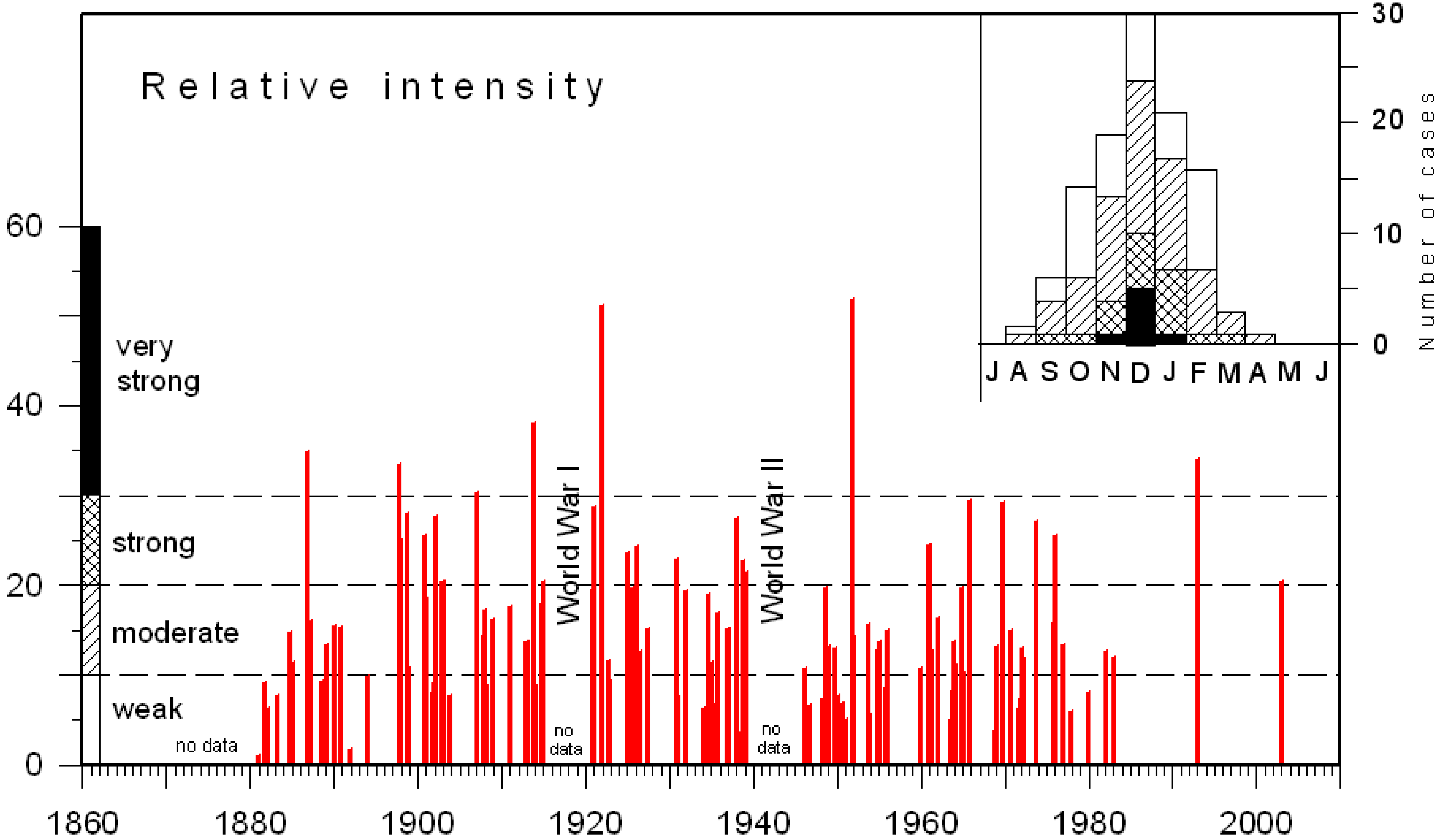


(source: Johan Rodhe)

Schematic view of the large-scale circulation in the Baltic Sea (Elken and Matthäus, 2008)



Saltwater inflows during 1898-2008

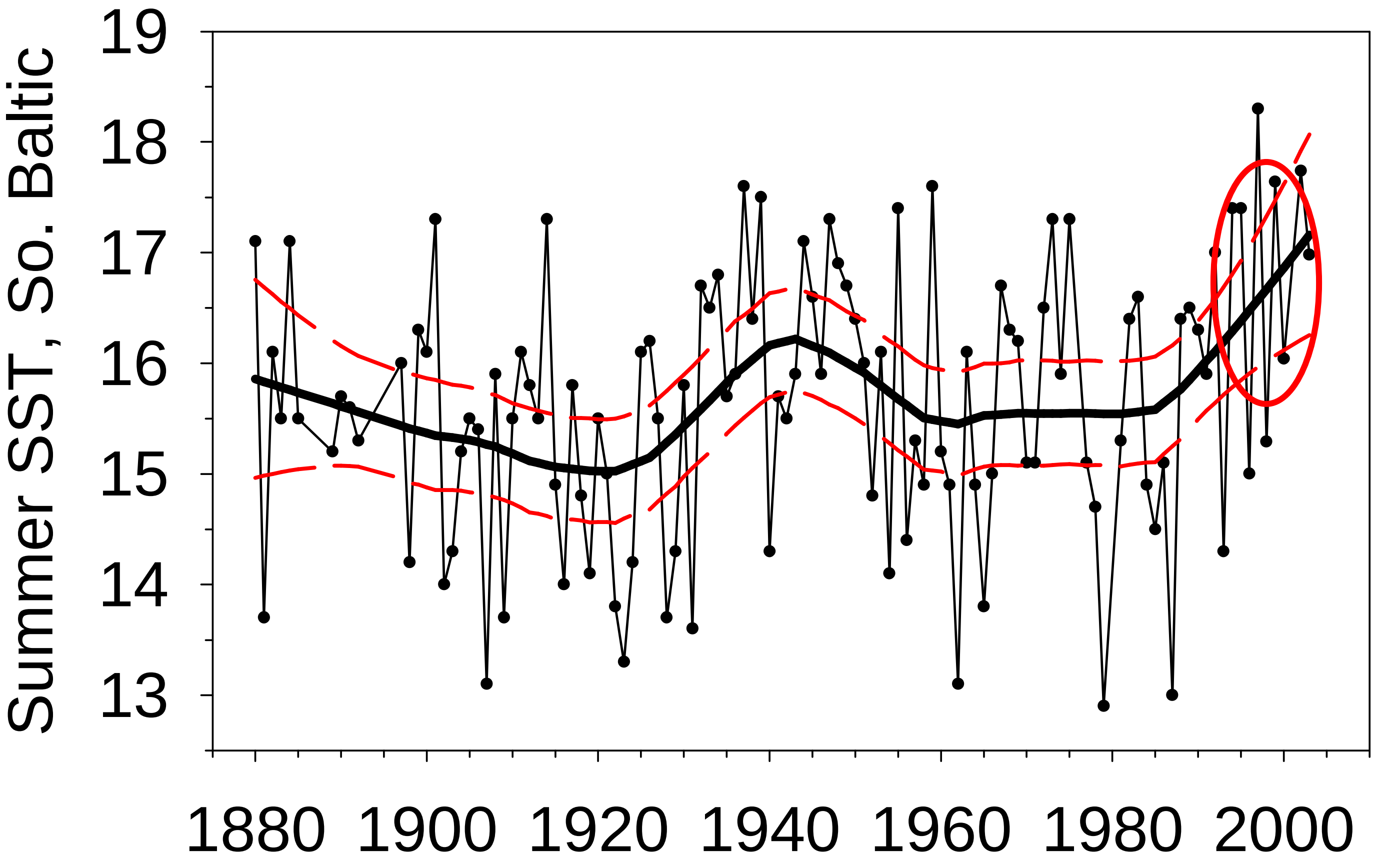


(Matthäus & Franck 1992, Fischer & Matthäus 1996)

2. Decadal climate variability

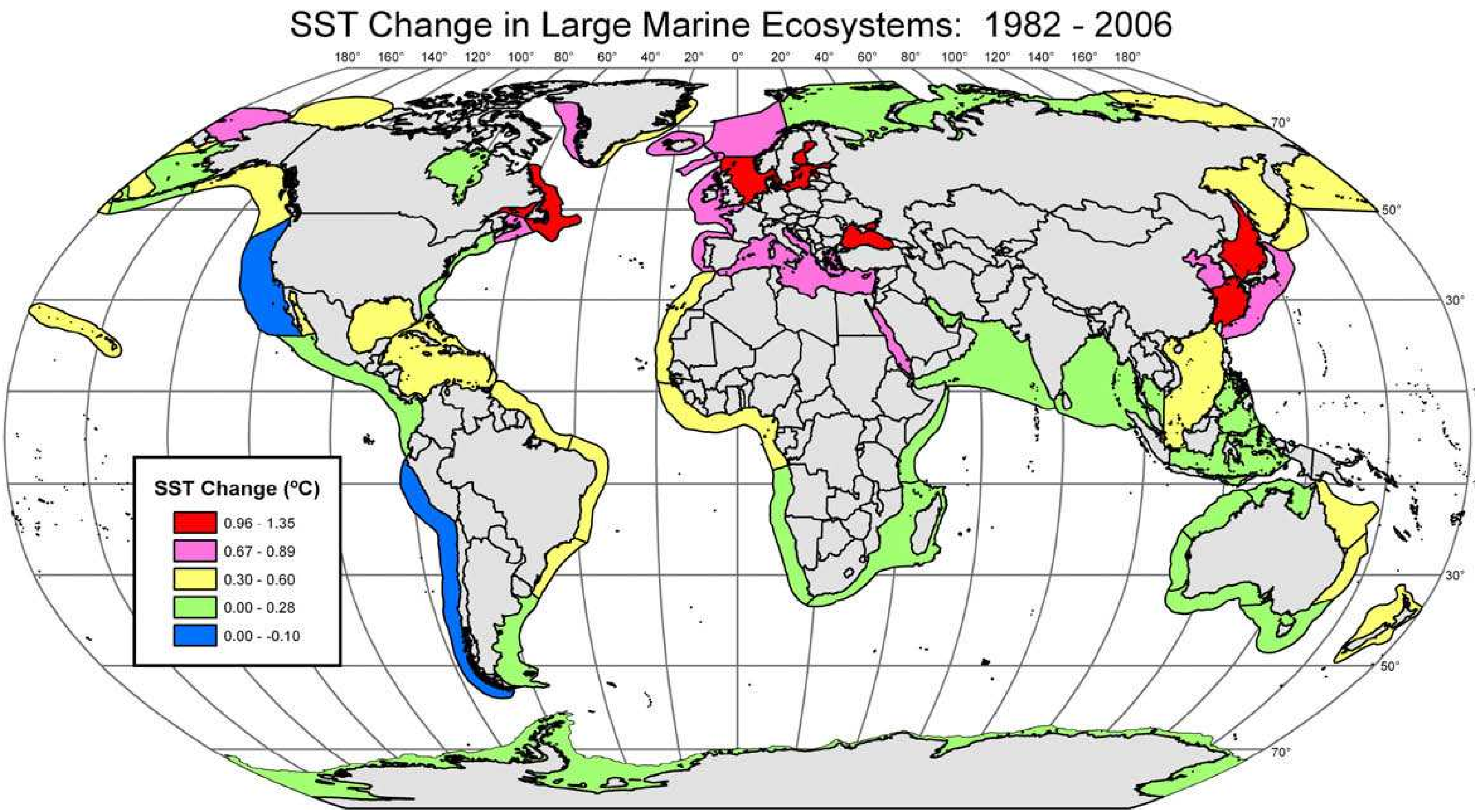
Positive trend of temperature during the 20th century at almost all stations and depths (Fonselius and Valderrama, 2003), no significant trend of salinity (Winsor et al., 2001; Meier and Kauker, 2003a)

Summer (JAS) SST
1880-2003



warm conditions during 1990s-2000s

(Source: MacKenzie & Schiedek 2007)

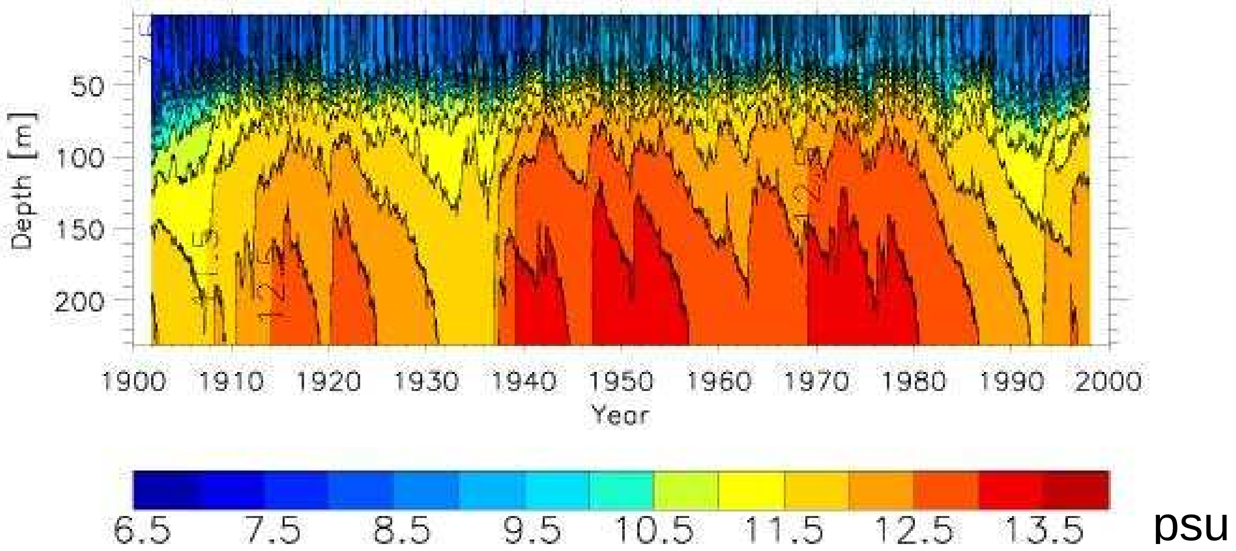


Net SST change (C) in Large Marine Ecosystems, 1982–2006

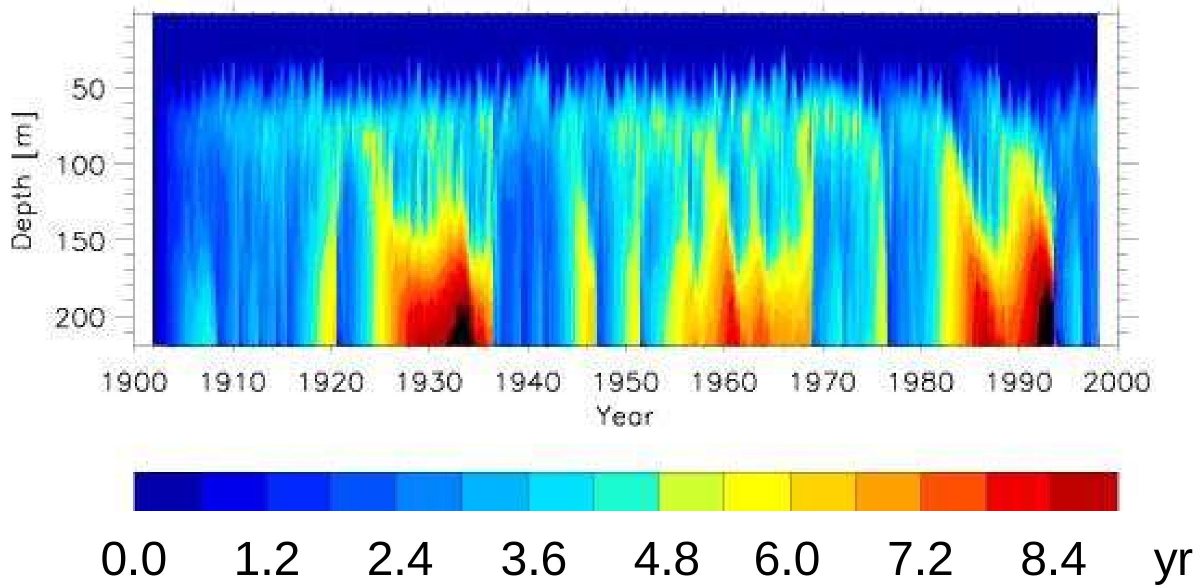
(Source: Belkin 2009)

Salinity and age at Gotland Deep

Salinity



Age

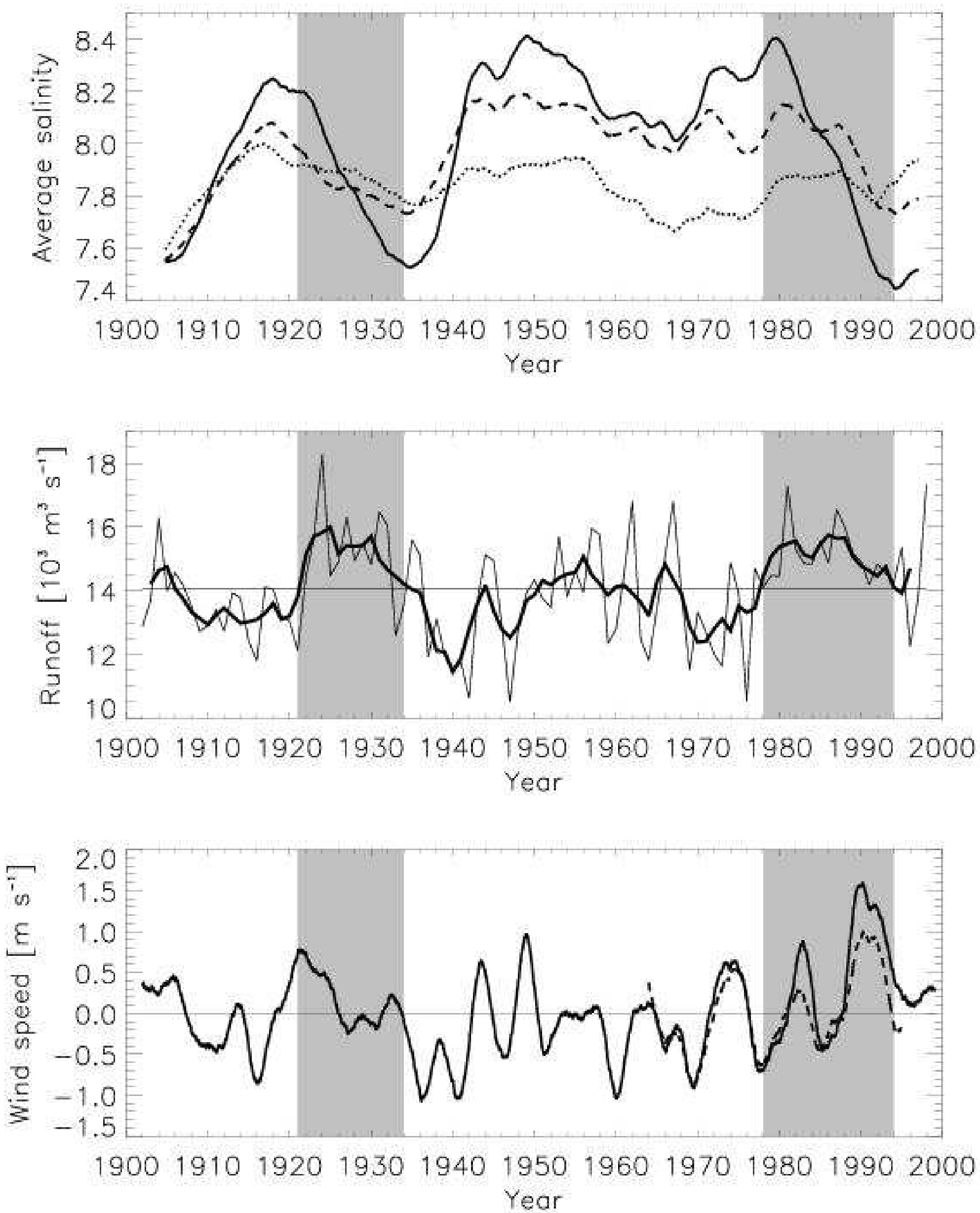


(Meier, 2005)

Salinity

Runoff

Wind



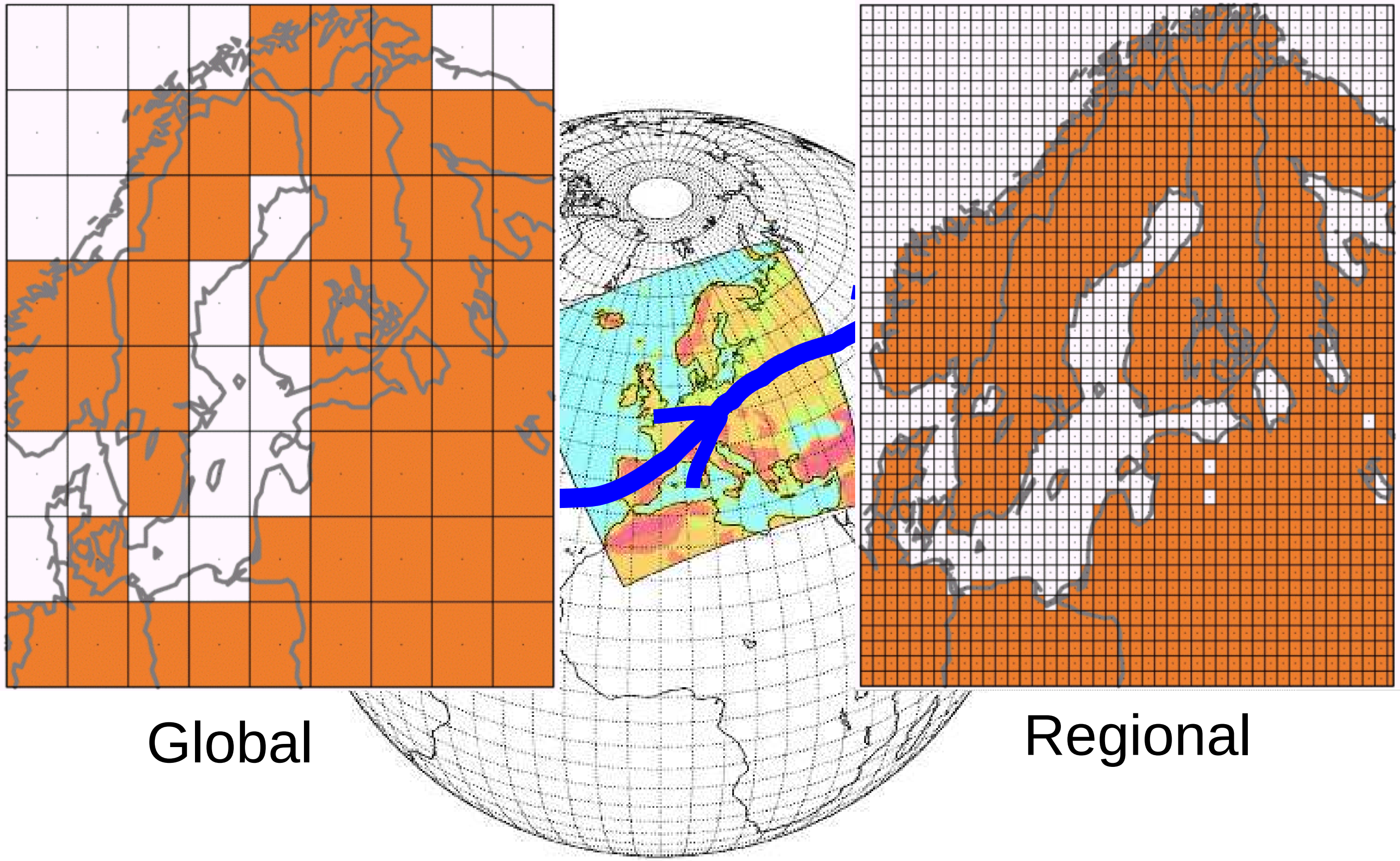
— 4-yr running mean

Stagnation periods are shaded

(Meier and Kauker, 2003a)

3. Regional climate models and dynamical downscaling

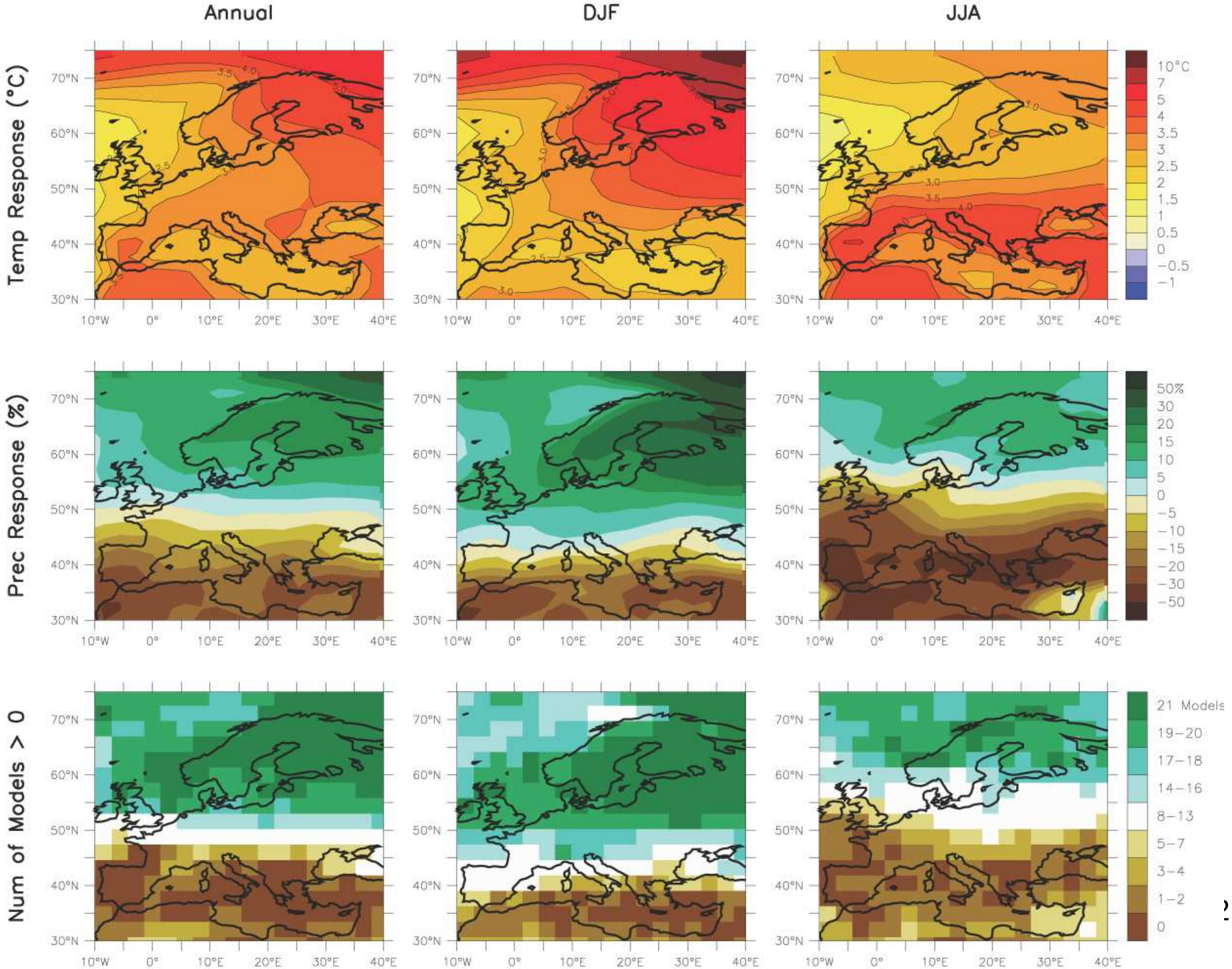
Regional climate modeling at SMHI



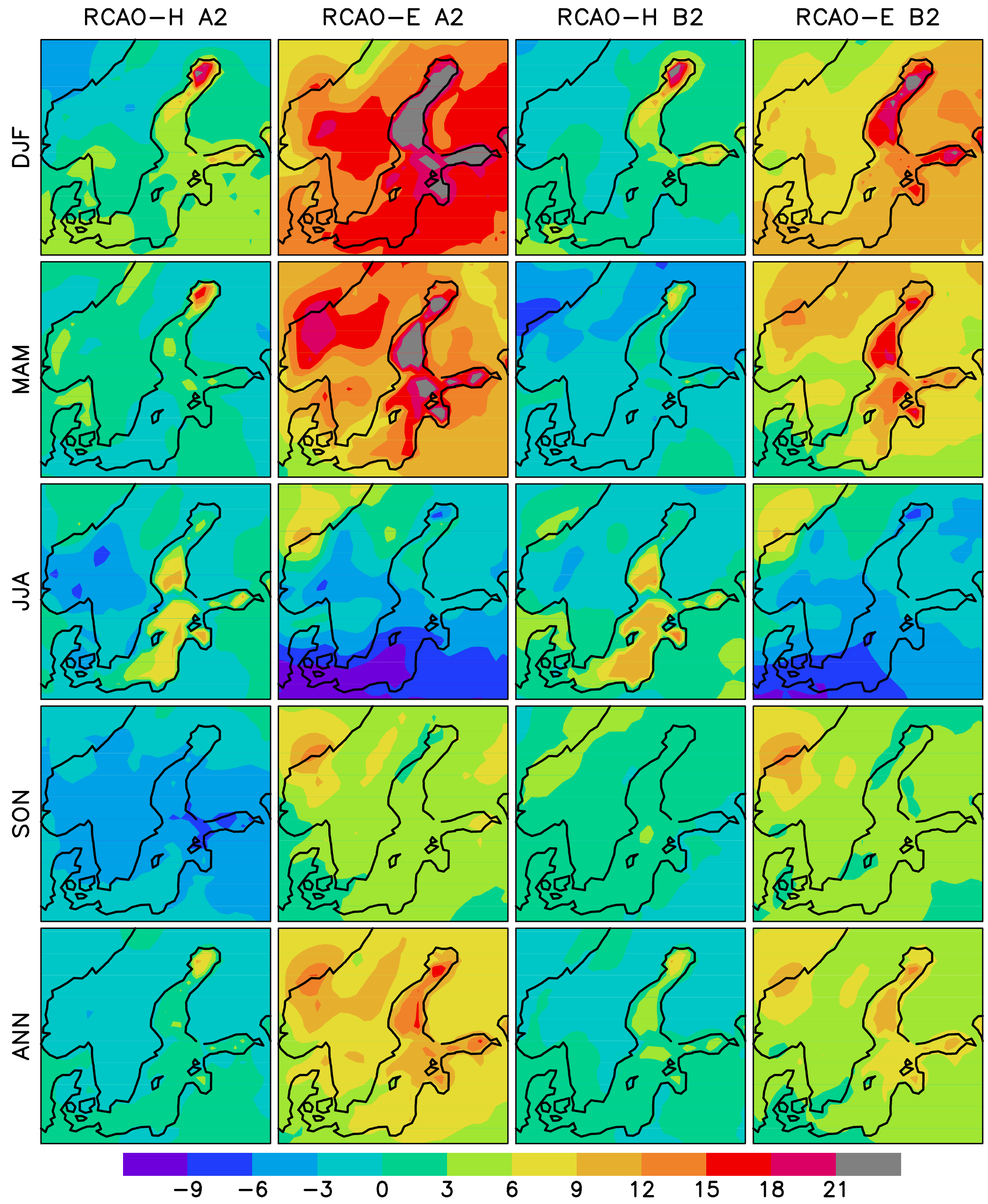
4. Projections of Baltic Sea climate at the end of the 21st century - physics

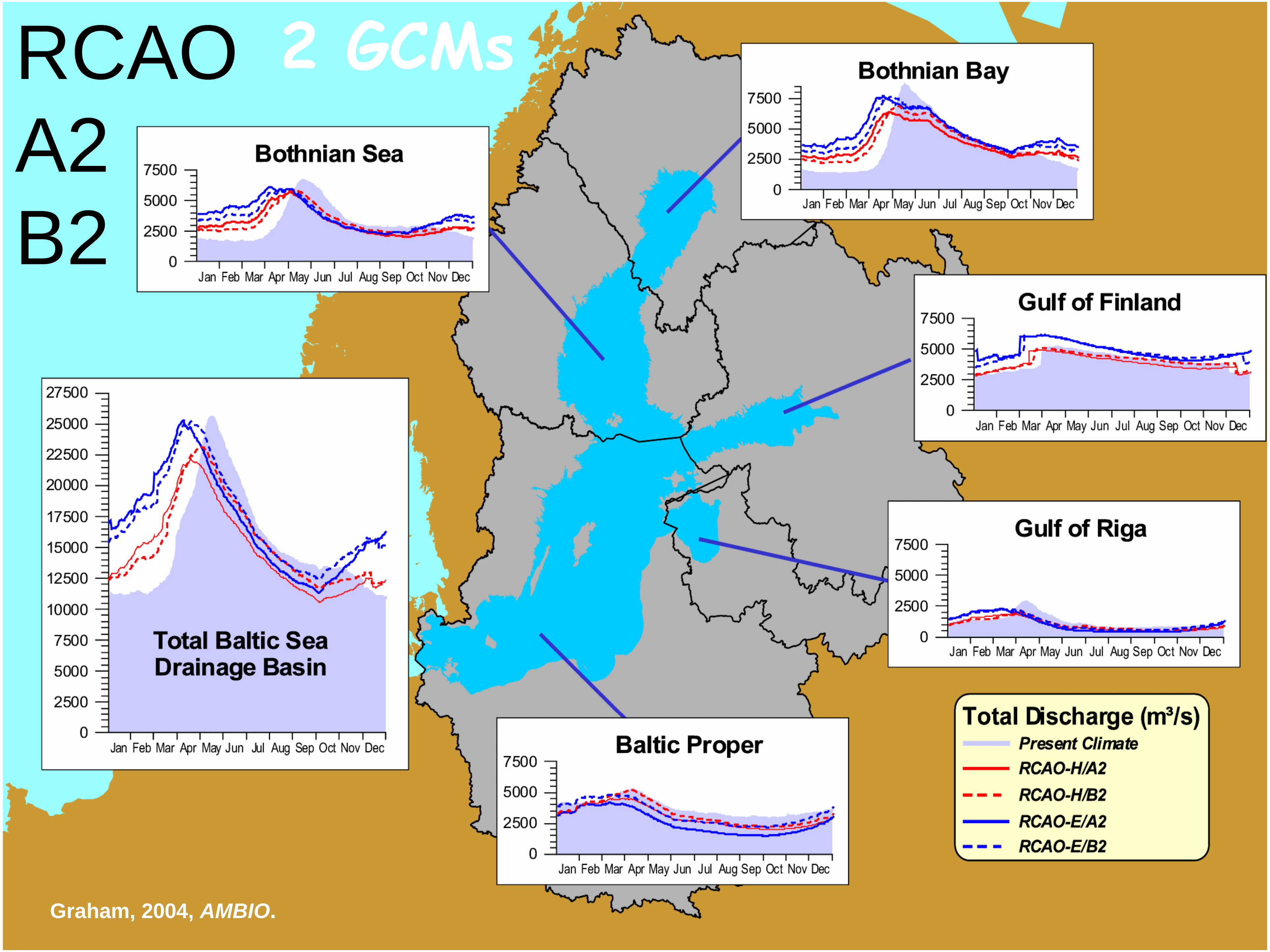
Changes in the atmosphere and on the land surface

Temperature and precipitation changes over Europe in the A1B model ensemble

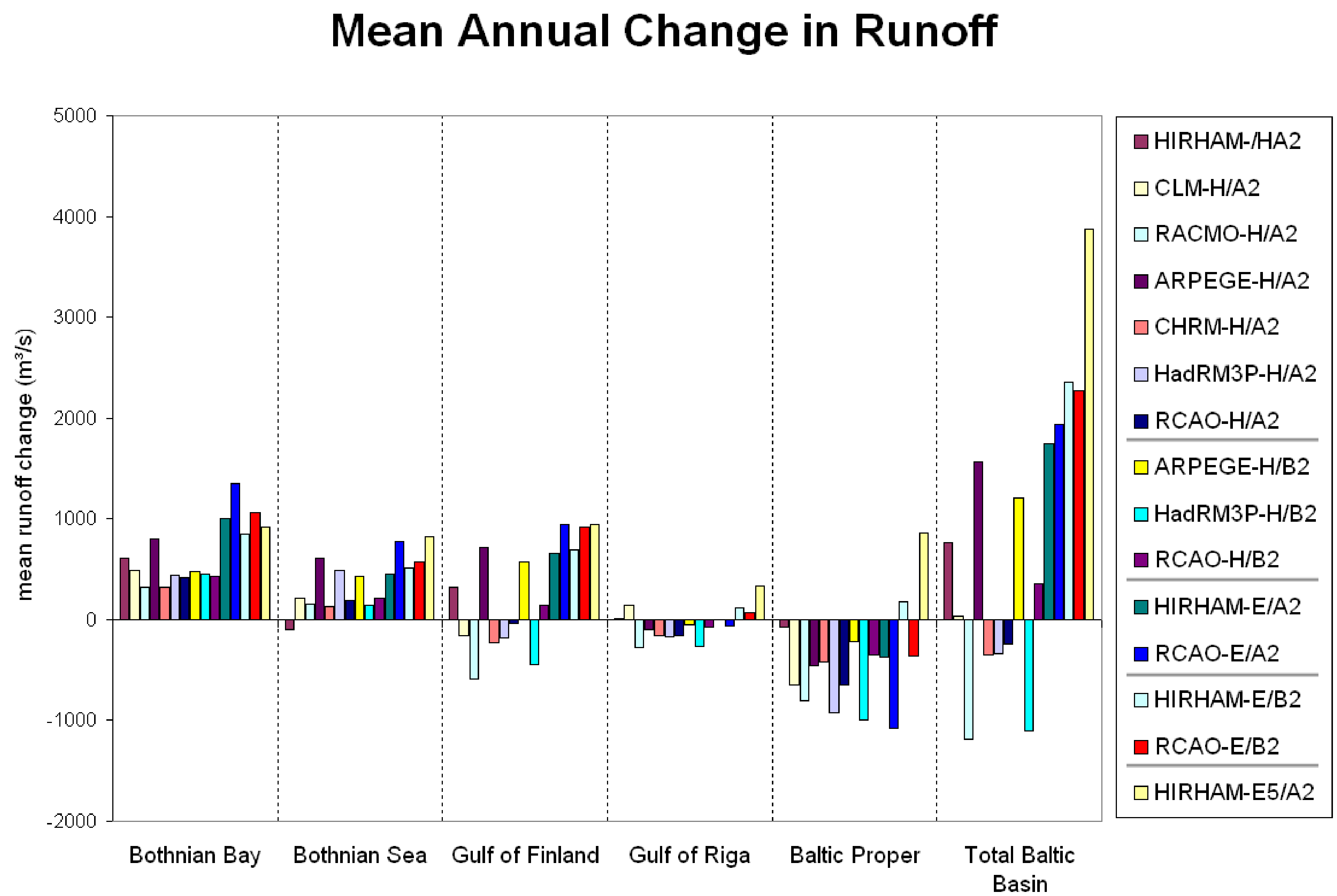


Wind speed changes [%]





RCAO
2 GCMs
A2
B2
Bothnian Sea
Bothnian Bay
Gulf of Finland
Gulf of Riga
Total Baltic Sea Drainage Basin
Baltic Proper
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Total Discharge (m³/s)
Present Climate
RCAO-H/A2
RCAO-H/B2
RCAO-E/A2
RCAO-E/B2
Graham, 2004, AMBIO.



(Source: Phil Graham, SMHI)

Changes in the ice-ocean

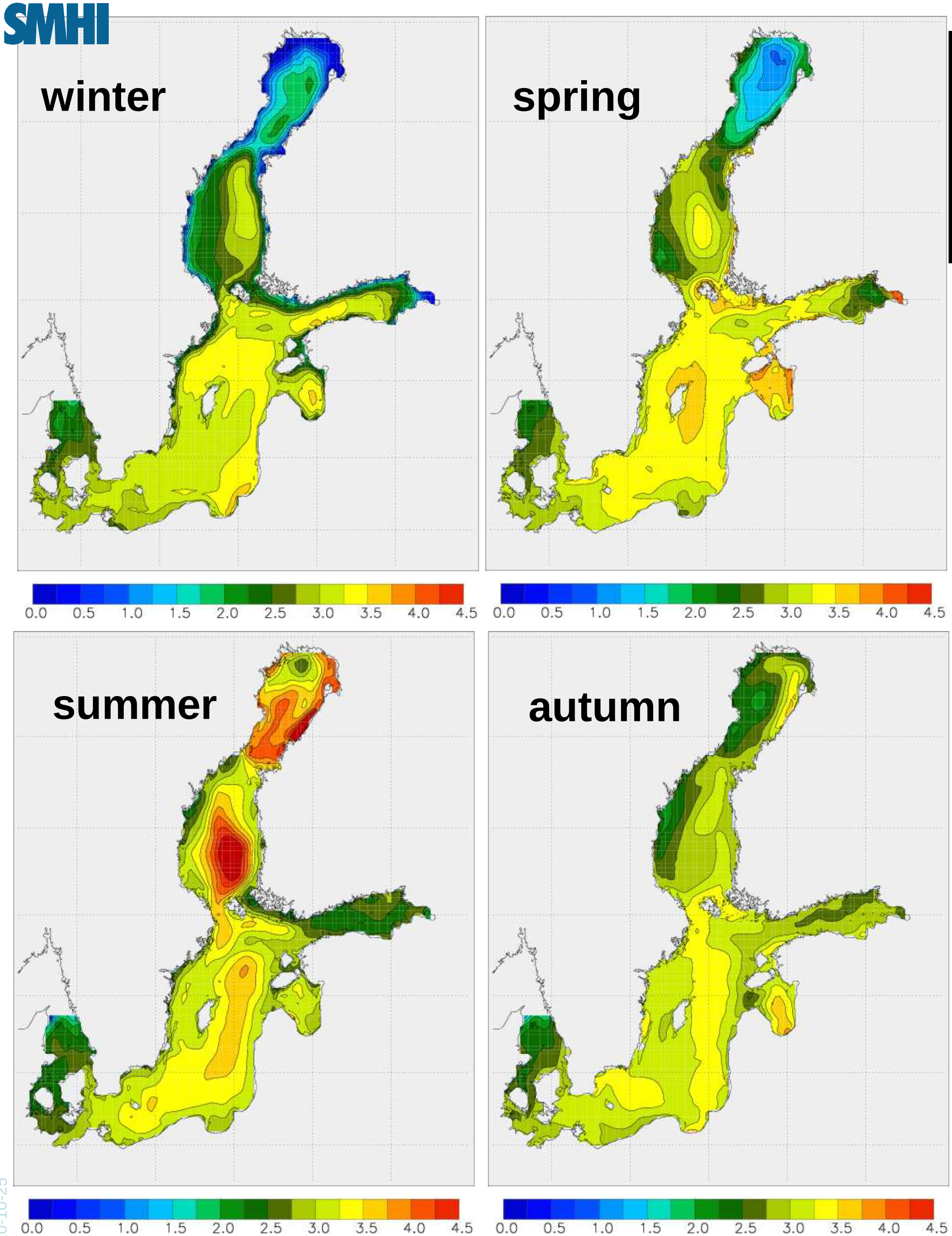
Four climate scenarios using RCAO forced with two emission scenarios (A2, B2) and two GCMs (SMHI):

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

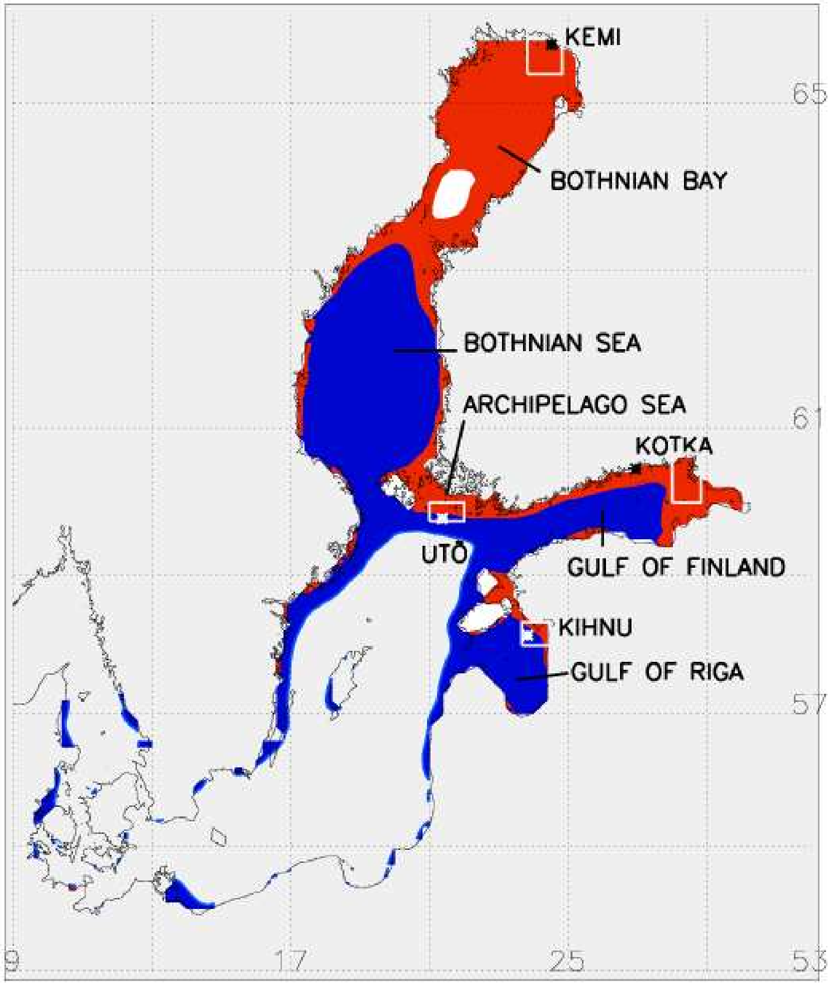
4) HADAM3H/B2: SST +2.1ºC



Annual mean sea surface temperature change:
+ 2-4℃

Seasonal mean SST differences between the ensemble average scenario and simulated present climate (in ℃): DJF (upper left), MAM (upper right), JJA (lower left), and SON (lower right) (Meier, 2006).

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



Mean maximum ice extent change: - 60-70%

(Meier et al., 2004c)

Salinity at Gotland Deep

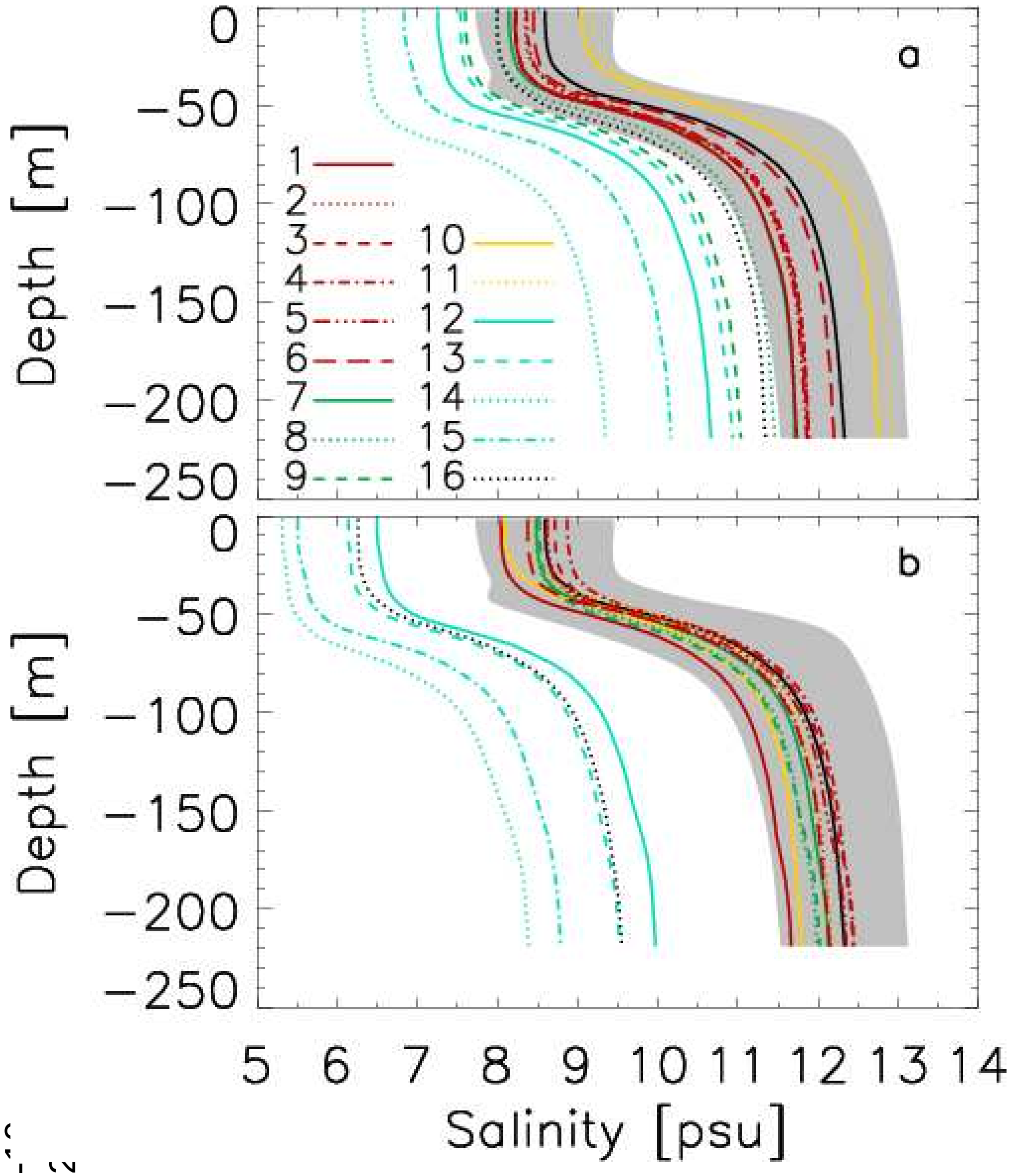
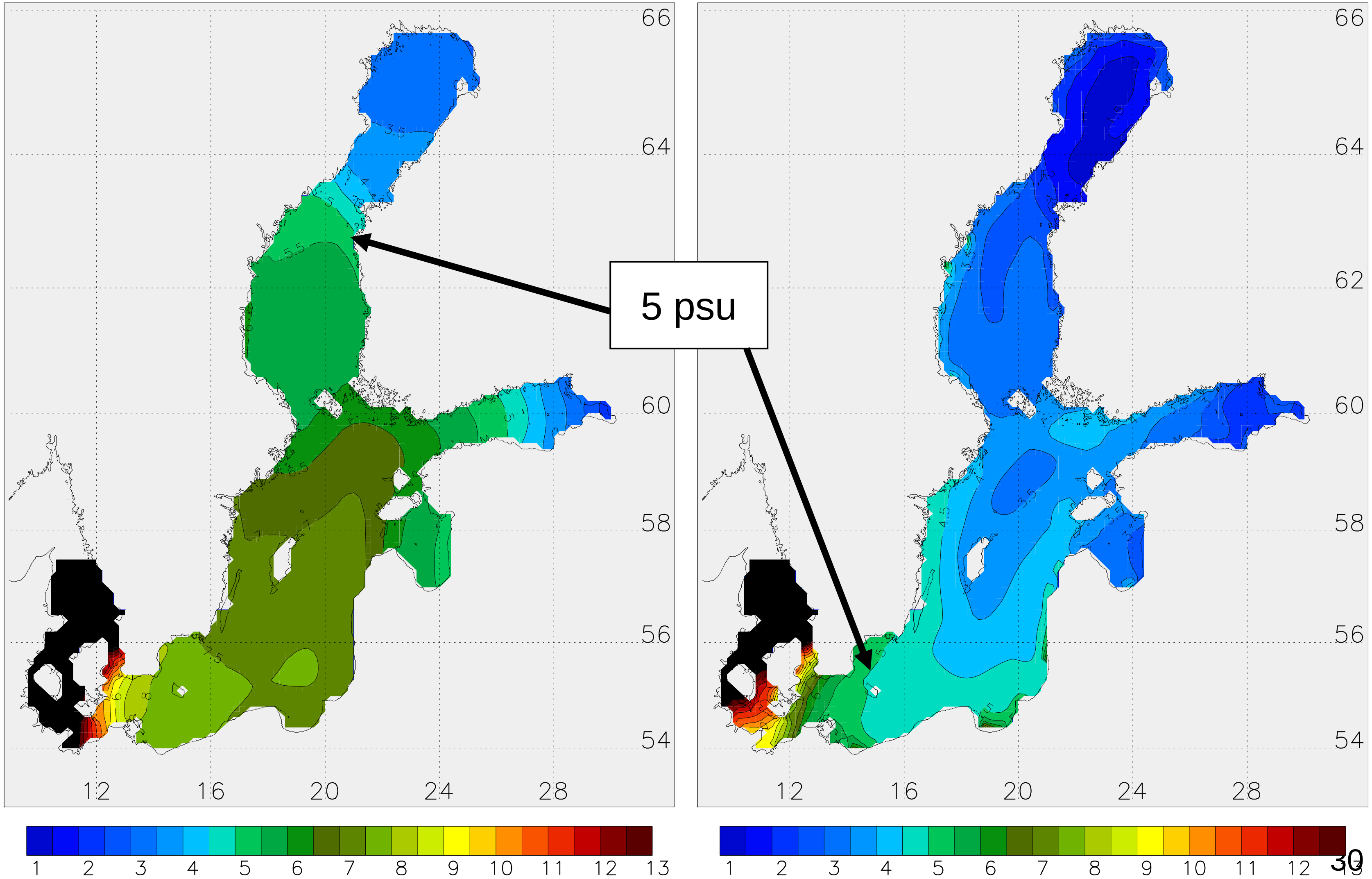


Figure 1. Median profiles of salinity at monitoring station BY15 for present climate 1961-1990 (black solid line, shaded areas indicate the +/- 2 standard deviation band calculated from two-daily values for 1903-1998) and in projections for 2071-2100 (colored lines). In (a) only effects from wind changes are considered whereas in (b) projections based upon wind and freshwater inflow changes are shown. Numbers in the legend correspond to the different scenario runs (see Tab.1). The figure is taken from Meier et al. (2006, Fig.2).

Sea surface salinity

Present climate

Projection with the largest change
RCAO-ECHAM4/A2



Meier et al. (2006)

5. Projections of future biogeochemical cycles

Three nutrient load scenarios (Baltic Nest Institute):

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

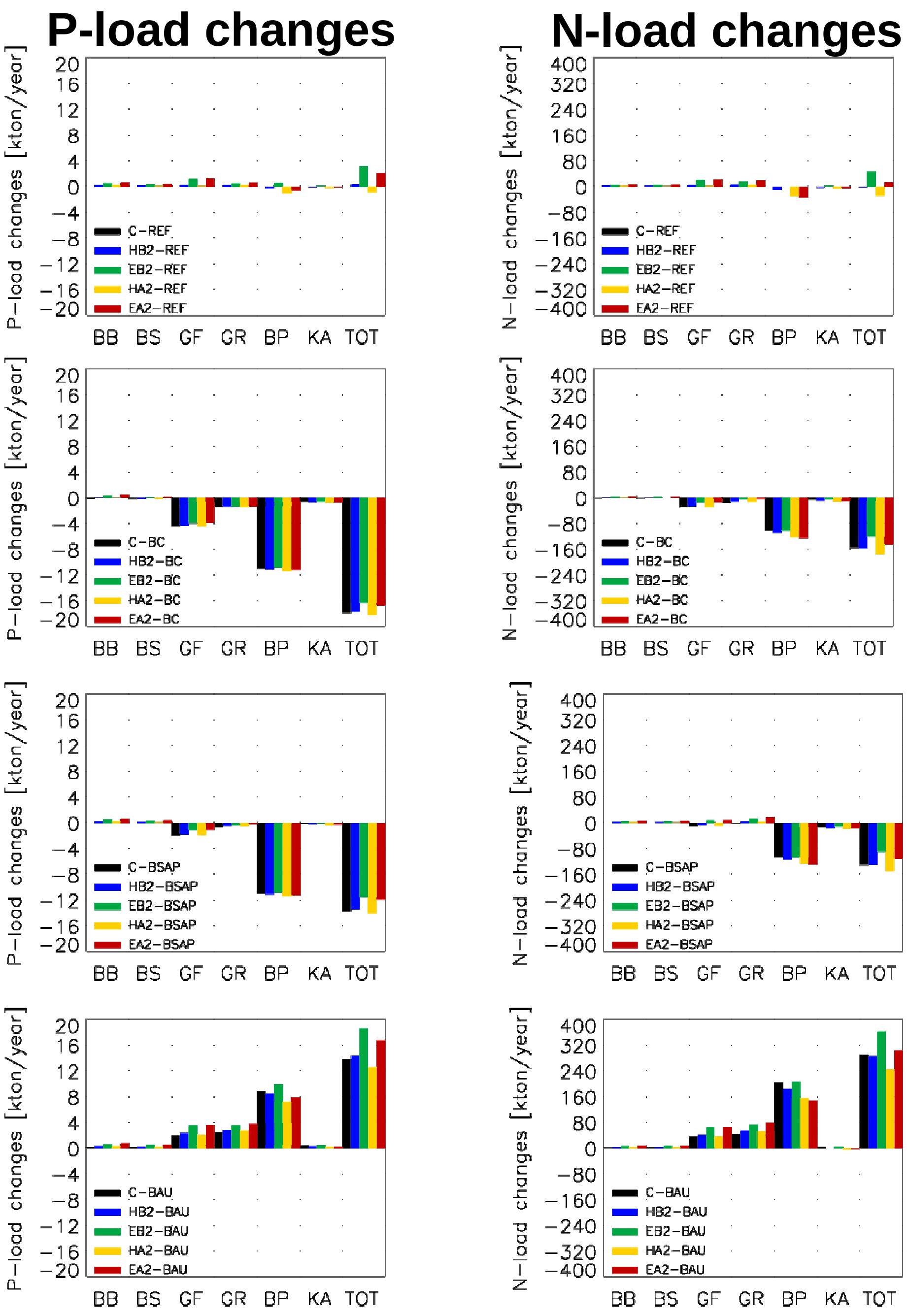
Reference loads

Best case

BSAP

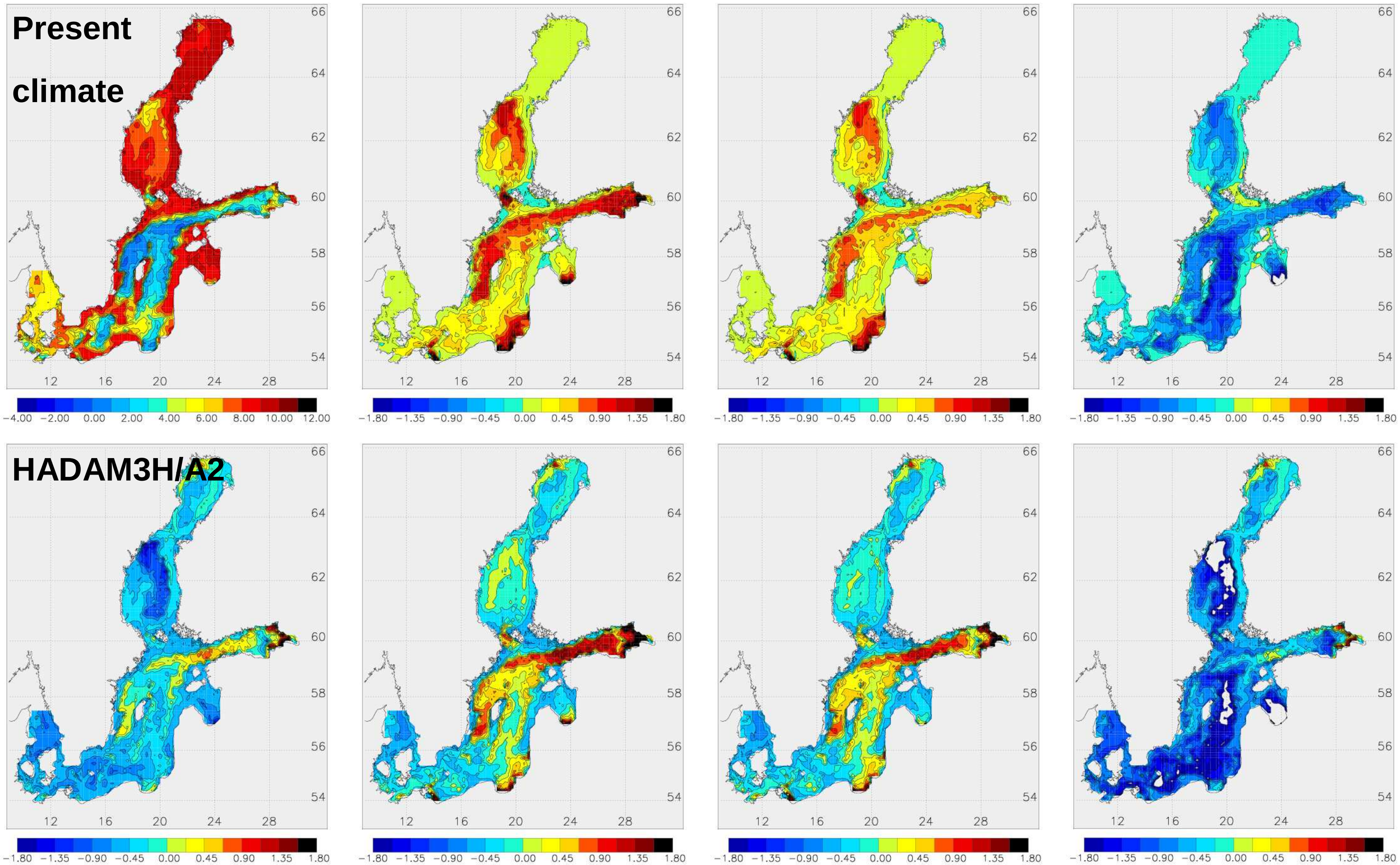
Business as

usual



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

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



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

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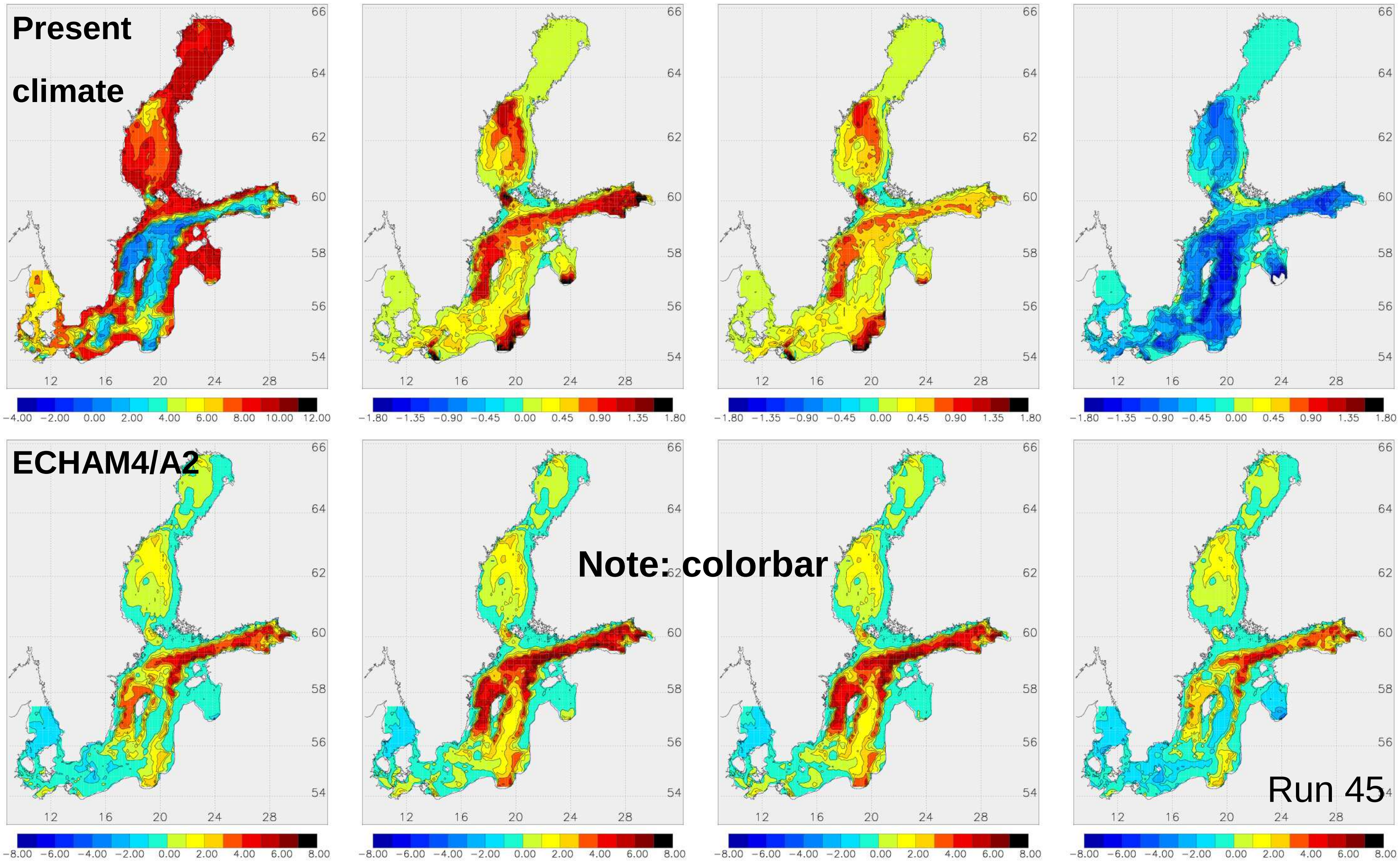

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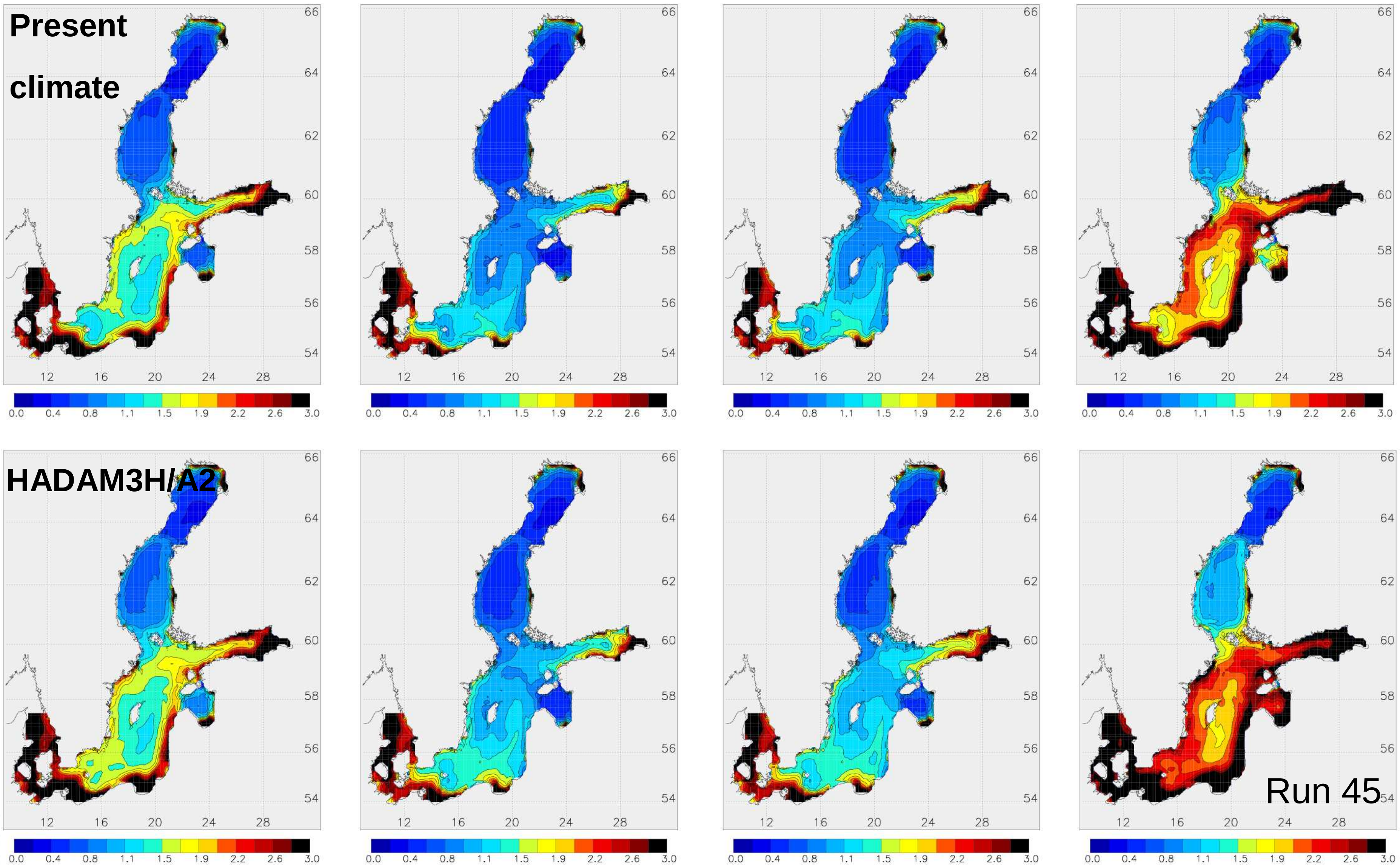
Annual mean phytoplankton concentration [mgChl/m^3] (0-10m)

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



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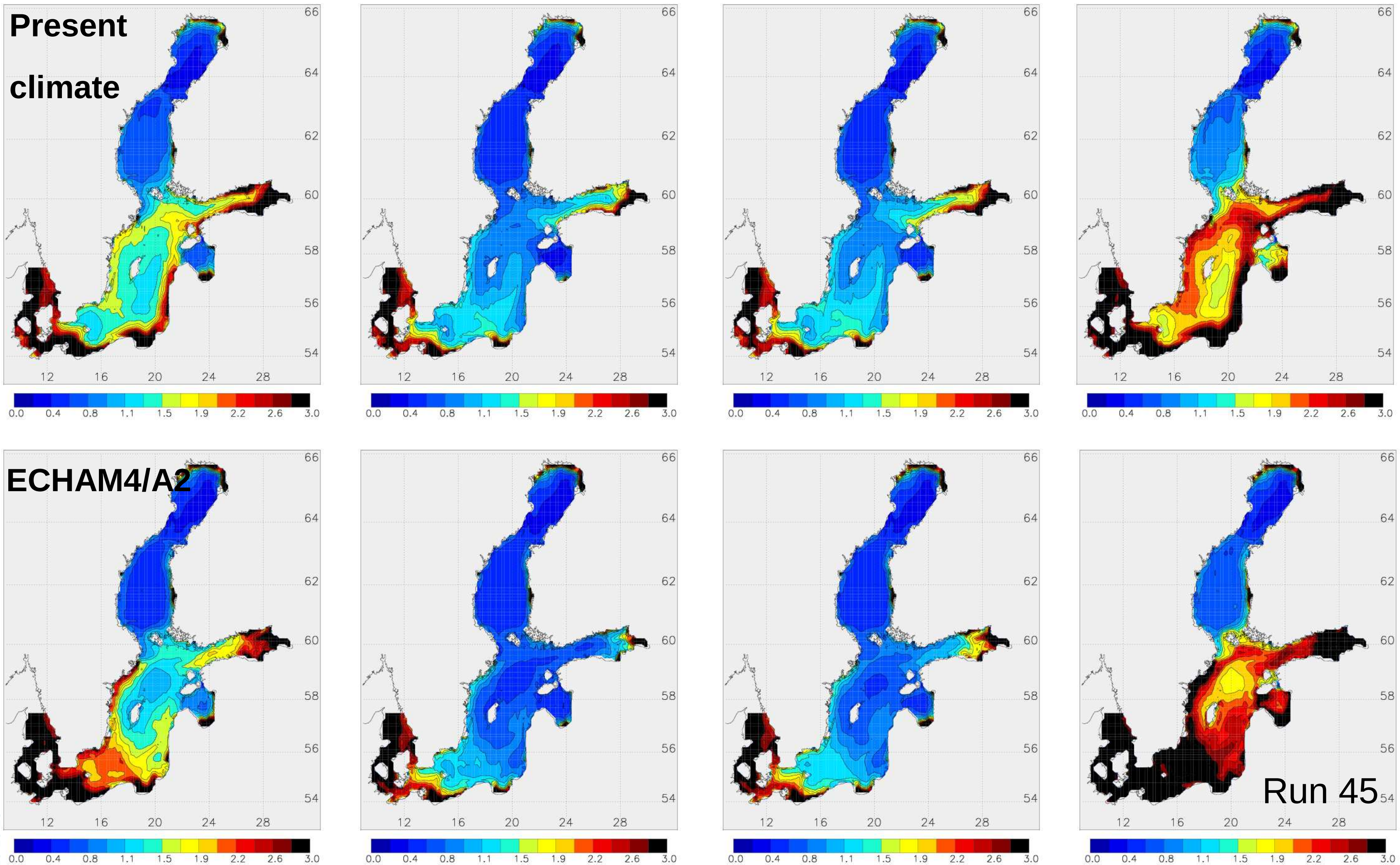

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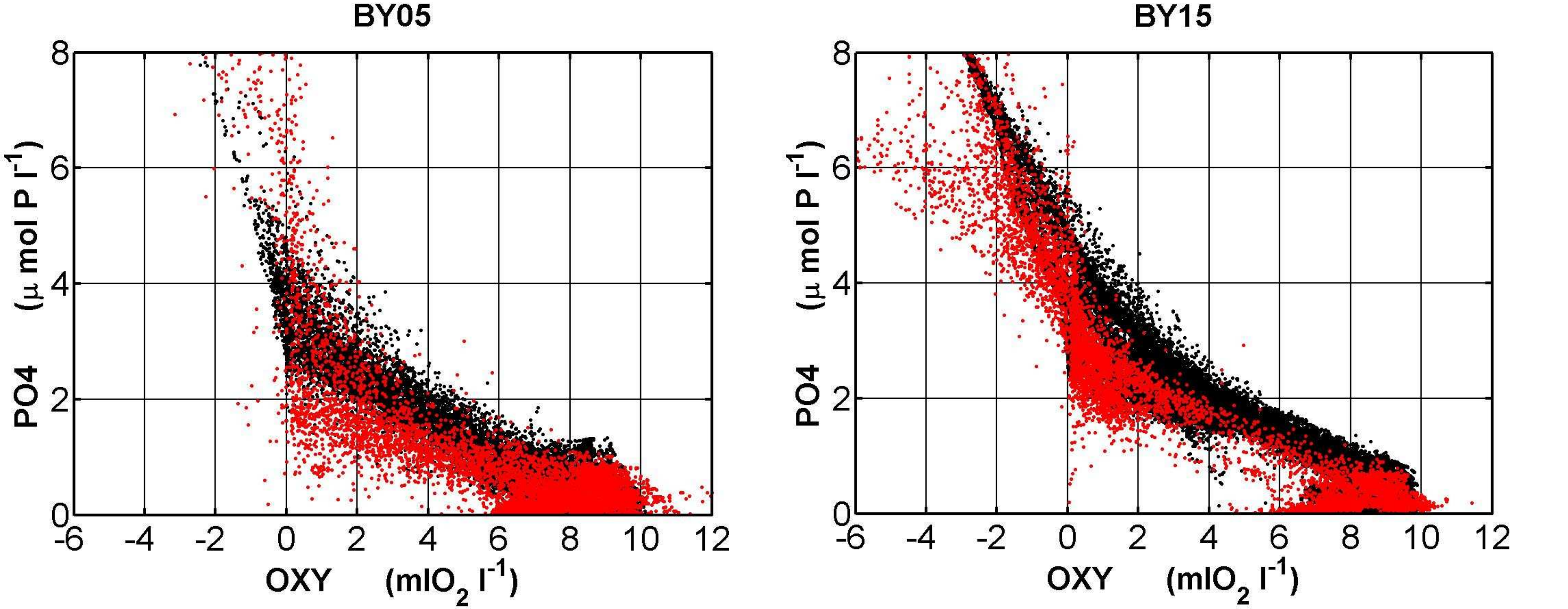
Results based on IPCC 2001 scenarios (Meier et al., 2010; under review)

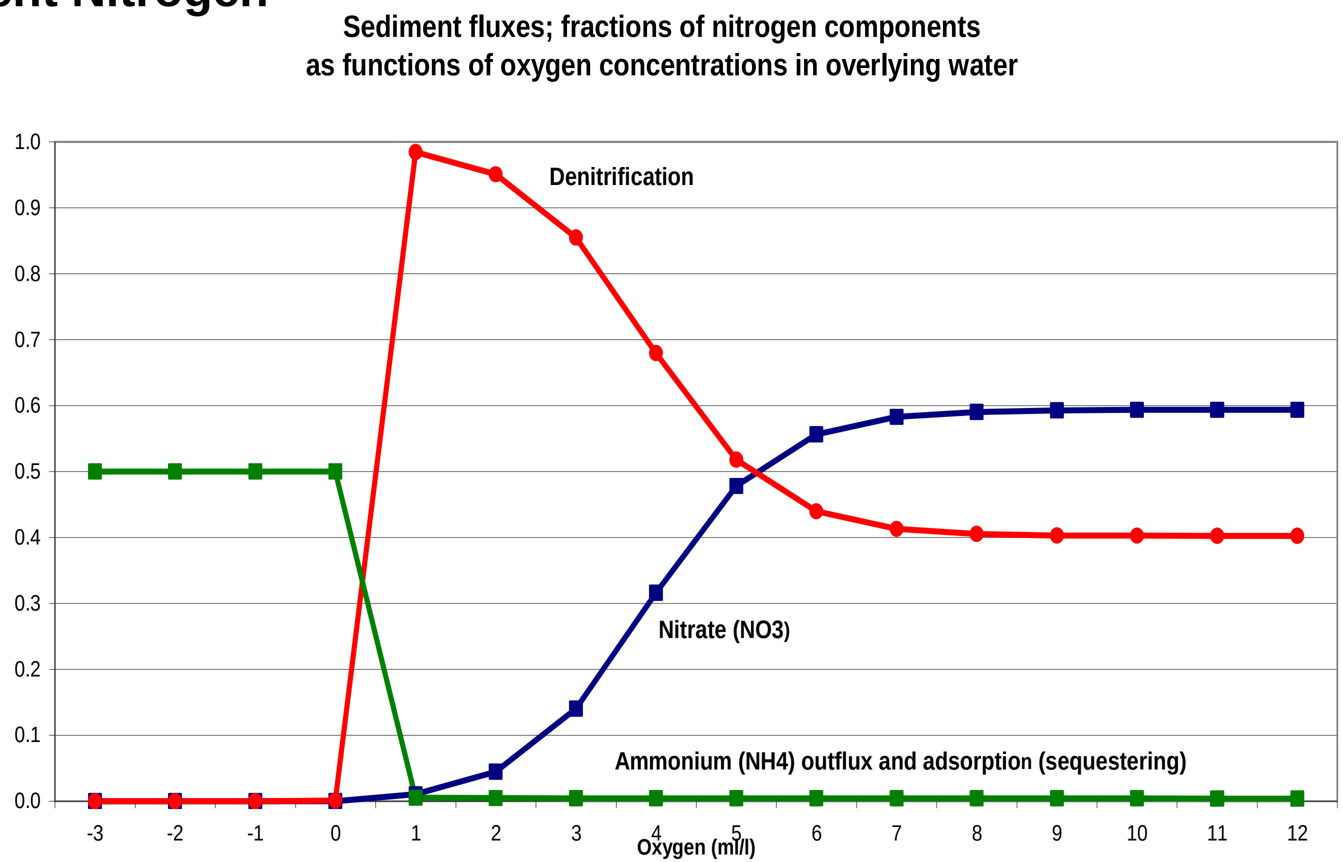
1. Future climate might be characterized by increased water temperatures, increased mixing, and (reduced loads) in the Baltic Proper
2. Increased water temperatures => decreased oxygen concentrations in all regions
3. Increased mixing (reduced stability) => increased oxygen concentrations below the halocline => reduced winter DIP and reduced denitrification (i.e. increased DIN)
4. Increased water temperature and increased mixing => increased (decreased) phytoplankton concentrations in the south-western (northern) Baltic Proper depending on the N/P ratio
5. In future climate the ”business-as-usual in agricultural practices” scenario may have larger impacts than in present climate
6. The BSAP will likely reduce the phytoplankton concentrations also in future climate

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

Sediment Nitrogen Fluxes



O2<0; Outflux of NH4

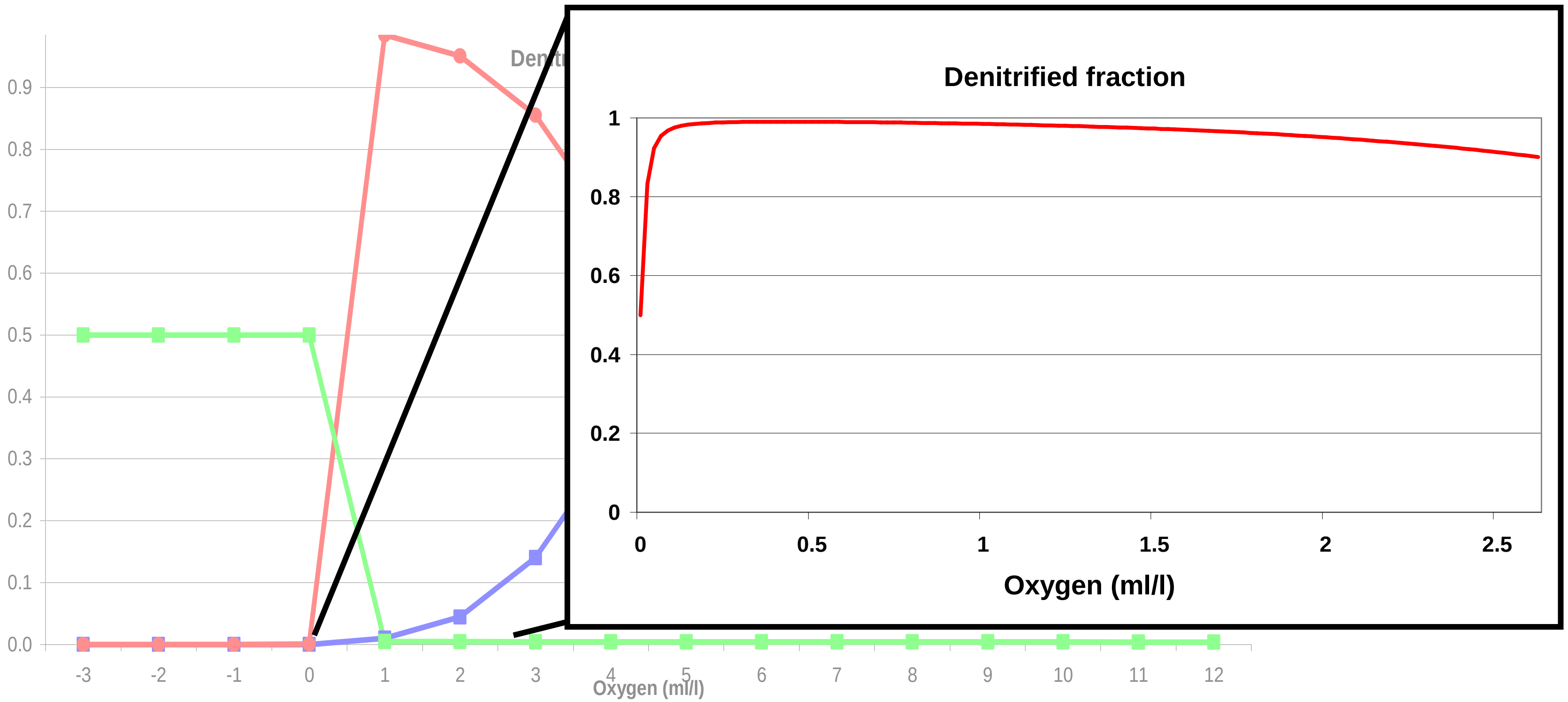
50% of N is removed

O2>0; Outflux of NO3

O2> 6; 40% of N is removed

$$S_{NBT} = {}^{d}SINKI_{BPHY} + {}^{c}SINKI_{BDET} - SEDOUT_{NH4} - SEDOUT_{NO3} - DENIT_{NBT} - SEQN_{NBT} - SEDNLOSS_{NBT} - BURIAL_{NBT}$$

Sediment Nitrogen



$0 \approx< O_2 < 1; \rightarrow \approx$ No Outflux of bioavailable N

about100% of mineralized N is removed (transformed to N_2)

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