Climate change scenarios and impacts for the Baltic Sea basin

Based on results of the Second Assessment of Climate Change for the Baltic Sea Region (BACC II)

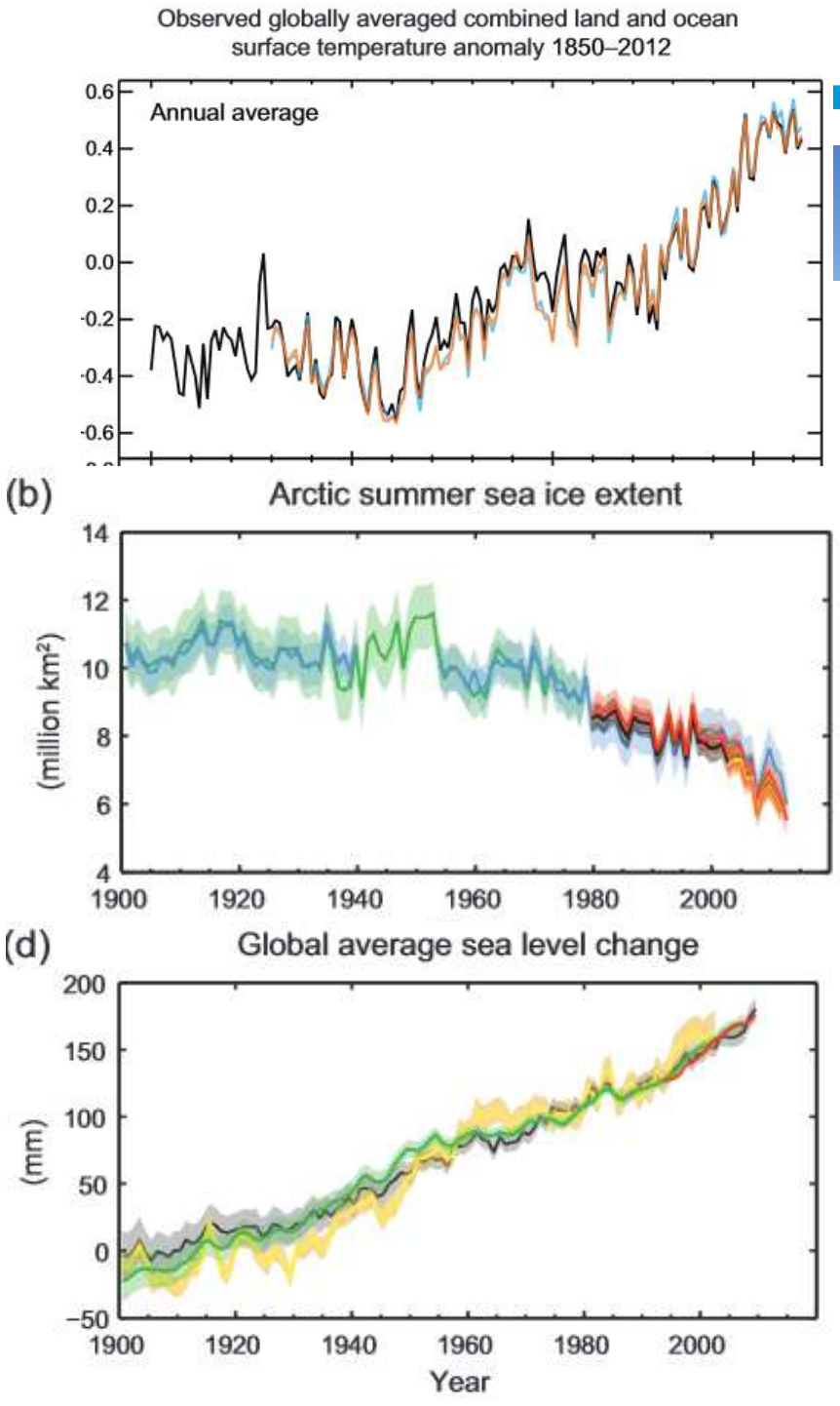
Baltic Earth
Earth System Science for the Baltic Sea Region

Martin Stendel

Dept. for Arctic and Climate
Danish Meteorological Institute
Copenhagen, Denmark

on behalf of the BACC II author team

Global climate change



Baltic Earth

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

→ **IPCC Assessment Report 5 (2013)**

"Warming of the climate system is **unequivocal**,

and since the 1950s, many of the observed changes are **unprecedented** over decades to millennia.

The **atmosphere and ocean have warmed**,

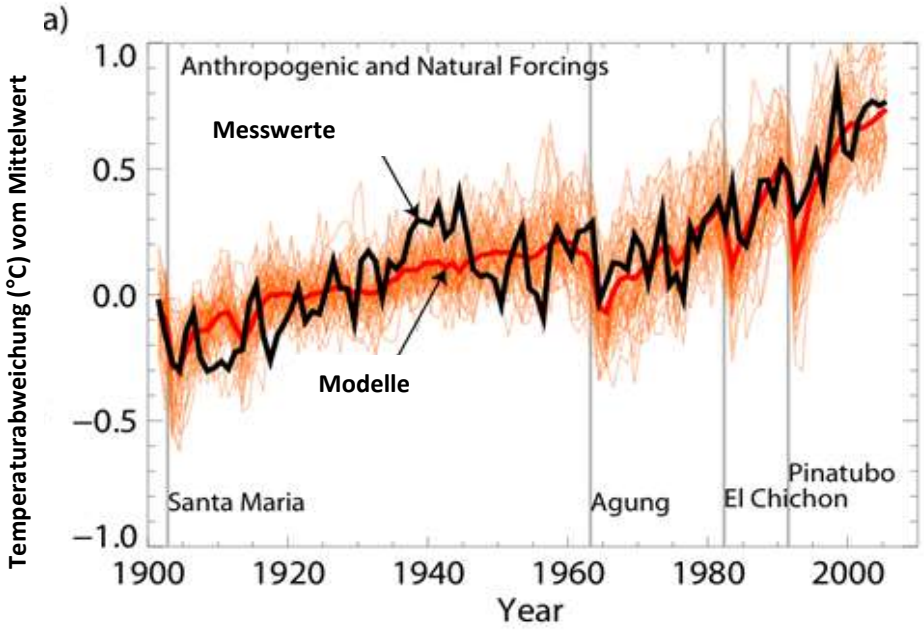
the **amounts of snow and ice have diminished**,

sea level has risen, and the

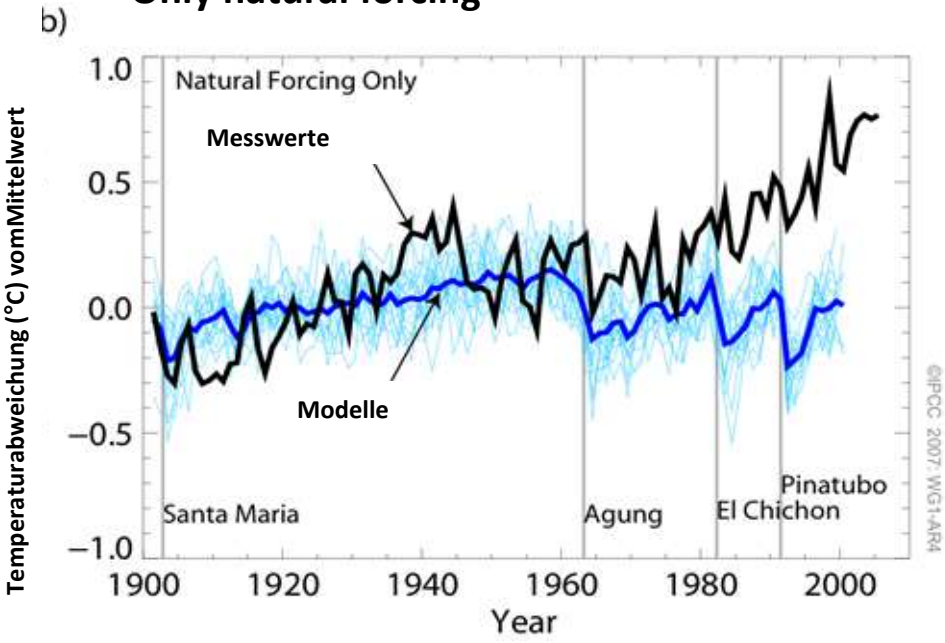
concentrations of greenhouse gases have increased."

Natural or anthropogenic forcing?

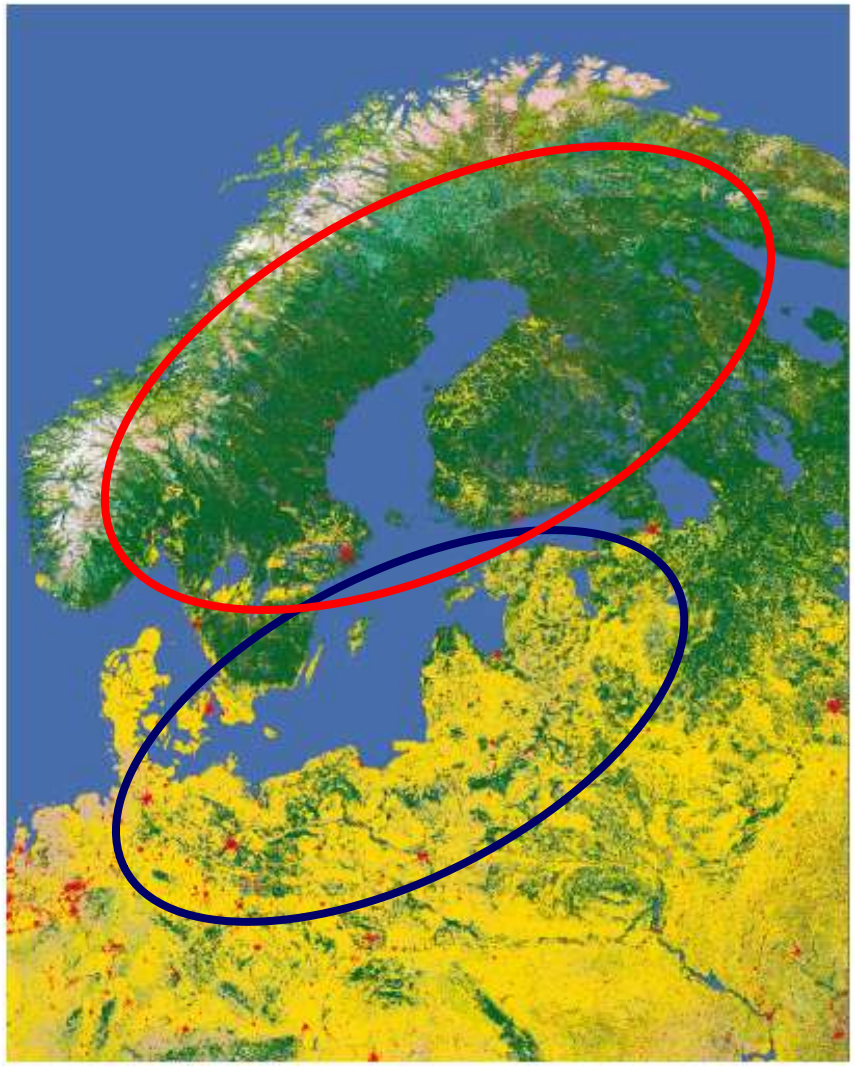
Natural and anthropogenic forcing



Only natural forcing



Regional climate change - The Baltic Sea region



The North …

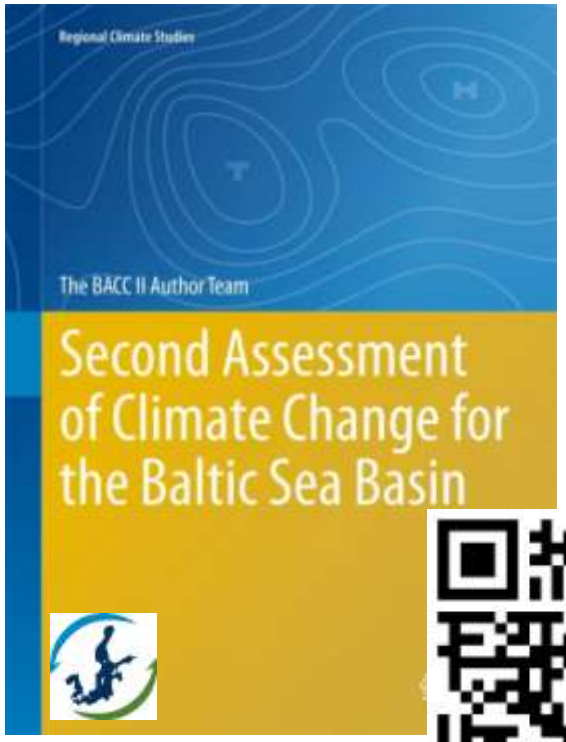
- → Large forests
- → Few people
- → Mainly rocky beaches
- → Subarctic climate in winter

The South …

- → Mainly agricultural
- → Densely inhabited
- → Mainly sandy beaches
- → Mild climate in winter

- → In terms of climate (and climate change), north and south behave quite differently

Baltic Earth Assessment of Climate Change for the Baltic Sea region (2015)



Second Assessment of Climate Change for the Baltic Sea region (BACC II)

New book 7 years after BACC I, following its format

- **What we currently know about climate change and its impacts in the Baltic Sea region**
- **Compiled by 141 authors from 12 countries**
- **Science Steering Group**
- **Peer reviewed**
- **Open Access (Springer)**

Planned based on BACC II:

Extended summaries of the scientific material

→ **In English plus all languages of the Baltic Sea region plus (Danish, Swedish, Finnish, Russian, Estonian, Latvian, Lithuanian, Polish, German)**

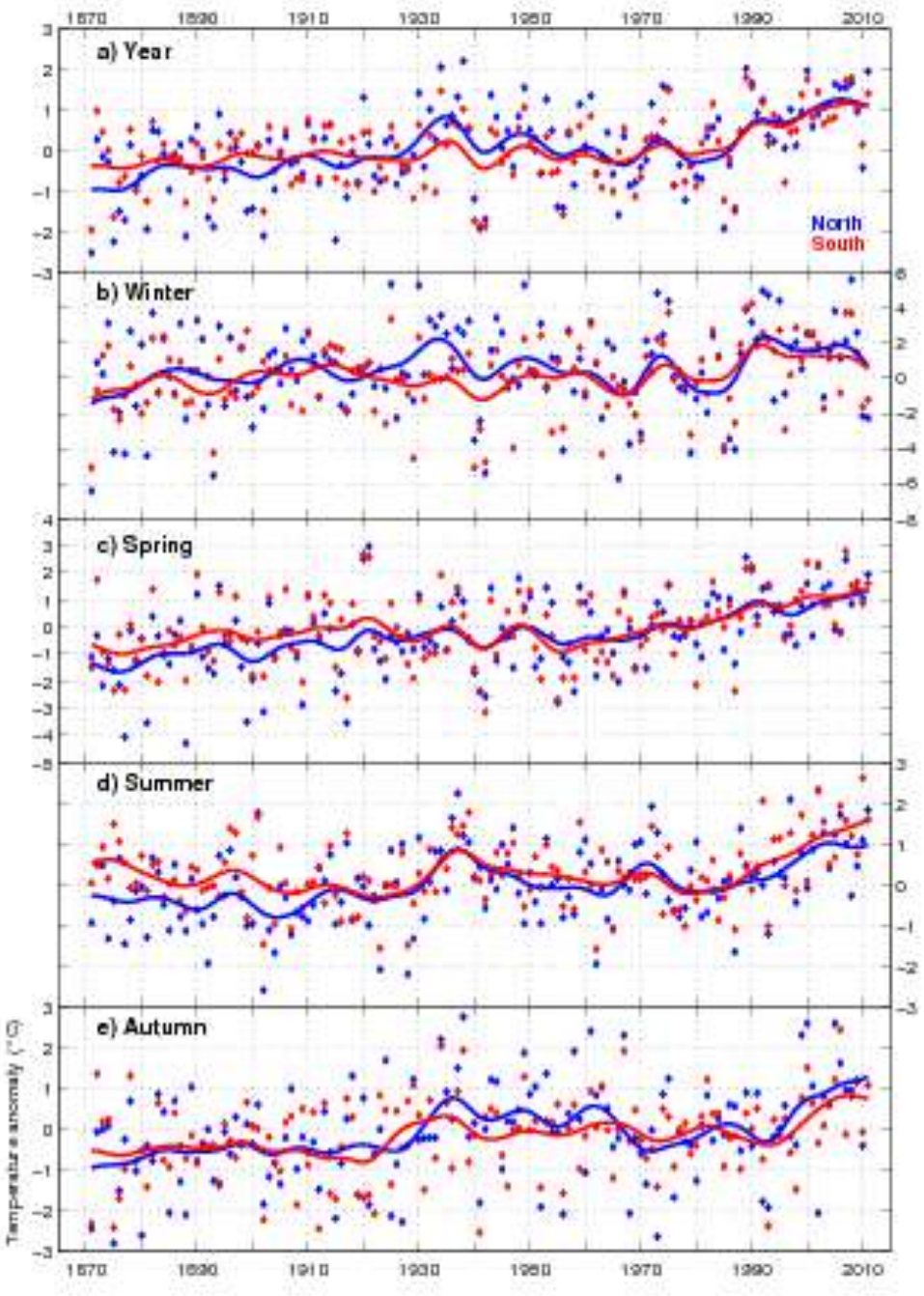
→ **Understandable for non-scientists**

→ **Emphasizing on regional conditions**

Chapters on

- **Long-term climate change**
- **Recent climate change (instrumental, last 200 years)**
- **Future climate change**
- **Environmental and socio-economic impacts of climate change**
- **Drivers of regional climate change**

Changes in air temperature



→ **Warming trend**

→ **Regionally and seasonally different**

Table 4.1 Linear surface air temperature trends (°C per decade) for 1871–2011 in the Baltic Sea basin. Trends shown in bold are significant at the $p < 0.05$ level. The trends were also tested by the non-parametric Mann-Kendall test. The results were consistent with the linear trend test. Data from the CRUTEM3v dataset (Brohan et al. 2006)

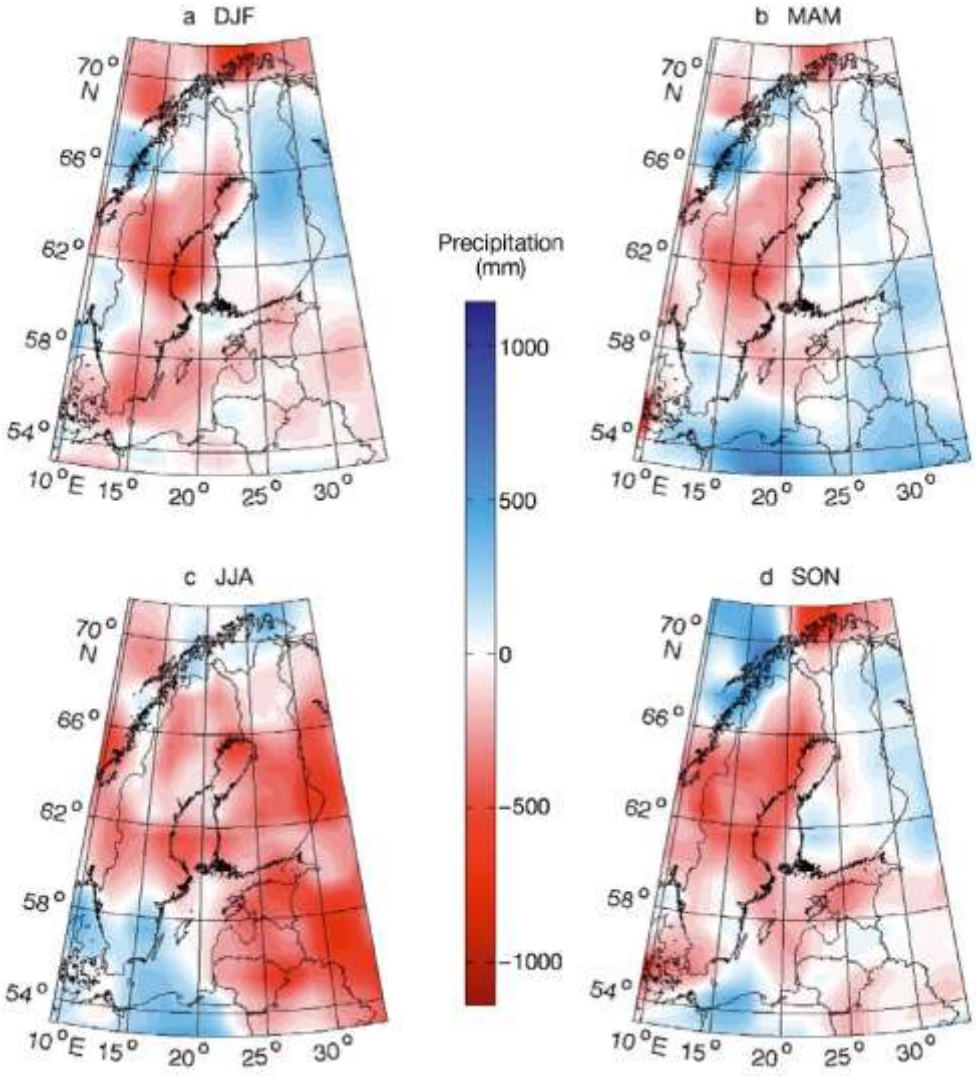
Data sets	Annual	Winter	Spring	Summer	Autumn
Northern area (north of 60° N)	**0.11**	0.10	**0.15**	**0.08**	**0.10**
Southern area (south of 60° N)	**0.08**	**0.10**	**0.10**	**0.04**	**0.07**

BACC 2

Chapter 4

Changes in precipitation

(1994-2008) minus (1979-1993)

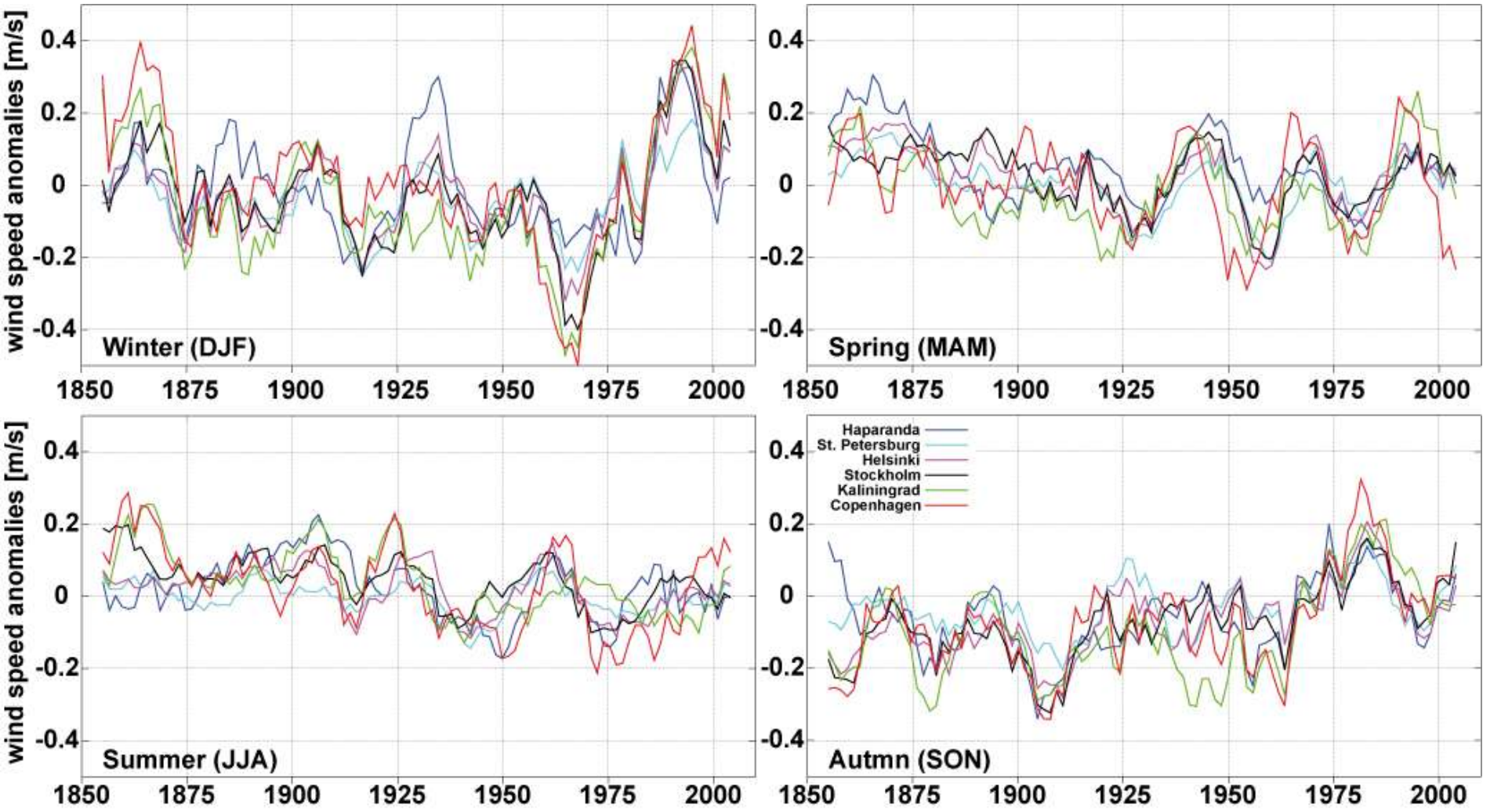


→ **Large seasonal and regional differences**

→ **Large decadal variability**

→ **Small increase over the 20th century**

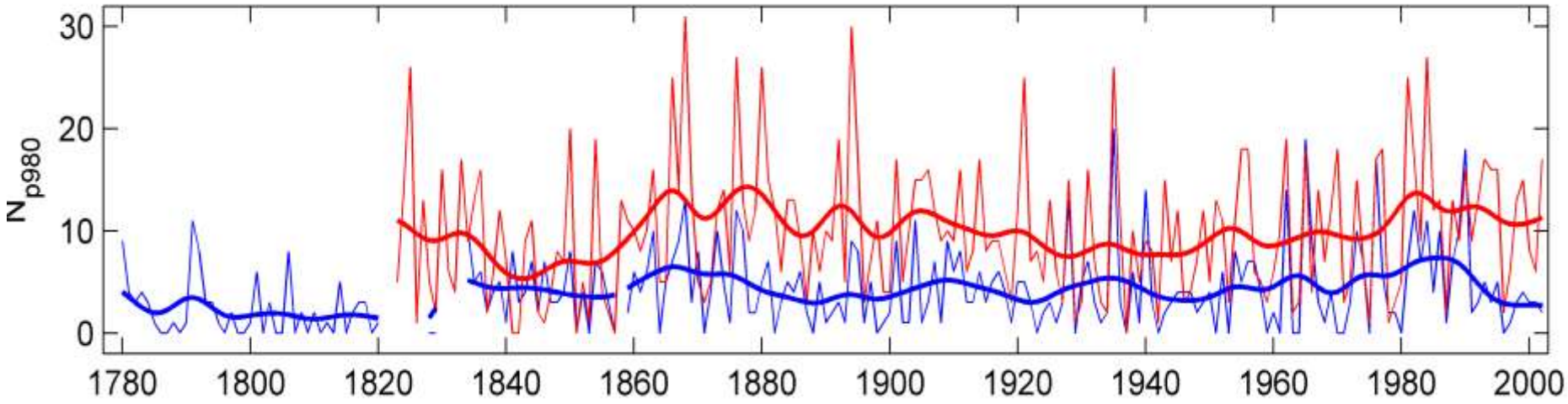
Changes in wind speed



Sliding decadal (11-y) mean seasonal wind speed anomalies for the Baltic Sea regions for 1850-2009. Anomalies are calculated by subtracting the mean of 1958-2007. Time series are drawn from the gridded fields of HiResAFF (Schenk and Zorita 2011, 2012). Grid points are selected in the closest vicinity of Haparanda, Saint Petersburg, Helsinki, Stockholm, Kaliningrad and Copenhagen.

→ **Large variability, decadal but no long-term trends in storminess**

Changes in storminess



Number of lows with p_{core}< 980 hPa in Stockholm and Lund

→ **No obvious trend**

Changes in river and lake ice

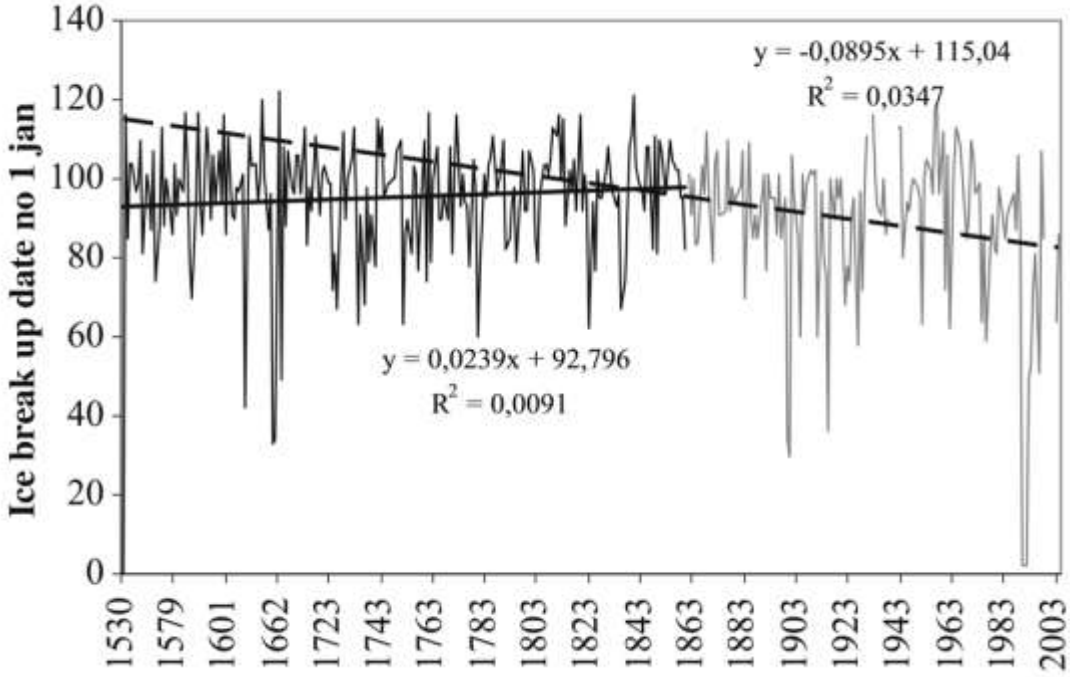
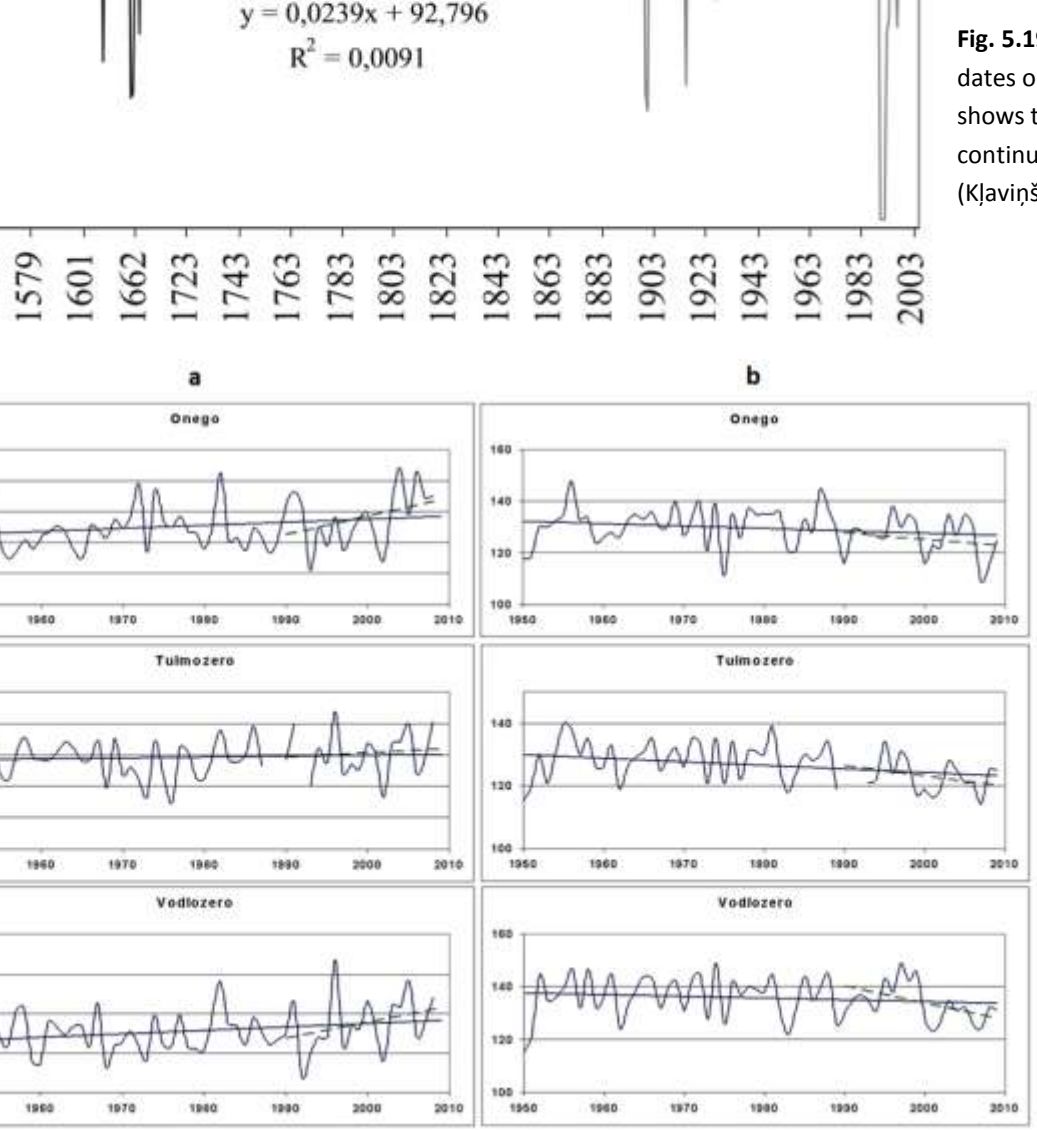


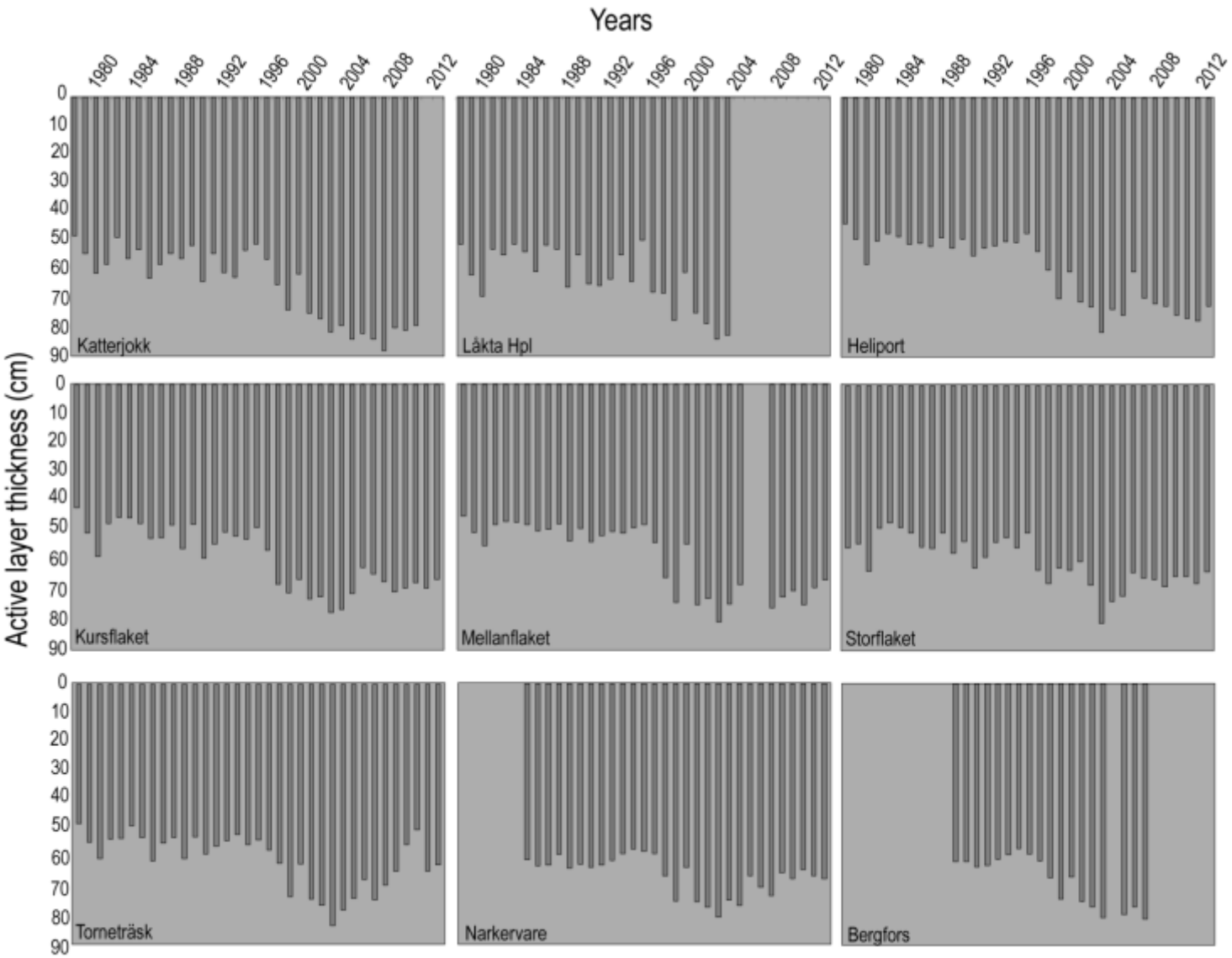
Fig. 5.19 Time series of ice break-up dates on River Daugava (dashed line shows trend from 1860 to 2003 and continuous line from 1530 to 1859) (Kļaviņš et al. 2009)



- → Ice freeze-up and breakup dates have changed
- → Duration of ice cover decreases
- → Ice thickness decreases

Fig. 5.21 Date of a) freeze-up and b) break-up on a large lake (Onego), a middle size lake (Vodlozero) and a small lake (Tulmozero) for 1950–2009. The linear trends for 1950–2009 and 1990–2009 are shown by the solid and dashed line, respectively (Efremova and Palshin 2011)

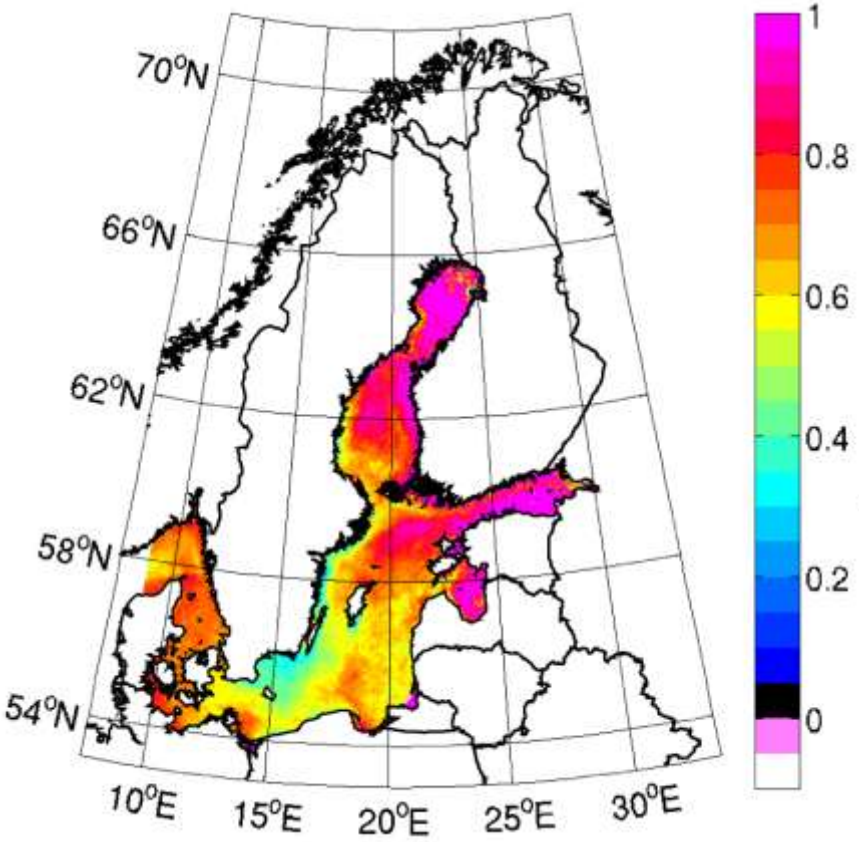
Changes in permafrost



→ **Increase of active layer depth**

Active-layer thickness from 1978 to 2006 at the nine sites in sub-arctic Sweden. The active layer has become thicker over the monitoring period, especially during the last decade (from Åkerman and Johansson, 2008; figure 4 on page 285; published by Wiley).

Changes in sea surface temperatures



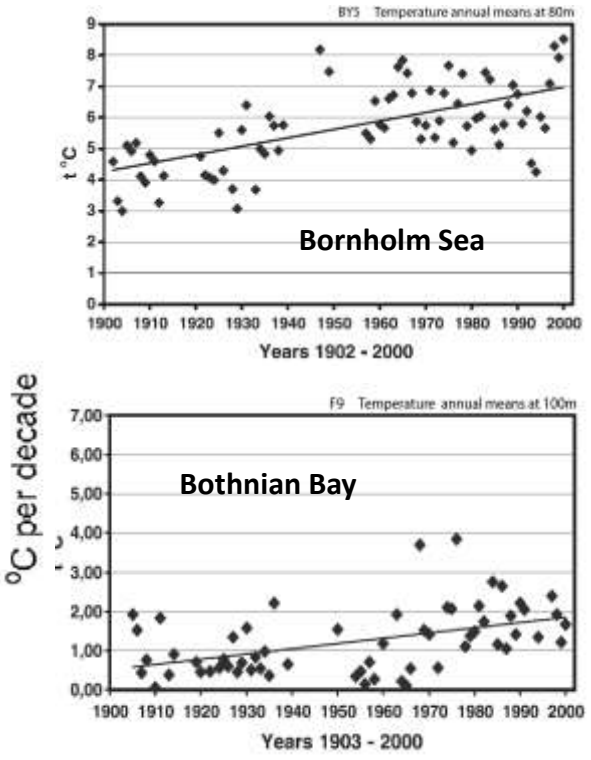


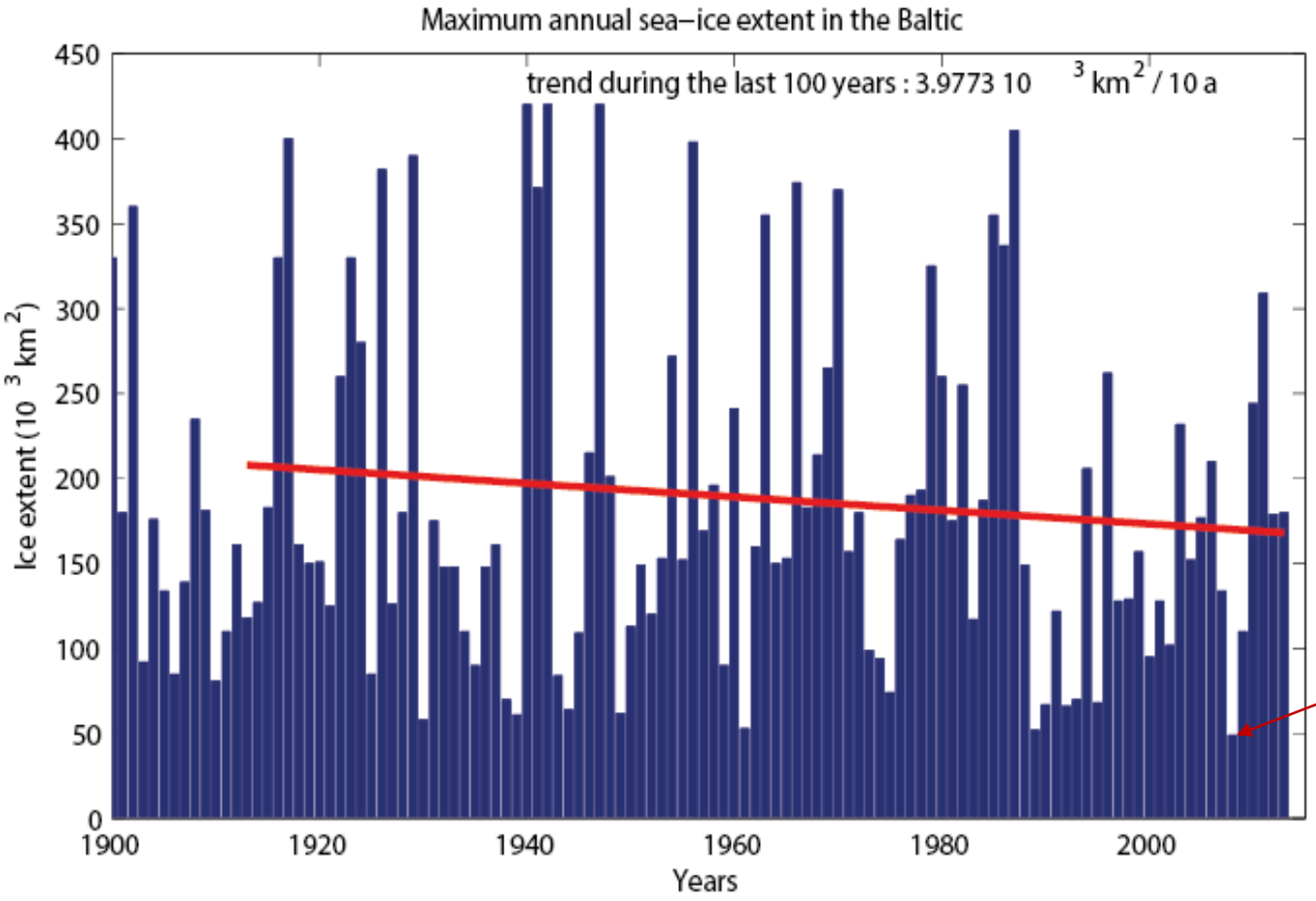
Fig. 7.2 Linear trend in annual mean sea surface temperature based on infrared satellite data (1990–2008) provided by the Federal Maritime and Hydrographic Agency (BSH), Hamburg (Lehmann et al. 2011)

→ **Since 1990 strong surface warming in Bothian Bay and Gulf of Finland**

→ **Detectable warming of the Baltic Sea, surface and deep water**

BACC Ch. 3
BACC 2
Chapter 7

Changes in sea ice cover



→ **Frequency of mild ice winters has increased**

Winter 2007/2008 lowest ever recorded ice cover

Fig. 8.3 The maximum extent of sea-ice cover in the Baltic Sea, 1900–2012. The red line shows a long-term declining trend of ~2% per decade

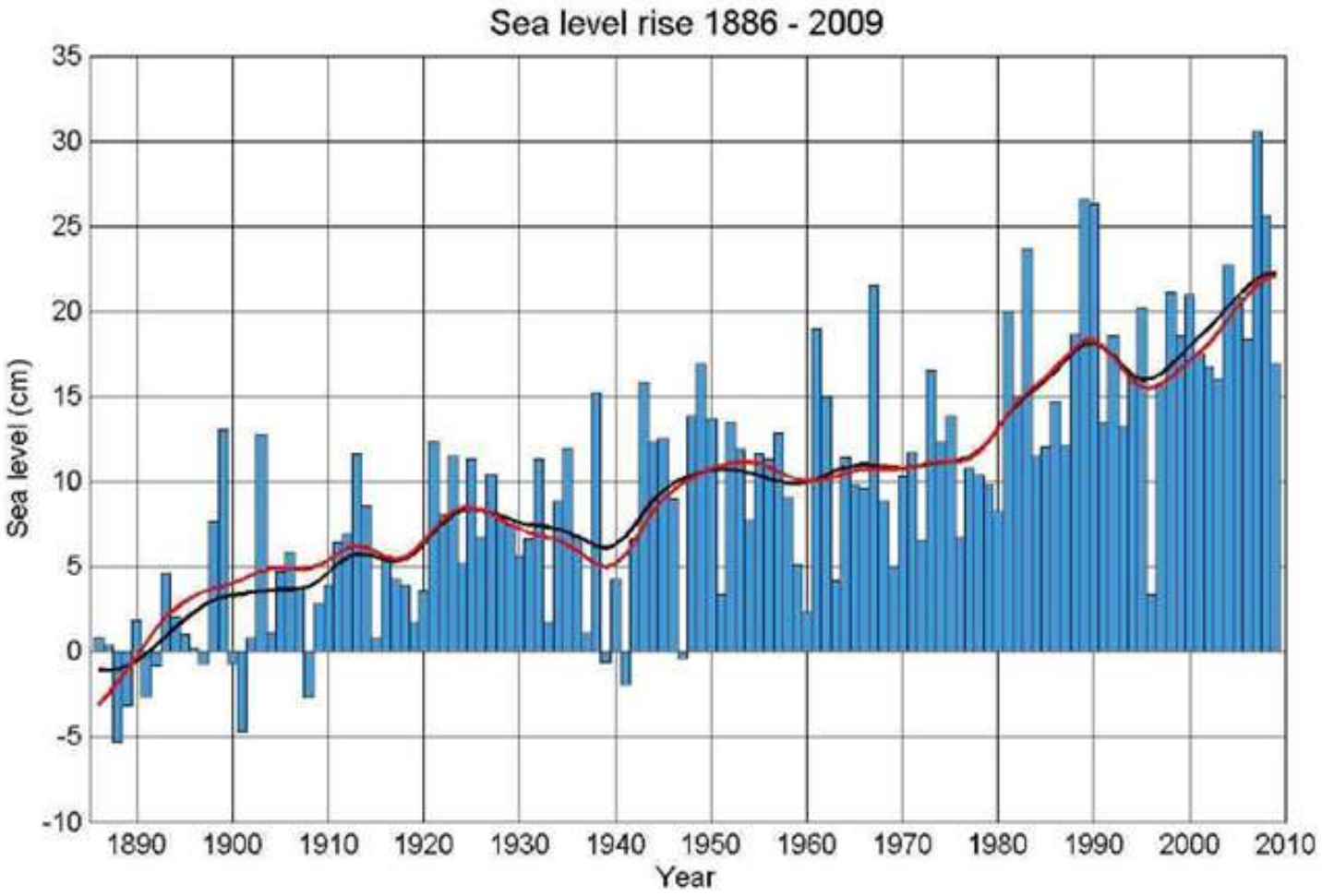
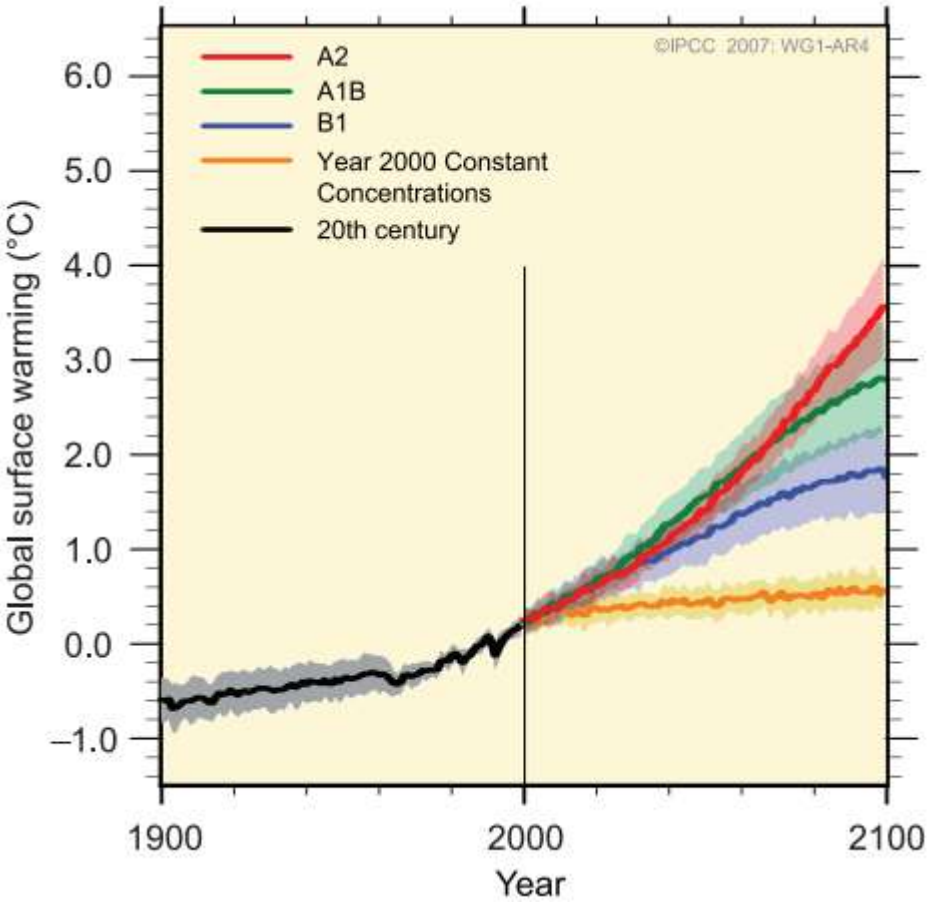


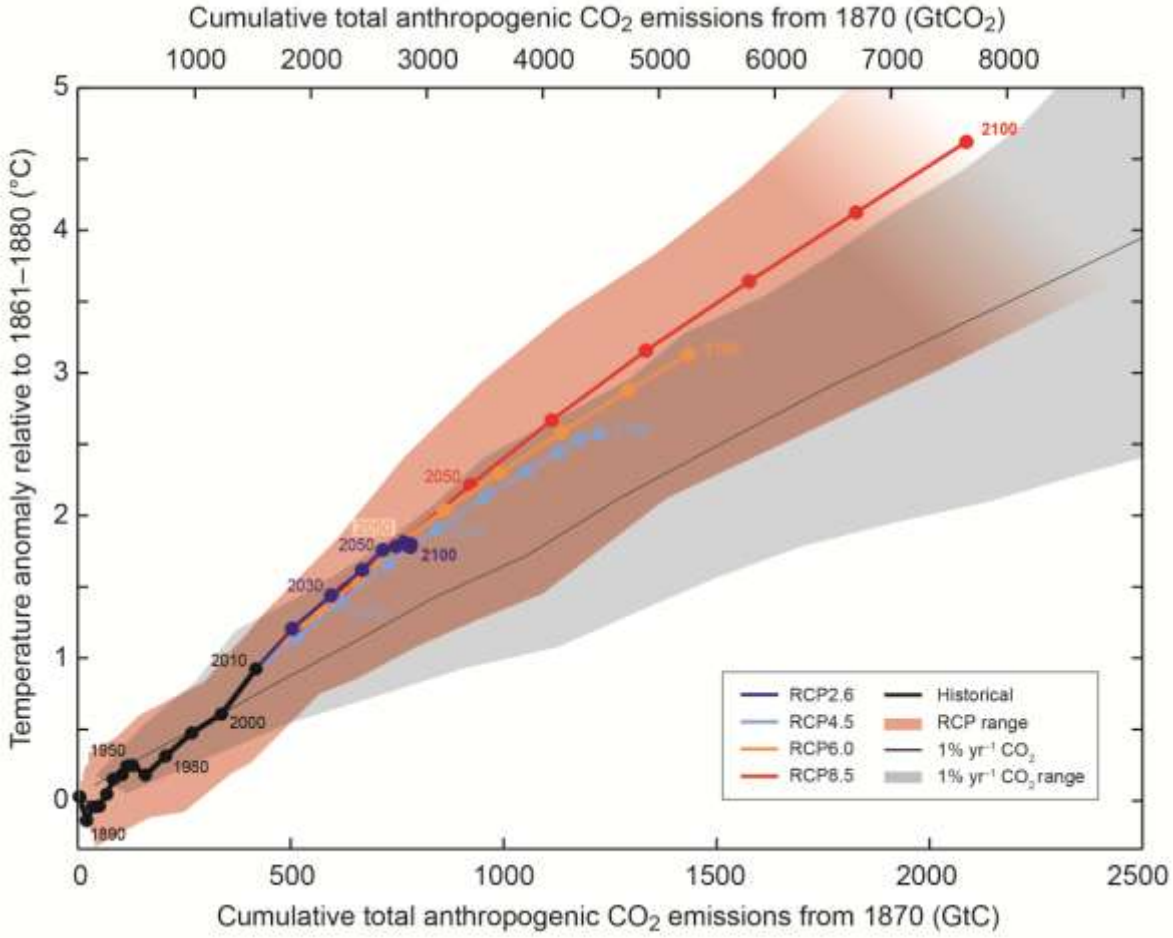
Fig. 9.5 Annual sea level means averaged for 14 Swedish sea level records corrected for land uplift and compared to the 1886 level. Black line: time-filtered version together with the filtered Stockholm sea level time series (red line) (Hammarklint 2009)

→ **Current estimations for the Baltic Sea coast: 1,3 mm/yr – 1,8 mm/yr, comparable with the global rise (1,7 mm/yr ± 0,5)**

Projected future change…

“Prediction is very difficult, especially if it's about the future.” (Niels Bohr)

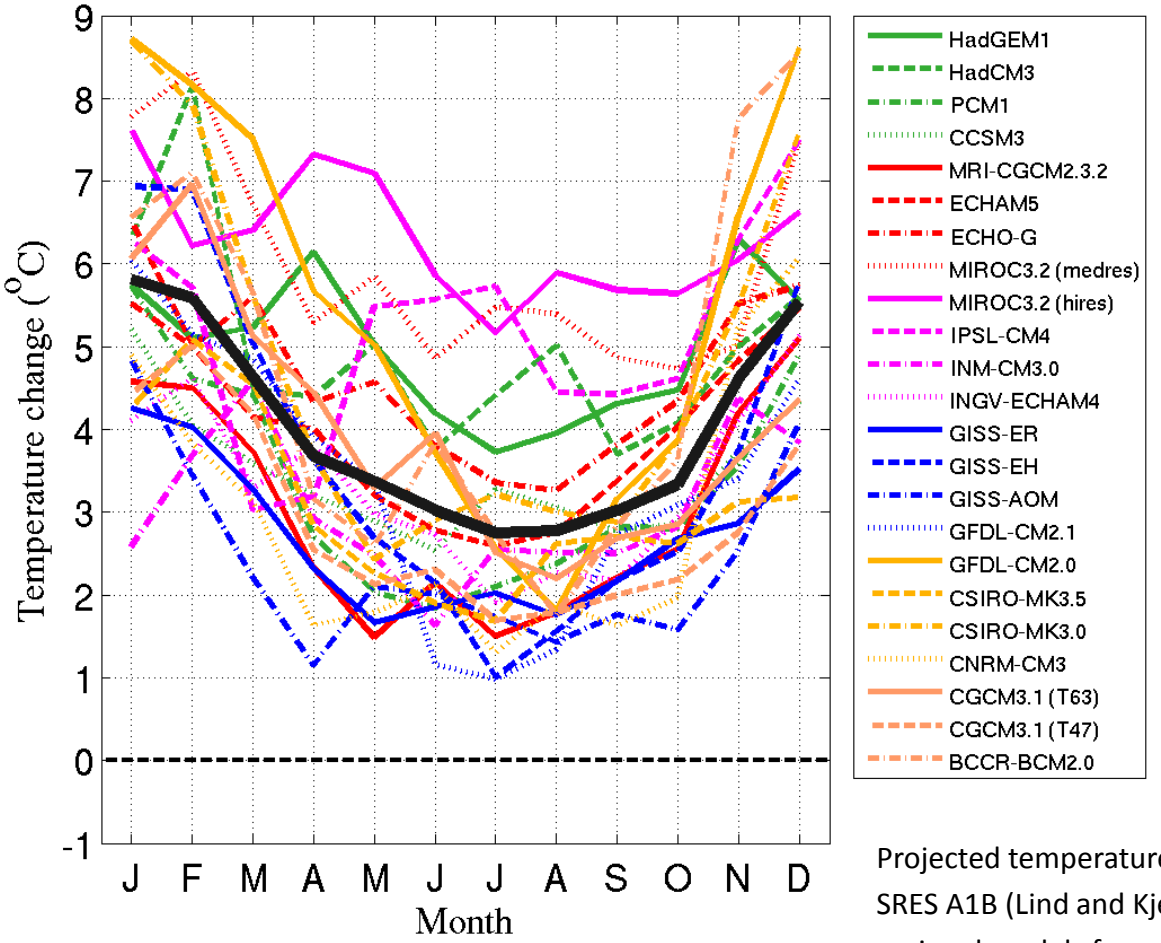




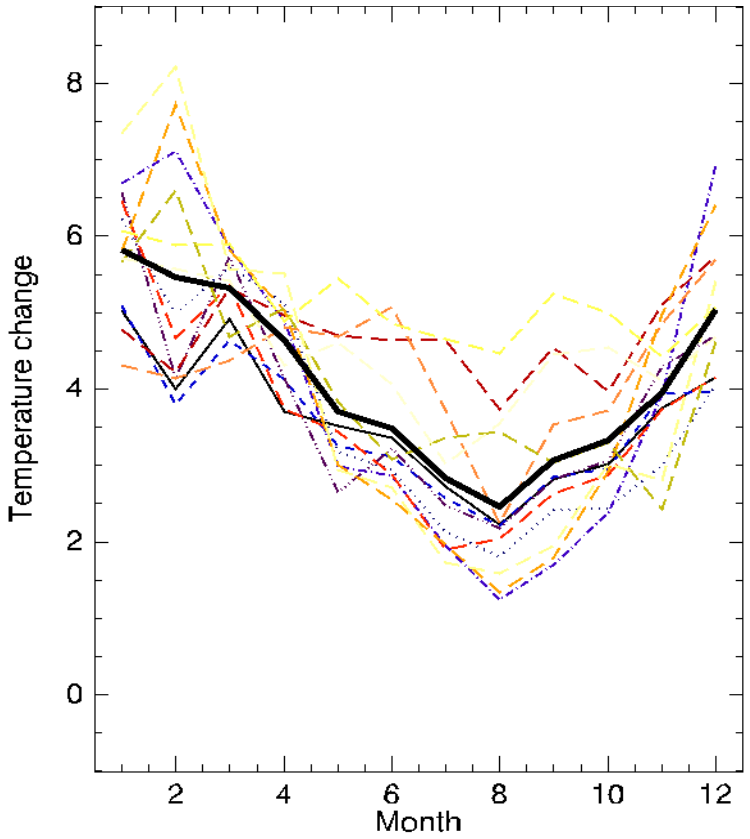
Projected future change…

Global and regional climate model "ensembles"

→ Global climate models



→ Regionale climate models

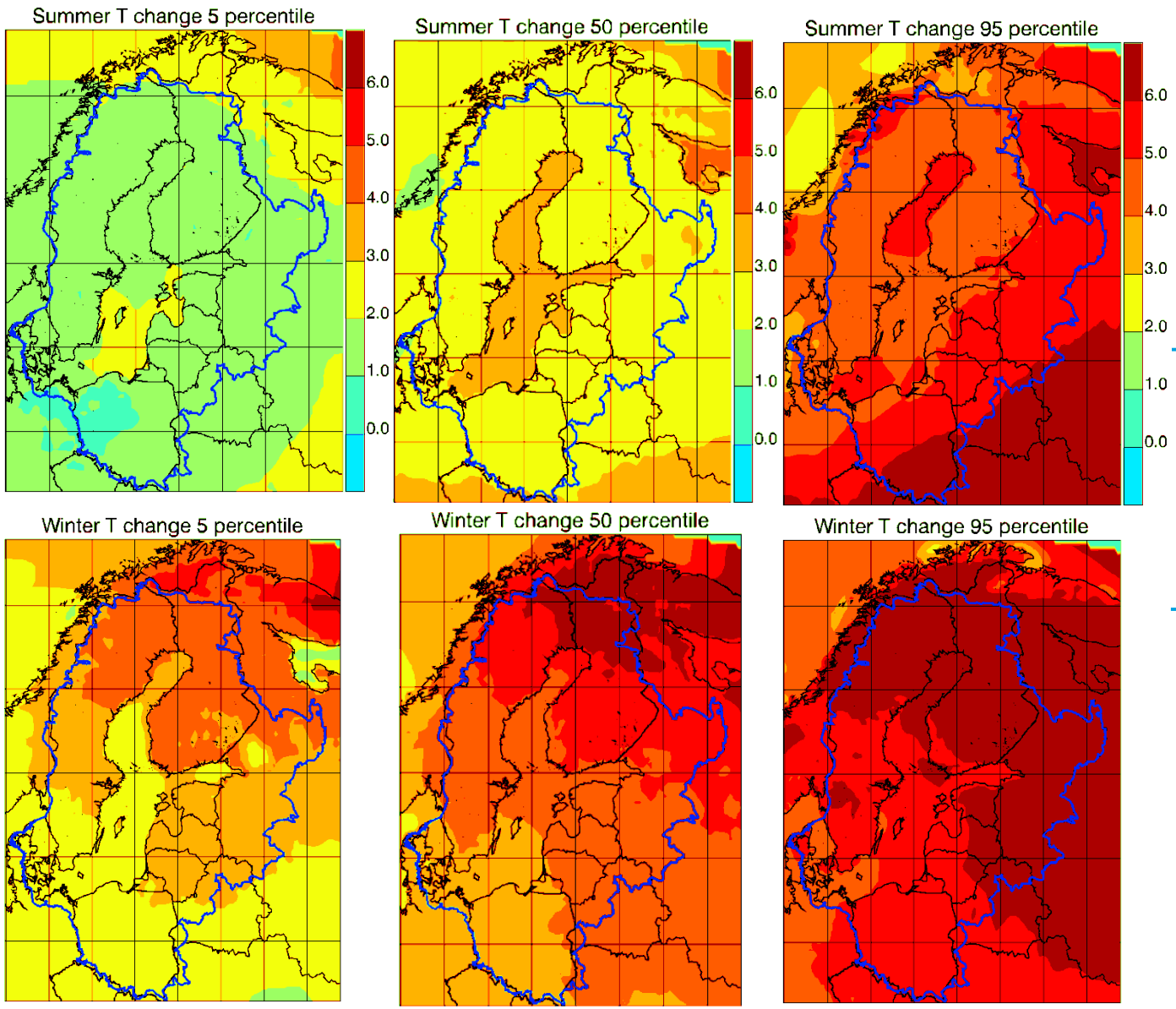


Projected temperature change in northern Sweden. Left panel: 23 CMIP3 AOGCM-simulations, SRES A1B (Lind and Kjellström, 2008), (2071-2100) – (1961-1990). Right panel: Same for 13 regional models from the ENSEMBLES project.

Projected changes in air temperature

Summer

Winter



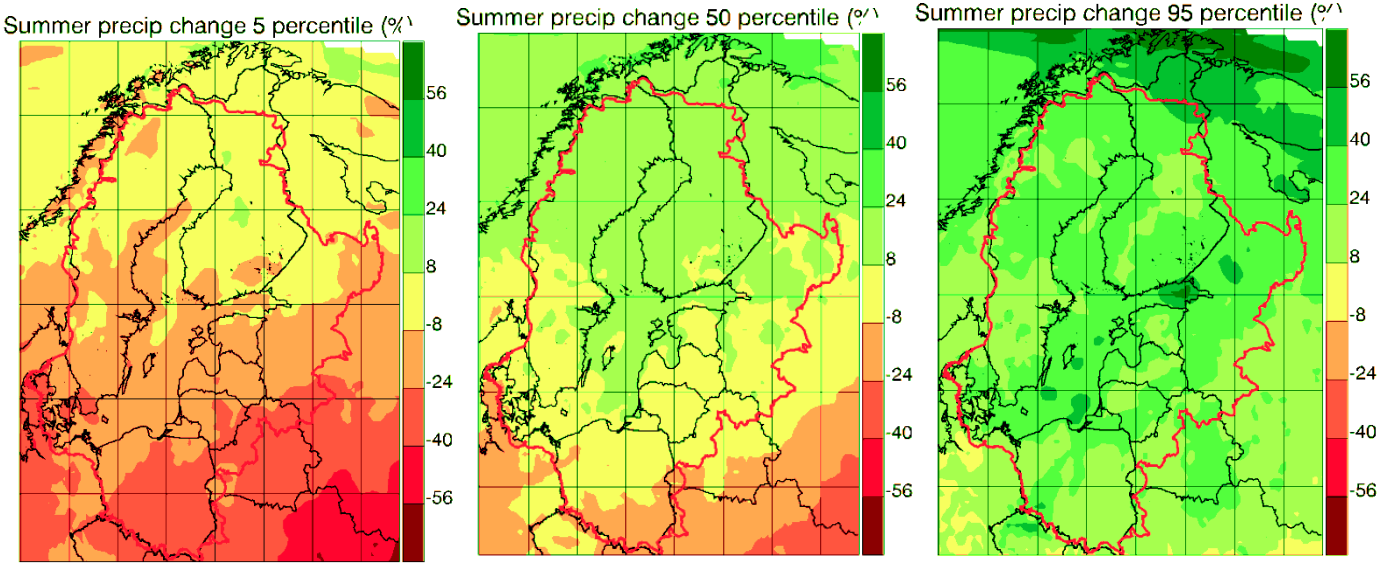
Change between 1961-1990 and 2070-2099

→ **Overall warming (winter: 4-8°C, summer: 1.5-4°C)**

→ **Strongest in the North**

Projected changes in precipitation

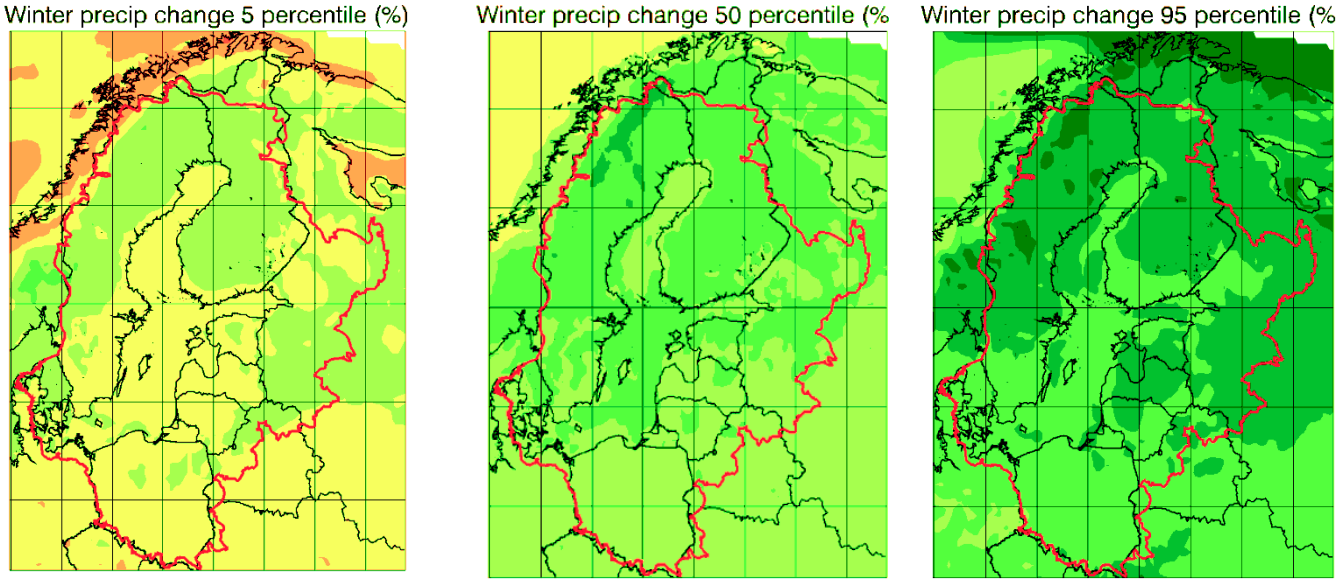
Summer



Change between 1961-1990 and 2070-2099

→ Generally wetter

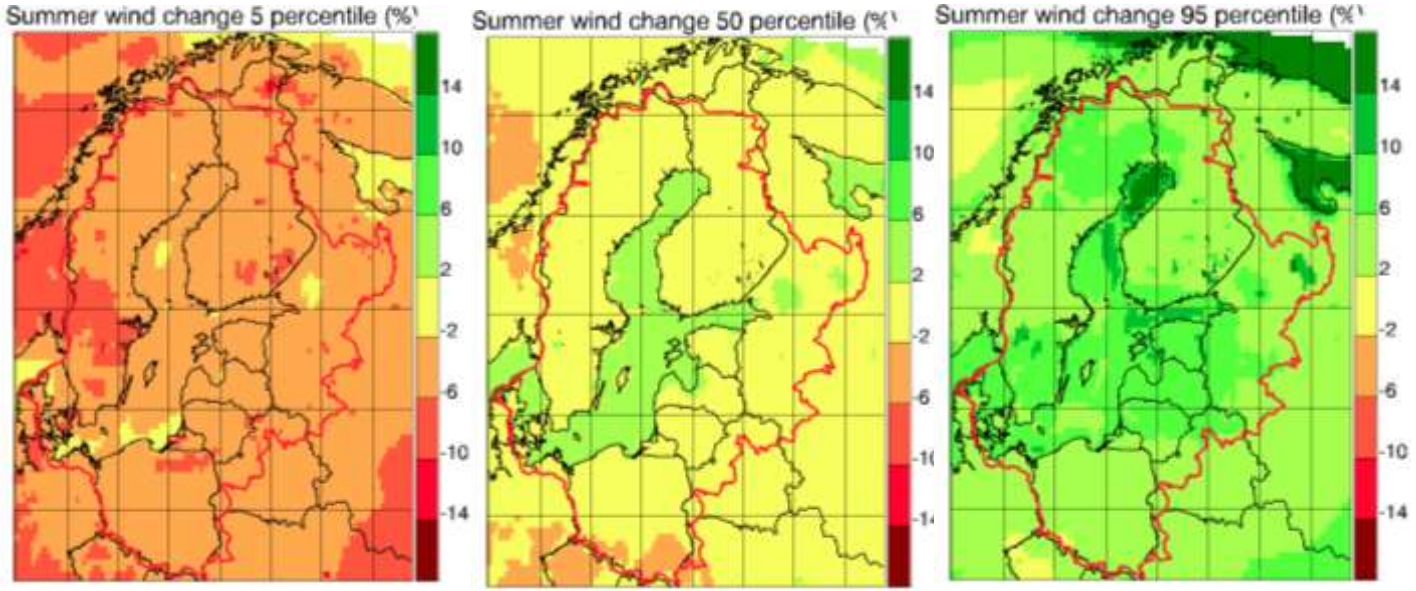
Winter



→ Possibly dryer in summer and in the south

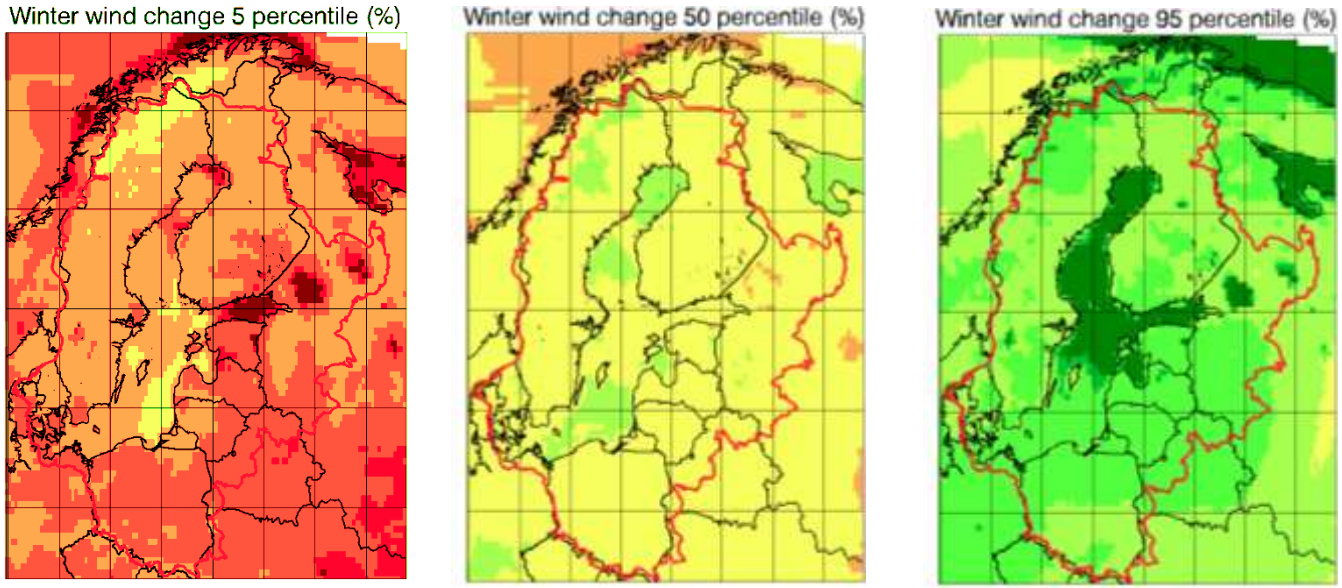
Projected changes in wind speed

Summer



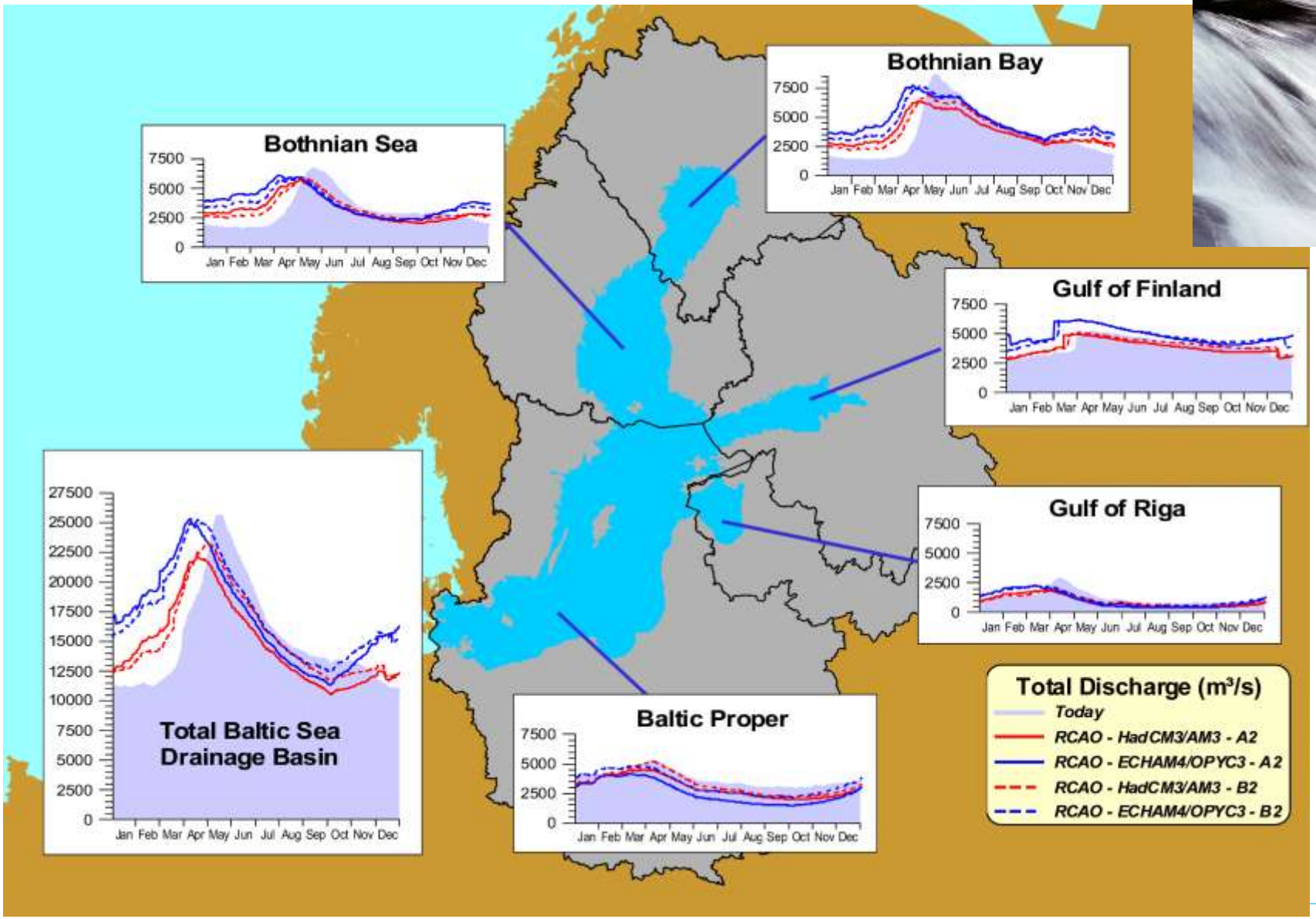
Change between 1961-1990 and 2070-2099

Winter



→ No clear trend

Projected changes in runoff



→ More runoff expected (+15 bis +22%)

→ earlier peaks

→ Decreasing salinity?

Projected changes in sea surface temperature

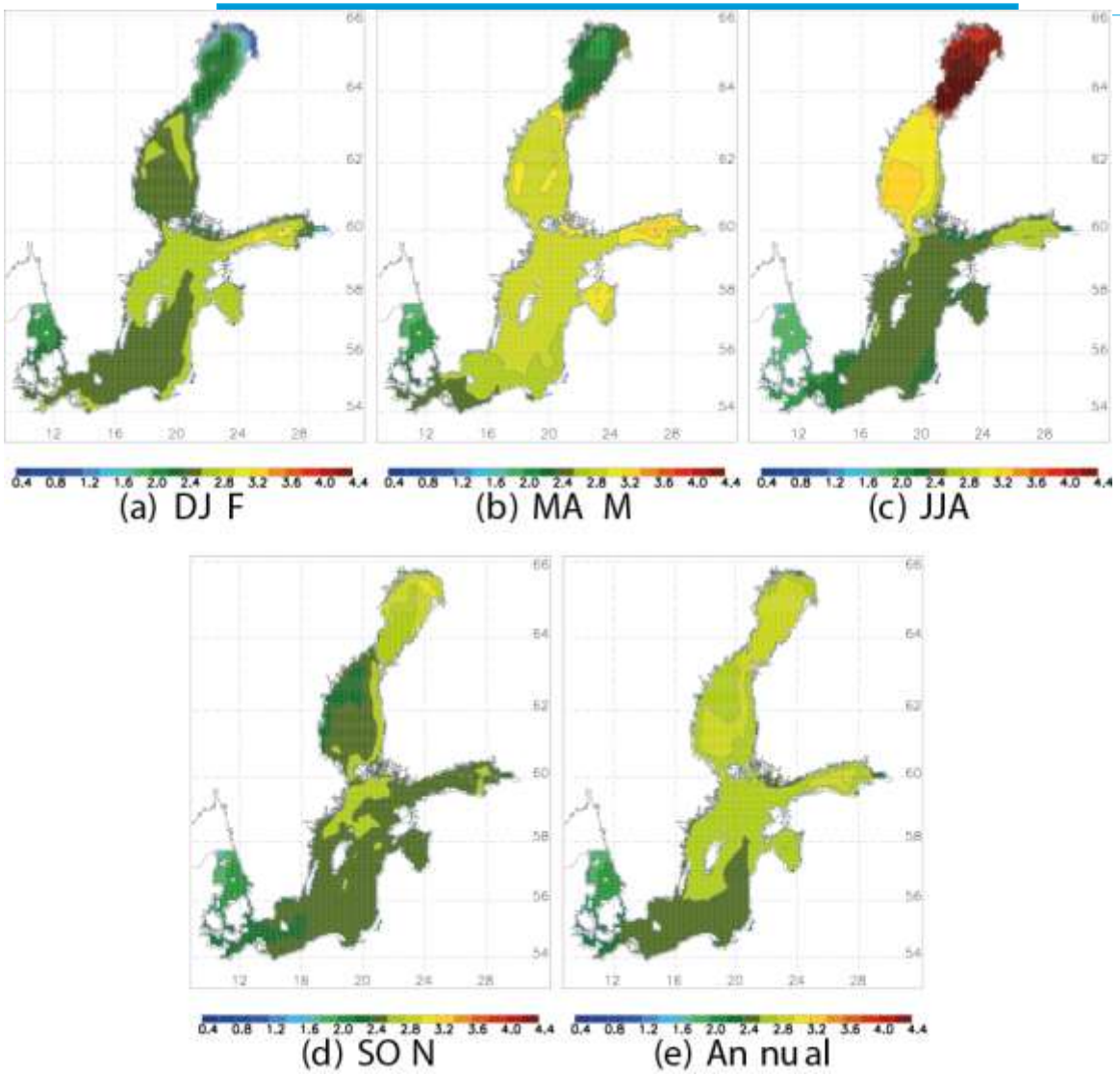


Fig. 13.2 Projected change in seasonal (DJF, MAM, JJA, SON) and annual mean ensemble average sea-surface temperatures for 2069–2098 relative to a baseline of 1978–2007. See Meier et al. (2012a)

Sea surface temperatures

→ **Temperatures:**

Projected increase of sea surface temperatures, in the summer in the north up to 4°C, deep water temperatures projected to increase up to 2°C

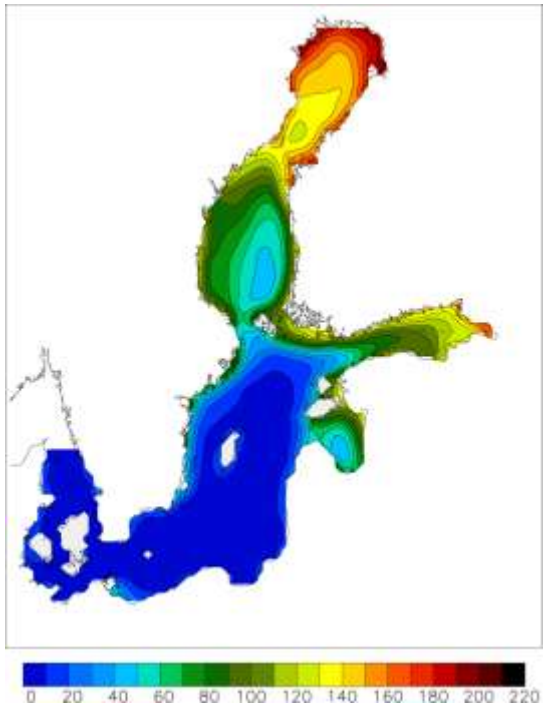
→ **Salinity:**

Changes uniform across seasons, small reduction in the northern and central parts, larger in the Kattegat and Skagerrak

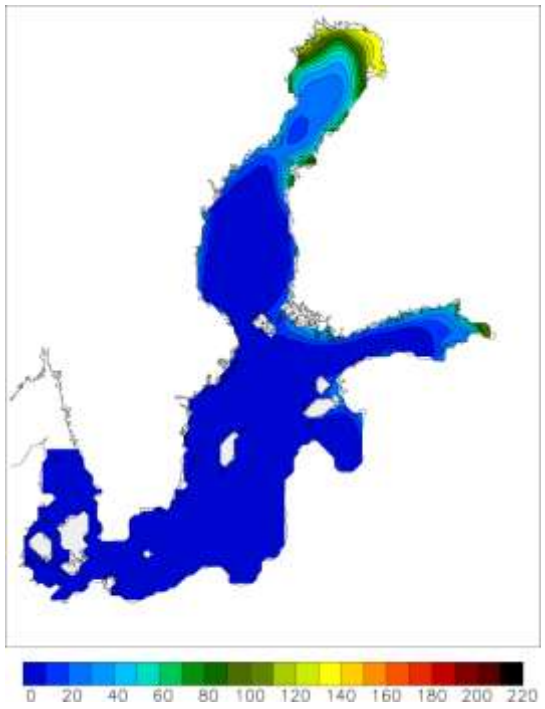
Projected changes in sea ice extent

Sea ice extent

1961-1990



2071-2100



Number of days with ice cover

→ **Strong decrease of sea ice extent projected (50 – 80 %)**

→ **Shortened ice season expected**

Projected changes in sea level

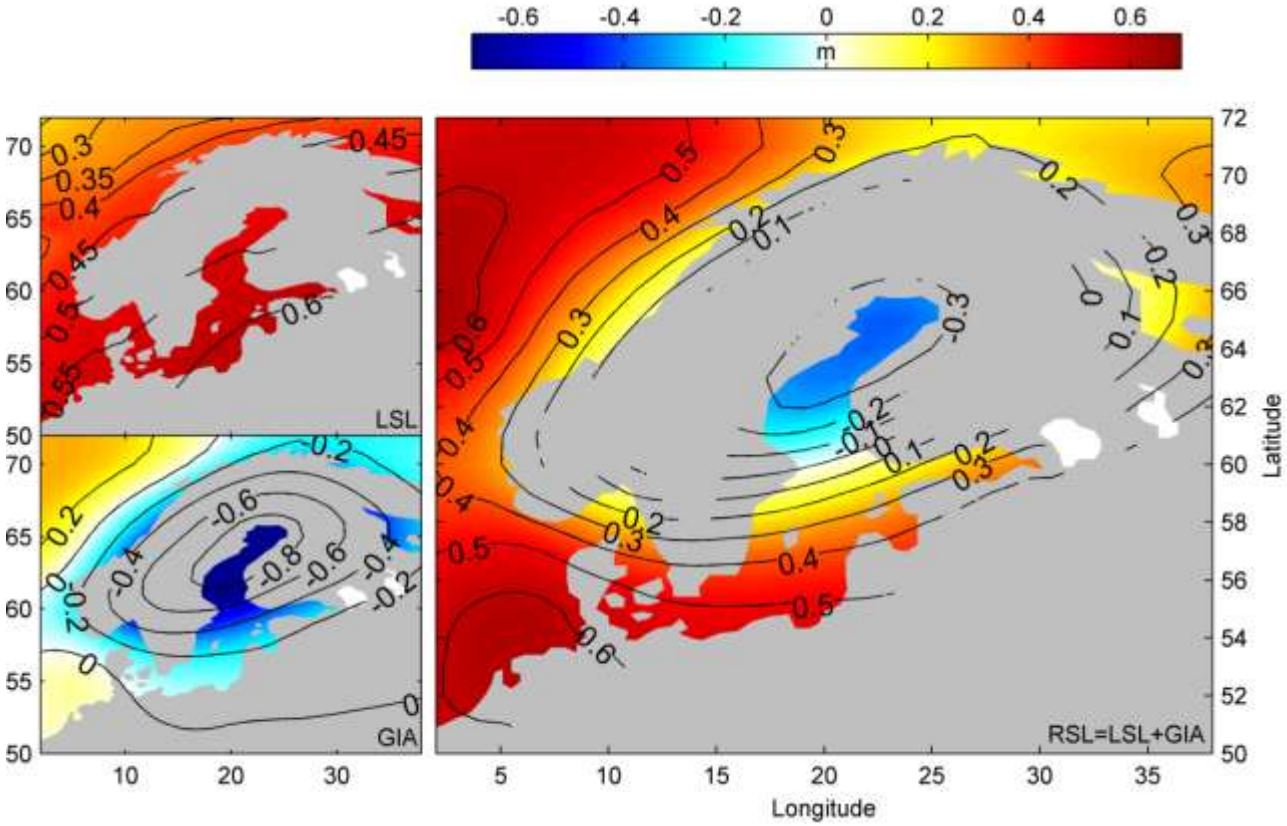


Fig. 14.3 (Right) Regional sea-level rise for 2090–2099 relative to 1990–1999, SRES A1B scenario, decomposed into local sea-level rise (upper left) and glacial isostatic adjustment (lower left; Hill et al. 2010).

→ **IPCC AR5 Global projections range from 0.20 to 0.82 m, depending on emission scenario**

→ **Estimation for the Baltic Sea 0.70 ± 0.30 m based on the SRES A1B emission scenario**

Impacts

Atmosphere

→ Main changes in **air pollution** are due to **changes in emissions rather than to climate change**

→ Future developments depend strongly on **policy developments**

BACC 2 Chapter 15

Land ecosystems

→ **Longer** vegetation period

→ **Northward** migration of species (**fragmentation** of spaces is **limiting**)

→ **New** species

BACC Ch. 4, BACC 2, Ch 16 BACC 2, Ch 21

→ **Forest growth** in the North projected to **increase** (+22%)

→ Smaller increase in the south (+8%), Water limiting factor

→ **Positive effects on crop yield**, especially for winter crops

Impacts

→ Climate change **is one among many factors** for many observed changes (eutrophication, land use, pollution, overfishing)

→ **Complex interactions between climate change and other anthropogenic factors**

Possible socio-economic consequences

→ Tourism

→ Health and well-being, less cold stress in the North

→ Less heating in buildings

→ Increased growth conditions for plants where water is not a limiting factor

→ Loss of valuable goods at the coast and in coastal cities

→ Increasing costs for coastal protection (south) and adaptation

Agriculture and Forestry

Urban complexes

Coastal erosion

BACC 2 Chapter 20-22

Regional Attribution

→ Question:

Is it possible to attribute recent regional climate change to human influence and other causes?

Particular focus on the external forcing mechanisms that have been identified to be related to recent global warming

→ **Anthropogenic greenhouse gas emissions**
Emerging anthropogenic signal in seasonal temperature
Evidence too weak for precipitation, wind, etc.

→ **Natural and anthropogenic emissions of aerosols**
Aerosol emissions over Europe may have an effect on large-scale circulation over Europe and the Baltic Sea region, but evidence is vague
Few analyses on regional aerosol effects, models unable to simulate aerosol–climate interactions

→ **Changes in land use and land cover**
Can have counteracting effects on climate (biogeochemical vs. biogeophysical effects)
No indication of land use and land cover effects on recent climate change
Further understanding and modelling efforts urgently necessary

BACC 2 Chapter 23-25

Summary

→ Clearly observed increases in temperature (air und water) as well as sea level ; connected changes in freezing and melting dates, ice cover, coastal erosion, vegetation periods, plant growth

→ Uncertainties in precipitation and wind

→ Further warming and sea level rise expected (but land uplift in the North counteracts sea level rise)

→ Anthropogenic climate warming is only one man-made factor for observed environmental changes . Other factors e.g. eutrophication, land use changes, pollution, overfishing)

→ Further research necessary, particularly in the role of land cover and aerosols for the regional climate