Temperature variability of the Baltic Sea since 1850 and attribution to atmospheric forcing variables

(Kniebusch et al., 2018, in review)

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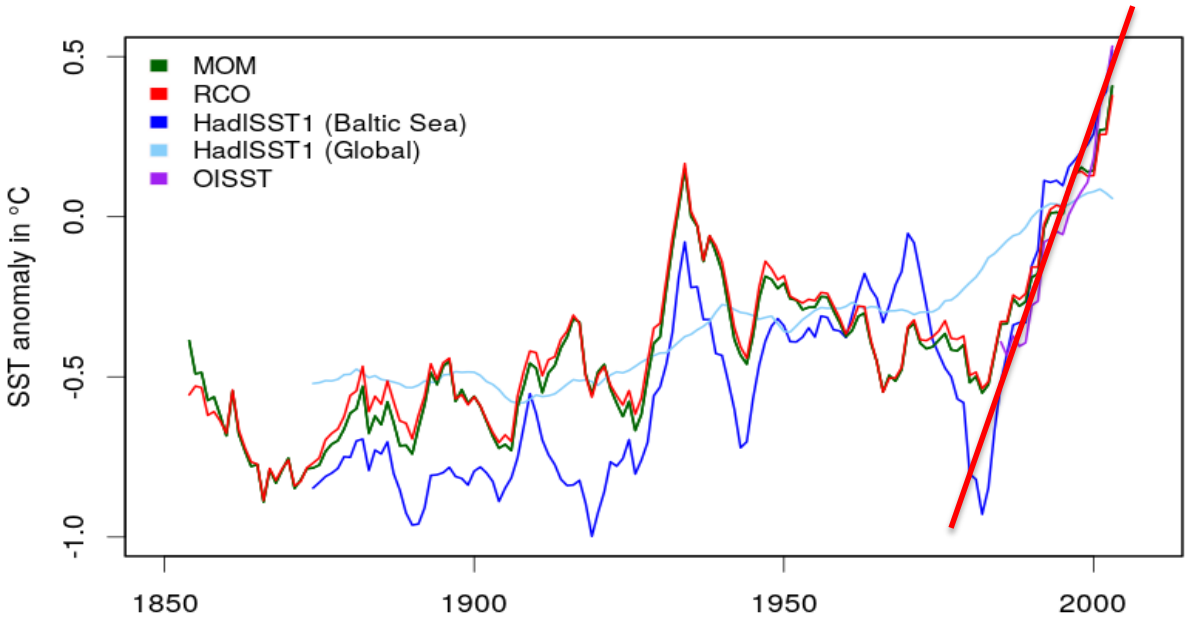
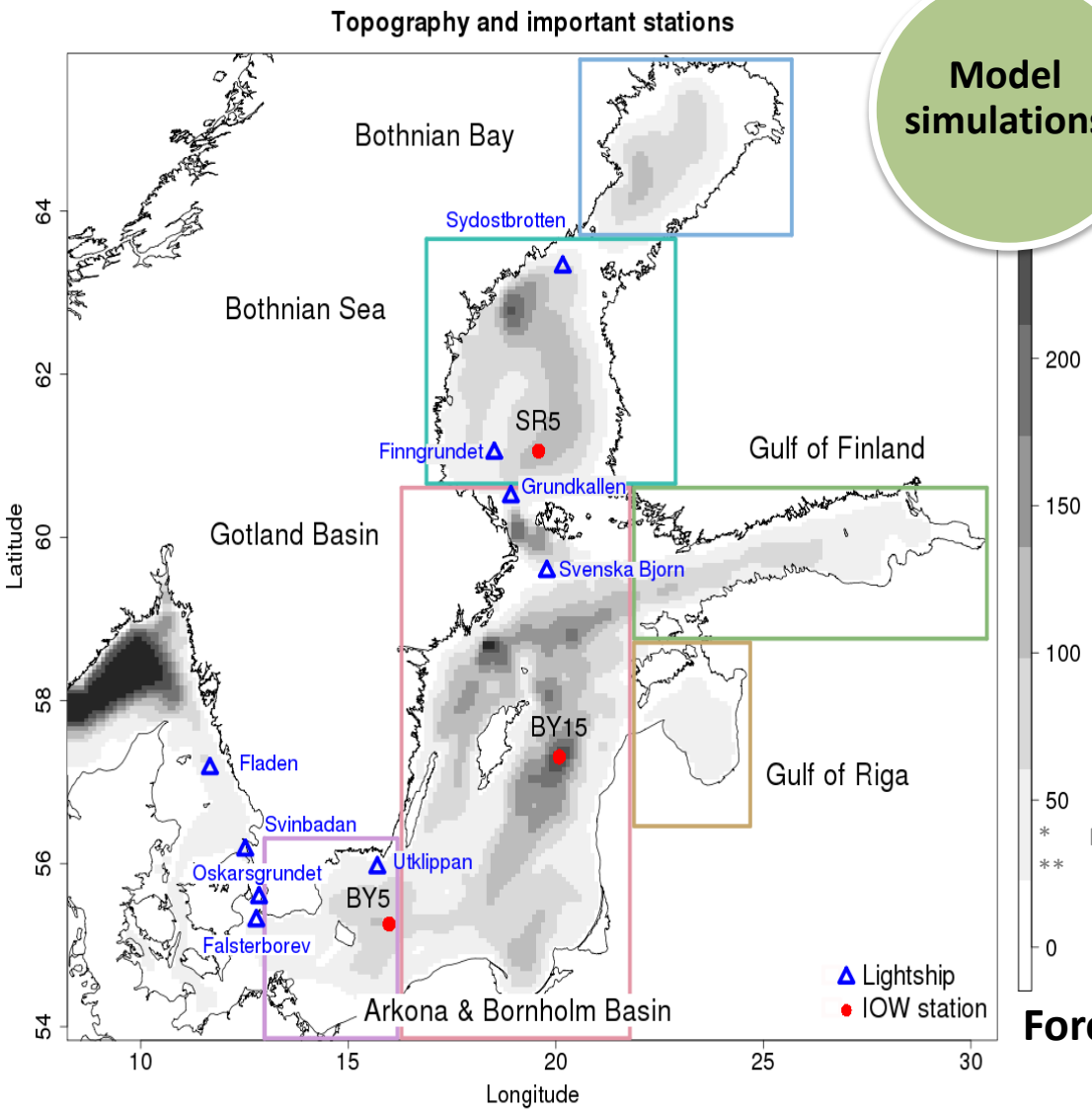
Motivation

- Baltic Sea was the fastest warming large marine ecosystem between 1982-2006 (Belkin, 2009)
- Trends in HadSST1: Baltic Sea mean SST: 0.53 +- 0.27 K/decade
  (Rayner, 2003) global mean SST: 0.11 +- 0.05 K/decade



Model simulations and observational data



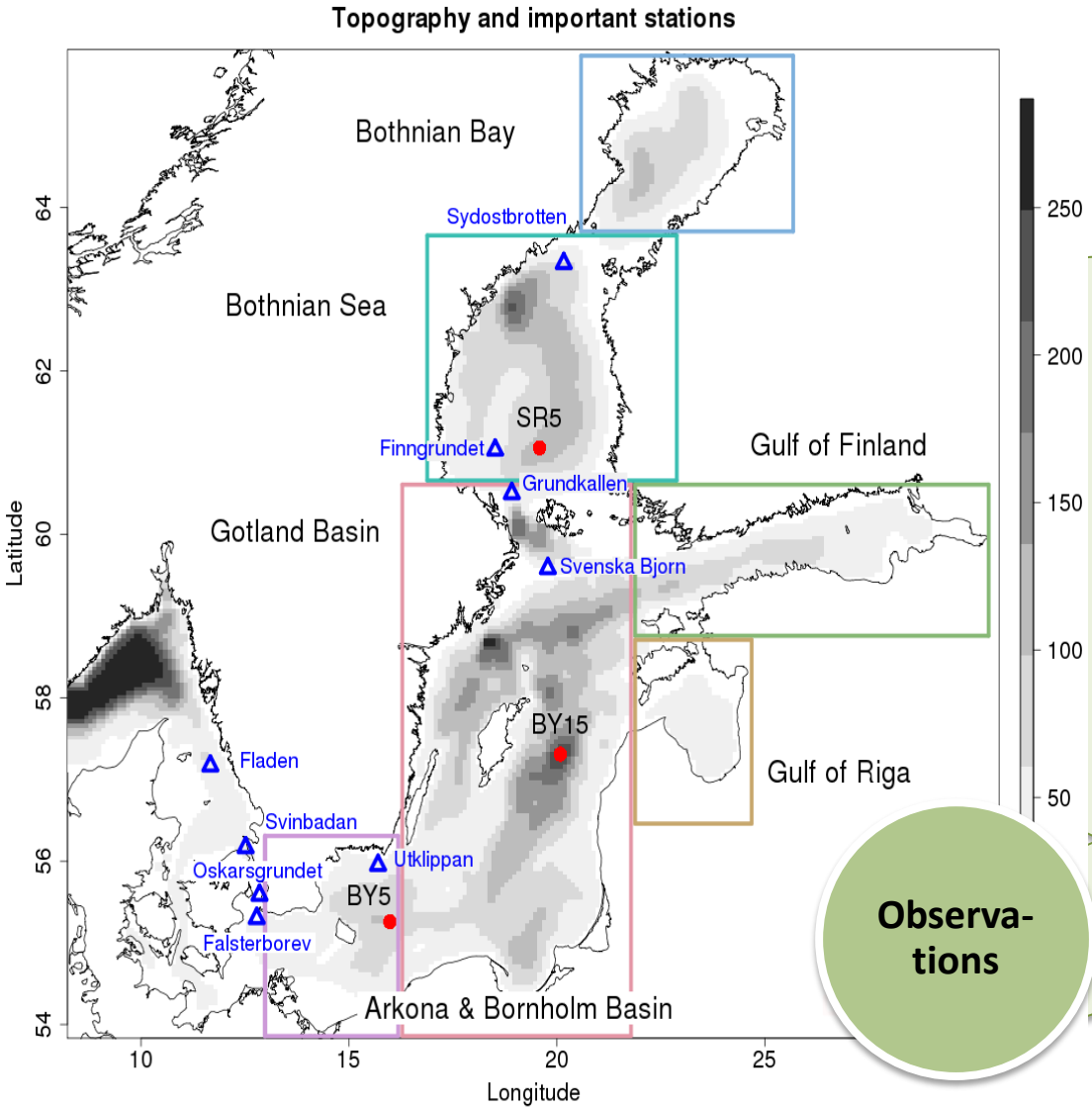
Model simulations

	MOM-Ergom*	RCO-Scobi**
reference	IOW (Neumann & Schernewski 2008)	SMHI (Sweden) (Meier et al. 2003)
spatial resolution (h,v)	3nm, 2m	2nm, 3m
temporal resolution	monthly (stations: hourly)	2 days
time slice	01.02.1850 – 01.08.2009	03.01.1850 – 31.12.2008

Modular Ocean Model & Ecological Regional Ocean Model Rossby Centre Ocean circulation model & Swedish Coastal and Ocean Biogeochemical model

Forcing data: HiResAFF (Schenk & Zorita 2012)

Model simulations and observational data

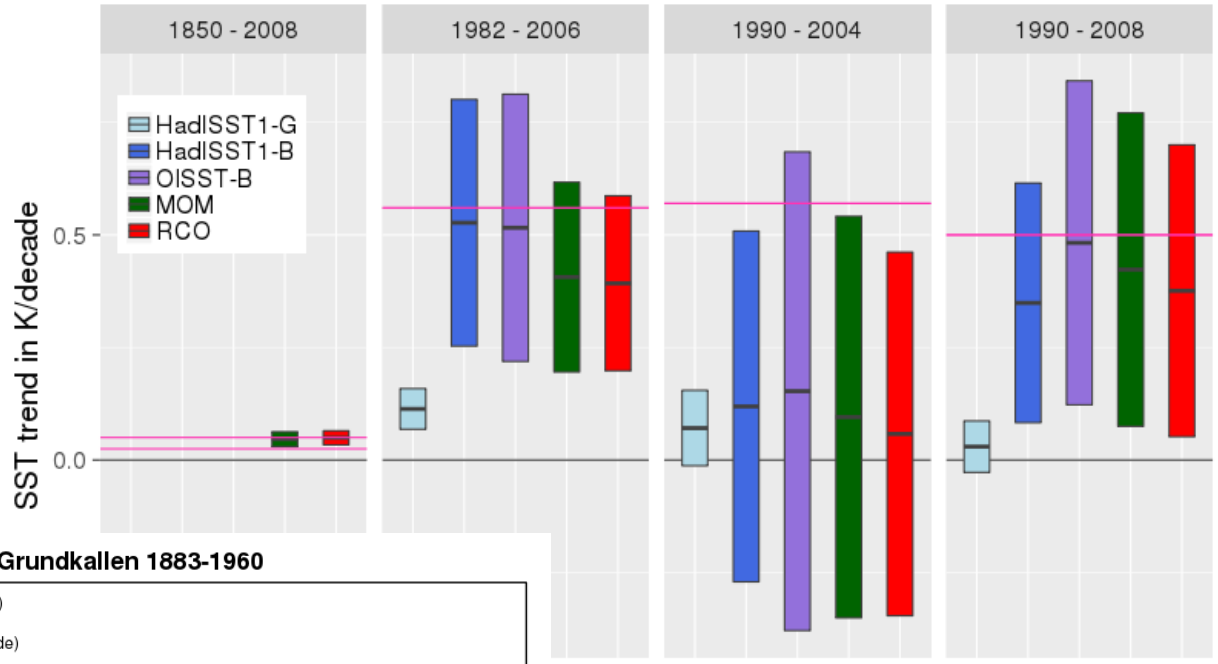


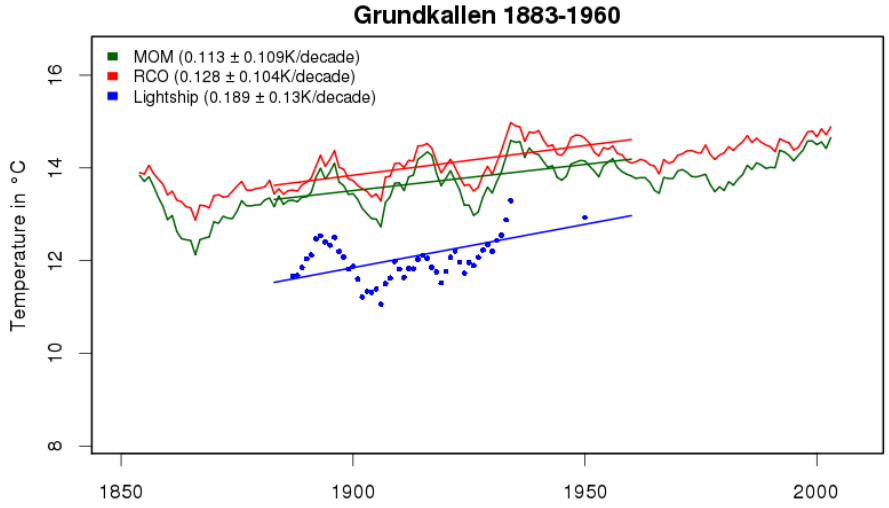
Observa-tions

- in-situ observations (e.g. IOW, BED, SHARK database)
- Satellite data for SST (OISST, Reynolds, 2007)
- Reconstructed SST (HadSST1, Rayner, 2003)
- Lightship data
- Published trend analysises

Detection and attribution of SST trends

SST trends in model results and publications

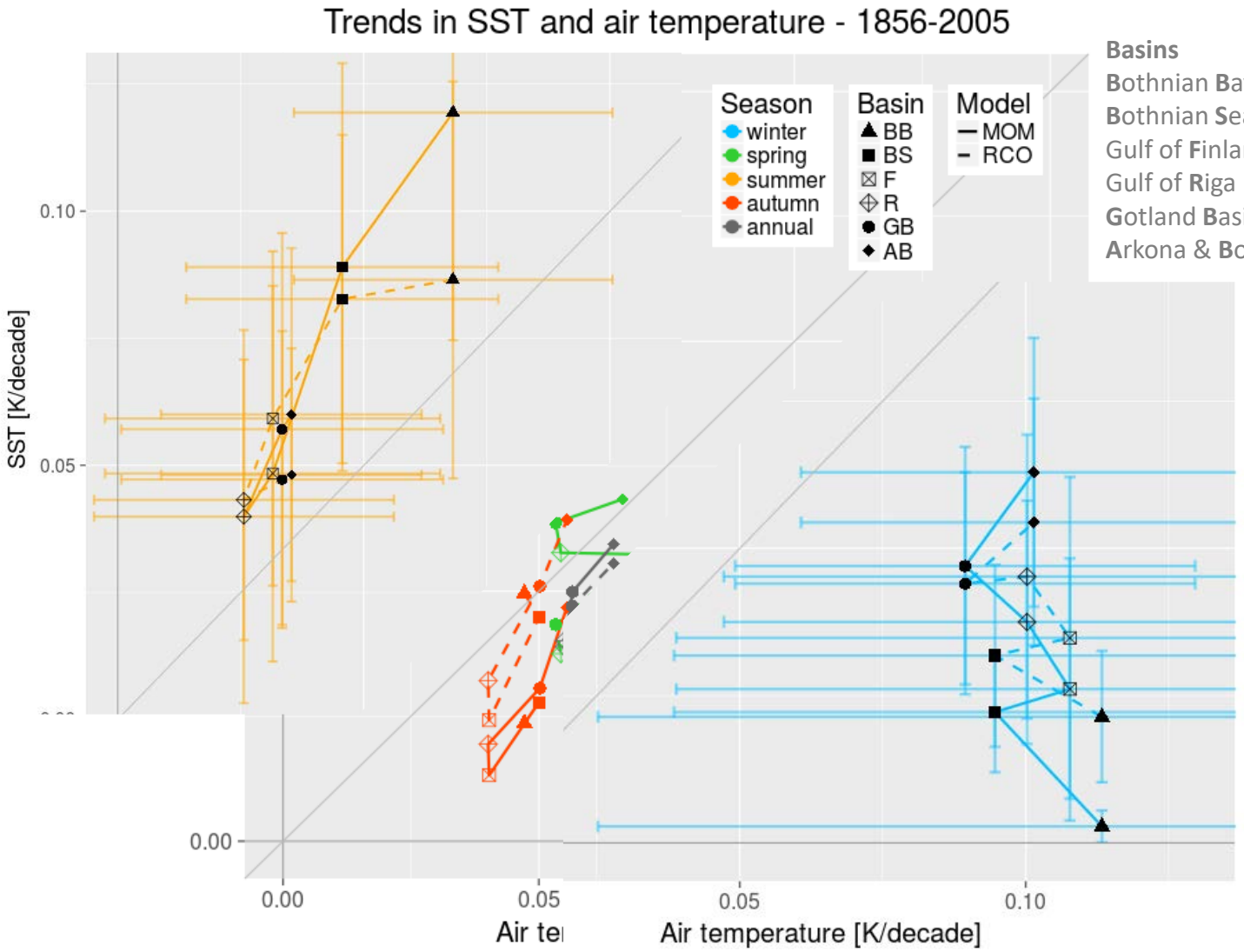




References (left to right):

- Gustavsson et al., 2012
- Belkin, 2009
- Siegel et al., 2006
- Lehmann et al., 2001

Detection and attribution of SST trends

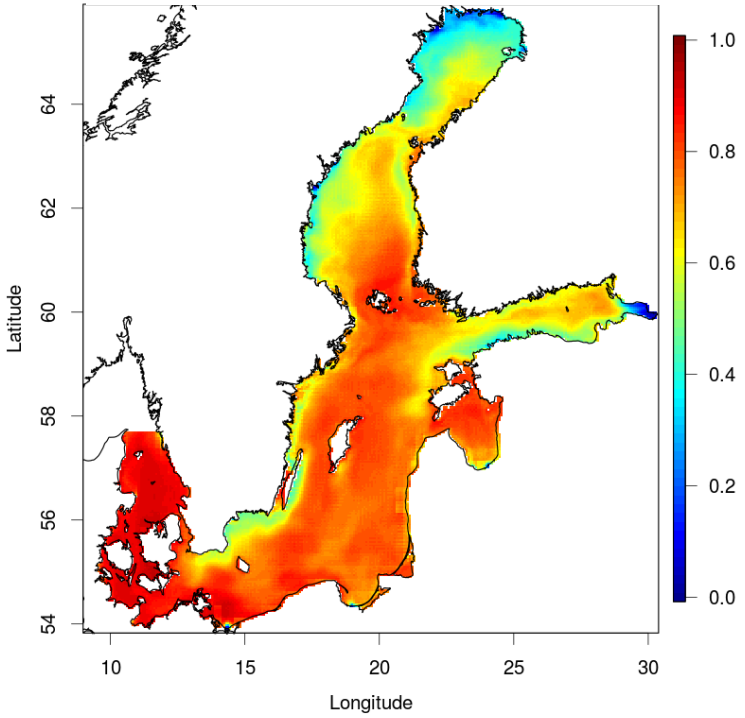


Basins
Bothnian **B**ay
Bothnian **S**ea
Gulf of **F**inland
Gulf of **R**iga
Gotland **B**asin
Arkona & **B**ornholm Basin

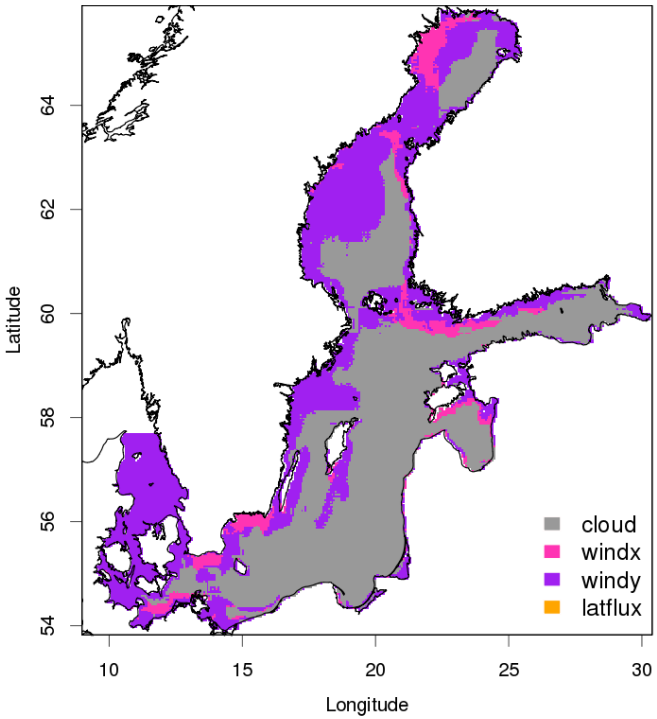
Detection and attribution of SST trends

Cross correlation analysis SST ~ SAT, latent heat flux, wind and cloudiness

Explained variance of annual SST from air temperature



Second important variables due to explained variance of airT-"detrended" SST

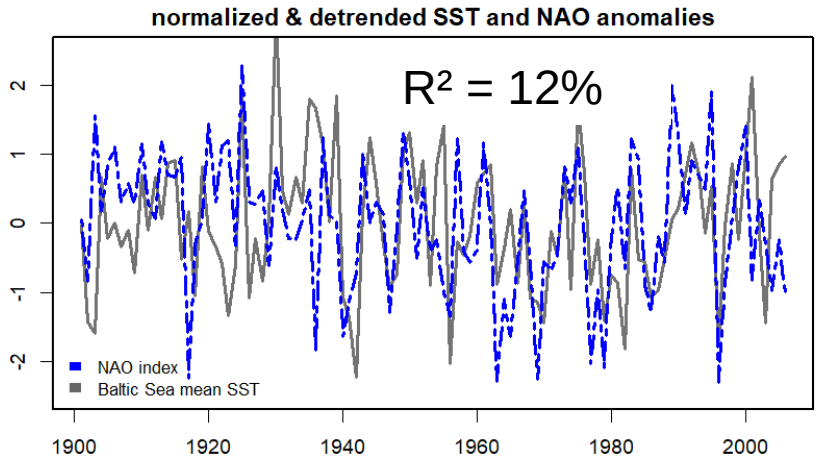


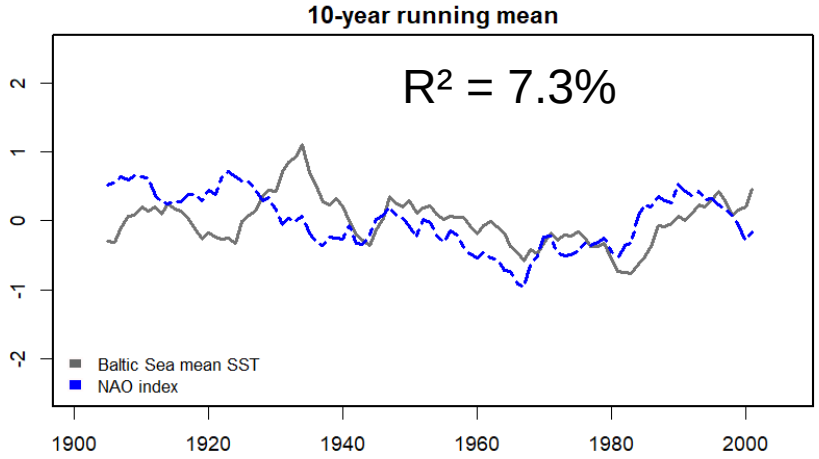
Detection and attribution of SST trends

Comparison with variability in **NAO** and **AMO**

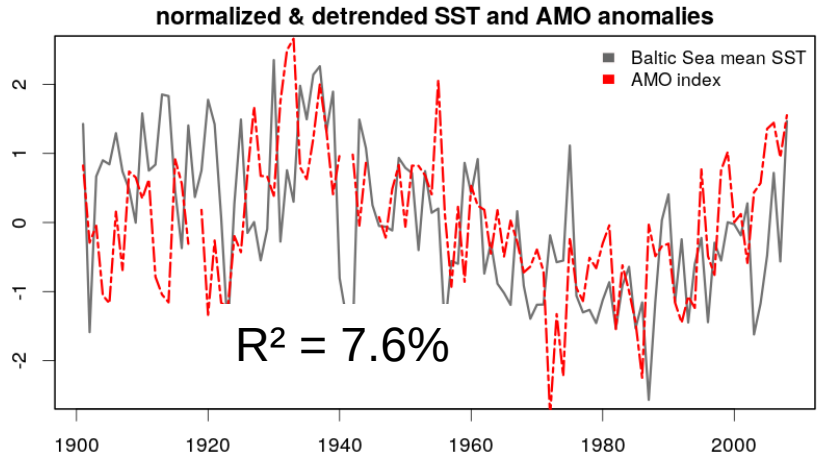
→ why was the Baltic Sea warming so fast since the 1980s?

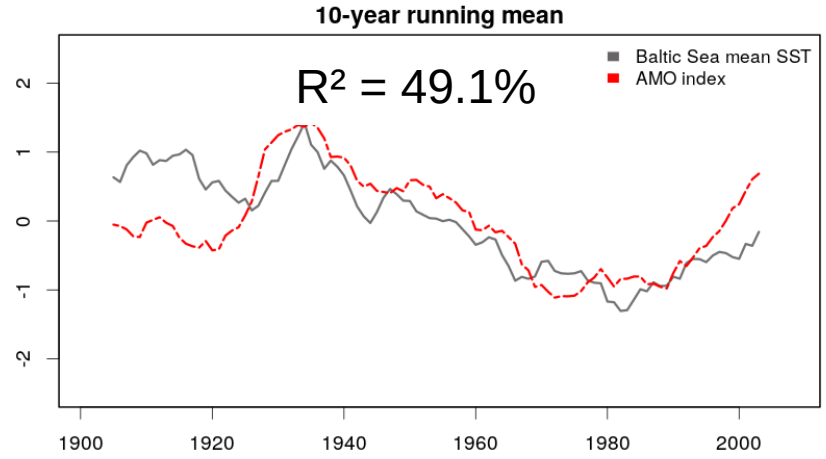
DJF





Annual mean





4. Summary and discussion

- Analysis of two models with same forcing and several observational datasets back to 1850
- Baltic Sea mean SST shows high variability (annually and seasonally) → high uncertainties
- same conclusions from both models although parameterization and resolution are different

Most important drivers:

1. air temperature (sensible heat fluxes & sea ice/freezing point)
2. latent heat flux
3. wind & cloudiness

Reasons for high SST trends since the 1980s:

- Superposition of climate change and increase in AMO index
- polar amplification and semi-enclosed basin

References

- **Belkin**, I. M. Rapid warming of large marine ecosystems. Progress inOceanography, 81 (1), pp. 207–213, **2009**.
- **Gustafsson**, B. G., F. Schenk, T. Blenckner, K. Eilola, H. E. M. Meier, B. Müller-Karulis, T. Neumann, T. Ruoho-Airola, O. P. Savchuk, and E. Zorita: Reconstructing the development of Baltic Sea eutrophication 1850–2006, Ambio, 41(6), 534–548, **2012**.
- **Meier**, H.E.M., Döscher, R., and Faxén, T. A multiprocessor coupled ice-ocean model for the baltic sea: Application to salt inflow. Journal of Geophysical Research: Oceans, 108(C8), **2003**.
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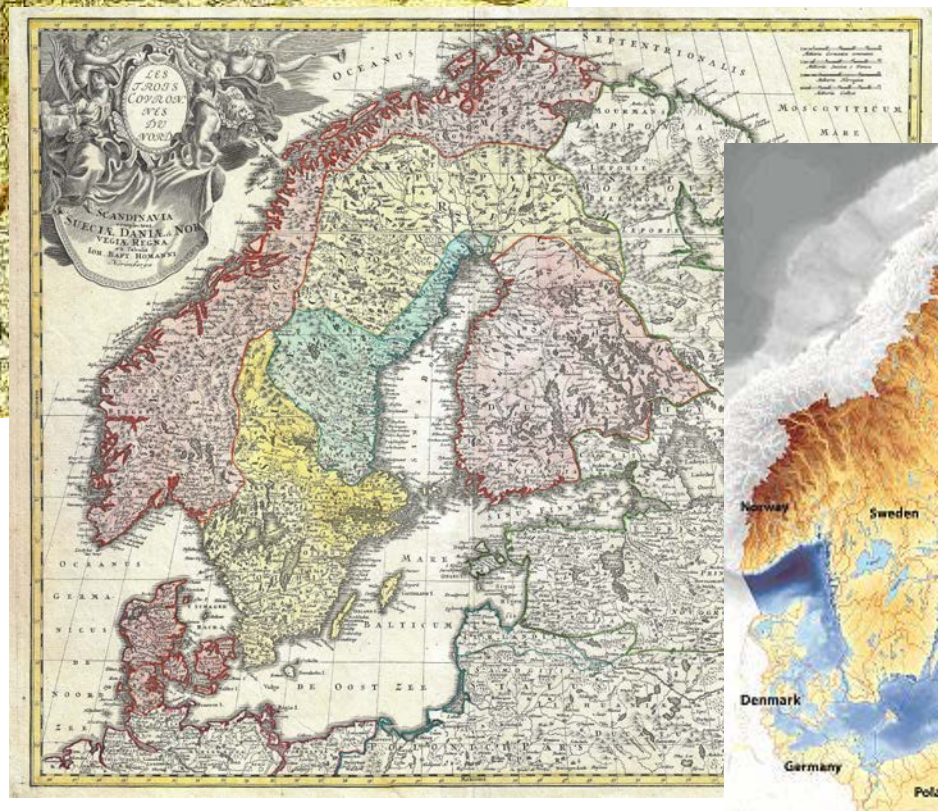
- **Rayner**, N., Parker, D. E., Horton, E., Folland, C., Alexander, L., Rowell, D., Kent, E., and Kaplan, A. Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. Journal of Geophysical Research: Atmospheres, 108(D14), **2003**.
- **Reynolds**, R. W., T. M. Smith, C. Liu, D. B. Chelton, K. S. Casey, and M. G. Schlax: Daily high-resolution-blended analyses for sea surface temperature, Journal of Climate, 20(22), 5473–5496, **2007**
- **Schenk, F. and Zorita**, E. Reconstruction of high resolution atmospheric fields for northern europe using analog-upscaling. Clim. Past Discuss, 8, pp. 819–868, **2012**.
- **Siegel**, H., Gerth, M., and Tschersich, G. Sea surface temperature development of the baltic sea in the period 1990-2004. Oceanologia, 48(S), **2006**.

16th century

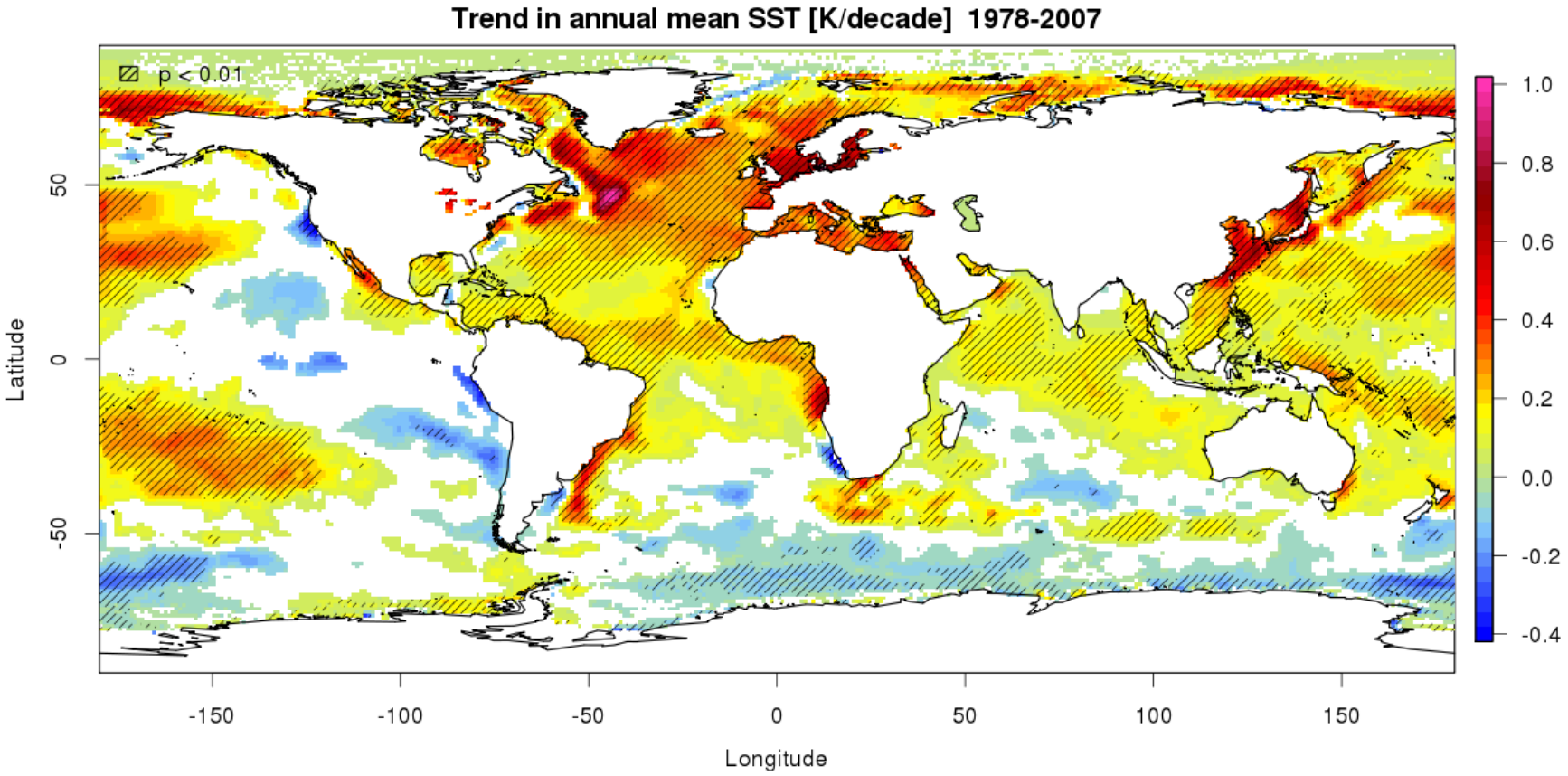
Thank you for your attention!

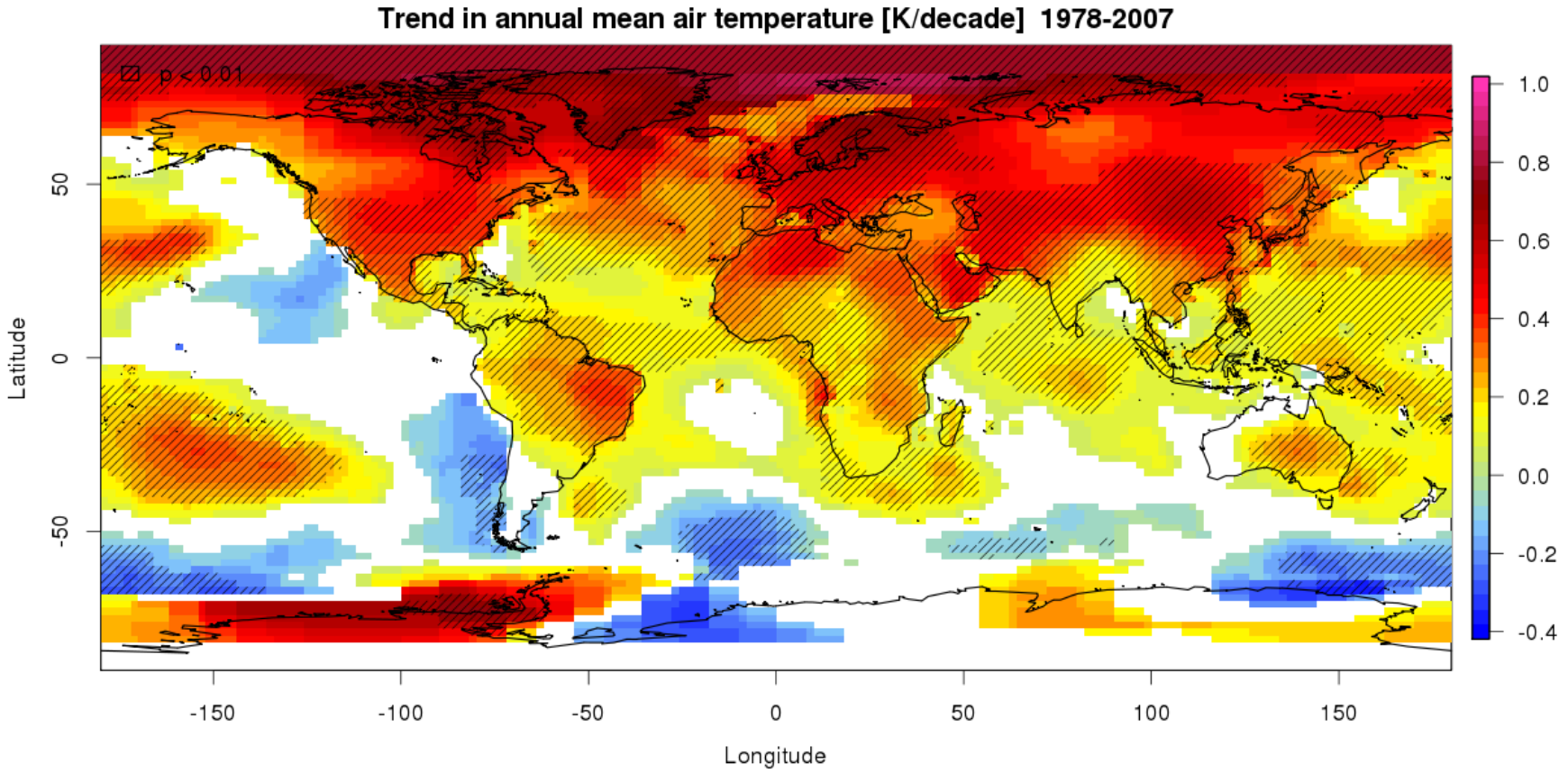


ca. 1715

today

Appendices


Trend in annual mean SST [K/decade] 1978-2007
p < 0.01
Latitude
50
0
-50
-150
-100
-50
0
50
100
150
Longitude
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4


Trend in annual mean air temperature [K/decade] 1978-2007
p < 0.01
Latitude
50
0
-50
-150
-100
-50
0
50
100
150
Longitude
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4

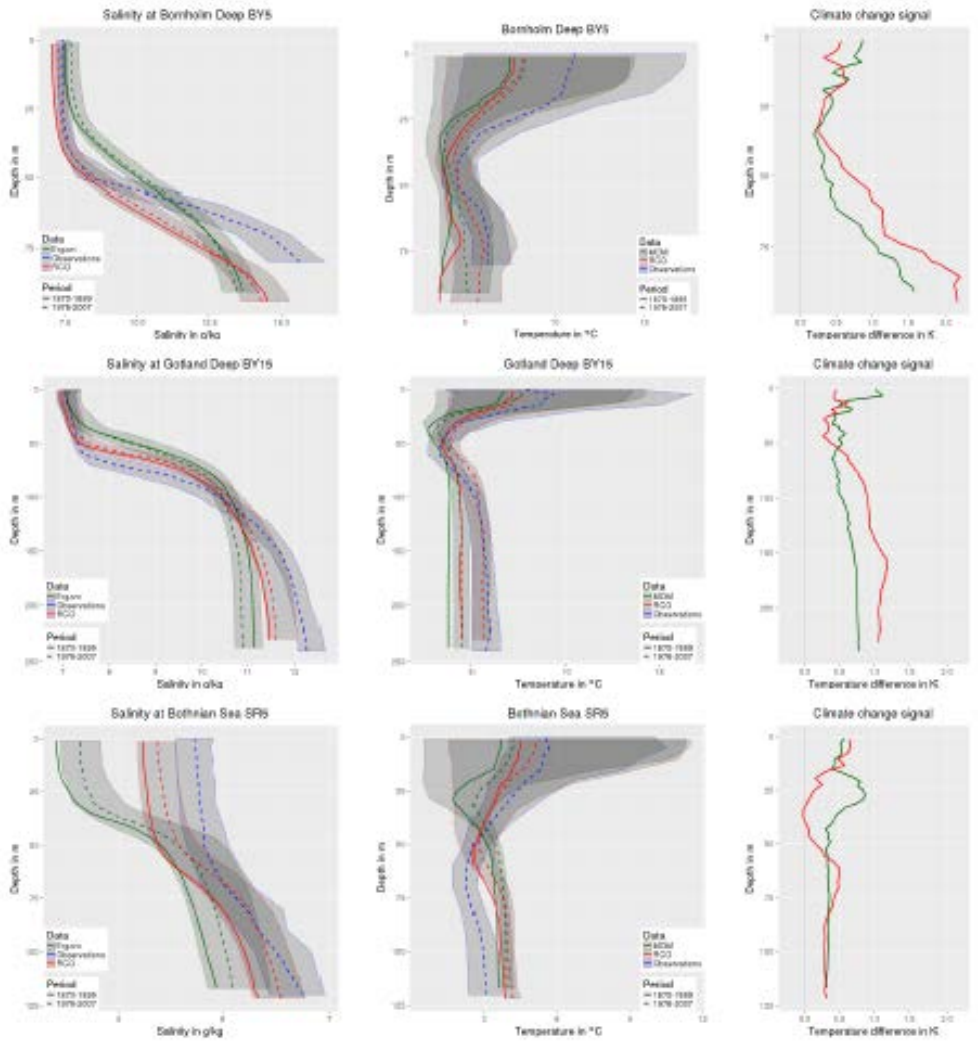
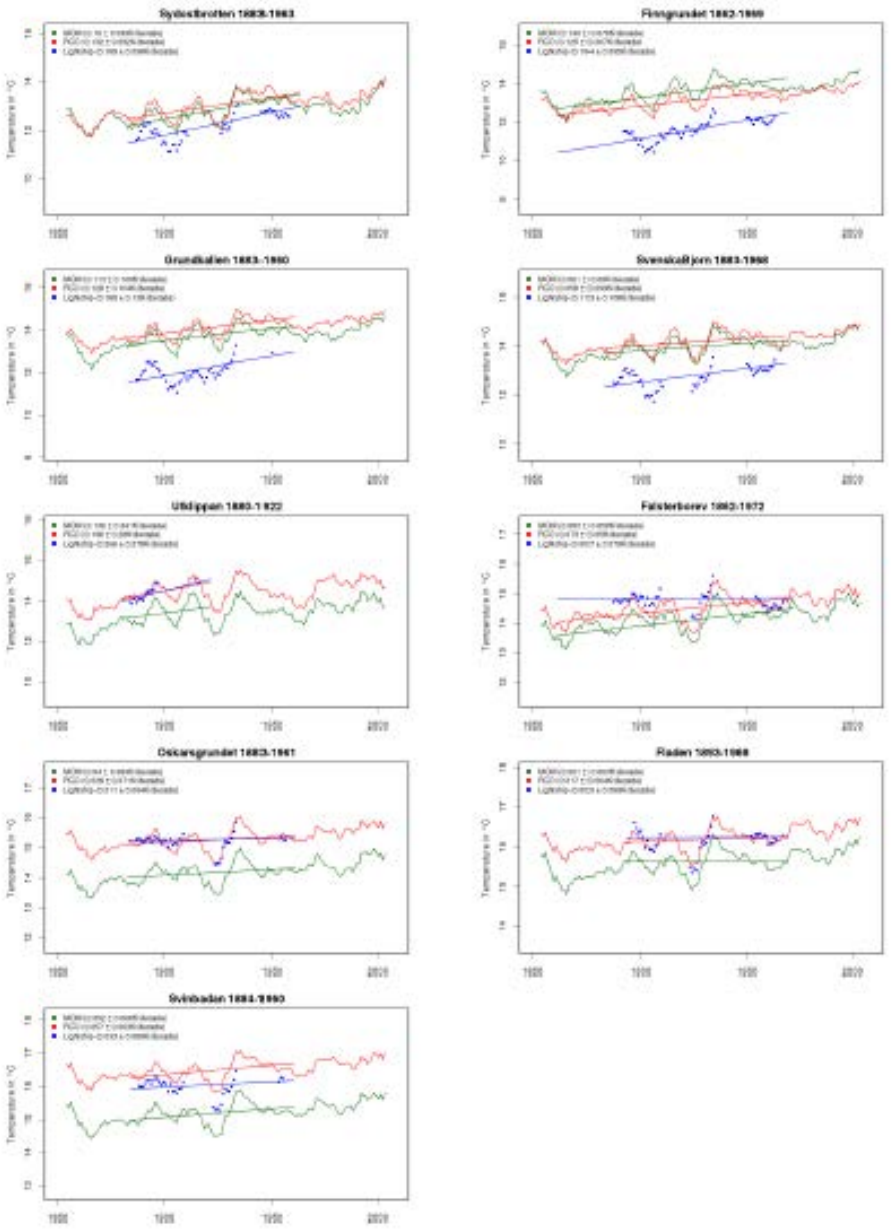
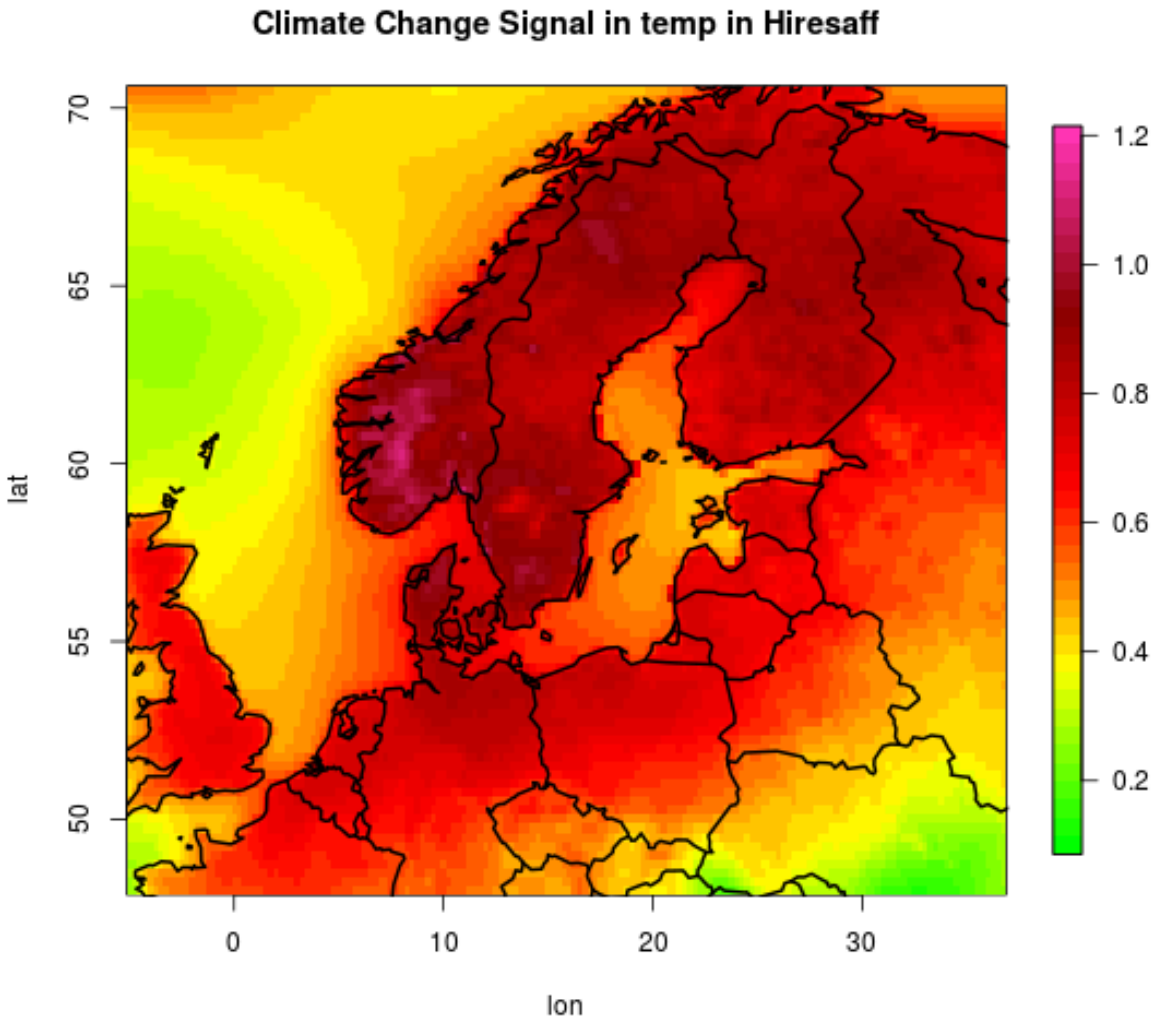


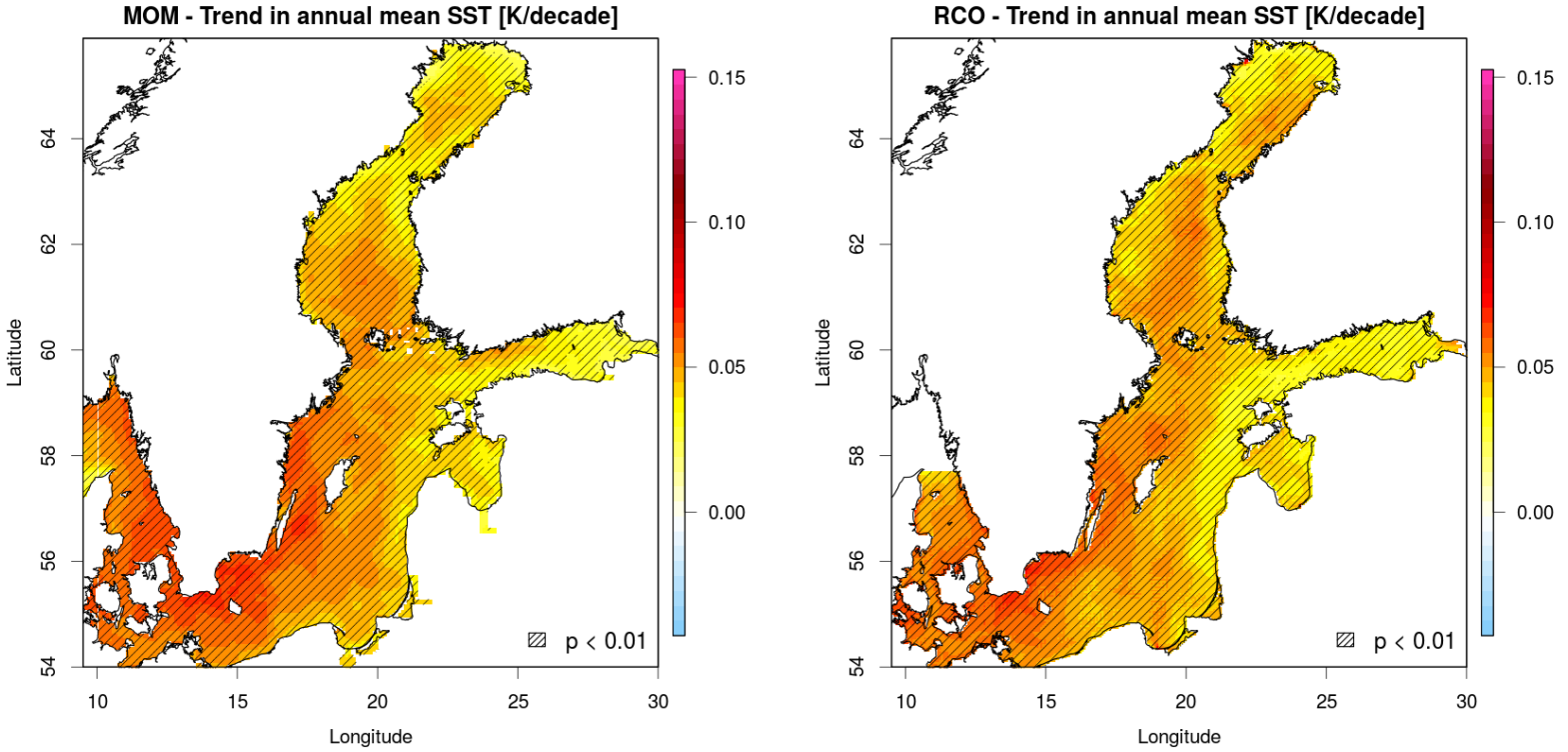
Figure 2: Median and 25/75. percentiles of Temperature and Salinity profiles in both simulations and from the observations (1978-2007). In the right figures, the climate change signal in temperature comparing the periods 1870-1899 and 1978-2007




Climate Change Signal in temp in Hiresaff
lat
70
65
60
55
50
0
10
20
30
lon
1.2
1.0
0.8
0.6
0.4
0.2

1st main author Paper – Detection and attribution of SST trends

1856-2005



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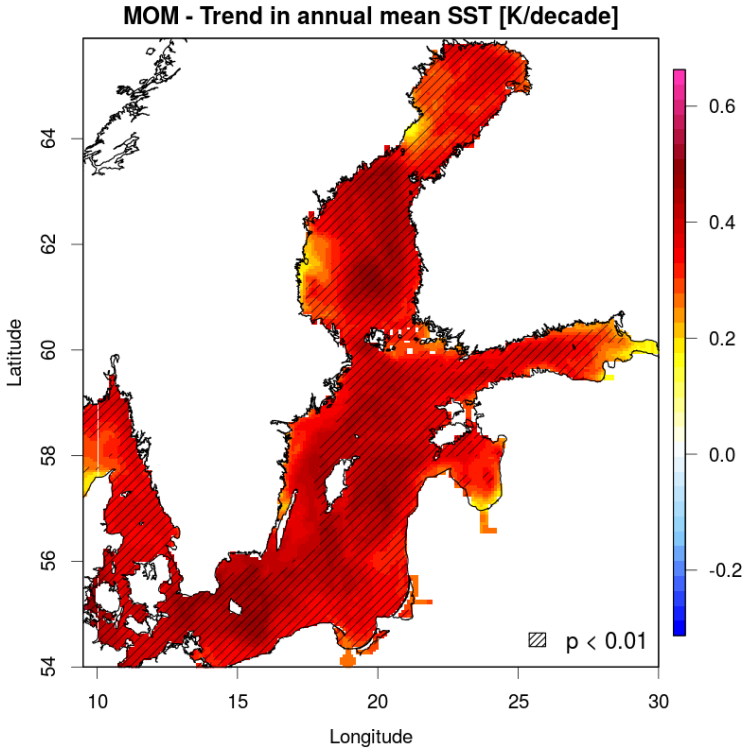
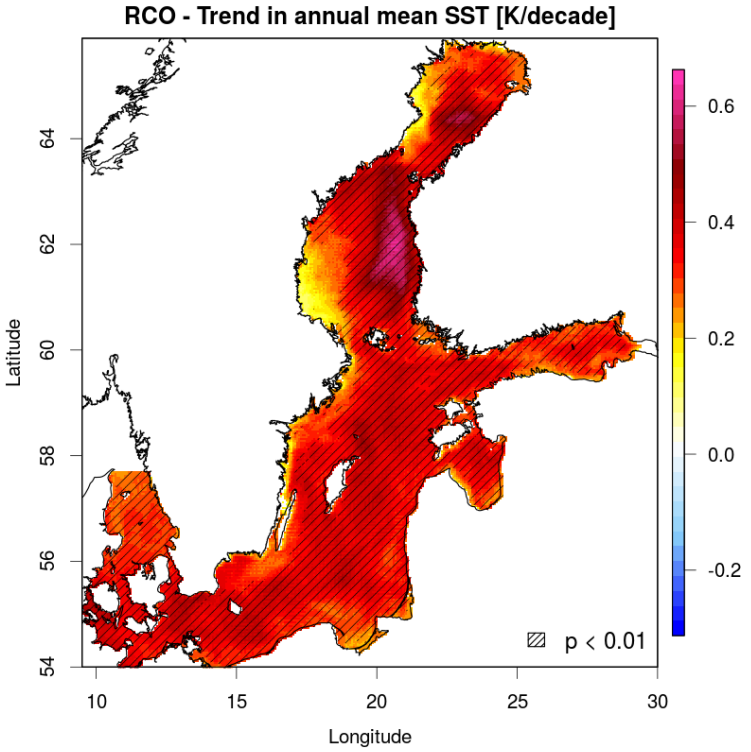
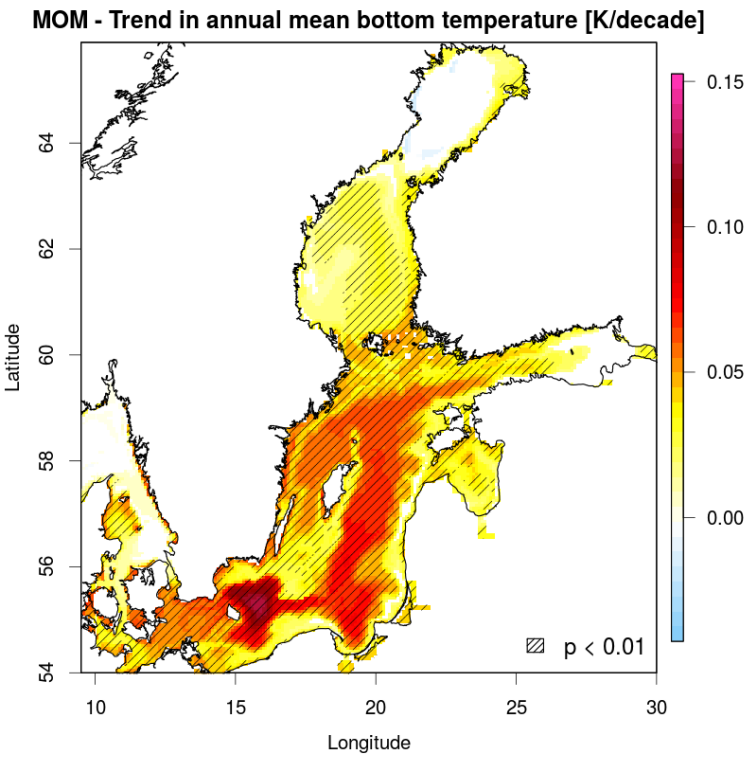
1978-2007

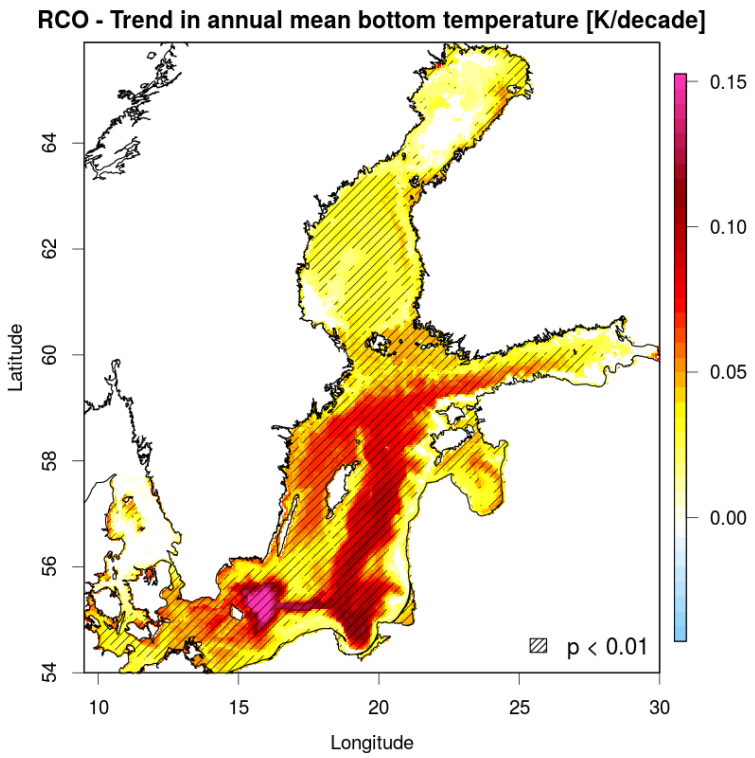




Spatial distribution of bottom temperature trends

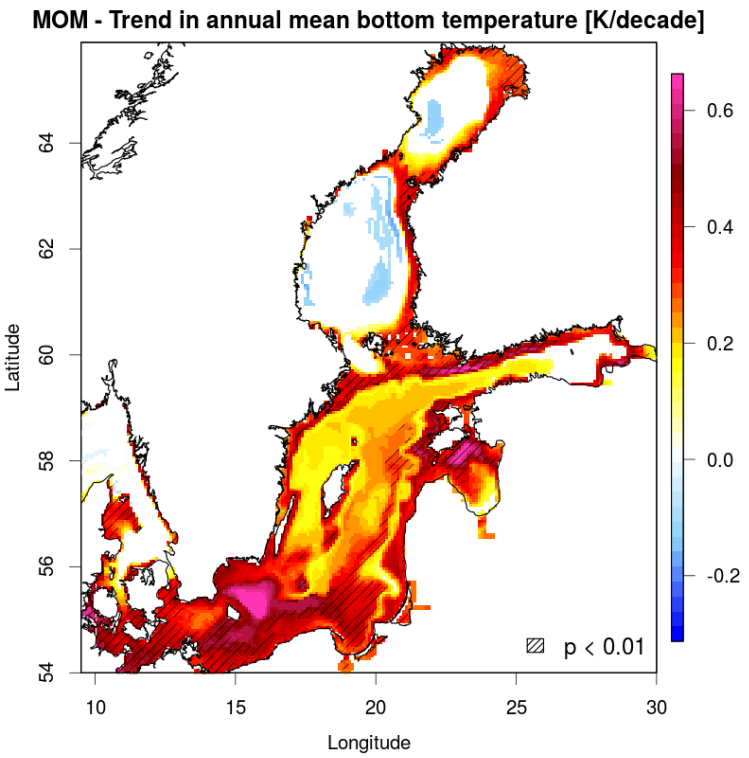
1856-2005

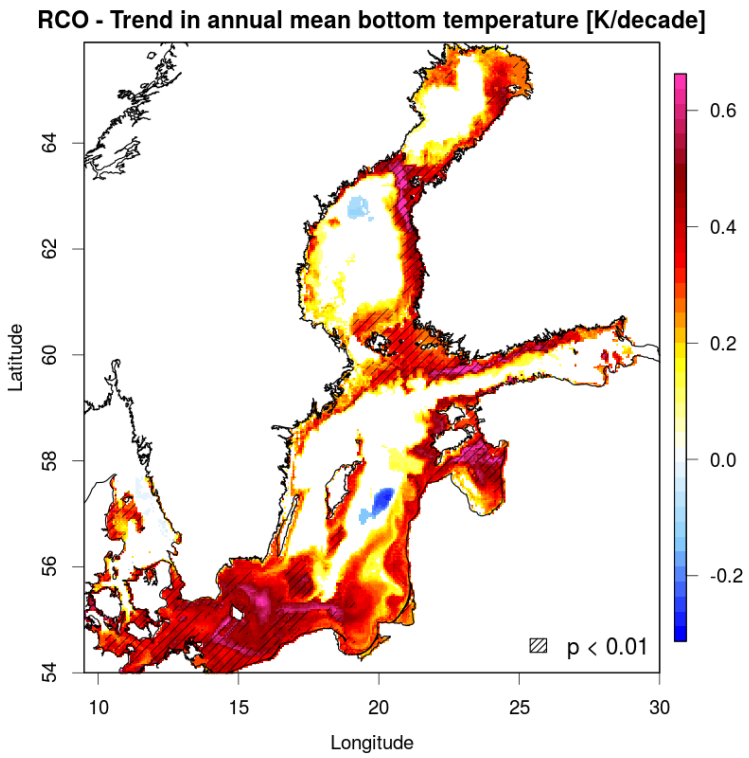




Spatial distribution of bottom temperature trends

1978-2007





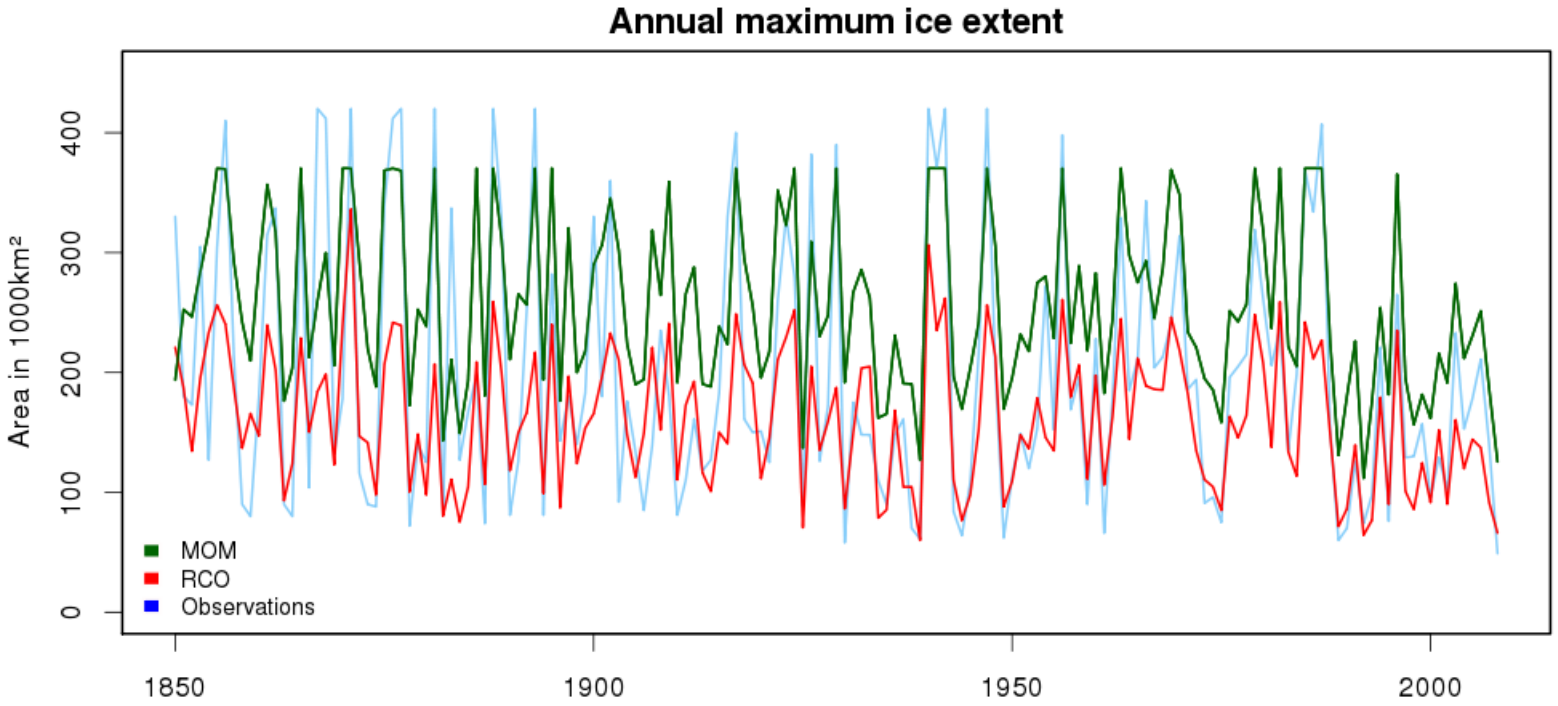
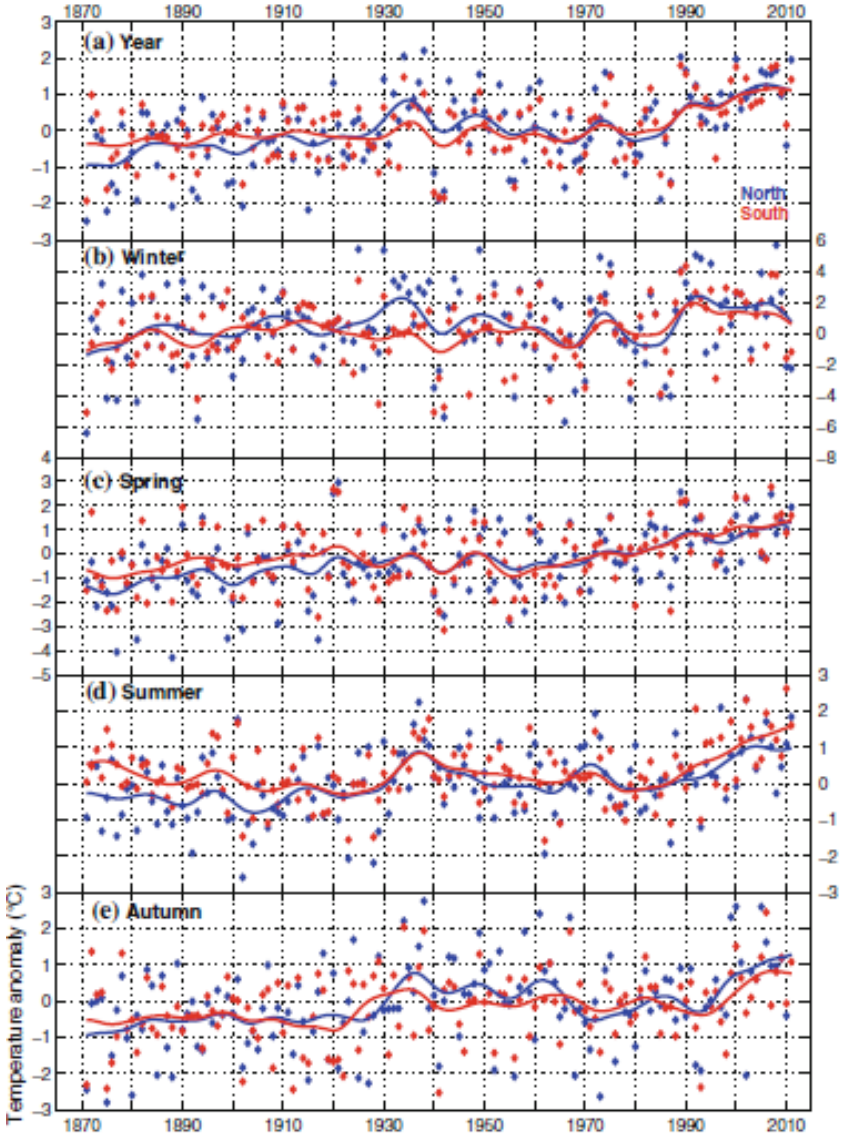
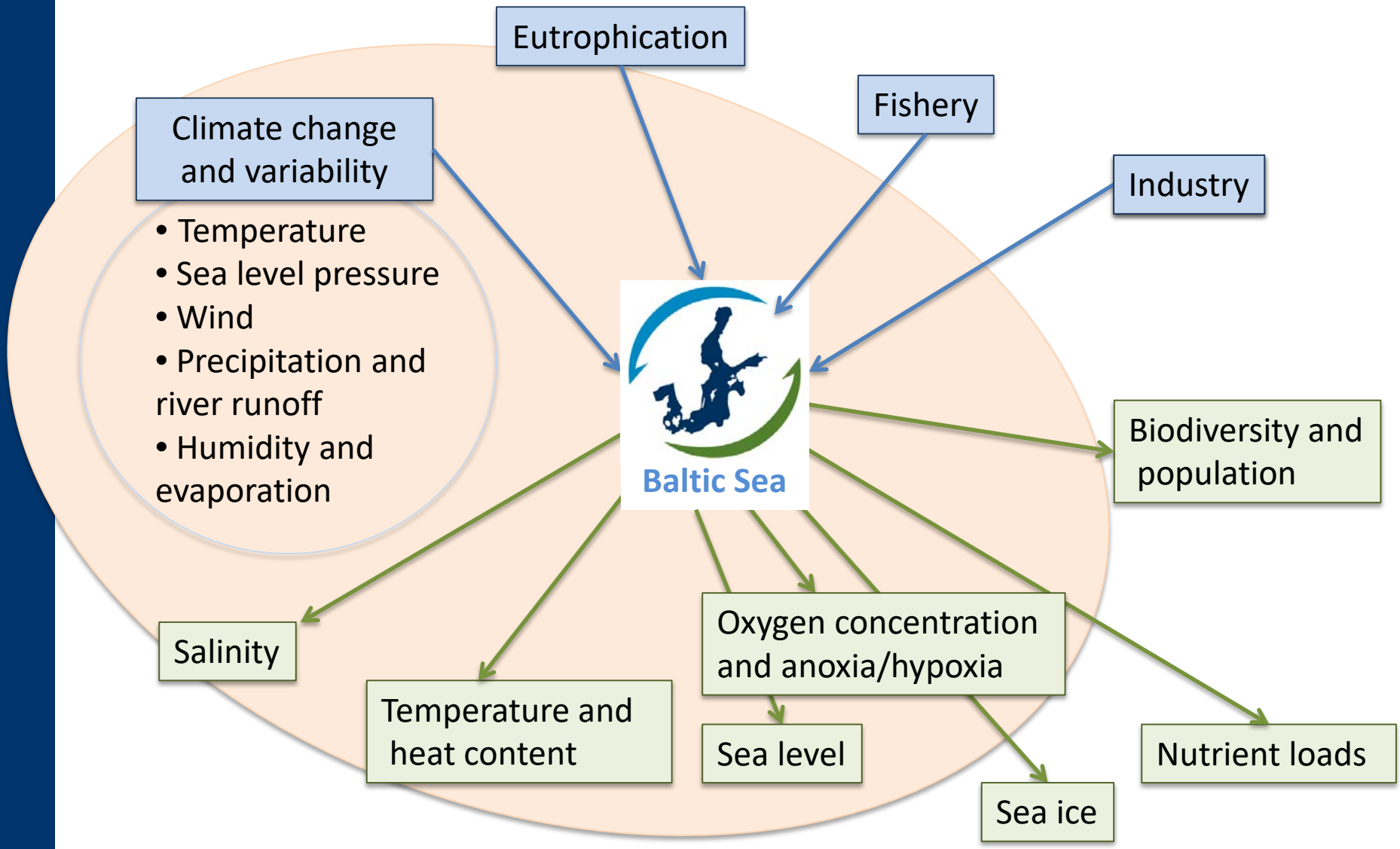

Annual maximum ice extent
Area in 1000km²
0
100
200
300
400
1850
1900
1950
2000
MOM
RCO
Observations

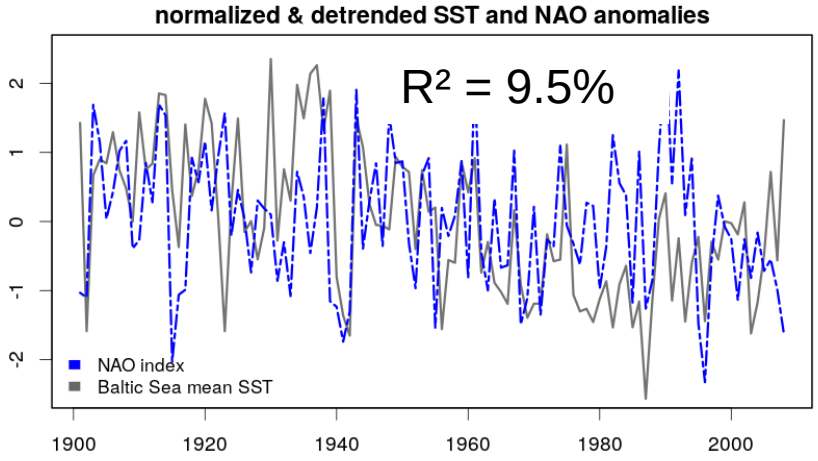
Fig. 1.1 Annual and seasonal mean surface air temperature anomalies (relative to 1960–1991) for the Baltic Sea basin 1871–2011, calculated from 5° by 5° latitude, longitude box average taken from the CRUTEM3v data set (Brohan et al. 2006) based on land stations (from *top* to *bottom* **a** annual, **b** winter (DJF), **c** spring (MAM), **d** summer (JJA), **e** autumn (SON)). *Blue* comprises the Baltic Sea basin north of 60°N, and *red* south of 60°N. The *dots* represent individual years, and the *smoothed curves* (Gaussian filter, $\sigma = 3$) highlight variability on timescales longer than 10 years

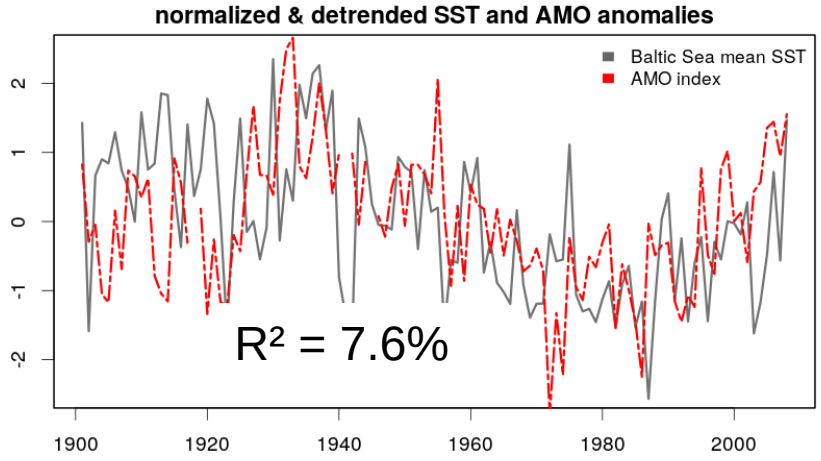


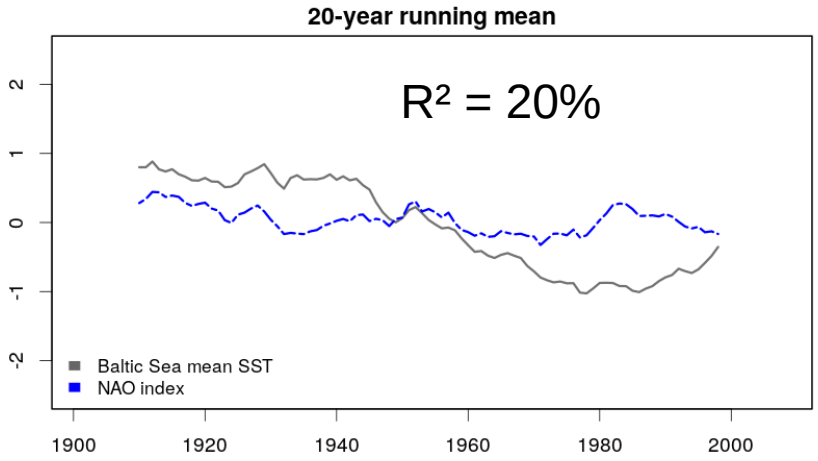

Eutrophication
Fishery
Industry
Climate change and variability
• Temperature
• Sea level pressure
• Wind
• Precipitation and river runoff
• Humidity and evaporation
Baltic Sea
Biodiversity and population
Salinity
Oxygen concentration and anoxia/hypoxia
Temperature and heat content
Sea level
Nutrient loads
Sea ice

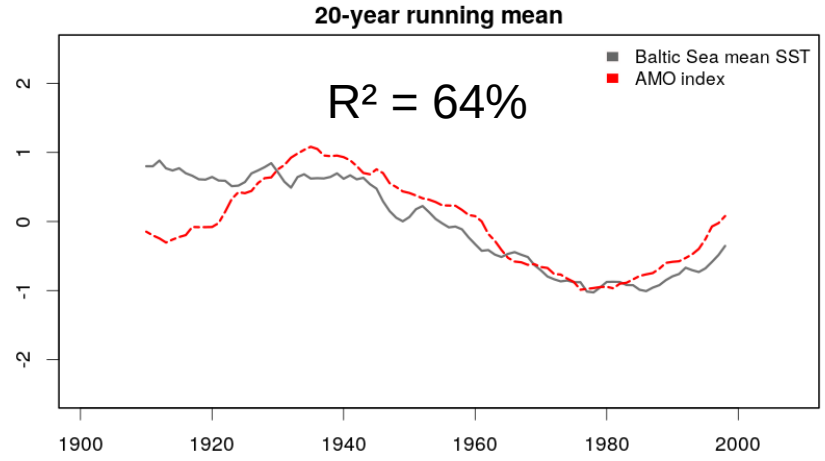
Why was the Baltic Sea warming so fast since 1982?

Comparison with NAO and AMO









Outline

1. Model Setup
2. Detection and attribution of temperature trends
3. Accelerated trends since 1980s
4. Summary and discussion
5. References