Detection and attribution of climate change for the Baltic Sea Region – a discussion of progress

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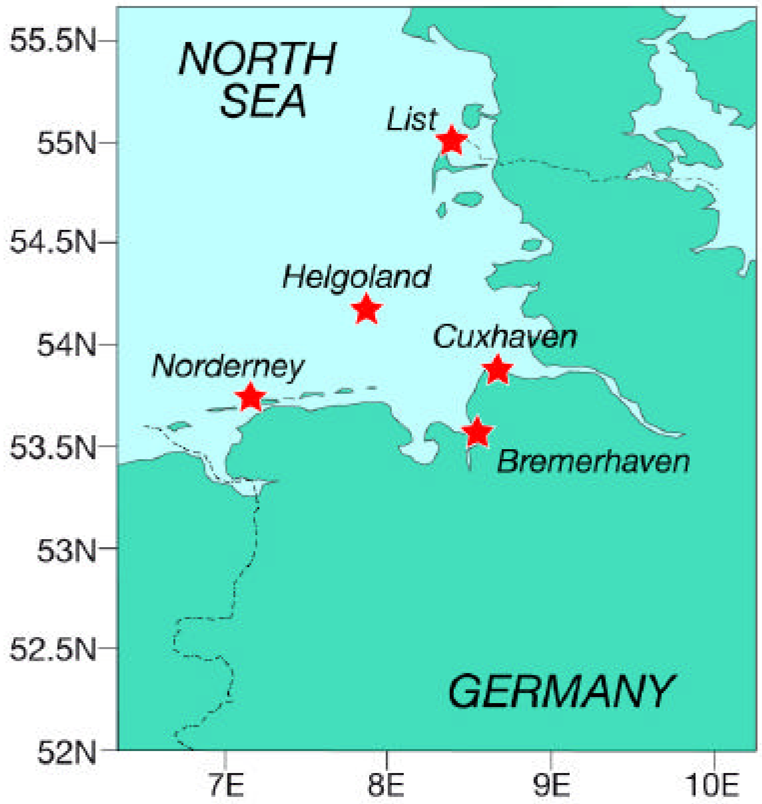
Assessing change

- First task: Describing change
- Second task: “**Detection**” - Assessing change if consistent with natural variability (does the explanation need invoking external causes?)
- Third task: “**Attribution**” – If the presence of a cause is “detected”, determining which mix of causes describes the present change best

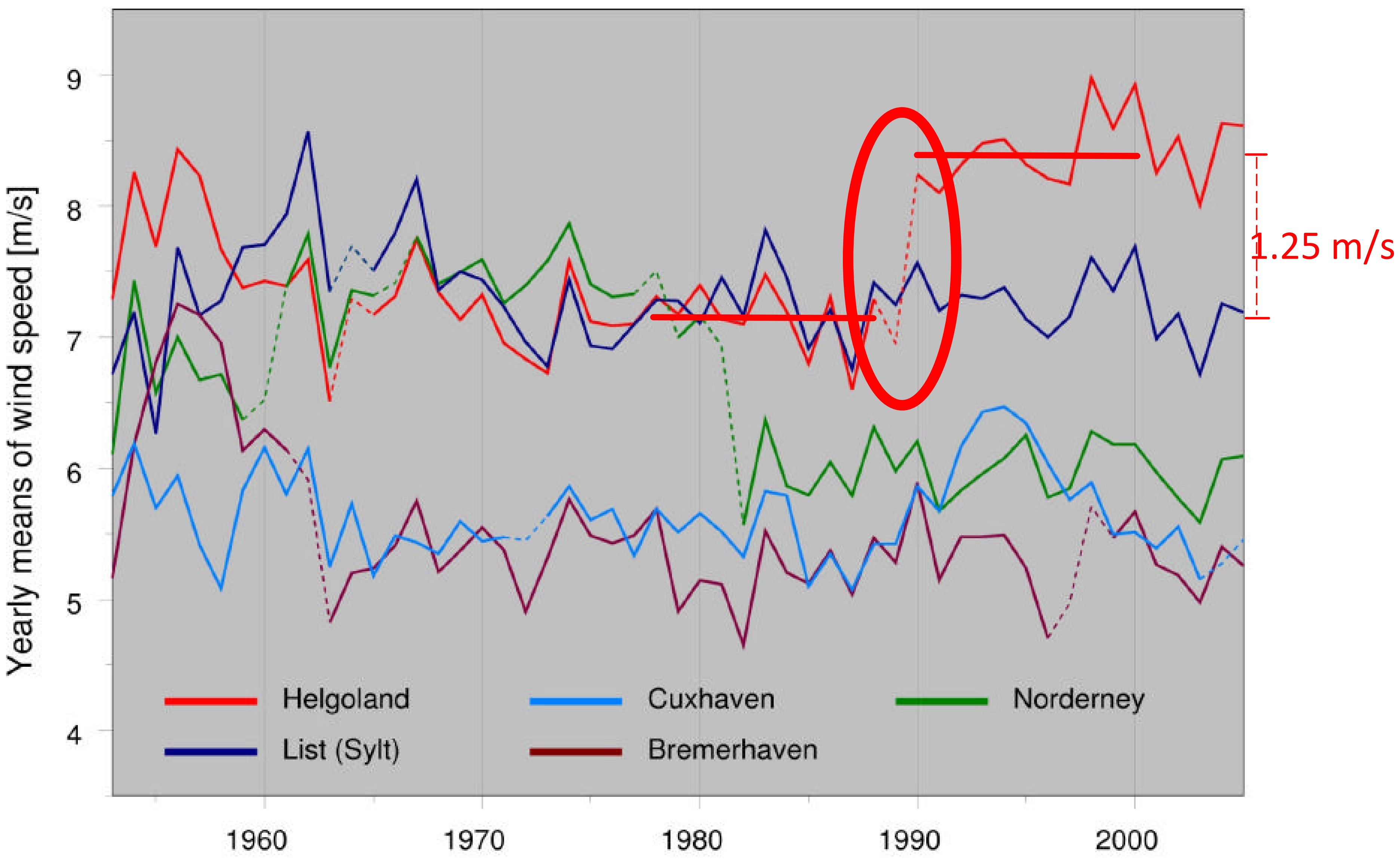
First task: Example of inhomogeneous data



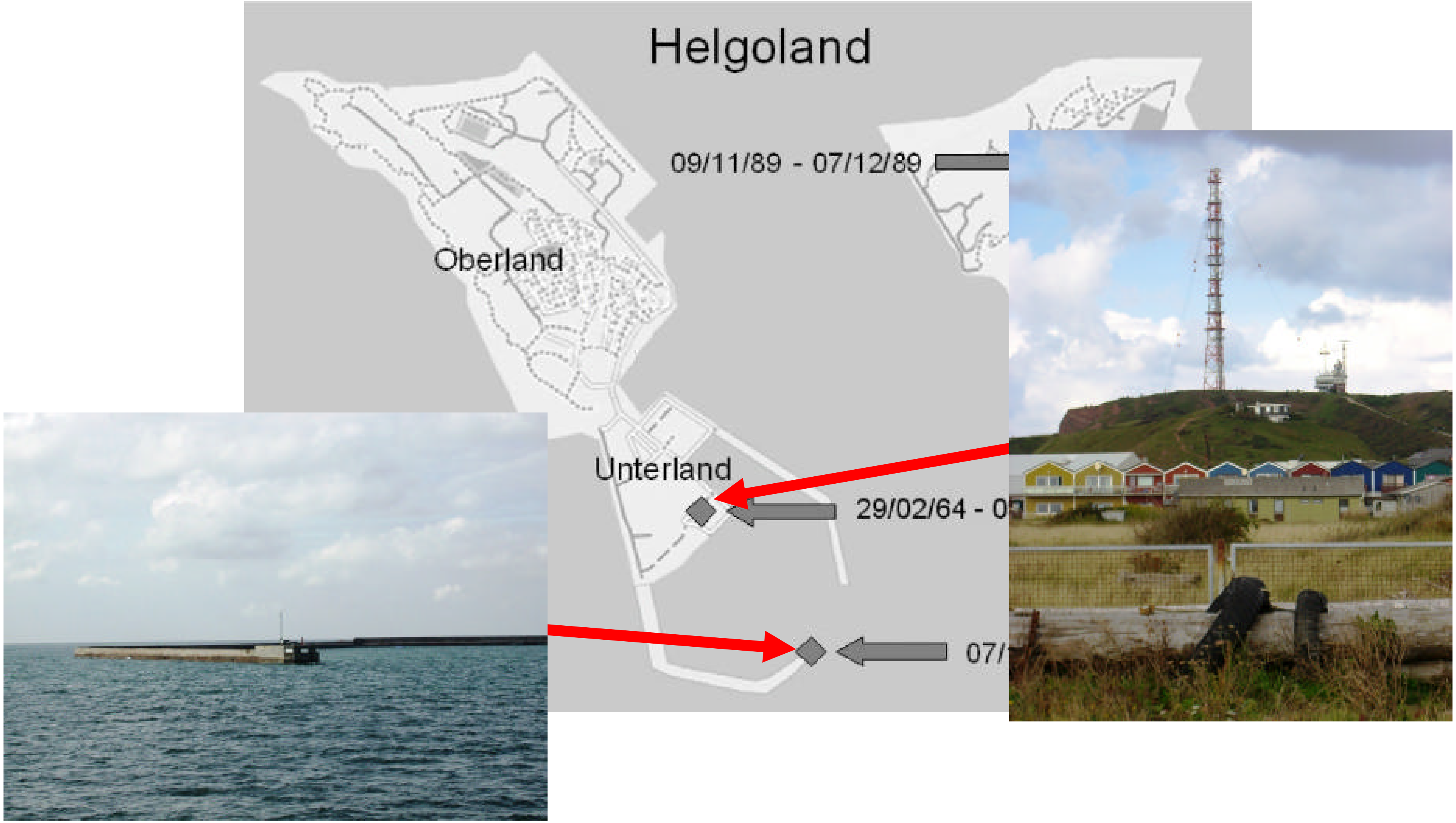
- **Wind speed measurements**
  - SYNOP Measuring net (DWD)
  - Coastal stations at the German Bight
  - Observation period: 1953-2005

This and the next 3 transparencies:
Janna Lindenberg, HZG

First task: Inhomogeneity of wind data



First task: Inhomogeneity of wind data



The issue is deconstructing a given record

with the intention to identify „predictable“ components.

„Predictable“

-- either natural processes, which are known of having limited life times,

-- or man-made processes, which are subject to decisions (e.g., GHG, urban effect)

„Significant“ trends

Often, an anthropogenic influence is assumed to be in operation when trends are found to be „significant“.

• If the null-hypothesis is correctly rejected, then the conclusion to be drawn is – *if the data collection exercise would be repeated, then we may expect to see again a similar trend*.

• Example: N European warming trend “April to July” as part of the seasonal cycle.

• It does not imply that the trend will continue into the future (beyond the time scale of serial correlation).

• Example: Usually September is cooler than July.

„Significant“ trends

Establishing the statistical significance of a trend may be a necessary condition for claiming that the trend would represent evidence of anthropogenic influence.

Claims of a continuing trend require that the dynamical cause for the present trend is identified, and that the driver causing the trend itself is continuing to operate.

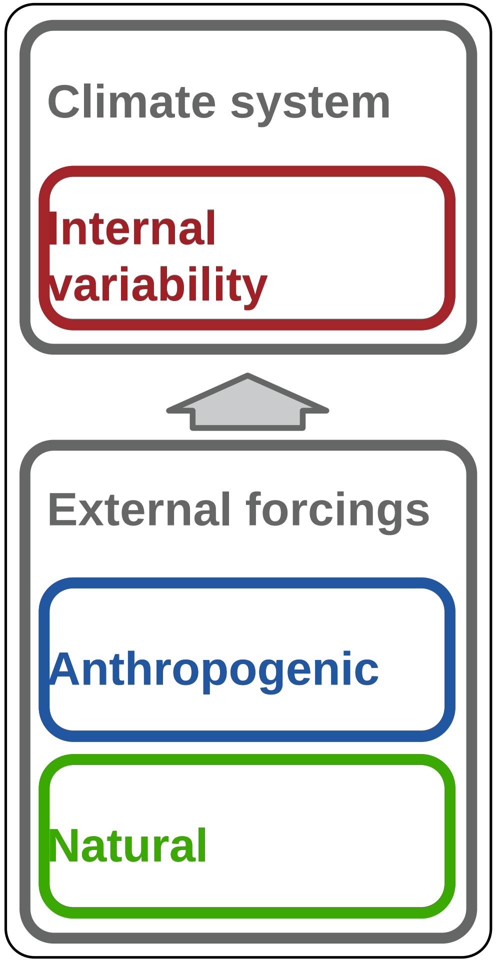
Thus, claims for extension of present trends into the future require
- empirical evidence for an ongoing trend, and
- theoretical reasoning for driver-response dynamics, and
- forecasts of future driver behavior.

Detection and attribution of non-natural ongoing change

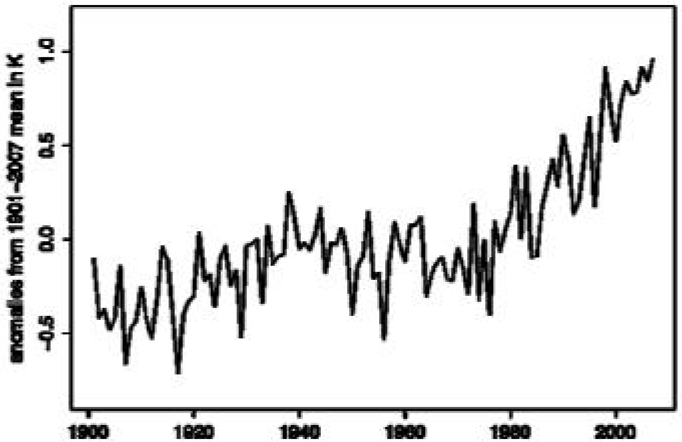
- Detection of the presence of non-natural signals: rejection of null hypothesis that recent trends are drawn from the distribution of trends given by the historical record. Statistical proof.

- Attribution of cause(s): Non-rejection of the null hypothesis that the observed change is made up of a sum of given signals. Plausibility argument.

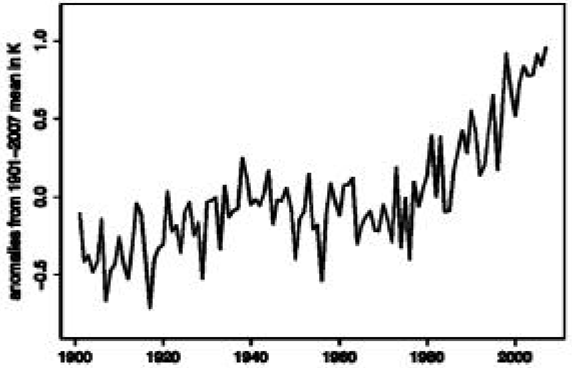
Detection and attribution



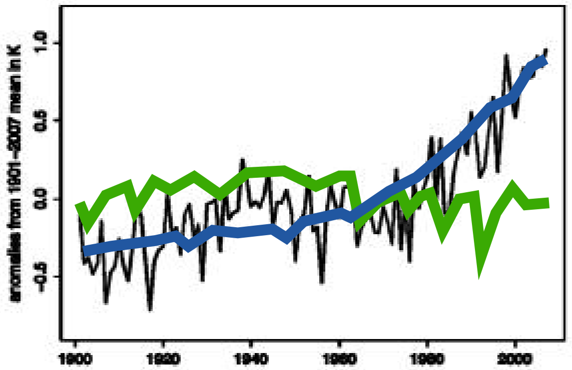
Observations



Detection



Attribution



Dimension of D&A

- **Purely scientific**
- Statistical rigor (D) and plausibility (A).
- D depends on assumptions about “internal variability”
- A depends on model-based concepts.
- Thus, *remaining doubts* exist beyond the specified.

Detection

Detection is the successful process of demonstrating that an event (in particular a trend) is not within the range of natural (or otherwise controlled) variability. **Successful detection means: there is a cause at work, which needs to be determined.**

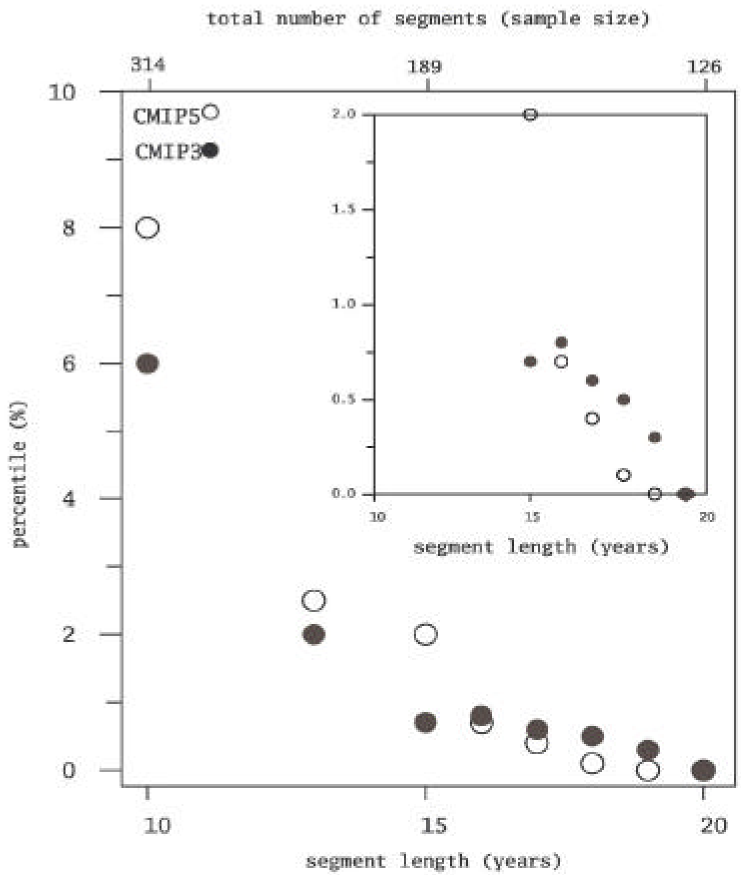
Detection takes the form of a statistical hypothesis testing.
The challenge is the determination of the range of natural variability; often control simulations of GCMs are used.
When trying to enhance the signal-to-noise ratio (Hasselmann, 1979), the pattern of the expected event is used to project on the event – good knowledge about the future helps to succeed in detecting .

The detection concept can also be used to demonstrate that a possible cause is – within the uncertainty of hypothesis testing – not alone at work.

Example: Hiatus

Motivation:
The Hiatus problem

- A 15-year trend of 0.0041 °C/year, which was determined for 1998-2012 using HadCRUT4, shows up in less than 1% of the time in CMIP3 and CMIP5 scenarios.
- Thus, when considering the GCM responses to elevated GHG levels as realistic, the recent trend can not be explained by these GHG increases alone.
  That means:
  - the effect of **GHG is overestimated** in the scenarios , or
  - **other factors** are at work as well
- Or, the inconsistency is related to a **too constraint dynamical response** of the climate systems in contemporary models (enhanced flow of heat into the ocean). Then, such models are compromised for the use as unbiased estimators for "natural variability" in detection studies.



Consistency between the recent trend of the global mean annual temperature and simulations with climate models: the figure shows the proportion of simulated trends that are smaller or equal to the observed global annual trend in the period 1998-2012 in the HadCRUT4 data set, $R_{hadcrut15}$.= 0.0041 °C/year. The ensemble of simulated trends has been calculated from non-overlapping periods of length *n* in the period 2001-2060. The climate models were driven by the emission scenarios RCP4.5 (CMIP5) and A1B (CMIP3). The inset shows an expanded view of the range 0% to 2%

von Storch, H. A. Barkhordarian, K. Hasselmann and E. Zorita, 2013: Can climate models explain the recent stagnation in global warming?. rejected by *nature*; available from academia.edu

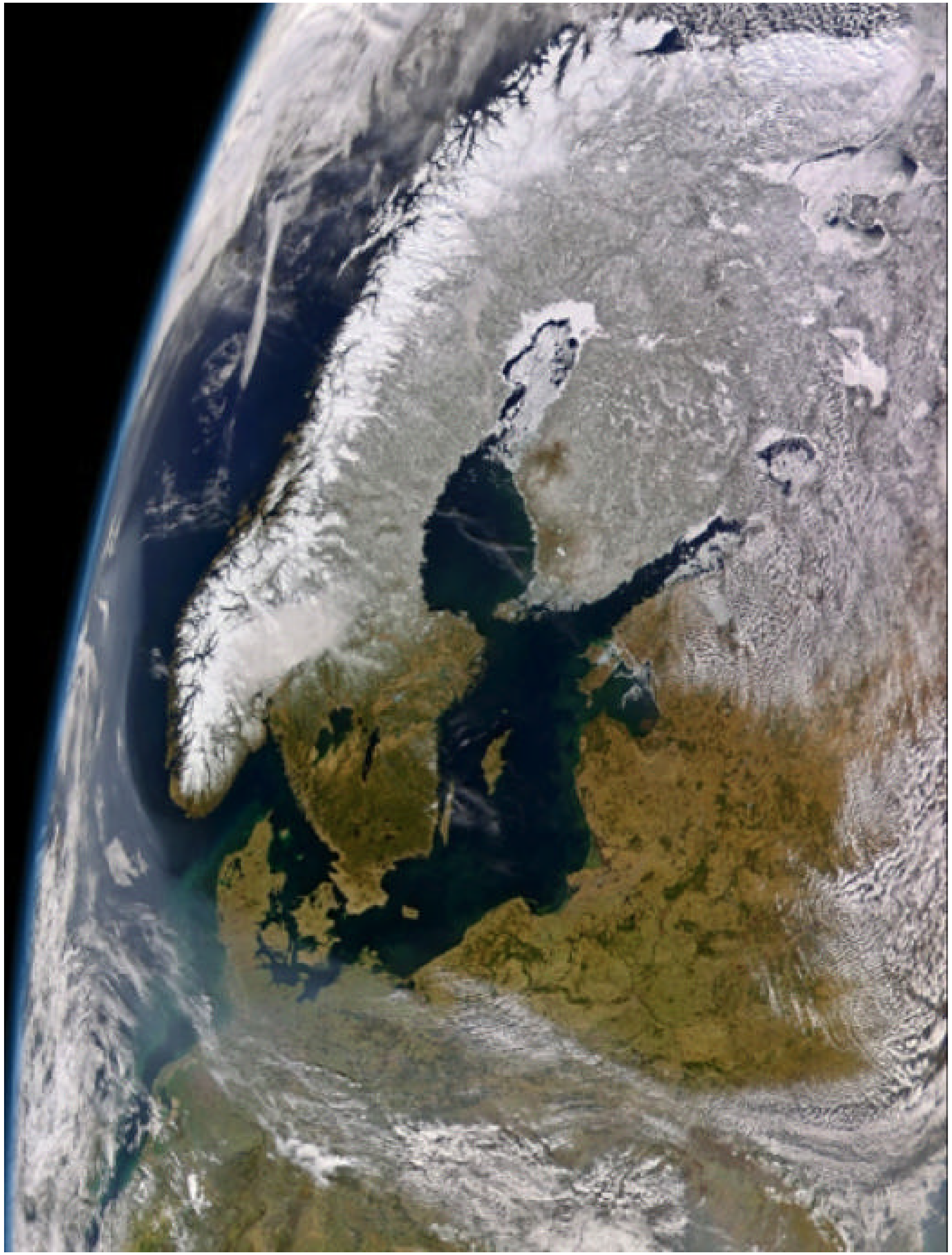
It is my perception that we collectively have hardly been interested in cases, when detection of something has been achieved, but attribution of a consistent explanation fails.

This perception may be false.

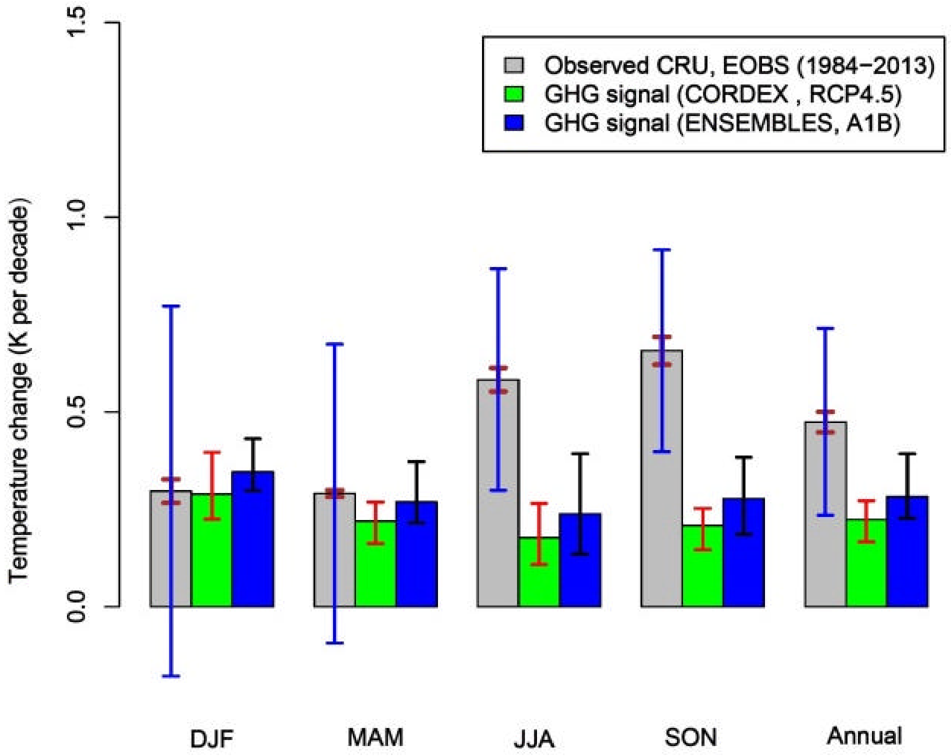
Regional detection of caused changes in temperature trends (1983-2012) in the Baltic Sea Region,

and determination of consistent causes

A project of Baltic Earth



Temperature trends (1983-2012) in the Baltic Sea Region



Observed area averaged changes of near surface temperature over the period 1984-2013 (*grey bars*) in comparison with GHG signal estimated from 9 CORDEX simulations based on RCP4.5 (*green bars*), 9 ENSEMBLES projections based on SRES A1B (*blue bars*). The *brown whiskers* denote the spread of trends of the two observational datasets (CRUv3, EOBS9.0). *The blue whiskers* indicate the 95^{th} %tile uncertainty range of observed trends, derived from 2,000-year paleosimulation. The *red* and *black whiskers* show the spread of trends of 9 RCP4.5 and 9 A1B climate change projections.

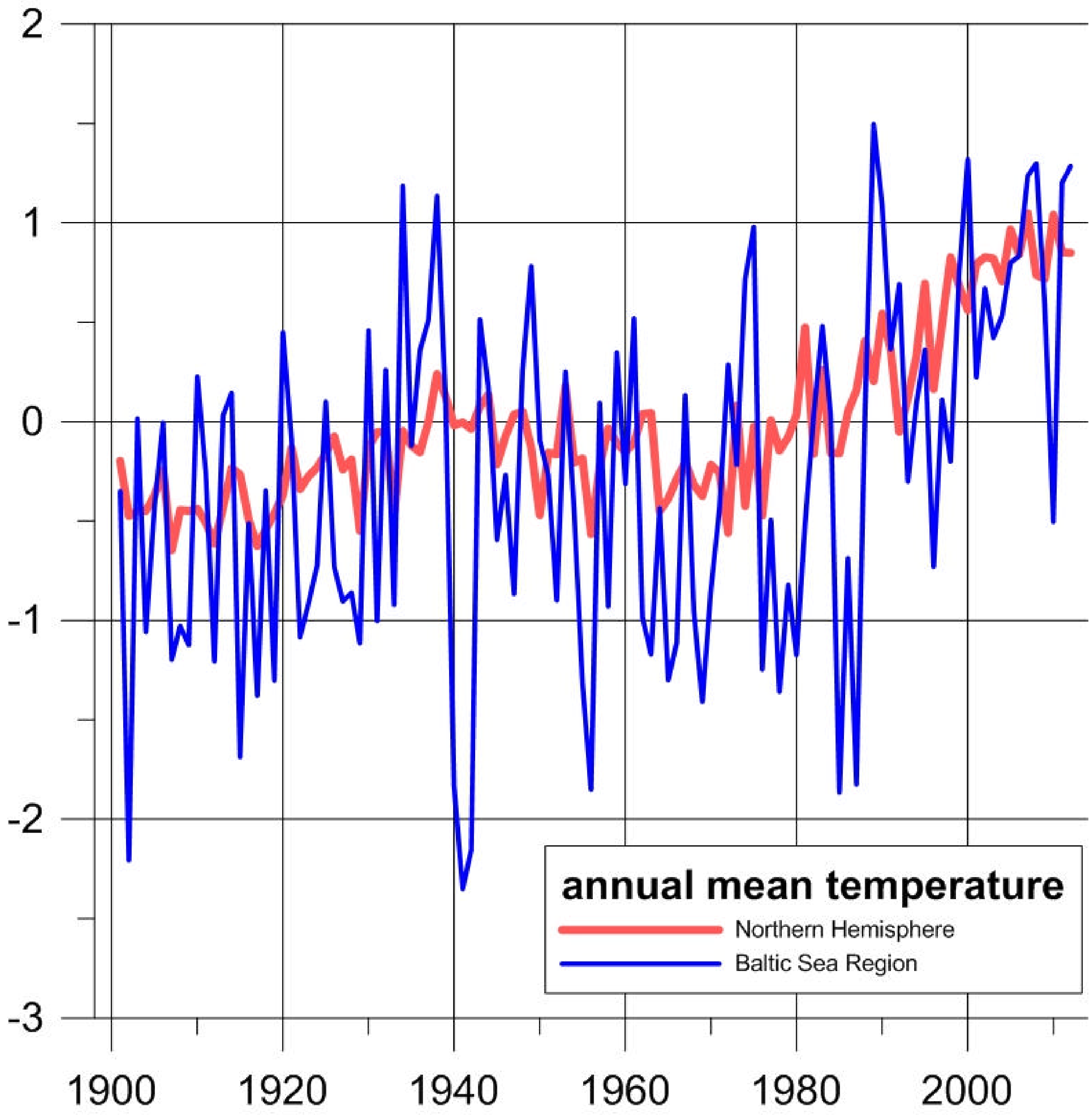
Detection of external driver

The observed (grey) trends in summer, and annually, are inconsistent with the hypothesis of internal/natural variations.

Detection of non-GHG-driver

The warming in JJA, SON and annually can hardly be explained with the driver acting in the scenario simulations (mostly GHGs).

Thus, external drivers are most probably at work. GHG may be among them, but alone fail to explain the trends. Thus, other external drivers must be at work as well.



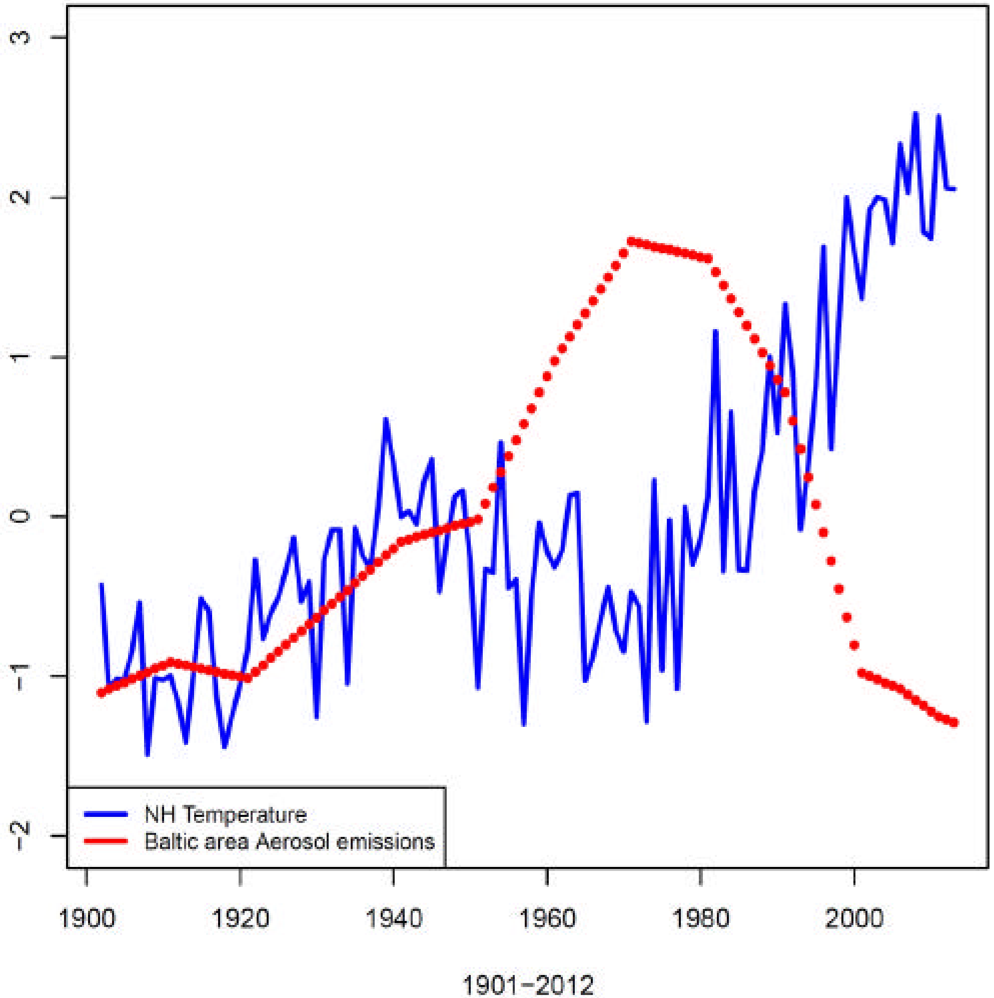
annual mean temperature
Northern Hemisphere
Baltic Sea Region
2
1
0
-1
-2
-3
1900
1920
1940
1960
1980
2000

Determining a regression model

$$T(t) = a_T \times T_{NH}^*(t) + b_T \times A_{BSR}^*(t) + c_T$$

$$P(t) = a_P \times T_{NH}^*(t) + b_P \times A_{BSR}^*(t) + c_P$$

- **Predictands:**
  - Baltic Sea Region (BSR) *air temperature* and
  - BSR *precipitation* amount
- **Predictors:**
  - *Northern Hemisphere temperature* (considered representative for the change related to ever increasing concentrations of greenhouse gases).
  - Annual *regional emissions of aerosols* in Northern Europe. (Only decadal estimates are available to us between 1911 and 2012)
- **Data**: 1900-2012
- **Fit**: stepwise

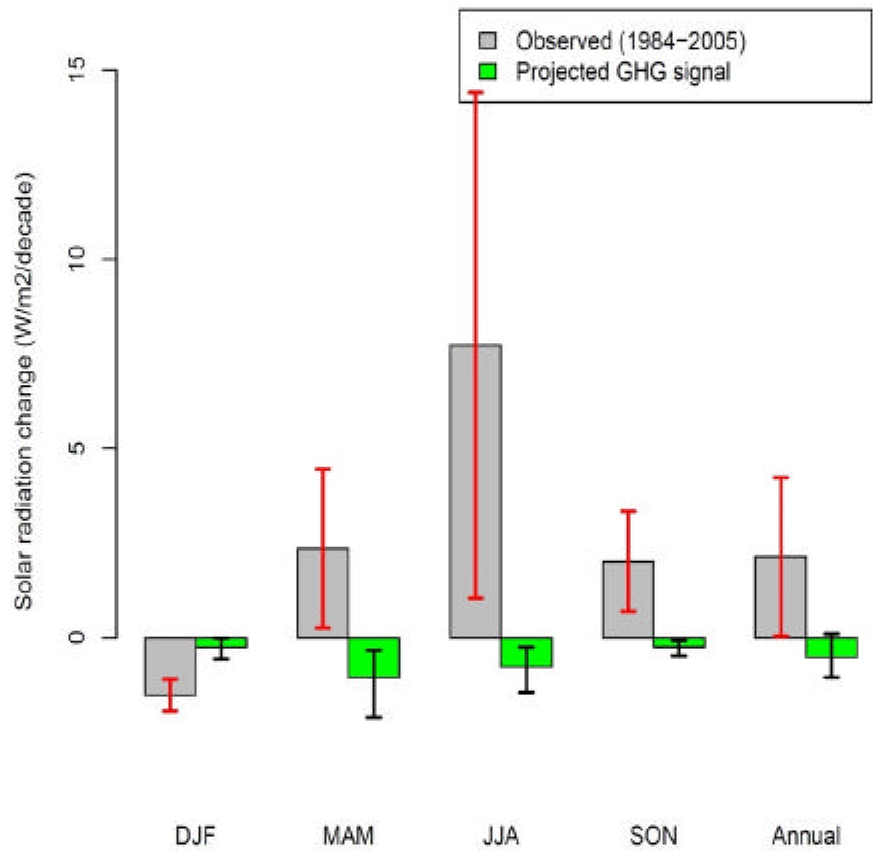


The two normalized predictors, the annually resolved Northern Hemisphere air temperature T_{NH}^* *and the decadally resolved Baltic Sea region aerosol emission* A_{BSR}^* *.*

Other driver

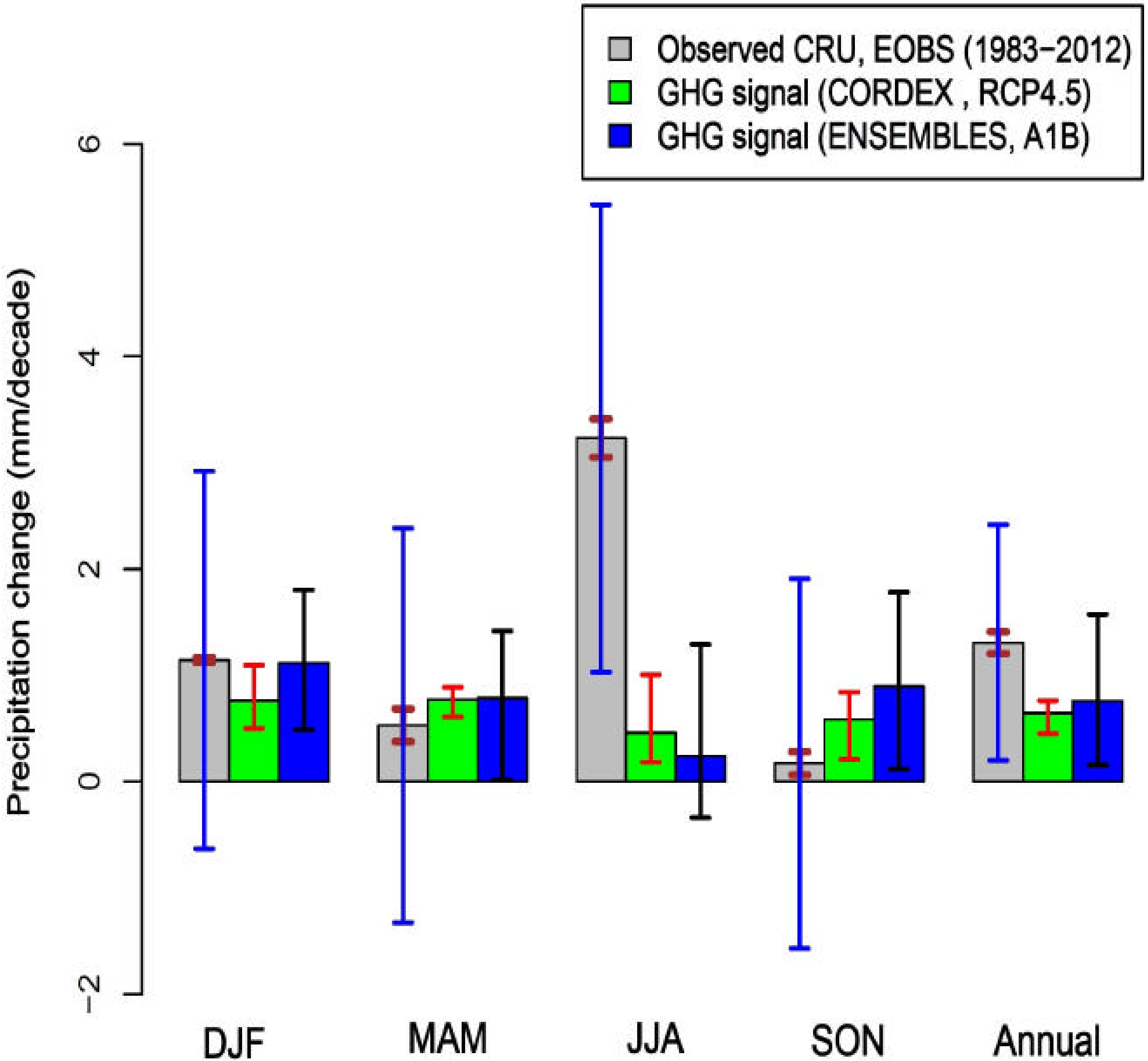
Candidate: regionally emitted aerosols.

Detection of positive trend (1984-2005) of surface solar radiation annually as well as seasonally in MAM, JJA and SON. Inconsistent with the trends in RCM scenarios.

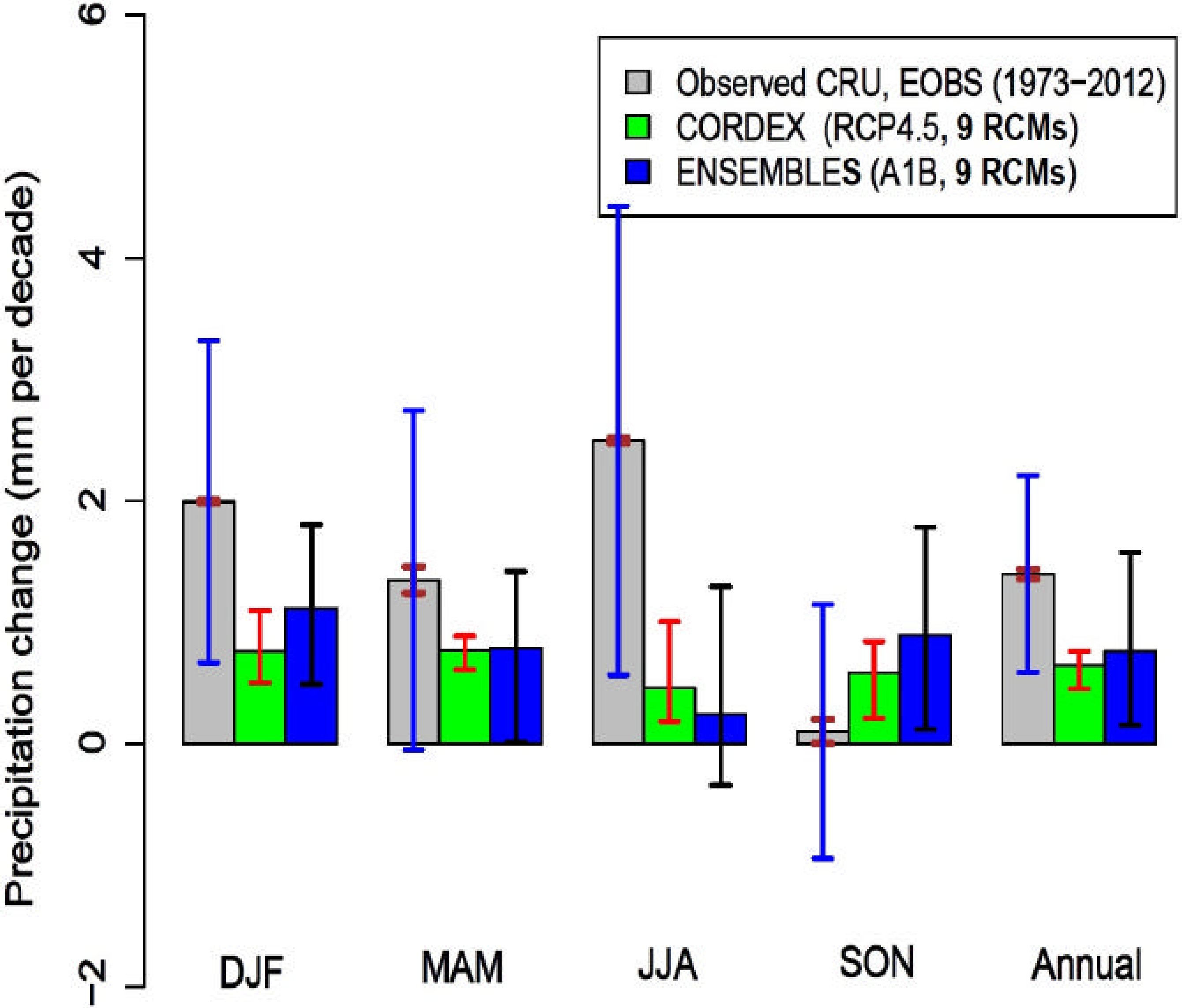


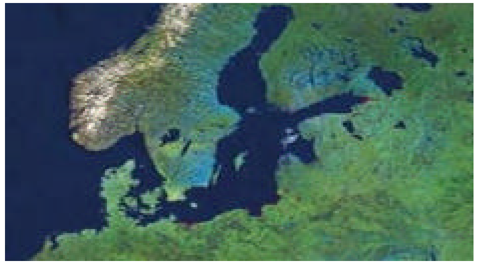
Seasonal area mean changes of observed surface solar radiation (W/m2/Decade) according to the CDR satellite data over the period 1984-2005 over the Baltic Sea region in comparison with the anthropogenic signal derived from the multi-model mean of RCM; simulations.
The black whiskers indicate the spread of the trends of 10 climate change projections. The red whiskers denote the 90% uncertainty range of observed trends derived from 2,000 year paleo-simulations.

Precipitation (1983-2012)



Precipitation (1973-2012)





Observed trends in 1973-2012

Projected GHG signal (RCP4.5
9 runs, CORDEX

Projected GHG signal, A1B
9 runs, ENSEMBLES

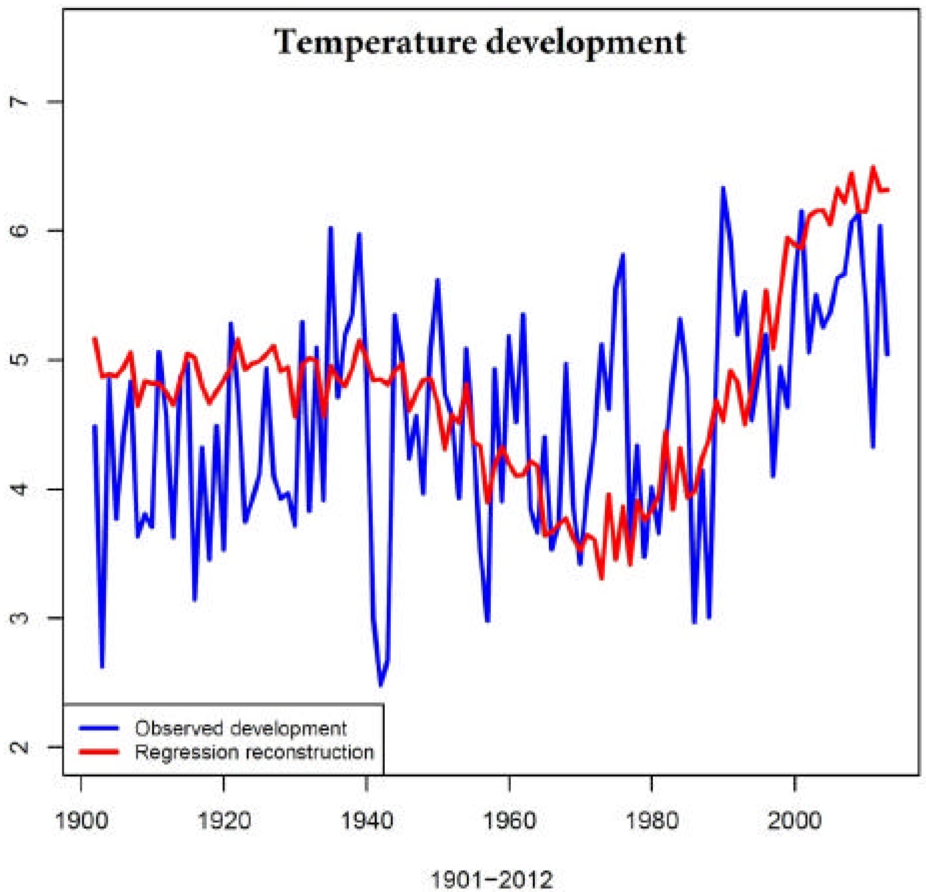
95th-%tile of „non-GHG“
variability, derived from
2,000-year palaeo-simulations

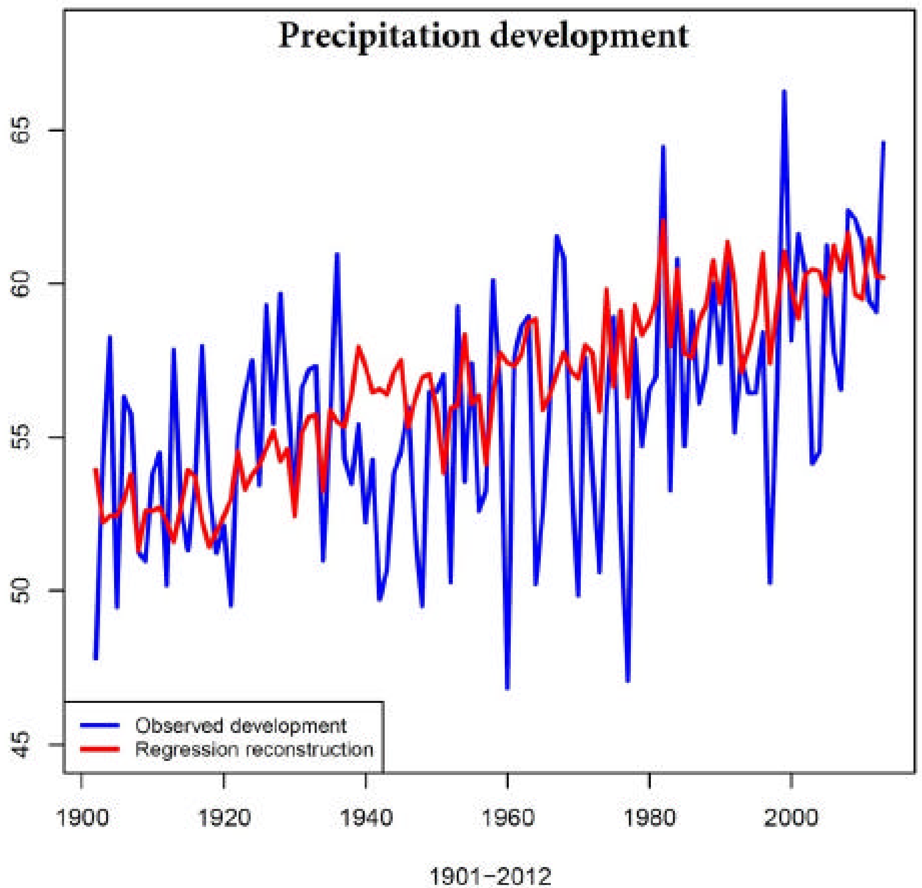
The regression model

$$T(t) = a_T \times T_{NH}^*(t) + b_T \times A_{BSR}^*(t) + c_T$$

$$P(t) = a_P \times T_{NH}^*(t) + b_P \times A_{BSR}^*(t) + c_P$$

Baltic Sea region	units	a	b	c
Temperature	deg	0.43	-0.53	4.76
Precipitation	mm	2.56	1.22	56.93





Estimating the relative climatic importance of aerosol emissions

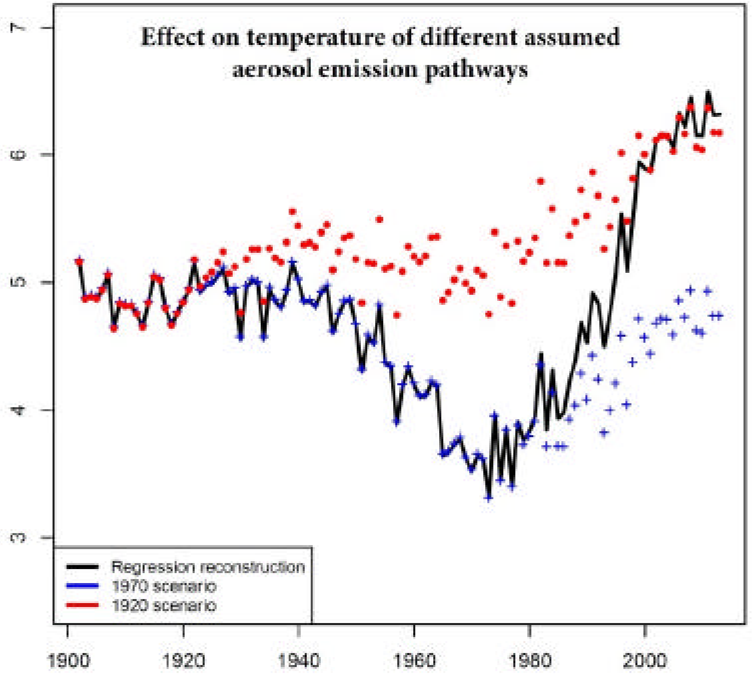
For determining the relative importance of the regional emissions of aerosols we use the regression model to estimate the possible regional temperature and precipitation developments under assumed emissions.

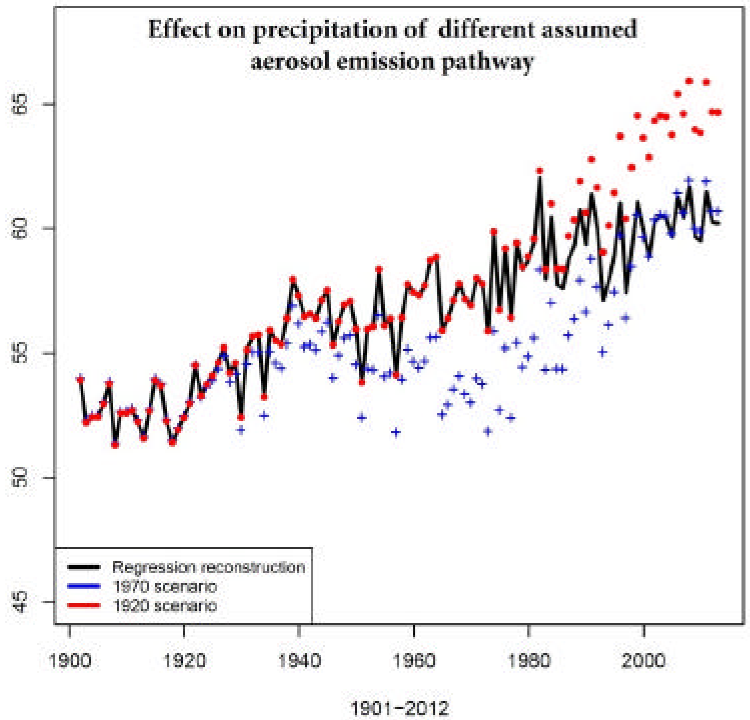
Three such as assumed emission

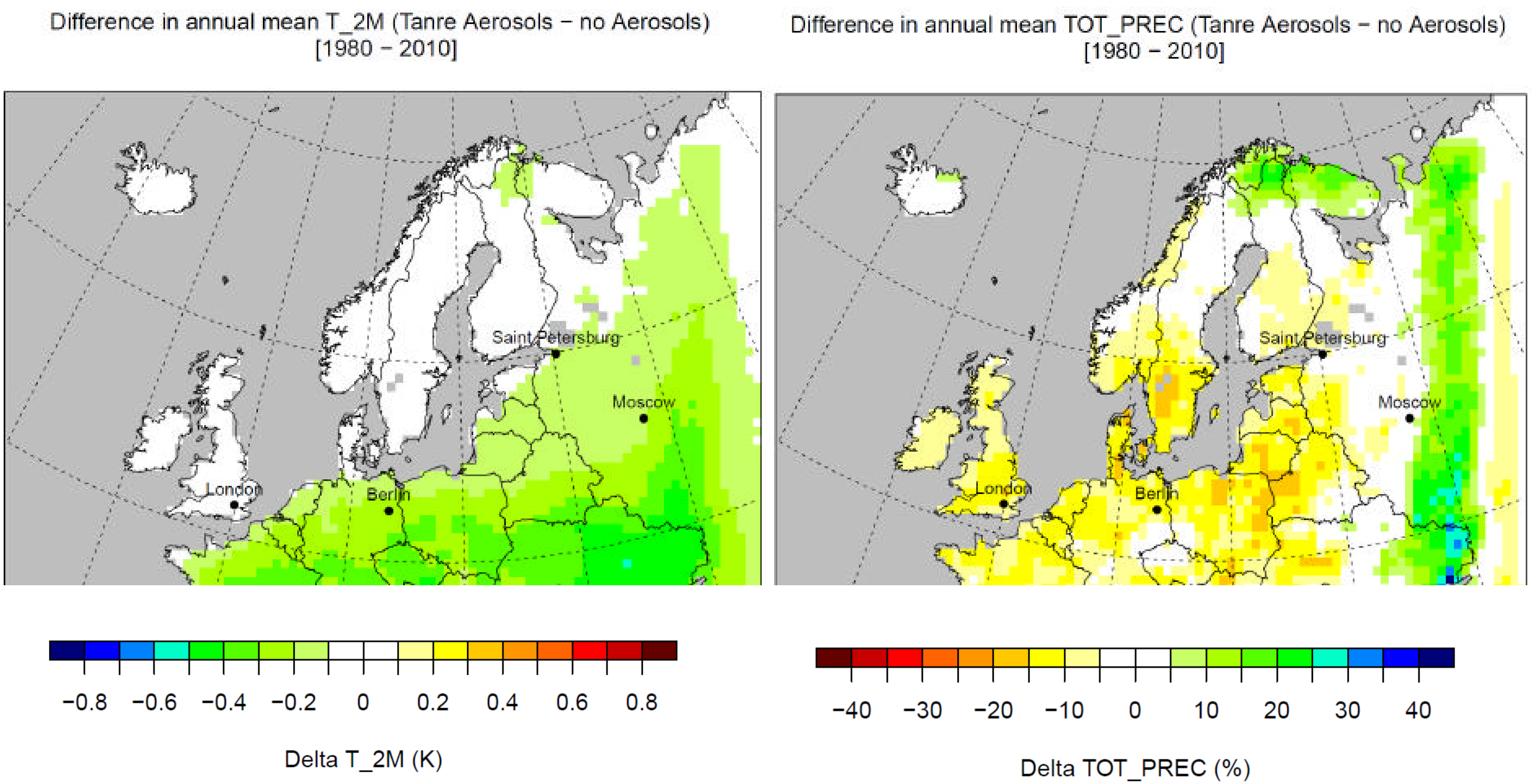
•"Control": a continuation of emissions through 2001 to 2012 as in the year 2000.

•"1920 scenario": a continuation of emissions as in 1920 in the years afterwards.

•"1980 scenario": a continuations of emissions as in 1980 in the years afterwards.







First results form an RCM experiment running with an aerosol concentration as at the peak of the emissions (“1980”) and no aerosols (“2010”)

- In b oth cases, temp and precip, the aerosol lead to a reduction.

Markus Schultze, Burkhardt Rockel, pers. comm.

Conclusions

- In case of **Baltic Sea Region** temperature, GHGs are positively insufficient for explaining recent warming patterns
- A plausible co-driver of temperature change is regional aerosol emissions.
- Conditional upon skill of regression model, the relative importance of GHG/regional aerosol forcing is about 5/4.
- The rgression model suggest that he decrease of global temperature before 1970s and the simultaneous increase in aerosol emissions caused a regional cooling of 1 - 1.5K.
- The strong global temperature increase and the simultaneous decrease of regional aerosols went along with a strong regional temperature increase of 1,5 - 2 K since 1980.
- The inconsistency of RCM scenarios and recent temperature change may originate from the strong regional aerosol influence, which is not considered in the RCM scenarios.
- The skill of the precipitation regression model is questionable.
- First results from RCM experimentation point to considerably smaller temp changes, and opposite precip changes.