Regime Shift and Trends in the Baltic Sea area: a statistical approach.

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Motivation 1

Regime shift in the Baltic Sea 1987, detected in the data, by Alheit ea 2005, but the used statistical method is not described? See Fig.4 from paper:

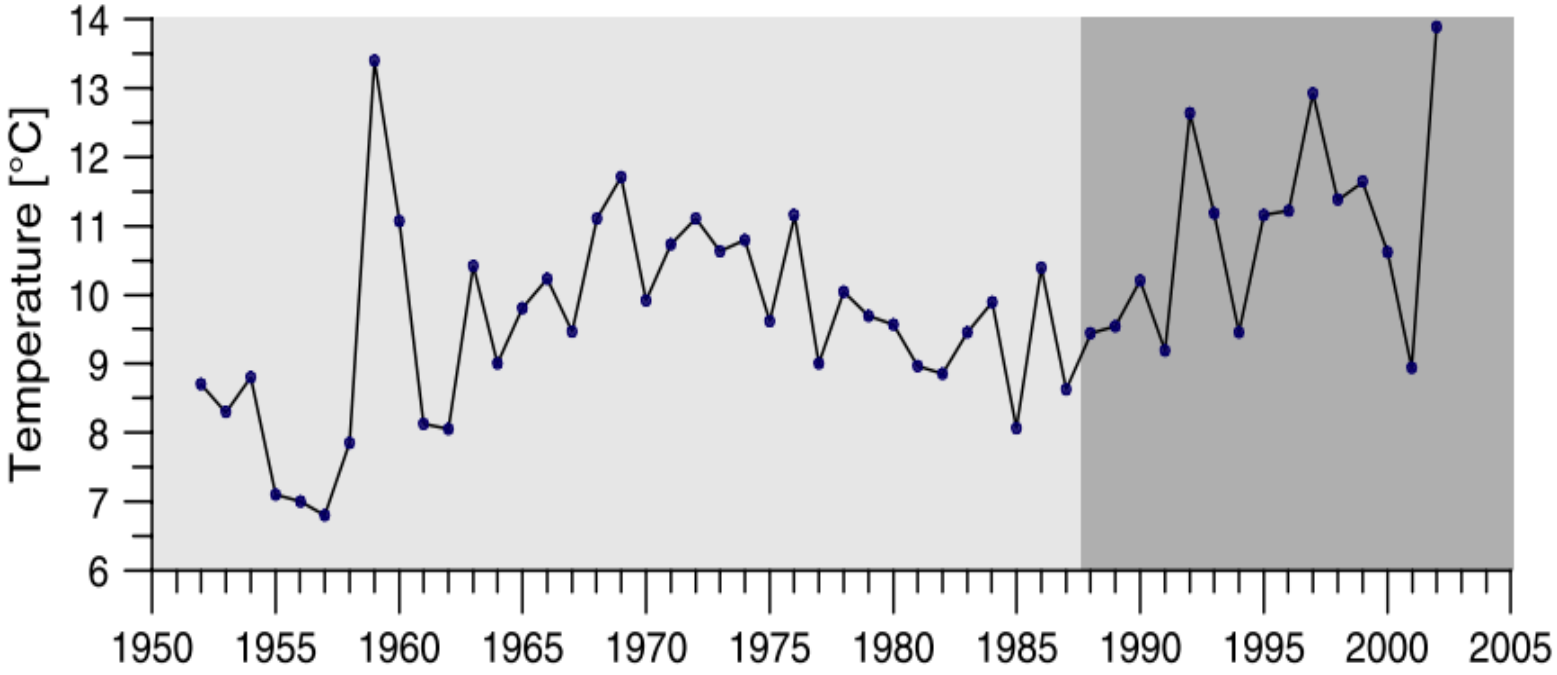
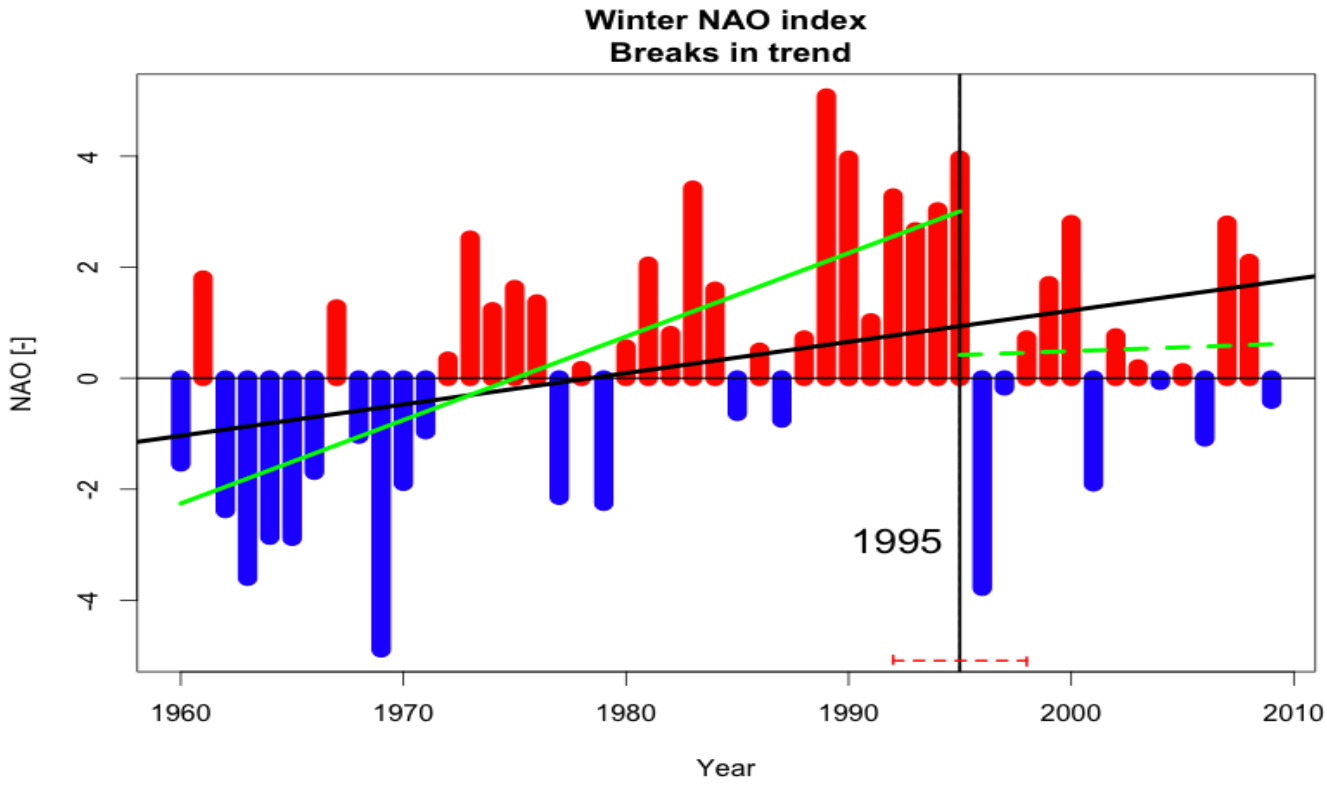


Figure 4. Annual temperature maximum in the halocline (55–70 m) of the Bornholm Basin (Station K2).

Motivation 2

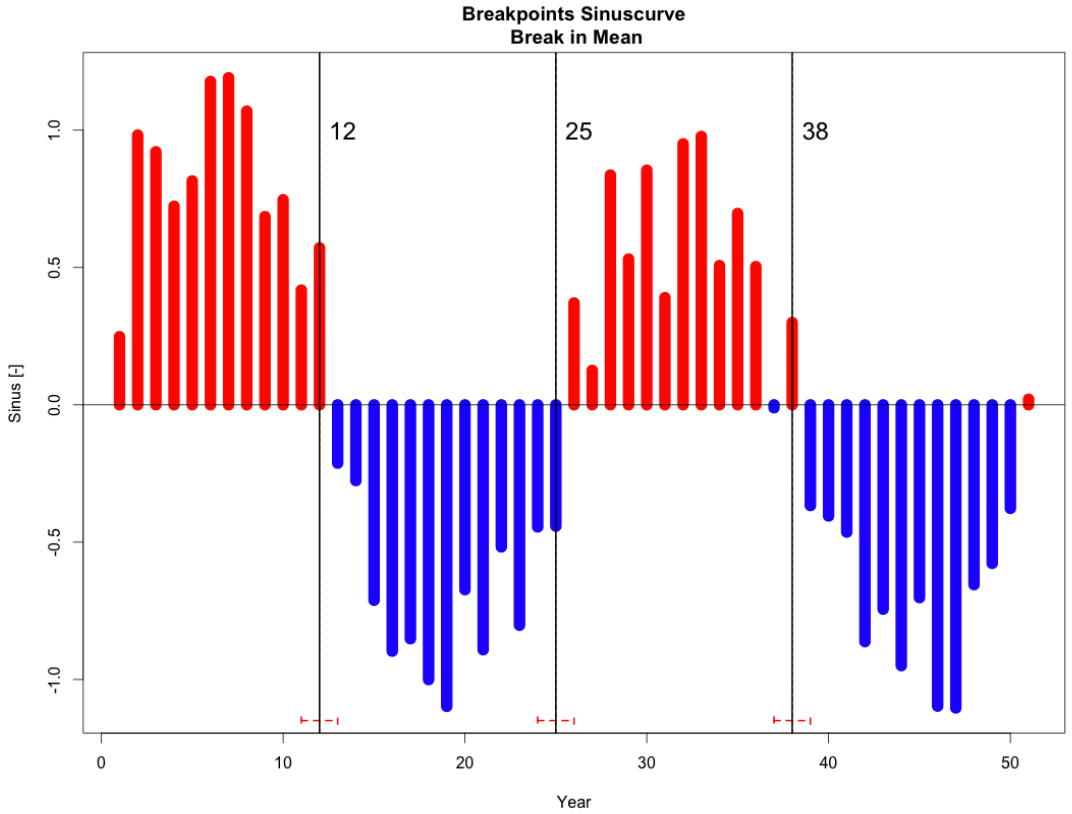
- Proposed "Regime shift" in the Baltic Sea ~1987 (for example, Alheit ea 2005), related to North Sea and "caused" by a sign change in the North Atlantic Oscillation (NAO) index
- But there are many sign changes: 1972, 1978, 1987, 1996, 2000, 2008 – what is so specific about 1987?



Breakpoint detection method

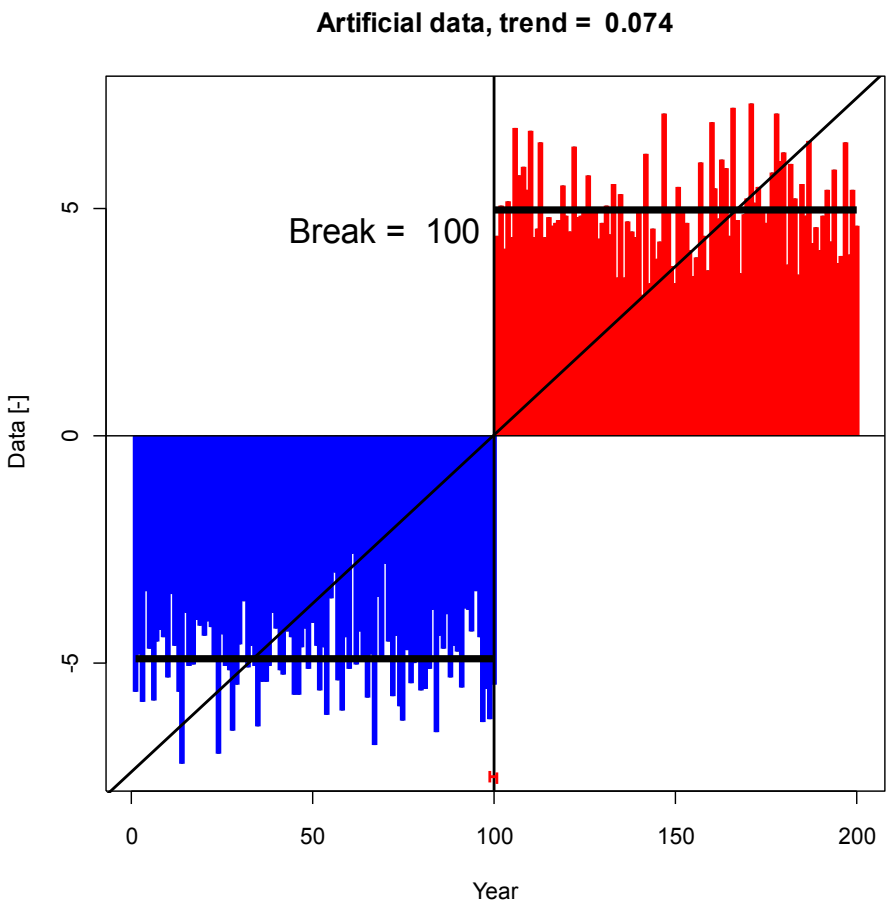
Can we confirm this "regime shift" using objective statistical methods? Description by trend or breakpoint?

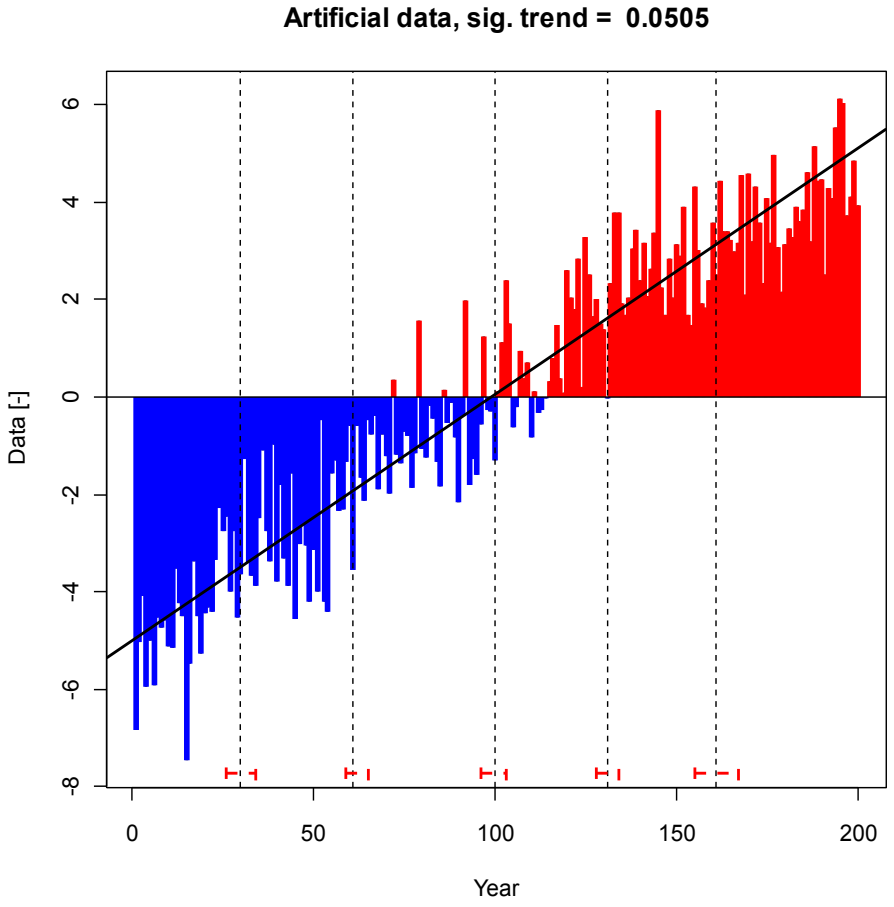
Several methods exist – we used "Structural changes", software package for the R language *strucchange*



- Sinusoidal time series of 50 years length
- Period of 24 years with some random noise added
- Software does find the breakpoints easily when doing the structural change test
- Very significant having narrow confidence intervals
- Useful for finding sign changes!

Breakpoint&trend detection method: pitfalls



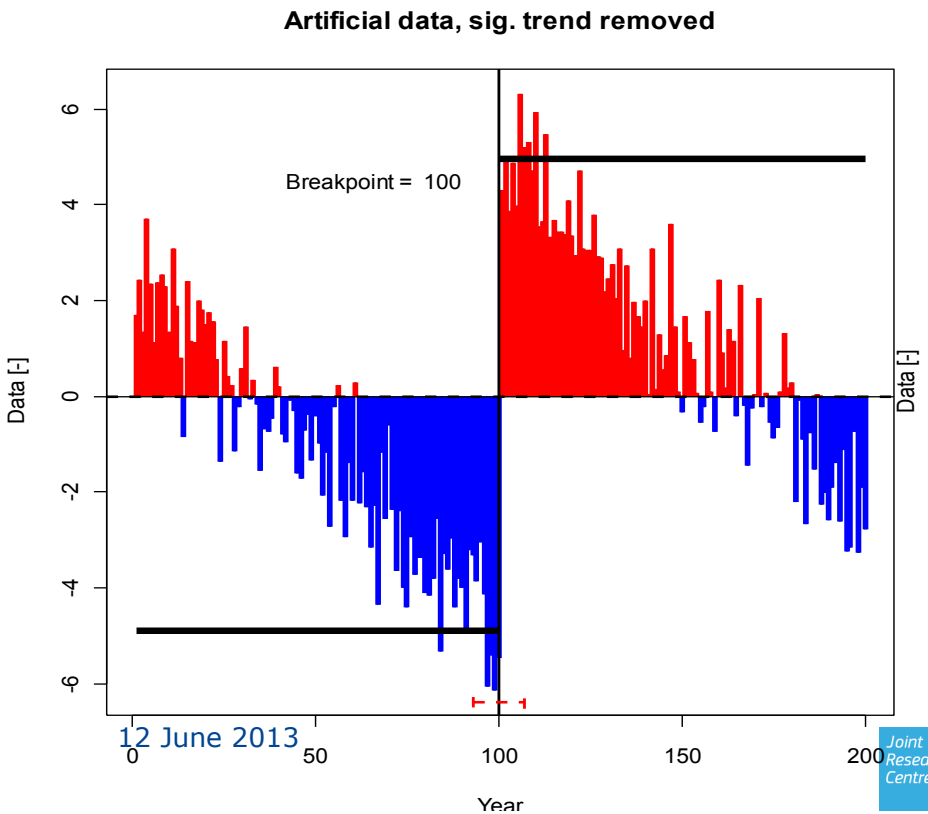


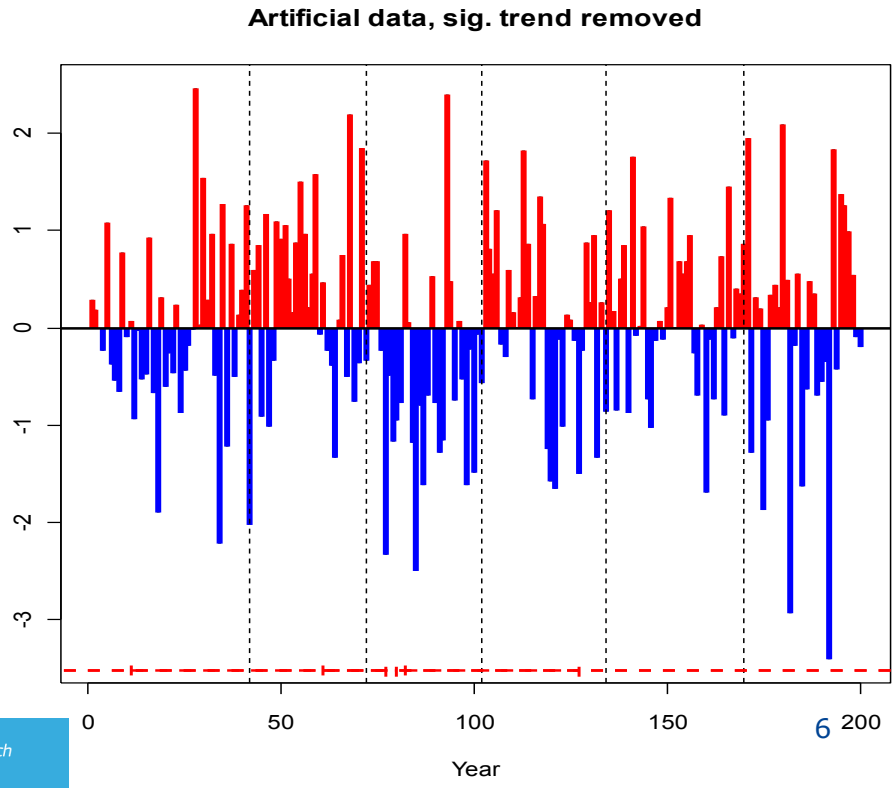
Data generated to have a trend do have significant breakpoints, as well as regime shift data have a significant trend! We need to understand the system to decide what is the appropriate description.

Conclusion 1 – statistics is a tool

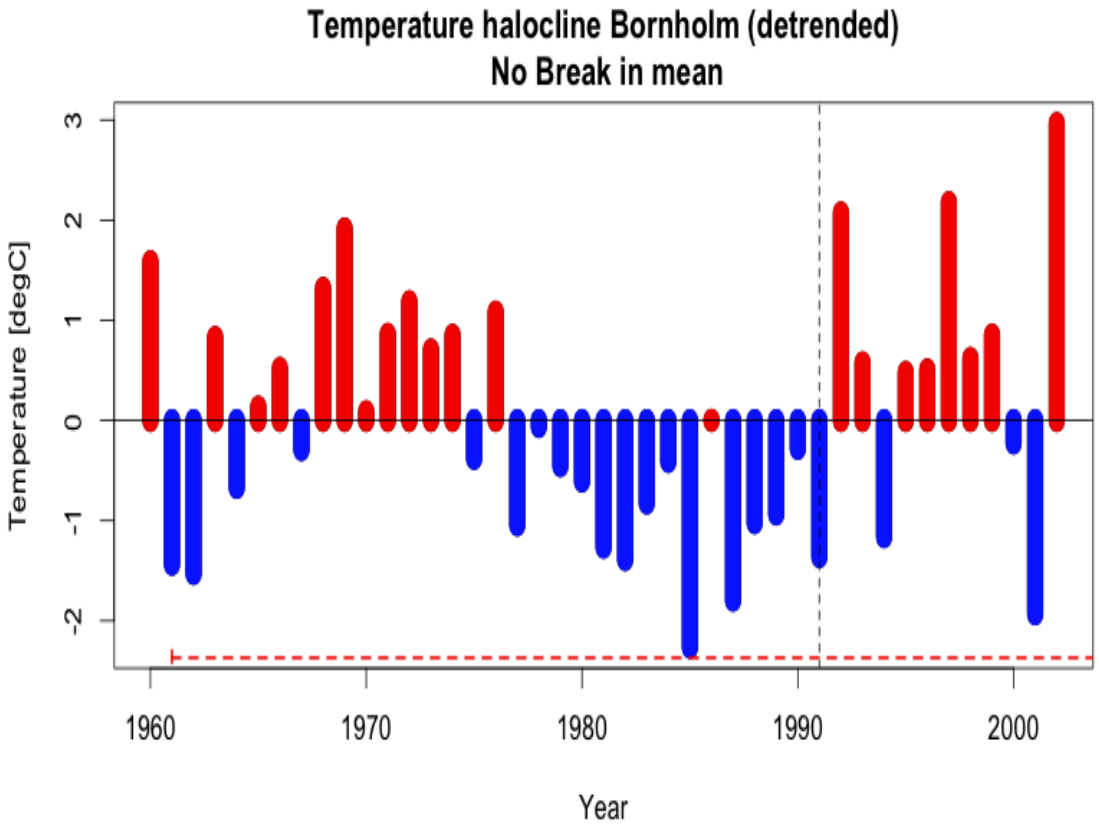
10000 Monte Carlo simulations of time series with trend and white noise, do lead to significant breakpoints in more then 90% of the cases, therefore:

De-trending is needed – (statistics is not a substitute for understanding the system)





Check break - 1: temperature in halocline



- Temperature time series Bornholm Sea halocline
- Increasing trend 0.033K/year
- =>Detrending
- No break in mean
- No objective regime shift found!

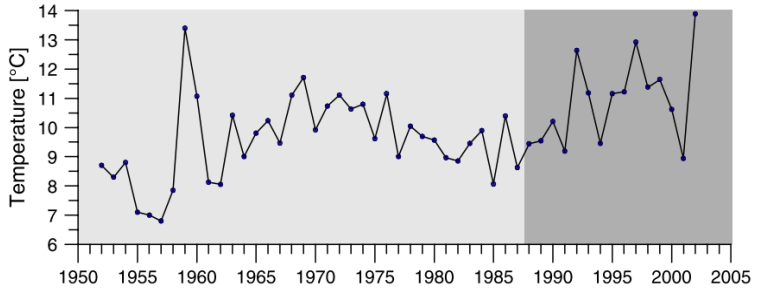
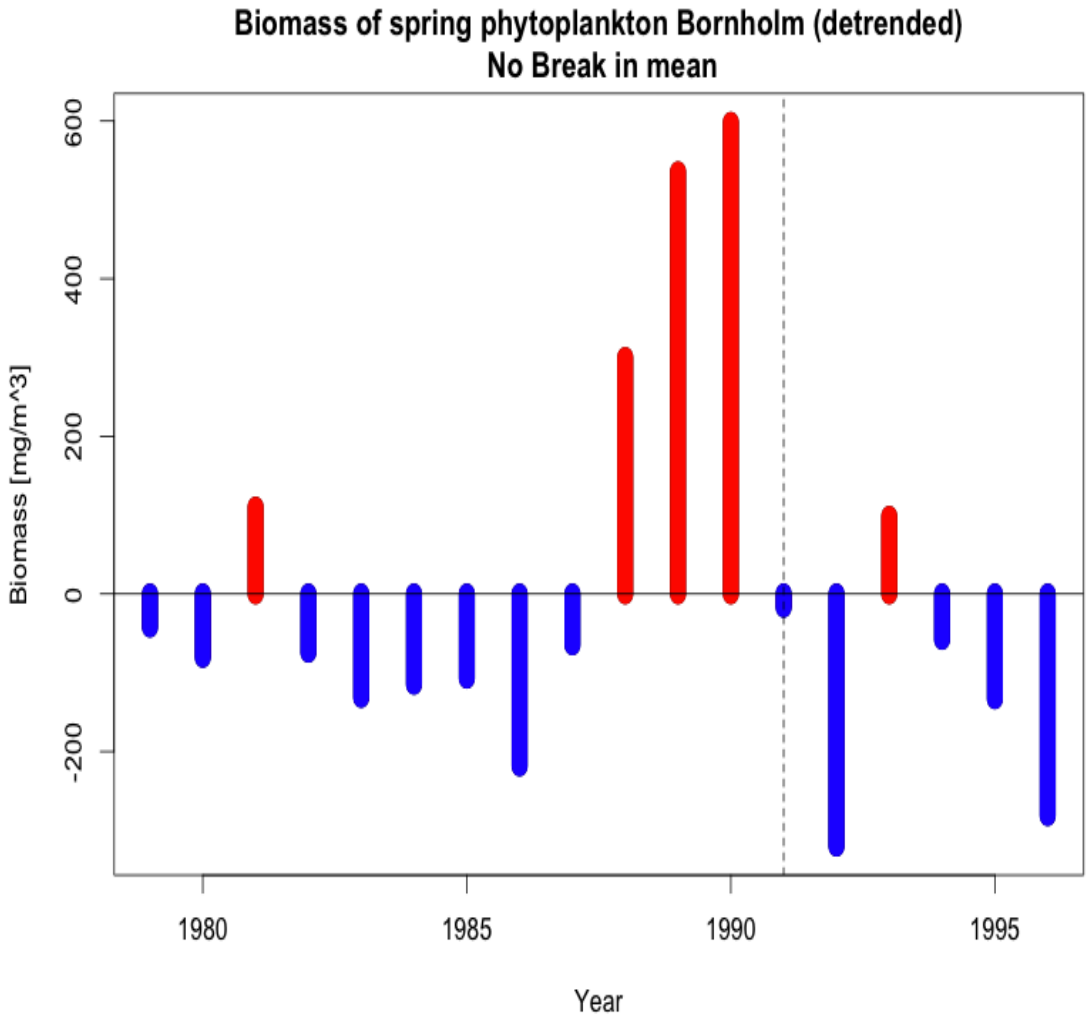


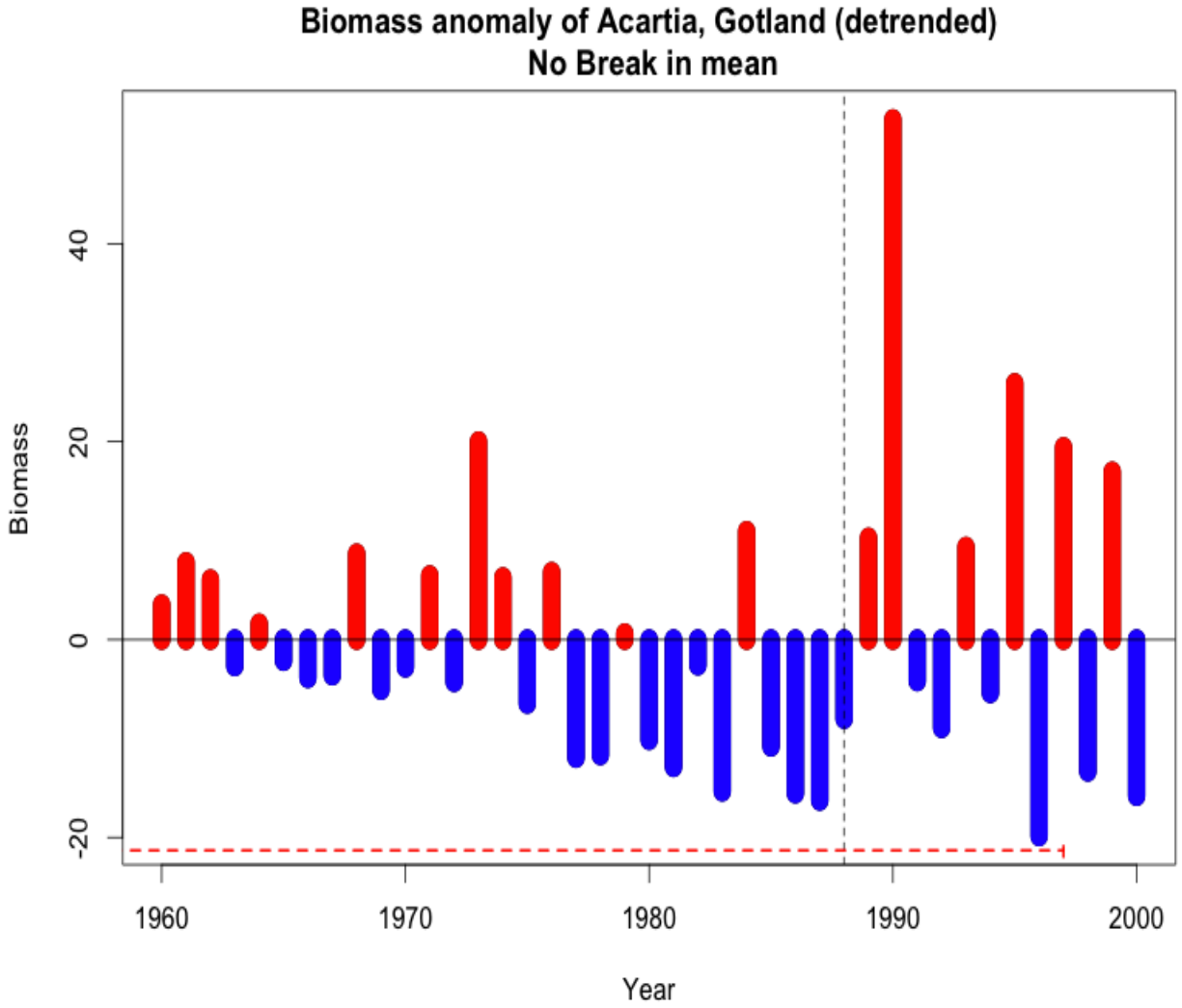
Figure 4. Annual temperature maximum in the halocline (55–70 m) of the Bornholm Basin (Station K2).

Check break - 2: Phytoplankton



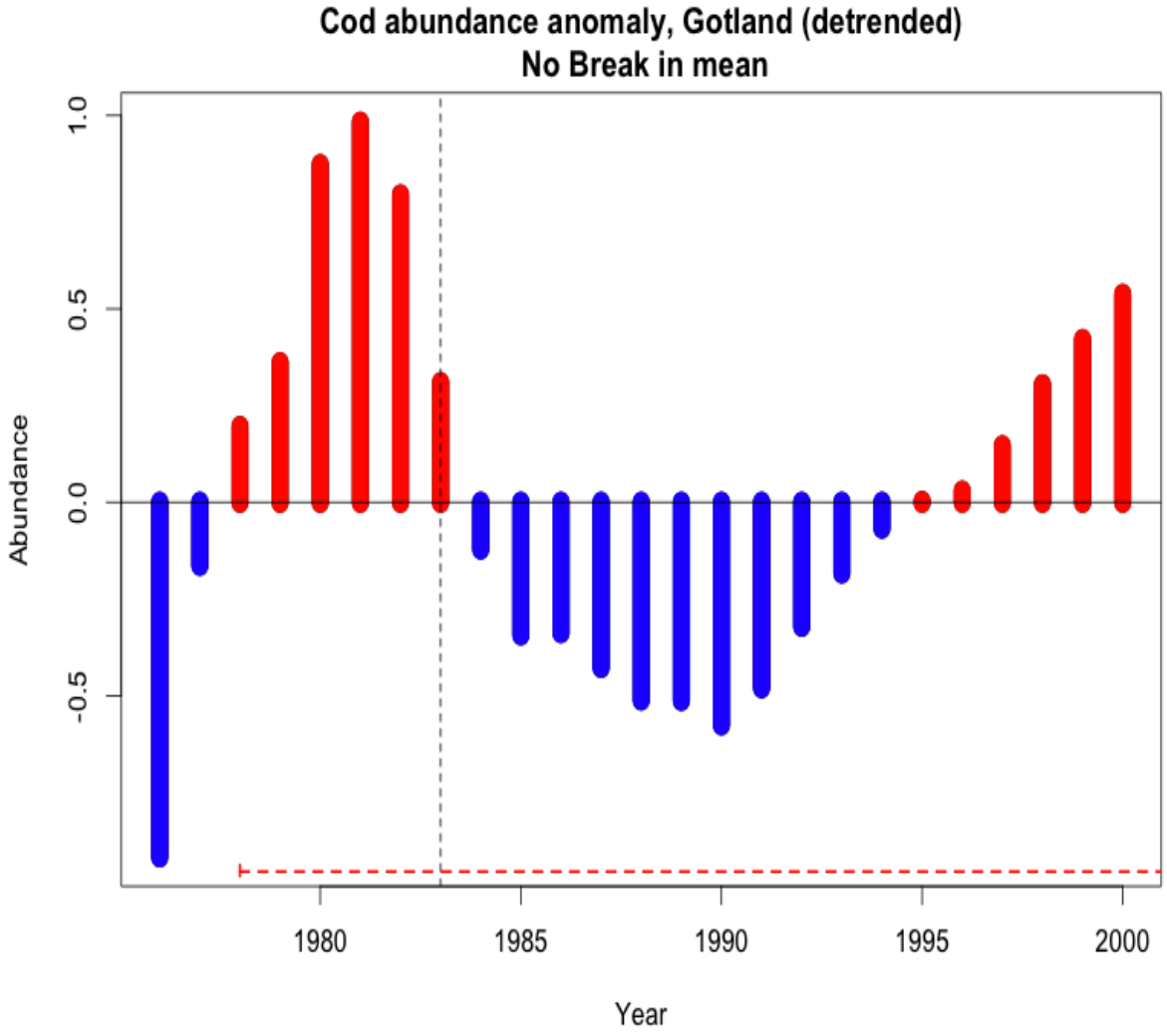
- Spring phytoplankton (only short time series!)
- Increasing trend of 38 mg/m^3/year
- =>Detrending
- No break in mean!

Check break - 3: Zooplankton



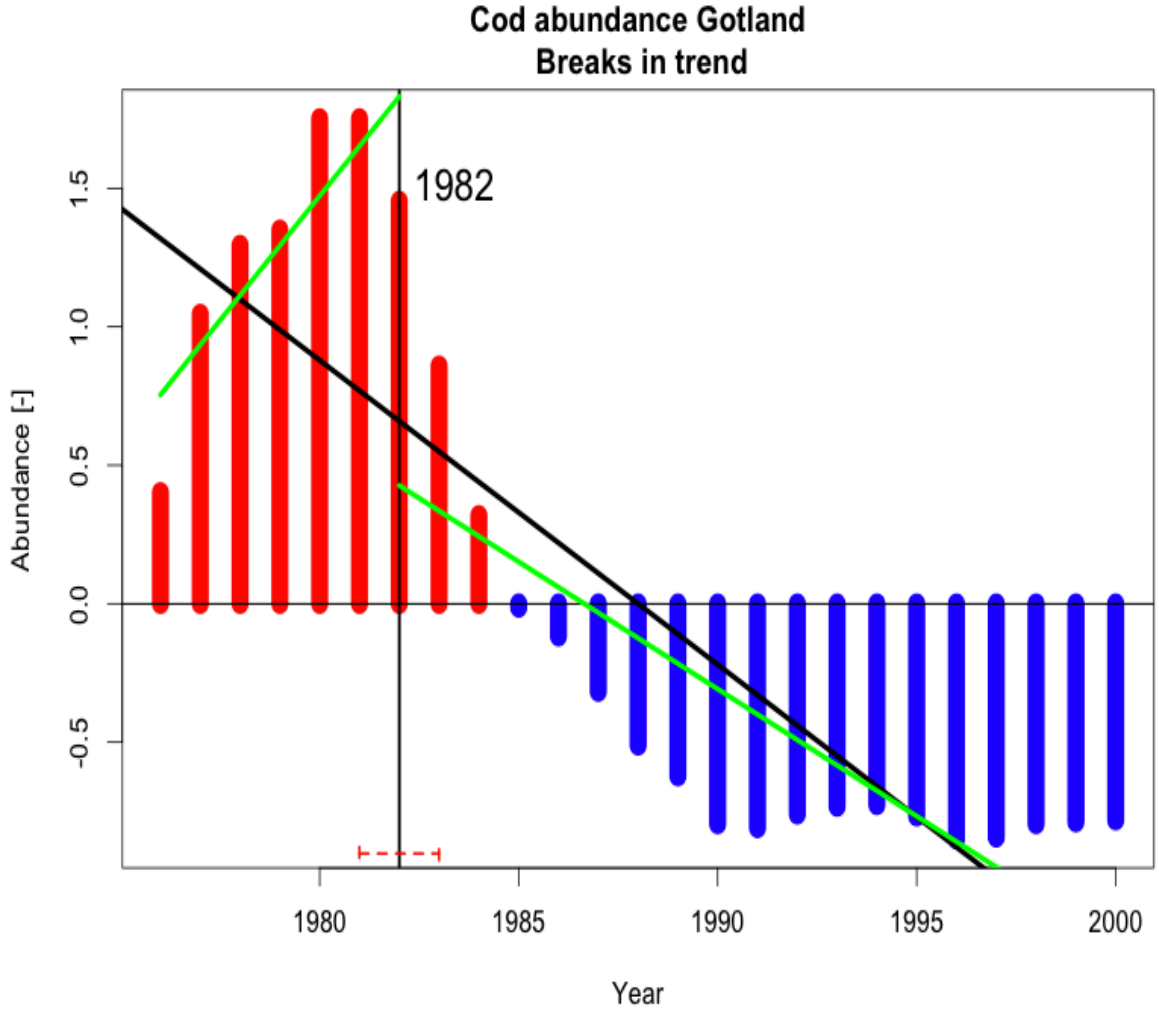
Biomass anomaly of zooplankton (Acartia) Gotland
Increasing trend (0.7/y)
=> Detrending
No break in mean!

Check break - 4: Cod abundance



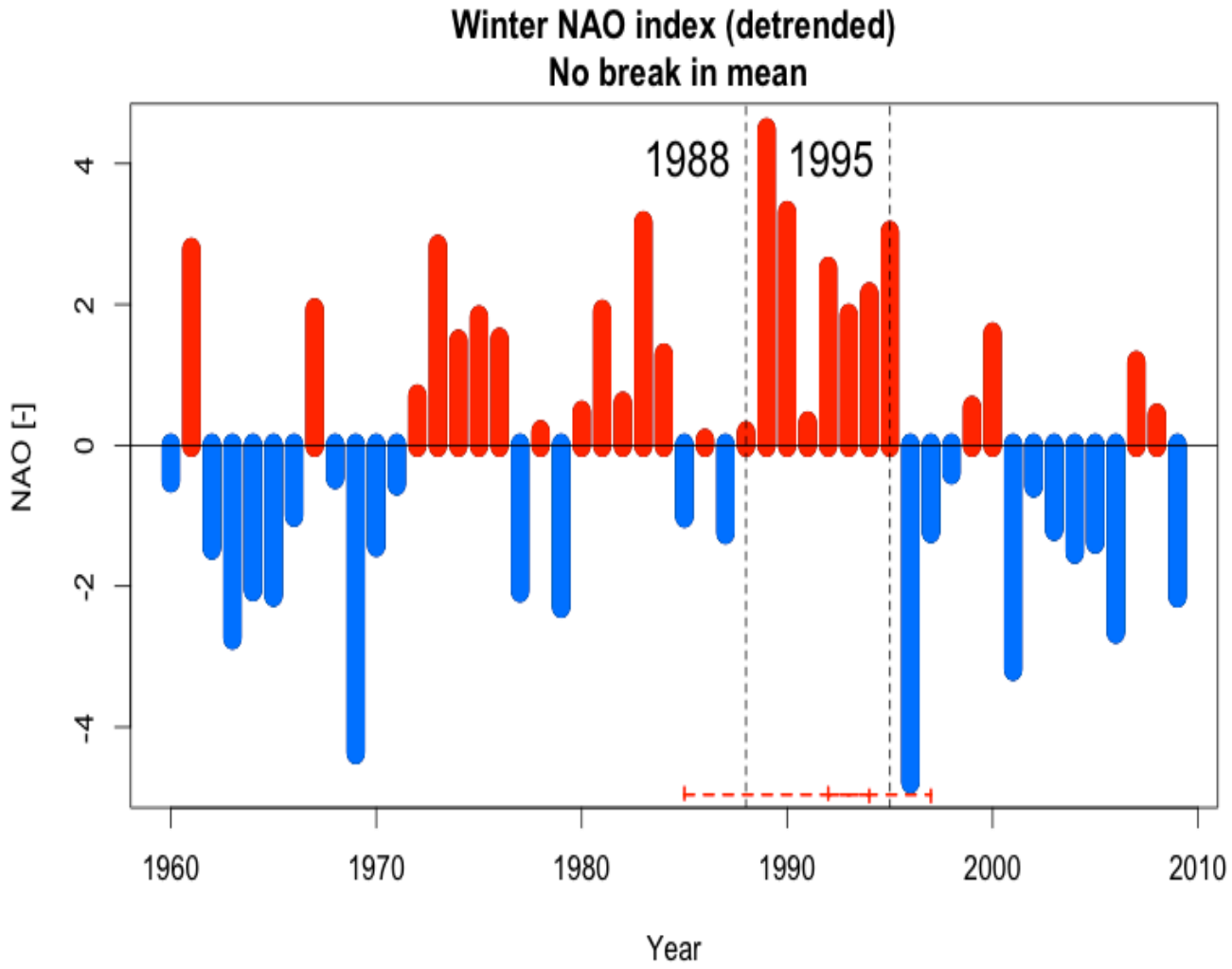
- Cod abundance Gotland
- Decreasing trend -0.11 (r.u./year)
- => Detrending
- No break in mean!

Check break trend - 1: Cod abundance



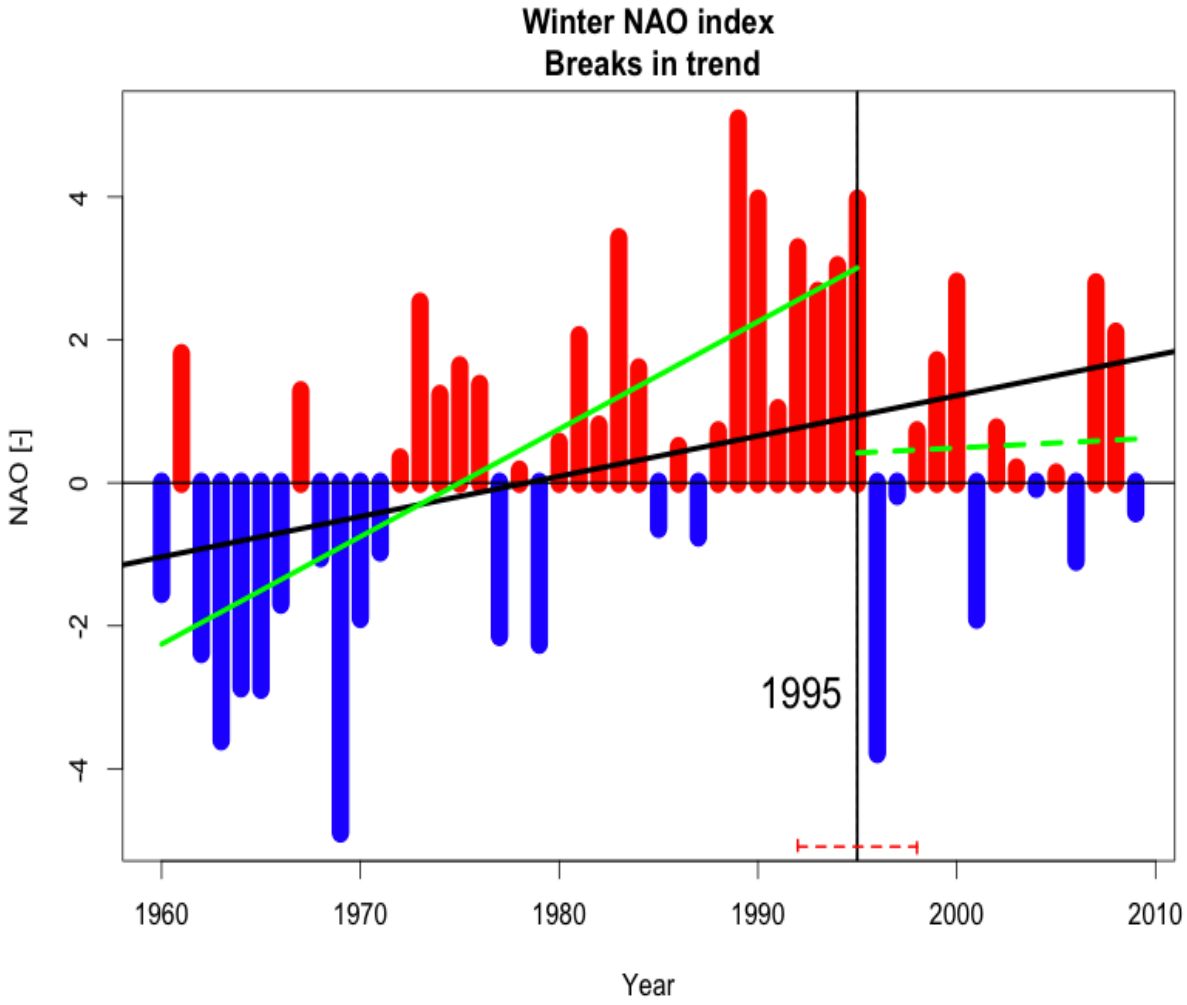
- Cod abundance Gotland
- Decreasing trend -0.11 (r.u./year)
- Break in trend 1982
- Before – increasing
- After - decreasing

Check break mean - 5: NAO



- **Winter NAO index**
- **Increasing trend!**
- **No break in mean!**
- **No significant sign change**

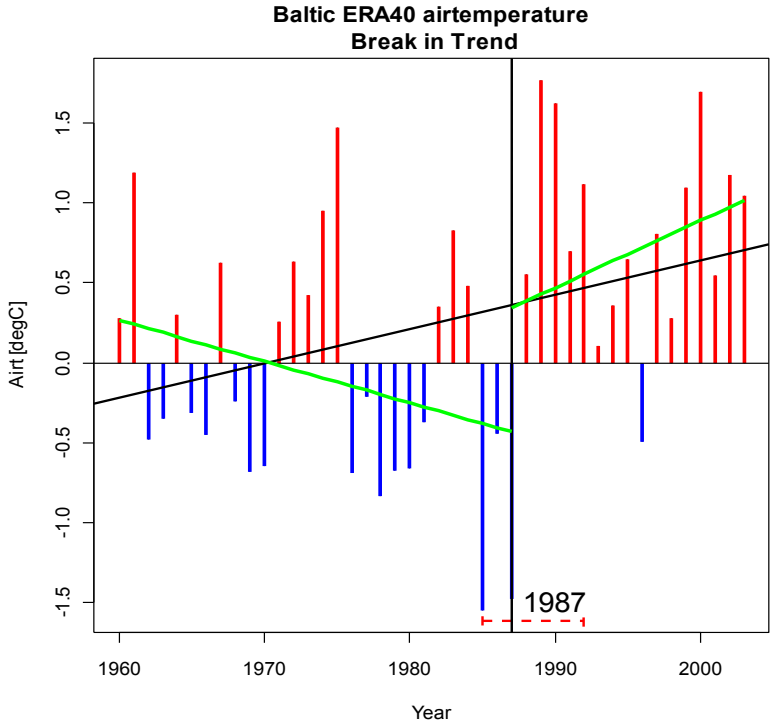
Check break – trend - 2: NAO

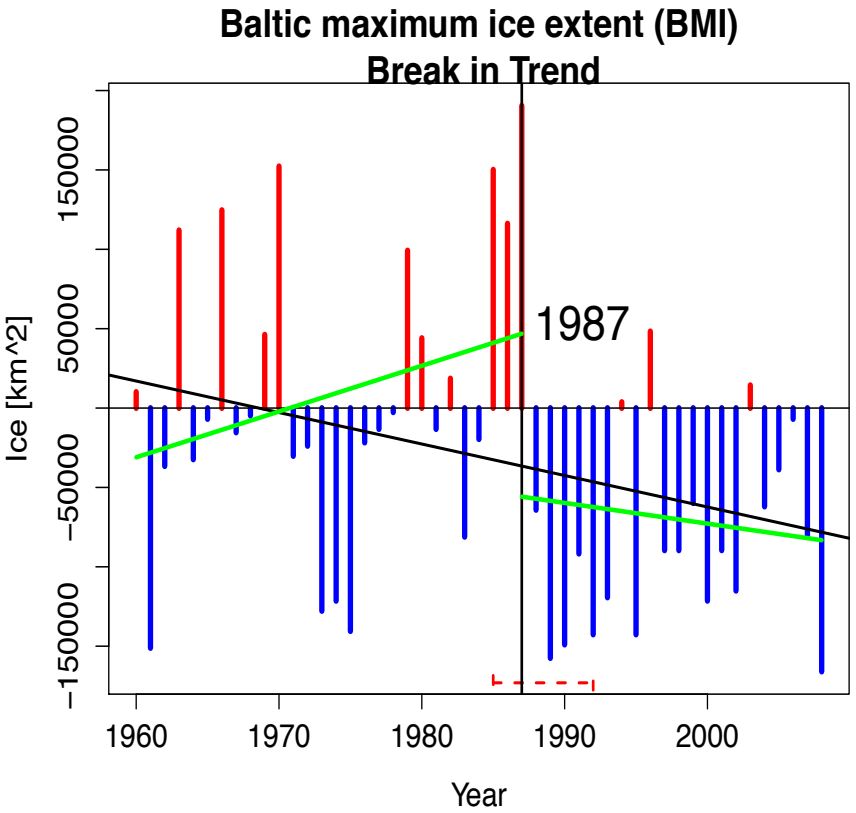


- **Winter NAO index**
- **Increasing trend!**
- **Break in trend 1995!**
- **Before – increasing**
- **After – no trend**

Objective evidence?

Not in the proposed variables!
What about air temperature,
SST, wind, ice,..?





- NO break in mean for temperature
- One breakpoint 1987 for trend in ERA40 air temperature
- Increasing trend!

- NO break in mean for BMI!
- One breakpoint 1987 for trend in BMI
- Slight decreasing trend in BMI

Conclusions:

- There are NO clear breakpoints in most physical and biological variables and in the most common climate indices!
- Change of the NAO sign around 1987 is not a statistically significant breakpoint.
- Therefore the statistical evidence for a regime shift in the Baltic Sea at the end of the 1980ties is rather weak, most investigated ecological variables are better described by least square regression analysis.
- Only some physical variables do have a breakpoint at end of 80ties.
- We strongly advocate to apply sound statistical procedures for detecting regime shifts (not qualitative descriptions).
- Indeed most time series are best described by a trend!
- Confirming a causal chain that could lead from climate change to a regime shift in ecosystems requires a much deeper understanding of the complex geophysical and ecosystem interactions!