

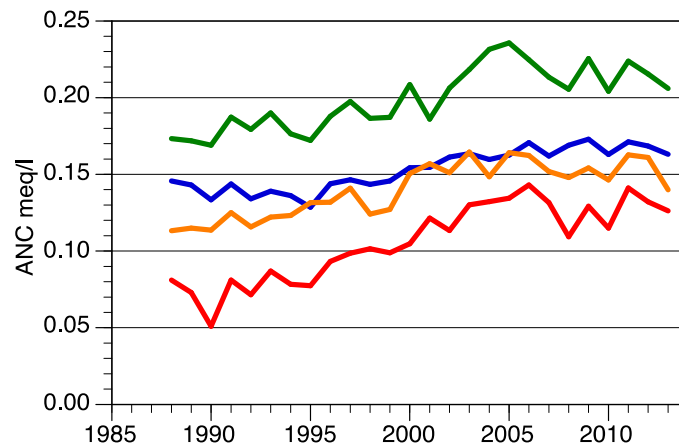
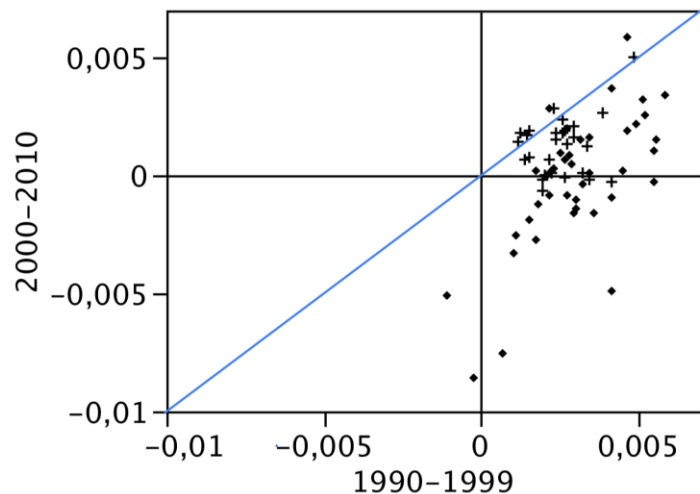
Acidification and recovery in Swedish lakes and streams

Application of GAMM-models on multiple time series

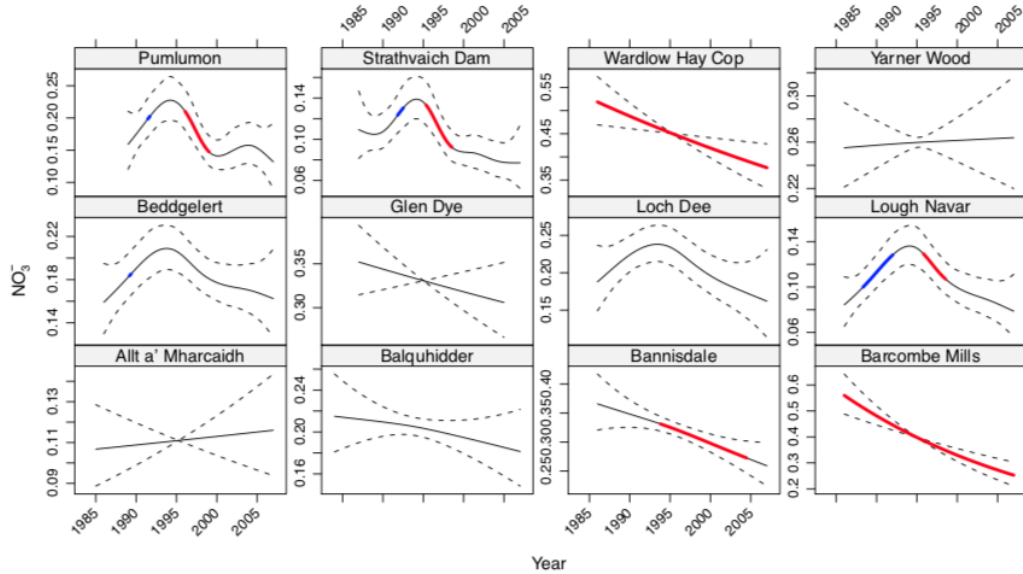
Jens Fölster and Claudia von Brömsen
Swedish University of Agricultural Sciences

How to present time series showing declining recovery?

ANC-trend mekv/l



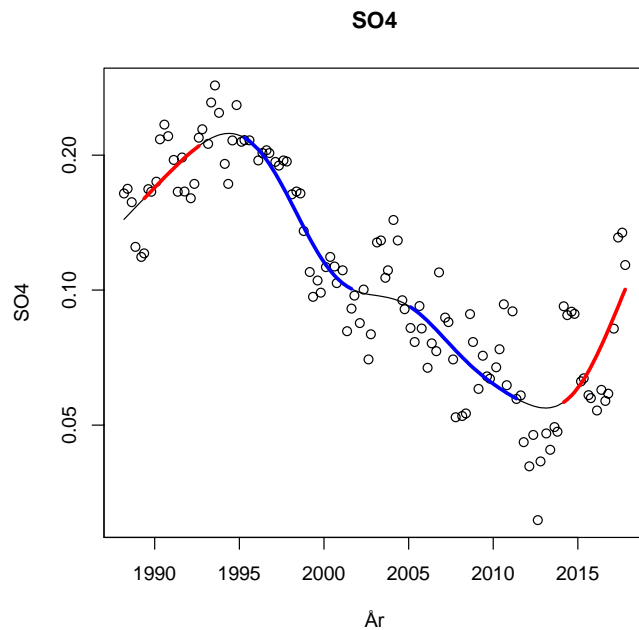
GA(M)M –models developed by Gavin Simson (Generalised Additive (Mixed) Models)



Recovery of lakes and streams in the UK from the effects of acid rain
UK Acid Waters Monitoring Network 20 Year Interpretative Report

Eds. M. Kernan, R.W. Battarbee, C. J. Curtis, D. T. Monteith & E. M. Shilland
July 2010

Sulphate in Stora Skärsjön

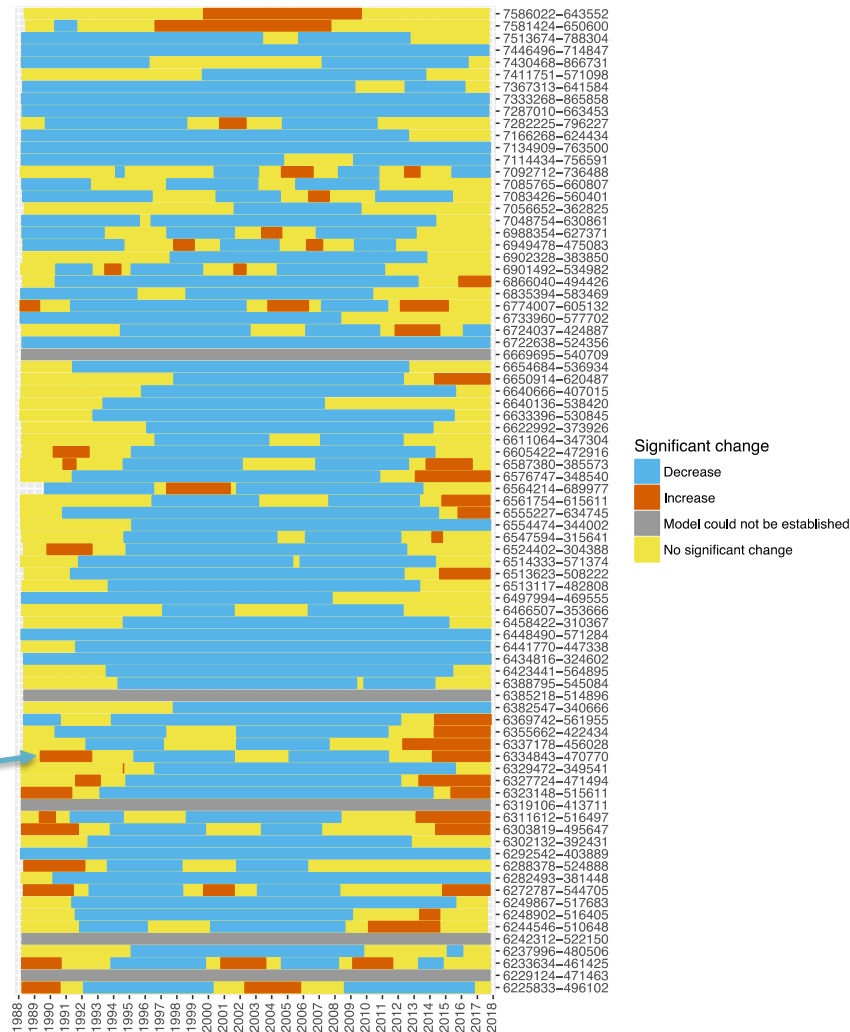
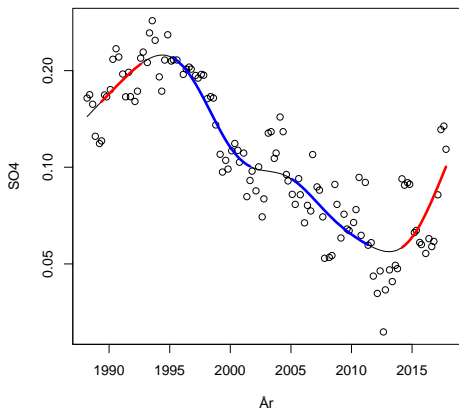


GAMM models on data from Swedish national monitoring data

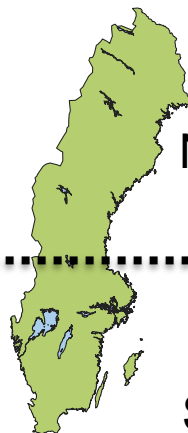
- Subset of waterbodies with ANC < 300 μ g/l
- 81 lakes (4 samples per year)
- 51 streams (monthly sampling)

SO₄* in 81 lakes ANC < 0,3 meq/l

SO₄

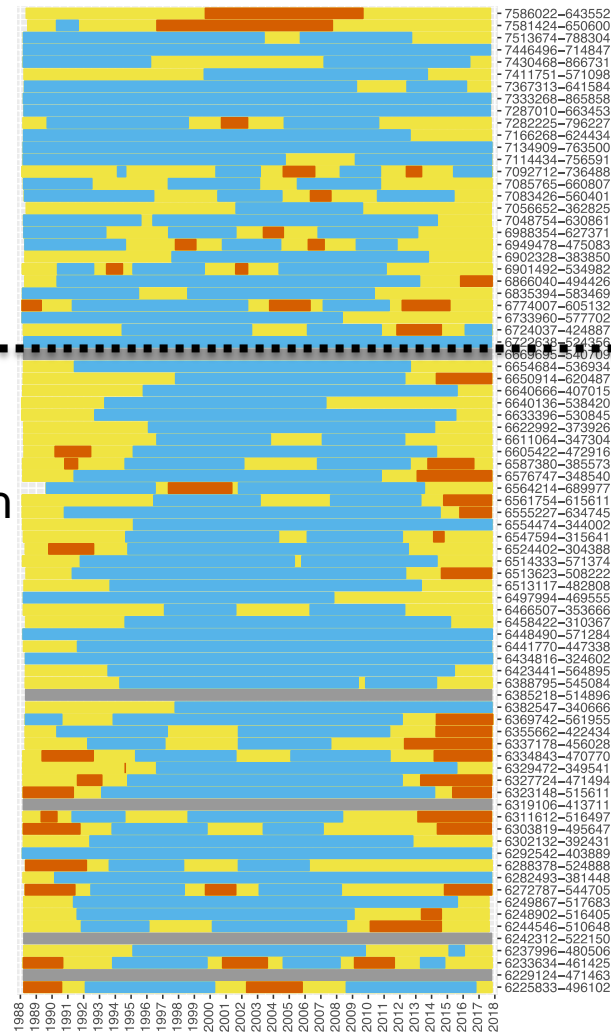
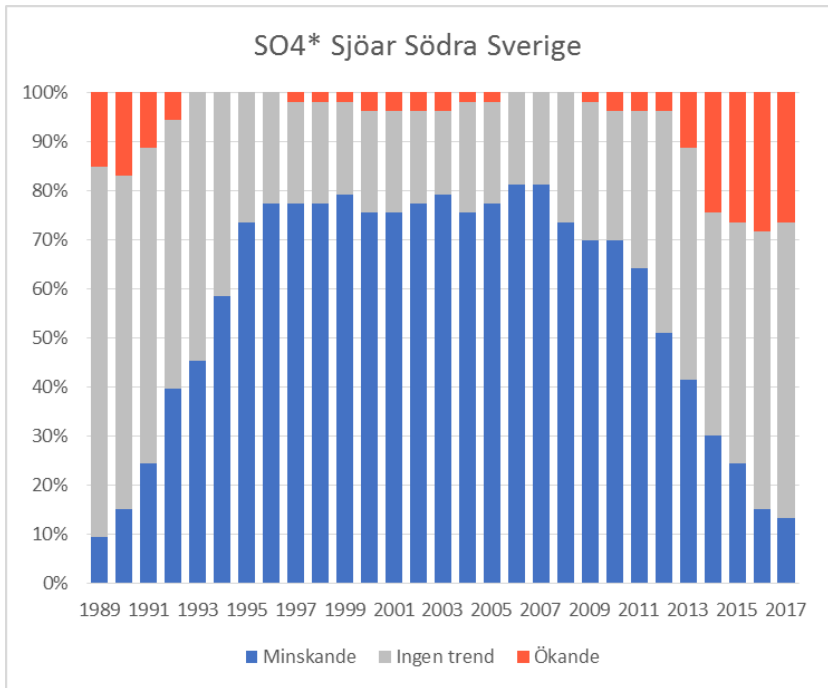


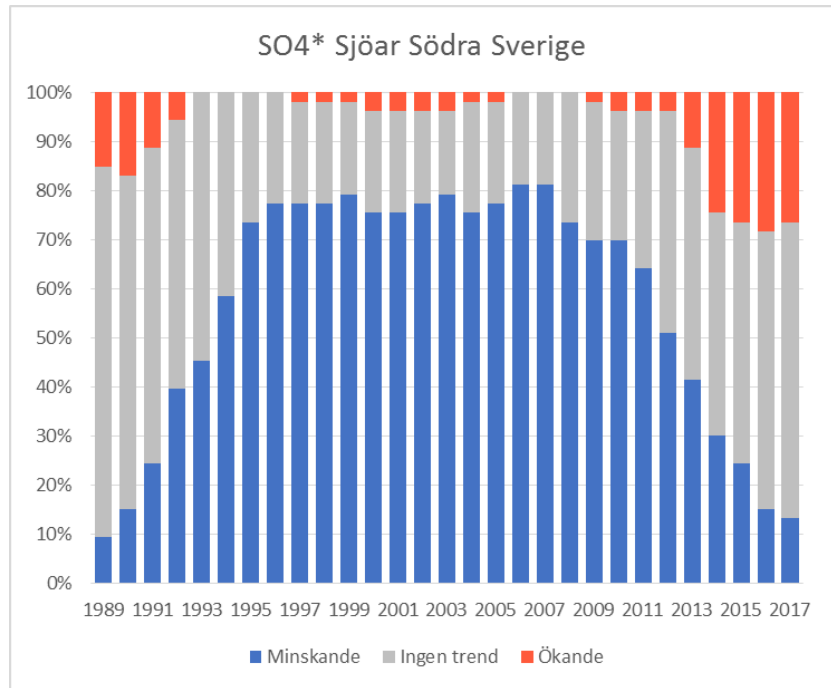
SO₄* trends in 53 lakes in southern Sweden



North

South





More acidic

Less acidic

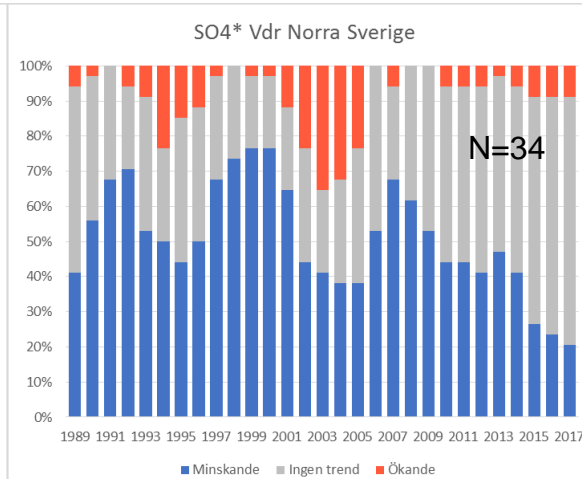
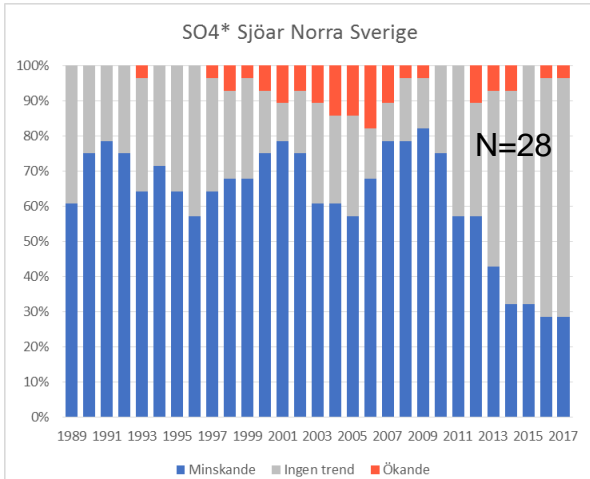
Lower bars – recovery related

SO₄*

Lakes

Streams

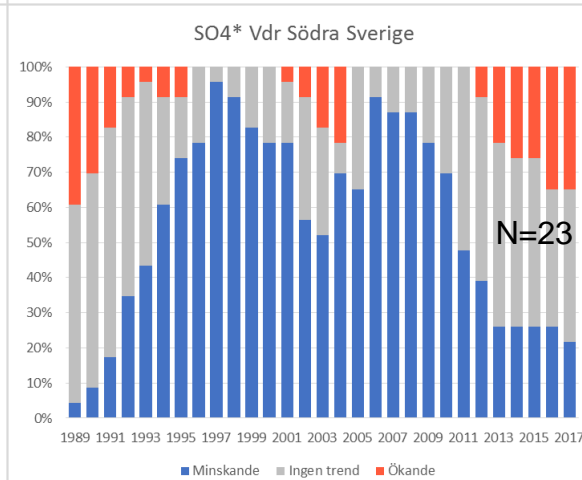
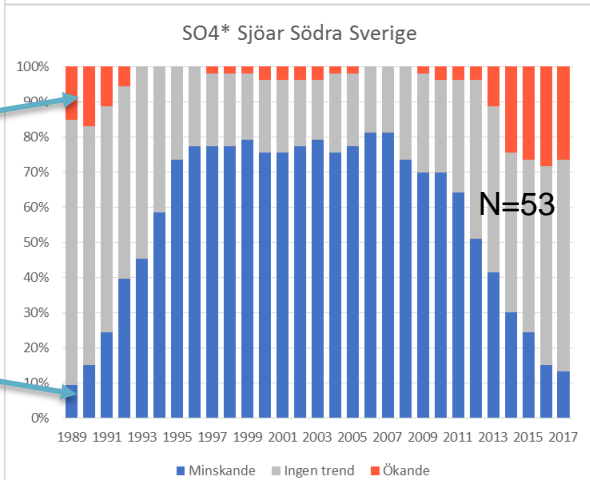
North



Increase



Decrease



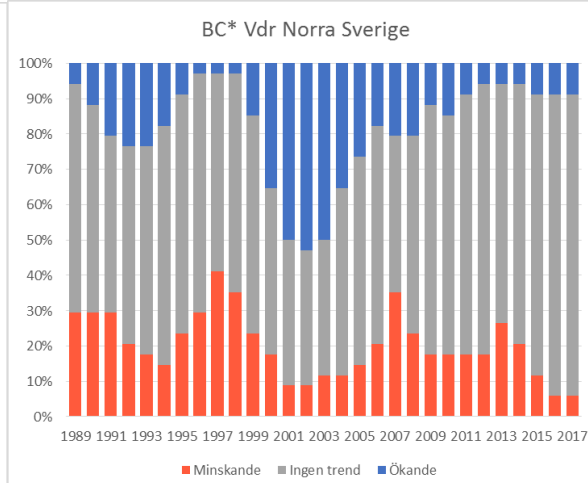
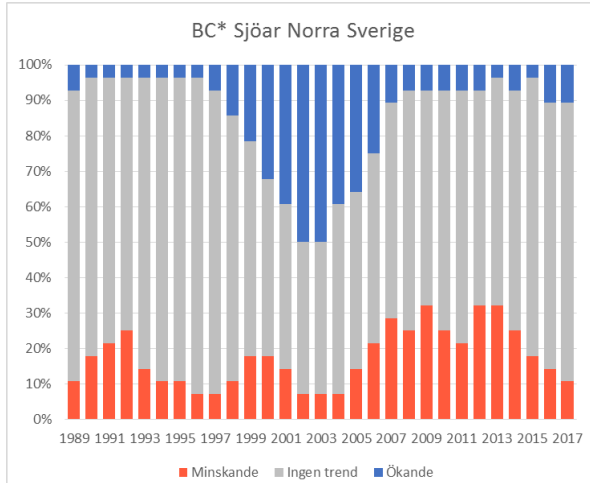
South

BC*

Lakes

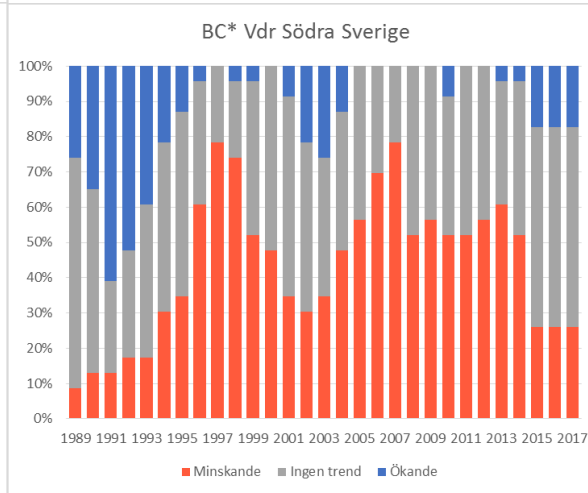
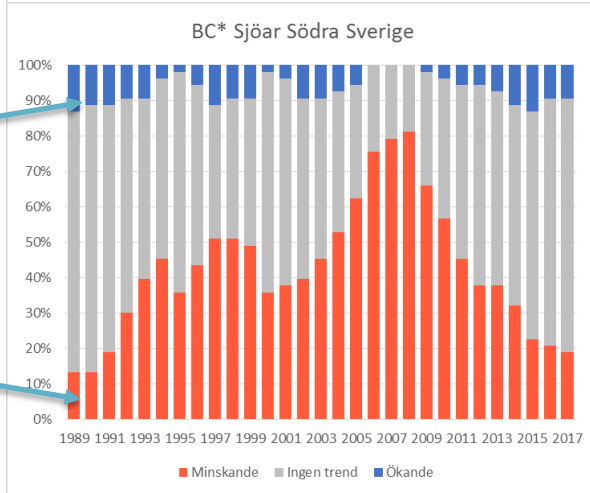
Streams

North



Increase

Decrease



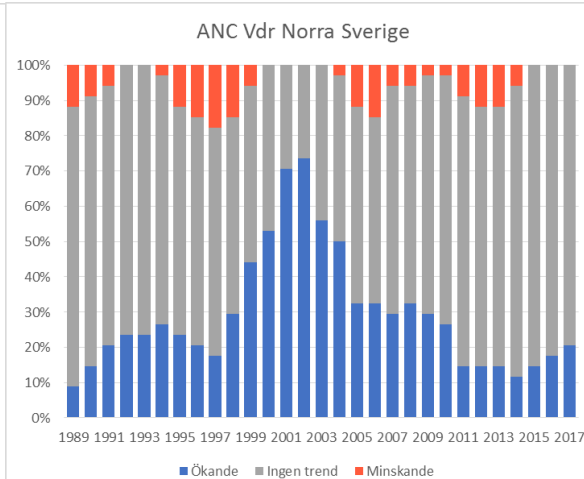
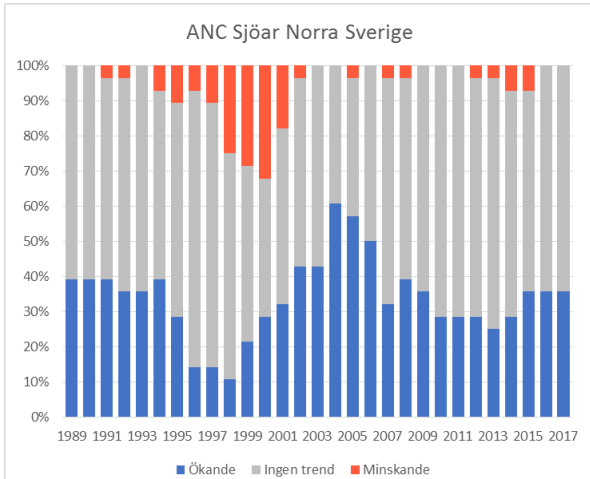
South

ANC

Lakes

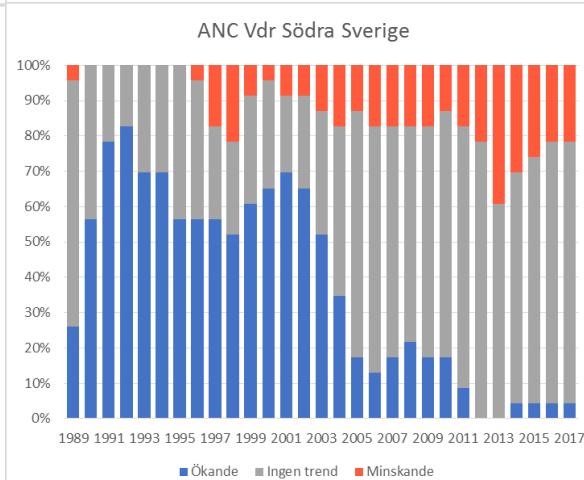
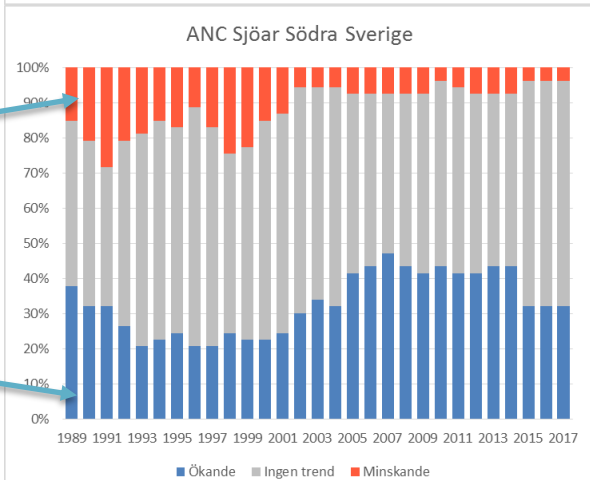
Streams

North



Decrease

Increase



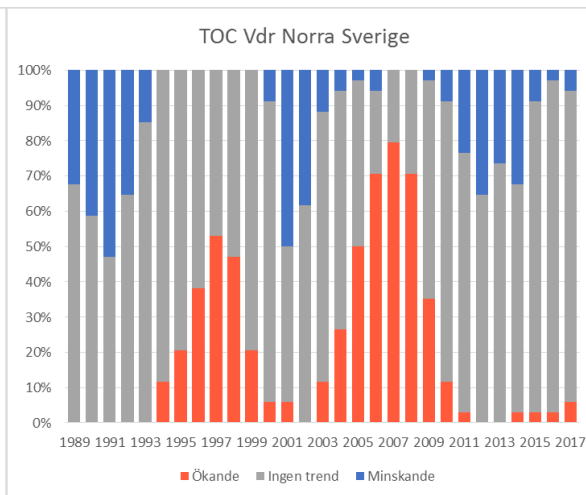
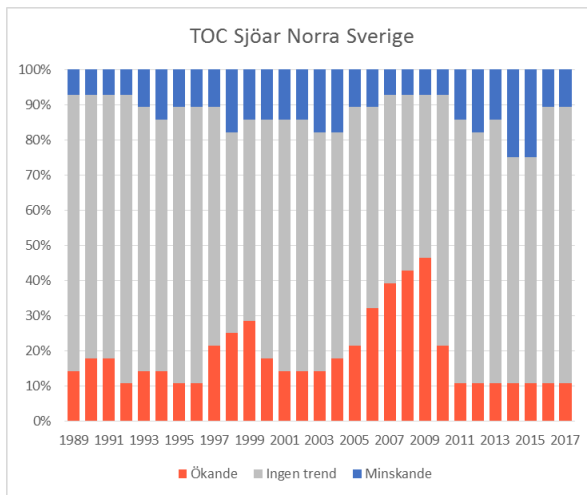
South

TOC

Lakes

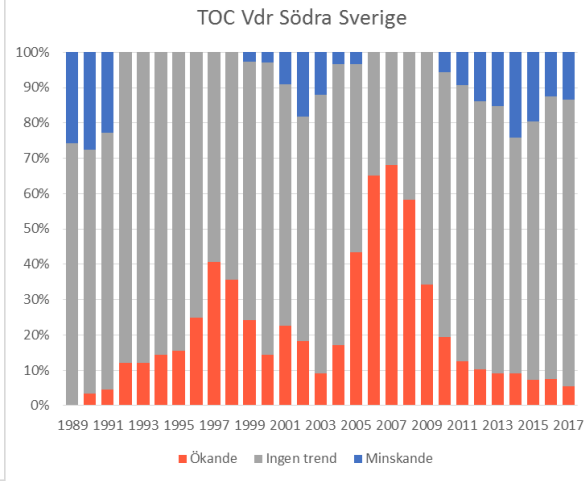
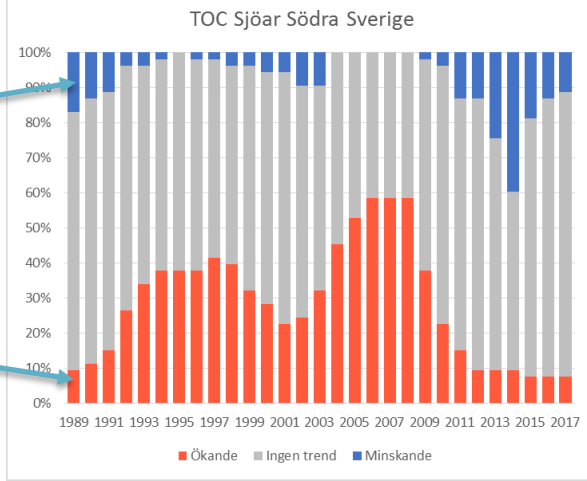
Streams

North



Decrease

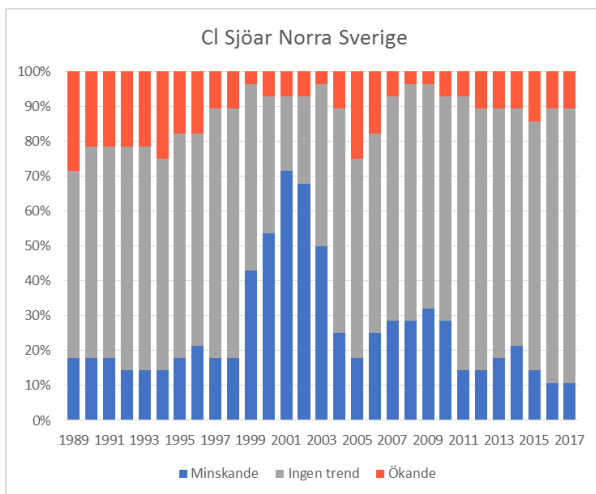
Increase



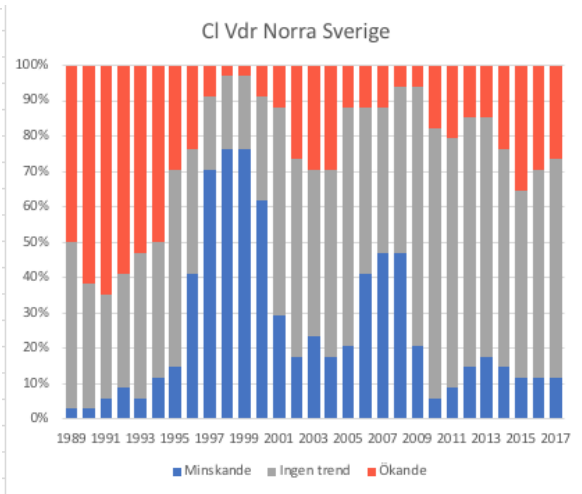
South

CI

Lakes



Streams

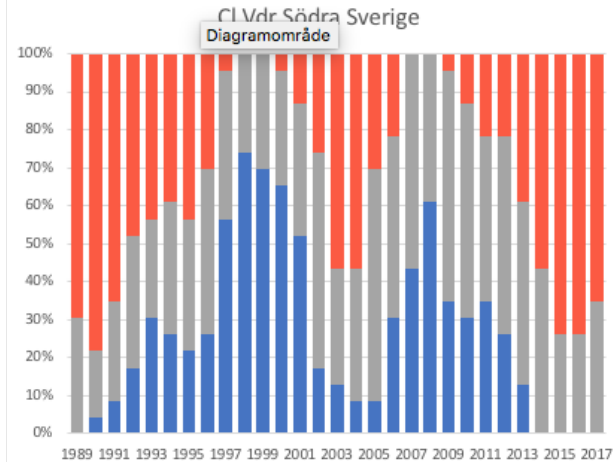
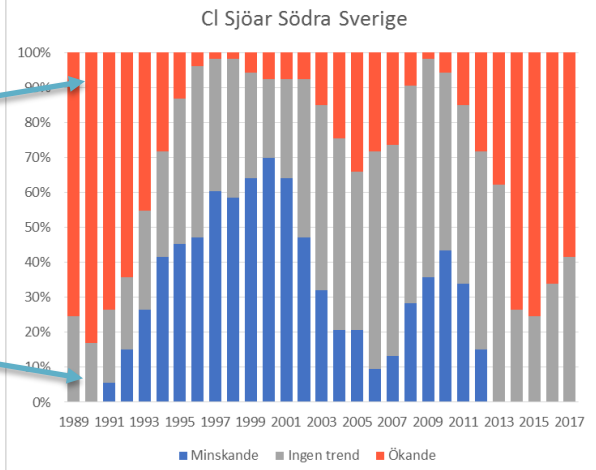


North

Increase



Decrease



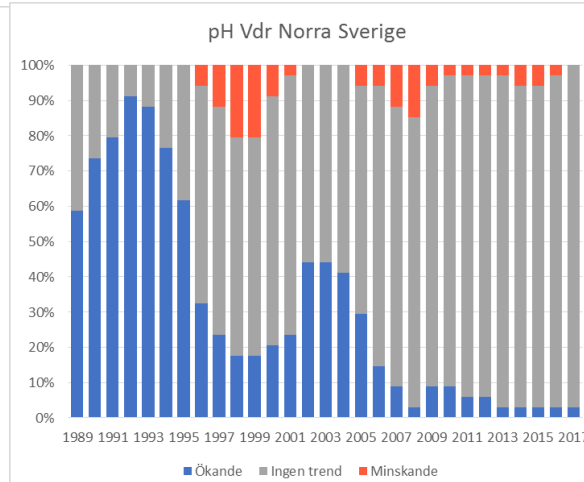
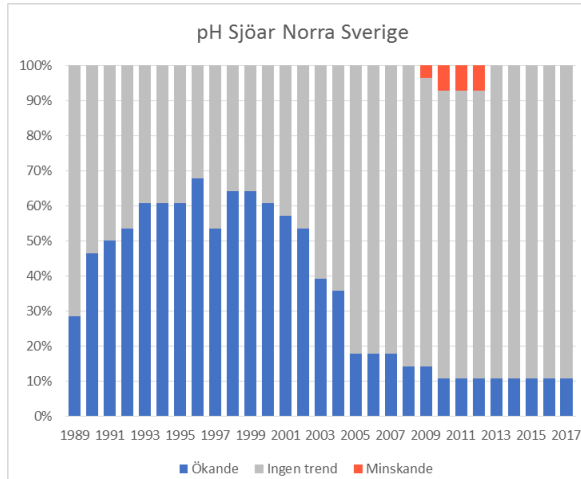
South

pH

Lakes

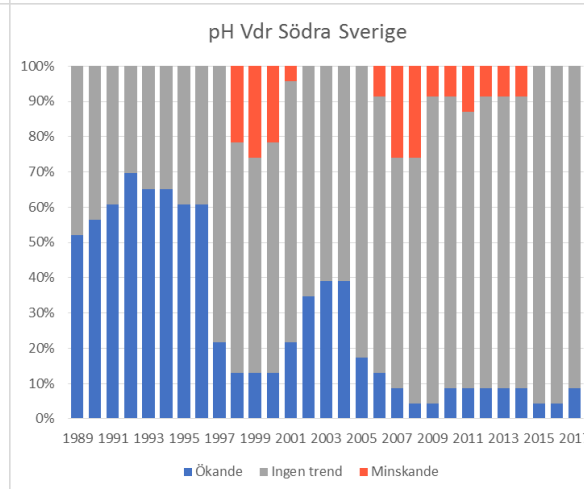
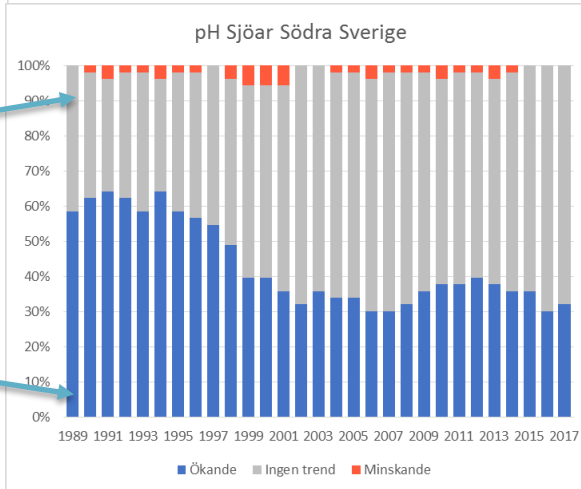
Streams

North



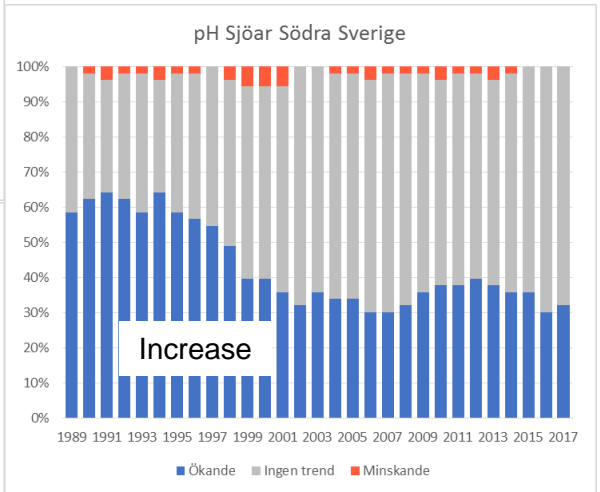
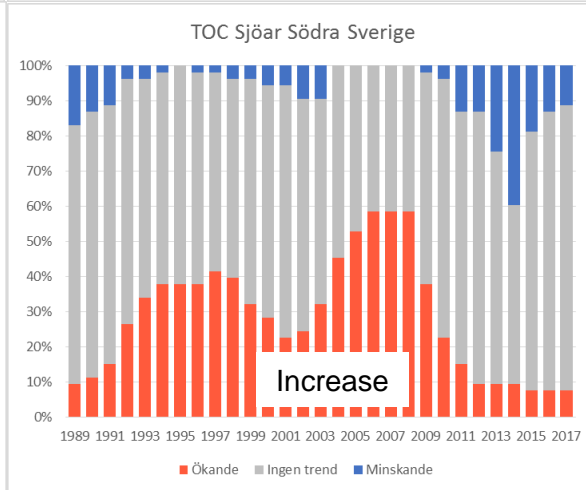
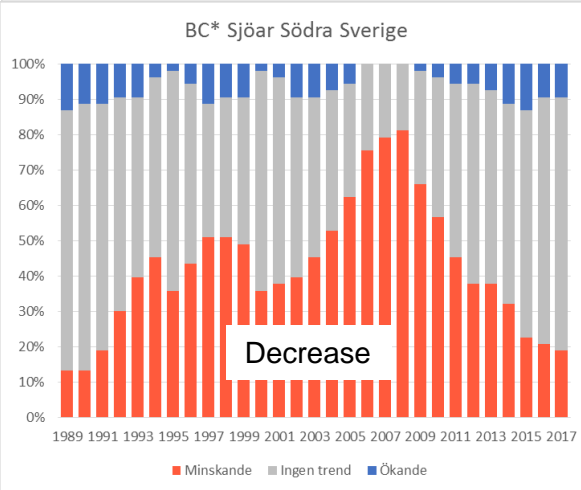
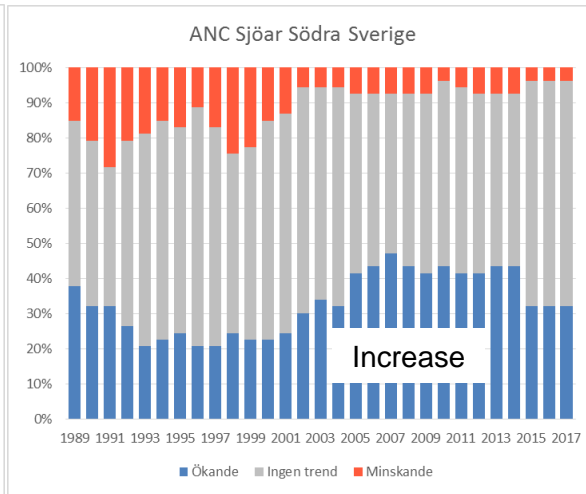
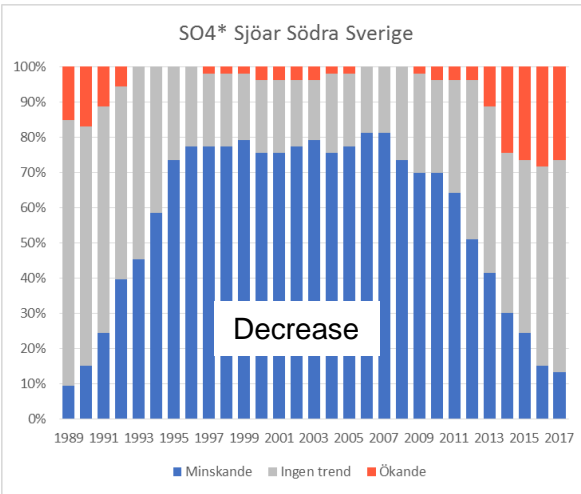
Decrease

Increase



South

Lakes in Southern Sweden (n=51)



Same with modelled pH?

$$H^+ = (SO_4 + NO_3 + Cl + HCO_3 + CO_3 + OH^- + RCOO^-) - (Ca + Mg + Na + K + Al^{n+})$$

$$H^+ = HCO_3 + CO_3 + RCOO^- + ANC - \cancel{Al^{n+}}$$

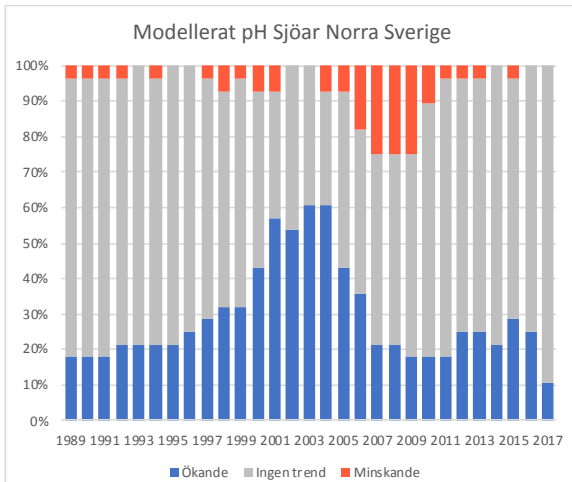
$$RCOO^- = f(DOC) \text{ (Triprotic model by Köhler, 2014)}$$

$$pH = f(ANC, DOC, pCO_2)$$

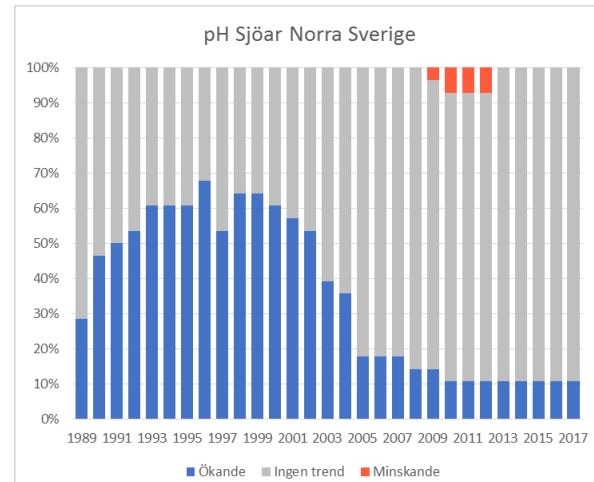
$$pCO_2 = f(DOC) \text{ (Sobek, 2003)}$$

Lakes

Modelled pH



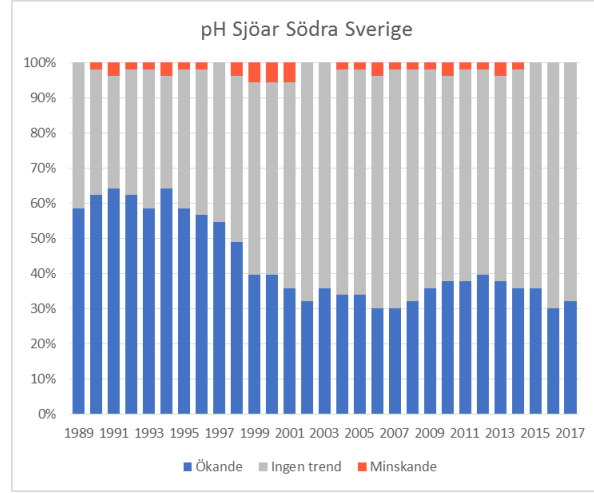
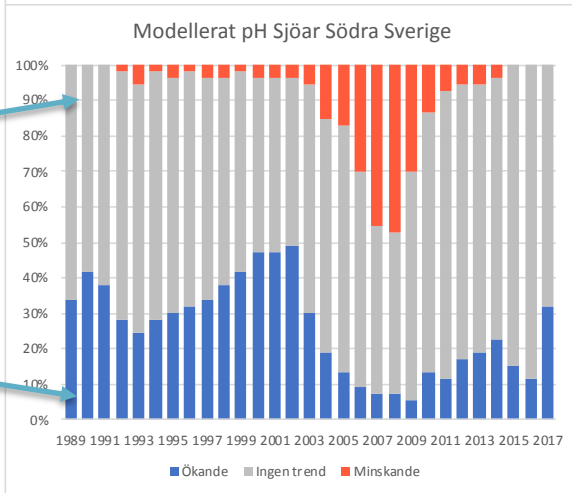
Measured pH



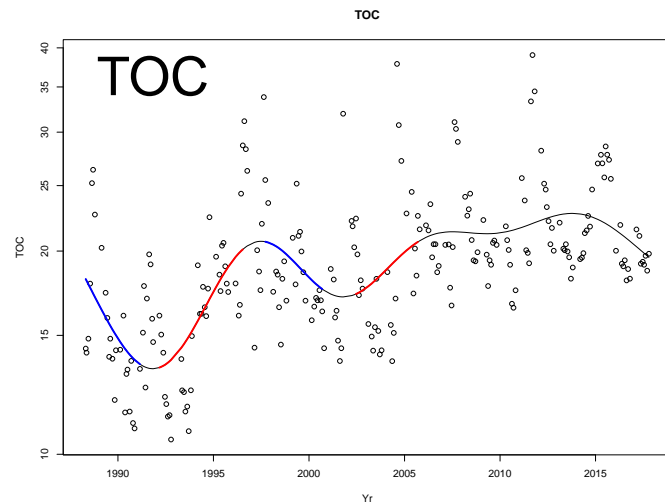
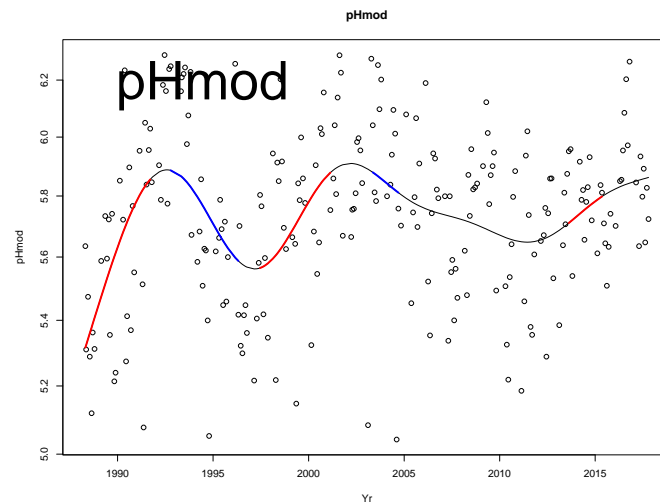
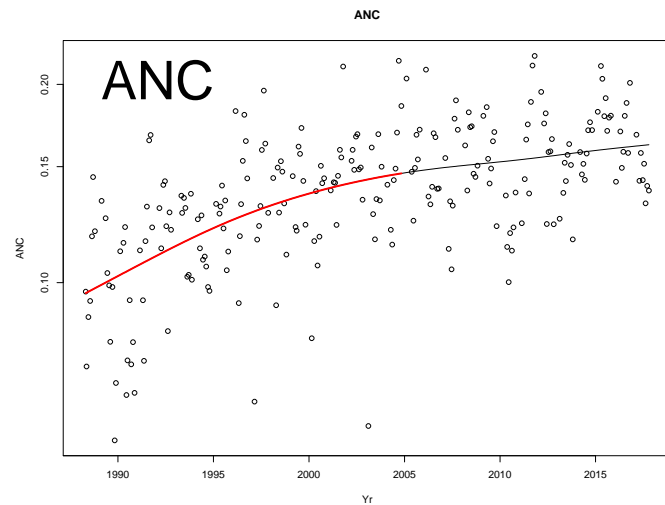
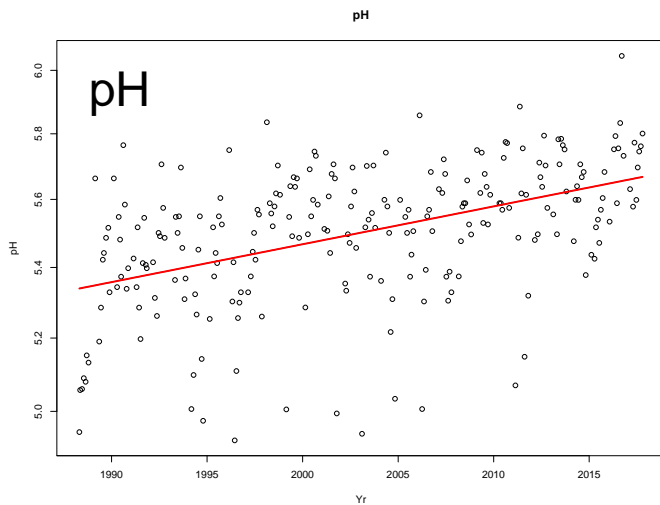
Decrease



Increase



Example: Brunnsjön



Conclusions

- GAMM models can be used to reveal large scale patterns in time series and to generate hypothesis
- The strong trends in declining SO₄ have now leveled out and been replaced by a climate driven cyclic pattern.
- Streams shows a stronger response to climatic fluctuations compared to lakes.
- SO₄ decreases are accompanied by BC decreases.
- ANC increases dominates over decreases, but in the streams, decreases has taken over
- Brownification show a strong climatic fluctuating component, with dominating decreases of TOC the last years
- pH increases the whole time period. For many time series a linear trend was fitted

Thank You!

