Credible acidification assessments in a changable environment

Estimating the natural acidity of boreal lakes in Sweden

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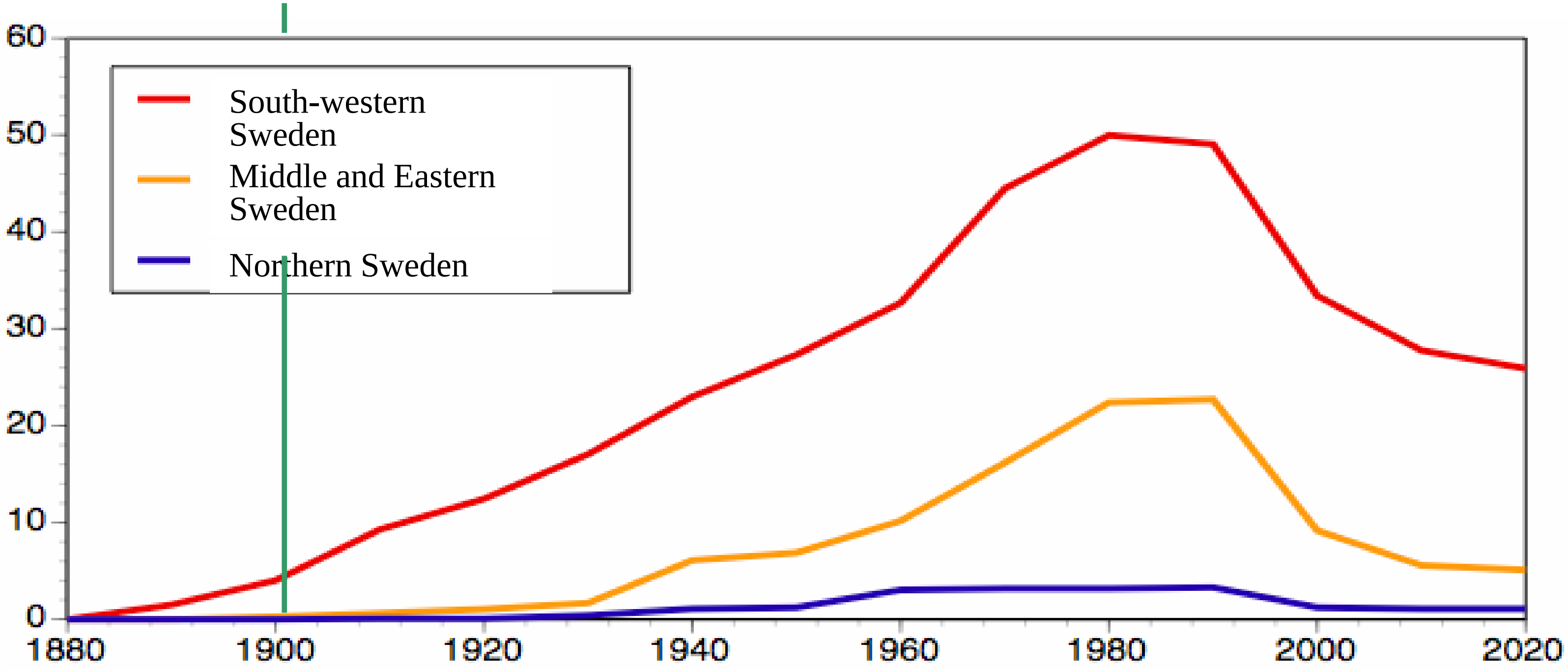
Acidification

Proportion of acidified lakes in Sweden by region, 1880-2020



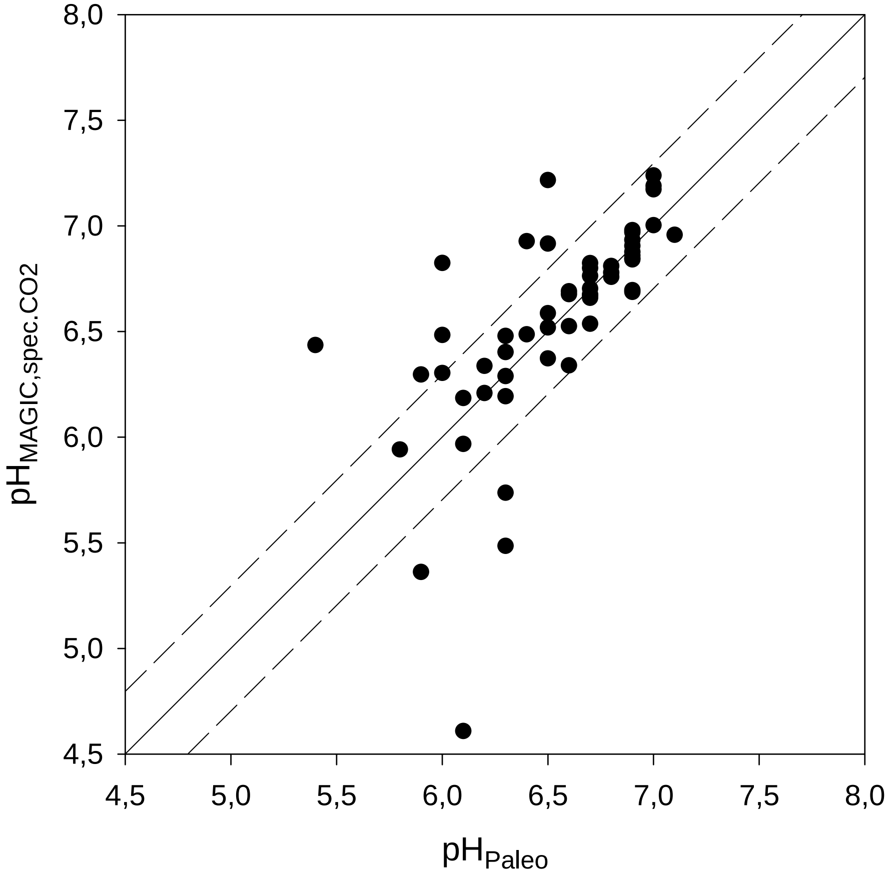
6 good reasons to study acidification in the 21th century

- The recovery will take time (decades), and lakes will be more sensitive to ”acid episodes”, due to soil acidification
- Climate change will affect the recovery process
- Acidification problems are increasing in other parts of the world (i.e. China)
- N-saturation and increased biomass harvest for biofuel may cause re-acidification
- New legislative demands
- Higher demands are put on accuracy as acidity is moving closer to its natural levels

Paper I – Comparing MAGIC with paleolimnological reconstructions

- Reconstructions of pre-industrial acidity have been made with both methods for 55 Swedish lakes (Moldan et al. 2004, Guhrén et al. 2003).
- The paleolimnological reconstruction predicts pH.
- MAGIC predicts both pH and buffering capacity (ANC), but pH reconstructions are less reliable.

Long term, lake-specific values of TOC and pCO_2



Mean difference: 0.03 units

Mean *absolute* difference: 0.22 units

Expected difference in the interval [-0.07 ; 0.13] units

$EpCO_2$: mean 90-04 (1.4-11.1)
TOC: mean 90-04 (1.5-17.9 mg/l)

Paper II – Construction of a meta-model based on MAGIC ($meta_{MAGIC}$)

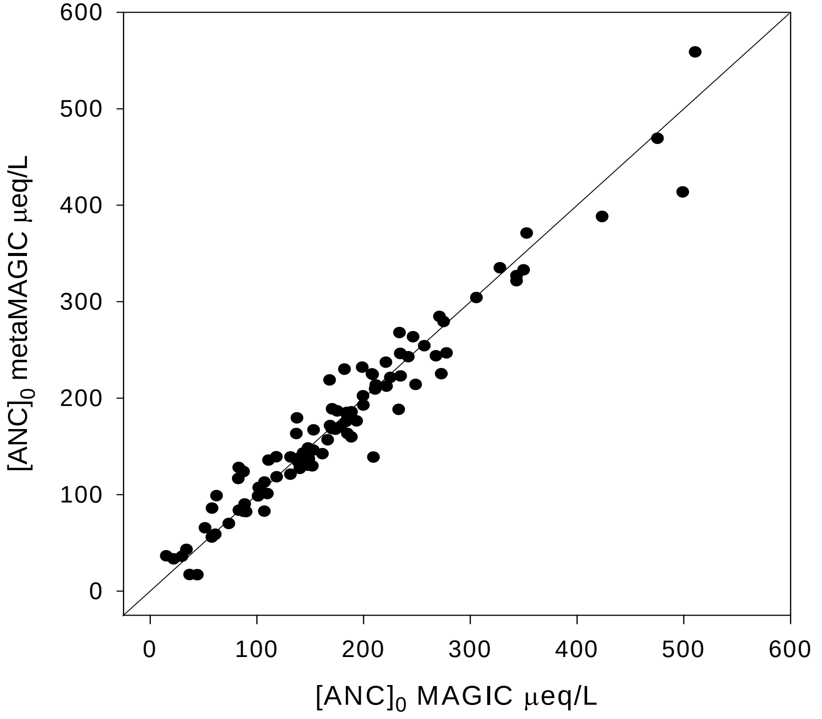
- F-factor does not work during recovery
- MAGIC or Paleo to expencive
- The concept: To create a model that aims to reproduce the results from MAGIC – a meta-model.
- $Meta_{MAGIC}$ was calibrated for 95 lakes, for the years 1990-2004

Parameters tested for calibrating meta$_{MAGIC}$

Chemical parameters	Alkalinity, pH, **BC**, **SO_4**, NO_3, **Cl**, ANC, TOC
Land use parameters (%)	Forest, Wetland, Farmland, Open Water
Lake morphology parameters	Catchment area, Lake volume, Retention time
Geographical parameters	Latitude, Longitude, Mean runoff, Altitude

The $\text{meta}_{\text{MAGIC}}$ equation

$$[ANC]_0 = b_1 \cdot [BC^*]_t + b_2 \cdot [SO_4^*]_t + b_3 \cdot [Cl^-] + b_4 \cdot [BC^*]_t^2 + b_5$$

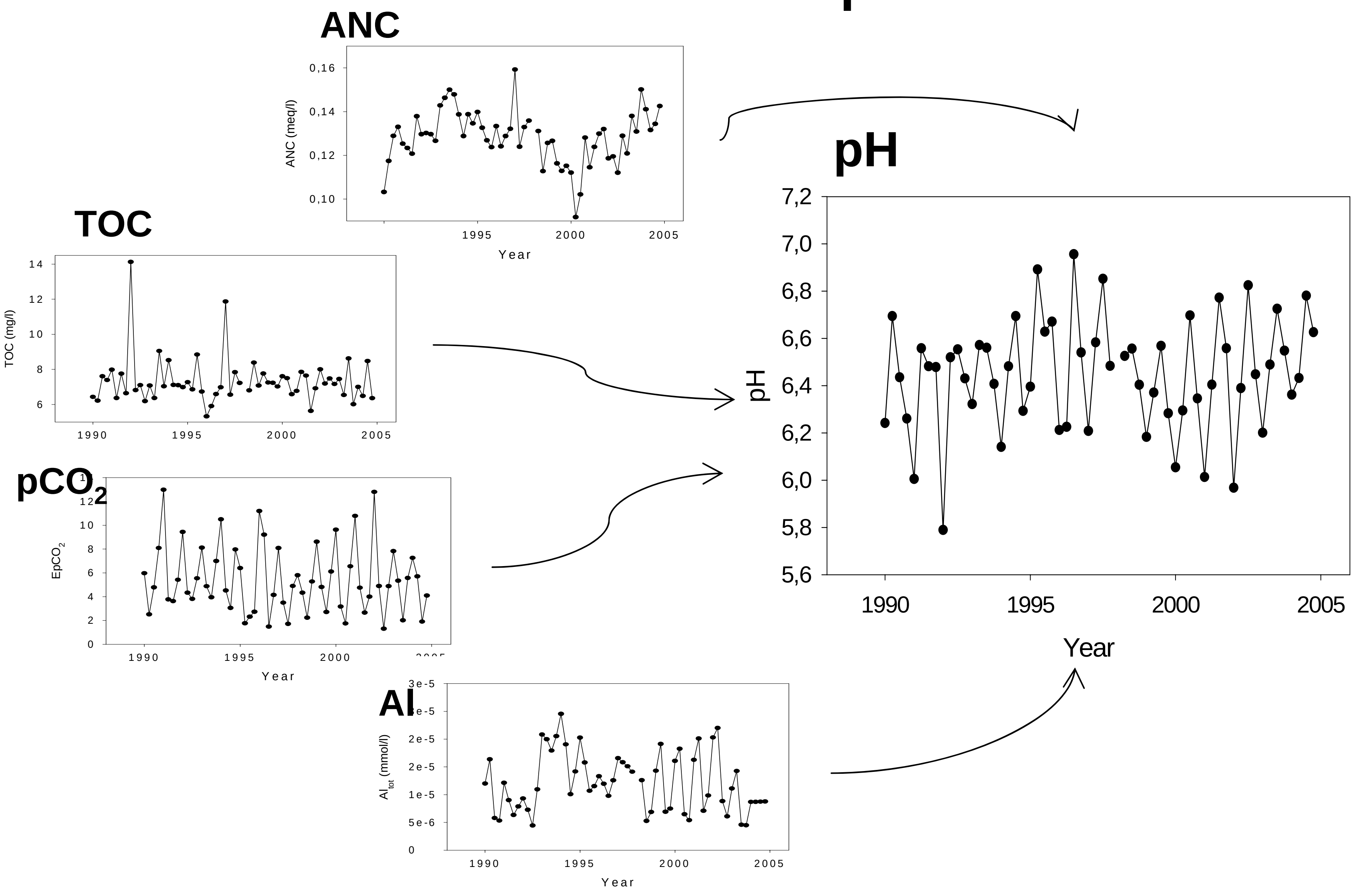


Median error: 13.2 μeq/l

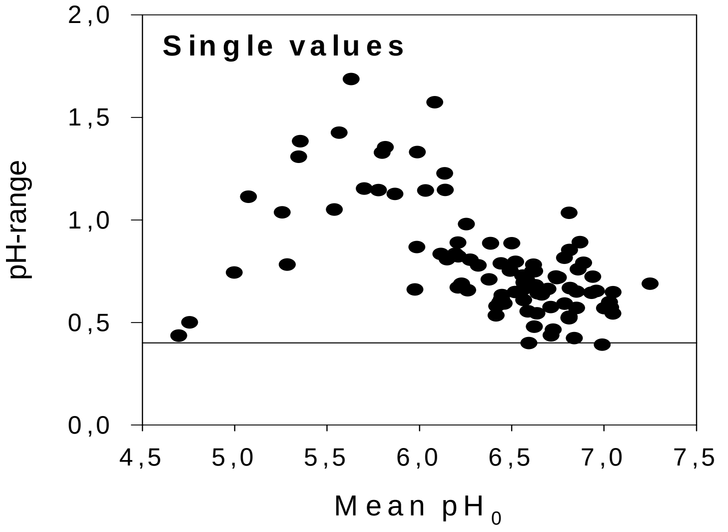
Paper III – Variability of reference pH during a 15 year period

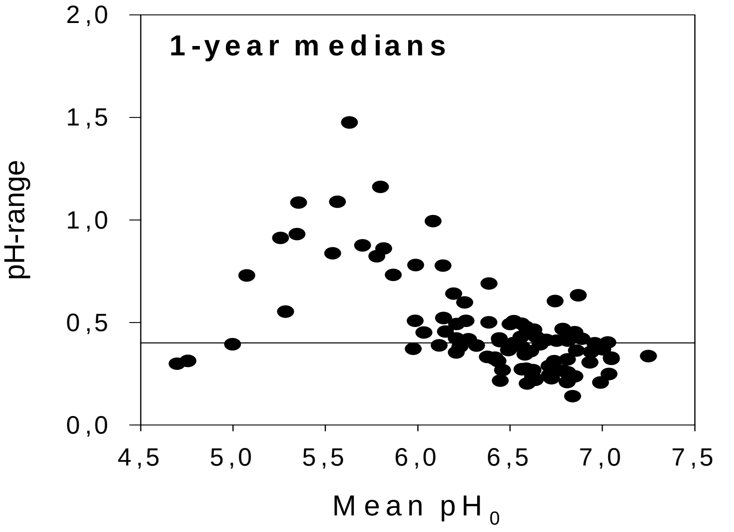
- The variability in reference pH was examined on *seasonal, interannual* and *decadal* time scales
- Full time series 1990-2004 of reference pH (4 observations/year) were reconstructed for 95 Swedish lakes

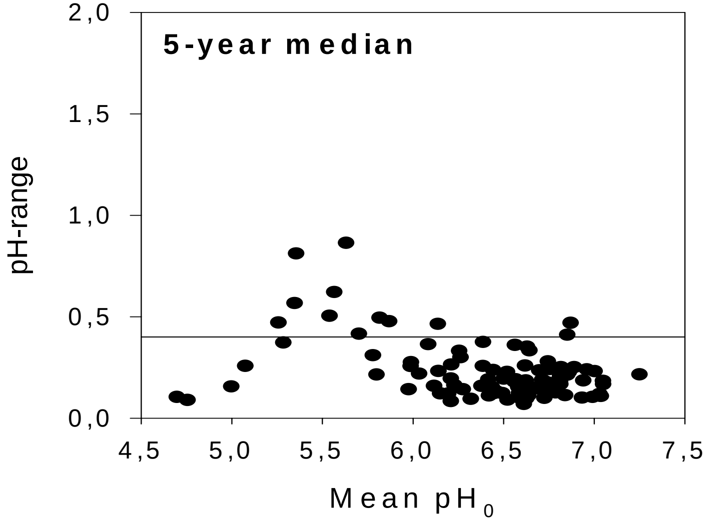
Reconstructing time series of pre-industrial pH



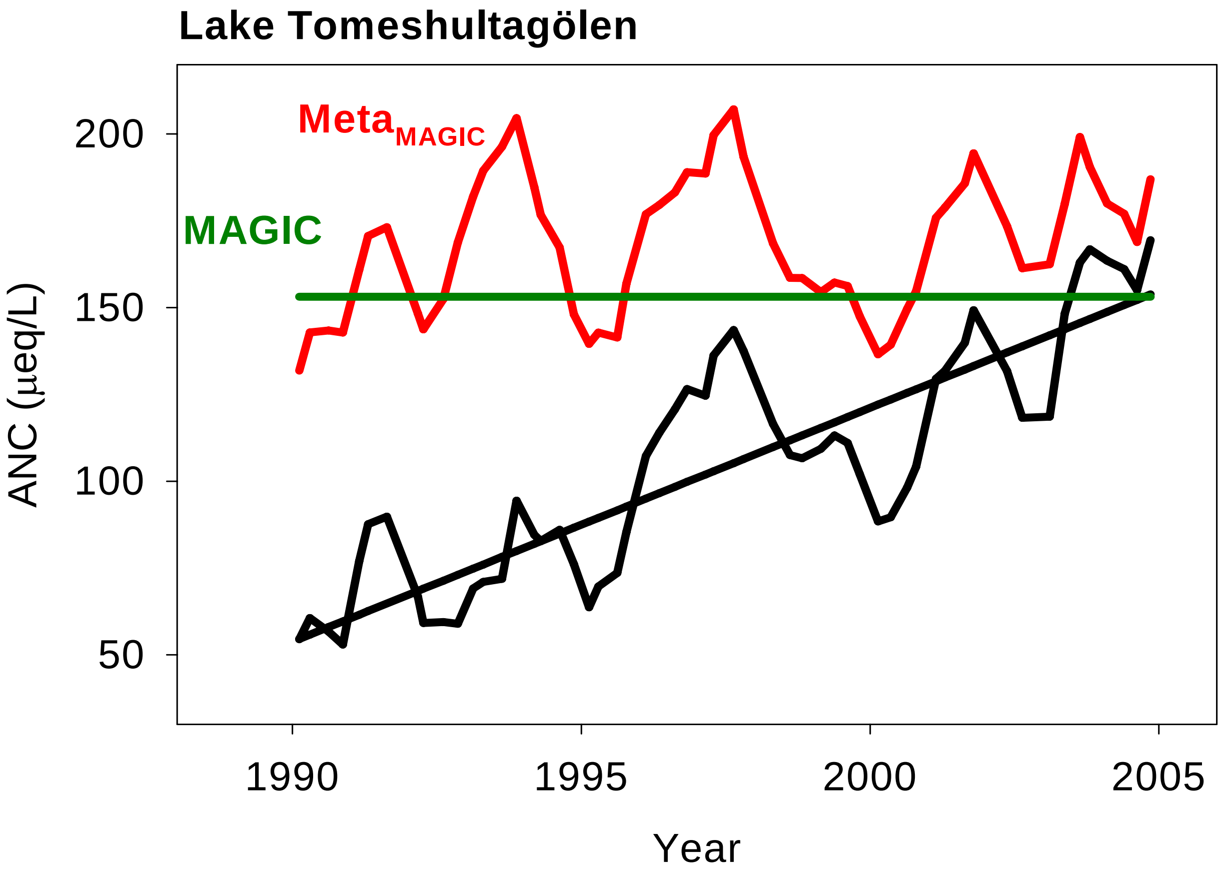
Ranges of reference pH (difference between 90th and 10th percentile)







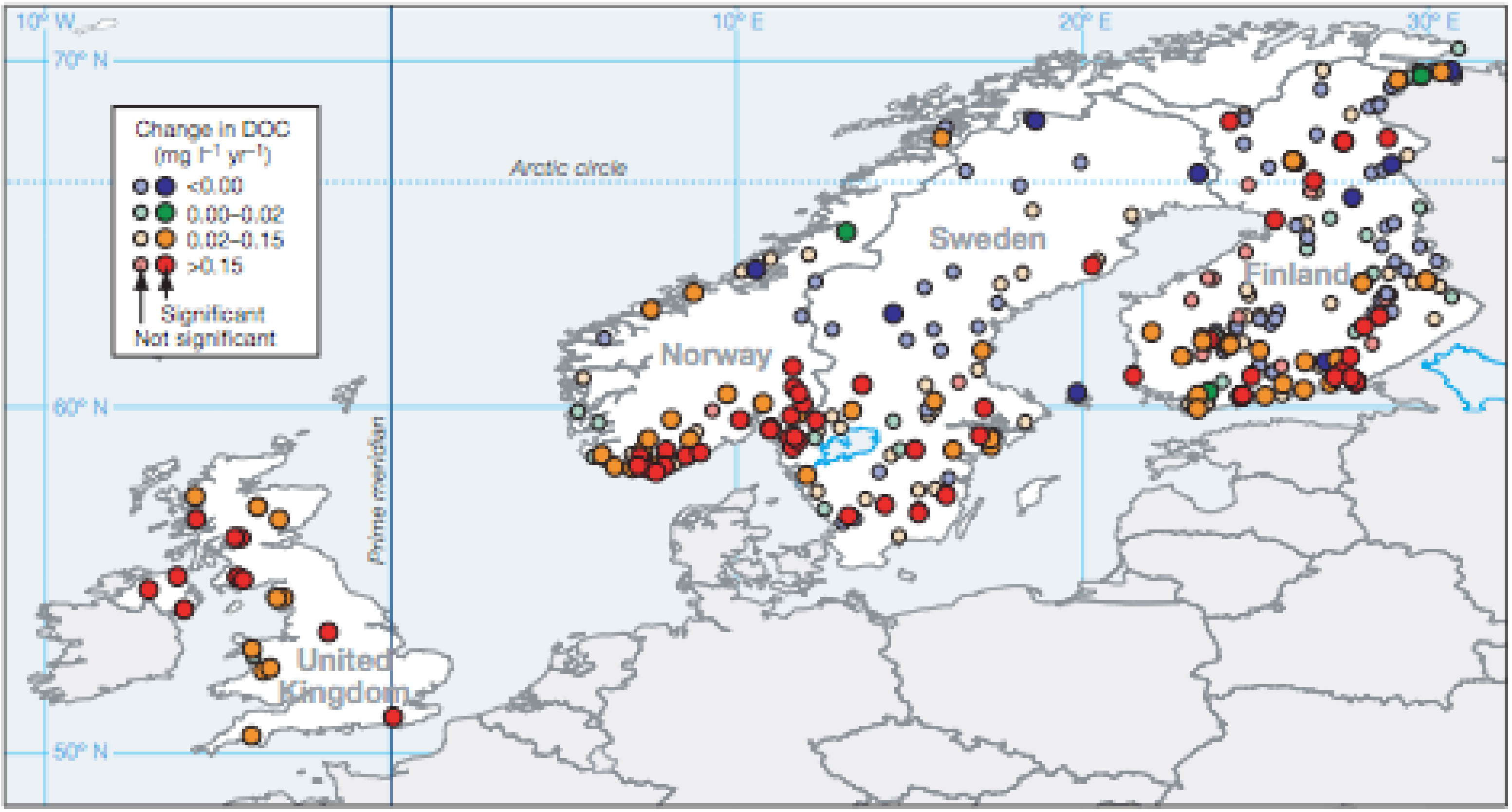
Meta$_{MAGIC}$ – a way to handle variable reference levels?



Monteith et al 2007 Nature

15-year time series 1990-2004

Support for the acidification supression hypothesis

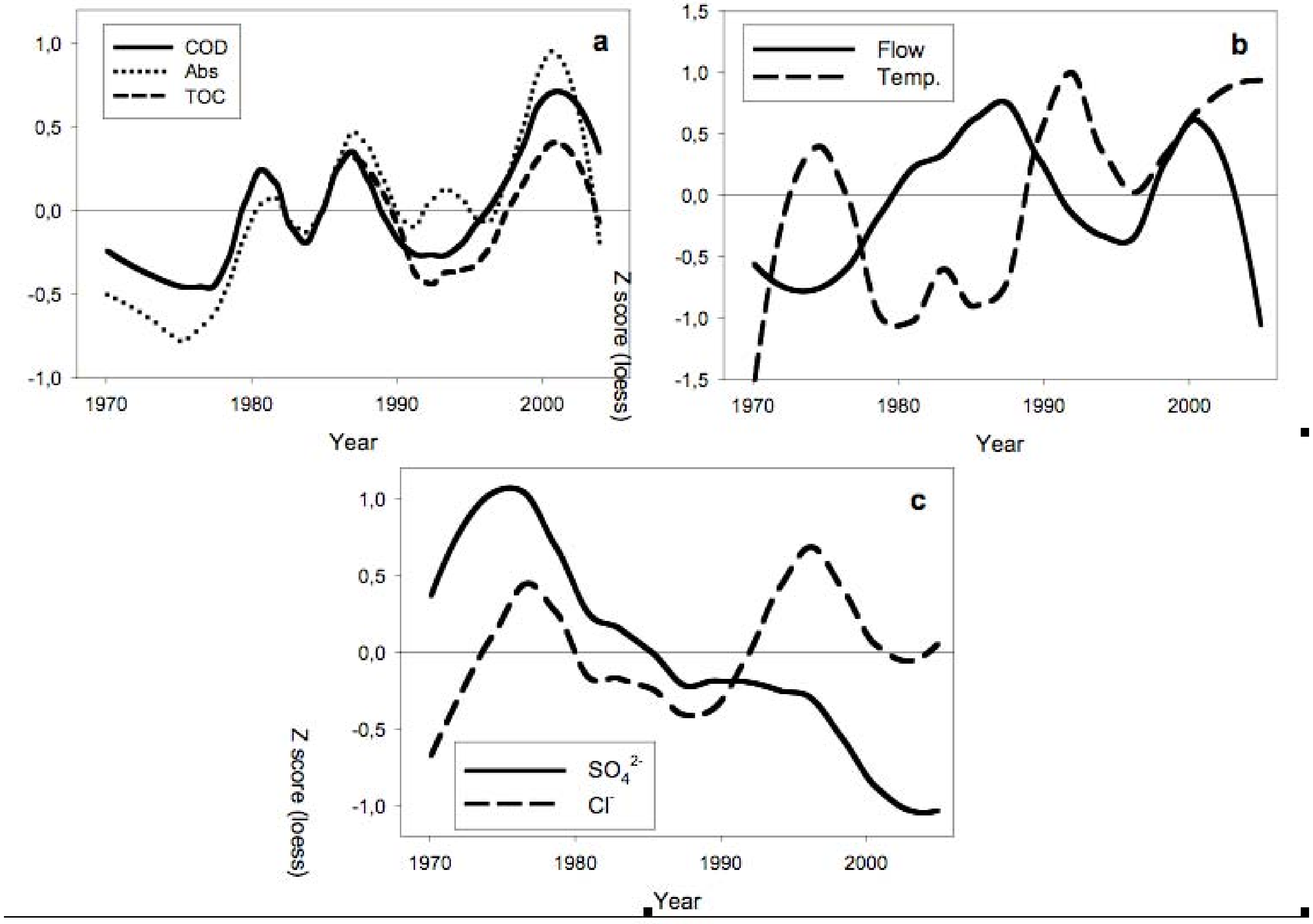


Erlandsson, M., I. Buffam, J. Folster, H. Laudon, J. Temnerud, G. A. Weyhenmeyer and K. Bishop (2008).

"Thirty-five years of synchrony in the organic matter concentrations of Swedish rivers explained by variation in flow and sulphate."

Global Change Biology 14(5): 1191-1198.

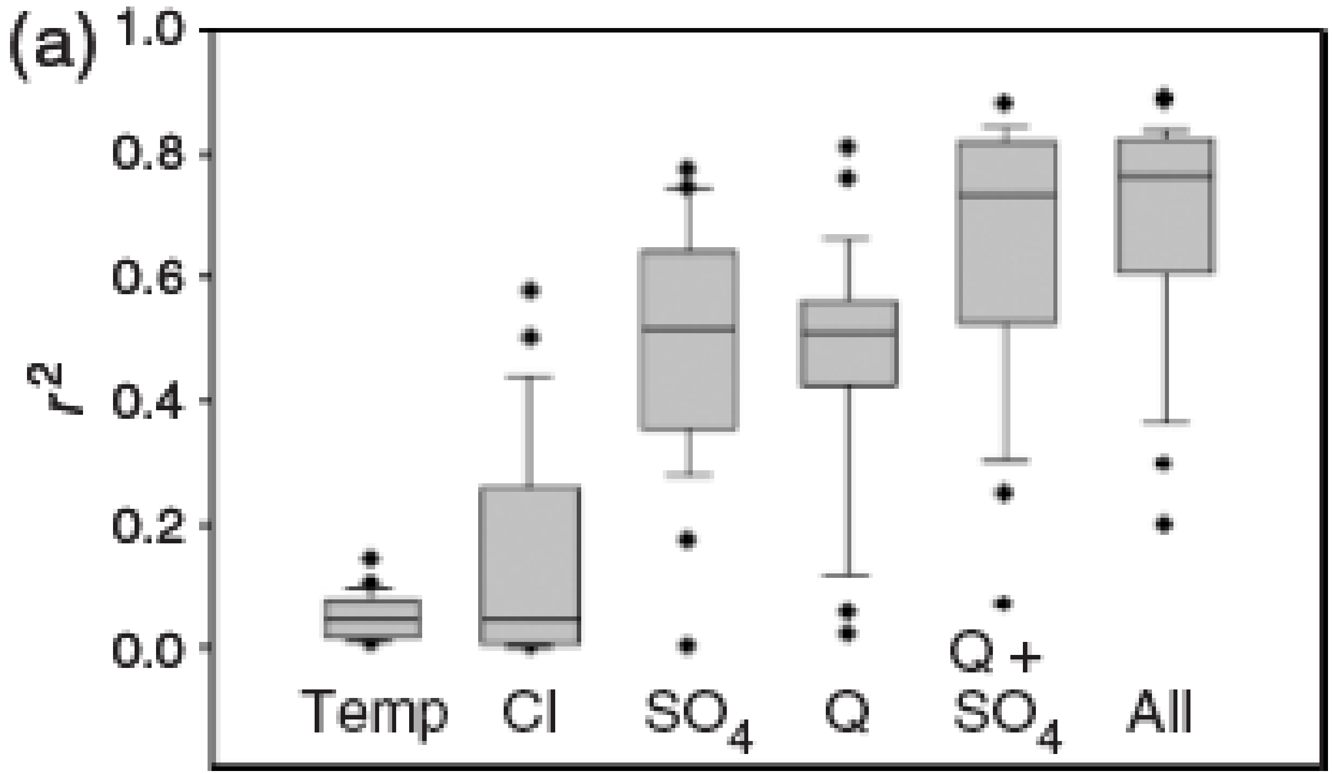
35-year time series in 28 Swedish streams



Erlandsson m fl
2008 GCB

Q and SO4 explained 88% of the Abs-variation and 78% of the COD- variation

Linear regressions of Abs F420



Paper IV – Impact of increasing TOC on acidification and recovery

- Increasing levels of organic acids affects the acidity, and can be seen as:
  - A change in natural acidity *or*
  - A complication in defining the natural acidity
- The effects on acidification/recovery were studied in 24 lakes with a TOC increase of at least 30 % between 1990 and 2004

The acidification supression hypothesis (AS)

- TOC was suppressed during the acidification phase, and is now returning to its ”natural” levels
  - pH was modelled for 1990, using TOC concentrations equal to those in 2006, to examine how much suppression of TOC buffered against acidification

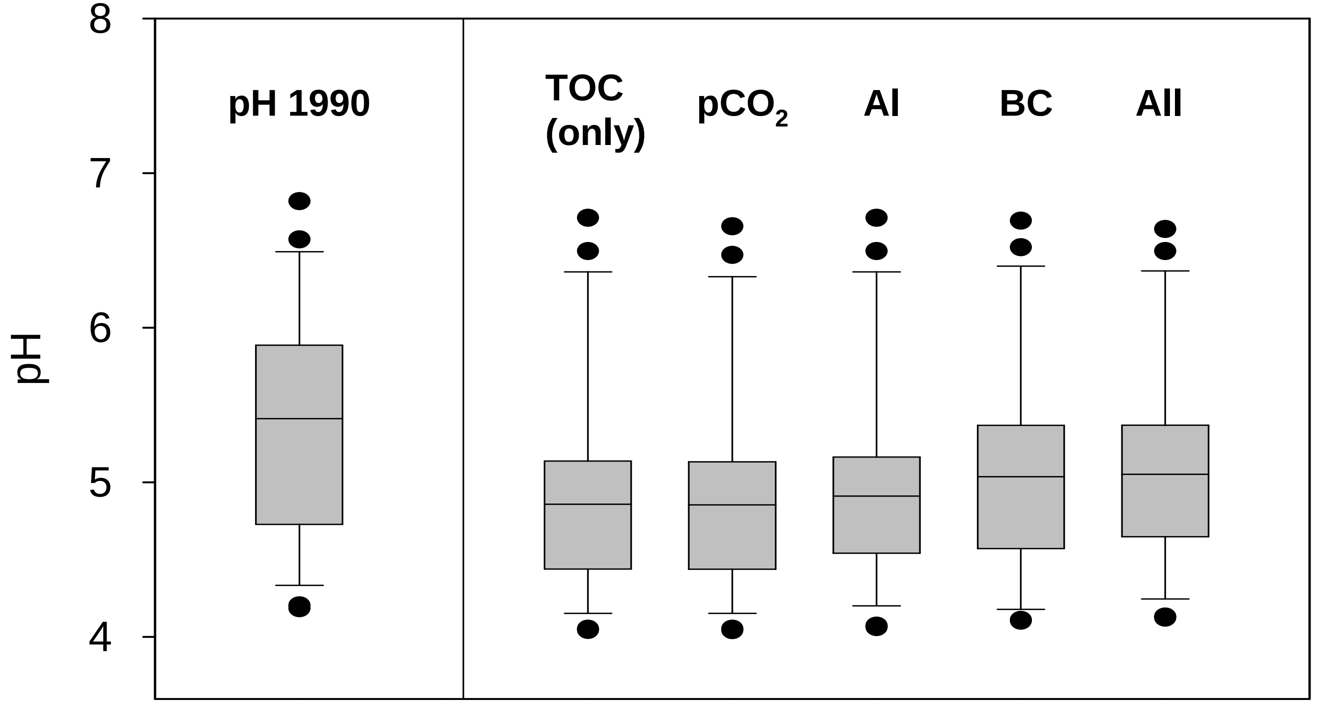
The Climate Change Enhancement hypothesis (CCE)

- TOC is increasing to previously unprecedented levels due to climate change
  - pH was modelled for 2006, using TOC concentrations equal to those in 1990, to examine how much increasing TOC has set back the recovery from acidification

Ancillary factors

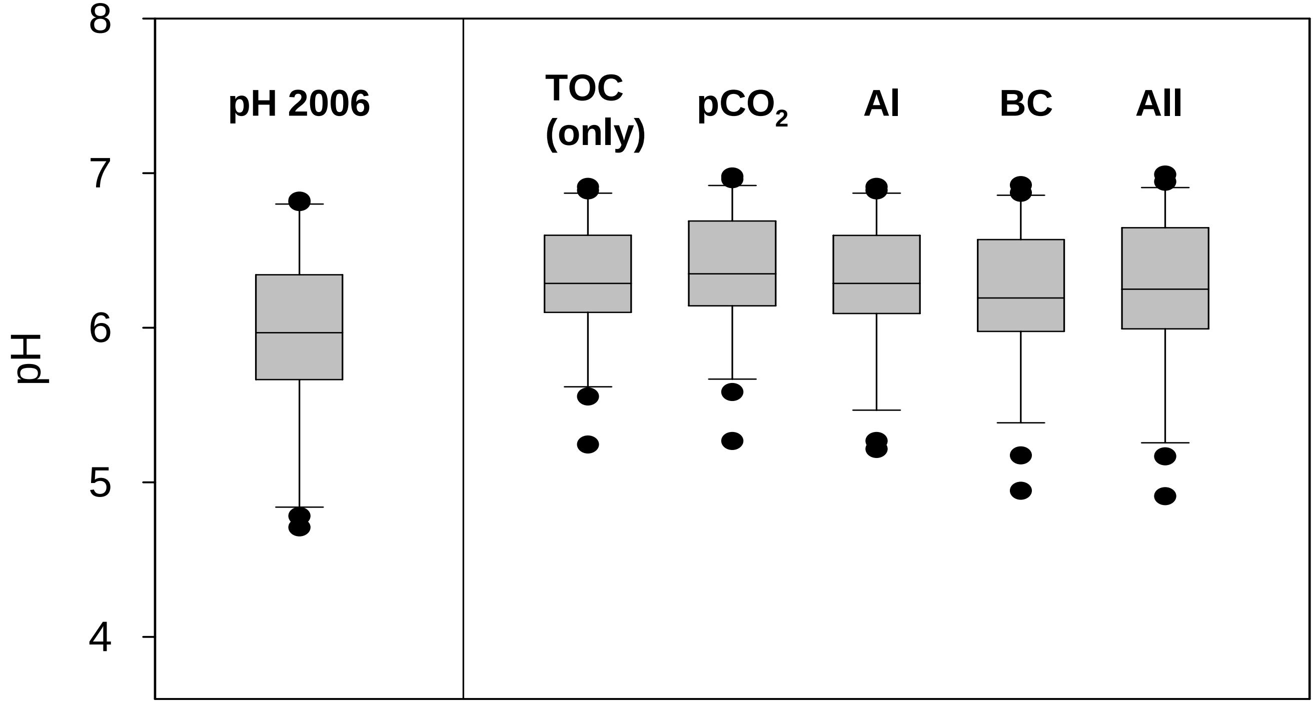
- Increasing TOC may also cause:
  - Increases in pCO_2 (positive feedback)
  - Increases in Al-concentrations (negative feedback)
  - Increases in base cation-concentrations (negative feedback)

AS-scenario: Buffering of acidification from suppression of organic acids



Median buffering of pH: 0.24 units Max buffering: 0.80 units

CCE-scenario: Setback in recovery from acidification due to increasing



Median setback in recovery: 0.24 units Max buffering: 0.74 units

Conclusions

- MAGIC gives reliable results compared to paleo-studies
- MAGIC can be simplified into a metamodel with a low demand on data
- The reference value of pH is variable in different time scales. The variablity could be handled by the metamodel.
- The range of the natural variability is often larger than the accepted change for Good Status (WFD).
- Flow and stream flow was equally important for DOC
- TOC change has affected pH by in average 0.2 units