Trends in surface water chemistry

Trend analysis up to 2016, outline for the report and first results

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Previous ICP Waters reports on (temporal) trends in surface water chemistry

Year	Title (abbreviated)	Period
1991	3-year report. Summary and results 1987-1989	-1989
1994	6-year report: Dose/response relationships and long term trends.	-1991
1997	9-year report: Long-term Developments (1980s and 1990s)	-1994
2000	12-year report: Trends, biological recovery and heavy metals	1989-1998
2003	15-year report: Acidification and recovery, dynamic modelling and heavy metals.	1990-2001
2007	Trends in surface water chemistry and biota; The importance of confounding factors	1990-2001 1994-2004
2011	Trends in precipitation chemistry, surface water chemistry and aquatic biota	1990-1999 1999-2008
2015	Chemical and biological recovery in acid-sensitive waters: trends and prognosis	2000-2011

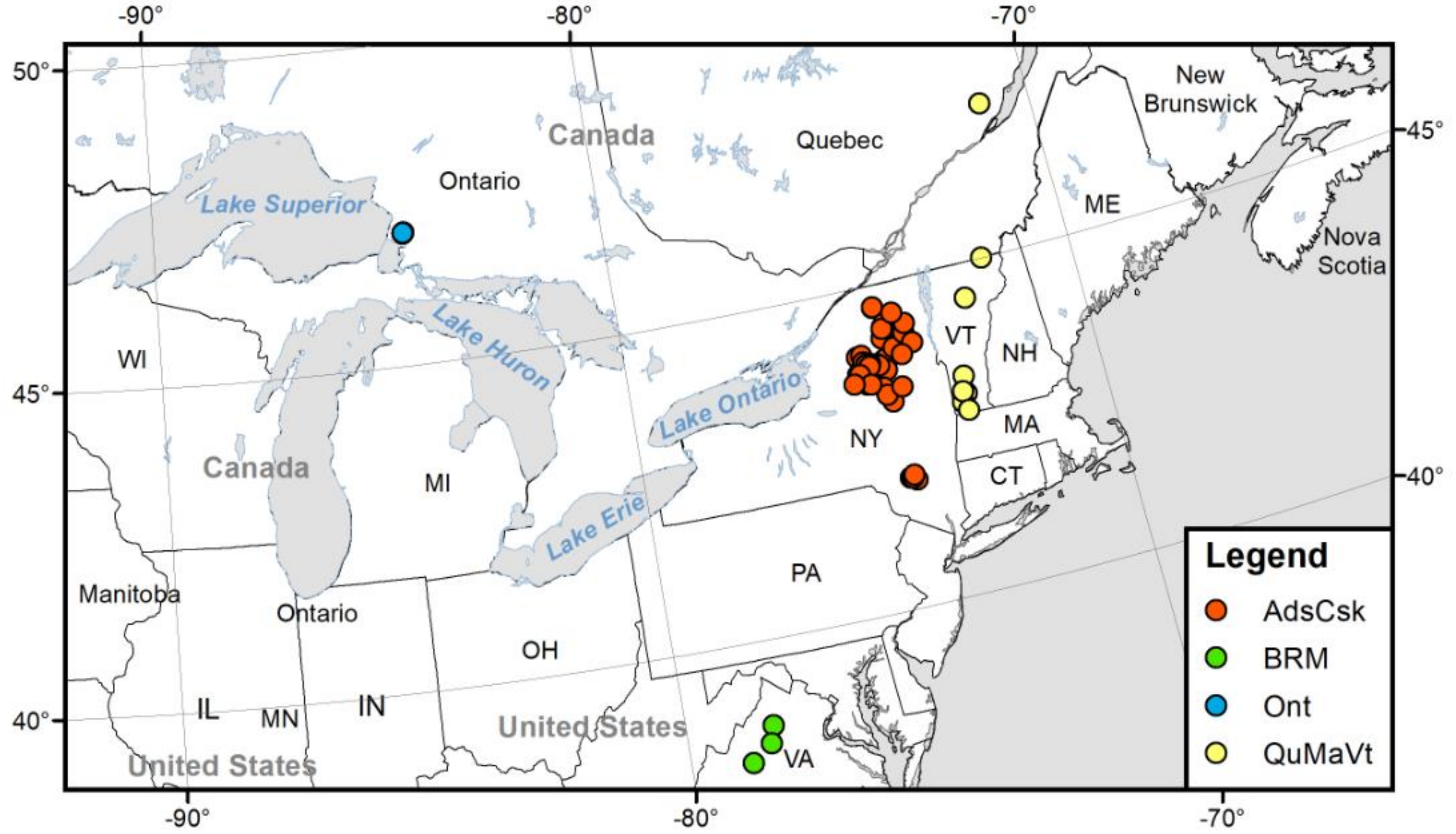
What should we do in the current trend report?

The plan for the report

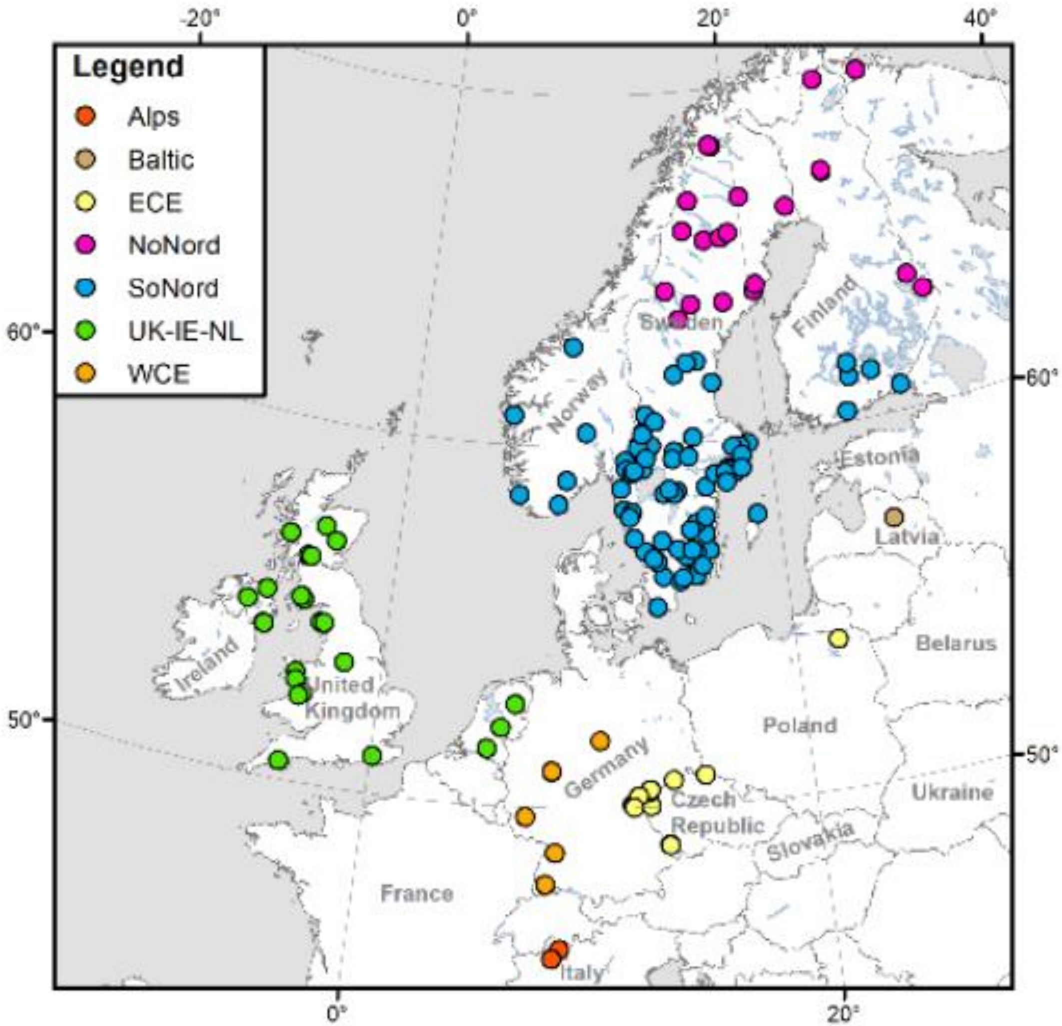
1. «Traditional» trend analysis with MK, Sen slopes and Regional Kendall for the period 1990-2016
2. Analyse trends in episode severity (minimum ANC, minimum pH)
3. Analyse change points. Are there breakpoints in the time series? If so, when, where and for which parameters?
4. Chapter reviewing effects of changes in land use on recovery

The data

- Data from an extended set of 556 stations have been compiled
- Combination of the ≈260 core stations of ICP Waters and 296 extra stations
- Criteria for initial site selection
    - *Lakes – seasonal sampling*
    - *Rivers/streams – monthly sampling*
    - *Fewer than 25% of values between 1995 and 2011 missing*
- Time series from 231 stations met the criteria
- Intend to look at median trends from more stations later, applying less strict criteria for sampling frequency

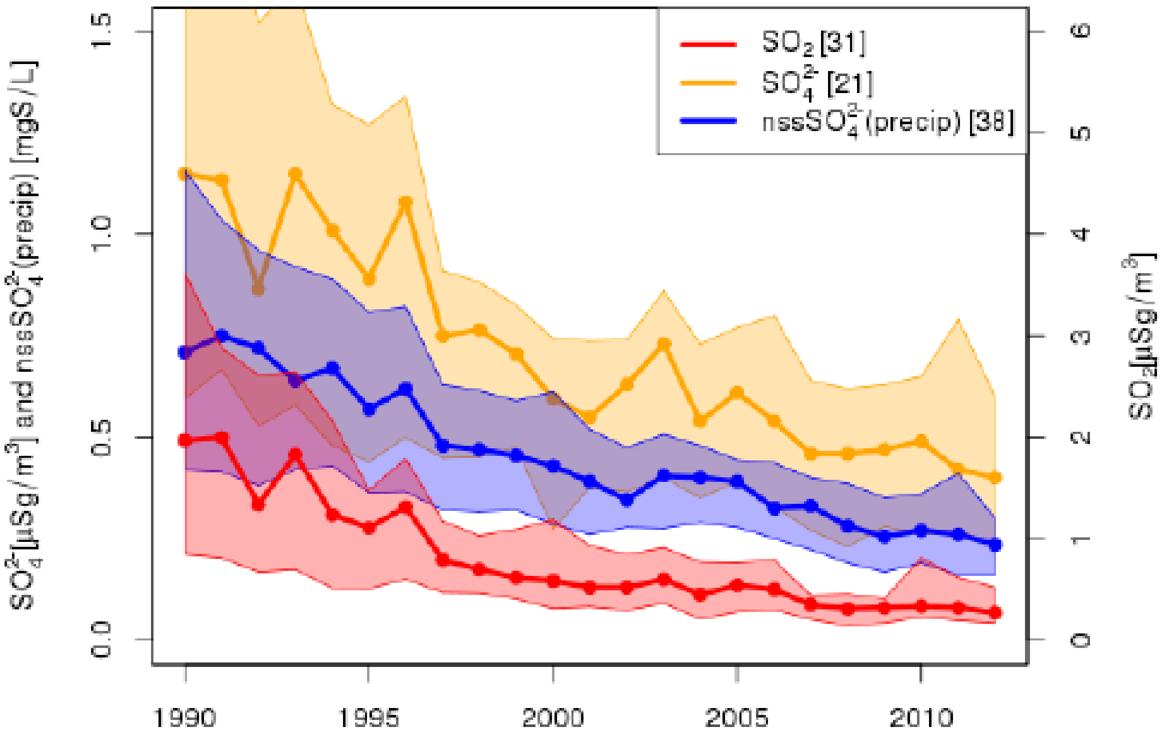


75 sites in N. America, 68 lakes and 7 rivers/streams



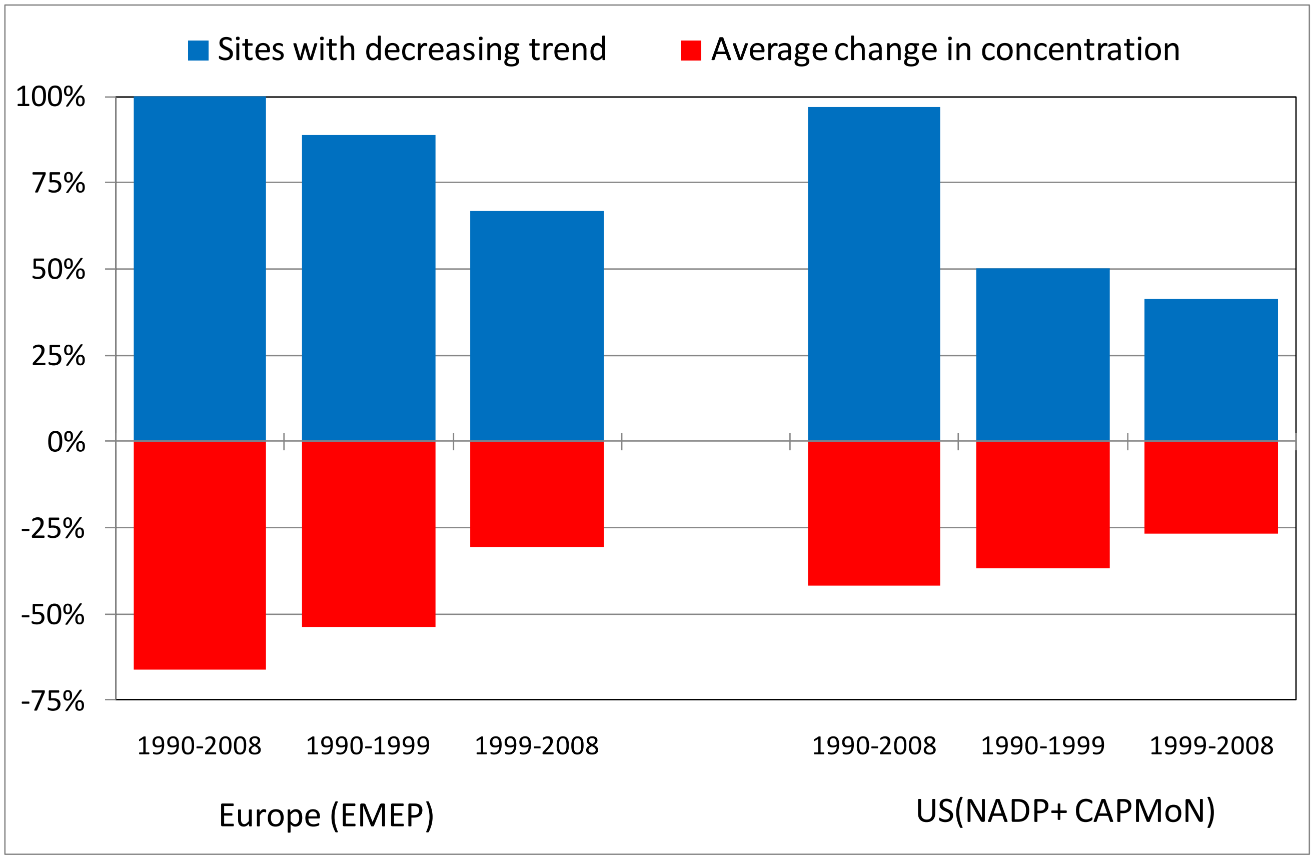
156 sites in Europe, 112 lakes and 44 rivers/streams

Trends in oxidized sulphur deposition



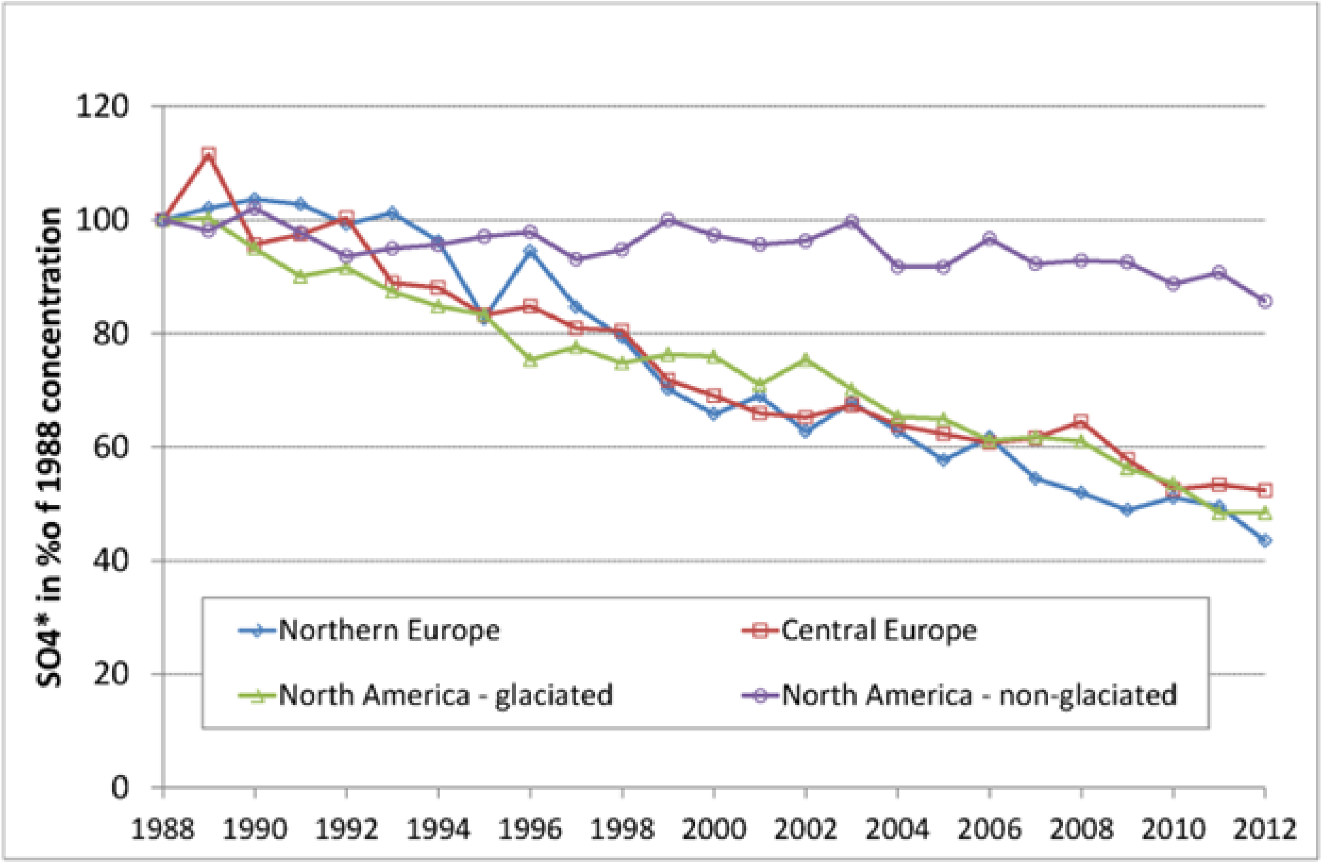
Median time series across EMEP (Colette et al. 2016)

Non-seasalt sulphur in precipitation



From ICP Waters report 106/2011

Steady decline of sulphate in surface waters



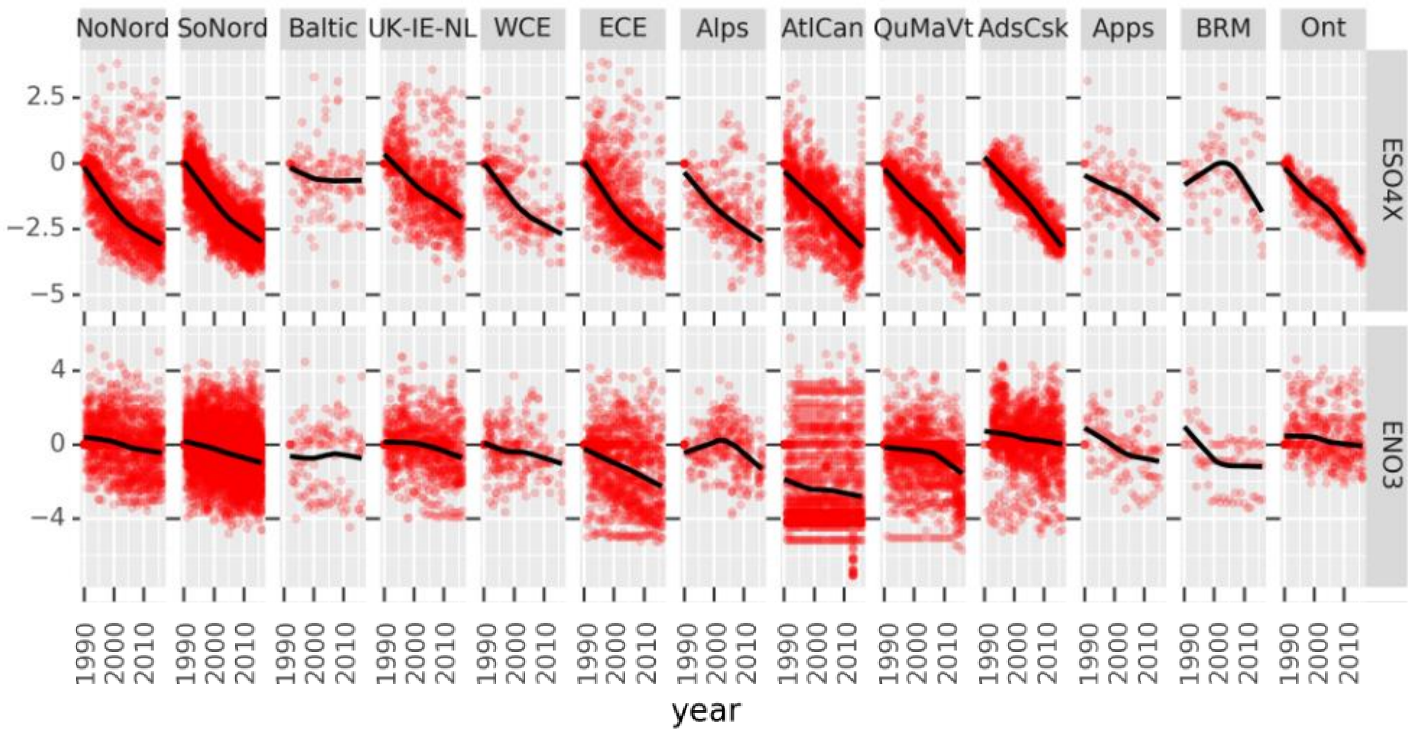
Time series average 1989-2012

de Wit et al. 2015. ICP Waters no. 125.

Methods

- Mann-Kendall test for trends 1990-2016
- Sen slopes
- Regional Kendall
- Bayesian Analysis of Change Point (BCP)
- Also tried Prophet for sites with high frequency sampling

Sulphate and nitrate 1990-2016



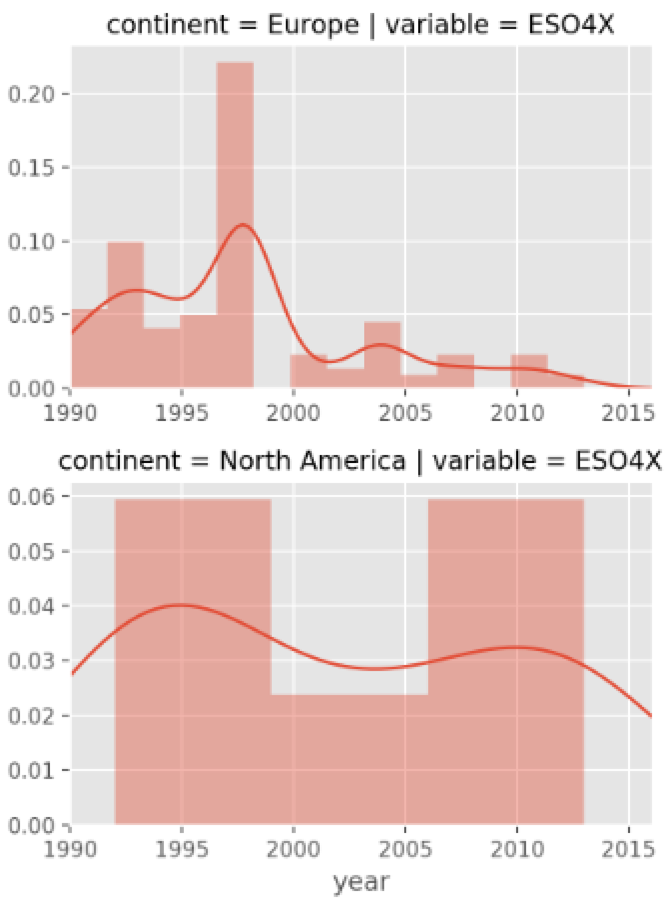
97% of sites ⇩

37% of sites ⇩

8% of sites ⇧

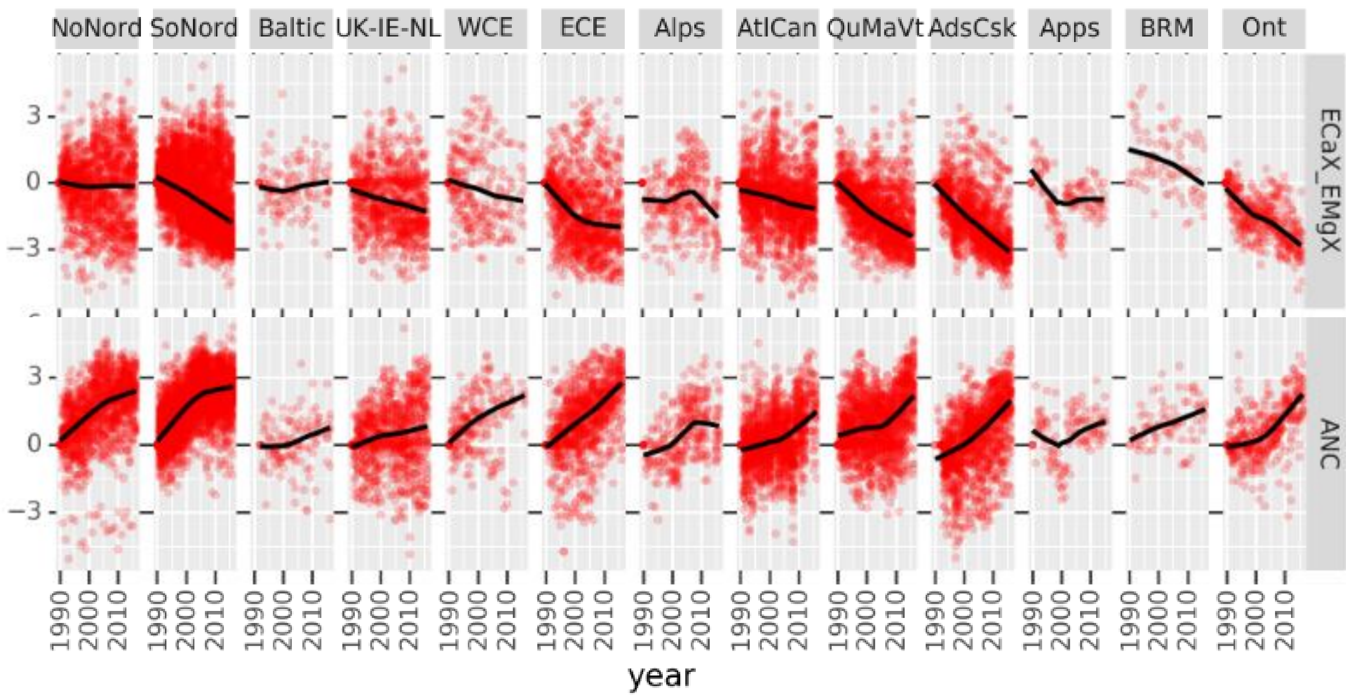
- Sulphate: 40-60 % decrease in all regions except Appalachians and Blue Ridge mountains
- Nitrate: Trends are more variable, but decline more common than increase

SO4 and NO3 change points



- Europe: Most change points in sulphate trends ocurred just before year 2000
- Change points in N. America more evenly distributed
- Same is true for nitrate across both continents

Base cations and ANC 1990-2016



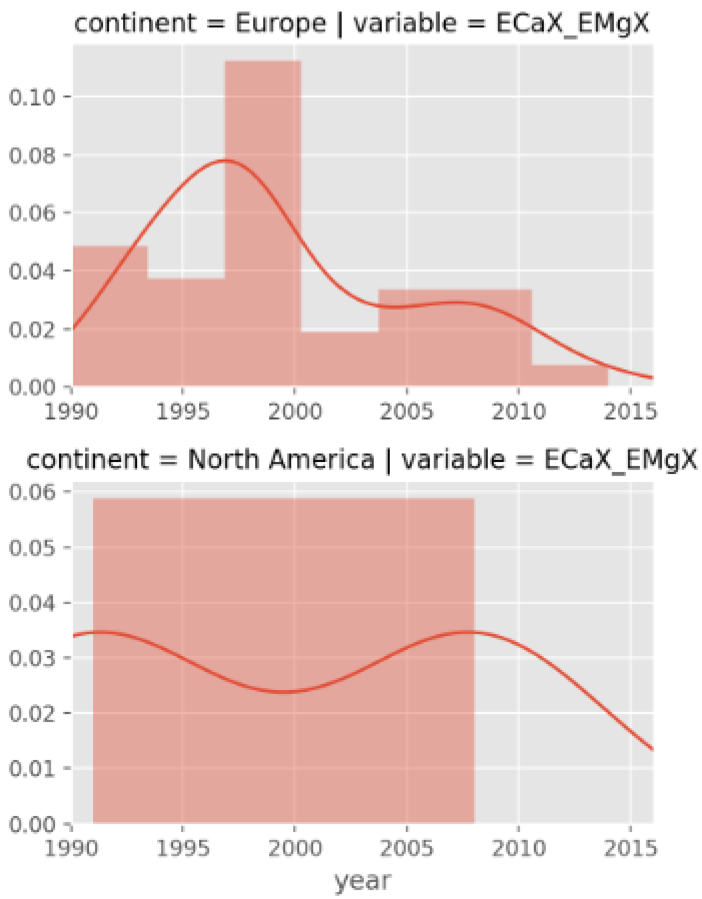
77% of sites ⇩

6% of sites ⇧

83% of sites ⇧

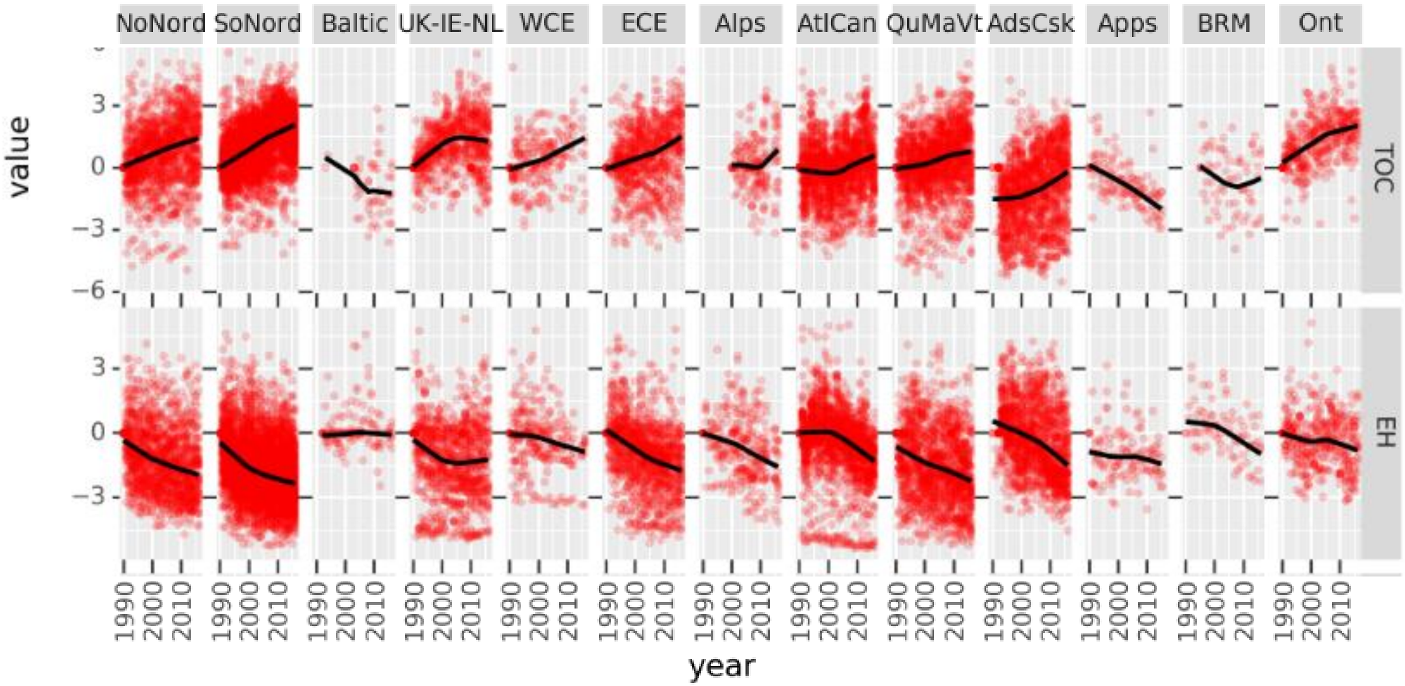
- Base cations: 20-30 % decrease in the most heavily affected regions
- ANC: Increase in almost all regions.

Base cations and ANC change points



- Europe: Most change points in BC and ANC occurred just before year 2000 (as for SO4)
- Change points in N. America more evenly distributed, i.e. no common pattern

TOC and pH

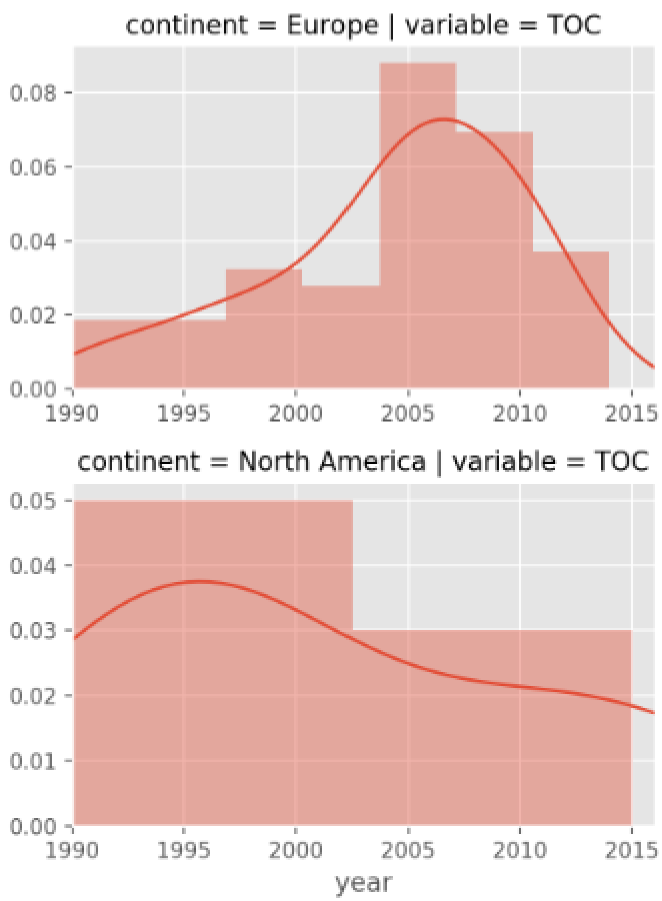


71% of sites ⇧

57 % of sites ⇩

- TOC: Increase in the European regions (except Baltic). More complicated pattern in North America
- pH: Increase in almost all regions

TOC and pH change points

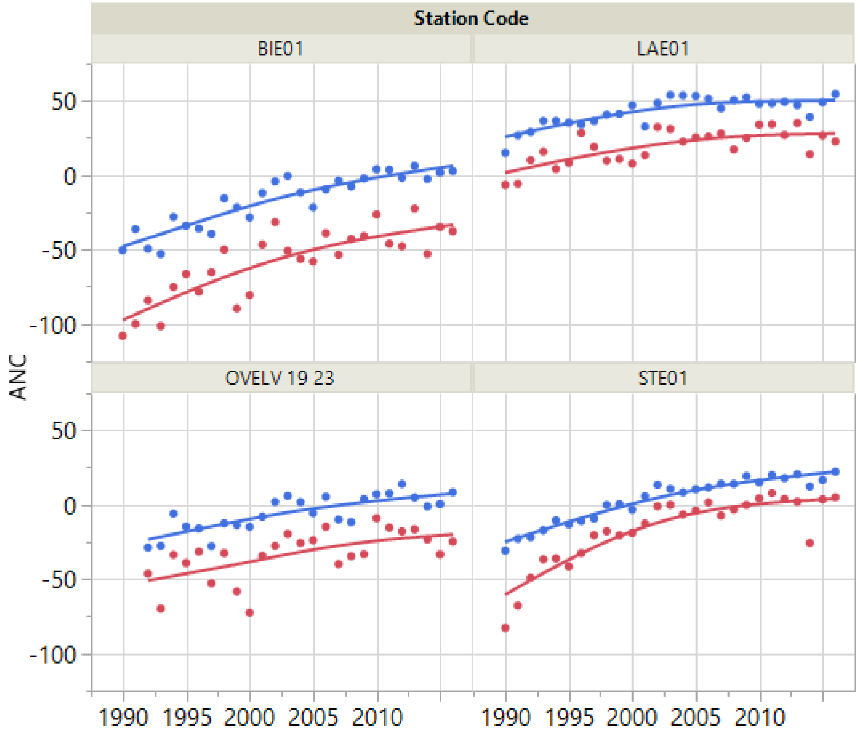


- Europe: Most change points in TOC occurred around 2007 (almost a decade later than for sulphate)
- Change points in N. America more evenly distributed, i.e. no common pattern
- pH change points in Europe more common before year 2000

Analyse trends in episode severity

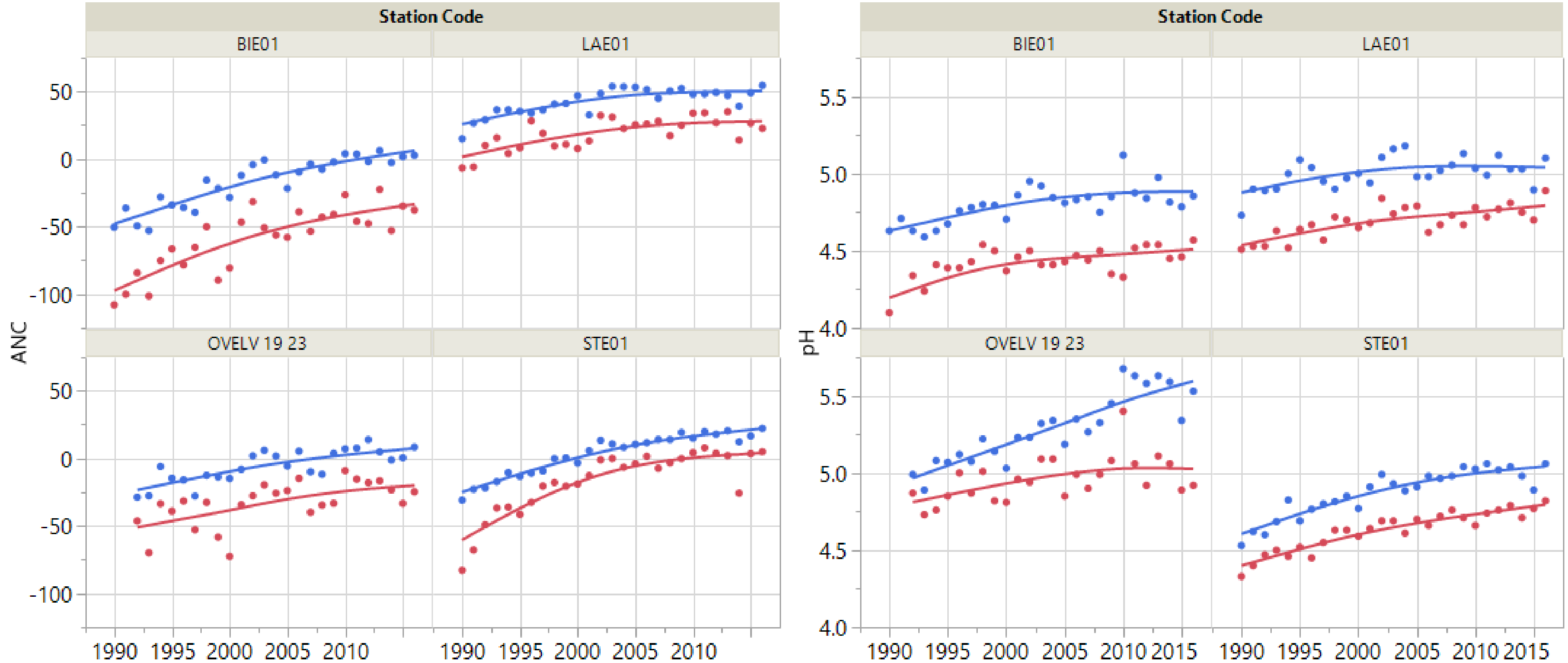
Are trends in annual median water chemistry reflecting the lessening severity of episodes?

Four time series examples



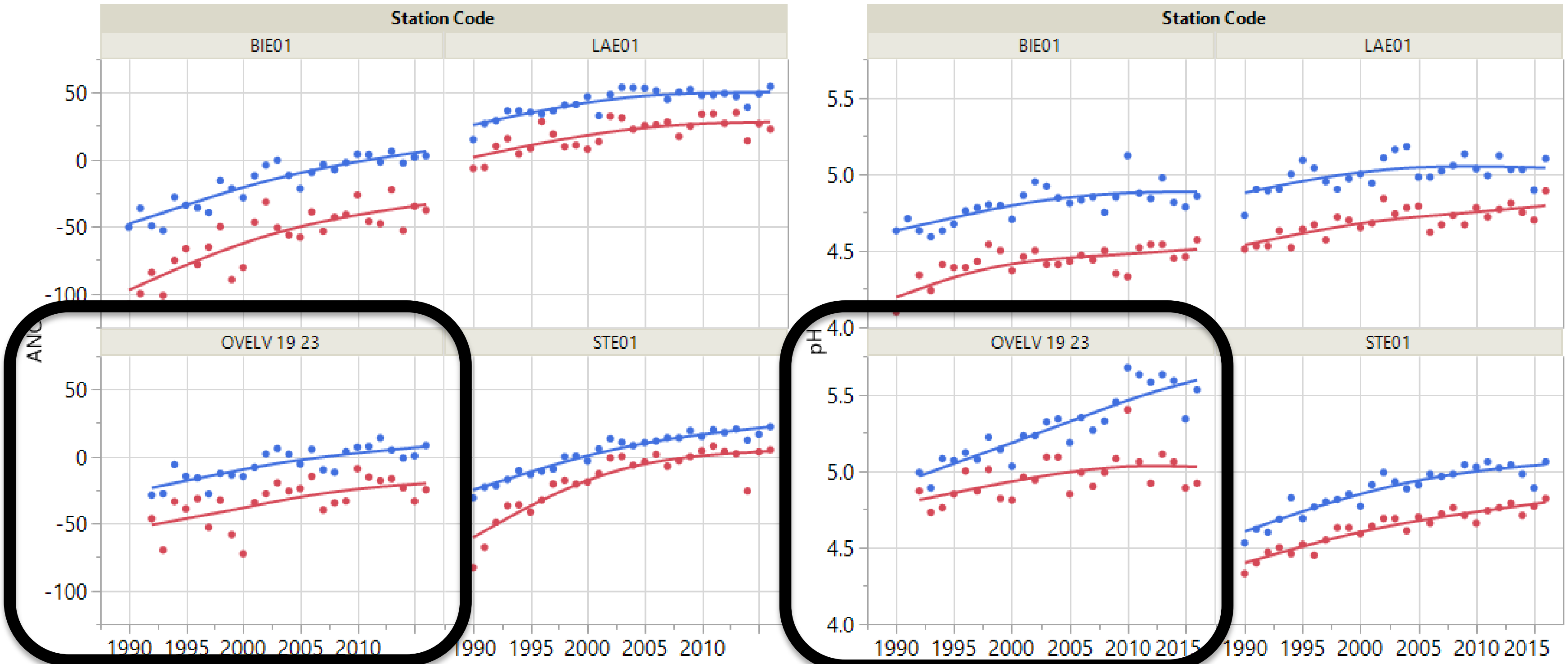
Blue: annual median. Red: annual minimum

Four time series examples



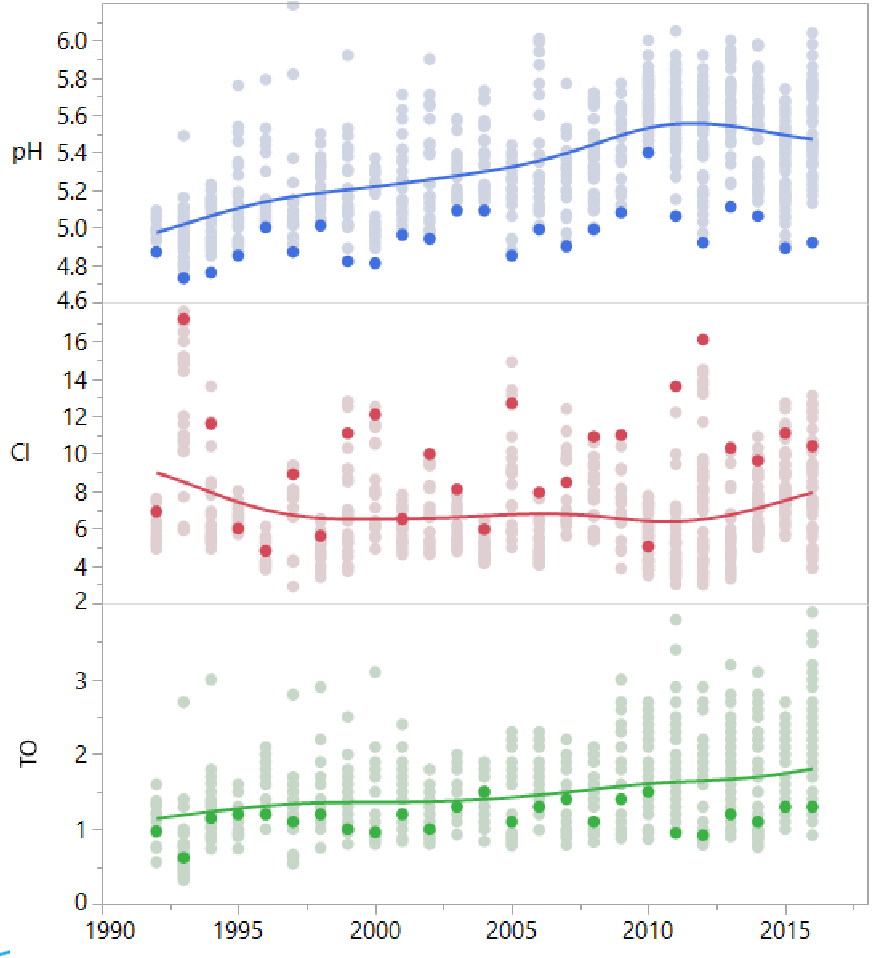
Blue: annual median. Red: annual minimum

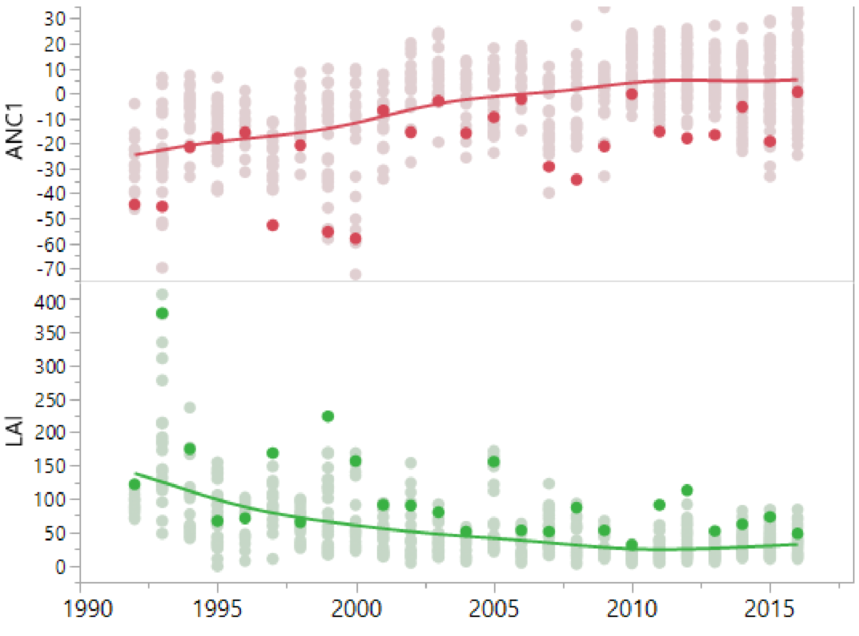
Four time series examples



Blue: annual median. Red: annual minimum

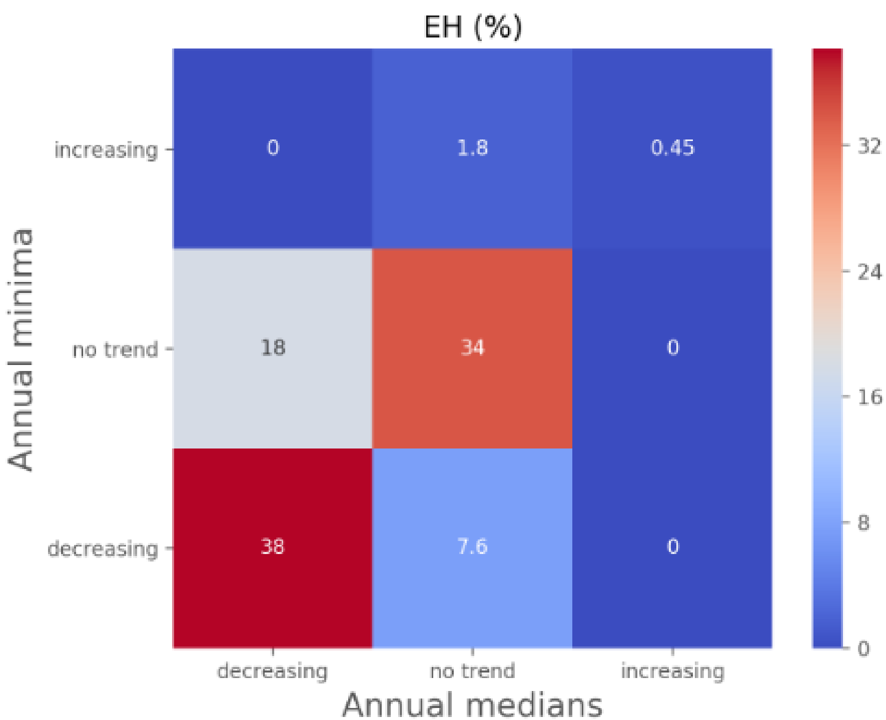
Ovelv 19 23: Chemistry at minimum pH

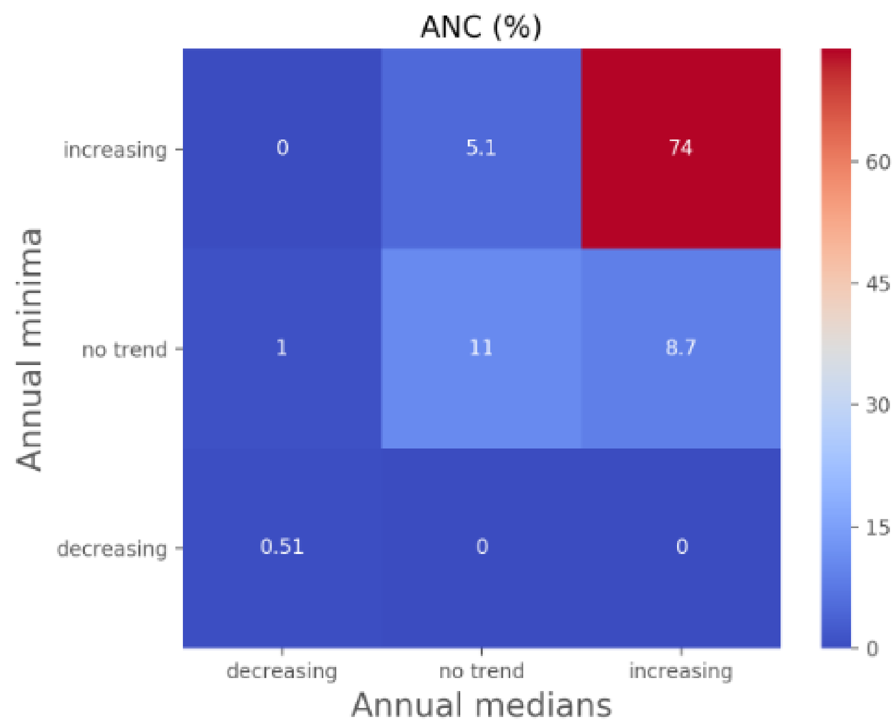




Labile aluminium at minimum pH has decreased

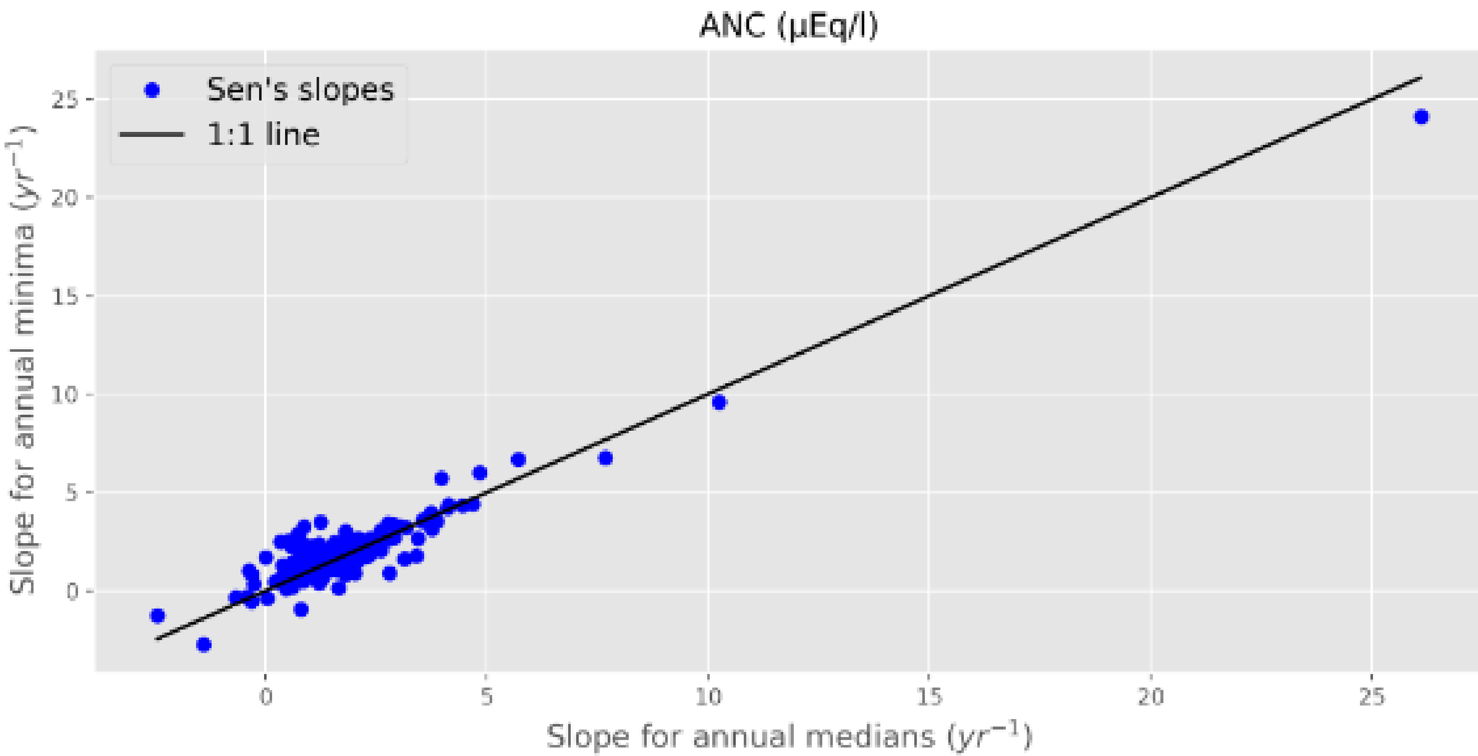
Trends in annual median versus annual minimum values for the ICP Waters sites





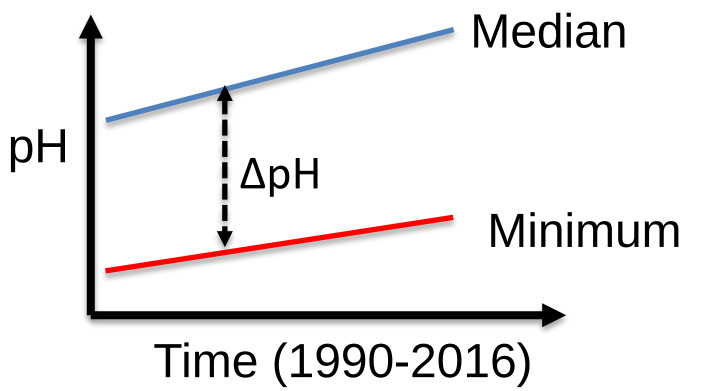
Trends in annual medians and minima are consistent

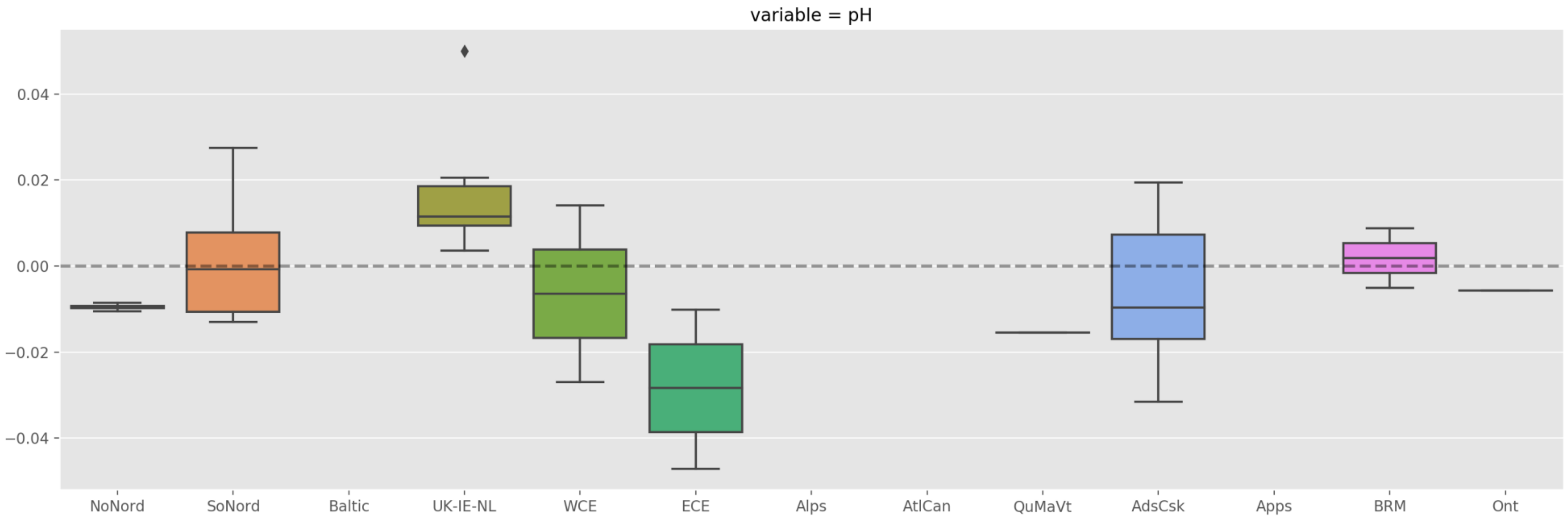
Trends in median versus minimum values



No systematic difference in trends for ANC medians and minima

Trends over time in ΔpH





Increasing gap between annual median and minimum pH in UK-IE-NL and some South Nordic sites. Sea salt effects? In East Central Europe, the gap is decreasing.

ICP Waters – trend report 2019

Proposed chapter on:

Land-use change as a **confounding** factor for **recovery** from acidification

Background and aim

- Environmental factors other than acid deposition, so-called “confounding factors”, might slow down recovery after reduced acid deposition
- Effects of climate as a confounding factor was described in an earlier trend report (*de Wit and Skjelkvåle 2007*)
- For this year’s trend report, we propose a chapter on **land use change** as a confounding factor for recovery

Examples of land use changes

- Intensified forestry (as climate mitigation measure)

  - Forest fertilization

  - Afforestation on new areas

  - Increased biomass removal (whole-tree harvest)

- Reduced summer farming, livestock grazing and heath burning

- Overgrowing, expansion of upper forest boundary

- Forest decline caused by drought or insect attacks

Inputs wanted

- Types of land use change that should be considered?
- Anyone want to contribute with own data?
- Anyone who knows European or country wise statistics / trends related to?
  - *Changes in in forested area (due to afforestation / overgrowing)*
  - *Insect attacks / forest dieback*
  - *Forest fertilization*
  - *Extent of whole-tree harvest vs. stem-only harvest*
  - *Total volume harvested per year*

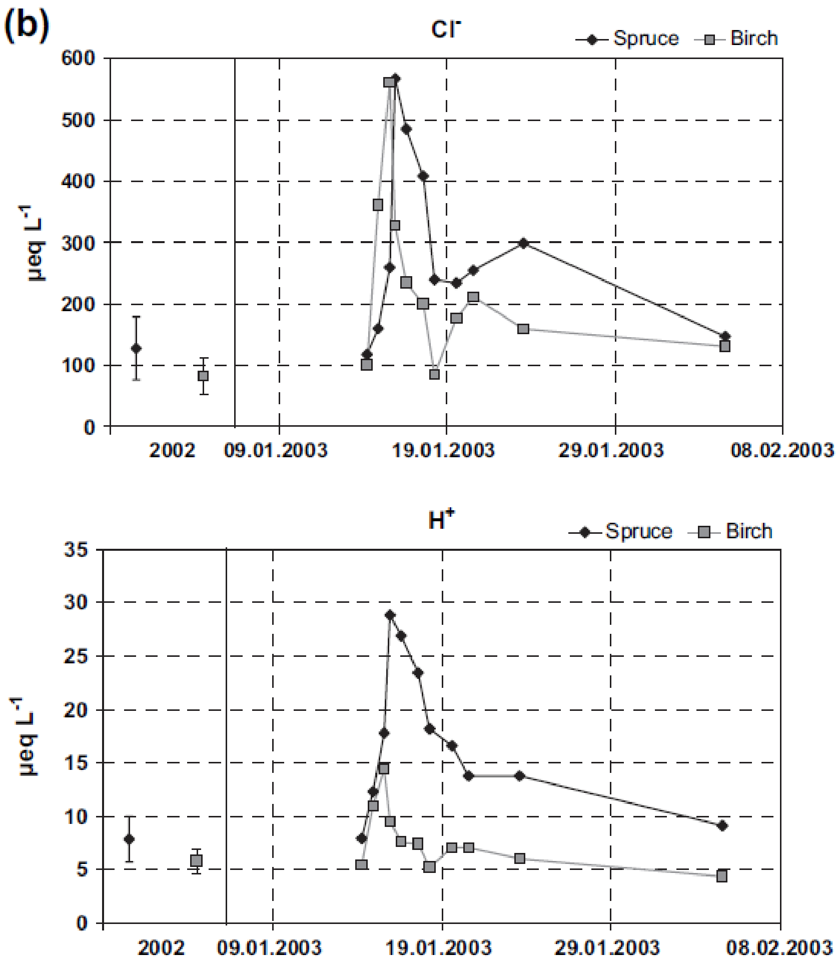
Examples

- Afforestation
- Forest harvest
- Insect attacks/forest decline

Afforestation

Streamwater chemistry during the January 2003 storm. The figures show a stronger sea-salt effect and acid pulse in the catchment **afforested with spruce** compared with an adjacent catchments with **native birch**

(Larssen & Holme 2006, Environ. Pollut.)

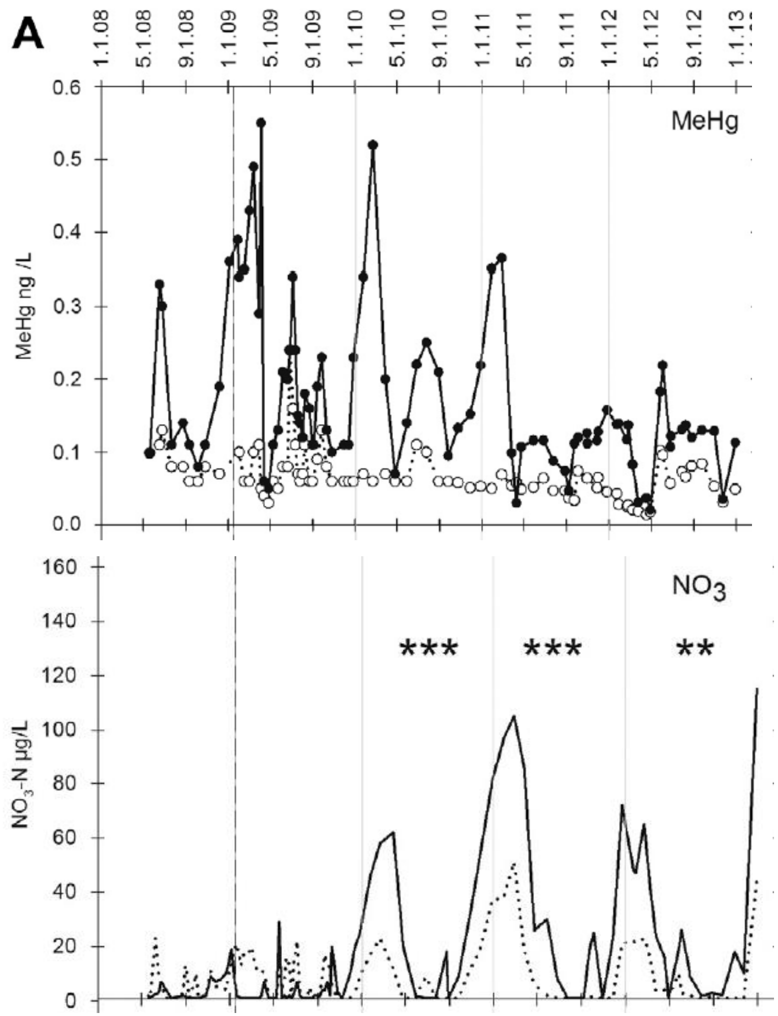


Forest harvest

Langtjern (Norway)

Stream water concentrations in catchment LAE03 (reference) and LAE11 (treated) catchments from June 2008 until December 2012.

(de Wit et al. 2014, For. Ecol. Manage.)

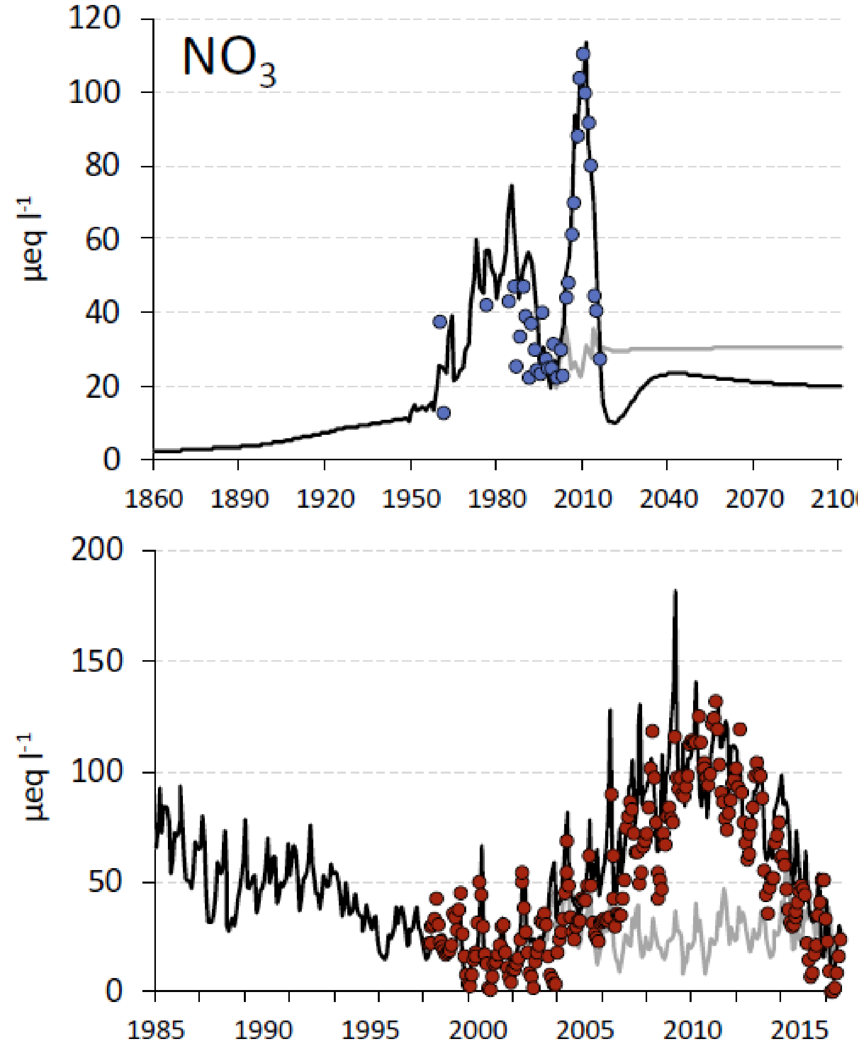


Bark beetle attack

Plesne Lake (Cz)

Concentrations of NO3 in lakewater observed annually (blue dots) and monthly (red dots) and
simulated by the MAGIC model (black lines).
Grey line is the control scenario (without bark beetle disturbance)

(Oulehle et al. 2018, Ecosystems)



Summary

We have started work on the the trend report by doing the following:

- Selected sites from an extended set according to criteria for data continuity and sampling frequency
- Analysed trends in annual median and minima (ANC and pH)
- Looked for change points
- Outlined a chapter reviewing effects of changes in land use on recovery from acidification

Topics for discussion (ICP Waters session)

- Have we chosen the right time period?
- Is it timely to look at change points and episodes or should we focus on something else?
- Input wanted for the chapter on effects of changes in land use

Topics for discussion (cont.)

- How should we estimate the «non-marine» fraction?
- Are the criteria for selection of sites appropriate?
- Are MK and Sen slope statistics still a good choice for trend analysis?
- Is BCP a suitable choice for analysis of change points in our time series?
- How should we analyse for trends in «episode severity»?

Estimation of non-marine fraction

Corrections (denoted by `X`) are calculated as

$$EParX = EPar_{sample} - \left[\left(\frac{EPar}{ECl} \right)_{ref} * ECl_{sample} \right]$$

Where $\left(\frac{EPar}{ECl} \right)_{ref}$ is a reference ratio assumed to be constant for all locations:

Species	Molar mass	Valency	Ref. ratio
SO4	96	2	0.103
Cl	35	1	1
Ca	40	2	0.037
Mg	24	2	0.196
NO3-N	14	1	N/A

Criteria for selection of sites

- Lakes – seasonal sampling
- Rivers/streams – monthly sampling
- Fewer than 25% of values between 1995 and 2011 missing