Trend in DOC in Europe and North America

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Background

- Follow-up of Monteith et al. 2007 (Nature)
- Are lakes and rivers still browning?
- Is acidification still the key driver of browning waters?
- Is climate change affecting browning?

Database

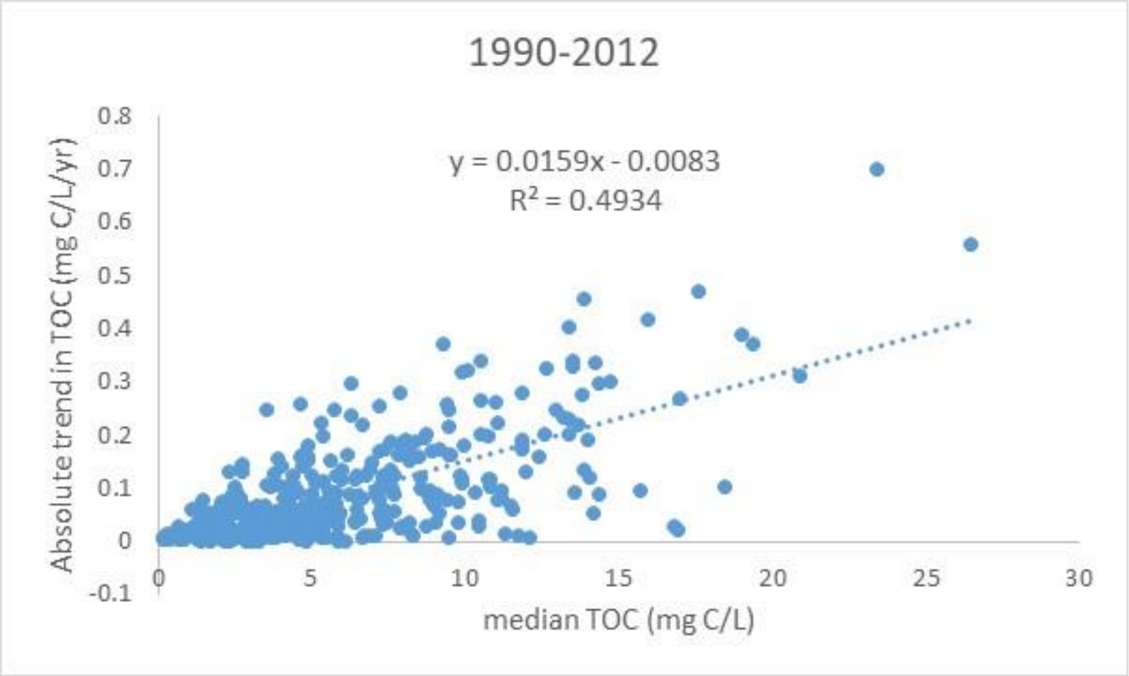
- Semi-natural headwaters with little influence from local pollution and catchment disturbance
- 432 sites with annual (preferably seasonal) water chemistry for 1990-2012 (allowing some data gaps) in Europe and North America
- Climate data on temperature and precipation (CRU database, 0.5^{o}x0.5^o), temperature corrected for elevation
- Quality assurance

Methods

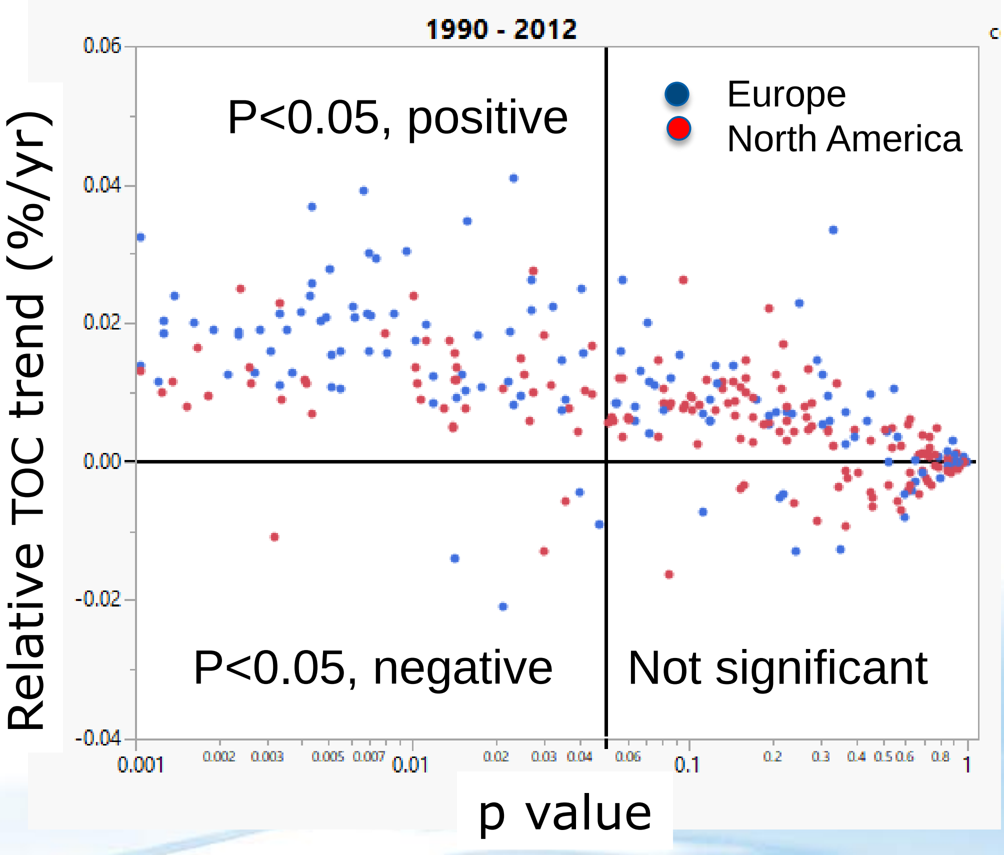
- Estimation of trends in water chemistry and climate (Mann-Kendal test, Senslope)
- 1990-2012, 1990-2004 (‘1990s’), 1998-2012 (‘2000s’)
- Build statistical models to explain variation in trends
- Test for differences in trend strength between 1990s
- Use statistics to explain differences in trend strength

Results

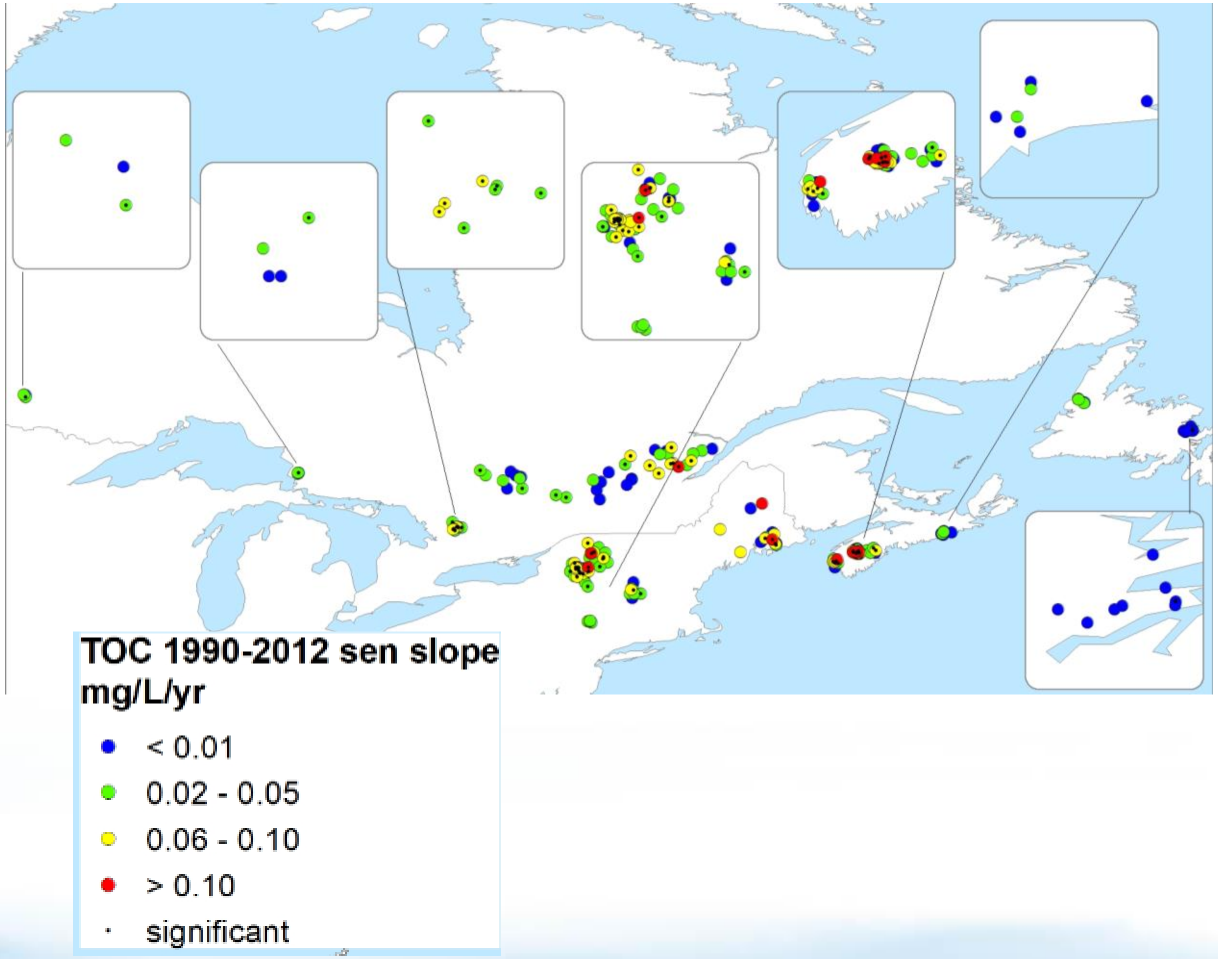
Absolute TOC trend depends on concentration

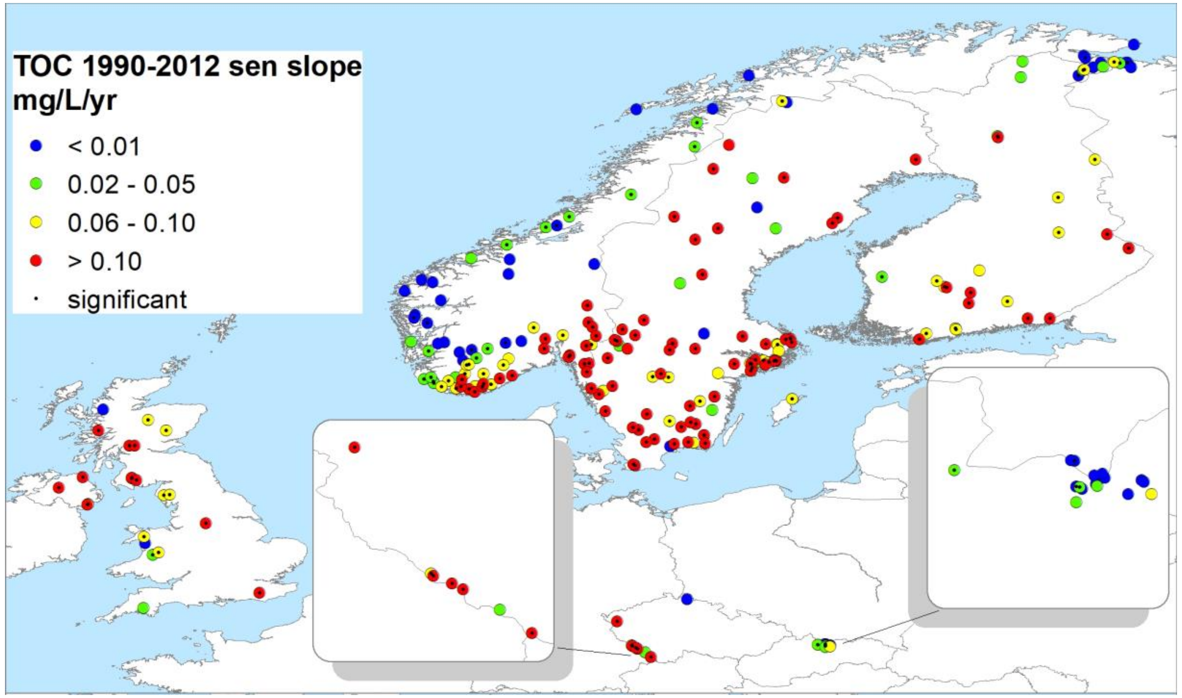


Significant trends 1990-2012
(54% positive and significant)

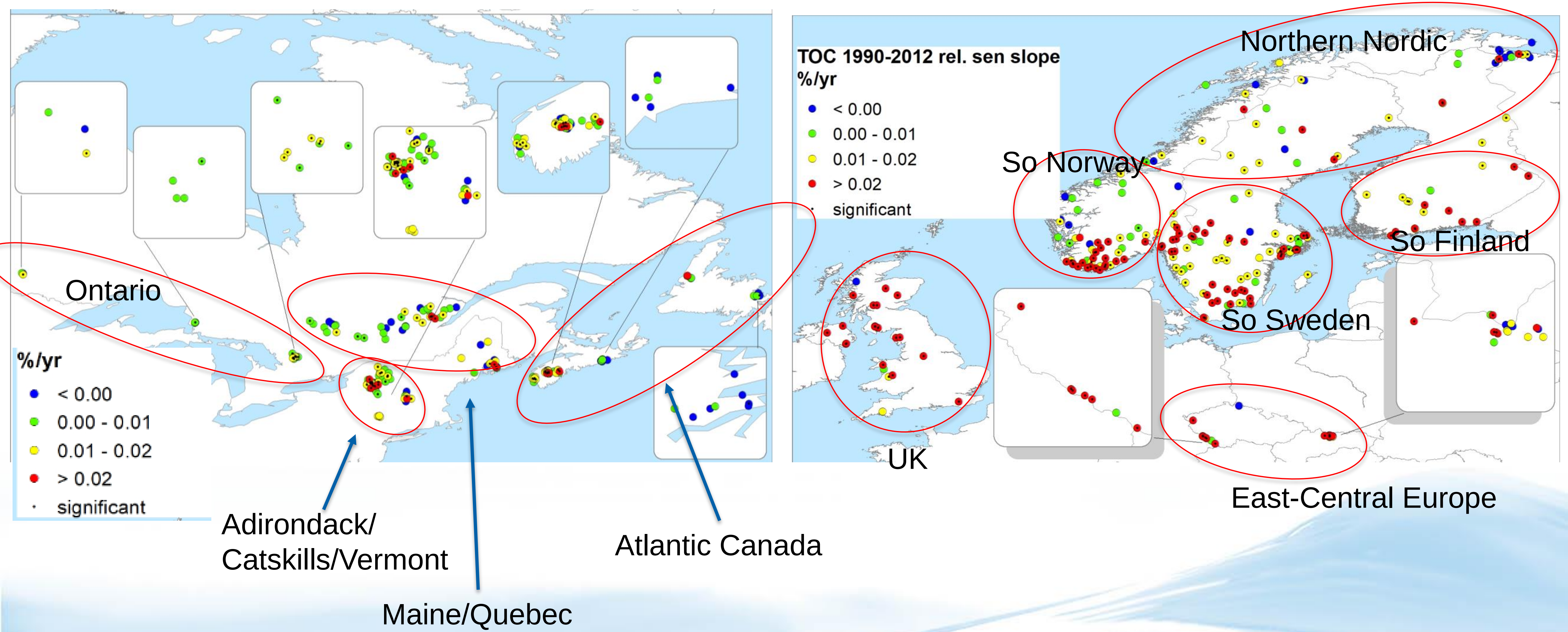


Trends 1990-2012 (mg C/L/yr)





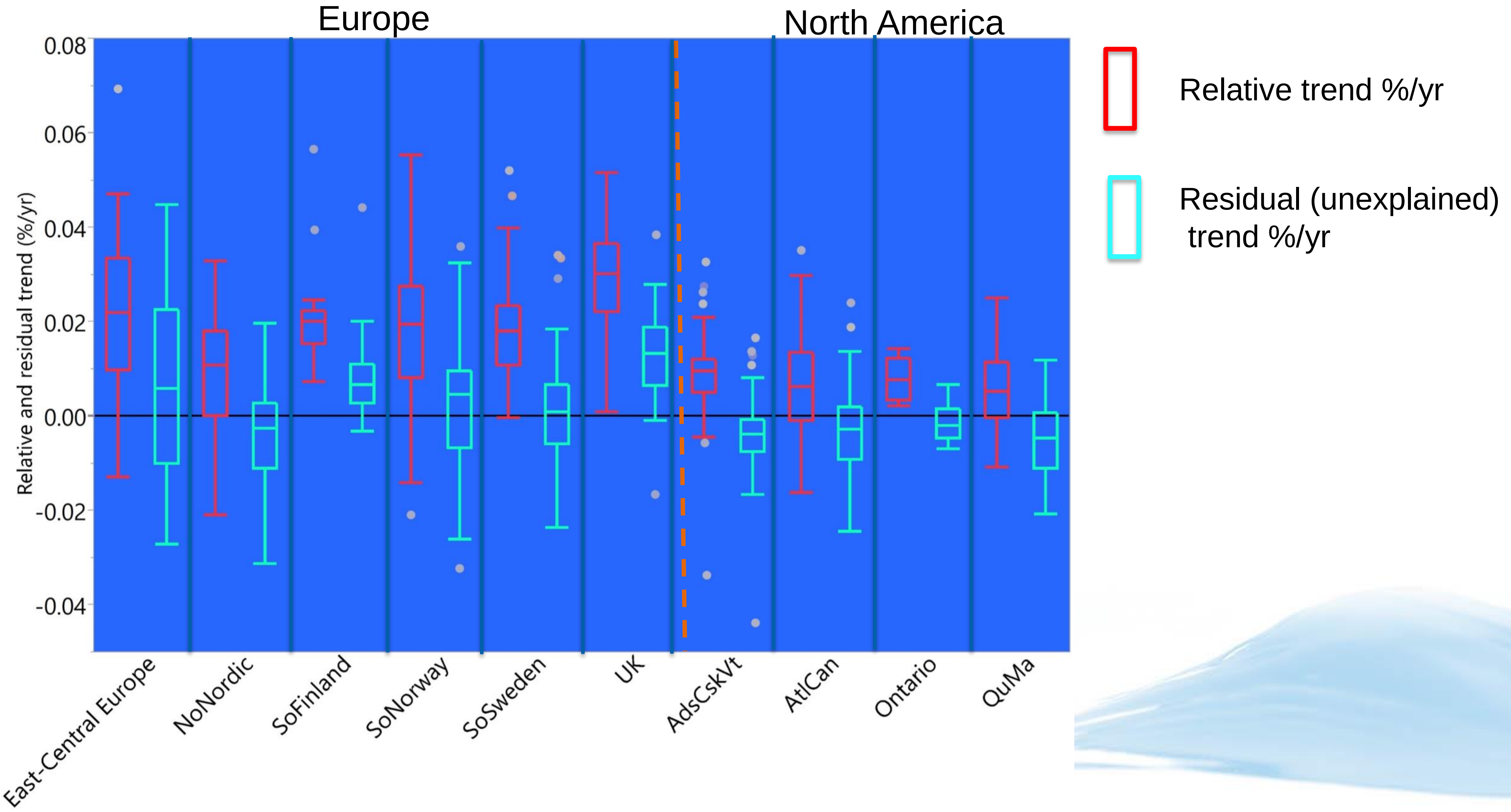
Relative trends 1990-2012 (%/yr)



Explanation of 1990-2012 relative trend

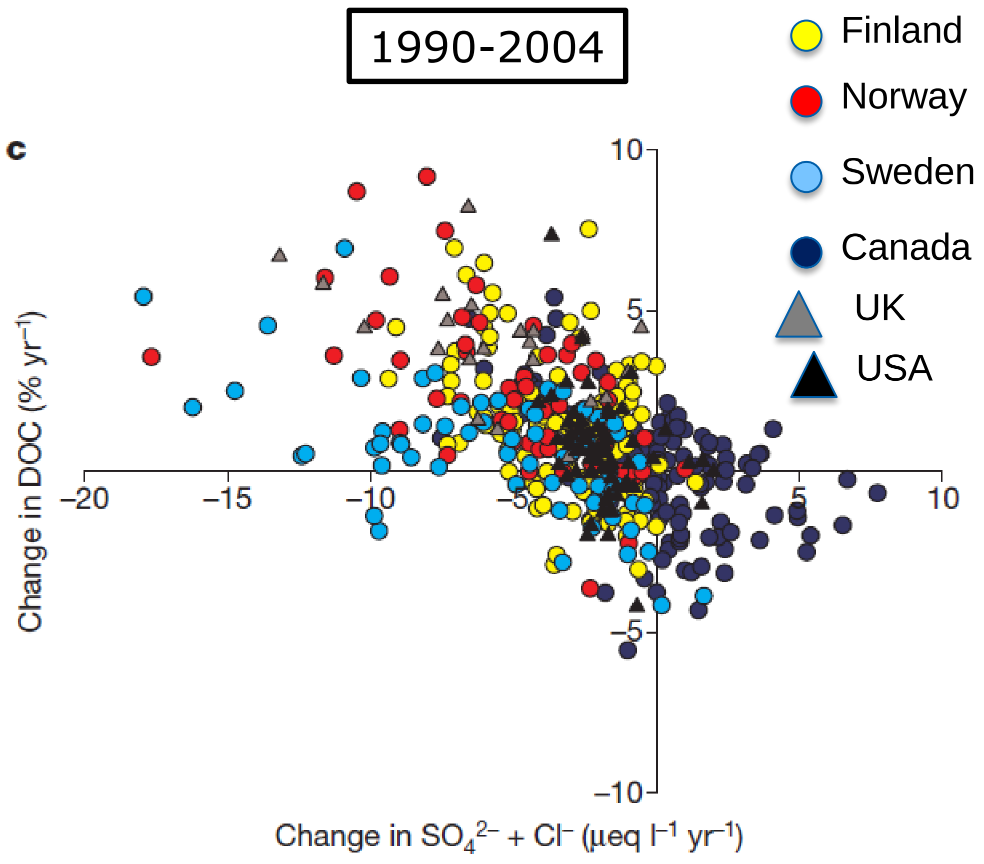
Use stepwise forward selection

- Eligible variables
  - Trends in SO4, Cl, SO4+Cl, H
  - Median sum(Ca+Mg)
  - Trends in annual and summer temperature and precipitation
  - Mean climate (annual and summer temperature and precipitation)
- Internally correlated variables not allowed
  - Tested for correlations
- AIC criterion

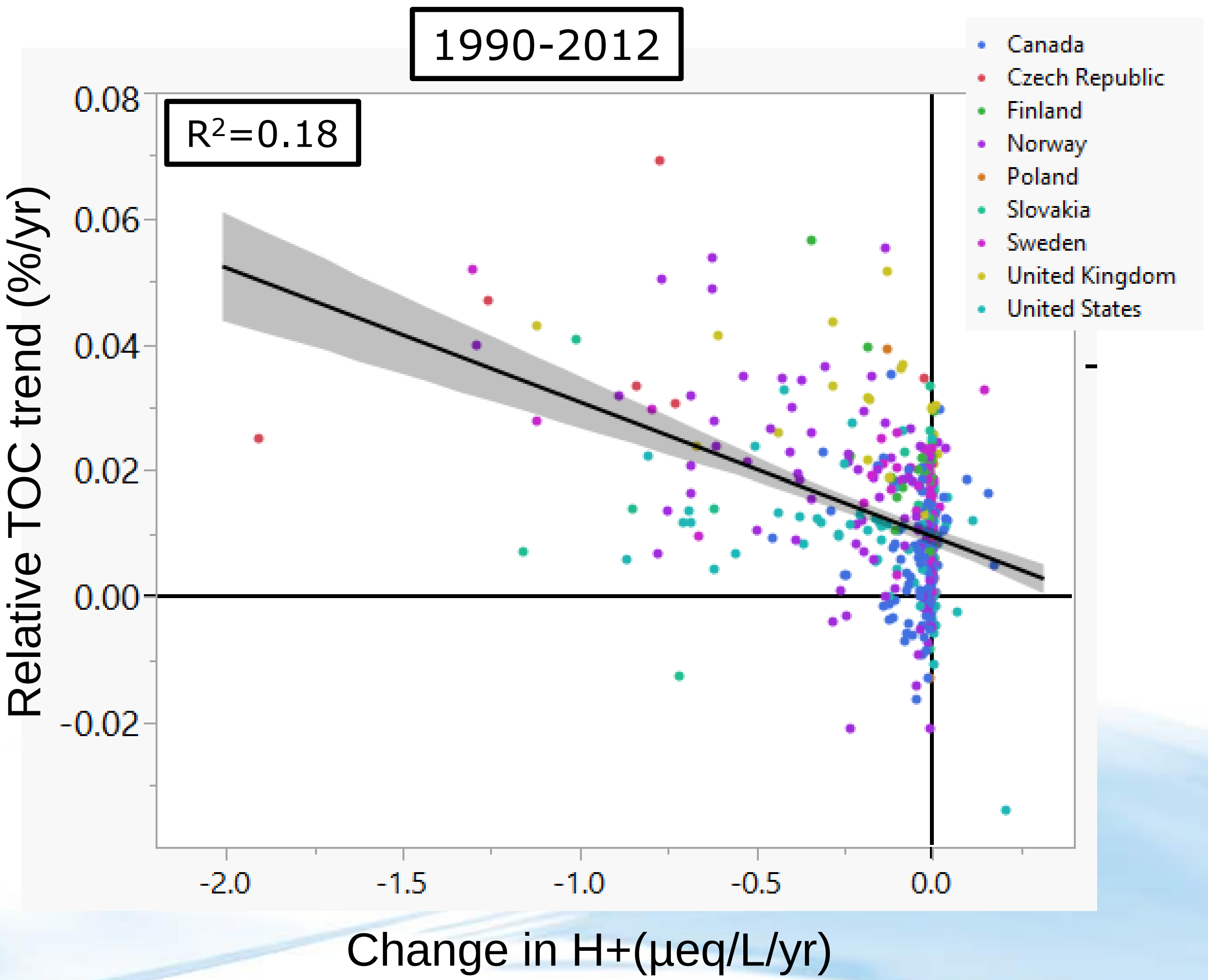


Europe
North America
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
Relative and residual trend (%/yr)
East-Central Europe
NoNordic
SoFinland
SoNorway
SoSweden
UK
AdsCskVt
AtlCan
Ontario
QuMa
Relative trend %/yr
Residual (unexplained) trend %/yr

Comparison with Monteith et al. 2007



Monteith et al 2007



1990-2004: 39% explained

Table 1 | Results of stepwise multiple regression for %ΔDOC

Variable	Estimate	*P*	Cumulative R^2
Intercept	0.250	0.0004	NA
Change in SO_4^{2-} ($\mu eq\ l^{-1}\ yr^{-1}$)	−0.557	<0.0001	0.237
Median CaMg* ($\mu eq\ l^{-1}$)	−0.005	<0.0001	0.316
Change in Cl^- ($\mu eq\ l^{-1}\ yr^{-1}$)	−0.504	<0.0001	0.360
Median CaMg* ($\mu eq\ l^{-1}$) × change in Cl^- ($\mu eq\ l^{-1}\ yr^{-1}$)	0.0033	<0.0001	0.393

See Methods Summary. Estimates for intercept and slope of individual relationships are for the final three variable plus one interaction model. NA, not applicable. μeq, microequivalents.
*Sea-salt-corrected divalent cation concentration.

Changes in atmospheric chemistry and soil acid-sensitivity explain trends in DOC

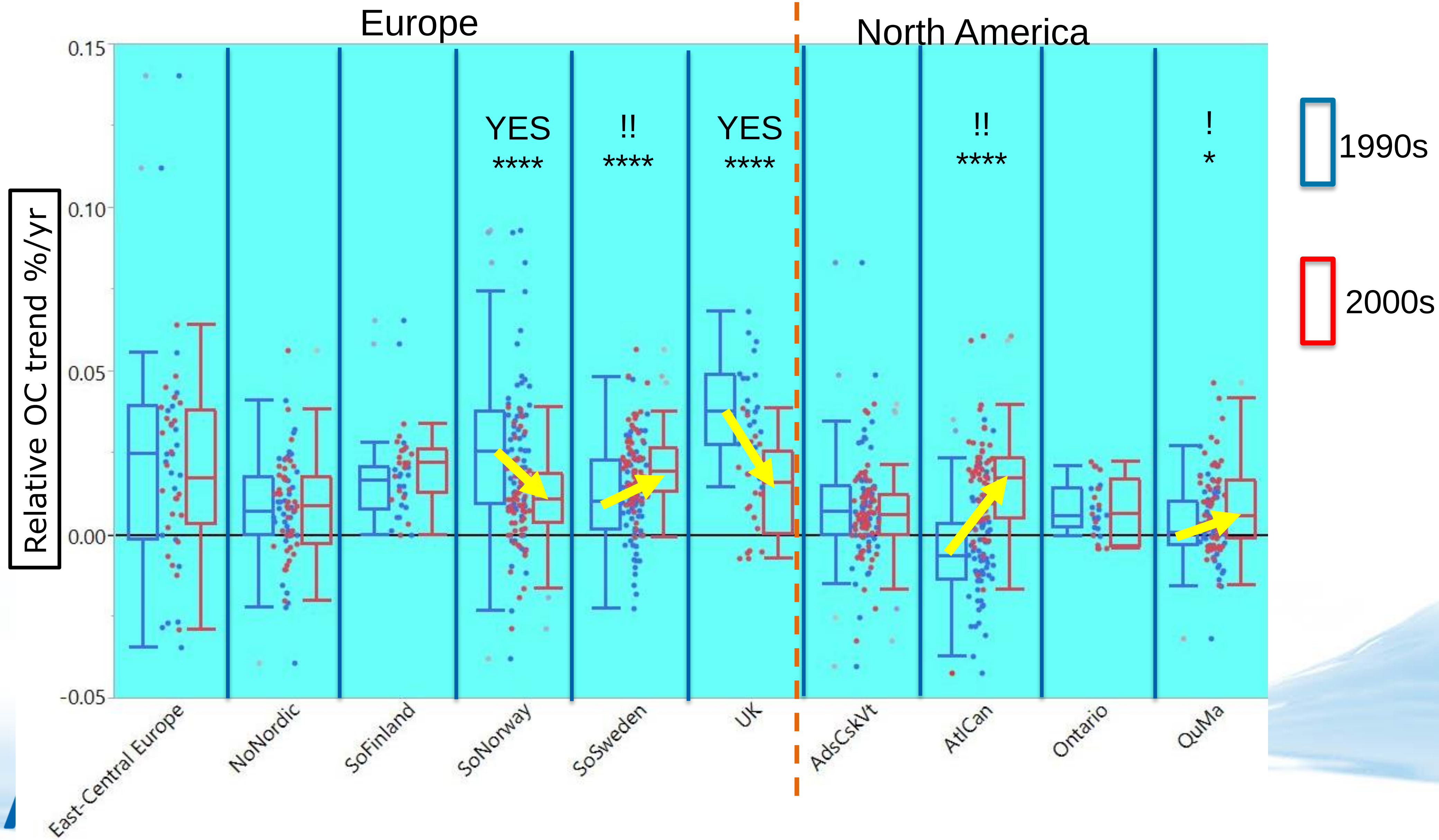
1990-2012 34% explained

Order of selection	Trend	cumulative R2	estimate	
1	H	0.18	-0.0162	less acidity promotes browning
2	Cl	0.26	-0.0023	lower seasalts promote browning
3	summer P	0.30	0.0014	wetter summer promote browning
4	annual T	0.31	-0.1077	warming reduces browning
5	annual P	0.33	-0.0004	correction of summer precip effect
6	summer T	0.34	0.0788	correction of warming effect

Changes in atmospheric chemistry remain dominant driver
Climate change also impacts trends in DOC

NIVA

Are the TOC trends levelling off?



Why temporal contrasts in TOC trends between 1990s and 2000s?

	Europe		North America		
change in	1990s	2000s	1990s	2000s	
SO4	-2.8	-1.5	-1.4	-1.8	µeq/L/yr
Cl	-0.9	-0.1	0.0	-0.1	µeq/L/yr
precipitation	1.9	3.8	-0.3	3.8	mm/yr
temperature	0.020	0.014	-0.002	0.026	^{o}C/yr

Summarizing

- Surface waters continue to increase in TOC
- Most prominently in Europe (relative trends)
- Atmospheric chemistry remains the dominating driver
- Changes in precipitation and temperature also affect long-term trends
- Not one single factor explains differences trends between 1990s and 2000s