Predicting DOC response to reductions in acid deposition

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With particular thanks to:

Peter Henrys, Jakub Hruška,

Heleen De Wit, Pavel Krám,

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Gloria Pereira, Antii Räike,

John Stoddard & Chris Evans

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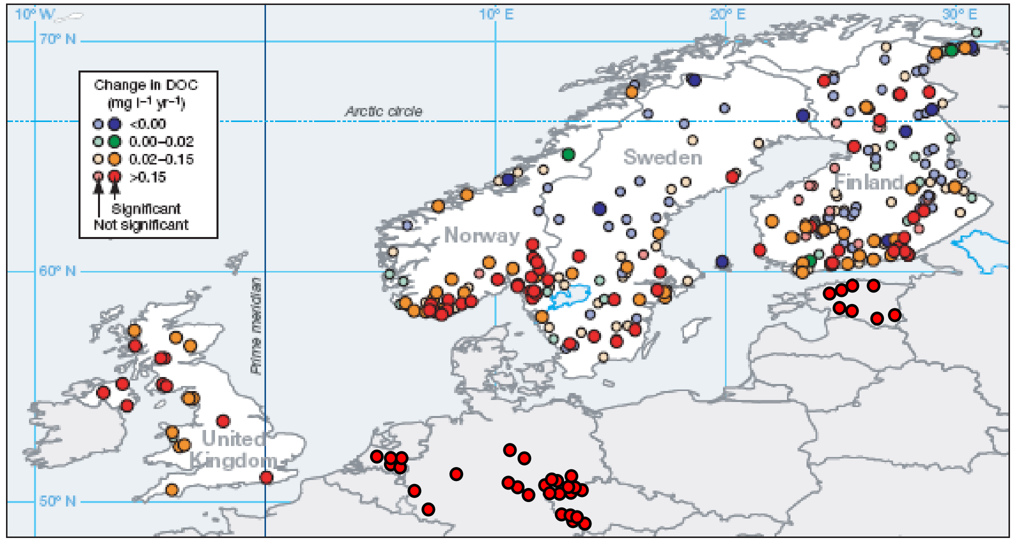
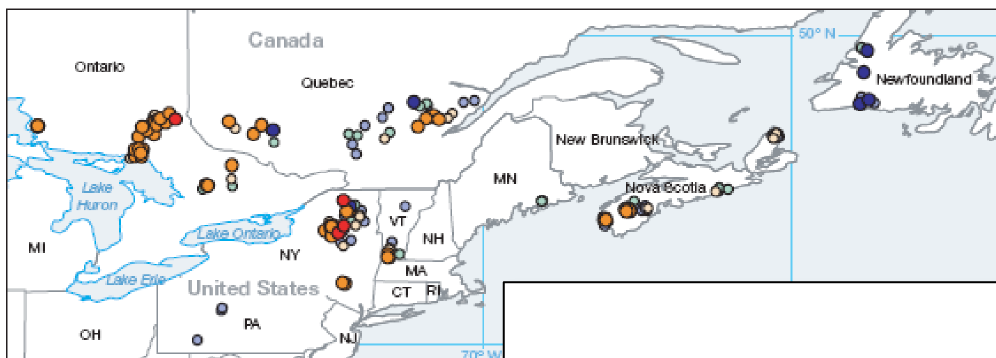
Hemispheric scale increase in Dissolved Organic Carbon (DOC) over recent decades





LETTERS

Dissolved organic carbon trends resulting from changes in atmospheric deposition chemistry

Donald T. Monteith[1]*, John L. Stoddard[2]*, Christopher D. Evans[3], Heleen A. de Wit[4], Martin Forsius[5], Tore Høgåsen[4], Anders Wilander[6], Brit Lisa Skjelkvåle[4], Dean S. Jeffries[7], Jussi Vuorenmaa[5], Bill Keller[8], Jiri Kopácek[9] & Josef Vesely[10]‡

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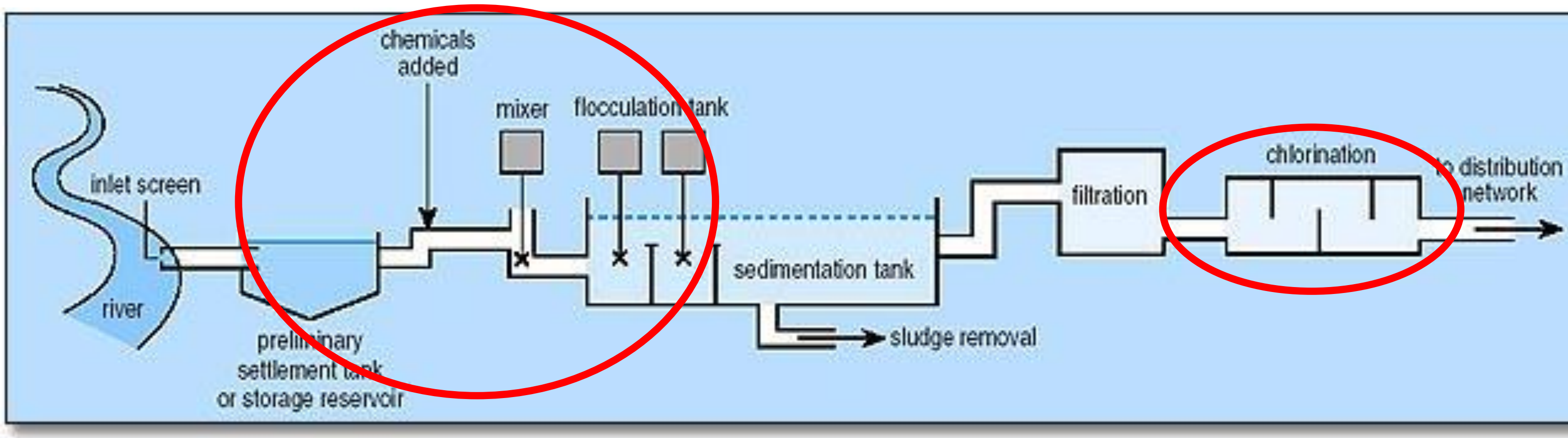
Economics of Dissolved Organic Matter (DOM)

- Upland catchments with organic-rich soils provide 70% of UK drinking water (Defra, 2011)
- DOM + chlorination = Trihalomethanes (THMs)



- DOM removal for typical plant (processing 60 ML/day)

  = £480K per year. (NEA, 2010)

- Scaled up for 70% UK population (150 litres/person)

  £50 million per year

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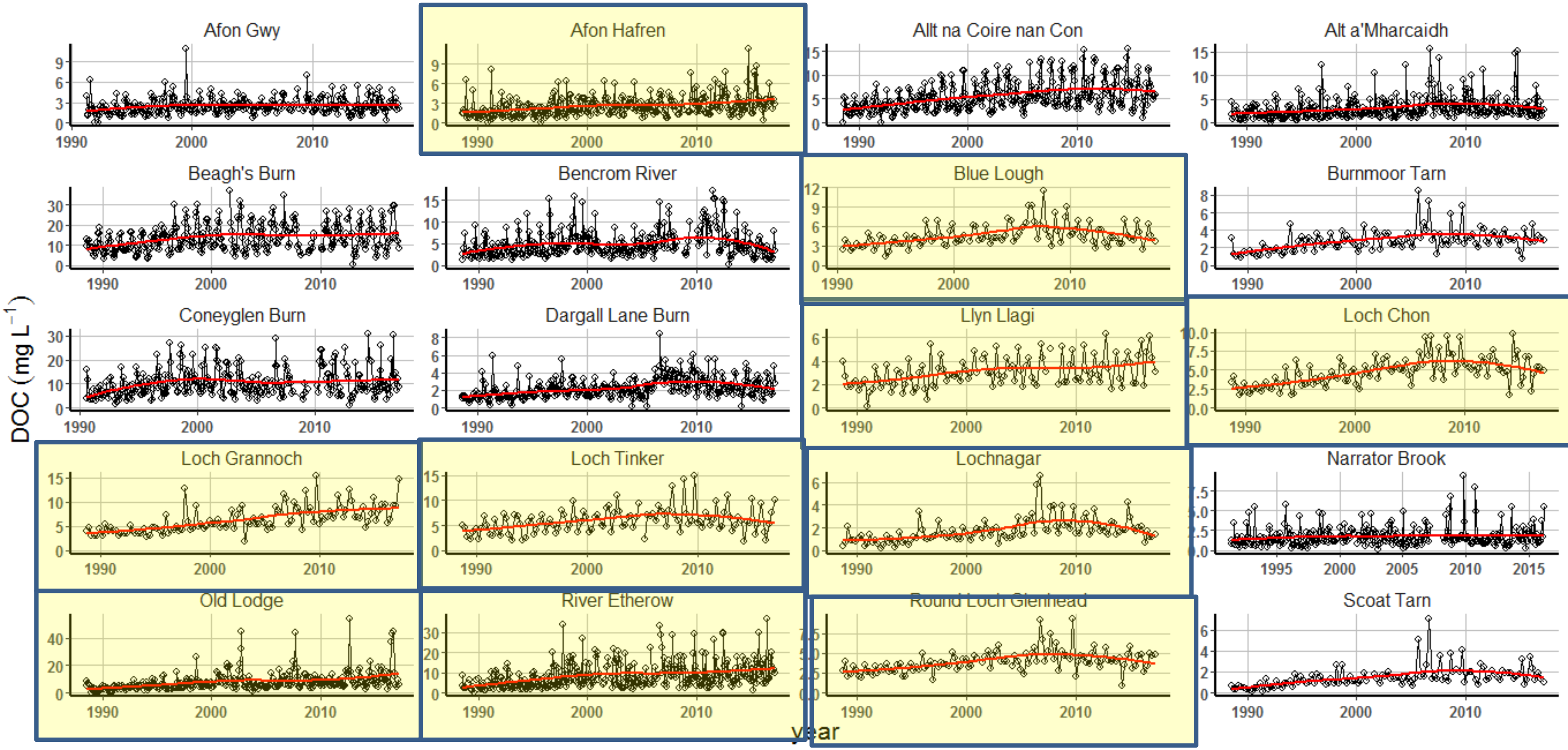
Continuing or flattening out in the UK?



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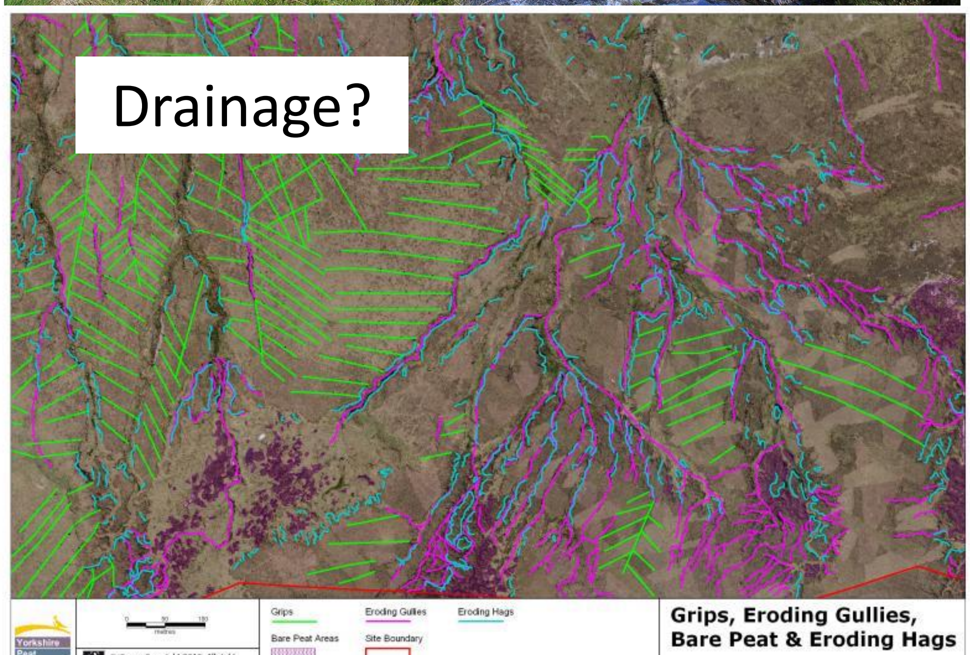
Industry needs to know what will happen next

in order to:

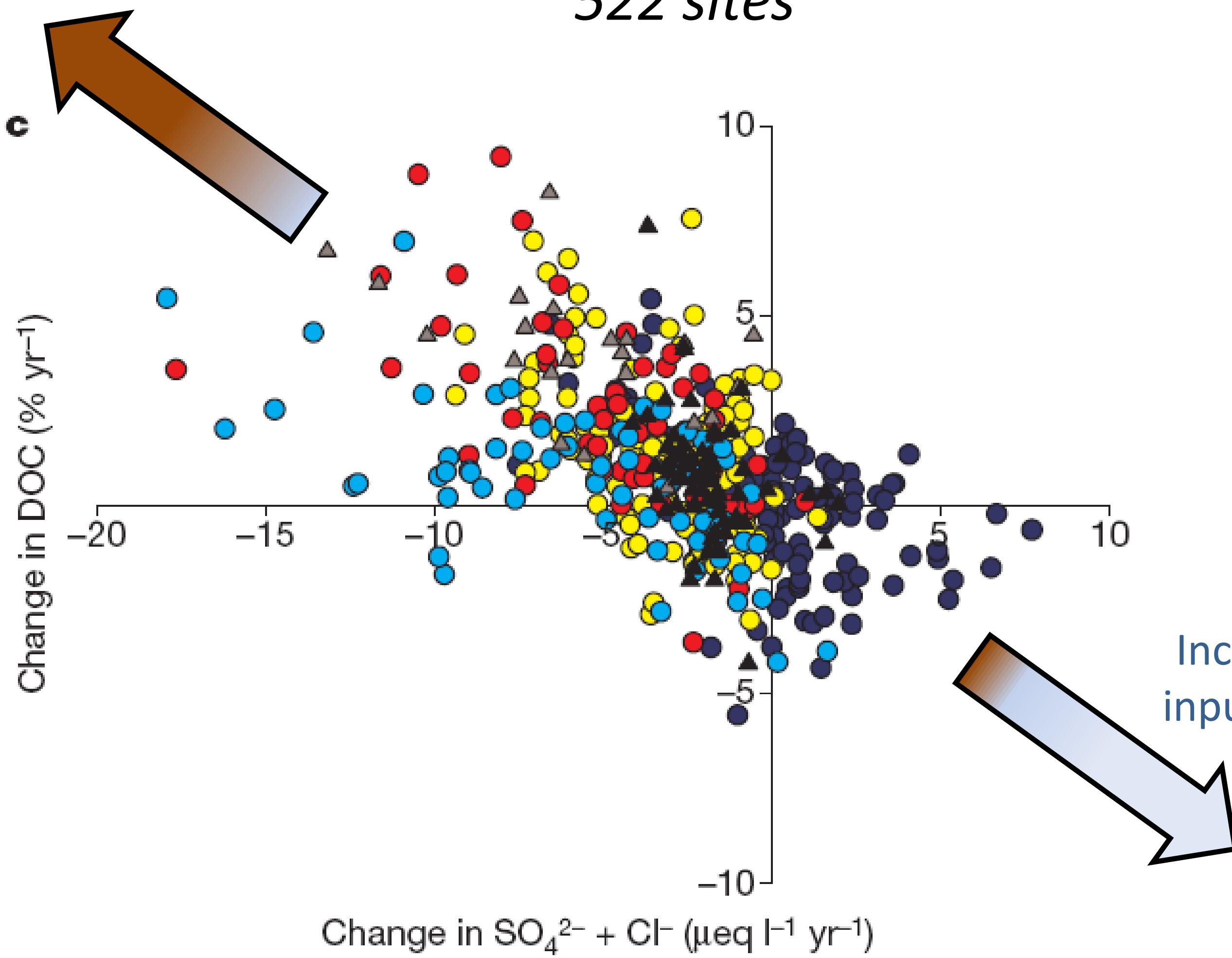
- Identify water treatment plants most at risk of exceeding threshold concentrations
- Plan for future coagulant use
- Determine potential to intervene at catchment level

Would it help to control………………..?



DOC trends linked to trends in acid anions

DOC change versus acid anion change:
522 sites



Increasing acid inputs = clearer water

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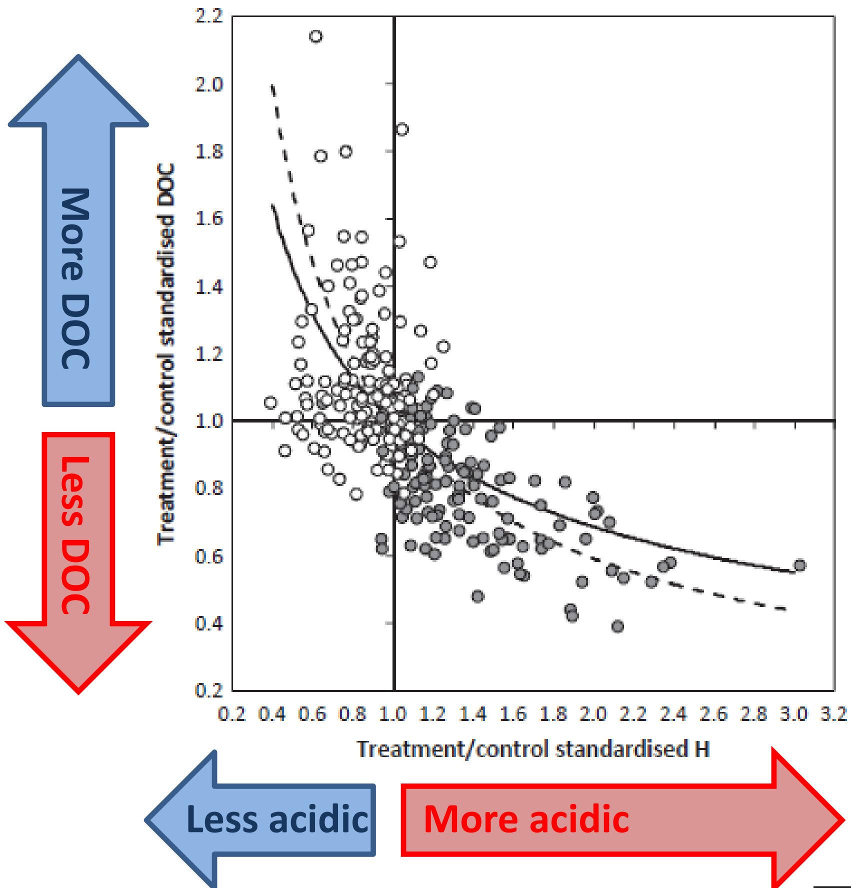
Monteith et al., Nature 2007

and soil acidity



Global Change Biology

Global Change Biology (2012) 18, 3317–3331, doi: 10.1111/j.1365-2486.2012.02794.x

Acidity controls on dissolved organic carbon mobility in organic soils

CHRIS D. EVANS*, TIM G. JONES†, ANNETTE BURDEN*, NICK OSTLE‡, PIOTR ZIELIŃSKI†,§, MARK D. A. COOPER*†, MIKE PEACOCK†, JOANNA M. CLARK¶, FILIP OULEHLE*||, DAVID COOPER* and CHRIS FREEMAN†

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………and ionic strength of runoff

$$IS = 0.5 \times \Sigma_i c_i Z_i^2$$

Environmental Science & Technology

Increased Dissolved Organic Carbon (DOC) in Central European Streams is Driven by Reductions in Ionic Strength Rather than Climate Change or Decreasing Acidity

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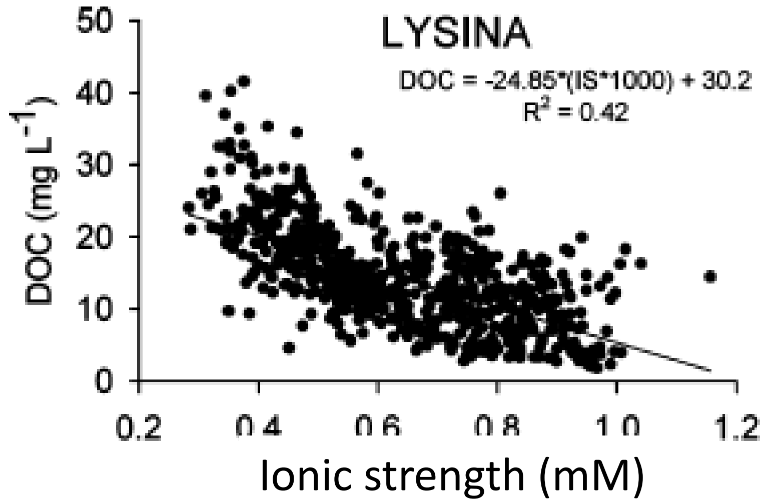
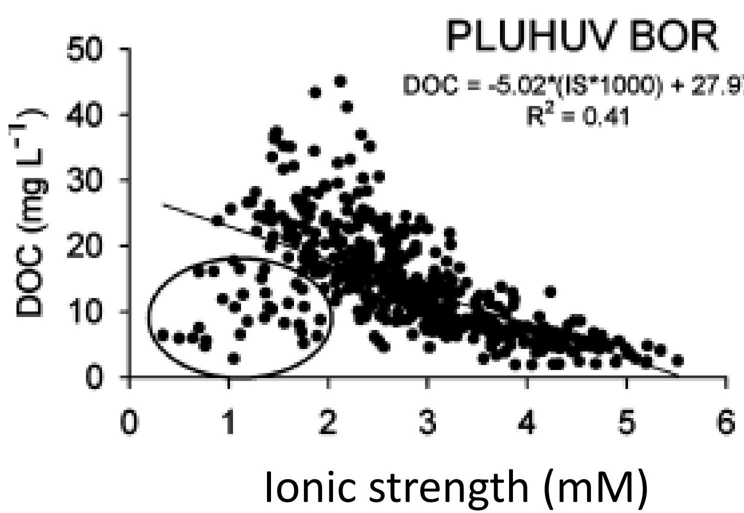
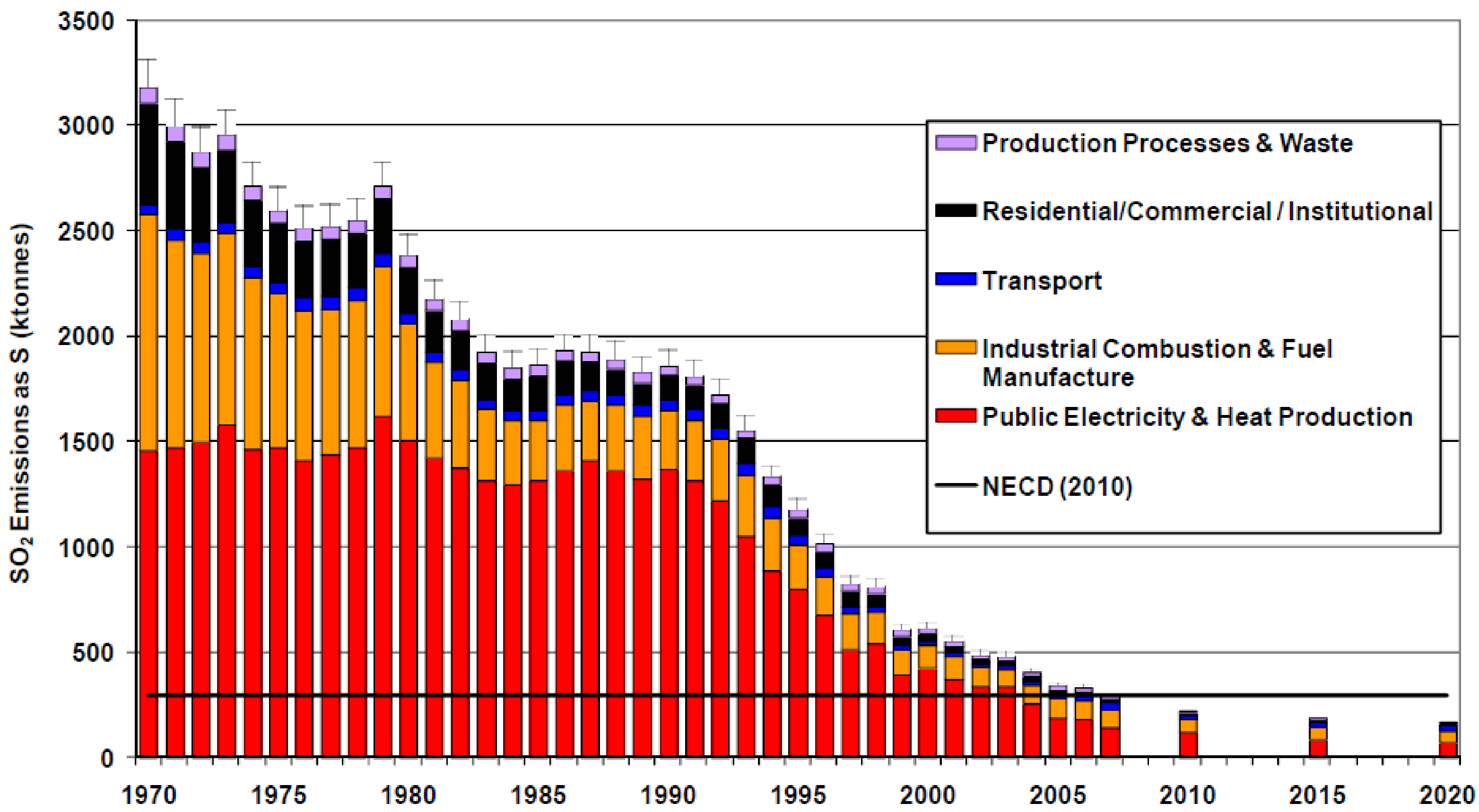
Czech Geological Survey, Klárov 3, 118 21, Prague 1, Czech Republic, and Department of Natural Resources and the Environment, University of New Hampshire, Durham, New Hampshire 03824





Last few decades - huge reduction in UK sulphur emissions and sulphur deposition



NEGTAP: 2010

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UK Monitoring Starts

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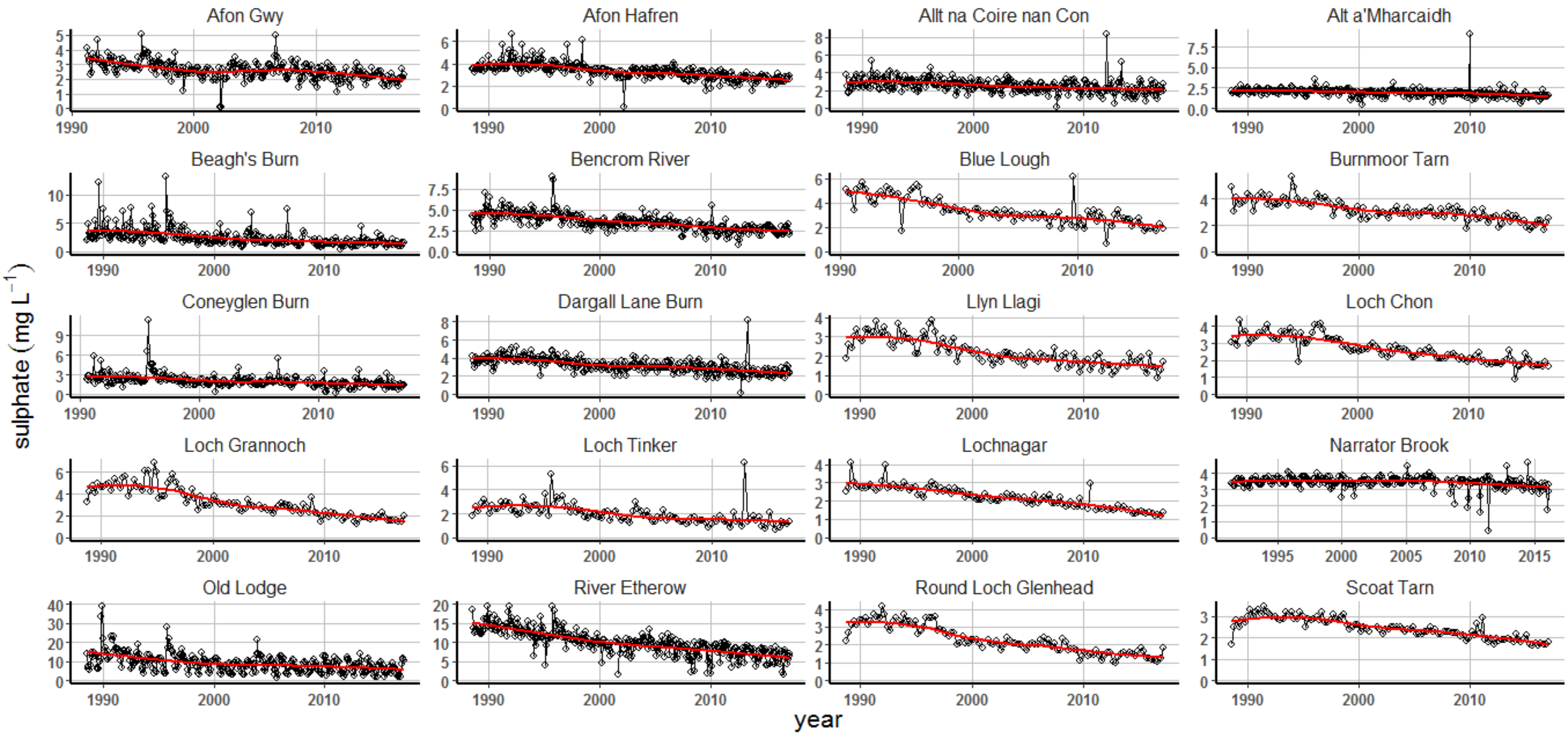
Lagged response in surface water sulphate.
Concentrations continue to trend downwards at several sites



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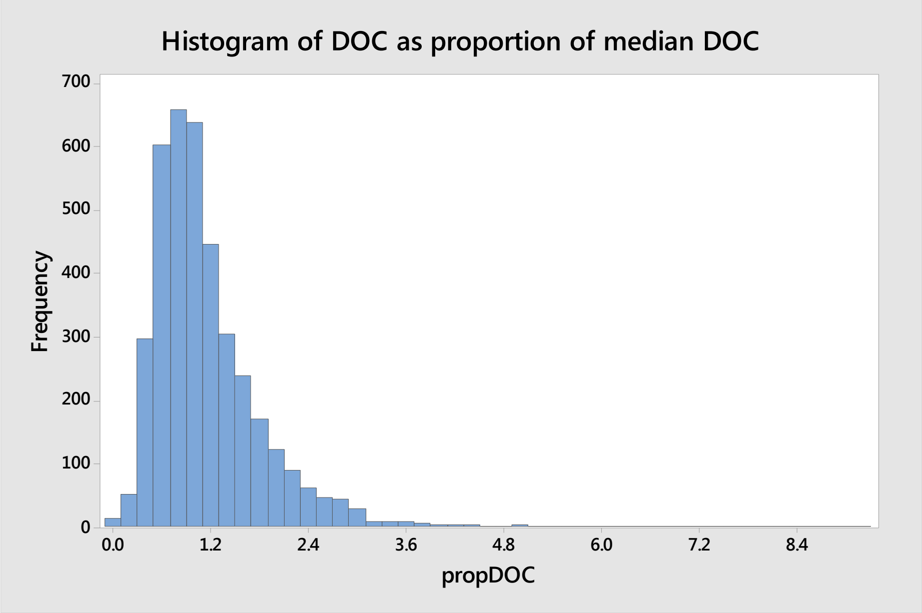
UK DOC data (20 sites, 3700 data points) transformed to: proportion of site median DOC



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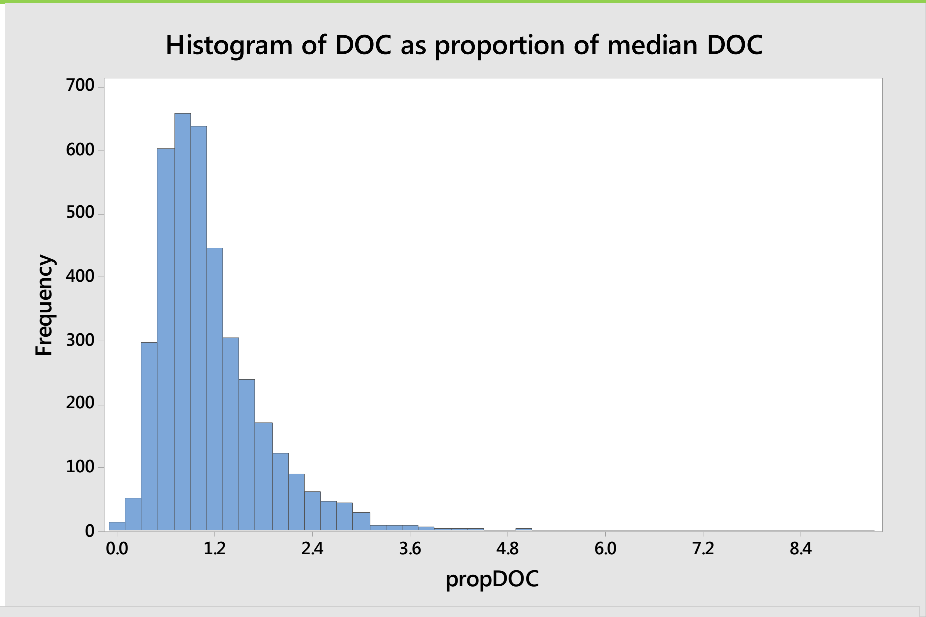
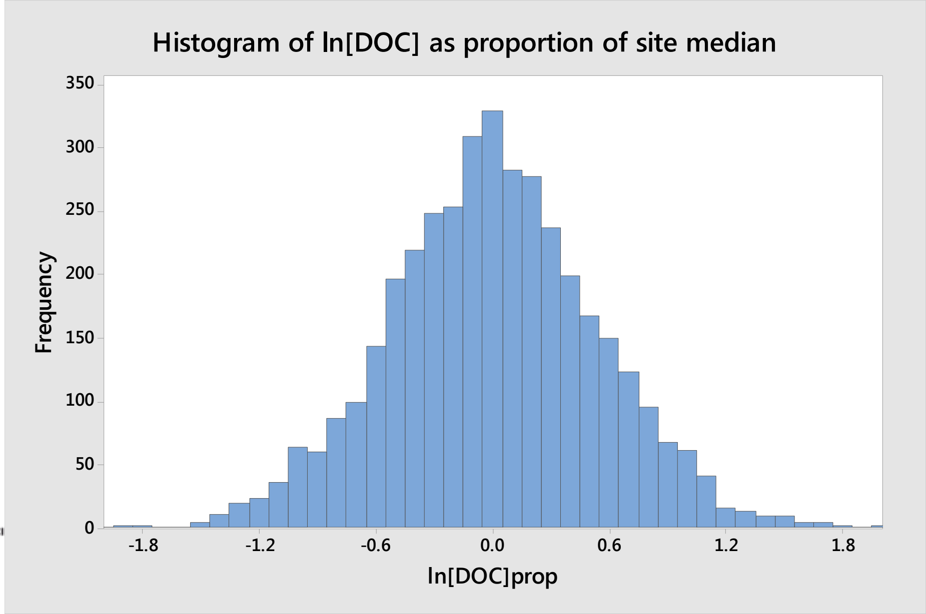
UK DOC data transformed to: proportion of site median…………..and then logged (ln DOC_{prop})





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What hydrochemical variables best explain variation in ln DOC_{prop}?

Candidates

- SO_4^{2-} concentration
- Cl^- concentration
- Sum Acid Anions (SAA) ($SO_4^{2-} + Cl^- + NO_3^-$)
- ANC (Sum Base Cations – Sum Acid Anions)
- Ionic strength (IS)

$$IS = 0.5 \times \Sigma_i c_i Z_i^2$$

Expressed as:

- Absolute concentrations
- Difference from site mean concentration
- Proportion of site mean concentration

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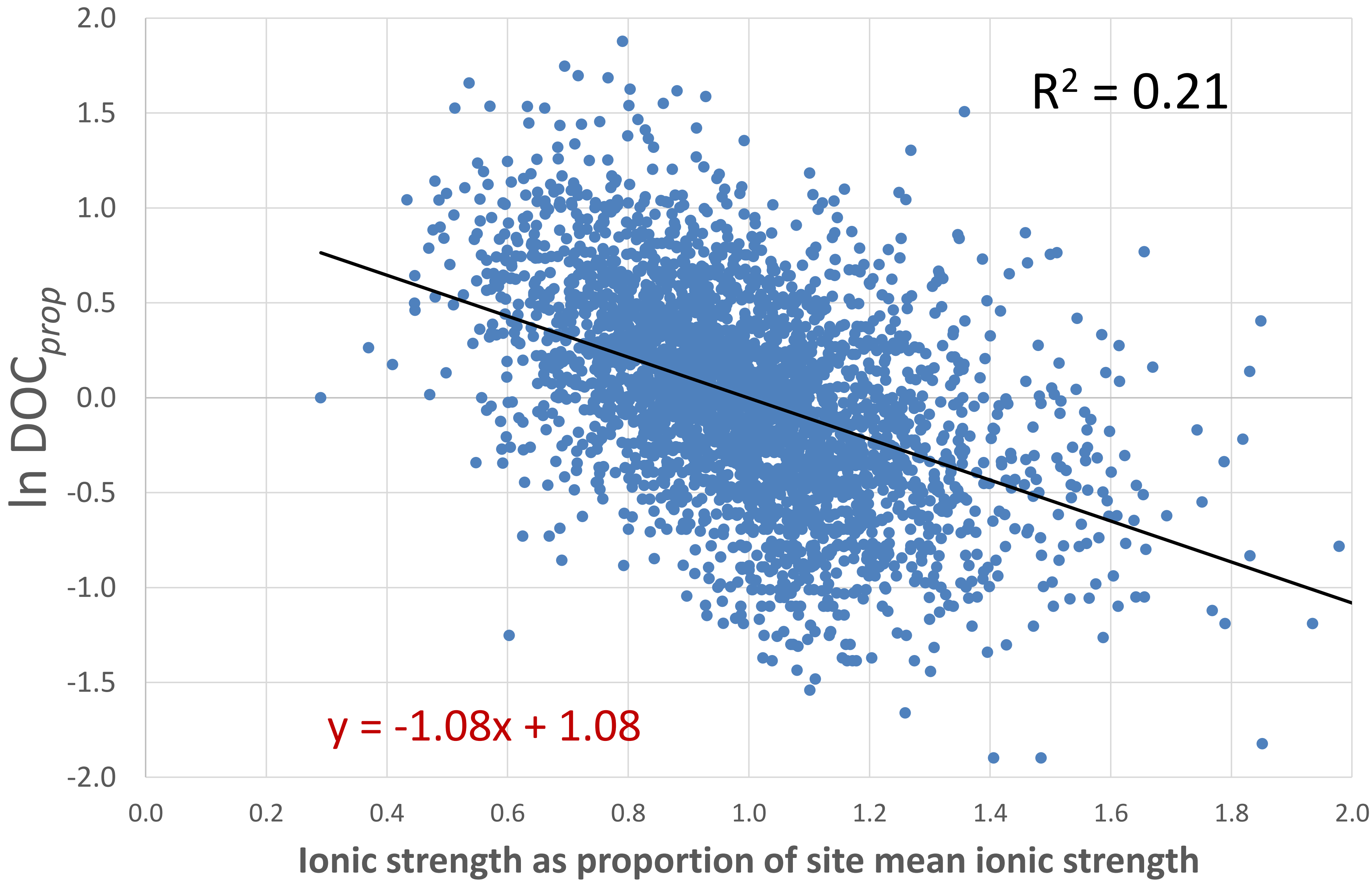
$\ln DOC_{prop} = 1 - \text{Ionic strength}_{prop}$



Model refined by site-specific calibration

site *i*
time *t*

$$\ln \mathrm{DOC}_{prop(i,t)} = \mathrm{f} - \mathrm{f}^*\mathrm{IS}_{\mathrm{prop}\,(i,t)}$$

$$\mathrm{DOC}_{(i,t)} = \mathrm{DOC}\bar{x}_{(i)}.e^{(\mathrm{f} - \mathrm{f}*\mathrm{ISprop(i,t)})}$$

Where f = site-specific IS – DOC calibrated constant
Ranging from 1 - 3 depending on base-flow index

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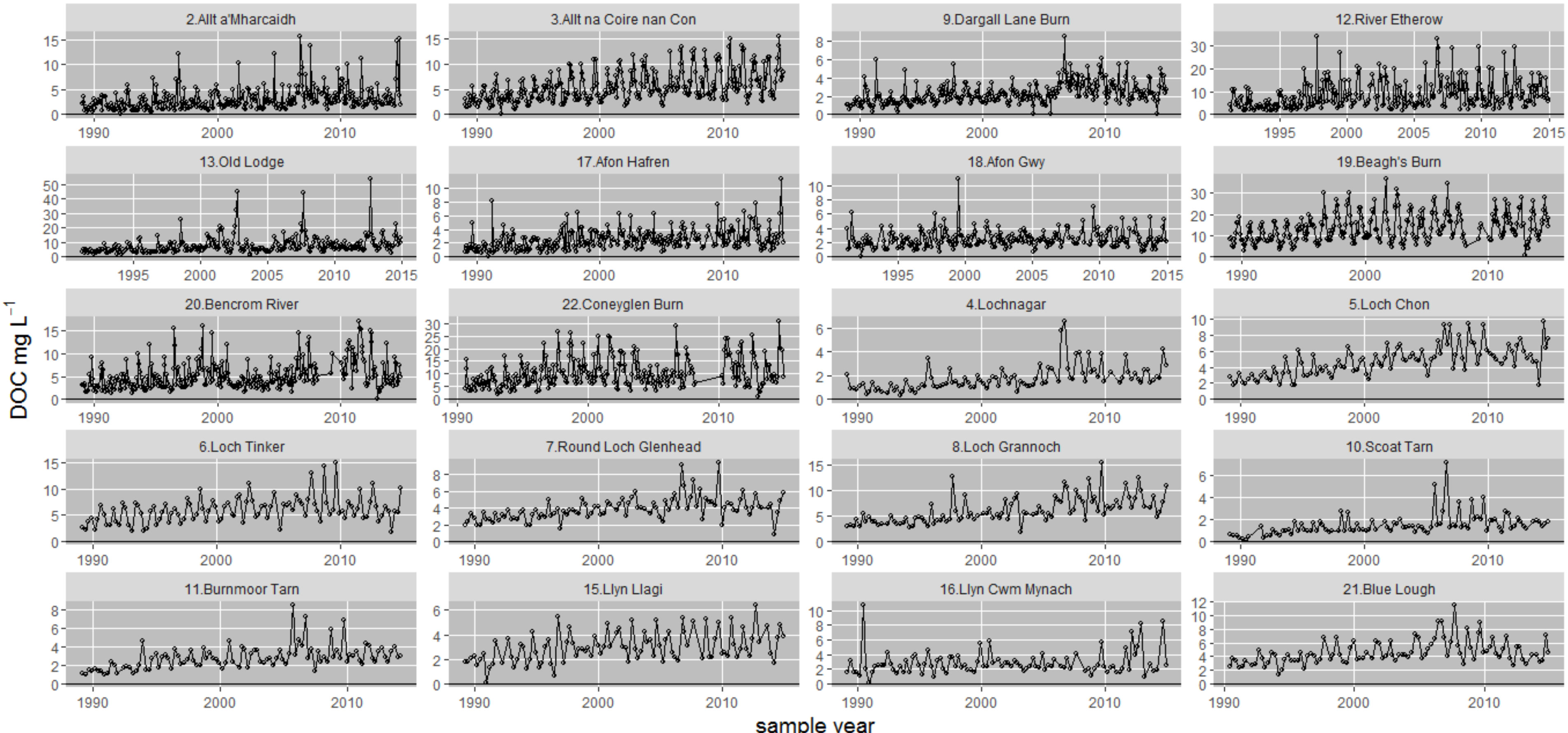
Baseline DOC trend predictable from trend in ionic strength



Black trace = Measured DOC

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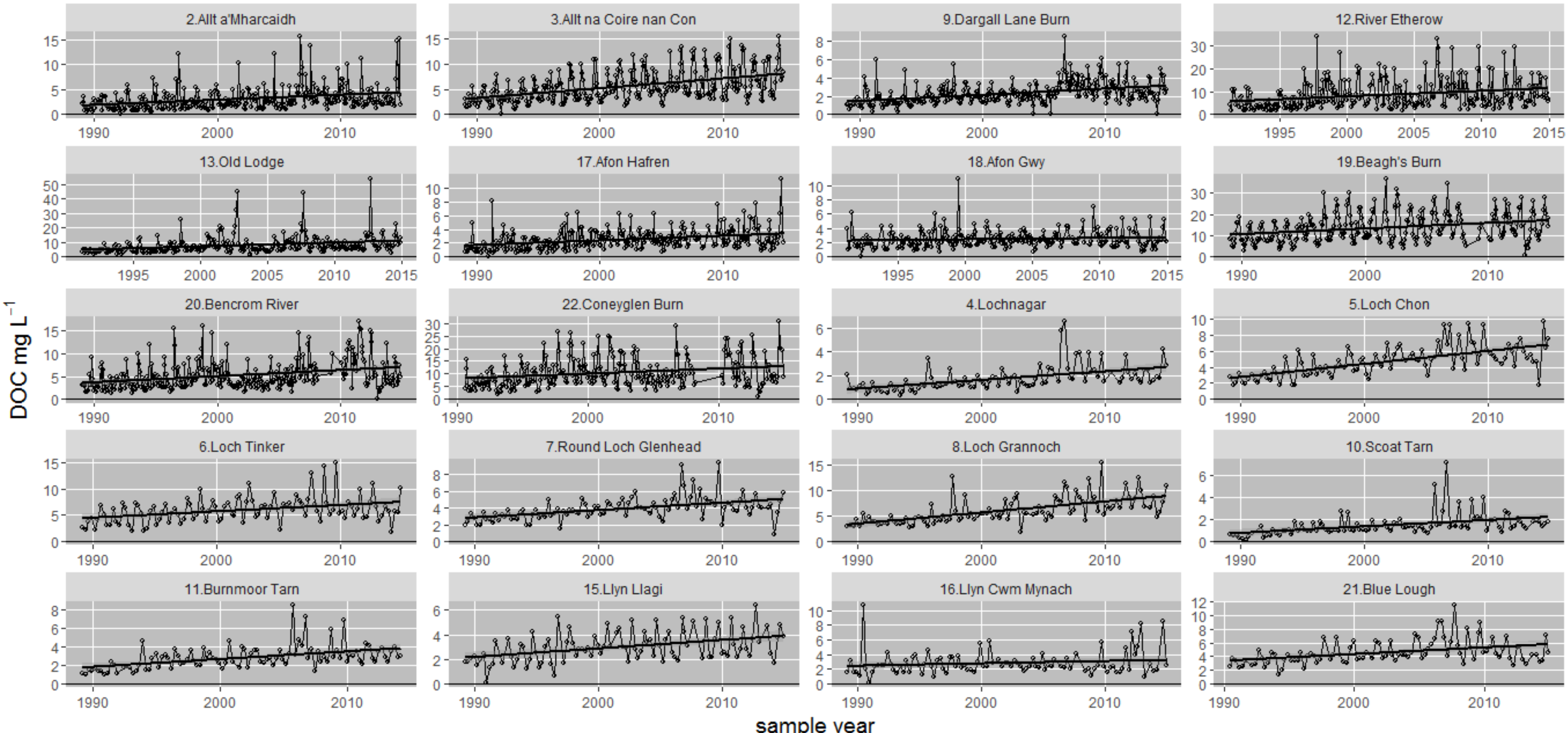
Baseline DOC trend predictable from trend in ionic strength



Black trace = Measured DOC

Black line = linear DOC trend

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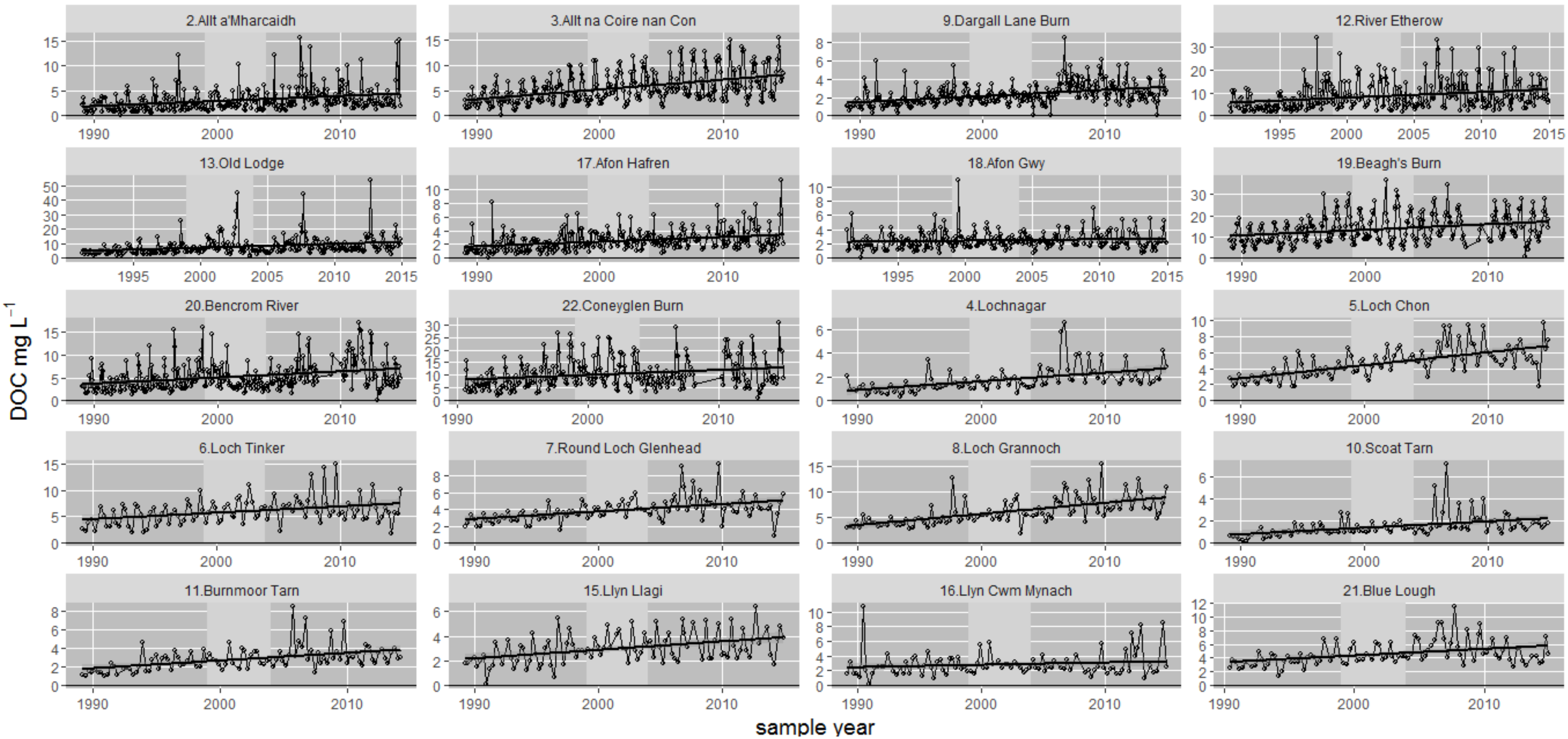
Baseline DOC trend predictable from trend in ionic strength



Black trace = Measured DOC

Black line = linear DOC trend

Light grey hatching = DOC vs IS calibration period

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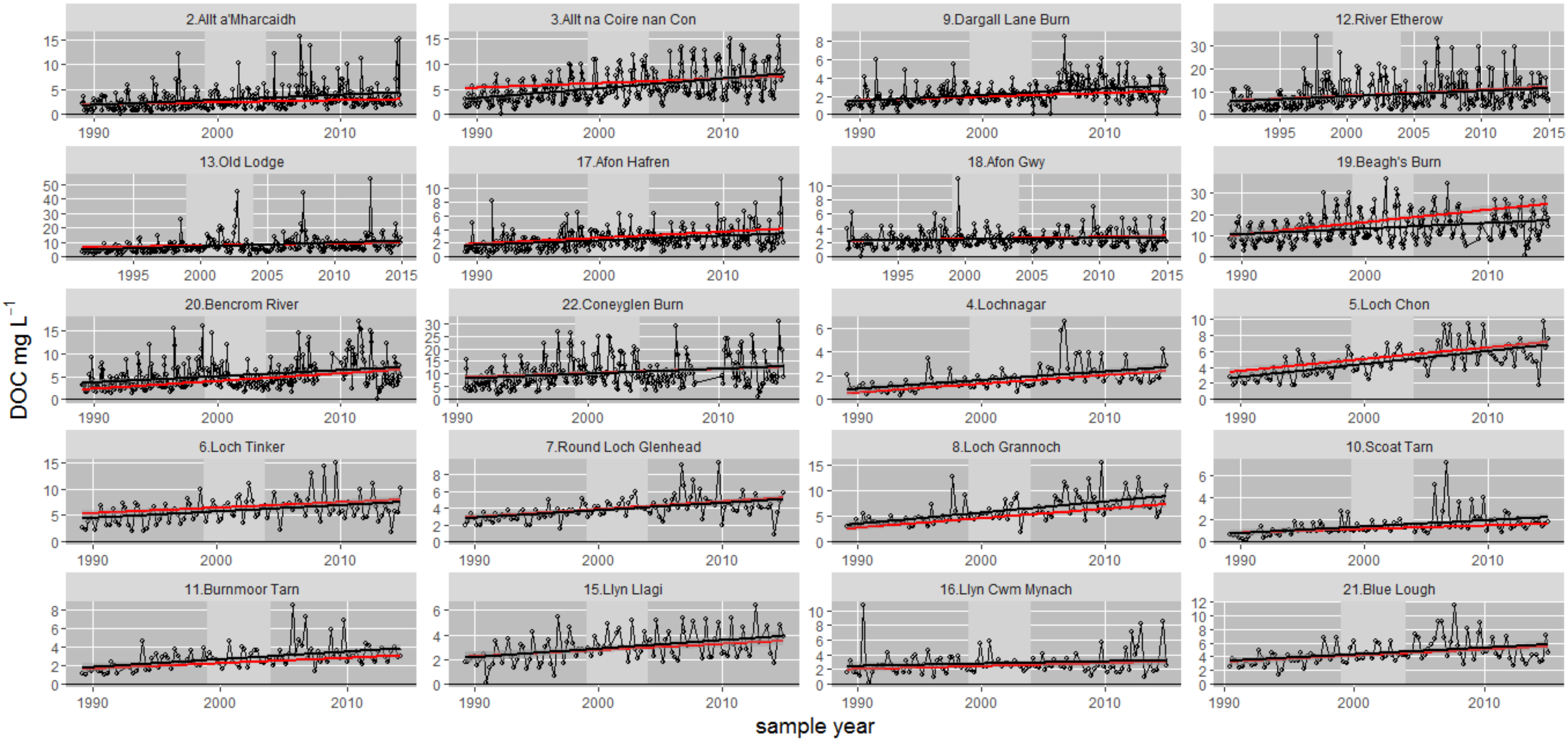
Baseline DOC trend predictable from trend in ionic strength



Black trace = Measured DOC

Black line = linear DOC trend

Red line = linear modelled DOC trend

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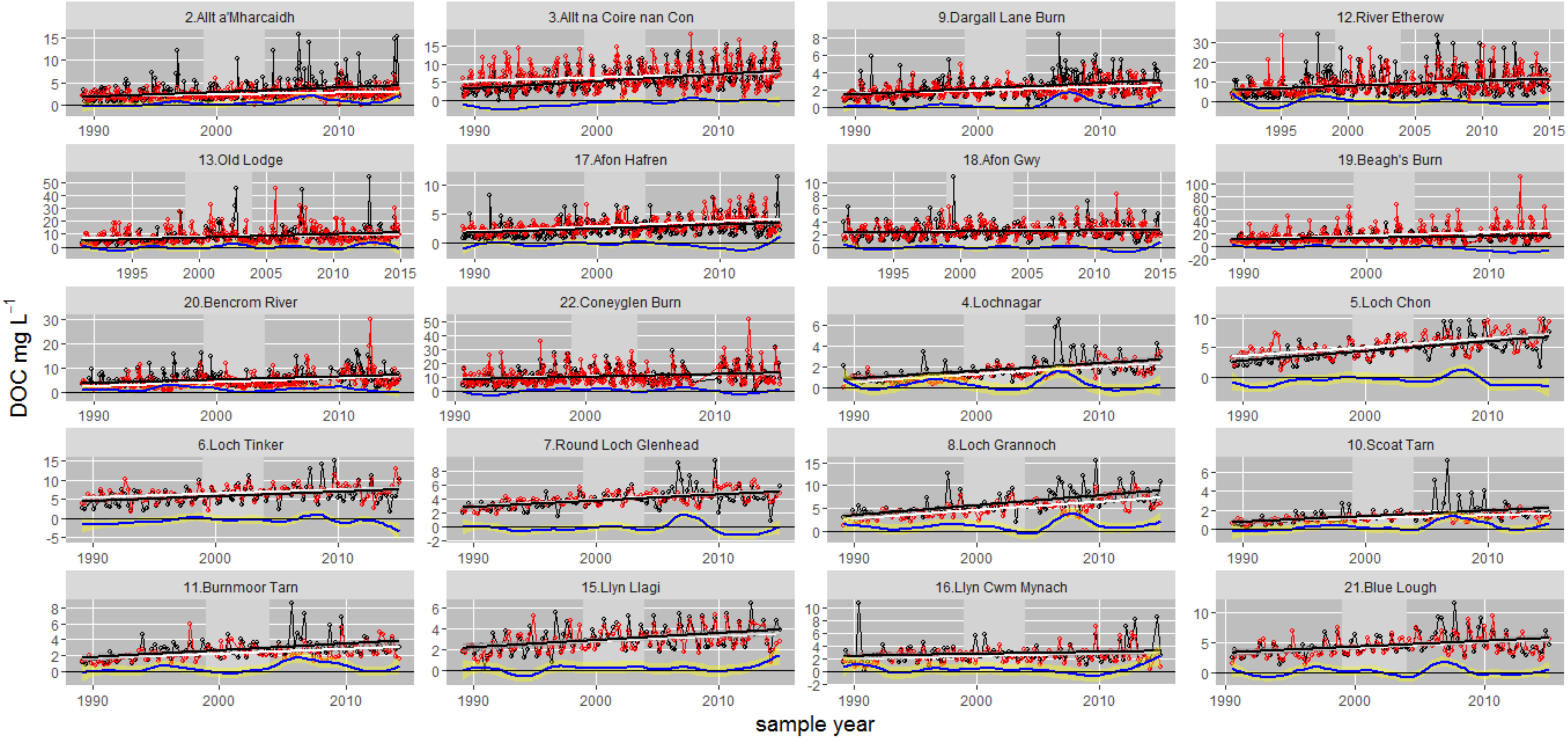
Model including fixed seasonal component



Black trace = Measured DOC

Black line = linear DOC trend

white line = linear modelled DOC trend

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Predicting the moving DOC baseline

- If we have access to:
  1. short-term runs of DOC and IS or conductivity data to calibrate f
  2. current non-marine sulphate concentration
  3. knowledge of regional non-marine sulphate trend

- We can then:
  - Predict how IS will respond to further declines in non-marine sulphate
  - And hence the DOC response

summary

- For a wide range of surface waters logged DOC concentrations vary in inverse proportion to change in ionic strength
- Relationships are similar across sites but vary depending on base flow contribution
- Relationships likely reflect effects of variation in soil acidity on soil organic matter solubility
- Potential to apply relationship to predict likely future behaviour of the DOC baseline in response to expected further reductions in IS
- This provides a framework against which we can then attempt to superimpose catchment-specific effects (e.g. land use manipulations).