

Developing user-friendly tools to explore future changes in dissolved organic matter in upland drinking water sources

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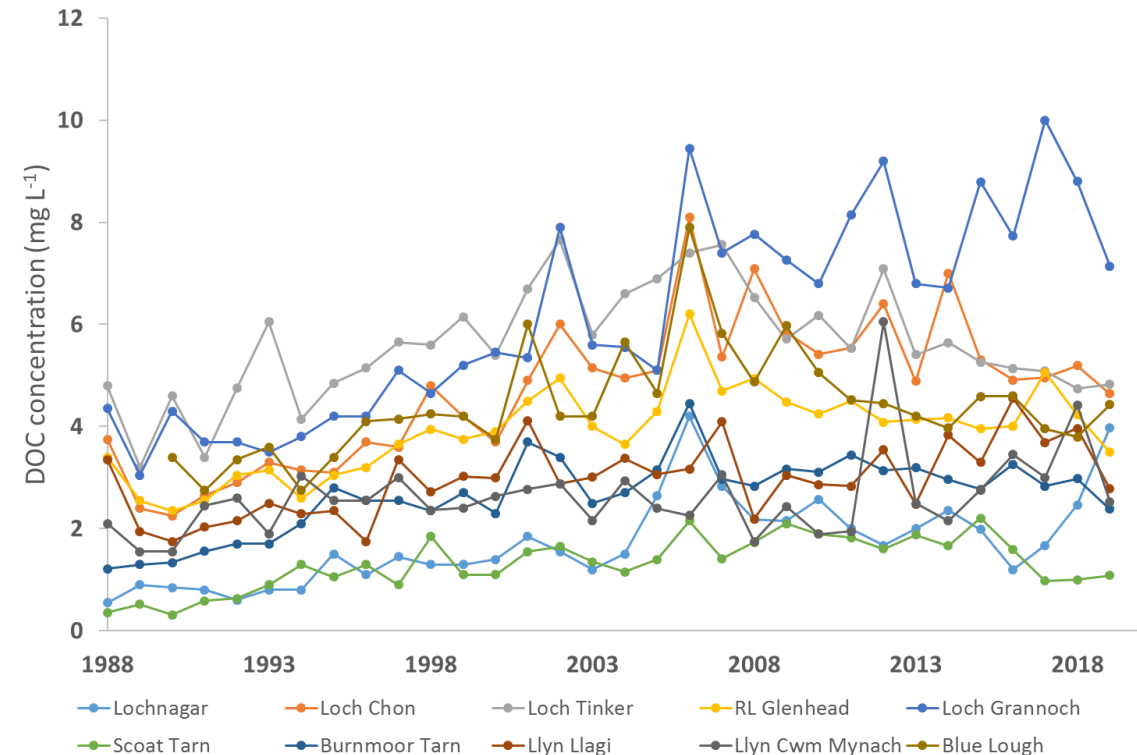
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Special thanks to local Scottish Water staff

The water industry problem

- Soils of upland drinking water catchments in the UK often contain high amounts of organic matter
- A significant proportion of this ends up in streams and lakes in the form of Dissolved Organic Matter (DOM)
- These catchments have experienced increases in DOM in recent decades
- The Water Industry must minimise DOM levels to avoid:
 - Taste and odour problems
 - Fouling of plant
 - Disinfection Byproduct (DBP) formation
- Significant cost implications for:
 - Coagulant use
 - Sludge removal
 - Energy consumption
 - New infrastructure

Trends in Dissolved Organic Carbon in UK Upland Waters Monitoring Network lakes (1988 - 2016)



The FREEDOM project

Forecasting Risks to upland water treatment assets from the Environmental Exacerbation of Dissolved Organic Matter levels

- **Funded under NERC Environmental Risks to Infrastructure Innovation Programme (ERIIP) – with co-funding from Scottish Water**
- **Initial challenges issued by Scottish Water:**
 - “to gain a better understanding of drivers of change in the quantity and quality of DOM in raw water reaching treatment plant”
 - “to develop capability to predict DOM changes in light of future environmental change”
- **Major project aim:**
 - To develop a visualisation tool to inform the water industry of likely future DOM trajectories for its source waters

Operational definitions

- **Dissolved Organic Matter (DOM):**

All organic matter in water passing through a fine filter (e.g. 0.45 μm)

- **Dissolved Organic Carbon (DOC)**

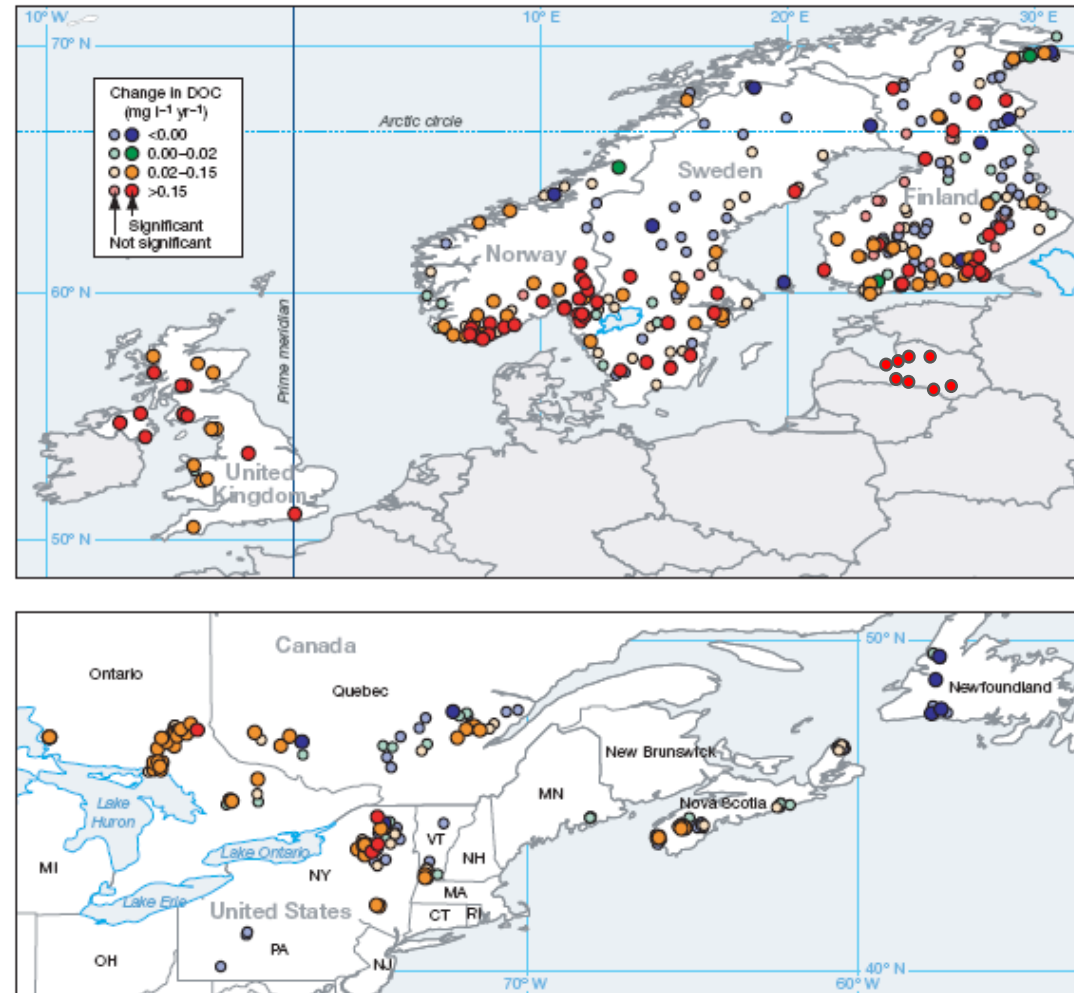
The carbon contained within DOM

- **Total Organic Carbon (TOC)**

All organic carbon in unfiltered water

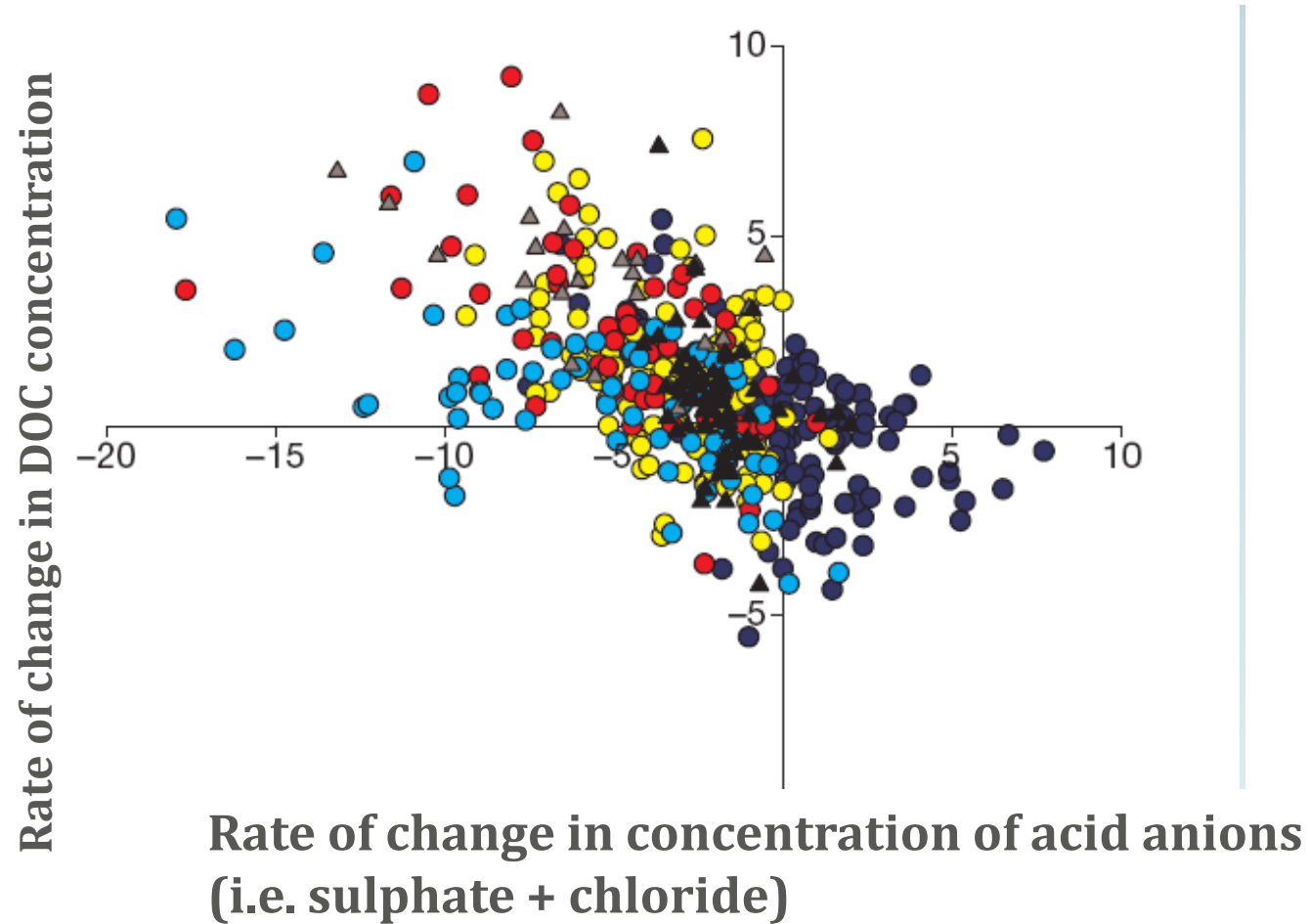


Rising DOC concentrations in remote surface waters (1990 – 2004)

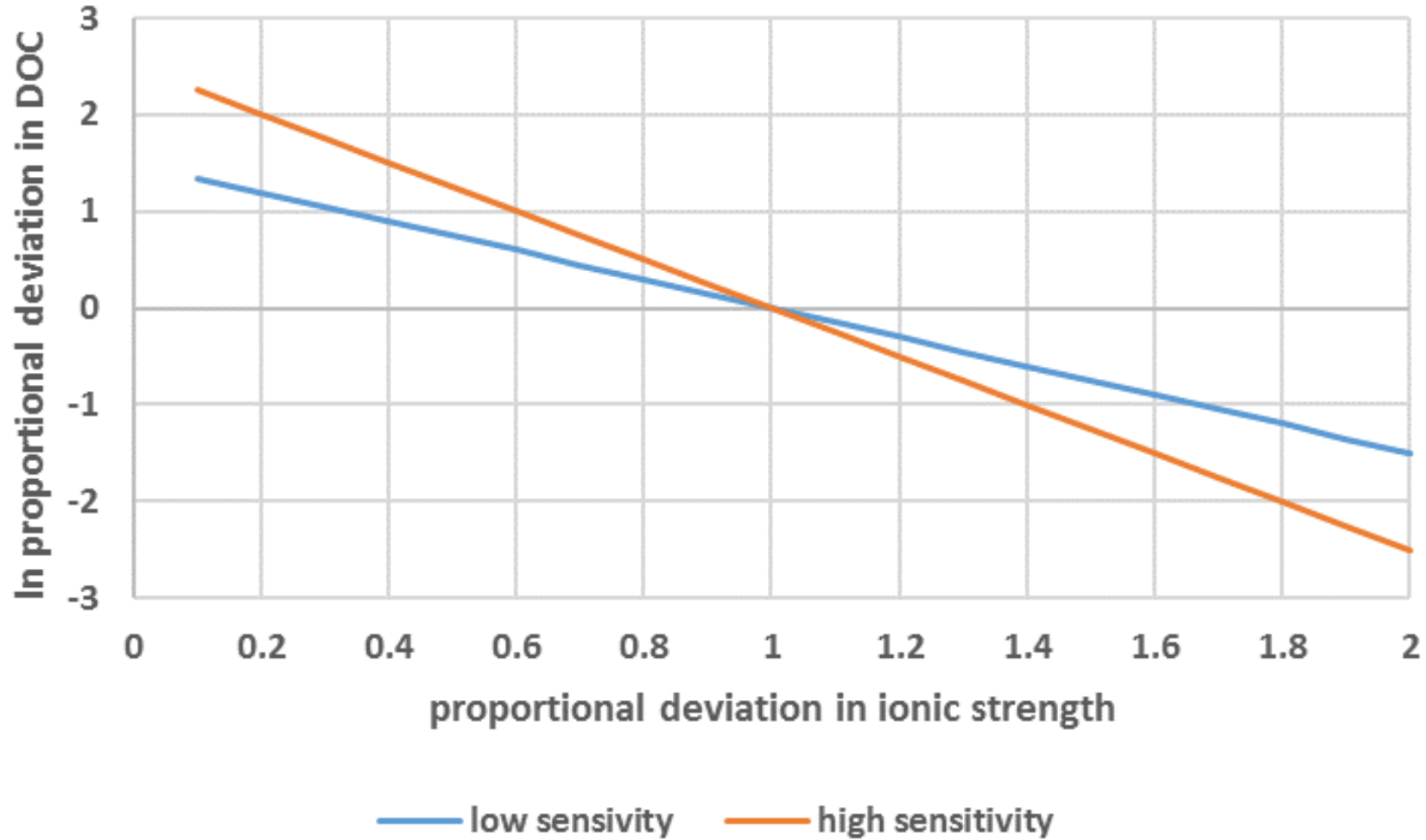


DOC increasing in proportion to reduction in acid pollutants

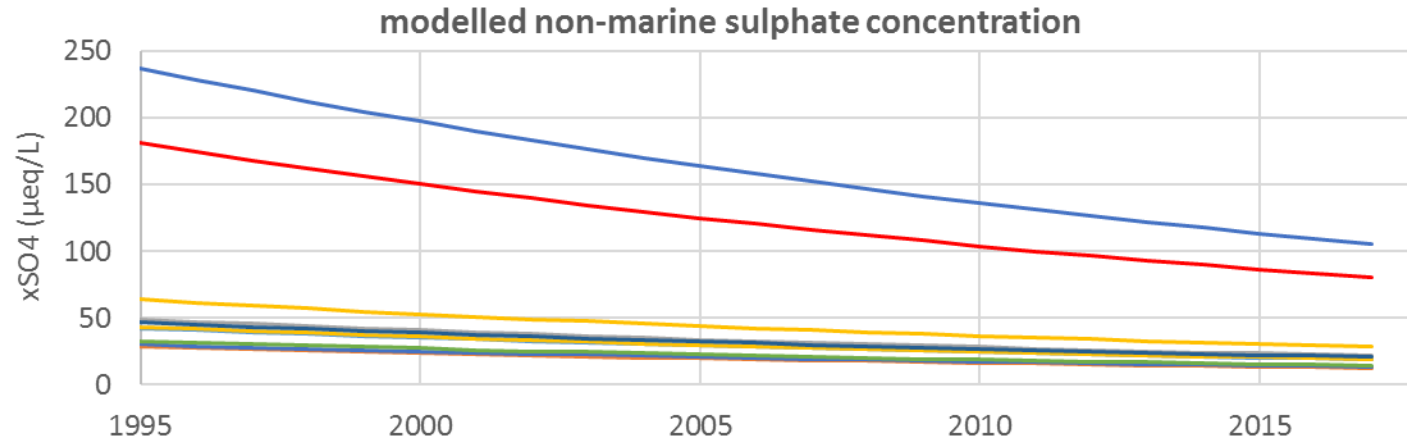
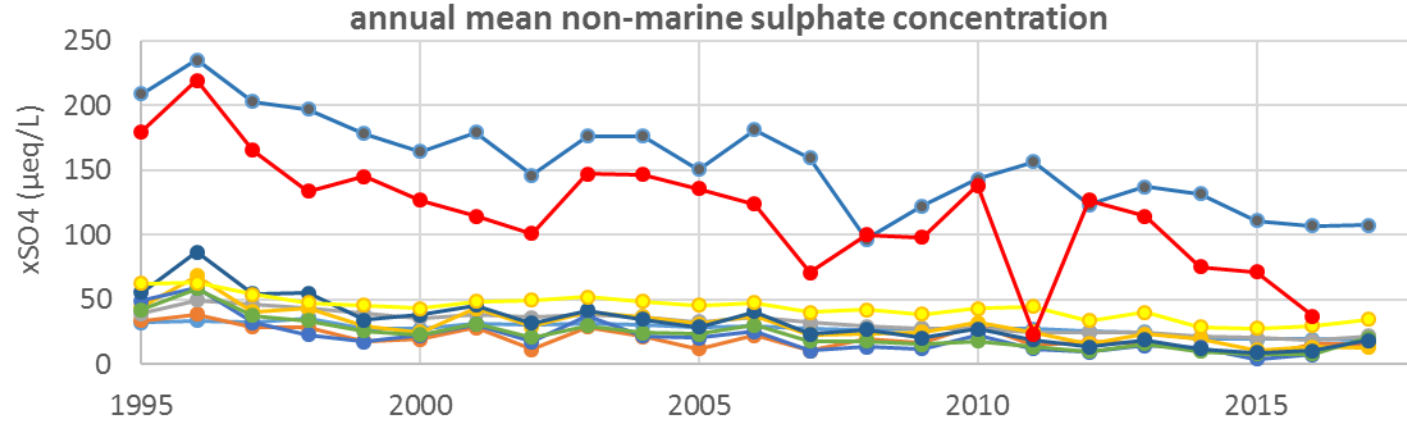
DOC change versus acid anion change: 522 sites



relationship between ionic strength and DOC in UK upland waters

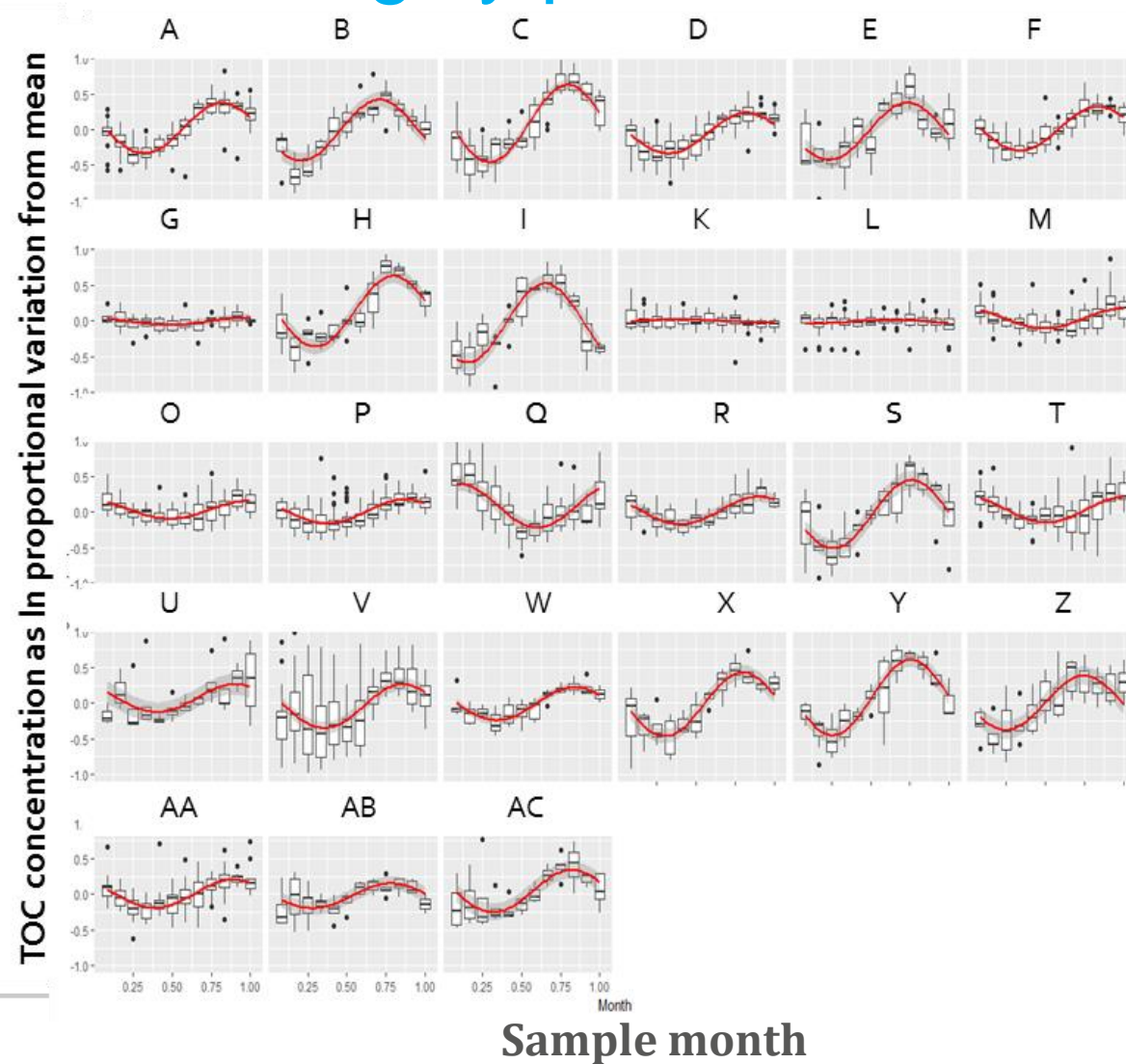


Rate of long term rate of change in non-marine sulphate can be predicted from current concentration



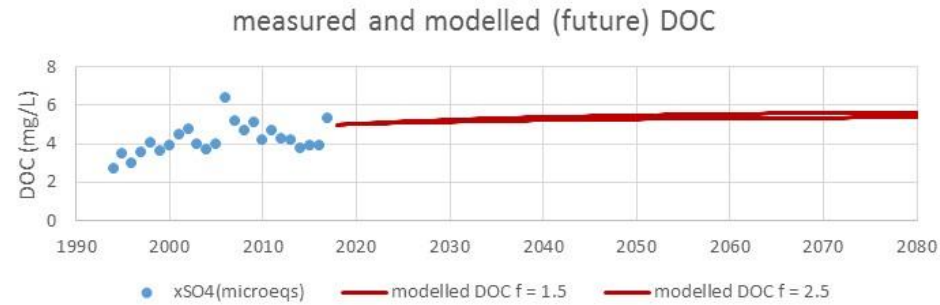
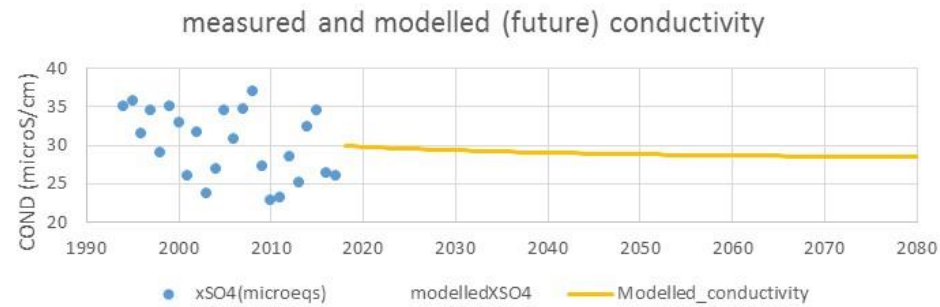
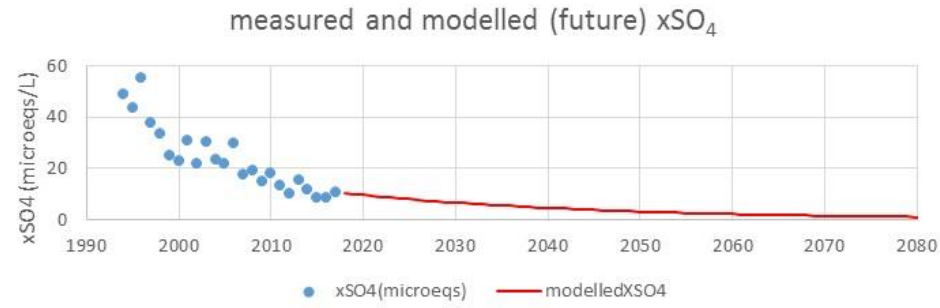
- Allt a'Mharcaidh
- Loch Chon
- Loch Grannoch
- Old Lodge
- Allt na Coire nan Con
- Loch Tinker
- Dargall Lane Burn
- Lochnagar
- Round Loch Glenhead
- River Etherow

Seasonal variation in DOC in upland waters is highly predictable

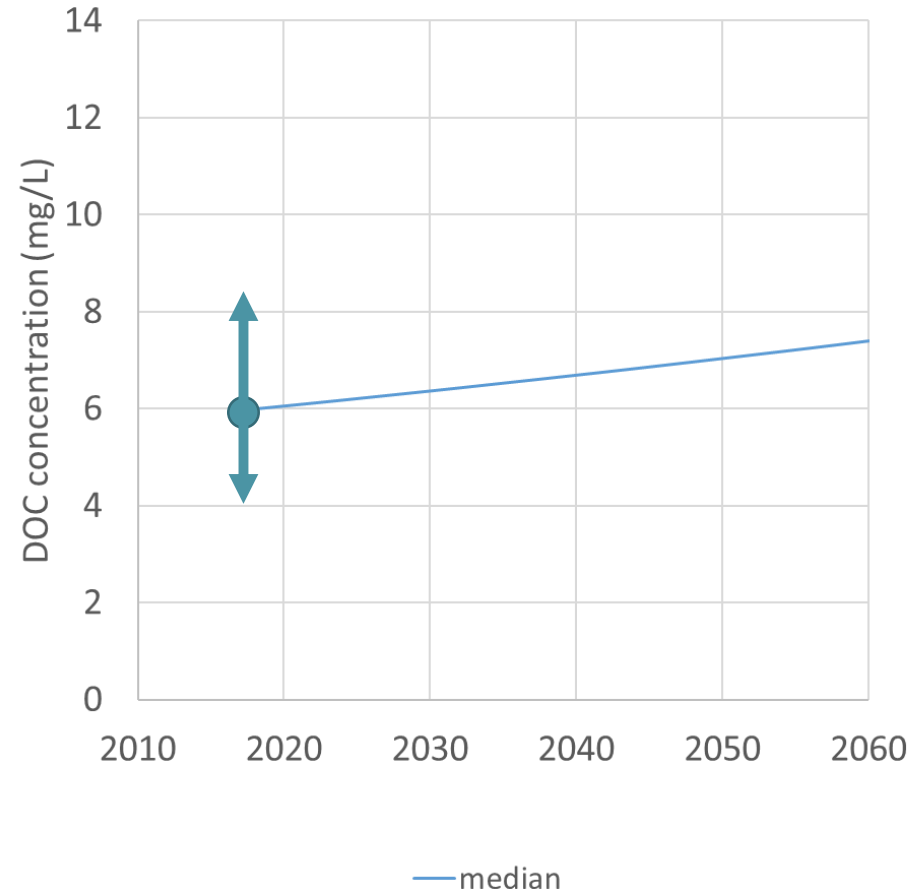


**TOC variation
in 27 Scottish
Water Source
Waters**

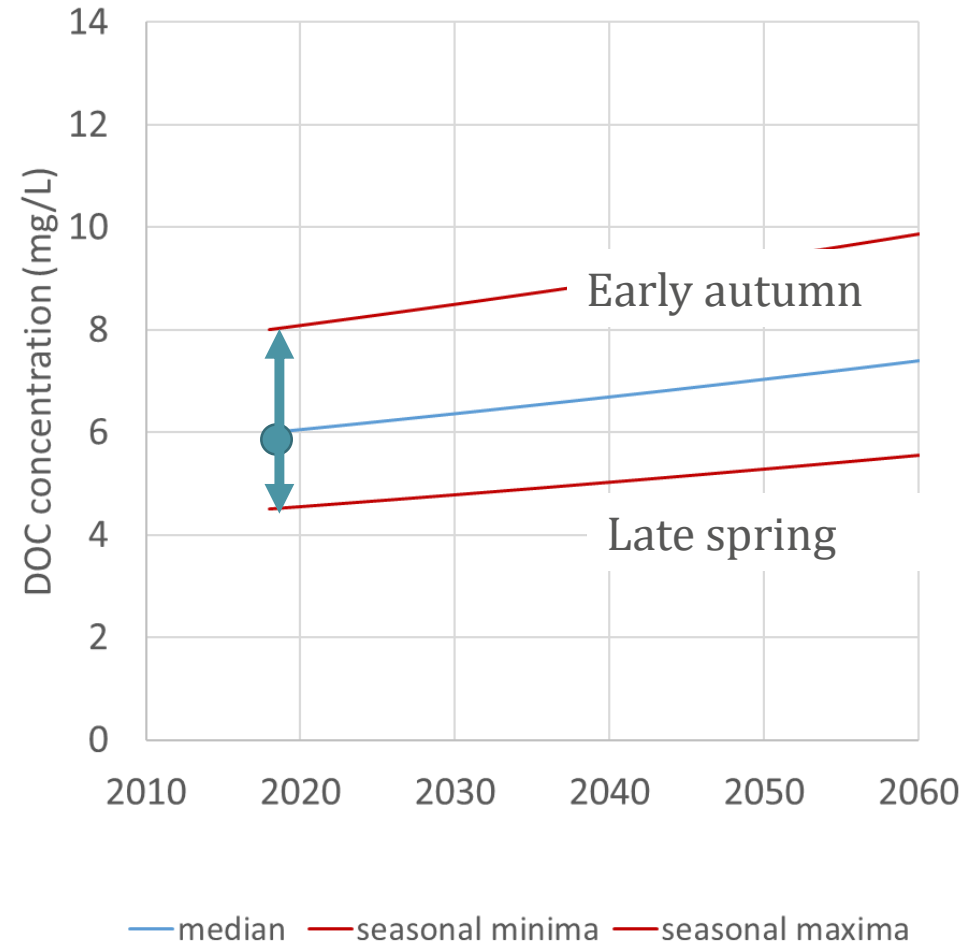
modelled sulphate \longrightarrow modelled conductivity \longrightarrow modelled DOC



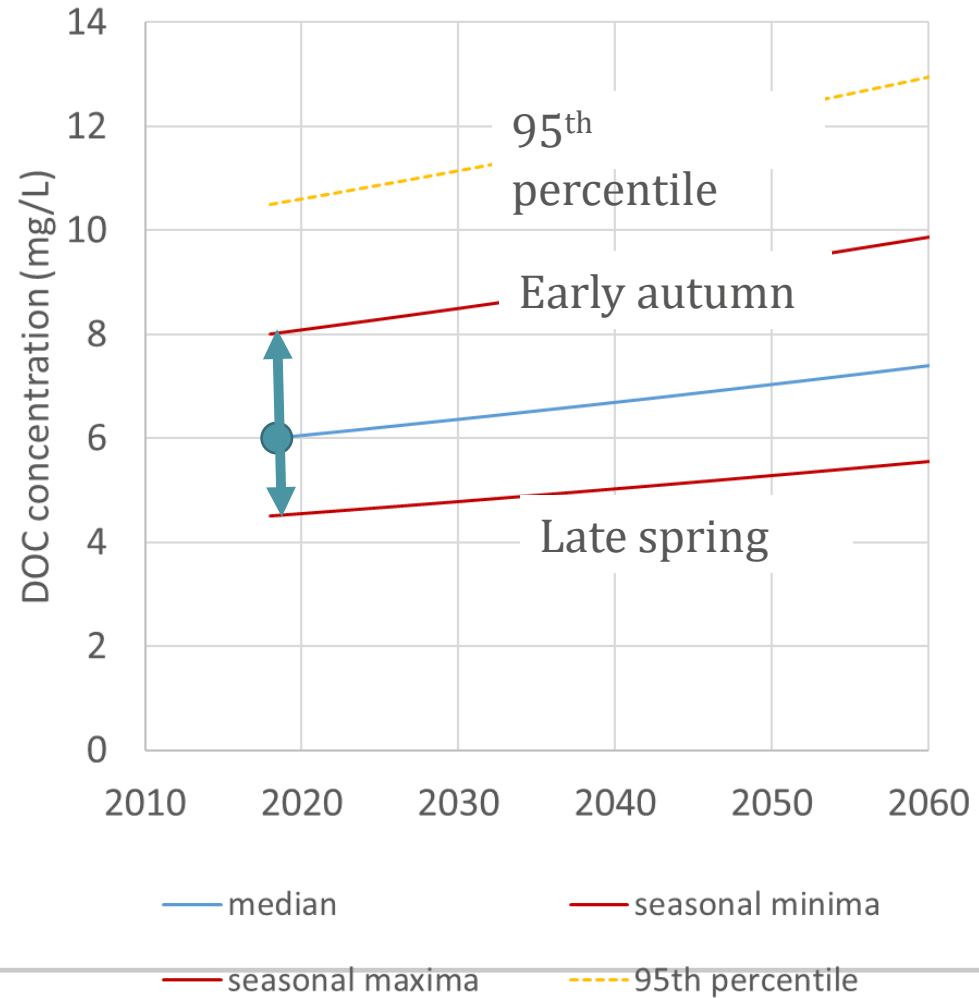
The modelled “moving baseline”



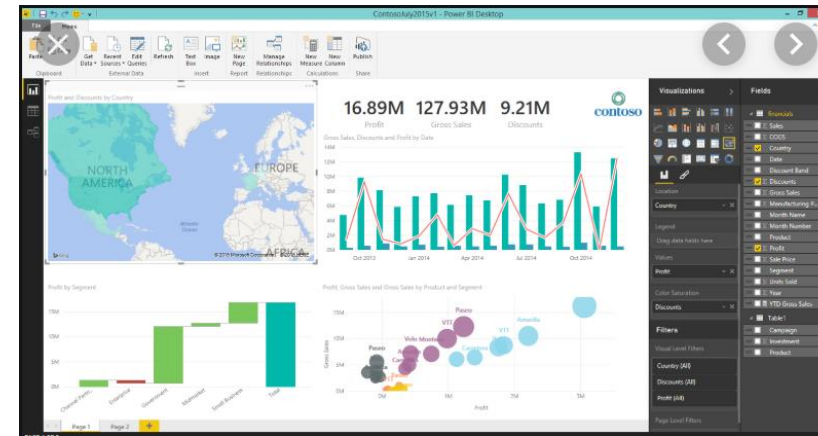
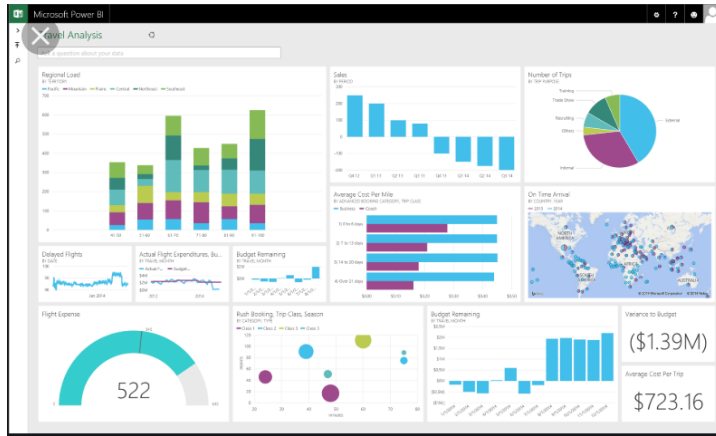
adding a seasonal envelope



adding episodic extremes



Building the FREEDOM Decision Support Tool (DST): Microsoft Power BI as a data visualisation platform



- Business analytics service
- Provides interactive visualisation
- Can visualise underlying computer coded graphs (R)
- Requested as platform by Scottish Water– fits with existing systems
- Has not reached its full potential yet

Underpinned by R programming language

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#####  
##### FREEDOM R script #####  
####for analysis of TOC data, baseline modelling predictions and ####  
#####generating tables for Decision support tool #####  
#####
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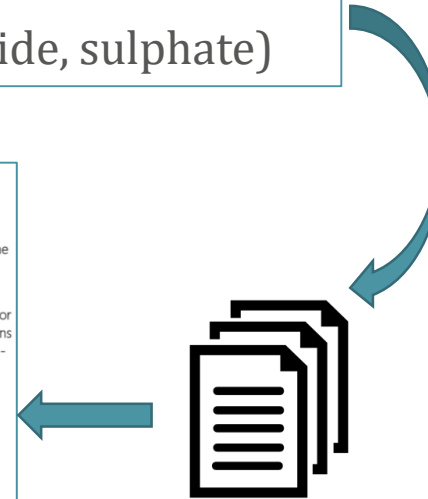

New data
(TOC, chloride, sulphate)

FREEDOM project: Decision support tool

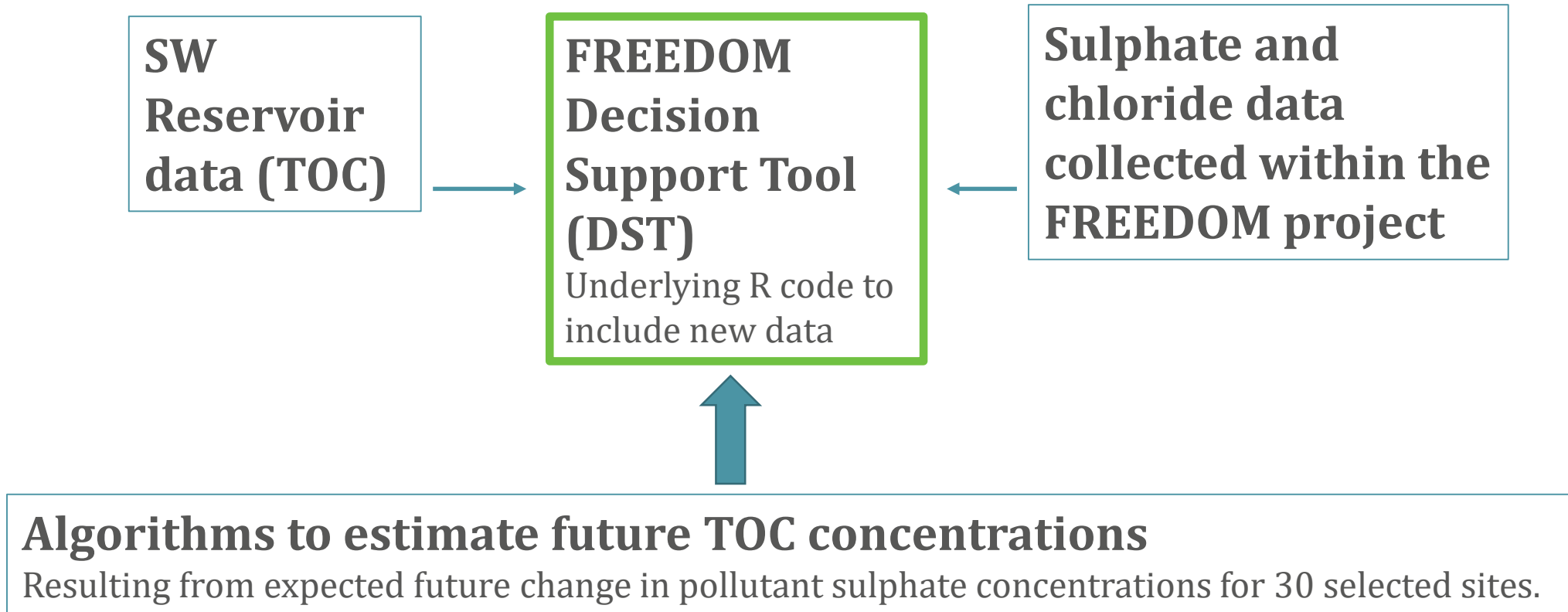
The FREEDOM (Forecasting Risks of Environmental Exacerbation of Dissolved Organic Matter) project aimed to monitor dissolved organic matter dynamics in 30 selected Scottish Water Reservoirs and forecast organic matter concentrations for the next 40 years.

This decision support tool is focussed on the prediction of long term changes in total organic carbon (TOC) in response to continuing reductions in soil acidity that are resulting from long term reductions in the deposition of atmospheric pollutants (or 'acid rain'). It visualises measured TOC concentrations from 2013 onwards, and provides predictions of how TOC concentrations are likely to have changed since 1990 and how they are expected to change up to 2060 in response to continuing deposition-related effects.

In its current form, the tool output assumes that current short term variation in TOC that may be attributable to effects of weather remains unaltered over the next four decades. Incorporation of climate change effects within the tool are being developed under the current FREEDOM BCCR (Building Climate Change Resilience) project. The project initially aimed to incorporate the impact of changes in land use and management within catchments within the tool, but there is currently too much uncertainty regarding these potential effects to include them. Work on this is ongoing.



FREEDOM Decision Support Tool (DST)



FREEDOM DST: regional view

This map shows the location of the 30 selected reservoirs. The sites were selected by various criteria:

- Loch/reservoir sources only
- WTWs with less than three water source sample points
- Sites with good availability of TOC data
- Sites where additional data on organic matter quality is available
- Good geographical spread
- Data checked by Asset Capability and Sustainable Land Management teams.

The size of the circle represents the concentration of TOC measured in the Source Water (except for Daer Reservoir where raw water measurements were used).

Move the mouse over the circles for information on average (mean) TOC and reservoir names.



FREEDOM DST: site summaries

Total organic carbon concentrations
of the 30 selected reservoirs from 2013

Please select one site for graphs to work

Site	TOC Average	TOC Max
Source Water A	14.8	30.9
Source Water B		30
Source Water C		50
Source Water D		30
Source Water E		10
Source Water F		50
Source Water G		30
Source Water H		20
Source Water I		30
Source Water J		20
Source Water K		30
Source Water L		70
Source Water M		70
Source Water N		10

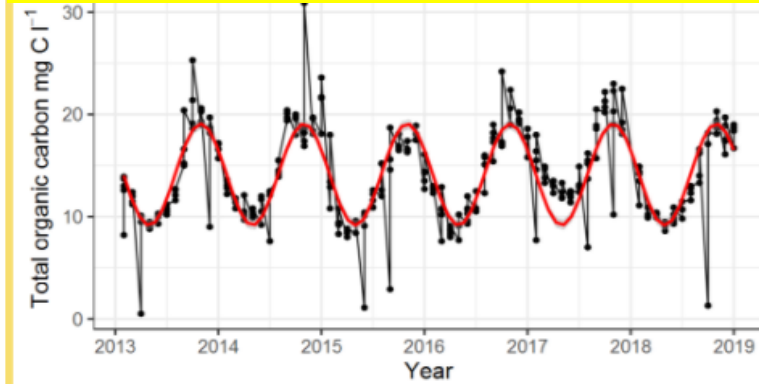
Please select year(s)

2013 2018



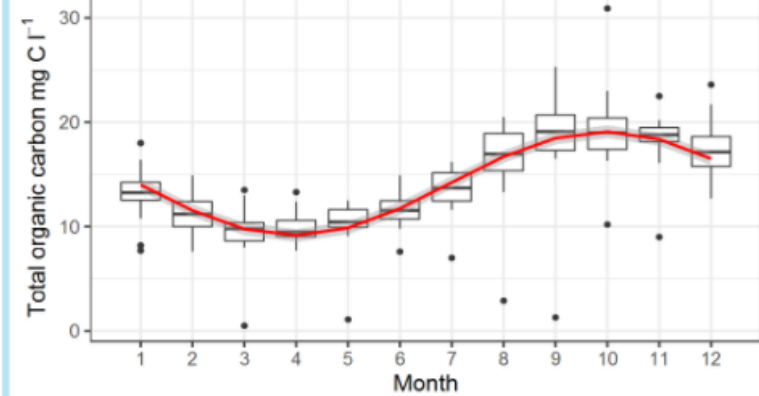
TOC over time with sinusoidal curve fitting

Source Water A



Monthly averaged TOC with sinusoidal curve fitting

Source Water A



FREEDOM DST: site summaries

Total organic carbon concentrations
of the 30 selected reservoirs from 2013

Please select one site for graphs to work

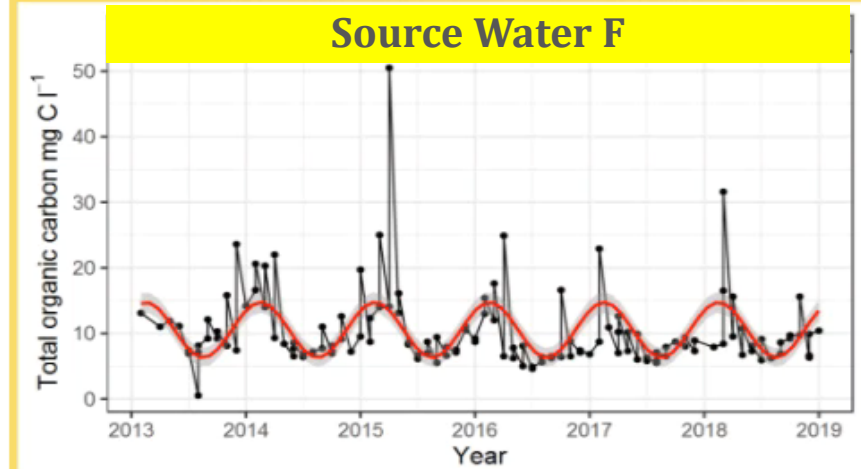
Site	TOC Average	TOC Max
Source Water A		
Source Water B		
Source Water C		
Source Water D		
Source Water E		
Source Water F	10.0	50.2
Source Water G		
Source Water H		
Source Water I		
Source Water J		
Source Water K		
Source Water L		
Source Water M		
Source Water N		

Please select year(s)

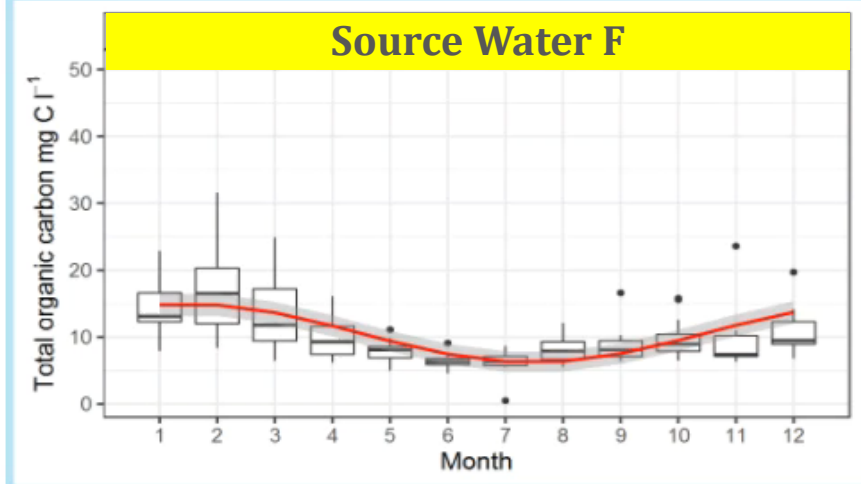
2013 2018



TOC over time with sinusoidal curve fitting



Monthly averaged TOC with sinusoidal curve fitting



FREEDOM DST: Future DOM projections

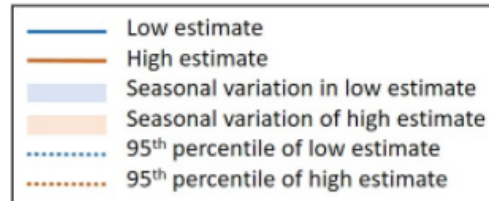
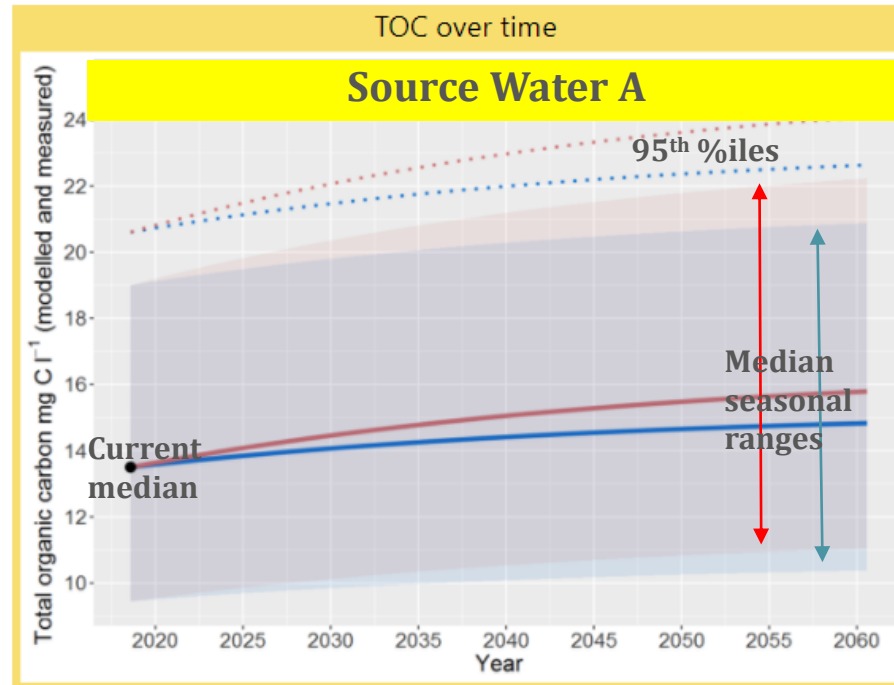
Total organic carbon concentrations projections for median yearly values

Please select one site for graphs to work...

TOC concentrations are modelled from a predicted change in electrical conductivity which in turn is based on a theoretical future change in non-marine sulphate concentration. The latter assumes that current measured non-marine sulphate concentration is due to atmospheric pollutants only and that these will decline at a rate observed in recent years across a range of UK upland waters.

Relationships between conductivity and TOC vary between sites. There is currently insufficient data available to enable site specific calibration of this relationship. This plot therefore provides two potential scenarios (blue and red lines) and the seasonal range (shaded areas). The blue line provides a lower estimate and the red line an upper estimate of the likely response in the annual median concentration.

The dot indicates the average (median) of the TOC data used for the model (2013-2018) attributed to 2018.



Site
Source Water A
Source Water B
Source Water C
Source Water D
Source Water E
Source Water F
Source Water G
Source Water H
Source Water I
Source Water J
Source Water K
Source Water L
Source Water M
Source Water N

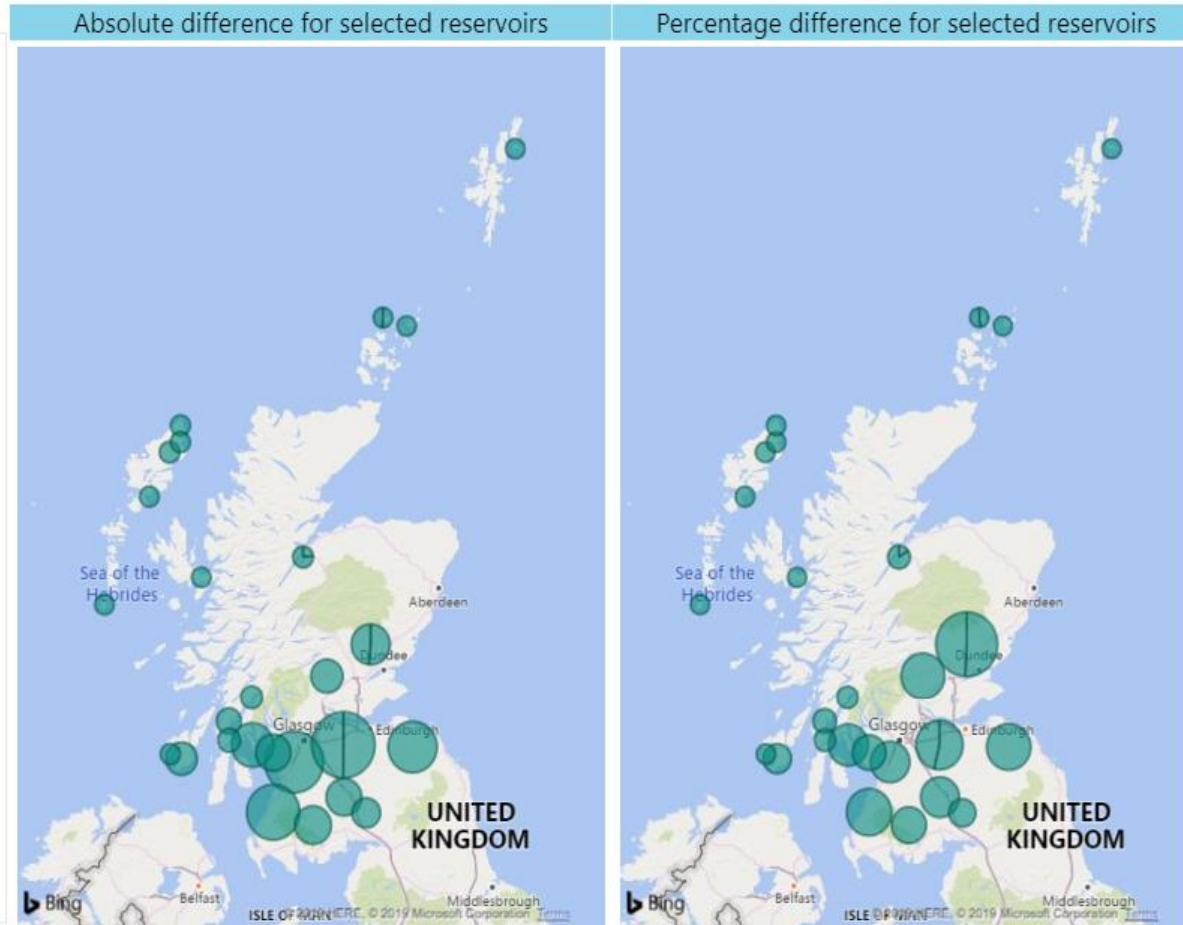
FREEDOM DST: Regional comparisons of projected TOC change

Spatial variation in projected change in annual median TOC

These maps provide an estimate of change in modelled TOC from 2018 to 2060 in terms of both absolute (mg Carbon /L) change (left) and percentage change in TOC relative to 2018 (right), in response to the anticipated future change in non-marine sulphate concentration.

The estimated change is derived from the average of the low and high estimates presented in the 'Projections of baseline over time' page.

Move the mouse over the circles for information on absolute and percentage change in TOC and reservoir names.



summary

As part of the FREEDOM project, we set out to develop a tool to project future DOM in raw waters reaching a range of Scottish Water plant.

Focus has been on:

- developing capability to project a “moving baseline” for DOC (response to reduction in acid deposition) for a range of sites for which some historical data are available
- The FREEDOM tool takes the form of a computer-based graphical interface driven by computer code that draws from an updatable central database
- Provides a foundation for a more widely applicable tool. Considerable potential for further development of the tool to address other stressors, e.g. climate change, and application to other regions

FORECASTING RISKS OF ENVIRONMENTAL EXACERBATION OF DISSOLVED ORGANIC MATTER – BUILDING CLIMATE CHANGE RESILIENCE (FREEDOM-BCCR)

Don Monteith (UKCEH) and Fraser Leith (Scottish Water)
4th November 2020



<https://www.ukclimateresilience.org/news-events/1955/>