Process inference from high frequency temporal variations in DOC dynamics across nested spatial scales

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Background

Dissolved organic carbon (DOC) is a fundamental component of water quality in northern catchments reflecting the integration of hydrological and biogeochemical processes which connects landscapes and riverscapes.

DOC concentrations are highly dynamic; however, our understanding at short, high frequency timescales is still limited.

Optical sensors can provide proxies for DOC and the opportunity to investigate near-continuous DOC variations in order to understand the hydrological and biogeochemical processes that control both temporal and spatial variations

Objectives

Aim: To use high frequency DOC measurements to infer the dominant biogeochemical and hydrological processes influencing catchment functioning

Investigate:

1. Temporal and spatial variability in DOC
2. DOC dynamics at short, high frequency timescales
3. Scaling and transferability of findings to other catchments

Study site and method

NE Scotland
Annual precipitation: ~1100 mm
Annual runoff: ~700 mm
Elevation: 240-862 m

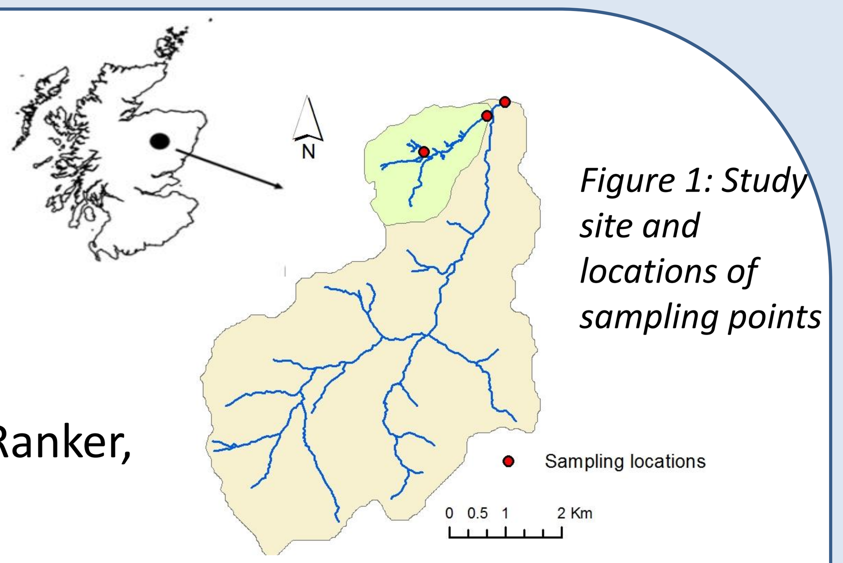
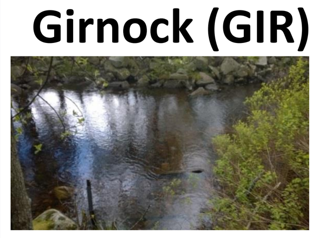


Figure 1: Study site and locations of sampling points

Girnock (GIR)



30 km^2
Soil types: Podzols & Ranker, Peaty gleys and Peats

Bruntland Burn (BB)

3.2 km^2
Soil types: Podzols & Ranker, Peaty gleys and Peats

Bog head water (Bog)

~1 km^2
Soil type: Peat

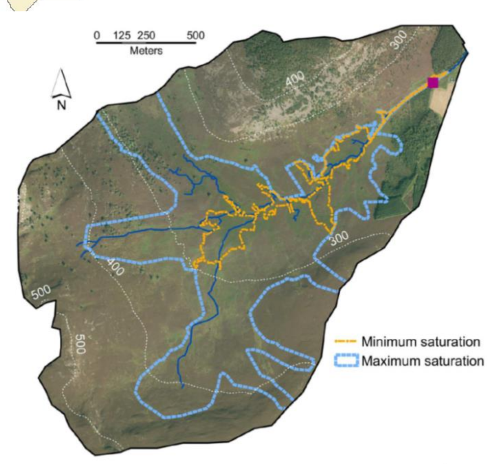


Figure 2: Saturation extent of the Bruntland Burn

FDOM method

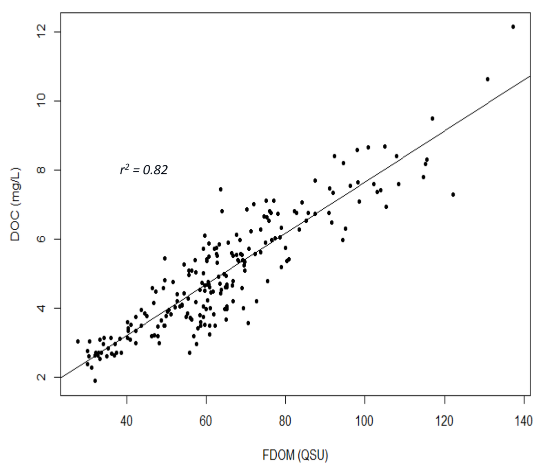


Figure 3: Relationship between FDOM (QSU) and discrete DOC (mg l^{-1})

In situ optical sensor
Measures the fluorescent component of DOC (FDOM)
DOC pool absorbs UV ~370 nm, fluoresces ~430-460 nm
15 minute resolution
Concentration of DOC proportional to magnitude of FDOM emission, $r^2 = 0.82$

Temporal variability

Seasonal dynamics

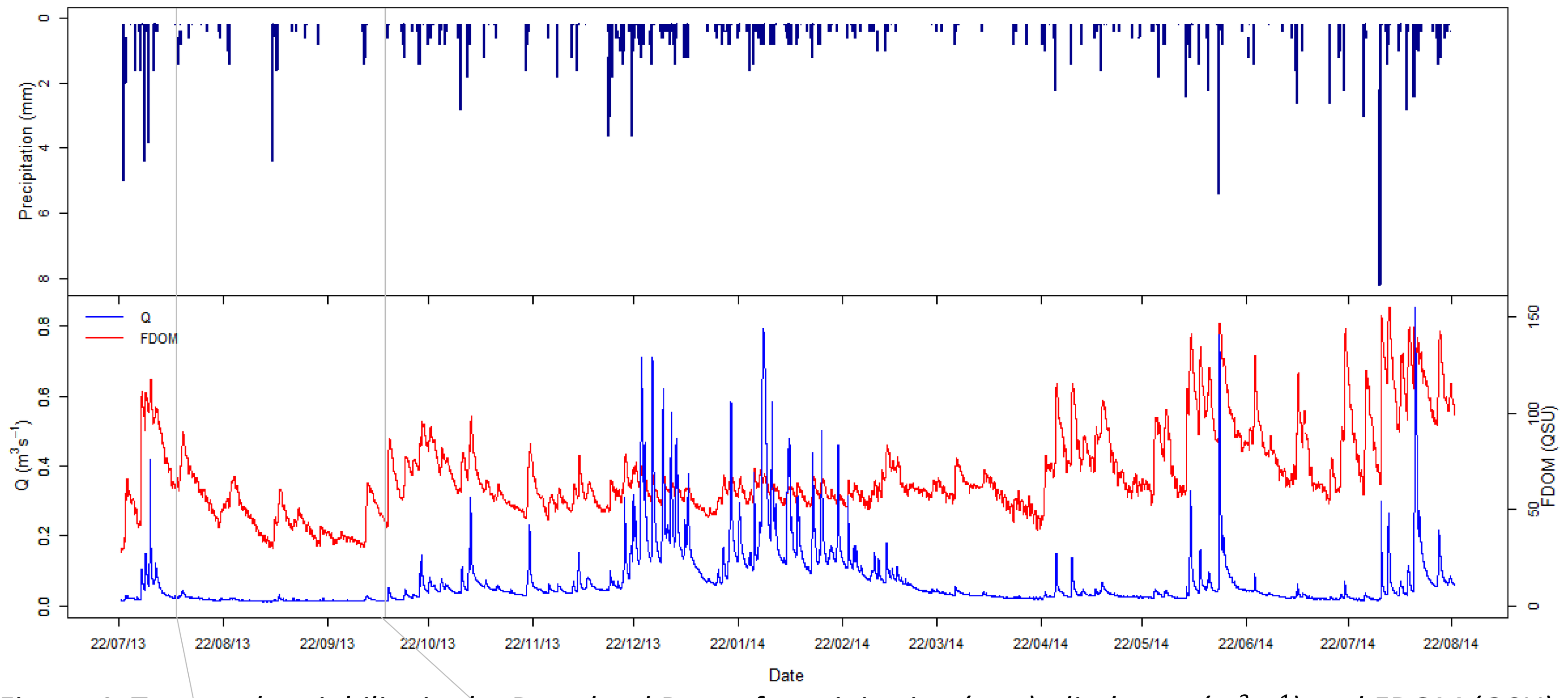


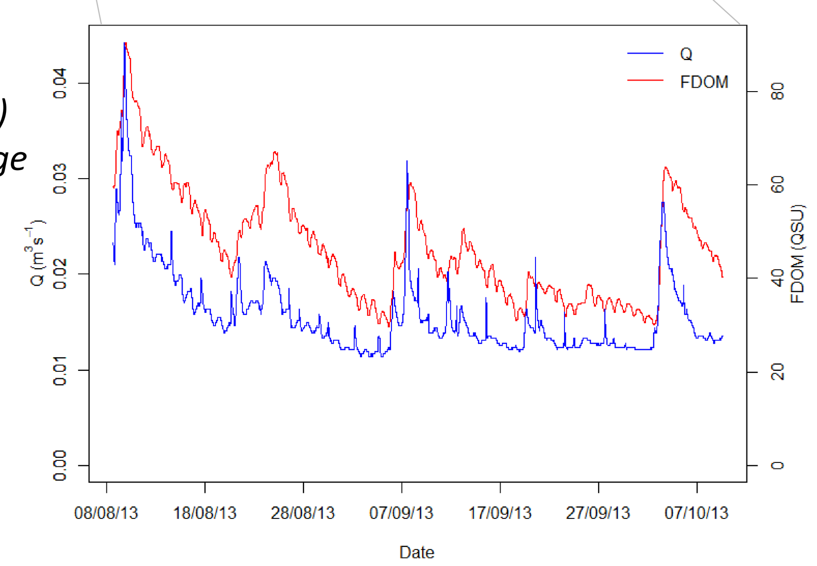
Figure 4: Temporal variability in the Bruntland Burn of precipitation (mm), discharge (m^3 s^{-1}) and FDOM (QSU)

Close relationship between precipitation (P) and discharge (Q) followed by a peak in FDOM.

Winter: less marked response to Q. Reduction in biological processing of soil carbon due to lower temperature. Production limited.

Summer: more marked responses. Transport limited.

Figure 5: FDOM (QSU) and discharge dynamics during dry period in Bruntland Burn



Summer 2013: 10 year return dry period.

FDOM very responsive to Q.

DOC builds up in soil because it is transport limited. Any subsequent increase in Q flushes DOC.

Event dynamics

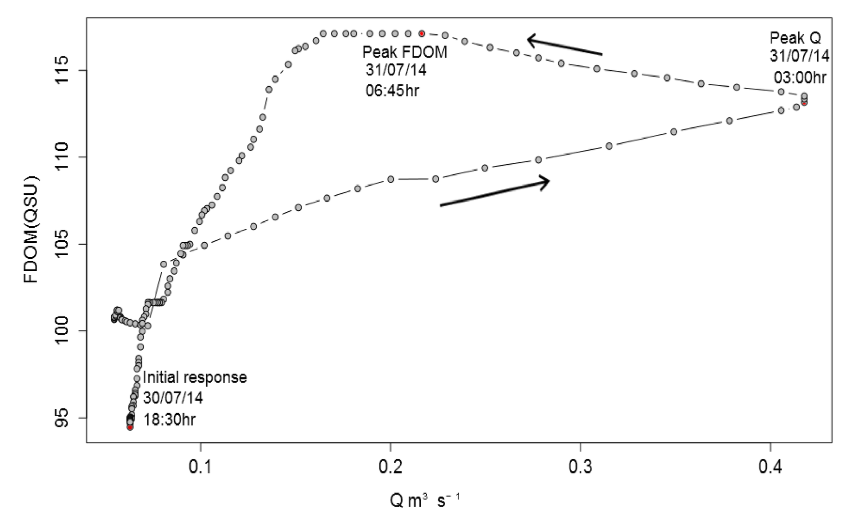


Figure 6: Discharge (m^3 s^{-1}) and FDOM (QSU) during a storm event

All events show anticlockwise hysteresis

Delayed contribution of DOC as riparian zone expands and increases connectivity

Lag time varies between events due to variability in antecedent conditions

Diurnal dynamics

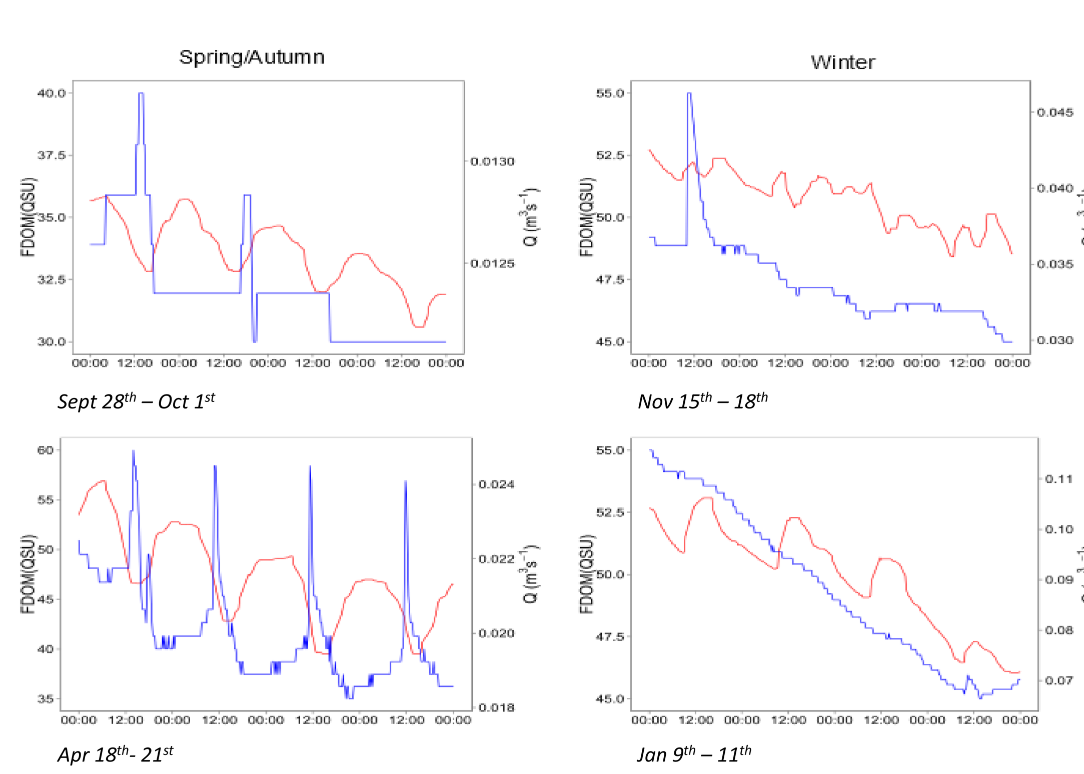


Figure 7: Diurnal variability of FDOM (red) and discharge (blue) during spring/autumn and winter

High resolution FDOM reveals:

- Spring/Autumn months: diurnal variation in DOC. This is likely caused by Photo-oxidation/evaporative/ biological influences of DOC during day
- Winter months: diurnal variability less apparent

Spatial variability

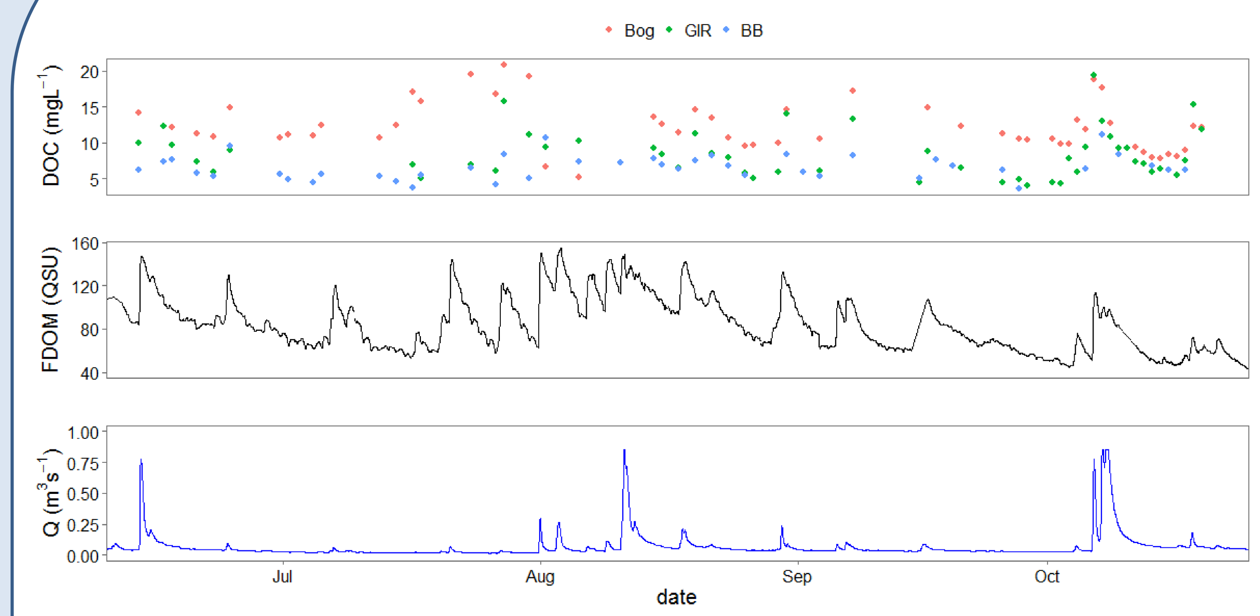


Figure 8: Time series showing: variability in DOC across the 3 spatial scales (top), Bruntland Burn FDOM (QSU) (middle) and Bruntland Burn discharge (m^3 s^{-1}) (bottom)

Higher % peat in the Bog results in highest DOC conc.

GIR and BB similar despite differences in scale.

Higher % peat in the GIR results in higher DOC conc during events as the peat "source areas" become connected.

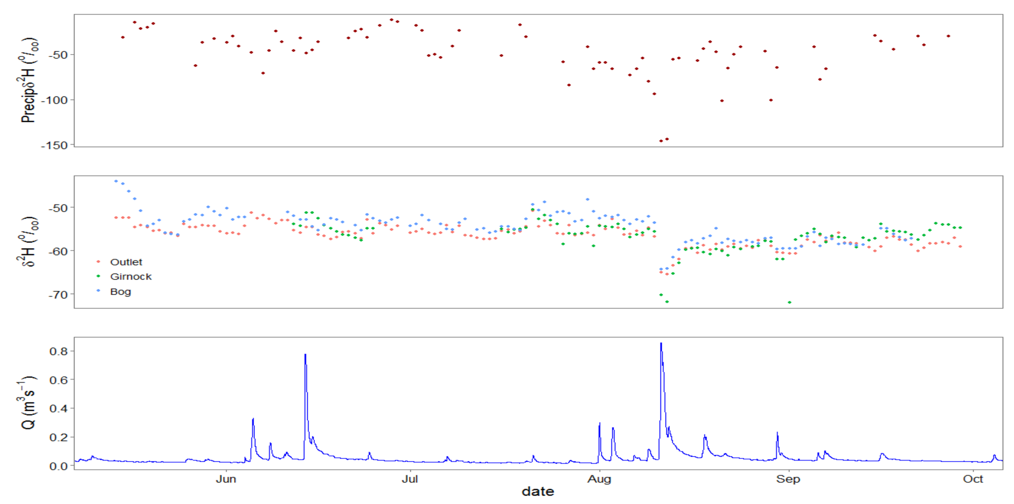


Figure 9: Time series showing: δ^2H of precipitation (top), δ^2H of stream water from all 3 sites (middle) and BB discharge (m^3 s^{-1})

In addition, stable isotopes measured to determine catchment functioning. Results show:

- Bog site generally more enriched: more evaporation. Winter months difference less significant
- All sites damped, indicating mixing with stored water
- Displacement of stored water during events

Conclusions:

- DOC very responsive to changes in discharge: during events the connectivity to the organic rich riparian zone increases and hence DOC is flushed out. This process varies seasonally as DOC is production limited during winter and transport limited during summer.
- High frequency optical sensors indicate diurnal variability of DOC during spring/autumn due to photo-oxidation and biological influences. Such diurnal variability is less marked during winter months.
- Spatial variation in DOC is dependent on % peat in the catchment and not scale per se.

Acknowledgements: We thank the European Research Council ERC (project GA 335910 VEWA) for funding the VeWa project.