Using an in-situ spectrophotometer to study dissolved organic carbon in a New England forest

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Introduction

- Harvard Forest Long-Term Ecological Reserve (HF) is a forest research site in central MA
- Forest **carbon cycling** is key to global carbon models and understanding the impacts of climate change
- Attention to stream water **dissolved organic carbon** (DOC) and **dissolved organic matter** (DOM) because streams transport carbon between carbon pools (plant matter, soil, etc.)

- Traditional methods of studying DOC via grab sampling have drawbacks
- **Colored dissolved organic matter** (CDOM) is the light-absorbing portion of DOC and is closely tied to overall DOC
- Measurements of CDOM facilitate study of DOC

PURPOSE OF THIS STUDY:
- Enable continuous in situ measurement to study CDOM/DOC with greater detail and accuracy
- Understand DOC dynamics in forested wetlands and assess future climate impacts on carbon cycle

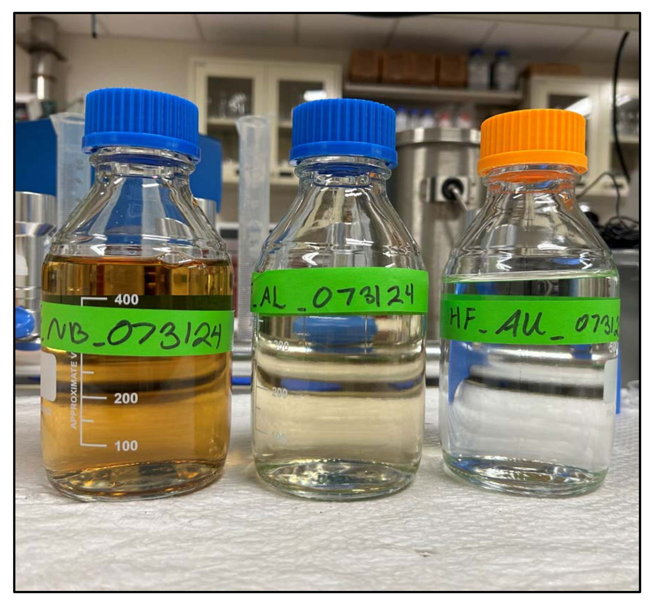


Fig. 1 Example of CDOM in Harvard Forest stream water samples. The different colors are due to varying amounts of CDOM.

Study site and methods

- Studied a stream in HF named Arthur Brook Lower
  - Drains Beaver Swamp, a recently formed swamp
  - Beaver Swamp is fed by Arthur Brook Upper
- Used **UV-Visible spectrophotometry** to study CDOM
  - Measures across range of wavelengths to produce CDOM absorption spectrum
- **Absorption coefficient a_g** quantifies the amount of light absorbed by CDOM in a sample

Fig. 3 s::can spectro::lyser set up in Arthur Lower.

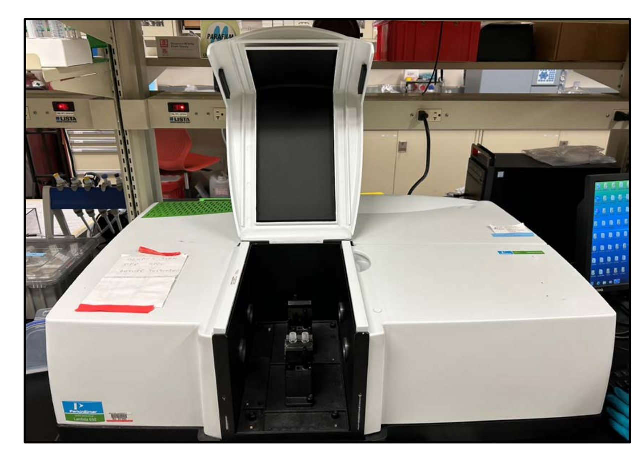


Fig. 2 Laboratory spectrophotometer.

- Magnitude and shape of CDOM spectrum related to DOC concentration and composition
- Spectrophotometry can be done in the lab (Fig. 2) or in-situ (Fig 3.)
  - Using **s::can spectro::lyser** for in-situ measurements
  - Sensor deployed during fall 2023 and spring 2024

Correction scheme

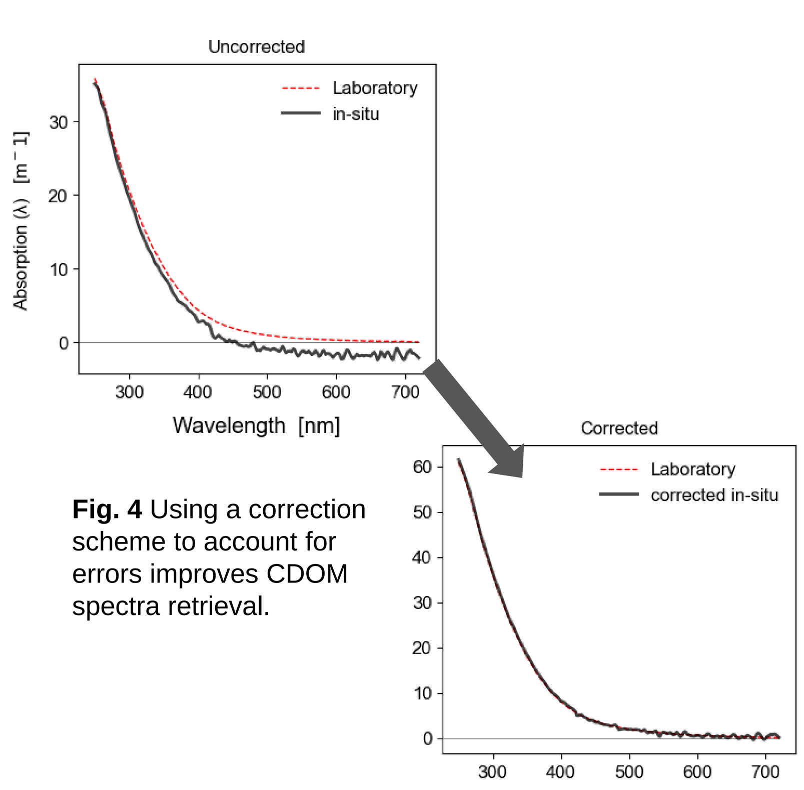


Fig. 4 Using a correction scheme to account for errors improves CDOM spectra retrieval.

- An **empirical correction scheme** was developed and applied to in-situ spectra from the s::can
- Lab CDOM spectra and measurements used as reference
- Scheme corrects for errors due to sensor drift, detection limits, instrument features, etc.

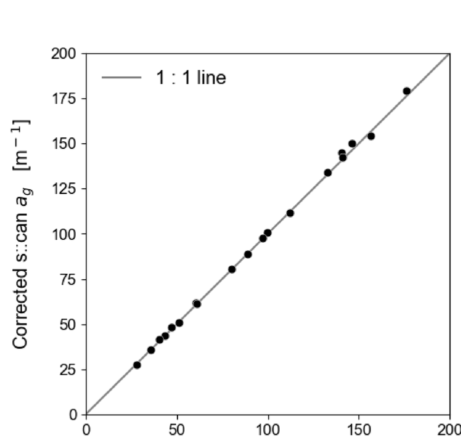


Fig. 5 CDOM Absorption at 250 nm, laboratory measurements and corrected in-situ data. *Avg % error = < 1%*

DOC estimation

- CDOM absorption is closely tied to overall DOM/DOC properties and can be used as a **proxy for DOC concentration**

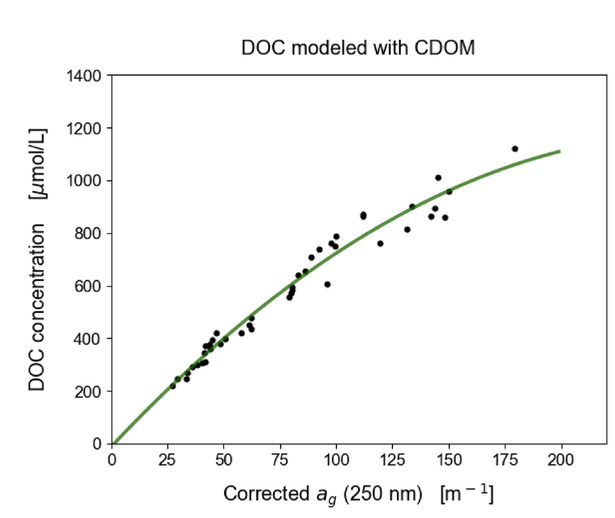


Fig. 6 Quadratic fit between DOC and CDOM absorption coefficient at 250 nm (r^2 = 0.967). Applied to all s::can data.

- Relationship between DOC and absorption differs between environments
- DOC **varies nonlinearly** with a_g in Arthur Brook
  - Predicted with a **quadratic fit**
- Model using s::can absorption predicts DOC concentration within +/- 5.9%
- Error distributed evenly around 0

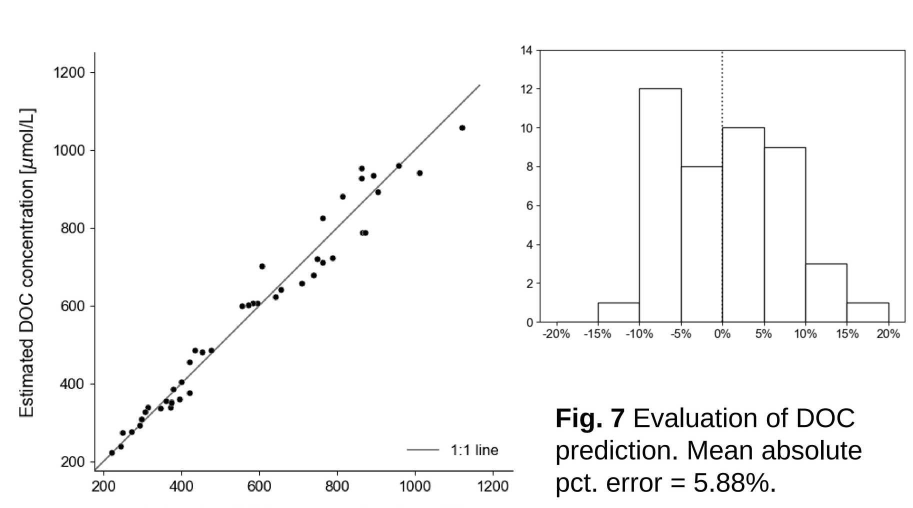


Fig. 7 Evaluation of DOC prediction. Mean absolute pct. error = 5.88%.

Calculation of DOC flux

- Continuous s::can measurements yield high resolution DOC data
- **DOC flux**, the mass of DOC moved by the stream per unit time, was calculated as: DOC concentration * stream discharge

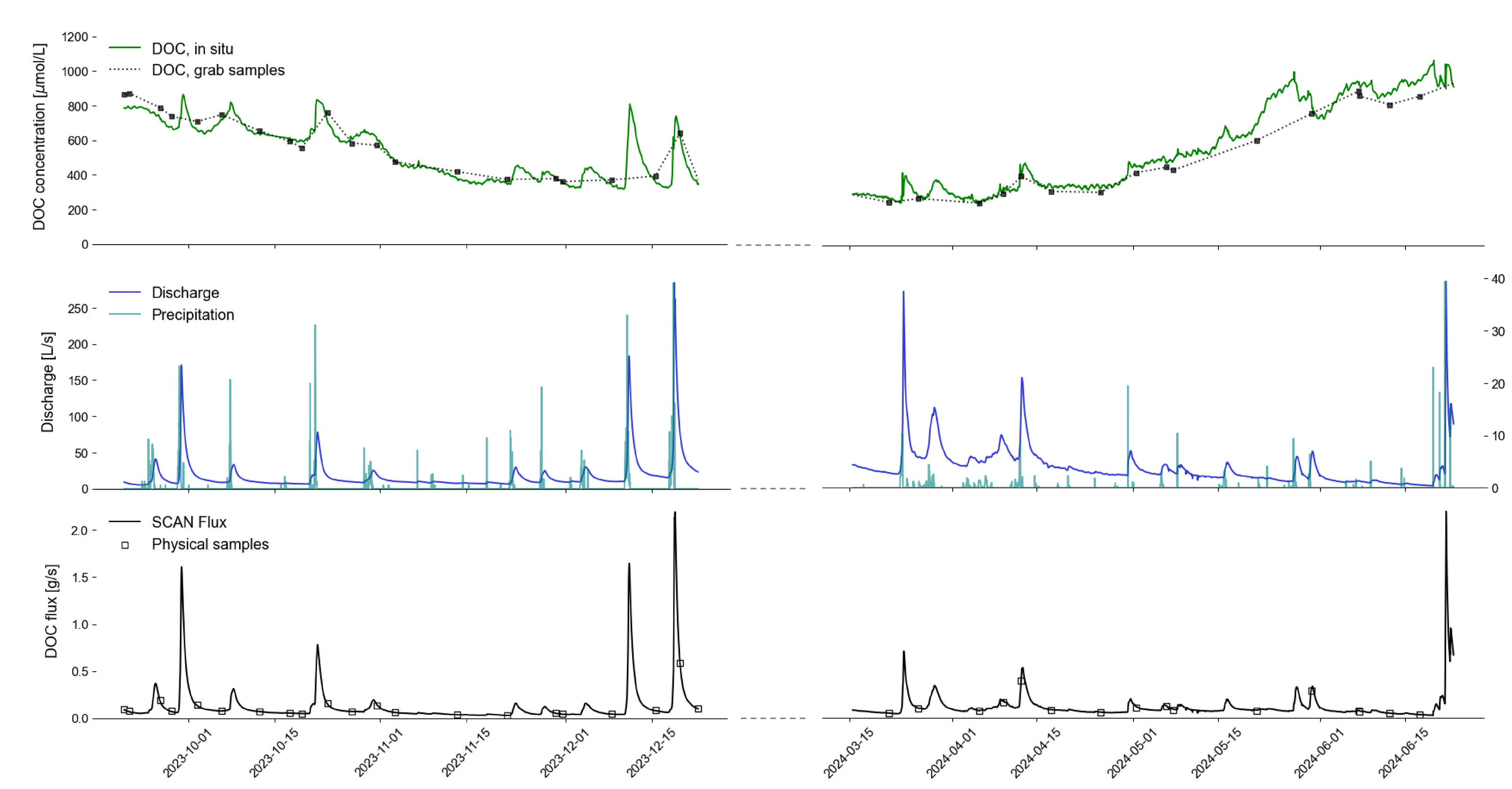
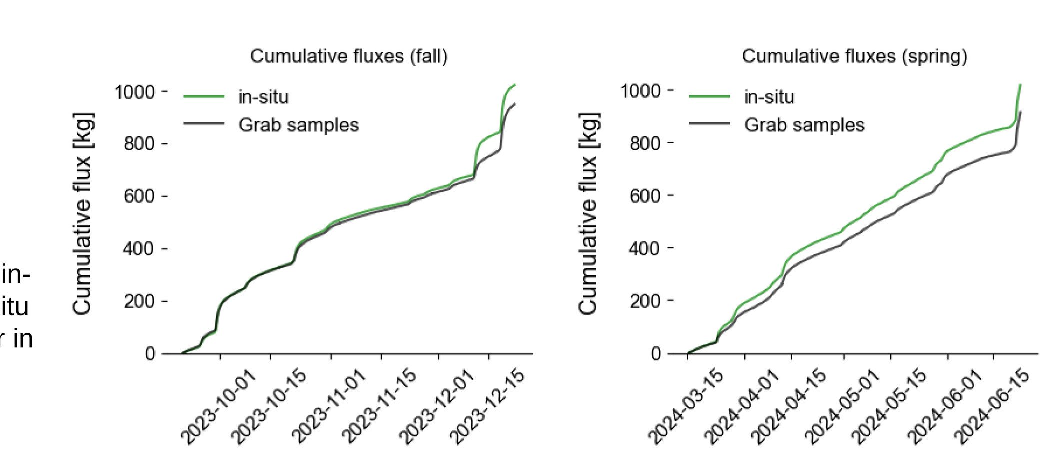


Fig. 8 DOC and hydrological data for fall 2023 and spring 2024. Discharge and precipitation data from the HF data archive.

- Total fall DOC flux: 1021 kg; total spring DOC flux: 1017 kg
  - Compared to 947 kg (fall) and 913 kg (spring) estimated from grab samples
  - **Annual DOC export**: approx. 4 metric tons

Fig. 9 Cumulative DOC fluxes based on in-situ observations and grab samples. In-situ estimates of total DOC were 7.8% higher in fall, and 11.4% higher in spring.



Discussion

- Absorption spectra from the s::can spectro::lyser can be **successfully corrected** to match laboratory measurements
  - Correction crucial for measuring advanced parameters such as spectral slope; useful for more detailed DOC analysis in the future
- **Future deployment** of s::can instrument to more remote environments is feasible
- Continuous observation and high temporal resolution are valuable
  - Detection of short but extreme "pulses" of DOC improved, giving more accurate flux estimates

- **Discharge** is closely tied to DOC concentration and is the **main driver of DOC flux**
  - Suggests Arthur Lower's DOC is largely material flushed from Beaver Swamp
  - Study of Arthur Upper necessary to clarify exact details of the swamp
- Climate change impacts are likely to affect DOC flux
  - Longer growing season and increased precipitation could lead to **increased DOC concentration, discharge, and flux**
  - Higher frequency of intense storms furthers **importance of large DOC "pulse" events** and high-resolution data collection

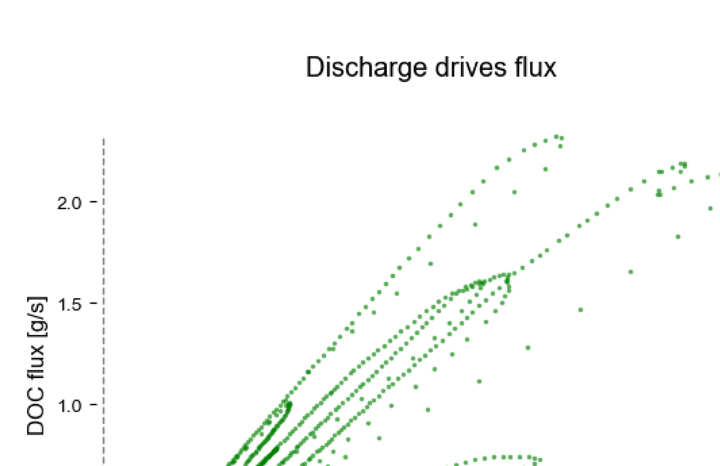


Fig. 10 DOC flux plotted against discharge for each flux observation.

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References

1. Boose E, VanScoy M. 2024. Prospect Hill Hydrological Stations at Harvard Forest since 2005. Harvard Forest Data Archive: HF070 (v.35). Environmental Data Initiative: https://doi.org/10.6073/pasta/8cd773bd8046f42e5d4bb8826fc e6f24.

2. Finzi, A. C., Giasson, M., Barker Plotkin, A. A., Aber, J. D., Boose, E. R., Davidson, E. A., … Foster, D. R. (2020a). Carbon budget of the Harvard Forest Long-Term ecological research site: Pattern, process, and response to global change. Ecological Monographs, 90(4). doi:10.1002/ecm.1423