

Author's response to reviewer 1

Legend:

- Reviewer comments in blue
 - Author's responses in black
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General comments: Rosset et al. reported high-resolution sensor data to investigate the mechanisms driving DOC concentration at the outlet of a bog and a fen in the French Pyrenees. The data and results are interesting. However, the paper can be improved further by explaining how complete are the sensor data, and providing discussion on how water temperature is related with the input and output of organic carbon in the bog and the fen. Specific comments are below, which the authors may consider when revising the manuscript.

We thank the reviewer for this overall positive evaluation of our manuscript. Following the reviewer's suggestions, we have improved the manuscript to include details on the data on which the analysis is based. The effect of temperature on DOC inputs and outputs have been clarified in the discussion section. The answers to the specific comments can be found below.

p. 4, line 10-24: What is the percent of data for which gap-filling models were used? Also, has there been any period of power outage? The merit of this paper is on the high-resolution 'sensor' data. Thus, the information is needed on the number (or the percentage) of data points that has been actually collected.

The gap filling represents between 5 and 80 % of data. Details have been included for each parameter in the manuscript (Section 3.1 P4 L15 to 26).

p. 5, line 8-: How accurate was the analysis? What was the recovery of the reference material?

The quantification limit was 1 mg. L⁻¹. Above this value, the analytical uncertainty was evaluated to ± 0.1 mg.L⁻¹. Reference material included ION-915 ([DOC]= $1,37 \pm 0,41$ mg C L⁻¹) and ION 96.4 ([DOC]= $4,64 \pm 0,70$ mg C L⁻¹) (Environment and Climate Change Canada, Canada). This was detailed P5 L 16 to 19

p. 5, line 12-: If the data with >20 FNU were ignored, what is the percentage of those "ignored" data points compared to the total?

Also, considering that [DOC] can be high with high flow, those data points are potentially important in interpreting the results. If included, could they change the conclusions?

The removed data related to high turbidity represent only 0,2% of the fDOM time series. In addition, the turbidity peaks occur before the fDOM peaks. Their removal from the timeserie does not affect our analysis. Some details have been added in the manuscript (P5 L23 to 26).

I think the graphs showing the relationship between the [DOC] and fDOM would be helpful. Can you add the graph as a supporting information?

Graphs showing the linear relationship between [DOC] and fDOM were added in Appendix A1

p. 5, line 16: number of observations 174 vs. 27. Why are these so different?

The different observation numbers are related to the different observation periods in the two sites. The survey started in 2015 in Bernadouze and in 2017 in Ech. Moreover, the number of flood event sampling (~20 samples each in average) differ between the two sites. Seven events could be sampled in Bernadouze, when only one was sampled in Ech. The number of observations at Ech was actually 28, it has been modified in the manuscript P5 L30

p. 5, line 27: what is the K in the equation 1? Please explain the terms in the equation.

K in the equation 1 was a constant. We replaced K by B in this second version of the manuscript to avoid confusion with K, commonly used in hydrology to describe the hydraulic conductivity. Details have been added in the text to mention that B is constant P6 L14

p. 6, line 11: Have you used “DOC_max” for the analysis? If not, why didn't you include it for the analysis?

DOC_max was used in the analysis to calculate DOC_increase ($\text{DOC_increase} = (\text{DOC_max} - \text{DOC_initial})$).

p. 7, line 3-: So, did log- or square root-transformation satisfy the assumption? Was non-parametric analysis unnecessary?

Prior to the analyses we checked the distribution of each variable using histograms and found substantial deviations from normality for some of them (mainly right-skewed distributions). Therefore, we transformed these variables using log-or square-root to approach normality (see Table 1 in the main text) considering that in linear modelling the point is not the reach strict normality of the data but to approximate normality in order to obtain satisfying distribution of the residuals i.e. Normality and Homoscedasticity of the error distribution (Venables & Ripley, 2002. Zuur et al. 2009). We then surveyed each best model using diagnostic plots in order to detect deviations from normality and homoscedasticity in the residuals and to identify outliers. No specific deviations and outlier were detected (See figures below) and we are therefore confident that our modelling approach and associated results are robust.

The use of non-parametric tests is always an option when normality assumption is grossly violated and when data-transformation cannot overcome deviation to normal distribution. However, non-parametric tests do not cope well with complex dataset and complex modelling. For instance, there is no non-parametric form of any regression. Regression means you are assuming that a particular parameterized model generated your data, and you try to find the parameters. Non-parametric tests are test that make no assumptions about the model that generated your data. Those two approaches are therefore incompatible.

In our study, we clearly favored parametric approaches in order propose hypothetical models explaining our two targeted variables i.e. DOC_increase and DOC_initial.

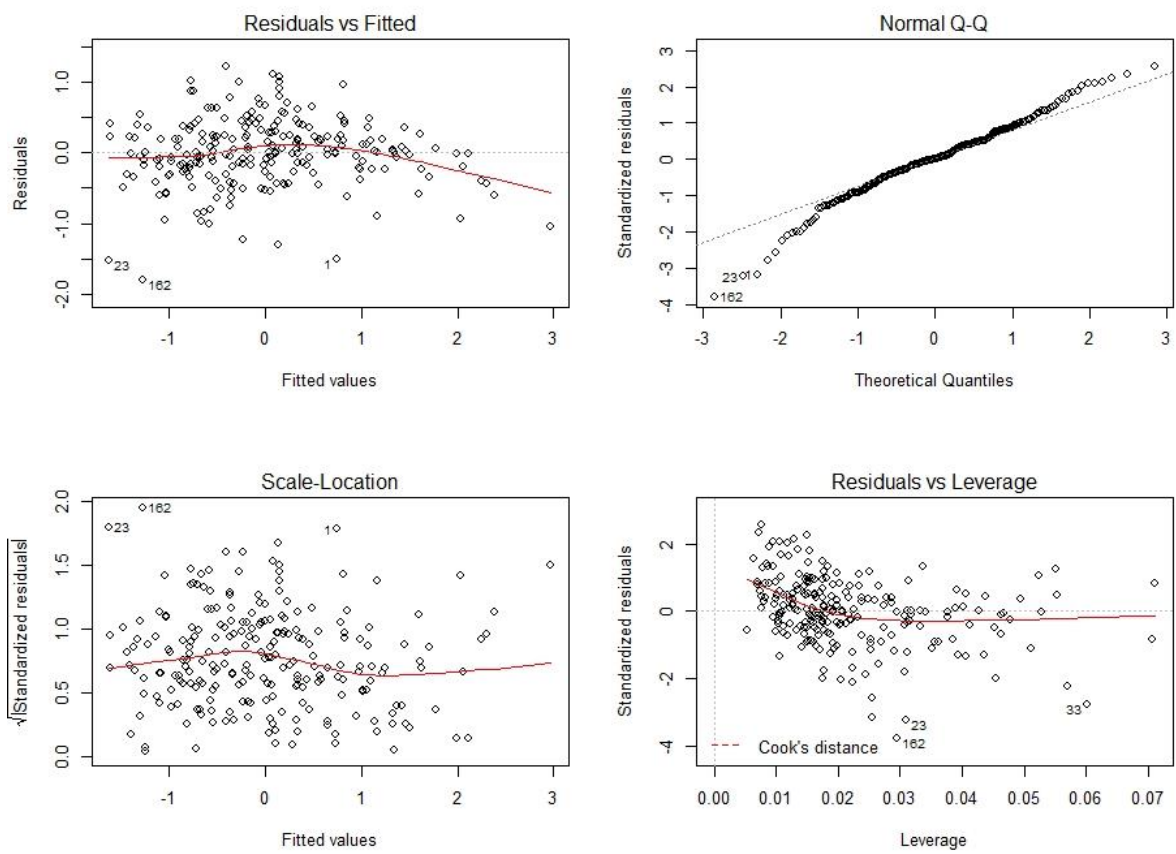


Figure review 1 Diagnostic plots of the DOC concentration increase in Bernadouze

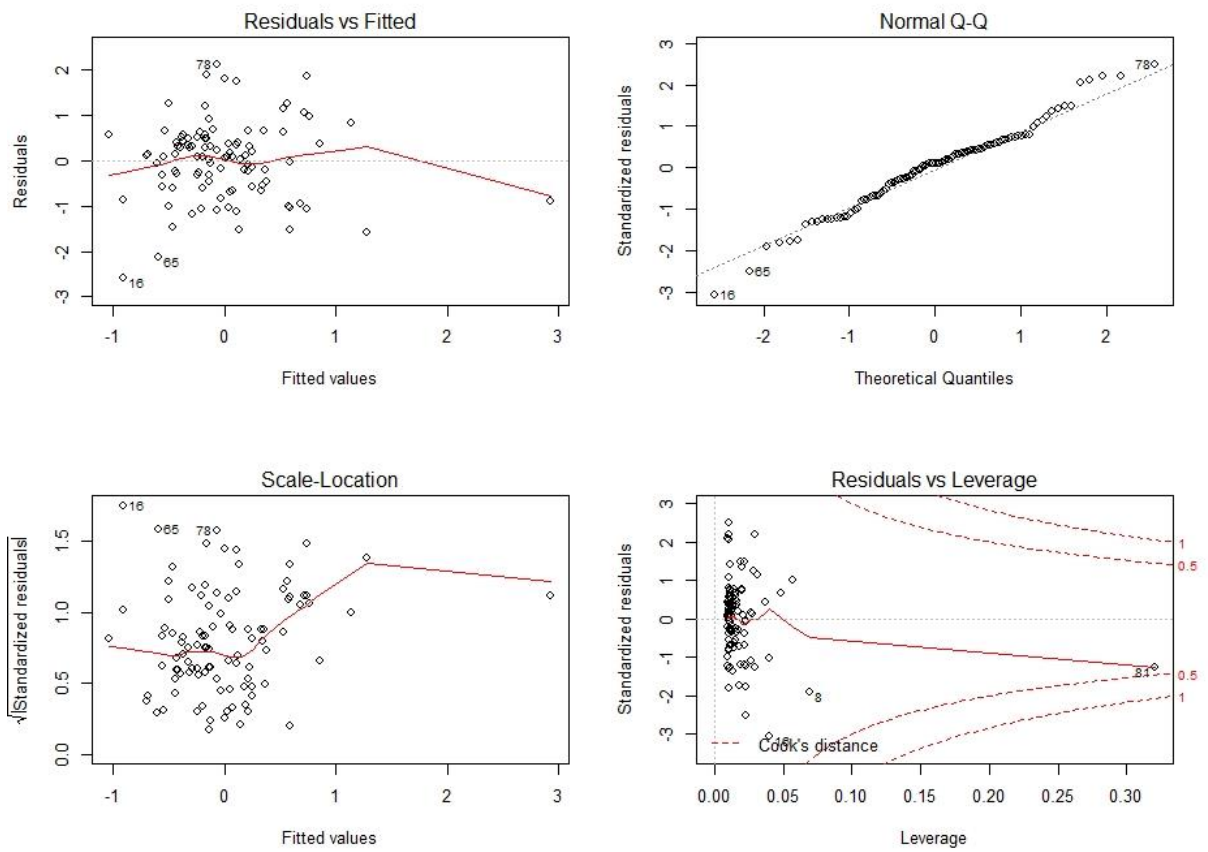


Figure review 2 Diagnostic plots of the DOC concentration increase in Ech

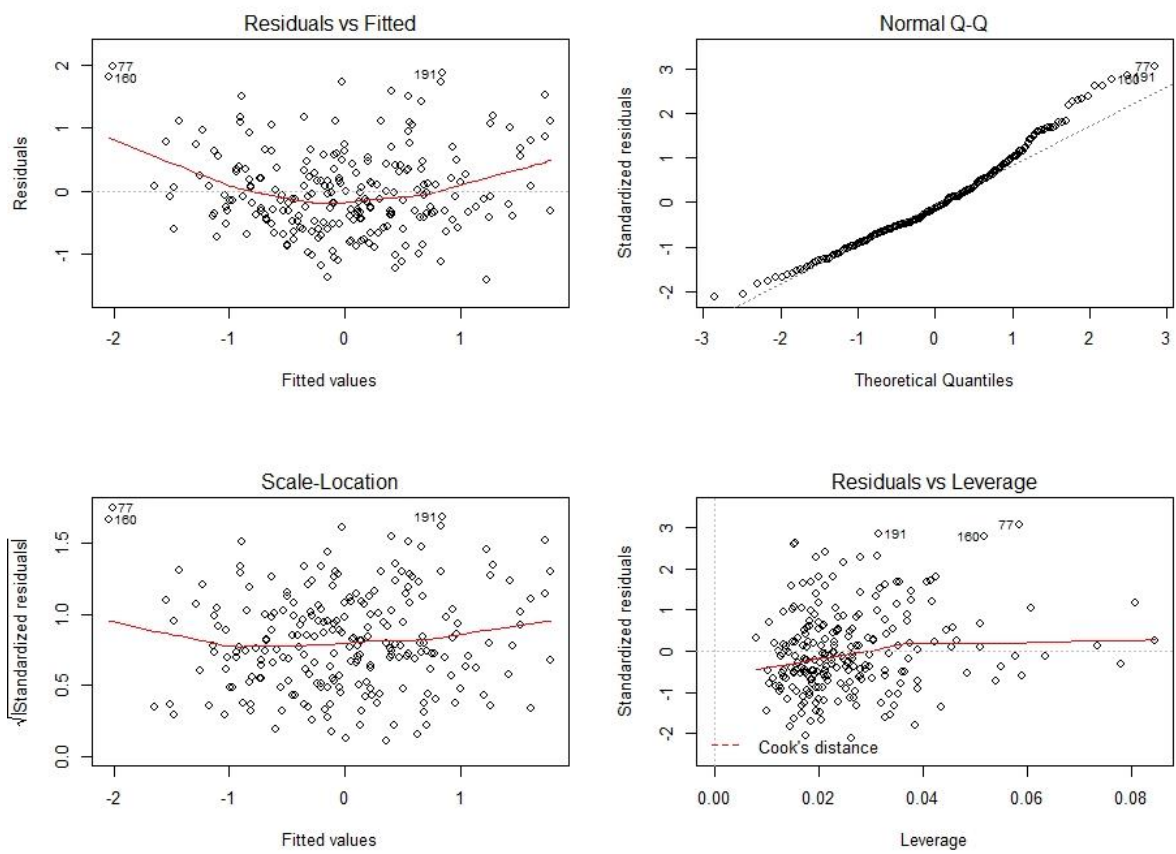


Figure review 3 Diagnostic plots of the DOC concentration initial in Bernadouze

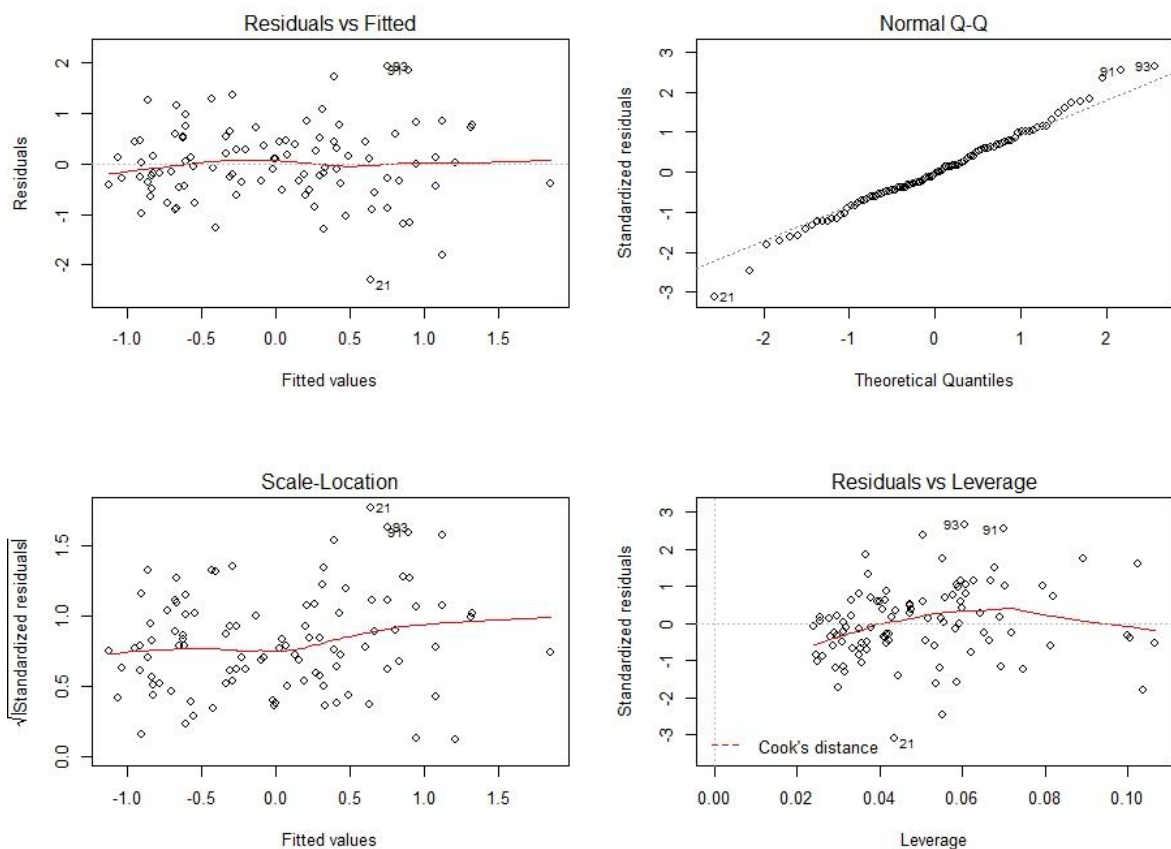


Figure review 4 Diagnostic plots of the DOC concentration initial in Ech

Fig. 1: Is the boundary of the watershed for the 'outlets' correct? Watershed boundary can be delineated for any point of a stream using DEM data. The watershed area for the red circles should be larger than the boundary of the fen or the bog (orange lines in Fig. 1). I wonder the DOC dynamics at the outlets could be significantly influenced by non-wetland areas considering that the stream lines are extended beyond the orange lines.

At both sites watershed boundaries have been delineated using DEM models, however only the peatland areas (3% of the watershed area in Bernadouze and 6% in Ech) were delineated on the figure 1 (orange lines). Peatlands are the main contributors of DOC at the outlets as reported in Rosset et al., 2019. This was explicitly written in the manuscript P4 L 7

Fig. 3: Is the purpose of this research on comparison between the fen and the bog? If so, which period should be used? The same overlapped period (May, 2017 to Jan 2019)? Or any period with available data? If you have chosen the second option (any period with available data) to maximize analysis power, why did you omit the period of Jan. 2015 to Sep. 2015 (Rosset et al., 2019, JGR-Bioigeosciences)?

The purpose of this research is not a direct comparison between a fen and a bog site. The purpose of this manuscript is to identify the drivers of the DOC concentration variability at peatland sites in general, so the period used for the analysis do not need to overlap. Moreover, the period between January and September 2015 was omitted in Bernadouze because almost 60% of the water table level sensors shot down during this period, preventing a good characterization of the mean water table level in the fen and consistent analysis.

Fig. 4: Interesting graphs. (a) When $\log(\text{DOC initial})$ is ~ 2.0 , the DOC initial should be ~ 100 mg/L. But, the maximum [DOC] in the Fig. 3d is ~ 30 mg/L. Why are these this so different? (b) What are the meanings of the y-intercept? When water table increase is 0, the $\log(\text{DOC increase})$ is about -1 (fen) and +1 (bog). Then, DOC increase should be 0.1 mg/L (fen) and 10 mg/L (bog) even without the water table increase.

This is a mistake in the notation. The Logarithm (log) in this figure refers to natural logarithm, or neperian logarithm ($\ln(e) = 1$) and not as logarithm used with a base 10 ($\log_{10}(10) = 1$). This has been corrected in an updated version of the figure.

What kind of mechanism is working? Concentration of DOC shows the dynamic balance between the input and output of organic carbon. How water temperature is related with the input and output of organic carbon in the bog and the fen?

We agree that concentration of DOC shows the dynamic balance between the input and output of organic carbon; However in these mountainous peatlands we observed that DOC concentrations are really lower at the inlet than at the outlet, as mentioned by Rosset et al., (2019). Thus, the mechanisms which control DOC concentration at the outlet occurs mainly within these peatlands and we did not consider that input of organic carbon from the inlet was a valuable variable to investigate, as input water temperature. However, the role of water temperature was investigated both within the peatland in the piezometer well and at the outlet in the stream. We highlight significant influence of peat temperature on seasonal variation of DOC concentration. This is discussed in detail at section 5.2.

Fig. 5: The graphs include many information and are hard to digest. I recommend to leave essential information only and provide the rest as a supporting material. Or figure caption can include in-detail explanation on the symbols

The figure caption has been modified for clarity. In addition, the legend in the figure has been enlarged.

Cited references:

Rosset, T., Gandois, L., Le Roux, G., Teisserenc, R., Durantez Jimenez, P., Camboulive, T., & Binet, S. (2019). Peatland contribution to stream organic carbon exports from a montane watershed. *Journal of Geophysical Research: Biogeosciences*.

Venables and Ripley. 2002. *Modern Applied Statistics with S*. Springer, New York. 4th edition.

Zuur, A., Ieno, E. N., Walker, N., Saveliev, A. A., & Smith, G. M. (2009). *Mixed effects models and extensions in ecology with R*. Springer Science

Author's response to reviewer 2

Legend:

- Reviewer comments in green
- Author's responses in black

The manuscript of Thomas Rosset et al. aims at disentangling drivers of DOC dynamics in different peatland catchments. It utilizes a spectrofluorometric probe to monitoring frequency DOC concentrations. Additionally, parameters like temperature, precipitation, stream and peat water level were recorded to explain DOC concentration variability by means of statistic modelling. The generated dataset is quite extensive and worth to be published in Biogeosciences. As I was really pleased by the title and abstract I must say that the main part of the manuscript is rather descriptive and lacks a clear message or novelty. A major drawback of this manuscript is the lack of discussion of major processes and drivers concerning DOC export from peatlands, like hydrological flow paths, biogeochemistry and hydrologic preconditions. In its current state, the study is too much focused on the statistical results of their modelling, but no or little mechanistic explanation of the modelling results. What exactly happens during a rainfall/discharge/DOC concentration event in the different systems and concerning the hydrologic conditions? In general, I think that this paper needs a stronger discussion on hydrologic flow paths in peatland systems. Flow paths are not discussed until the very end. I miss a description of e.g. a simple acrotelm/catotelm distinction, which provide different hydraulic conductivities and thus lead to a distinct hydrograph. I miss a discussion of pre-event conditions, or of hydraulic conductivities in general, contributing to different flow paths. The interpretation of the piezometer data is difficult, as there is no information provided about depth of installation, hydraulic conductivities and thus how to interpret recession times. I miss mentioning importance of pH (DOC solubility!), do you have data about this? It is mentioned that the fen site is on limestone, while bog systems are generally acidic systems. As the authors are throwing in the term "bio-geochemical hotspot" in the end: I would be pleased to hear more about this earlier on in the manuscript. The introduction on second paragraph is rather superficial. Furthermore, I am very concerned by the representativeness of the bog site especially when it is compared to a fen as exemplary system (Scientific objective no 3, P3 line3). There are several factors differing between the sites, besides just fen/bog: climate (e.g. 4 months snow covered – no snow hardly sub-zero temperatures), anthropogenic influence (burned – unburned). Additionally, mentioning agro-pastoral practices: does this mean the bog is used for grazing? Could these systems thus be considered as representative? Besides this, from the location maps I draw conclusions that apparently the monitoring spot also receives water which is not originating from the peatlands it-self. Is there any data about it? Do you have any idea about the whole catchment and how much water contributes to the discharge that is not from the peatlands? This is one of my major concerns, as I feel like the authors completely disregard this. If the concentration pattern are driven by discharge from other areas, the discussion of concentration pattern and water levels at the monitoring spot and within the peatland would be difficult. Did you calculate also total DOC export fluxes next to the concentrations? This would highlight, how important this carbon output is to the system, as the concentrations seem to be quite low. Besides from this: Did you also compare the Bernadouze and Ech sites over a time period, where data from both sites are available? This would help to access, if there is any bias by having two different time periods here. Weather conditions can be very different each year having a very dry or wet year or season, re-spectively. I am no native speaker myself, so it is not easy for me to criticize language issues. But even though in your acknowledgement you state a language assistance, I am sure that there are some unusual or wrong wordings in the text (e.g. confusing age of "contrasted" "strong concentrations"). So, from my point of view this needs further editing. Furthermore, your expression is imprecise at some points. Please edit (e.g. header of Table 1; P5 Lines 2-5: it is not clear what you mean; or speaking of "stream level increase") Please, check your figures for clear distinction and readability when not color printed (e.g. Fig 1 stream/peatland boundary, Fig. 5 Ech/Ber). In summary I see a very valuable dataset

of potentially high interest. However, in its current state the discussion seems too superficial and the study remains rather descriptive. Therefore, I recommend major revisions before this study can be accepted for publication.

We thank the reviewer for constructive comments on our manuscript. Following the general comments, we have worked on improving the manuscript. First, we have improved the site description, including previous work (P4 L. 7). Then, we have included more details on the piezometers in the manuscript and added a table including installation depths, MRC, pH and DOC values for each study plot. Finally, we have improved the discussion section. We have tried to better emphasize the novelty and the contribution of our study (Section 5.1). We have included more discussion on hydrological processes that can be inferred from our study (Section 5.3 P11 L22 to P12 L20). We hope these improvements have clarified the manuscript. The answers to the specific comments can be found below.

P1 L 10/P2 L2: A very common number I know is 30% of global carbon stock. Please check more references for the number you give.

Organic carbon stock in peatlands is a number constantly updated, at the submission time 20% was a figure obtained by crossing figures from Lefield and Menichetti, 2018 and Schalermann et al., 2014. According to the recent article from Nichols and Peteet, 2019, this figure is updated to 30%. We want to highlight the uncertainty of this figure writing ~20-30%

P2 L 12-15: too simplistic statements. Drivers of DOC concentration are not dependent on latitude, but mostly on the system studied and climate

The sentence has been removed.

P 2 L 32: “seasonal climatic conditions are contrasted” what does this mean?

We meant that different abiotic parameters (temperature, precipitation, hydrology) evolves along both seasonal and event (snowmelt, rainstorms) scales. The sentence has been removed. Some details have been added in the text (P2 L. 34).

P3 L 19: What “logging activities” do you mean?

Selective logging (1 tree out of three was cut) was carried out during the autumn 2016 in the lowest forested area surrounding the peatland, producing no significant hydrological and biogeochemical offsets at the outlet of the peatland. These details have been added in the text P3 L21

P4 L 21: In which depths are the piezometers connected to the peat body? This is very important if you talk about recession times and peat water temperature. Maybe also interesting: What diameter have these wells?

The piezometer wells are 50 mm diameter PVC tubes slotted from the bottom to 10 cm below the soil surface. The average depth in Bernadouze is about 1.2 ± 0.3 m, except for two piezometers in the center of the peatland which were drilled to 2.2 m depth. The average depth of the Ech piezometers is 2.4 ± 0.1 m. These details have been added in a table as Appendix B and in the text (P4 L. 30)

Or did you attempt to determine hydraulic conductivities by a slug test?

- + comment P13 L 8 ff: This is nothing else than hydraulic conductivities
- + comment P13 L 20: hydraulic conductivity? Acrotelm/catotelm in bog vs fen?

We agree that MRC are proxies of the hydraulic conductivities. To characterize the hydrodynamic properties of the peat, MRC were preferred to hydraulic conductivity estimation from slug tests because they can be performed directly with the water table dataset. Thus, the proposed model could be more easily tested on other peatlands. Details have been added to the manuscript P6 L8 to explain our choice

in the methodology and some sentences have been modified in the discussion to P13 L31/ P14 L2 to refer to hydraulic conductivity.

P5 L 2 “Flood sampling” is a weird expression. What about event sampling?

Expression has been changed. P5 L11

P5 L 12: when did “the turbidity events” occur? I assume this is mostly the case during high discharge. How much of your DOC event data is affected by this?

High turbidity events occurs occasionally at the beginning of high discharge events (Rosset et al.,2019). The high turbidity period (> 20 FNU) are sporadic representing only 0.2% of the fDOM time series. Turbidity peaks do not affect the DOC event data, since DOC peaks occur after turbidity events. These details have been added in the manuscript (P5 L. 23).

P5 L 11: Reference not correctly inserted in text, happens occasionally in the manuscript

The references have been modified (P5 L22 /P7 L11 / P7 L17)

P6 L 20: which variables were selected? Next sentences are unclear.

The text has been rephrased for clarity (P7 L6).

P7 L 31 “...1.36 and 0.35. in...” unit missing

The meter unit (m) has been added P8 L11

P7 L 19: why? You did not introduce site heterogeneity before (Introduction). I would also like to have an introduction in hydrologic connectivity, so are the different spots relevant for the discharge? What about the rest of the catchment?

Site heterogeneity is discussed in the section 3.1 P4 L29.

The first step of our investigation was based on an average peat water table (section 3.3), in order to explore the link with DOC dynamics on the longest possible record. After the selection of the main explanatory variables, we investigated how different model performances between the bog and the fen with could be explained using the different recession times observed in the piezometer wells.

P8 L 4: Discuss different pre-conditions, changes in hydrologic conductivity with depth.

This sentence aims at giving a general description of the water table depth at both site. This study focuses on DOC concentration peaks. Pre-conditions of each events were taken into account by defining explanatory variables integrating these pre-conditions as mentioned in Table 1 (water table level at the beginning of the DOC event, air and water temperature integrated on the 7 days prior the event, precipitation integrated on the 24 hours before the event, and time between peaks). Then, these pre-conditions are discussed in case they appeared as significant variable in the models.

P8 L 9: give conc. maxima. I am very surprised by the low mean values. When you have 2 and 7 mg/L mean DOC concentrations I am about to doubt the significance for the carbon balance. This only gives me the idea that you have a lot of water not originating from the peatlands itself. Calculating fluxes might be helpful here. You might check literature and compare.

P8 – L21 Our study sites are mountain peatlands, located in calcareous watersheds. The measured DOC concentration at the outlet are, as noticed by the reviewer, in the lower end of what can be expected in peatland sites. At the Bernadouze site, we performed an extensive study, including a high frequency survey at the inlet and outlet of the peatland. From this study (Rosset et al., 2019), we could conclude that the peatlands area contributed to 60 to 80 % of the fluvial carbon export. The specific fluxes estimated for the two sites range from 16.7 ± 0.4 to 31.9 ± 1.4 $\text{g} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$ for bernadouze and 18.8 ± 4.2 to

22±6.7 g.m⁻².yr⁻¹ for Ech which is the high range of specific fluxes published for temperate peatlands and will be significant when establishing the carbon balance.

P8 L 31/32: Is this much? More than half cannot be explained by your model in Ech, other factors seem very important as well. Which could this be?

The different model performance between the two sites are discussed in terms of hydraulic conductivity (MRC) in the section 5.5 of the manuscript.

P 9 L 1: Peat water temperature dependent on depth?

Peat water temperature was monitored in the piezometers and is representative of a mix of the whole water column.

P 9 L 9: speaking from “water table increase” and “water level increase” is confusing to me. Give more precise names, maybe include “stream” or “peat” for clear distinction

The term stream and peat have been added when needed in the manuscript to make a clear distinction between water table and stream (section 4.4 and 5.5)

P9 L 19: This is a very simple statement and would be very odd, if this is not the case.

This section describes the results, including simple statements like this one. However, the sentence has been slightly modified to shorten the description part (P10 L2).

P9 L 27: what is a “strong concentration”?

The text has been modified to “higher concentration”. P10 L 10

P9 L 29: Please reword

The title of the section has been modified to ‘Long term high frequency in situ monitoring’ P10 L13

P9 L 30: Is this important? What is the novel statement/finding of your study? So far I mainly see confirmation of former results

We do believe the high frequency survey is important for our results. First, without high frequency monitoring, the DOC peaks (< 32 hours) would never have been identified. This is a specificity of our mountain peatlands and such high numbers of events have never been reported. Then, the coupled analysis of DOC concentration and controlling parameter has allowed, to relate peat water table variation to DOC concentration at a very fine temporal scale. This, we are confident of, is a contribution to the literature since most study relate DOC and peat water table dynamic at the seasonal scale.

The paragraph has been reworked to replace our study in the emerging literature on high frequency nutrient monitoring (P10 L. 14 to 24).

P 10 L 2 ff: Biogeochemistry? This is new and not mentioned before. Please introduce, the biogeochemical background or processes could be much more discussed in this paper

P 10 L 5: expression “Thanks to” sounds uncommon, please reword.

As stated just above, the whole paragraph has been reworded.

P. 10 L 7 following: Chapter 5.2 is badly structured. If evapotranspiration is unlikely don’t put it there so prominent. The discussion of this part is interrupted and starts again further below -> confusing

This section has been restructured to start with the discussion with the seasonal control on DOC concentration and later discuss other hypotheses for our site. Moreover a new section 5.4 has been created to discuss about snow influence and to enhance the clarity of our manuscript.

P11 L 1: Peat pore water DOC: You did not mention those in the result section. A short description/discussion about those concentrations would be nice.

The peat porewater sampling and characterization has been added in the method section (P5 L5). The average DOC and pH for each piezometer have been detailed in the table A2 included in the appendix section. The discussion on peat porewater DOC concentration has been moved to section 5.5 P12 L14.

P11 L 3 f: What differences? Explanatory variables? Leachable Pools is a good keyword, but please discuss this on your data and not switch directly to the next topic.

The discussion on difference on porewater DOC concentrations between the two sites, as stated above, has been rephrased and move to the section 5.5.

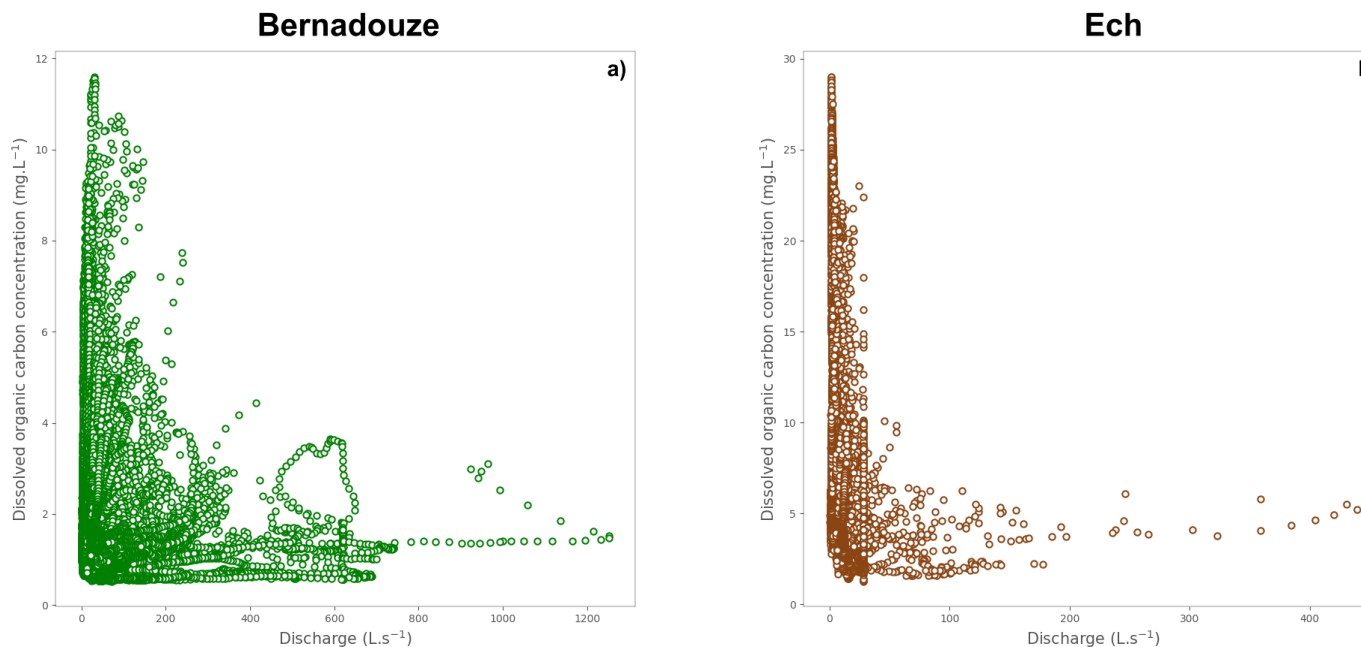
P11 L 8. This is indicative for the discussion. There is just an isolated statement that vegetation type plays a role for DOC production. How is this related to your findings?

Concerning the two last comments, this related discussion part has been moved to section 5.5 P12 L14 since we think that parameters such as recession time, pH and main vegetation cover are interdependent in peatlands, all being related to hydrology. In this manuscript, we chose to emphasize the relationship between DOC concentration and the recession time since we assume that hydrology is the principal driver of the peatland biogeochemistry.

P 11 L 21: This is not true! Please try some more literature search

This formulation was unfortunate and was modified in the manuscript P11 L28. We wanted to emphasize the scarcity of studies coupling high frequency data of DOC concentrations in the stream and peat water table depth.

P 11 L 22: Discuss flow paths. Try e.g. DOC concentration vs Q plots. You throw in “non-linear flow DOC concentration relationship”, try to discuss this.



The DOC vs Q plots are included here for the reviewer’s reference. The DOC vs Q plots are included here for the reviewer’s reference. No systematic relationship is observed between DOC concentration and discharge values.

P 11 L 30: just single observations, discuss mechanisms

This section 5. 3 of the discussion has been expanded to describe the mechanisms involved during flood events. See P11 L22 to P12 L22.

P 12 L 3-4. Provide references

+

P12 L3-12: This is all described before! Provide references and try to discuss more about pre-event conditions

+

P12 L 8f: This finding is not new. Give references.

Answer to the three comments above. This section has been restructured. The revised text includes references on the link between the volume of aerated peat and DOC production on one hand and DOC transfer in the other hand P12 L5.

P12 L 13- P13 L13: Missing point: Conductivity in peatlands typically changes/decreases with depth! What depths are your piezometer? Give references! This is not a new topic! An important keyword here would be ‘transmissivity feedback’ or a similar effect.

To characterize the hydrodynamic properties of the peat, MRC where preferred to hydraulic conductivity estimation from slug tests because they can be performed directly with the water table dataset. Thus, the proposed model could be more easily tested on other peatlands.

Information regarding piezometer installation depths have been included in the revised manuscript, in the Appendix section (Table A2).

P13 L 18: introduce the term “hot moments”; what are the processes inducing hot moments

The term “hot moment” has been introduced in the first section of the discussion (section 5.1 P10 L20) and refers to (McClain et al., 2003).

Fig. 1: Additionally, as your catchment is in a mountain area, it might be helpful to have some contour lines.

Altitudes of the peatlands were added in the figure caption. We prefer not to add the contour lines, since the figure are focused on the peatland areas, and not the whole catchment.

Fig. 2: showing an exemplary DOC event and way of examination is helpful. I would also like to see corresponding discharge values. In general an evaluation of DOC versus discharge (DOC/Q plot) might improve understanding of flow paths and DOC origin

The DOC vs Q plots have been included above. However, we prefer not to include them in the manuscript.

Fig. 3: maybe add a line in the Bernadouze data set where the Ech dataset starts ->better comparability We do not want to compare two similar period, since climatic conditions are not the same from one site to the other. Instead we chose to discuss the statistical models which are built in order to be independent from climatic variabilities.

Fig. 6: I am a bit lost what you want to show here. This is not how a peatland complex looks like and far too generalized trends that you cannot state like this.

This figure is a conceptual schema to describe the two characteristic type of peat units (bog/fen) which may contribute to the DOC transfer at the outlet of a peatland complex. This was intentionally generalized to present the extremum of contribution in term of peat units, one with a low hydraulic conductivity (long recession time) and the second with a high hydraulic conductivity (short recession time).

Table 1: Header is not self-explanatory. Why did you choose peat water temperature at the beginning of DOC event and not weekly mean like at the other parameter?

Peat water temperature does not vary as the air, or stream temperature do at the event scale. We chose the beginning of the DOC event since peat water temperature is an integrative variable, evolving mainly at the seasonal scale.

Table 2: Check time period given for Ech. It seems to be incorrect (2015-2017?)

It was a mistake. As you mentioned, the monitored time period in Ech was 22nd May 2017 to 13th February 2019

Cited references:

Leifeld, J., & Menichetti, L. (2018). The underappreciated potential of peatlands in global climate change mitigation strategies. *Nature communications*, 9(1), 1071.

Nichols, J. E., & Peteet, D. M. (2019). Rapid expansion of northern peatlands and doubled estimate of carbon storage. *Nature Geoscience*, 12(11), 917-921.

Rosset, T., Binet, S., Antoine, J. M., Lerigoleur, E., Rigal, F., & Gandois, L. Drivers of seasonal and event scale DOC dynamics at the outlet of mountainous peatlands revealed by high frequency monitoring.

Scharlemann, J. P., Tanner, E. V., Hiederer, R. and Kapos, V.: Global soil carbon: understanding and managing the largest terrestrial carbon pool, *Carbon Manag.*, 5(1), 81–91, doi:10.4155/cmt.13.77, 2014.

Author's response to associate editor

Legend:

- Associate editor's comments in brown
- Author's responses in black

I agree with the second reviewer that you need to strengthen the discussion of controlling mechanisms for the hydrologic export of DOC. In particular, I wondered if your statement “stream water level only poorly contributed to explaining the variability of DOC increases during flood events 25 (Table 3 and Fig.5 a)” would be valid, given the significant p level and, as you mentioned, the “non-linear flow-DOC concentration relationship”. The non-linear hysteresis relationship between discharge and DOC concentrations might lower r square values, but you cannot say that discharge relationships do not play a role in hydrologic DOC export. Please refer to papers on this hysteresis discharge relationship and check out how your data conform to or depart from the reported patterns. An upland case based on high-resolution sensor data: Jeong et al.: Differential storm responses of dissolved and particulate organic carbon in a mountainous headwater stream, investigated by high-frequency, in situ optical measurements, *J. Geophys. Res.-Biogeosci.*, 117, G03013, doi:10.1029/2012JG001999, 2012.

We thank the associate editor for adding new comments on our manuscript. In the new version of the manuscript we highlighted that our study was a statistical investigation of a large dataset to infer main abiotic parameters controlling stream DOC concentration at the outlet of peatlands. This a first step to understand the whole mechanism driving the DOC exports from peatlands and a preliminary study before creating mechanistic models (as suggested by reviewer 2). However, discussion has been strengthened to give more details about the potential mechanisms driving the DOC export at the outlet of the peatlands, in particular explaining the DOC flush occurring in the acrotelm when water table increase during a flood event.

Besides, regarding to the specific comment about the contribution of stream water level to stream DOC concentration prediction, we would like to emphasize that the sentence refers to the R² contribution of the stream water level in the MLR model. This figure is obtained using the hierarchical variance partitioning (Chevan and Sutherland, 1991) (See section 3.6). Even if this parameter is significant according to the p-value, its contribution is statistically poor compared to other parameters such as water table increase (R² contribution in Table 3).

p11 122 Few sentences dealing with non-linearity and hysteretic patterns between DOC concentration and discharge has been incorporated in the manuscript. The suggested publication has been mentioned as other references about hysteresis analysis which are useful to describe mechanisms of nutrient exports but as mentioned in the manuscript that are not reliable DOC concentration predictors.

Finally, as suggested by the reviewer 2, the manuscript has been reviewed to correct language mistakes and improve the written English.

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Drivers of seasonal and event scale DOC dynamics at the outlet of mountainous peatlands revealed by high frequency monitoring

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Abstract. Peatlands store ~20-30 % of the global soil organic carbon stock and are an important source of dissolved organic carbon (DOC) for inland waters. Recent improvements for *in situ* optical monitoring revealed that the DOC concentration in streams draining peatlands is highly variable, showing seasonal variation and short and intense DOC concentration peaks. This study aimed to **statistically** determine the variables driving stream DOC concentration variations at seasonal and event scales. Two mountainous peatlands (one fen and one bog) were monitored in the French Pyrenees to capture their outlet DOC concentration variability at a high frequency rate (30 min). Abiotic variables including precipitation, stream temperature and water level, water table depth and peat water temperature were also monitored at high frequency and used as potential predictors to explain DOC concentration variability. Results show that at both sites, DOC concentration time series can be decomposed into a seasonal baseline interrupted by many short and intense peaks of higher concentrations. The DOC concentration baseline is driven, at the seasonal scale, by peat water temperature. At the event scale, DOC concentration increases are mostly driven by **a rise in the water table** within the peat at both sites. Univariate linear models between DOC concentration and peat water temperature or water table increases show greater efficiency at the fen site. Water recession times were derived from water level time series using master recession curve coefficients. They vary greatly between bog and fen but also within one peatland site. They partly explain the differences between DOC dynamics in the studied peatlands, including **peat** porewater DOC concentrations and the links between stream DOC concentration and water table rise **within the peatlands**. This highlights that peatland complexes are composed of a mosaic of heterogeneous peat units distinctively producing or transferring DOC to streams.

1. Introduction

Aquatic carbon transfer from terrestrial ecosystems to inland waters is receiving increasing attention as it plays a major role in the watershed carbon balance (Webb et al., 2018) and in the global carbon cycle (Cole et al., 2007; Drake et al., 2017). The origin of aquatic carbon has been tracked and wetlands have been shown to be the main organic carbon suppliers to rivers at both local (Hope et al., 1997; Laudon et al., 2004; Ledesma et al., 2017) and continental scales (Hope et al., 1994; Spencer et al., 2013). Peatlands are specific wetlands which have accumulated organic matter through slow vegetation decomposition

1 processes (Joosten and Clarke, 2002; Limpens et al., 2008). Peatlands grow under different climates (Broder et al., 2012;
2 Dargie et al., 2017; Gorham, 1991; Page et al., 2011) and store **between 20 and 30 %** of the total global soil carbon stock
3 (**Leifeld and Menichetti, 2018; Nichols and Peteet, 2019; Scharlemann et al., 2014**). Stream outlets of peatlands have been
4 monitored at different latitudes (Billett et al., 2006; Leach et al., 2016; Moore et al., 2013) in order to quantify and understand
5 the aquatic carbon transfer between these organic carbon rich pools and their draining streams. Dissolved organic carbon
6 (DOC) is a key component of these fluxes as it contributes to more than 80% of the aquatic carbon exported from peatlands
7 (Dinsmore et al., 2010; Hope et al., 2001; Müller et al., 2015; Roulet et al., 2007). At the outlet of peatlands, DOC is not only
8 considered for its role in the carbon balance but also because it may be an issue for water treatment quality (Ritson, 2015) and
9 a conveyor of potentially harmful elements along inland waters (Broder and Biester, 2017; Rothwell et al., 2007; Tipping et
10 al., 2003).

11 Variability in the DOC concentration signals at the outlet of peatlands has been observed at the inter-annual (Fenner and
12 Freeman, 2011; Köhler et al., 2008), the seasonal (Leach et al., 2016; Tipping et al., 2010) and even the event scales (Austnes
13 et al., 2010; Dyson et al., 2011). **Different drivers have been identified depending on the latitude of the studied peatland sites
14 and the time scale considered.** DOC concentrations were found to be negatively correlated with discharge in boreal systems
15 (Köhler et al., 2008), positively correlated with discharge in temperate areas (Clark et al., 2007) or non-correlated with
16 discharge in mountainous areas (Rosset et al., 2019). Temperature was also reported as an important driver of seasonal
17 variations of DOC concentration in field (Billett et al., 2006) and mesocosm (Pastor et al., 2003) experiments since DOC
18 production is boosted by a greater **vegetation and** microbial activity during warmer periods. Higher temperatures were also
19 shown to enhance evapotranspiration from peatland resulting in a rise in DOC concentration in peat porewater and stream
20 waters during dry summer periods (Fraser et al., 2001). **Studies have highlighted that the heterogeneity of the hydraulic
21 conductivity within peatlands (Rycroft et al., 1975) influences the water table level fluctuations (Bernard-Jannin et al., 2018;
22 Kalbitz et al., 2002; Strack et al., 2008) and the oxygenation of the acrotelm (Freeman et al., 2001) , thus driving DOC
23 production and its transfer to streams.**

24 DOC concentration monitoring at the outlet of peatlands has generally consisted in a weekly or monthly stream water sampling
25 routine (Clark et al., 2008; Juutinen et al., 2013). Higher frequency sampling has been restricted to specific high precipitation
26 events (Austnes, 2010; Clark et al., 2007) or snowmelt (Laudon et al., 2004). Recently, new optical *in situ* sensors (Rode et
27 al., 2016) were used to track DOC concentration at a high frequency rate (~30 minutes) at the outlet of peatlands (Koehler et
28 al., 2009; Ryder et al., 2014; Tunaley et al., 2016), highlighting the strong variability of the DOC concentration signal over a
29 year. While diel DOC concentration cycles have been analyzed under steady hydrological conditions (Tunaley et al., 2018),
30 no analysis has yet been performed to understand the high frequency variability of the DOC concentration at a multi-year scale.
31 Mountains host many small peatland areas that are often neglected in global peatland assessments but which drastically
32 influence stream chemistry in headwater catchments (**Broder and Biester, 2015; Rosset et al., 2019**). The harsh mountainous
33 climatic conditions (from the montane to the alpine belt (Holdridge, 1967)) and the relief of those areas generate high gradients
34 of different abiotic parameters (temperature, precipitation, hydrology) **evolving along both seasonal and event (snowmelt,**

1 rainstorms) scales. Furthermore, seasonal climatic conditions are contrasted, making it possible to differentiate seasonal from
2 event scale stream DOC concentration variability. In the present study, a bog and a fen in the French Pyrenees mountains were
3 monitored for stream DOC concentration using an optical high frequency *in situ* sensor placed at their outlet. The scientific
4 objectives of this study were (1) to statistically identify the main abiotic parameters driving stream DOC concentration
5 variability at each site, (2) to identify the temporal scale of these drivers, and (3) to compare the DOC concentration patterns
6 between a bog and a fen.

7 2. Study sites

8 The peatland of Bernadouze (Fig.1-b) is situated in the Eastern part of the French Pyrenean mountains (42°48'9" N; 1°25'25"
9 E). The peatland lies at 1343 m.a.s.l. It belongs to a 1.4 km² watershed on limestone rocks dominated by the Mont Ceint =2088
10 m.a.s.l. and particularly steep (average slope=50%). From a post-glacial lake, a fen developed for 10 000 years at Bernadouze
11 site, reaching a peat accumulation depth of 2 m in average and more than 9.5 m at extreme locations (Jalut et al., 1982; Reille,
12 1990). As surficial runoff contributes to the water supply of the peatland, it is considered as a soligenous (minerotrophic) fen
13 (Joosten and Clarke, 2002). The fen is subject to an oceanic climatic influence but weather conditions can locally be contrasted
14 due to the specific mountainous topography. For the years 2015 to 2018, the mean annual temperature was 7.9±0.3 °C and the
15 mean annual precipitation was 1797±265 mm. Sub-zero temperatures and snow events are regularly observed at Bernadouze
16 site from mid-October to mid-May with a snow cover lasting around 85 days (Gascoin et al., 2015) from December to April
17 and sometimes exceeding 2m in height. Beech forest is the dominant vegetation cover in the watershed, except for the highest
18 grassland areas (> 1800 m) and the 4.7 ha of the peatland. Vegetation on the peatland is mainly composed of species
19 characteristic of minerotrophic peatlands such as *Carex demissa* and *Equisetum fluviatile*. However, some ombrotrophic
20 species such as *Sphagnum palustre* and *Sphagnum capillifolium* are observed on the southern part of the peatland, forming
21 small hummocks and revealing a progressive disconnection with the stream and the water table supply. Selective logging (one
22 tree out of three was cut) was carried out during autumn 2016 in the lowest forested area surrounding the peatland, producing
23 no clear hydrological and biogeochemical changes at the outlet of the peatland.

24 The peatland of Ech (Fig.1-c) culminates at 710 m.a.s.l. in the west-central part of the French Pyrenees (43°4'59" N; 0°5'39"
25 W). Dominated to the North by mount Cossaout (1099 m.a.s.l.), the peatland depends on a 0.86 km² watershed principally
26 composed of grasslands and grazing areas. The bog area is 5.3 ha and the peat deposit reaches 3.3 m in the center (Millet et
27 al., 2012). Peat formation started about 8200 years ago from a post glacial lake dammed by a recessional moraine in the South
28 (Rius et al., 2012). The peatland is classified as a bog since the surface vegetation depends only on water supplied by
29 precipitation. The site experiences a mountainous oceanic climate characterized by an average annual temperature of 11±0.2
30 °C and an annual precipitation of 1242±386 mm (data from 2015 to 2018). Sub-zero daily mean temperatures are rare (~10
31 days a year) and snow events are sparse in Ech. From the model of (Gascoin et al., 2015), the average duration of snow cover
32 does not exceed 10 days at this altitude in the Pyrenees. The vegetation observed is typical of ombrotrophic bogs with a large

1 blanket of *Sphagnum Capillifolium* and *Sphagnum Compactum*. Small birches and hummocks of *Molinia caerulea* have started
2 to develop within the peatland. Many burning events have been reported on the peatland since its formation (Rius et al., 2012).
3 Nowadays, agro-pastoral practices still use fire to limit the vegetation height and *Molinia caerulea* extension. The last burning
4 event at the Ech site occurred 8 weeks before the stream monitoring in April 2017 and concerned the North Eastern half of the
5 peatland. A second burning event occurred in February 2019 in the Western area of the site. It was decided to stop data
6 acquisition just before the fire to avoid potential shifts in DOC concentration induced by this anthropogenic disturbance
7 (Brown et al., 2015). **According to field observations and a previous study related specifically to DOC exports (Rosset et al.,**
8 **2019), these two mountainous peatlands are considered as the main DOC contributors in their watershed.**

9 **3. Material and methods**

10 **3.1. Site instrumentation**

11 This article presents high frequency data monitored from the 1st September 2015 to 31st December 2018 at Bernadouze site
12 and from 22nd May 2017 to 19th February 2019 at Ech site. Precipitation (liquid and solid) and air temperature were recorded
13 every 30 minutes at Bernadouze (Gascoïn and Fanise, 2018) and every 60 minutes at Ech by automatic weather stations located
14 respectively 300 and 15 meters from the peatlands in open areas. At both sites, sensor failures prevented data acquisition and
15 gap-filling models were used to complete the datasets. For **missing precipitation data in Bernadouze (27% of the monitored**
16 **timeline)**, a linear model ($r^2=0.99$, $p\text{-value} < 0.01$) based on cumulative precipitation recorded in Saint Girons (414 m.a.s.l,
17 $42^{\circ}58'58''\text{N}$, $1^{\circ}8'45''\text{E}$) was built to generate total daily precipitation. A similar model was built in Ech ($r^2=0.99$, $p\text{-value} <$
18 0.01) based on data recorded in Ossen (517m, $43^{\circ}4'0''\text{N}$, $0^{\circ}4'0''\text{W}$) to gap fill **80% of the timeline**. Missing air temperature
19 data (**5% of the timeline**) were estimated at Bernadouze from a linear regression model ($r^2=0.99$, $p\text{-value} < 0.01$) based on data
20 monitored at the same rate under the forest canopy 100 m away from the main weather station. In Ech, daily mean temperatures
21 were estimated (**80% of the timeline**) using a linear regression model ($r^2=0.88$, $p\text{-value} < 0.01$) with daily mean temperature
22 recorded in Tarbes (360 m.a.s.l. $43^{\circ}10'55''\text{N}$, $0^{\circ}0'2''\text{W}$).

23 At the outlet of each peatland, a multiparameter probe (Ysi Exo2, USA) measured fluorescence of the organic matter (fDOM,
24 $\lambda_{\text{excitation}}=365\pm 5$ nm / $\lambda_{\text{emission}}=480\pm 40$ nm), turbidity, water level and temperature every 30 minutes. Wiper sensors
25 prevented the optical sensors from biofouling before each measurement and the probes were inspected and calibrated monthly.
26 **In Bernadouze, battery or sensor dysfunctions and wiper failures prevented data acquisition during 14% of the monitored**
27 **period**. At both sites, a network of piezometer wells (8 in Bernadouze and 4 in Ech) was used to record hourly the water table
28 depth and the water temperature with automatic probes (Orpheus Mini Water Level Logger, OTT HydroMet, Germany).
29 Piezometer locations were selected so as to be representative of the different topographic and vegetation surfaces observed on
30 each peatland (hummocks, lawns, river banks) (Figure 1). **The piezometer wells are 50 mm diameter PVC tubes slotted from**
31 **the bottom to 10 cm below the soil surface. The average depth in Bernadouze is about 1.2 ± 0.3 m, except for two piezometers**

1 in the center of the peatland which were drilled to 2.2 m depth. The average depth of the Ech piezometers is 2.4 ± 0.1 m (Table
2 A2).

3 3.2. Water sampling and DOC calibration

4 Grab water sampling was performed every two weeks at the outlet of Bernadouze peatland and every two months at the outlet
5 of Ech. Piezometer wells were used to sample peat porewater on four occasions (2013, 2014, 2015, 2018) in Bernadouze and
6 on two occasions (2017, 2019) in Ech during stream baseflow periods. Grab water was collected using a manual peristaltic
7 pump and was directly filtered on site using $0.22 \mu\text{m}$ cellulose acetate filters (GSWP04700, Merck-Millipore, USA). To avoid
8 contamination from cellulose, the first millimeters of filtered water were discarded. Water samples were brought back to the
9 laboratory in a cool box and were stored at 6°C until analysis. High resolution water sampling was performed during 9 flood
10 events at the outlet of Bernadouze and once at Ech using automatic water samplers (ISCO 3700, USA) to collect water during
11 various hydrological conditions. Each sampling event consisted in collecting 24 samples of raw water (950 mL) at a frequency
12 defined thanks to the observed timelag of discharge (1 hour for rainfall and 4 hours for snowmelt driven flood events). Flood
13 water samples were collected within the 48 hours following the previous sampling and processed as grab water samples at the
14 laboratory.

15 For all samples (grab and flood samples), non-purgeable organic carbon (NPOC, referred to hereafter as DOC) concentration
16 was analyzed in filtered samples after acidification to pH 2 with a TOC-5000A analyzer (Shimadzu, Japan). The quantification
17 limit was 1 mg L^{-1} . Above this value, the analytical uncertainty was estimated at $\pm 0.1 \text{ mg L}^{-1}$. Reference material included
18 ION-915 ([DOC]= $1.37 \pm 0.41 \text{ mg C L}^{-1}$) and ION 96.4 ([DOC]= $4.64 \pm 0.70 \text{ mg C L}^{-1}$) (Environment and Climate Change
19 Canada, Canada).

20 The fluorescence of DOM (fDOM) data was explored for potential adjustments for temperature, inner filter effect and turbidity
21 (Downing et al., 2012; de Oliveira et al., 2018; Watras et al., 2011). fDOM data were corrected for temperature as described
22 by de Oliveira et al. (2018). The inner filter effect was adjusted at Ech for data showing absorbance values at 254 nm higher
23 than 0.6 (de Oliveira et al., 2018). Lastly, fDOM data recorded during high turbidity events ($>20 \text{ FNU}$) at the beginning of
24 high discharge events were ignored in the analysis as the fluorescence can be drastically attenuated by the presence of particles
25 (Downing et al., 2012). These periods were sporadic, accounting for only 0.2% of the fDOM time series and they do not alter
26 the fDOM variability which is delayed compared to the turbidity (Rosset et al., 2019). High frequency DOC concentrations
27 were calculated at each site using a site specific linear model ([DOC]= $a \cdot \text{fDOM} + b$) linking corrected fDOM data to DOC
28 concentration in flood and grab-water samples. The two models (Figure A1) are respectively described by the following
29 parameters: ($a=0.192$, $b=-0.031$, number of observations =174, $r^2=0.93$, $p\text{-value}<0.001$) for Bernadouze and ($a=0.290$, $b=-$
30 1.359 , number of observations =28, $r^2=0.73$, $p\text{-value}<0.001$) for Ech.

3.3. Water level fluctuation characterization

In order to provide an overall characterization of the peatlands, a mean peat water table depth, as well as a mean water temperature was calculated at each site by averaging peat water table depths and water temperature data at a given time from the set of piezometer probes. Calculations were performed only when all sensors were running (94% of the time period in Bernadouze and 100% in Ech). Hereafter, the mean water temperature in the piezometers is assimilated to peat water temperature.

Master Recession Curve (MRC) analyses were performed on water table and stream level time series, using the MRCTools v3.1 software (Posavec et al., 2017). In order to characterize the hydrodynamic properties of the peat, MRC were preferred to hydraulic conductivity estimations from slug tests because they can be performed directly with the water table level datasets and repeated easily on other peatlands. The MRC represents the average recession of the water level observed when only discharge flow occurs (no recharge). An exponential master recession curve was used to adjust the observed average MRC and to define a specific recession coefficient (α , unit= day^{-1}) characteristic of each monitoring point (Eq.(1)) where B is a constant.

$$\text{Master Recession Curve} \Leftrightarrow \text{Water level} = f(t) = B * e^{-\alpha t} \quad (1)$$

The exponential recession coefficient corresponds to the inverse of the average water recession time, called recession time, in the area of a piezometer or in a stream after a precipitation event. In the following, the recession time coefficient ($1/\alpha$) is used to characterize the hydraulic properties of peatlands and stream.

3.4. DOC peak selection and characterization

Peak selections in the DOC concentration time line were performed by running Python 3.6 (Python Software Foundation, 2019) scripts using the function find_peak available in the ScipY Signal library (Jones et al., 2001) and the arithmetic mean of the DOC concentration signal (DOC_mean) as an input parameter. Peak selection criteria were: to reach DOC_mean concentration and have a prominence higher than 0.25 times DOC_mean. Peaks occurring during an interval shorter than 12 hours apart were grouped under the highest DOC concentration peak. Each DOC concentration peak was defined by the time period delimited by the two nearest low points surrounding the peak event. Low points were located on the DOC concentration time lines by applying the find_peak function on the negatively transformed (-1*) DOC concentration signal previously processed with a Savitzky-Golay filter (window-length=23 and polyorder=2). Low points occurring during an interval shorter than 12 hours apart were grouped under the lowest DOC concentration point. Lastly, the DOC peak period could be manually adjusted to fit or correct a peculiar peak pattern. A DOC concentration peak period was characterized by different metrics (Fig.2): its initial value corresponding to the DOC concentration of the low point at the start of the peak period (DOC_initial), its maximum value corresponding to the DOC peak value (DOC_max), its range (DOC_increase) which was calculated by subtracting the initial value from the maximum value and finally by the rising time duration (rising_limb) which separates the initial low point time from the peaking time. In this study, initial values and increases of DOC were the targeted variables to

1 be explained. Initial values of DOC were used to determine a DOC concentration baseline (Fig.2). The following classification
2 was used to describe seasonal variations: winter (December, January, February), spring (March, April, May), summer (June,
3 July, August), and autumn (September, October, November).

4 **3.5. Explanatory variables selection and characterization**

5 In order to investigate DOC concentration variabilities (at two temporal scales: peak event and seasonal), nine explanatory
6 variables were chosen (Table 1). Variables were calculated for each DOC concentration peak event using similar metrics to
7 those previously described in the DOC peak characterization section (Fig.2).

8 The variables were abiotic parameters, chosen because they have been reported in the literature to have an explanatory potential
9 for stream DOC concentration variability (Table 1). Two categories of variables were distinguished depending on whether the
10 process they described was related to the production of DOC within peatlands or to the transfer of DOC from peatlands to
11 streams. After sensitivity tests and in accordance with the observations of Tunaley et al. (2018), a mean of seven days prior to
12 the event was defined as the best operator to characterize pre-event conditions of air and stream water temperatures.

13 **3.6. Correlation and statistical modeling**

14 Relationships between targeted variables (DOC_increase and DOC_initial) and the explanatory variables were investigated
15 using ordinary least squares (OLS) multiple regression analyses. Prior to the analyses, variables which did not satisfy a normal
16 distribution were log or square root transformed to improve normality (Table 1). Multicollinearity was assessed among all the
17 predictors using Pearson correlation with a threshold $|r| < 0.7$ following Dormann et al., (2013). When two variables were found
18 to be collinear, we selected the one that displayed the highest absolute correlation with the targeted variables. Then at both
19 sites, all variables were standardized to a mean of zero and a standard deviation of one to derive comparable estimates in the
20 following analysis. We performed a backward stepwise selection procedure on the full model (i.e. the model including the
21 variables retained after removing multicollinearity) to capture the best set of variables explaining each targeted variable. At
22 each step of the procedure, the non-significant variables (p-value > 0.05) with the highest p-value were dropped from the model
23 and the resulting reduced model was re-evaluated. This process was continued until there were no non-significant variables
24 remaining in the final model. To account for the time dependency of the variables in the analyses, time was also included as
25 an explanatory variable in the full model. This variable corresponds to the duration which separates each DOC peak event
26 from the start of the time line. Residuals of the final models were surveyed in order to detect deviations from normality and
27 homoscedasticity and to identify outliers. No specific deviations or outliers were detected. Model residuals were also checked
28 for autocorrelation to verify the absence of any cyclical variation in the variables set. When more than one variable was retained
29 in the final model, the relative contribution of each variable was assessed using hierarchical variance partitioning (Chevan and
30 Sutherland, 1991). According to the previous predictor selections for the MLR models of DOC concentration increases
31 (DOC_increase), OLS regression analyses were performed at each piezometer plot of a peatland site, replacing the mean water
32 table increase variable by the specific water table level increase values of each plot in order to test the importance of recession

1 **time heterogeneity in the observed correlations.** Similar OLS regression analyses were performed at the outlet of streams by
2 replacing the mean water table increase variable by the stream water level increase when necessary. R² and relative importance
3 (%) of **the stream or water table** level increase variable were reported for each OLS regression tested. All the analyses were
4 undertaken in R (R Core team, 2019) using the package *rms* (Harell, 2019) and *relaimpo* (Groemping and Matthias, 2018).

5 **4. Results**

6 **4.1. Climate, hydrology and DOC dynamics**

7 Climatic variables are contrasted between the two studied areas. In 2018, temperatures were higher in Ech than in Bernadouze
8 with an annual mean air temperature, water temperature and peat water temperature respectively of 11.3, 10.7, 11.9 °C
9 compared to 7.9, 7.1, 7.7 °C. Total precipitation reached 2151 mm in Bernadouze and 1140 mm in Ech. In these steep
10 mountainous headwaters, short and intense flood events were triggered by strong precipitation events and/or the snowmelt.
11 Over the whole timelines, the maximum and mean of the stream water level were respectively 1.36 and 0.35 m in Ech and
12 0.81 and 0.10 m in Bernadouze. These short flood events were followed by recession sequences revealed by the slow decreases
13 in the **peat** water table at both sites, especially in late summer and autumn (Fig.3-c). The average and minimum of the **peat**
14 water table depth in the two piezometer networks were respectively -0.23 and -0.43 m at Ech, and -0.15 and -0.45 m in
15 Bernadouze. No clear relationship was observed at either site between the stream **water level** and the **peat** water table time
16 series. The peat water levels responded differently to rain events depending on the season. For instance, a strong flood observed
17 in the stream can be contiguous with a low or high peat water table rise (i.e. July 2016 and February 2017 events in Bernadouze)
18 (Fig.3 b -c). **Peat porewater, occasionally sampled in the piezometers, showed an average DOC concentration of 12.4±8.3 mg**
19 **L⁻¹ in Bernadouze while it reached an average of 37.3±18.8 mg L⁻¹ in Ech (Table A2). Peat porewater was in average more**
20 **acidic in Ech, 5.0±0.4 than in Bernadouze 6.2±0.3.**

21 DOC concentration was highly variable at both sites during the monitored periods as highlighted by the numerous short DOC
22 peak events (~30 hour duration) in the two time series (Fig.3 and Table 2). At Bernadouze site, DOC concentration peaks
23 showing higher values were more frequent from April to November while this was less obvious at Ech site where DOC
24 concentration also peaked during winter. In 2018, the arithmetic means and flow weighted averages of DOC concentration
25 were higher at the outlet of Ech, reaching 7.1±6.1 and 4.6 mg L⁻¹, than in Bernadouze where they were 2.0±1.5 and 1.7 mg L⁻¹.
26

27 **4.2. DOC concentration peaks characterization**

28 Peak characterization (Table 2) revealed that the increases and **the** maxima of DOC concentration peaks were on average two
29 times higher in Ech than in Bernadouze. However, the ratio between the mean increase and the mean initial value of DOC
30 concentration was higher in Bernadouze (2.3) compared to Ech (1.9). DOC concentration peaks occurred more often at
31 Bernadouze compared to Ech (0.24 vs 0.16 peak per day in average) while their duration was slightly longer (32±14 vs 28±16

1 hours). Rising limbs of DOC concentration peaks lasted on average 10 ± 5 and 13 ± 14 hours at Bernadouze and Ech respectively
2 and they were slightly longer than the stream water rising limb averages monitored at the outlet of the two peatlands. In
3 contrast, rising limb duration of the water table in Ech was clearly longer (22 ± 12) compared to Bernadouze (13 ± 7 hours).

4
5 General mean and seasonal means of initial DOC concentrations were 2.5 and 3.1 times higher at Ech compared to Bernadouze
6 (Table 3). However, at both sites, **initial DOC concentrations** showed a clear seasonal variability. The lowest values were
7 observed in spring and the highest in autumn while in summer and winter DOC concentration was close to the annual mean.
8 DOC peak event frequencies also varied at the seasonal scale (Table 3). The highest frequencies were reported in autumn at
9 both sites. The lowest peak frequencies were observed in winter at Bernadouze and in summer at Ech.

10 **4.3. DOC concentration variations models**

11 Prior to multiple regression analyses, the air temperature over 7 days, the **maximum** stream water level and the initial level of
12 the water table were excluded from the analysis because of their strong correlation with other variables (Pearson's correlation
13 $|r| > 0.7$) (**Figure A3**). Multiple linear regressions (MLR) followed by backward stepwise selections showed that respectively
14 55% and 44% of the seasonal variation of DOC (DOC_initial) was explained by the final models at Bernadouze and Ech (Table
15 3). Peat water temperature was reported as an important predictor at both sites (72% of the variance explained by the final
16 model at Ech and 44% at Bernadouze). In Bernadouze, variance is similarly explained by the time between two peaks (44%).
17 Along the two years of monitoring in Ech, the strong DOC concentration values observed during the dry autumn 2018 (Fig.2)
18 created a positive general trend in the DOC concentration baseline. This peculiar trend drastically influenced the statistical
19 analysis and consequently the variable "time" became a significant predictor at the seasonal scale. Considering the high relative
20 importance of the peat water temperature in the two final models, two simple linear models (Fig.4 a) were built based on this
21 variable to illustrate the seasonal DOC concentration behavior in Bernadouze (slope=0.08, intercept=-0.16, n=231, $R^2=0.26$,
22 p-value<0.001) and in Ech (slope=0.10 intercept=0.50, n=100, $R^2=0.27$, p-value<0.001). **In the final models of increase of**
23 **DOC concentration**, water table increase was the most important variable at Bernadouze (67% of the variance explained) and
24 the single variable at Ech. In Bernadouze, other variables such as **stream** water temperature, **stream** water level increase and
25 the time between two peaks were significant enough to be integrated **in the final model of DOC concentration increase**. The
26 R^2 associated to the models varied strongly between the two sites, reaching 0.77 in Bernadouze and only 0.27 in Ech. Since
27 water table increase was the main explanatory variable for the DOC concentration increase model, two simple linear models
28 were built (Fig.4b) with the following parameters in Bernadouze (slope=8.44, intercept=-1.06, n=231, $R^2=0.68$, p-
29 value<0.001) and in Ech (slope=6.39, intercept=0.84, n=100, $R^2=0.27$, p-value<0.001).

4.4. Relationships between DOC dynamics and recession time

In the fen of Bernadouze the recession times in the peat ranged from 15 to 77 days whereas in the bog of Ech they were longer, ranging from 53 to 143 days (Fig.5). Stream recession times were shorter at both sites reaching 4 days in Bernadouze and 9 days in Ech. Results of the OLS regressions conducted at each peat water level monitoring plot using DOC increase final models, revealed that recession time influenced the model's efficiency (Fig.5 a). Piezometers characterized by shorter recession times showed greater determination coefficients R^2 (Fig.5 a). Peat water table increase was the most important predictor (pie charts Fig.5 a) for all piezometer plots, contributing at least 47% of the explained variance of the DOC increase models. In Bernadouze, the model based on stream water level was weaker ($R^2=0.37$) than the models based on peat water table data while in Ech the model based on stream water level was unable to explain at all the DOC increase variation ($R^2=0$). Recession times showed a positive relationship with DOC concentration measured in the piezometers and in the streams, higher concentrations being associated to longer recession times (Fig. 5 b).

5. Discussion

5.1. Long term high frequency monitoring

To our knowledge, this is the first time that stream DOC concentration and abiotic drivers, including peat water table depth fluctuations, have been analyzed at the outlet of peatland sites on a multi-year period at this frequency (30 min). Previously, DOC concentration variability was investigated either at lower frequencies (Clark, 2005; Dawson et al., 2011) or during shorter periods (Austnes et al., 2010; Koehler et al., 2009; Tunaley et al., 2016; Worrall et al., 2002). Recently, high frequency monitoring of nutrient dynamics in watersheds has developed and has revealed an unexpected variability of mobilization processes for these nutrients (Blaen et al., 2017; Rode et al., 2016; Tunaley et al., 2016). These acquisitions have allowed scientists to characterize the "hot moments" in the biogeochemical cycles of a watershed (McClain et al., 2003). A contribution of our study is to sequence extremely brief DOC concentration peaks and to statistically disentangle their event and seasonal drivers using synchronous high frequency monitoring of climatic and hydrological parameters. The representativeness of both seasonal and event scale statistical models is enhanced by the large number of events (252 peaks in Bernadouze and 101 peaks in Ech) captured at all seasons (Table 2).

5.2. Peat water temperature controls seasonal DOC concentration baseline

Clear seasonal variations in the DOC concentration baseline were observed at both sites (Figure.3 and Table 2). The DOC concentration baseline increased in late spring, peaked in autumn, decreased during winter and reached the lowest levels in early spring. Similar seasonal DOC concentration patterns have been observed at the outlet of other peatland sites in temperate regions (Austnes, 2010; Broder and Biester, 2015; Clark et al., 2005; Tunaley et al., 2016; Worrall et al., 2006; Zheng et al.,

2018) or after the snowmelt event in boreal areas (Jager et al., 2009; Köhler et al., 2008; Laudon et al., 2004; Olefeldt and Roulet, 2012; Whitfield et al., 2010).

In this study, linear regression models revealed that the seasonal variations of the DOC concentration baseline are mostly driven by peat water temperature (Table 3). At peatland sites, temperature is often identified as a DOC concentration driver at the seasonal scale (Billett et al., 2006; Clark et al., 2008; Dawson et al., 2011; Koehler et al., 2009). Warmer temperatures directly enhance DOC production by stimulating vegetation and microbial activity (Kalbitz et al., 2000; Pastor et al., 2003). Warmer temperatures are also indirectly linked to DOC production processes in temperate and northern peatlands since they often correspond to dry periods that lower water table levels. When the water table decreases, the “enzymic latch” (Freeman et al., 2001) is initiated on a greater volume of acrotelm (oxygenated peat) and enhances DOC production within the upper peat layers. DOC concentration relationships with peat water temperature have already been described in an acidic fen in France (Leroy et al., 2017) and in blanket peatlands from the North Pennine uplands in the UK (Clark et al., 2005); however, in these cases DOC concentrations were measured in peat porewater. A complementary study in the North Pennines (Clark et al., 2008) showed that peat porewater DOC concentrations and stream DOC concentration were strongly correlated, meaning that, by extension, the relationship between peat temperature and stream DOC concentration could be verified for these sites.

5.3. Water table increase controls DOC concentration peaks at the event scale

This study, coupling high frequency stream DOC concentration and water table depth monitoring at both peatland sites, revealed that peat water table increase is a strong predictor of stream DOC concentration increase at the event scale (Table 3 and Figure 4 b). Until now, stream DOC concentration variability at the event scale has been investigated in terms of discharge but rarely in terms of peat water table variation. Several studies have reported stream DOC concentration increases at the outlet of peatlands during flood events (Austnes, 2010; Ryder et al., 2014; Tranvik and Jansson, 2002; Yang et al., 2015), whereas others showed dilution during high flow events (Clark et al., 2007; Grayson and Holden, 2012; Laudon et al., 2004; Worrall et al., 2002). At the outlet of peatlands, non-linear discharge-DOC concentration relationships have been reported (Roulet et al., 2007; Tunaley et al., 2016); this seems to be the case at our sites where stream water level explains the variability of DOC increases during flood events (R^2 contribution in Table 3 and Figure .5 a) only poorly (Bernadouze) or not at all (Ech). Non-linear /hysteretic patterns (Hendrickson and Krieger, 1964; Walling and Foster, 1975) between DOC and discharge are commonly observed in upland watersheds (Jeong et al., 2012; Strohmeier et al., 2013) and are analyzed to infer DOC export mechanisms. However, these patterns cannot predict stream DOC concentration as an MLR model integrating water table increase appears to do. The link between DOC dynamics and peat water table has been largely investigated at the seasonal scale (Kalbitz et al., 2002; Strack et al., 2008; Hribljan et al., 2014;) or in mesocosm experiments (Pastor et al., 2003; Blodau et al., 2004). The peat water table is usually considered as a DOC production driver as it controls the oxygenated acrotelm volume (Billett et al., 2006; Freeman et al., 2001; Ritson et al., 2017). Therefore, different studies attempted to quantify the effect of water table position on DOC production rate in peatlands. In fen and bog mesocosms, Pastor et al., (2003) observed no DOC concentration variation in the stream water after long term peat water table decreases. Contrastingly, increasing DOC

1 concentrations were observed during the re-wetting phase of the acrotelm at fen sites in Germany (Kalbitz et al., 2002), in
2 Canada (Strack et al., 2008) and in the USA (Hribljan et al., 2014). Clark et al., (2009) reported similar observations after re-
3 wetting peat cores in controlled laboratory conditions. Our results are in line with these studies. Moreover, thanks to the high
4 frequency survey, they highlight, in addition to DOC production processes, specific hydrodynamic processes driving DOC
5 export from peatlands at the event scale. The correlation between DOC peak and water table increase can have different origins:
6 (1) the water table increases could create a piston flow that expels pre-flood water (Małoszewski et al., 1983), enriched in
7 DOC. At our sites, the delay (a few hours) between stream discharge peaks, peat water table increase and DOC peaks suggests
8 that DOC concentration peaks are not directly related to water pressure. As observed before in peat dominated head water
9 catchments by Rodgers et al. (2005), this observation rejects the piston flow hypothesis; (2) As DOC is mostly produced in
10 the oxygenated and unsaturated peat volume above the water table (Billett et al., 2006; Freeman et al., 2001; Ritson et al.,
11 2017), during a flood event, DOC can be flushed by flood water (Boyer *et al.*, 1997). This water reaches the water table. The
12 exponential decrease in hydraulic conductivity observed in the peat profile with depth (Rycroft et al, 1975) enables preferential
13 horizontal flows, above the water table (Quinton *et al*, 2008). Due to the exponential decrease in hydraulic conductivity
14 properties, pre-flood-water under the water table is less mobile than flood water located above. Our data support this second
15 hypothesis, with a very fast increase in DOC concentrations, and the rapid DOC concentration recession in the same order of
16 magnitude as sub-surface flow recession. This does not exclude the possibility that a fraction of pre-flood waters may reach
17 the stream during the recession time, but this mixing process is minor compared to flushing processes. Following this
18 hypothesis, if DOC production were the limiting factor, the linear regression (Fig.4b) should show a plateau for the high value
19 of water table increase. This is not the case. Thus the limiting factor appears to be the amount of water brought by the floods
20 and ultimately the full saturation of the peat. These observations support the practices for degraded peatland restoration, where
21 a general rise in the water table is recommended to limit water table increases and the DOC concentration peaks induced at
22 their outlets (Höll et al., 2009; Strack and Zuback, 2013).

23 **5.4. Influence of snow on DOC concentration**

24 The higher DOC concentration observed in summer could be explained by evapotranspiration processes that concentrate
25 solutes in stream water. However, the evapotranspiration rates in these mountainous environments are low (<300 mm year⁻¹)
26 compared to precipitation (>1200 mm year⁻¹) and should not drastically influence the seasonal DOC concentration baseline.
27 In Bernadouze, DOC concentration remained extremely low when the fen was snow-covered and it did not drop drastically
28 during the spring snowmelt as has been observed in boreal areas (Laudon et al., 2004; Leach et al., 2016). This pattern can be
29 explained by (1) the low initial DOC concentration which prevents a clear dilution being observed during the snowmelt event,
30 (2) the snowmelt regime in this Pyrenean catchment, which may be less sudden than in boreal regions and occurs from the
31 early snow deposit to the beginning of the growing season, continuously diluting the low winter DOC production within the
32 peatland.

1 In Bernadouze, contrary to the initial hypothesis (Table 1), the time between peaks was a negative significant predictor in both
2 seasonal and event DOC concentration models (Table 3). This is considered as an indirect consequence of the seasonal
3 temperature control on DOC concentration. Indeed, snow cover and the low temperatures associated to high water table
4 positions prevent the occurrence of DOC peaks in winter, creating large time gaps between two events (Table 2) of low initial
5 values. In contrast, DOC production is amplified during warmer periods, resulting in more frequent stream DOC concentration
6 peaks starting at higher initial values. In Ech, where average annual temperatures are higher and snow cover is reduced, the
7 initial hypothesis was verified since DOC concentrations were stronger in autumn after the long summer times between peaks
8 (Table 2). However, the variable was not significant enough to be integrated in any final model (Table 3).

9 **5.5. Contrasted DOC dynamics related to recession times**

10 Spatial analysis of water table variation within the peatland revealed that the studied sites are composed of several peat units,
11 characterized by contrasted recession times. In these mountainous peatlands, recession times are related to DOC dynamics,
12 driving model efficiency between DOC concentration increase and **peat** water table rise and explaining DOC concentration in
13 peat pore water.

14 In the present study, both stream and peat pore water DOC concentrations were higher at Ech compared to Bernadouze (Table
15 2 and A2 and Figure 5 b). This is consistent with mesocosm (Pastor et al., 2003) or field (Chanton et al., 2008; Chasar et al.,
16 2000; Moore, 1988) peat porewater observations which highlighted higher concentrations in bogs compared to fens.

17 Sphagnum species, which are dominant on bogs, usually produce relatively less labile and reactive DOC than vascular plants,
18 which are more abundant on fens (Chanton et al., 2008). Lower pH values are expected to reduce DOC solubility (Clark et al.,
19 2005). However, these relationships are not observed at our sites. As can be seen on Figure 5b, peat porewater DOC
20 concentrations are related to MRC, higher concentrations being associated to longer recession times. Beyond this hydrologic
21 control, other parameters, such as residence time, vegetation cover, linked to bog and fen conditions influence DOC
22 concentration levels in peat pore water.

23 In average the bog of Ech presented a longer recession time (111 days) than the fen of Bernadouze (20 days). **However, a large**
24 **variability is observed within each site.** For instance, a specific unit in the fen of Bernadouze was characterized by a long
25 recession time of 77 days. This unit shows surface bog vegetation and topographic patterns but is surrounded by typical fen
26 units characterized by **shorter** recession times (Fig.5). Thus a peatland complex must be considered as a patchwork of different
27 units and not as a uniform peat entity.

28 At the event scale, the univariate model between DOC concentration and **peat** water table increase showed a non-negligible
29 intercept at Ech contrasting with the model of Bernadouze (Figure 4 b). **This means that** in Ech, DOC concentration increases
30 can occur without water table increases. In this case, DOC is transferred from the upper peat layers via fast runoff flows without
31 any water table level fluctuation. Such a phenomenon is consistent with the **lower hydraulic conductivities (longer recession**
32 **times) measured in bogs (Figure 5).** In contrast, DOC stored in the upper peat layers of fen units is transferred to the stream
33 by fast percolating water **raising** water table levels and **supplying** sub-surface flows (Figure .6). This explains why the DOC

1 increase model based on **peat** water table increase is particularly efficient for fen units characterized by short recession times
2 (Fig.5 a). Recession times, **used as proxies of the hydraulic conductivity**, also explain the differences in peat porewater DOC
3 concentration observed between bog and fen sites. In the fen, recession times are short, meaning that the upper peat layers are
4 rapidly washed by precipitations, inducing sudden DOC pool depletions of the peat porewater (Fig.3 c). At the bog site, DOC
5 stored in the upper peat layers is slowly released to the stream after precipitation events and contributes to maintaining a high
6 stream baseline (Fig.3 c) and peat pore water DOC concentrations (Fig.5 a).
7 Thus, stream DOC concentration modelling at the outlet of peatlands must account for different proportions of fen-like or bog-
8 like units in peatland complexes to **reflect** the real seasonal and event DOC concentration variability. **Every** unit supplies DOC
9 to the stream at a different rate depending on its volume, distance **from** the stream and recession time (Fig.6). This end member
10 mix concurs with the model of Binet et al. (2013) describing event and seasonal water table variability in peatlands using a
11 double porosity parametrization. In that sense, recession time appears as a physical parameter able to characterize peatland
12 units **beyond** the binary typology of bog or fen. This would surely improve the efficiency of hydrological and biogeochemical
13 models. In the case of peatland complexes characterized by long recession times, further investigations of peatland runoffs and
14 sub-surface flows are needed, analyzing denser and stream directed piezometer transects in order to build stronger DOC
15 concentration models.

16 **6. Conclusion**

17 This study reports a statistical analysis of the stream DOC concentration variability at the outlet of two mountainous peatlands.
18 Multi-year *in situ* high frequency (30 minutes) monitoring revealed that at both sites, DOC concentration time series can be
19 decomposed into a seasonal baseline interrupted by many short, intense peaks of higher concentrations. At the seasonal scale,
20 DOC concentration baseline variations are mainly explained by peat water temperature which controls integrative DOC
21 production processes within the peatland. During the “hot moments” of peak events, DOC concentrations are well explained
22 at both sites by water table increases within the peatlands. Recession time is a relevant parameter to explain peat porewater
23 DOC concentration and the different model performances observed between bog and fen sites. Recession time assessments in
24 different locations on the two studied sites showed that peatlands are composed of different units presenting **contrasted**
25 **hydraulic conductivities**. Thus, peatlands should not be considered as uniform landscapes. Distinct peatland units within the
26 same peatland complex contribute differently to the DOC transfer processes to inland waters. Recession time assessment in
27 piezometers appears to be a simple and promising tool to investigate hydrological processes occurring in peatlands over time
28 and space. Indeed, water table time series are often under-used and only account for a seasonal mean or minimum depth.
29 Assessing recession times on peatlands is a first step to taking peatland water table dynamics into consideration and to
30 explaining potentially related biogeochemical processes.

31

1 **7. Data availability**

2 The data used in this manuscript are described and available on the Pangaea® data repository at:

3 <https://doi.pangaea.de/10.1594/PANGAEA.905838>

4 **8. Author contribution**

	CASRAI role	Rosset	Binet	Antoine	Le rigoleur	Rigal	Gandois
1	<i>Conceptualization</i>	x	x				x
2	<i>Data curation</i>	x			x	x	
3	<i>Formal analysis</i>	x	x			x	x
4	<i>Funding acquisition</i>		x				x
5	<i>Investigation</i>	x	x	x	x		x
6	<i>Methodology</i>	x	x	x			x
7	<i>Project administration</i>	x	x				x
8	<i>Resources</i>	x	x		x		x
9	<i>Software</i>	x			x	x	
1 0	<i>Supervision</i>		x		x		x
1 1	<i>Validation</i>	x	x				x
1 2	<i>Visualization</i>	x	x		x		x
1 3	<i>Writing – original draft</i>	x	x				x
1 4	<i>Writing – review & editing</i>	x	x	x	x	x	x

5

1 9. Competing interest

2 The authors declare that they have no conflict of interest.

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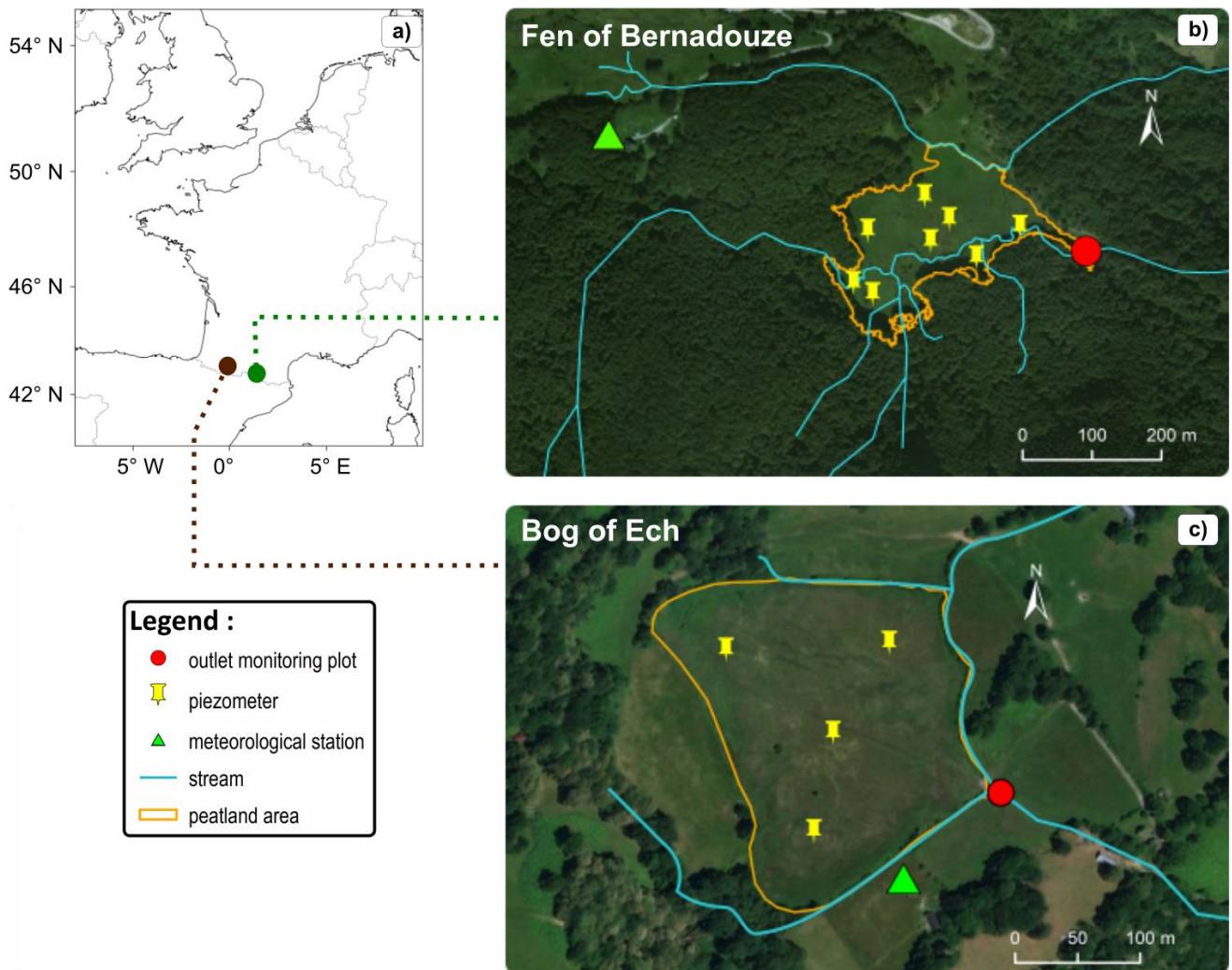
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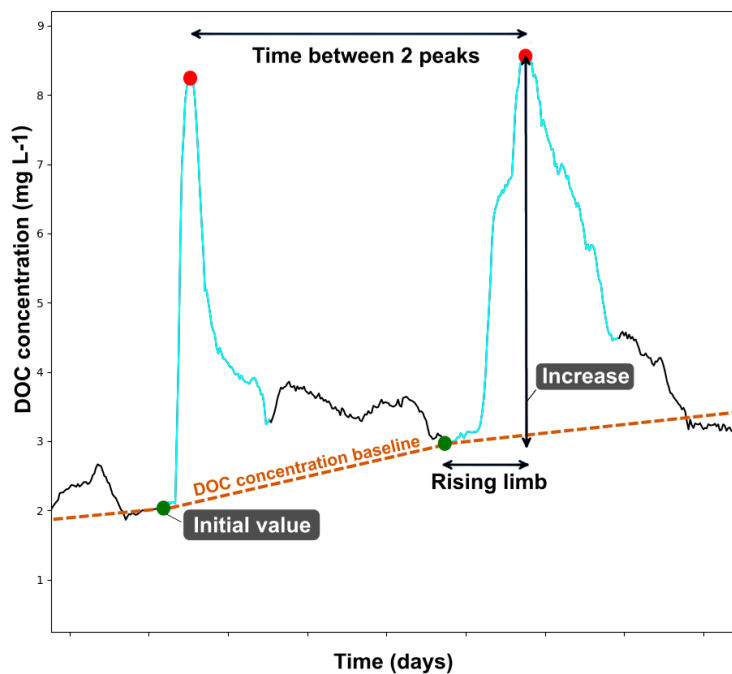
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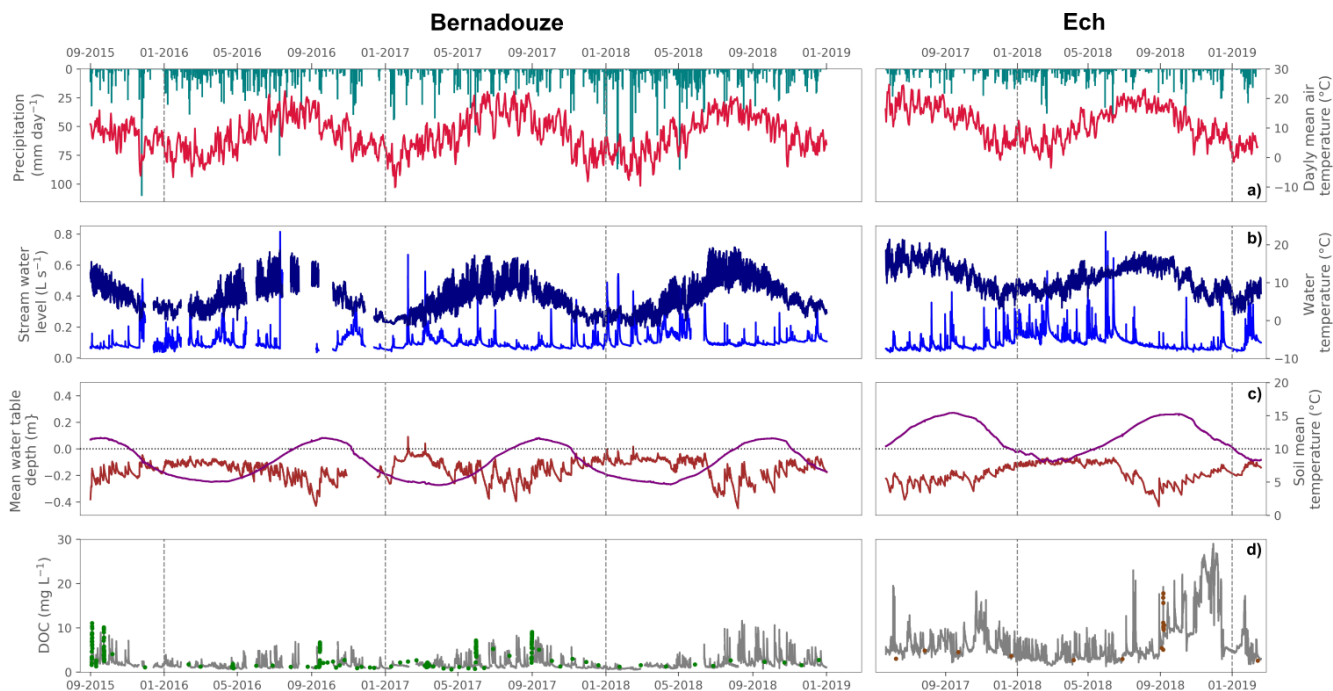


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11 **Figure 1:** a) Location map of Ech Bog (brown plot) and Bernadouze fen (green plot) in South Western Europe. Satellite views of the
 12 peatlands of b) Bernadouze (1343 m.a.s.l.) and c) Ech (706 m.a.s.l.) and location of the site instrumentation. Map source: Esri,

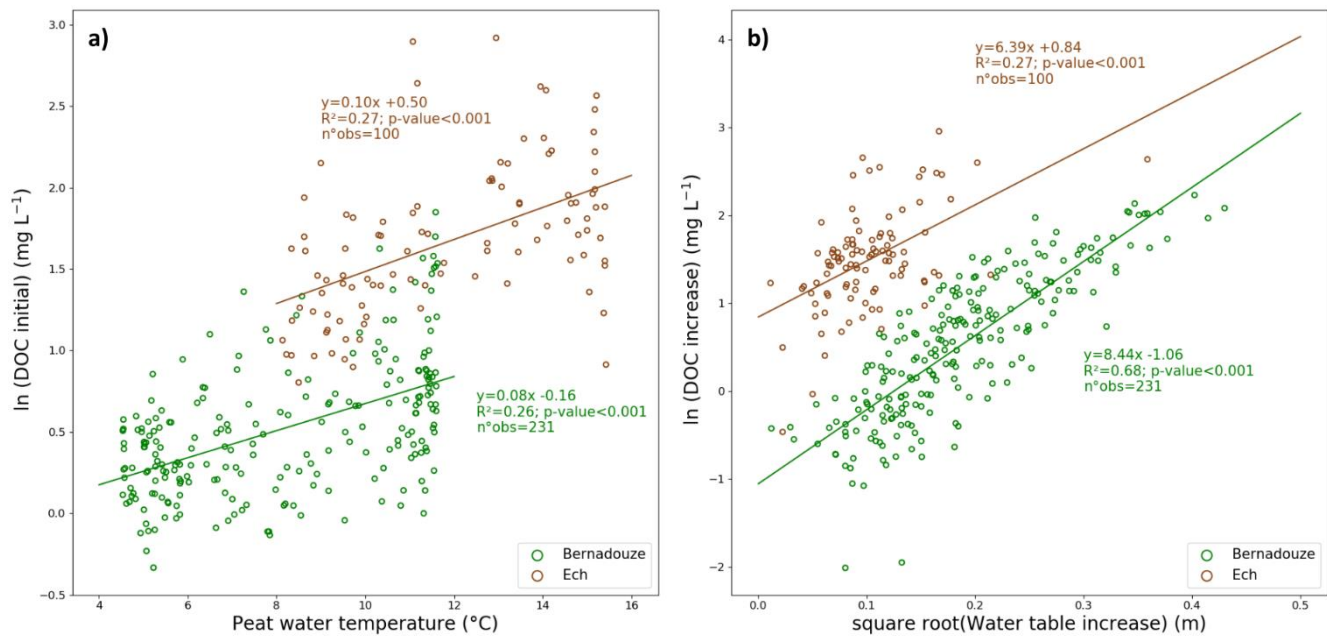


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4 **Figure 2: Characterization of DOC concentration peaks.** Peak events are identified on the DOC concentration time line in blue. Each
5 DOC concentration peak event is defined by an initial concentration (green points) and a maximum one (red points). DOC
6 concentration increase is calculated by subtracting the initial from the maximum concentration. The time between 2 maximum DOC
7 concentrations corresponds to the duration (seconds) separating two events and is used as an explanatory variable. The DOC
8 concentration baseline (orange dotted line) corresponds to the time series defined by all the initial values of each DOC concentration
9 peak.



1
 2 **Figure 3: Precipitation and air temperature (a), stream temperature and water level (b) high frequency DOC concentration (c),**
 3 **mean water table depth variation and peat water temperature (d). Time series observed at the outlet of the Bernadouze fen (left**
 4 **panel) from 1st September 2015 to 31st December 2018, at the outlet of Ech bog (right panel) from 22nd May 2015 to 13th February**
 5 **2019. The vertical grey lines represent a change of year. Green (for Bernadouze) and brown (for Ech) plots in time series (c) refer**
 6 **to DOC concentration measured in grab water samples and automated flood samples.**

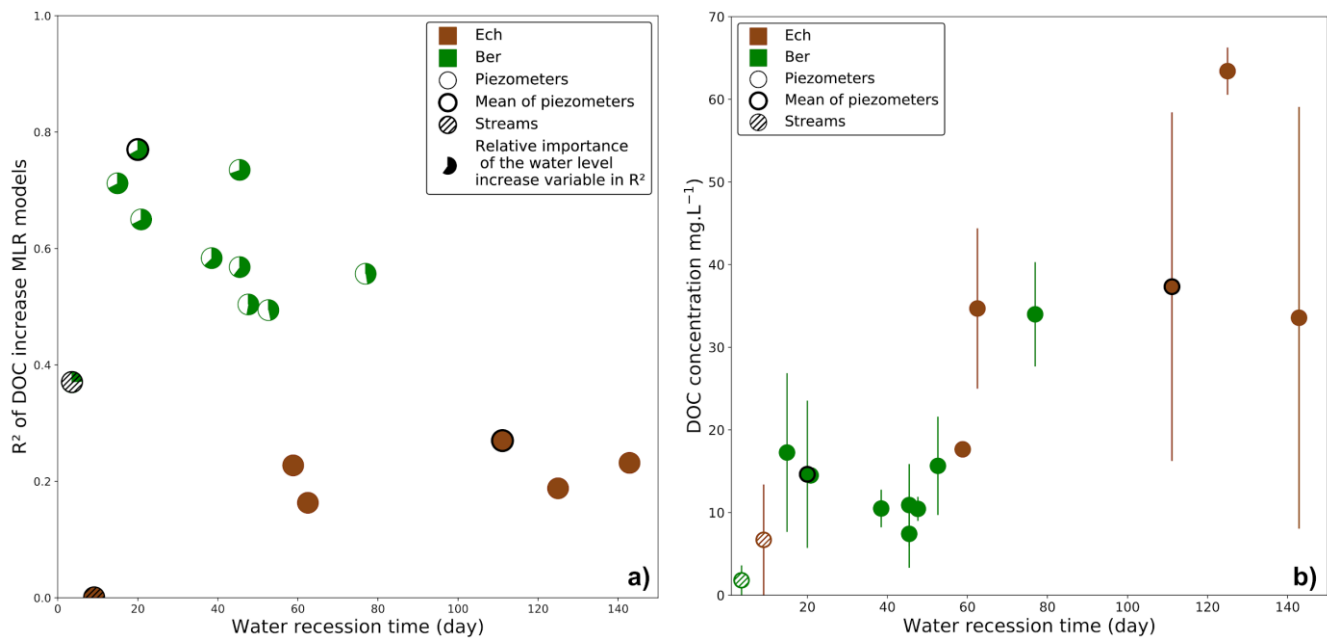
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2 **Figure 4: Relationships between (a) peat water temperature and natural logarithm of DOC concentration initial value and (b) square**
 3 **root of water table increase and natural logarithm of DOC concentration increase during peak events at Bernadouze (green) and**
 4 **Ech (brown). Regression coefficients (intercept and slope), p-values and R^2 are given in each panel.**

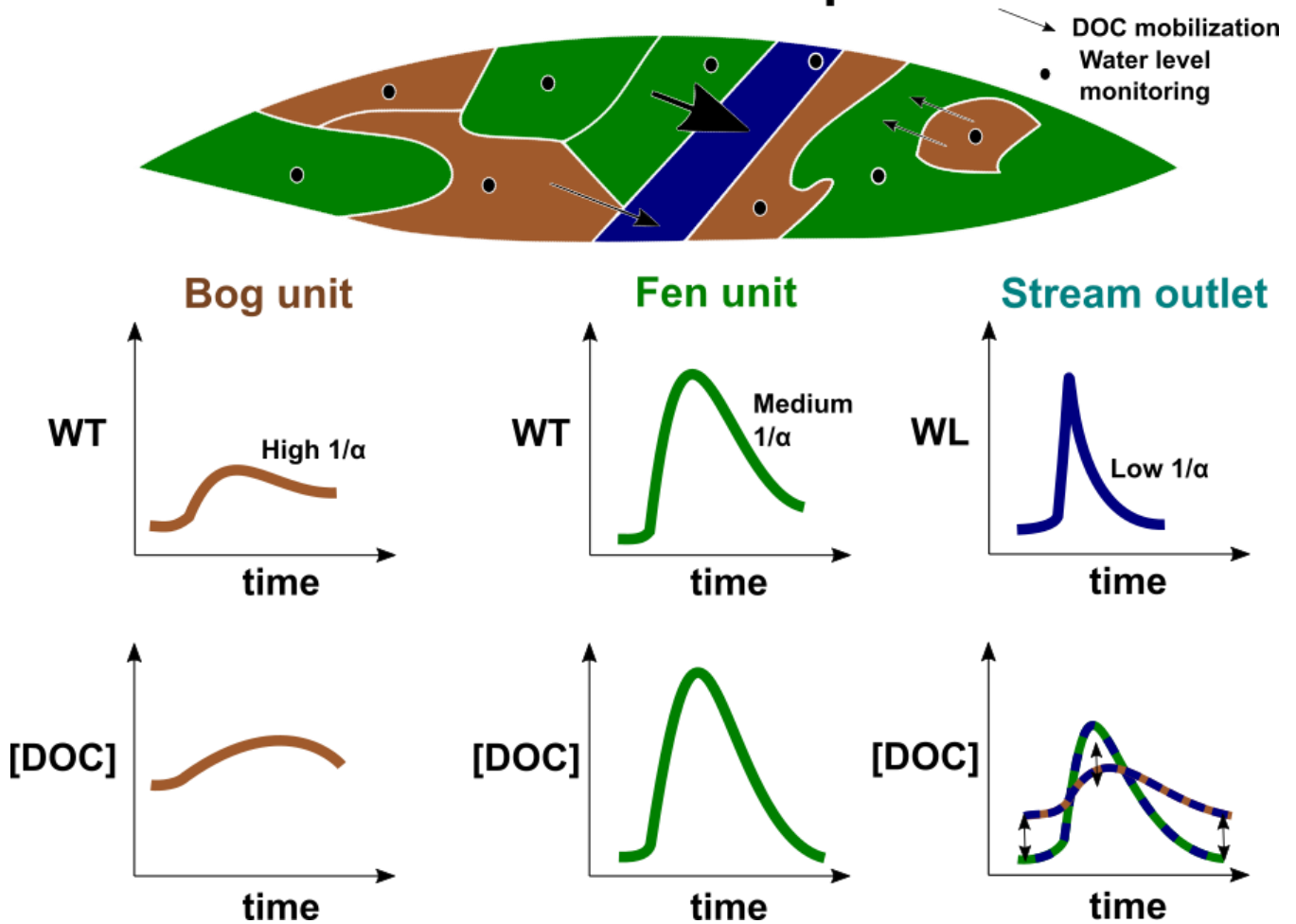
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2 **Figure 5: Relationship between water recession time coefficients and a) the R^2 of the DOC_increase MLR models or b) the DOC**
 3 **concentration of each water level monitoring plots at the peatland of Bernadouze (green) or Ech (brown). In both graphs, p**
 4 **piezometer plots are represented by solid circles while the mean of the piezometers at each site is surrounded in black. Stream plots**
 5 **correspond to the two black striped circles in each graph. In graph a), pie charts represent the relative importance of the water level**
 6 **increase variable in the R^2 of each model. In graph b), a marker represents the mean DOC concentration of a plot and vertical**
 7 **segments the standard deviation.**

Peatland complex



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Figure 6: Schematic overview of a peatland complex. Size of the arrows corresponds to DOC quantity mobilized from distinct peatland units. The DOC concentration observed in the stream depends on the contribution of the different peat units within the peatland complex.

1 **Table 1. Targeted and explanatory variables description**

	Designation	Variable description	Hypothesis	References	Statistical transformation
Targeted variables					
Seasonal scale	DOC initial	DOC concentration at the start of a DOC peak event	Define the stream DOC concentration baseline		Logarithmic
Event scale	DOC increase	Range between DOC concentration initial value and maximum observed during a DOC peak event			Logarithmic
Explanatory variables					
Production	Time between peaks	Duration between two DOC concentration peaks	Longer intervals between peaks promote DOC production and induce higher stream DOC concentration elevations during the next rewetting	(Fenner and Freeman, 2011; Ritson et al., 2017; Worrall et al., 2006)	Logarithmic
	Air temperature 7	Weekly mean of the water temperature prior to the DOC peak event	High temperatures enhance microbial and vegetation activity which increase DOC production within the peat and DOC concentration in the stream	(Billett et al., 2006; Clark et al., 2005, 2008, 2009; Koehler et al., 2009; Pastor et al., 2003)	
	Water temperature 7	Weekly mean of the water temperature prior to the DOC peak event			
	Peat water temperature	Water temperature observed at the beginning of the DOC peak event (from the mean water temperature of the piezometers)			

	Water table initial	Water table value at the beginning of the DOC peak event (from the mean water table level of the piezometers)	Initial water table value is an indicator of the non-saturated peat depth. A lower initial water table is related to a higher volume of oxygenated peat, where most of the DOC is produced.	(Bernard-Jannin et al., 2018; Billett et al., 2006; Clark et al., 2009; Fenner and Freeman, 2011; Ritson et al., 2017; Tunaley et al., 2016)	
Transfer	Stream level increase	Stream water level increase during the DOC concentration peak	DOC concentration increases with stream water elevations	(Austnes, 2010; Ryder et al., 2014)	Square-root
	Stream level maximum	Water level maximum during the DOC peak event			logarithmic
	Precipitation ¹	Total daily precipitation recorded during the rising period of the peak and the day prior to the DOC peak event	Precipitation triggers lateral transfer of DOC-rich water from peatland to surface water. Amount of precipitation is assumed to be representative of the surface runoff	(Raymond et al., 2016)	Square-root
	Water table increase	Water table increase during the DOC peak event (from the mean water table level of the piezometers)	Water table rise promotes DOC transfer to the stream through sub-surface flows. The greater the re-wetted peat volume (water table range), the stronger the stream DOC concentration	(Clark et al., 2009; Kalbitz et al., 2002; Strack et al., 2008)	Square-root

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1 **Table 2. Time series and DOC concentration peak metrics in Bernadouze over the 1st September 2015 to 31st December 2018 period**
 2 **and in Ech over the 22nd May 2015 to 13th February 2019 period. Mean notations correspond to arithmetic means which are given**
 3 **with standard deviations.**

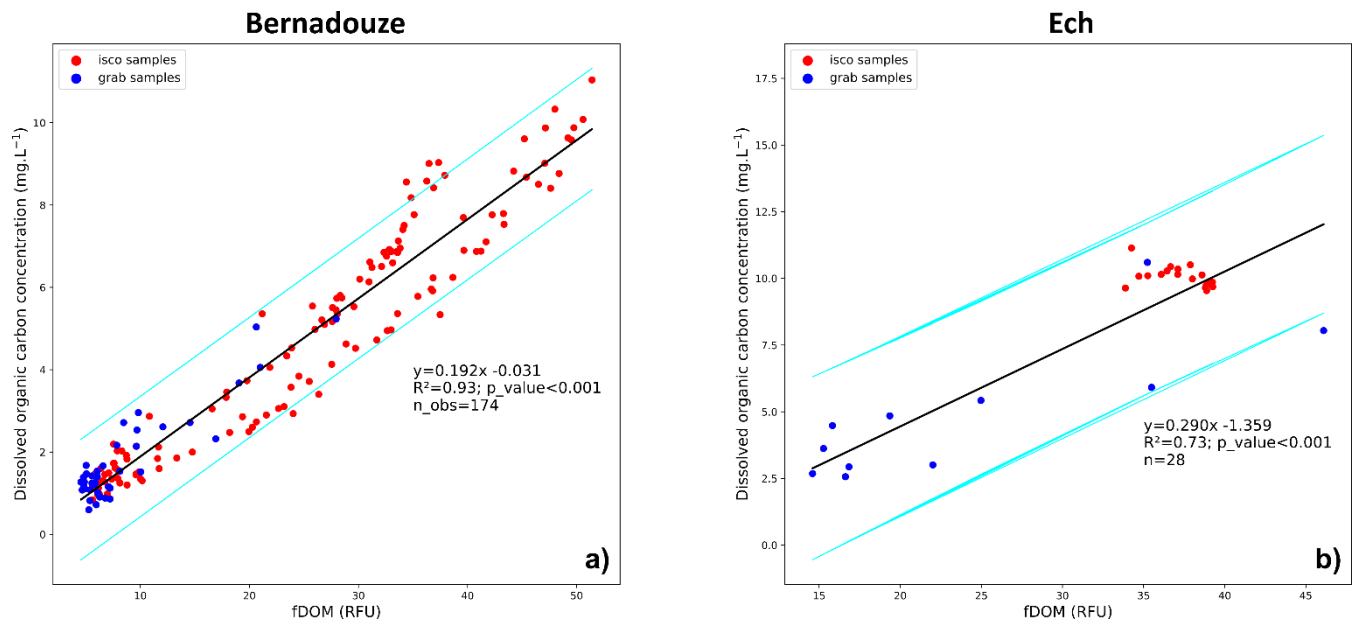
		Unit	Bernadouze	Ech
Time series	Days of study	Days	1218	638
	DOC data available	% time	86	99
	DOC (arithmetic mean)	mg L ⁻¹	1.8±1.2	6.7±4.9
	Discharge (arithmetic mean)	L s ⁻¹	34.1±74.2	8.4±12.0
	DOC concentration (flow weighted mean)	mg L ⁻¹	1.6	5.0
DOC concentration peaks	Number of peaks		252	101
	DOC maximum (maximum)	mg L ⁻¹	11.6	23.3
	DOC maximum (mean)		4.3±2.2	11.1±4.6
	DOC increase (maximum)		9.3	19.2
	DOC increase (mean)		2.4±1.9	5.2±3.3
	Water table increase (mean)	M	0.04±0.03	0.01±0.01
	DOC peak duration (mean)	H	32±14	28 ±16
	DOC peak rising duration (mean)		10±5	13±10
	Stream water level rising duration (mean)		10±7	12±11
	Water table rising duration (mean)		13±7	22±12
DOC concentration baseline	DOC initial (mean)	mg L ⁻¹	1,9±1.0	5,9±3.1
	Autumn		2,5±1.2	7,9±3.4
	Winter		1,7±0.7	5,3±3.5
	Spring		1,4±0.4	3,5±1.1
	Summer		1,7±0.9	5,6±1.2
	Time between peaks (Mean)	H	116±169	149±179
	Autumn		97±144	133±132
	Winter		196±221	140±219
	Spring		122±214	152±212
	Summer		105±111	180±172

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Table 3. Reduced models explaining DOC concentration during peak events (DOC_initial and DOC_increase) at the outlet of Bernadouze and Ech peatlands. Reduced models were obtained after a backward stepwise selection procedure applied on the full model (See details in Methods). Adjusted R² of each model are given as the predictors and their associated coefficient, p-value and R² contribution.

Response variable	Site	Adjusted R ² of the reduced models	Reduced models			
			Coefficients	Predictors	p-value	R ² contribution
DOC initial	Bernadouze	0.55	0.62	Peat temperature water	<0.001	0.24
			-0.50	Time between peaks	<0.001	0.24
			0.16	Precipitation 1	0.002	0.02
			-0.25	Water temperature 7	<0.001	0.03
			-0.14	Stream level increase	0.009	0.02
	Ech	0.44	0.84	Peat temperature water	<0.001	0.32
			0.24	Time	0.004	0.05
			-0.33	Water temperature 7	0.004	0.04
0.16			Precipitation 1	0.017	0.03	
DOC increase	Bernadouze	0.77	0.74	Water table increase	<0.001	0.52
			0.26	Water temperature 7	<0.001	0.17
			0.09	Stream level increase	0.019	0.07
			-0.14	Time between peaks	<0.001	0.02
	Ech	0.27	0.52	Water table increase	<0.001	0.27

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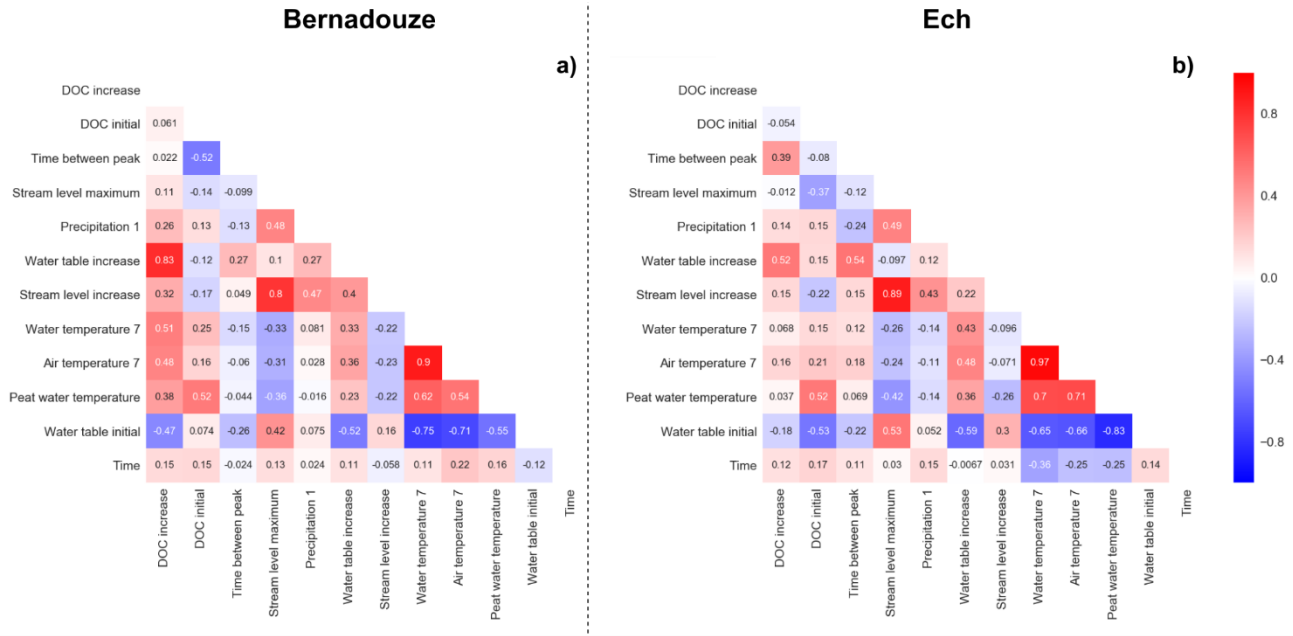
Figure A1. DOC concentration calibrations at the outlet of a) Bernadouze and b) Ech peatlands using in situ fDOM measurements from stream water manually (blue points) or automatically (red points) sampled. RFU stands for Relative Fluorescence Unit.

Peatland	Denomination	Depth (m)	pH	DOC concentration (mg. L ⁻¹)	Water recession time (day)
Bernadouze	PZ2	-2,20	5,7 ± 0,1	33,98 ± 6,3	77
	PZ3	-1,29	6,1 ± 0,2	15,65 ± 5,9	53
	PZ5	-1,73	6 ± 0,2	10,91 ± 5	45
	PZ6	-1,36	6,4 ± 0,3	10,49 ± 2,3	38
	PZ7	-2,15	6,6 ± 0,3	10,44 ± 1,5	48
	PZ8	-0,90	6,3 ± 0,1	7,42 ± 4,1	45
	PZ9	-0,98	6,1 ± 0,2	17,26 ± 9,6	15
	PZ10	-1,23	6,1 ± 0,2	14,49 ± 0,3	21
Ech	CEP1	-2,39	4,6 ± 0,7	17,7 ± 0,3	59
	CEP2	-2,38	5,5 ± 0,3	34,7 ± 9,7	63
	CEP3	-2,36	5,1 ± 0,3	33,6 ± 25,5	143
	CEP4	-2,28	4,6 ± 0,8	63,4 ± 2,9	125

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Table A2. Piezometer plot description. pH and DOC concentration were sampled four times in Bernadouze and 3 times in Ech. Water recession times were obtained from exponential master recession curve models.

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3 **Figure A3.** Pearson correlation matrices between the DOC concentration targeted variables and common explanatory variables at
 4 Bernadouze a) and Ech b). In view of their strong correlation with other variables (Pearson's correlation $|r| > 0.7$), the air
 5 temperature over 7 days (air_temp_bf7d), the stream water level maximum (log_water_level_max) and the initial water table level
 6 (piezo_level_initial) were excluded from the analysis. The air temperature over 7 days was preferentially excluded compared to
 7 water temperature over 7 days because of data reliability (air temperature was gap-filled at Ech).

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