Dear Dr Steven Bouillon

Our manuscript received two reviews and we carefully revised the text following their recommendations. We took into account minor issues of the 1st reviewer.

The 2nd reviewer raised two major issues: the addition of nutrients in experiments of biodegradation and the seasonality.

In the present work, we intentionally avoided addition of extra nutrients to experimental solutions. Our goal was to implement a standardized protocol of bio-degradation as recommended by Vonk et al (2015) for boreal and artic waters. In the literature, some studies were run with addition of (usually unrealistic) nutrient concentrations, and some were conducted without nutrients, with intact natural waters. This created quite an ambiguity in assessing the BDOC, and for these reasons, it was recommended to run biodegradation tests using a standardized protocol without nutrients (Vonk et al., 2015). In this paper, we followed this recommendation. We do present the nutrients concentrations in the Supplement. Note that the concentrations of nutrients are generally low because the peat is essentially oligotrophic and contains very little nutrients. Together with refractory nature of OM, it could be a cause of low biodegradability of DOM, but this is typical condition for large territory of frozen peatlands in Northern Eurasia. We agree with the reviewer that nutrients can be added by photochemical processes and nutrients might also be added downstream (away from the oligotrophic bogs), facilitating DOM degradation before discharge into the Arctic Ocean. However, the present study does not address the BDOC and PDOC export by the river to the Arctic Ocean.

As for the seasonality, our study was conducted in the middle of the summer, which matches the period used by other researchers for biodegradation assays. Thus we selected the month of July for consistency with other studies on bio- and photodegradation in the Arctic. Note that during spring flood, the DOM in the largest European Arctic River, Severnaya Dvina, which is similar to Pechora, is not at all biodegradable as shown in our recent work (Shirokova et al., 2017, Inland Waters). We added a big deal of discussion in revised section 4.3 in response to reviewer's comments.

Referee no 1

We fixed as recommended:

L111. "an important"; L128. "(iii)" and L561. Suggest changing "lack" to "... present a potentially..."

Referee No 2

This reviewer stated that the currently presented data is insufficient to support the far reaching conclusions. **We revised the speculative part of this study and moderated our far reaching conclusions via acknowledging a possible important role of seasonality and nutrients in bio- and photo-degradation assays.**

He/she further stated that the lack of freshet data and discussion is a major problem for the general conclusions drawn. **We do not consider carbon export by rivers and streams in the present work. However, we added pertinent discussion on seasonality in section 4.3. We would like to point out that previous works on biodegradation of Arctic waters revealed that aquatic BDOC in large streams and rivers decreased as the Arctic summer progressed, although this pattern was absent for soil leachates and small streams (Vonk et al., 2015), L 411-413.**

How much of the annual DOM and CO_2 flux is contributed during freshet (mid April to end of June)? **Seasonal variations of DOM export flux (concentration and discharge) in the Pechora river are shown in Fig R1, but there is no information on CO_2 flux. Note that the DOC concentration is the highest in July, when our experiments were conducted. There is no "DOM flux" in thermokarst thaw ponds and lakes as these are stagnant waters. The ice on lakes thaws in the beginning of June and everything is frozen from the middle April to middle May. The spring flood contributed about 60% of annual DOM transport by the Pechora River, but we do not see the link between this number and the bio- and photodegradation experiments in the present work. The DOM of spring flood is not bio-degradable (Shirokova et al., 2017b). For this reason, we focused on summer baseflow period.**

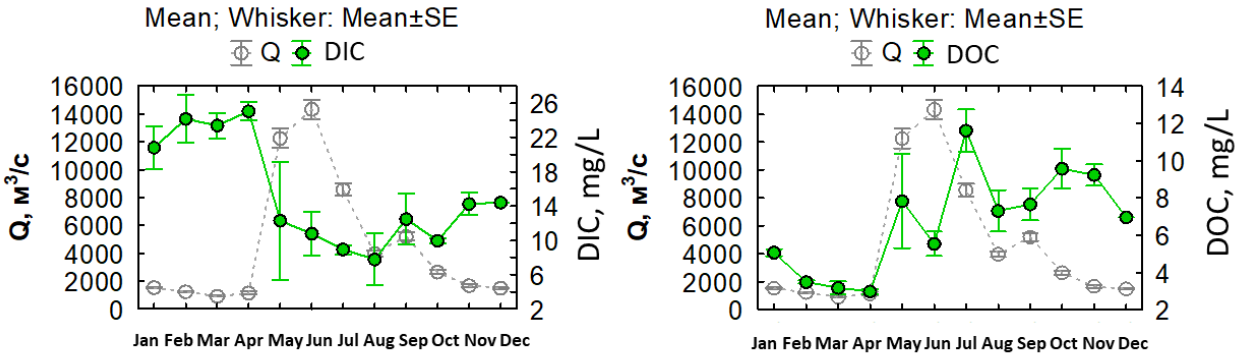

Fig R1. Seasonal variations of DOC and DIC concentrations together with discharge (Q) of the Pechora River (Chupakov et al., 2019 in preparation).

In the Ob watershed about 2/3rd of the annual terrigenous DOM flux occurs during freshet. **We are well aware of this fact as we demonstrated in our recent paper on the Ob River export of DOM (Vorobyev et al., 2019). The Ob watershed has only 20% permafrost coverage (unlike the thermokarst waters of the present work) and it is some 1000 km east from the Pechora watershed. We do not understand the link between the Ob River, cited by reviewer, and the objects of the present study. Further, we believe that biodegradation during freshet even in large river is not important as we stated in L 419-423: "In the estuarine zone of largest European Arctic permafrost-free river, Severnaya Dvina, there was no measurable biodegradation in spring, when the DOM was dominated by allochthonous sources, but a 15 to 20% decrease of DOC occurred during first 300 h in river water collected in August, when sizeable phytoplankton productivity was observed (Shirokova et al., 2017b)."**

The lack of combined photooxidation/bacterial decomposition experiments and the lack of nutrient additions during decomposition experiments also put a damper on their too general conclusions.

Following the reviewer's remark, we alerted the reader that the lack of seasonally-based data set and does not allow sufficient representability of results for the pan Arctic boreal environment (section 4.3). The addition of nutrients was intentionally avoided as we followed the standardized recommended protocol for biodegradation experiments. The combination of photooxidation/bacterial decomposition is certainly important as it is already acknowledged in the manuscript (L 82-85), but it goes beyond the objectives of this study.

Nutrients and labile DOM can be added by photochemical processes and nutrients might also be added downstream (away from the oligotrophic bogs), facilitating DOM degradation before discharge into the Arctic Ocean. **This is a valuable comment and we added this possibility to revised text (section 4.1). We agree that nutrient addition downstream can increase the capacity of DOM bio-degradation. However, this will be true solely for large river such as Pechora. For the other 3 water objects, there is no possibility of nutrient and labile DOM addition as they are entirely located within the oligotrophic bogs. We also stated in section 4.1 that "It is possible that in natural settings, the input of biolabile DOC from terrestrial vegetation may enhance the bioavailability of stable DOC (e.g., Textor et al., 2018) although this effect could not be tested in this study."**

In terms of CO_2 saturation in these waters. What is the seasonal fluctuation of DIC?

The seasonal fluctuations of DIC (together with DOC) for the Pechora River are shown in Fig R1. The minimal DIC concentrations are encountered during summer baseflow, when we performed our experiments. We do not see any link between DIC concentration in Pechora (which is mostly dependent on groundwater discharge from underlying carbonate rocks) and DOM photo- and biodegradability investigated in this study. It is clearly stated in the text that the DIC concentration cannot be a tracer of DOM degradation due to intrinsic analytical constraints (section 3.1, L 325-330).

The DOC, DIC, CO_2 concentration and CO_2 emission fluxes in thermokarst lakes and ponds of the Bolshezemelskaya Tundra are illustrated in Fig. R2 (Zabelina et al., 2019 in preparation). It can be seen that, contrary to expectations of the reviewer, the spring-time period does not exhibit any particularly high C concentrations in lentic waters of frozen peatlands of the Bolshezemelskaya Tundra. This is confirmed by other observations in similar context of permafrost-affected wetlands: the spring-time period does not exhibit any particularly high C concentration in thaw ponds and thermokarst lake waters of frozen peatlands (Manasypov et al., 2015), and CO_2 concentrations and emissions from rivers and lakes of permafrost-affected wetlands of western Siberia were not much higher in spring compared to other seasons (Serikova et al., 2018, 2019). We added necessary explanation in the text (section 4.3).

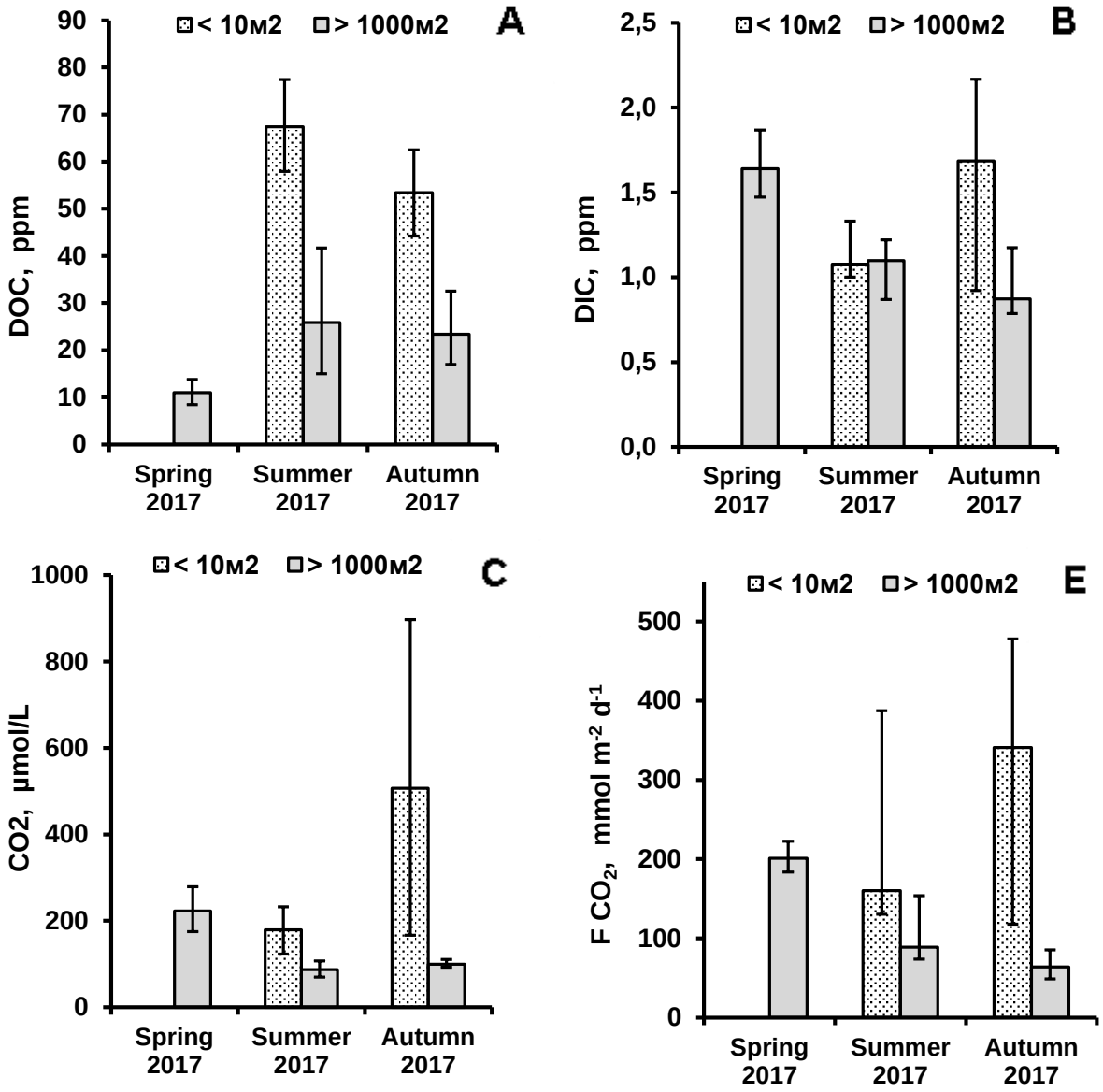

Fig R2. Median and interquartile concentrations of DOC (**A**), DIC (**B**) and CO_2 (**C**) as well as $_{CO2}$ emission fluxes (**E**) in small thaw ponds (< 10 m²) and thermokarst lakes (> 1000 m²) of the Bolshezemelskaya Tundra in 2017 (Zabelina et al., 2019 in preparation).

At the pH values presented in this manuscript most DIC will be in form of CO_2, so even a small DIC concentration of 1 mg/l would produce CO2 levels around 1400 ppm. **We agree with this remark but do not see the point of the reviewer. We did not design our study to monitor the pCO_2 or DIC variations in natural waters of the permafrost zone and we did not measure CO_2 during incubations. The paper is about bio- and photo-degradability of DOM.**

What is the seasonal contribution of carbonates? **There are no hydrological connections between frozen peat and silt of thermokarst water bodies and underlying carbonate rocks. As a result, there is no contribution of carbonate rocks to C pools of thaw ponds and lakes. The contribution of carbonate rocks to DIC concentrations in the Pechora River should be similar to that of other boreal and permafrost affected rivers of the Northern Eurasia (Pokrovsky et al., 2010; 2015) but this was not the objective of our study.**

What is the time scale of gas exchange? **The rate of gas exchange is certainly faster than the water residence time in studied thaw ponds and lakes. We demonstrated this in a number of thaw lakes and rivers of western Siberian Lowland (Serikova et al., 2018 Nature Geoscience; Serikova et al., 2019 Nature Communication). Moreover, there are diurnal variations of pCO_2, pH (but not DOC) in thermokarst lakes (Shirokova et al., 2019 unpublished results). However, we do not see the link of the question on gas exchange scale, raised by reviewer, and bio- and photo-degradability of DOM in thermokarst waters, studied in this work.**