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Comment on bg-2021-338

Anonymous Referee #2

Referee comment on "Soil carbon loss in warmed subarctic grasslands is rapid and restricted to topsoil" by Niel Verbrigghe et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-338-RC2, 2022

Interactive comment on "Soil carbon loss in warmed subarctic grasslands is rapid and restricted to topsoil" by Niel Verbrigghe et al.

General comments

I was attracted by the observation system set up to study the effects of global warming on SOC stocks and globally by the results obtained.

Beyond its originality, the observation system built offers above all a serious opportunity to study the response of C stocks in grassland soils both in the medium and long term, in a solid manner. Indeed, the observations were carried out in situ on local warming gradients applied naturally, i.e. by fully preserving the components of the ecosystems in place. This makes it possible to integrate *in situ* the combined responses of all these components on the soil C stock. It is rare and very valuable to have such observations. For this reason and in order to improve the readability of the document, a more explicit synthetic description of the device (distribution of the plots around the hot spots, number of plots...) should be presented in the main text (from line 30). Finaly, a reference to appendix A must be added in the main text.

I would like to emphasise that the observation set-up created by the authors shows remarkable rigour. Many precautions were taken in the design of the soil samples on transects distributed around the geothermal points. In addition, a great deal of expertise

was deployed to verify and characterise the heating gradients obtained at the soil surface and at depth. The measurement methods used are not only well documented but also show a high level of rigour in the acquisition of field data. I particularly appreciated the efforts made to estimate the SOC stocks by taking into account the evolution of the apparent soil densities under the effect of warming (corrected SOC stocks).

Thanks to all these investments, the results are mostly convincing. They clearly show an ephemeral SOC loss under warming from the upper soil layer. On the other hand, I am less attracted and convinced by the results and conclusions concerning the SOC dynamics in deep soils. Indeed, only soils under long-term warming could be sampled, which weakens the level of investigation on the response of deep SOC to warming. As a result, these deep SOC results and their interpretations are less robust and original than the previous ones, although 3 paragraphs are dedicated to them against only one previously (L79-83). A better balance between these two axes of results should be found, which would reinforce in this paper the place given to the temporal dynamics of the SOC response to warming, for which the results obtained in this original device are clearly convincing.

The ephemeral SOC loss under warming from the upper soil layer has been observed here on a natural warming device. These results are in line with other results showing an ephemeral increase of soil respiration but obtained under experimental (i.e. artificial) warming conditions. It is interesting to note that these studies, although distinct in terms of the ecosystem studied (artic grassland vs. temperate forest), share similar soil warming gradients and lead to similar durations of increase in C loss fluxes (5-6 years) before this positive response to warming disappears. Among the possible explanations already proposed in the literature to address this change in response to warming over time, several are mentioned here and sometimes tested in coherence with data collected on site when available. Nevertheless, one explanation proposed in the literature is totally absent, although it would offer an additional interpretation here that would be particularly consistent with the idea put forward by the authors regarding "the interplay between soil microbial biomass and activity" (L77). This is the positive temperature effect on enzyme inactivation which results in a reduction of the catalytic power of enzymes under warming (Alvarez et al. 2018). By accelerating the inactivation of enzymes produced by microbes, warming leads to a reduction of the enzymatic breakdown of soil organic C in the long term. Moreover, when taking into account this temperature-dependent process, which constrains the dynamics of the enzyme pool, simulation shows an ephemeral positive response of enzymatic activity, which is followed by a disappearance of the positive long-term effect of warming or even a negative effect. Considering this theory would also contribute to the discussion on the response of the soil microbial biomass (negative) and CUE reported by the authors. Finally, this theory would bring an additional element to the discussion on the carbon-climate feedbacks of warming.

Concerning data analysis I have some comments regarding the statistical models used to analyse the effect of warming on variables. In particular, I found it difficult to digest the construction made in figure 1 and thus to adhere completely to the interpretations made in terms of warming effect. My first concern was that the data used to construct the relationship combine the two sampling dates for each field plot, i.e. two different warming durations for each field plot (confonding effects). Reading the last paragraph of Appendix A, which briefly describes the mixed model used, reassured me a bit. Nevertheless, a more explicit presentation of this model with statistical results obtained and interpretation

for at least the SOC stock variable would be necessary in the appendix (with reference to appendix in the main text and the caption of Fig1).

Technical comments

L50 - I did not understand where the number in brackets "or 8.8 °C^{-1} " came from or its unit. Please clarify.

Appendix A - L163 – "we adopted a regression approach" Please specify briefly the purpose.

Appendix A - L185 – "for a some weeks" remove "a"

Fig 2a legend. SOC stocks are expressed as "kg ha^{-1}". Replace by ton ha^{-1} ?

Fig 2 legend. please add 0-10 cm to the axis units

Fig 2 - It is surprising to see only 2 data (points) for the 4.1-5.1°C warming, which are also well above the curve for this warming category. Are there any missing dots or is there a problem with the legend colors?

Figure B1 – In the caption, rather than "Reduction of…" I guess that it would be more appropriate "Uncorrected carbon stock…"

L70 - please move up the reference to fig3 from line 71 to line 70

Fig 3: The x-axis shows soil warming range from 0 to 18°C. This is different from the soil warming range 0-6.4°C. Please clarify and give explanation in the text.

L72, 73 and elsewhere – It would be more explicit to replace "soil C %" by "C

concentration" in soil fractions.

L70 – The name of fractions should be improved to increase direct readability without increasing words number. ">2 mm" corresponds to 2-8 mm, ">250 µm" corresponds to 2000-250 µm, ">63 µm" corresponds to 250-63 µm.

L76 – "emerged from the interplay between soil microbial biomass and activity". Wouldn't it be clearer to talk about a change in the specific activity of the microbial biomass?

L77 – "Warming at the same study site accelerated microbial growth and respiration (Marañón-Jiménez et al., 2018; Walker et al., 2020)" – Please could you clarify here whether these two warming-induced accelerations were observed only in the medium term or also in the long term?

L79 – Reference to fig B1a. Add "a" and "b" in fig B1.

With kind regards