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Interactive comment on "Dynamics of deep soil carbon – insights from ^{14}C time-series across a climatic gradient" *by* Tessa Sophia van der Voort et al.

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Response to Reviewer #2

This study aims at investigating the dynamics of carbon as a function of soil depth in five sites of the Swiss Alps. To reach this goal the authors realised 14C measurements on samples collected in late 90's and in 2014. Soils were sampled at different depths and a water extractable fraction was extracted. The authors derived C turnover rates from 14C data using a two-pool model. They identify a substantial fraction of fast-cycling C at depth and further investigate potential edaphic and climatic drivers of turnover. The data gathered in this study are of great interest, but at this stage, the manuscript

suffers from too severe limitations to be published.

–> Thank you very much for your positive feedback regarding the quality of the dataset and insights which can be gained from it. You indicated that the main limitation was the two-pool modelling, so we addressed this, details below. We have also addressed the other issues that have been raised. Thanks again for your helpful review, it helped further improve this paper.

In particular, the authors should decide what is precisely their objective: do they want to provide insights on deep C cycling or to offer a new method to compute turn-over time using 14C data? I would suspect the readers of Biogeosciences to be really interested in the first option, as there are only a limited number of studies on this topic (as claimed in l 276 of the discussion).

–> Thank you for posing this question. Indeed, our objective is to provide insights on deep soil C cycling, and not to develop a new model such as the likes of Century or RothC. We have clarified this and further simplified the modelling. We merely switch from an excel-based manual, iterative, time-consuming with limited error quantification optimization to an automated form in excel with error quantification.

Nevertheless, the data on C turn-over along the soil profile are mainly presented as supplementary, while there is a strong focus on methodological aspects in the main text.

We present the 14C data and 14C turnover data in graphs in the main texts (Figures 3-5), and the raw data can be found the SI. We have augmented our graphs.

The discussion should also be improved. Too many repetitions of the results in 4.1.1 and 4.1.2; 4.1.3 repeats some facts of 4.1.2. 4.2:

–> Thank you, we of course avoid repetition, we removed the overlapping content. The different sections do refer to the same data, so re-addressing certain patterns is unavoidable.

I could not find clear information in the materials and methods section about how the data supporting this section were collected.

–> Thank you, actually in sections 2.1 and 2.2 we detail that our samples are part of the long-term ecosystem monitoring program (LWF) of the Swiss Federal Institute for Forest, Snow and Landscape research, and that our ancillary data derived from publications related to this program.

The introduction/rational should refer to the needs of information on petrogenic C. 4.3: you could condense your message as you expose the same arguments for bulk C and WEOC.

–> Thank you, we have included this.

Some references to recent publications on deep C dynamics are lacking (i.e. He et al., 2016; Mathieu et al 2016; Balesdent et al 2018) while they could improve the discussion.

–> Thank you, some of these papers were already included, and we have added the rest.

I finally encourage the authors to carefully examine the relevance - and the quality - of their illustrations (see some comments below). A better focus of both the text and illustrations would guarantee a better understanding of the message the authors could deliver from the very exceptional dataset they collected.

–> Please see the comments below, indeed, visuals are key!

Some additional comments Could you indicate what is “Rsample,t” in Eq 1 and 2.

–> We have clarified this in the text

The model is based on the assumption that k1 is the turn-over of the WEOC pool. However, how do you justifythat m1 is not the size of the WEOC pool (please provide the C content of the WEOCin your MS). ?

–> Indeed, this is an assumption, we have adapted this in the text. We have included the WOEC concentration data in the Si, it is usually < 1%.

Clarify what do you mean by deep, and provide numerical value when you refer to depth in the text – currently you sometimes use it indifferently to refer to 30 cm or 80 cm, while the data strongly differ between both depths.

–> We mean > 20 cm (Mathieu et al., 2016), and have clarified this in the text.

Some Figures and Tables are offered to the readers while they are not utilised in the text: remove them (one example is Fig 3 - PS the information on the back curve is missing in the legend)

–> Thank you for noticing, we added this.

I do not understand Figure 2. How do you compute turn-over time using one individual time point?

–> We have clarified this in the text as well as the figure.

I suggest to remove Figure 5 as it is not precise – keep it for oral presentations - (what is vulnerable C?) and to provide Tables with exact numerical data in the main text.

–> Thank you, we have removed the portion about vulnerable carbon as suggested. As the heatmaps have accurate legends, we do believe it is precise enough to keep it in the paper.

Please provide the C content in for the samples measured for 14C. (Table 3 only show 3 different depths, while the data is available according to Fig 5)

–> Thank you, we have included the carbon stocks in the main text, which is most relevant when considering the turnover estimates. The carbon content data can be found in the SI as well as the Excel file with the raw data for this paper

You provide twice the particle size distribution (Tab 2 and 3).

–> Thank you, we have deleted the overlapping part. The difference between the tables is that Table 2 is an average Table 3 is per depth interval.

Some of your interpretations rely on soil waterlogging while this information is not clearly available (when you first mention waterlogged soil line224, the reader has not idea of which sites are concerned). In addition, I would not conclude that waterlogging is a driver of turnover by looking at the non-averaged values in Table S5.

–> Thank you, we have clarified this and adapted the interpretation.

Why are the radiocarbon signatures of WEOC different between waterlogged and non-waterlogged soils in 3.1, while calculated turnover rates are not?

–> Waterlogged soils have slower turnover, both in the bulk and in the WEOC. We have explained in the discussion that this is likely due to the impact of mineralogy as impacted by the geology, interacting with the climate.

Change your title: your gradient is not only a climatic one but a geologic one as well, with strong implication on C cycling.

–> We have highlighted the geological aspect in the introduction and discussion.

Figure 6: the colour code is not the same than in other figures.

–> Indeed, this figure shows the depth profiles dug from pits, and not the plot-averaged samples, that's why we opted for a different colour code.

I do not understand Table S1: how do you compute single resolved 14C data?

–> Thank you, this was not clear, we have clarified this in the text.

Fig S2: what stands at -20cm depth?

–> It is the 20 cm thick humus layer – we have adapted this and clarified it in the text.

Table S5: figures are not aligned in the table what makes the reading a bit tricky. The caption is not in the same order than the columns. The title of the 5th column is not

clear (=> proportion of labile pool would be better)

–> Thank you for highlighting this, we have adapted Table S5 accordingly.

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2018-361, 2018.

Response to Reviewer #2

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Fig. 1.

Dynamics of deep soil carbon – insights from ^{14}C time-series across a climatic gradient

Tessa Sophia van der Voort[1], Utsav Mannu[1,†], Frank Hagedorn[2], Cameron McIntyre[1,3], Lorenz Walthert[2], Patrick Schleppi[2], Negar Haghipour[1], Timothy Ian Eglinton[1]

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Abstract. Quantitative constraints on soil organic matter (SOM) dynamics are essential for comprehensive understanding of the terrestrial carbon cycle. Deep soil carbon is of particular interest, as it represents large stocks and its turnover rates remain highly uncertain. In this study, SOM dynamics in both the top and deep soil across a climatic (average temperature ~1-9 °C) gradient are determined using time-series (~20 years) ^{14}C data from bulk soil and water-extractable organic carbon (WEOC). Analytical measurements reveal enrichment of bomb-derived radiocarbon in the deep soil layers on the bulk level during the last two decades. The WEOC pool is strongly enriched in bomb-derived carbon, indicating that it is a dynamic pool. Turnover time estimates of both the bulk and WEOC pool show that the latter cycles up to a magnitude faster than the former. The presence of bomb-derived carbon in the deep soil, as well as the rapidly turning WEOC pool across the climatic gradient implies that there likely is a dynamic component of carbon in the deep soil. Precipitation and bedrock type appear to exert a stronger influence on soil C turnover and stocks as compared to temperature.

1 Introduction

Within the broad societal challenges accompanying climate and land use change, a better understanding of the drivers of turnover of carbon in the largest terrestrial reservoir of organic carbon, as constituted by soil organic matter (SOM), is essential (Batjes, 1996; Davidson and Janssens, 2006; Doetterl et al., 2015; Prietzel et al., 2016). Terrestrial carbon turnover remains one of the largest uncertainties in climate model predictions (Carvalhais et al., 2014; He et al., 2016). At present, there is no consensus on the net effect that climate and land use change will have on SOM stocks (Crowther et al., 2016; Gosheva et al., 2017; Melillo et al., 2002; Schimel et al., 2001; Trumbore and Czimczik, 2008). Deep soil carbon is of particular interest because of its large stocks (Jobbagy and Jackson, 2000; Balesdent et al., 2018; Rumpel and Kogel-Knabner, 2011) and perceived stability. The stability is indicated by low ^{14}C content (Rethemeyer et al., 2005; Schrumpf et al., 2013; van der Voort et al., 2016) and low microbial activity (Fierer et al., 2003). Despite its importance, deep soil carbon has been sparsely studied and remains poorly understood (Angst et al., 2016; Mathieu et al., 2016; Rumpel and Kogel-Knabner, 2011). The inherent complexity of SOM and the multitude of drivers controlling its stability further impedes the understanding of this globally significant carbon pool (Schmidt et al., 2011). In this framework, there is a particular interest in the portion of soil carbon that could be most vulnerable to change, especially in colder climates (Crowther et al., 2016). Water-exactable organic carbon (WEOC) is seen as a dynamic and potentially vulnerable carbon pool in the soil (Hagedorn et al., 2004; Lechleitner et al., 2016). Radiocarbon (^{14}C) can be a powerful tool to determine the dynamics of carbon turnover over decadal to millennial timescales

1

Fig. 2.