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Interactive comment on “Storage and transformation of organic matter fractions in cryoturbated permafrost soils across the Siberian Arctic” by N. Gentsch et al.

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Comments on Referee 3

Thank you very much for taking time to review our manuscript. We appreciate the valuable comments and tried to consider them in our manuscript wherever meaningful. In the following, the referee comments are given in bold, followed by our response as plain text.

No basic parameters of the soils were reported. For example it is only within the text that the reader learns about the high pH values of these soils, which are

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likely influencing all the chemical and even biological transformations occurring. I think that this may be a problem of data allocation to different manuscripts, as another one is submitted right now. However, such basic information needs to be included in the manuscript for the different soils/horizons sampled along with their elemental content and some information on mineral parameters, i.e. different extraction results.

All basic soil parameters are already presented in the supplementary material. Figure S1 shows the soil texture while table S1 presents soil pH and exchangeable cations across all sampling sites and soil horizon classes. We decided to publish these data in the supplements because of the overall size of the manuscript.

The manuscript would have benefitted from the inclusion of the 14C data, to give at least some indication on microbial activity/ decomposability. As such, the manuscript provides a lot of detailed information of SOM association to different fractions, which in the end does not lead to any additional progress. Also, it is not evident from the data presentation, why a longitudinal gradient was sampled? Is there any added value from the analyses of these well chosen samples or is it just nine separate sites? Can any longitudinal trends be indicated?

We agree that 14C data would improve the whole story. We have measured the 14C content and as well as OC mineralization in incubation experiments. However, these data are part of a second manuscript in preparation. The idea was to describe the sampling sites and soil characteristics including OC stocks in different fractions in a first publication. The benefit of this manuscript is that we, for the first time, quantified the storage of different OM fraction across a large number of permafrost soil pedons. In the second manuscript (in preparation), we will then directly refer to the OC stock

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data. Focus of the second manuscript will be the bioavailability of different SOM fractions and the temperature sensitivity of OC mineralization. Radiocarbon data and bioavailability from the east Siberian sampling sites are also shown in Gentsch et al. (2015), recently accepted for publication in EJSS. We selected the study sites according to the three main geographical regions in Siberia (East-, Central-, and West Siberia). With a longitude gradient we try to cover the dominant tundra ecosystems within the regions as shown in Table 1 (e.g. a gradient from grass tundra to forest tundra in Western Siberia). Initially, we emphasized to explore longitudinal gradients as well. However, the small scale heterogeneity of OC stocks at the sampling sites was larger than between the sampling sites across a longitudinal gradient. The only statistically significant gradient was found between main geographic regions. The small scale heterogeneity depends primarily on the abundance of cryogenic processes instead on shifts in plant communities and tundra ecosystems.

I have a problem with the sample preparation procedure. The samples were air dried. However, the authors mention in the text in some place the importance of changing redox conditions for the processes operating in these soils. What is the potential impact of airdrying on the results obtained?

The samples were dried before transport to the laboratory (also to reduce weight for helicopter flight). Surely, this is a weakness in our study and we therefore cannot draw direct conclusions about the redox conditions from the dried samples. However, the in situ redox conditions at the sampling sites were reflected by field determination of soil color, which changes in the soil profile along with the water content (determined on fresh samples). Moreover, we found high Feo/Fed ratios which are indicative for hydromorphic soils and mirror changing redox conditions (Cornell and Schwertmann, 2003). Air-drying, also tended to aggregate the soils. This was the reason to refuse the separation of an occluded organic matter fraction by density fractionation. Apart from that, we do not see that air-drying influenced the results of this study.

Moreover, I found curious that you used (Fep+Alp)/(Fed+Ald) as an indication of complexed OM. In my opinion the determination of C in the pyrophosphite extract would give a much better proxy.

The (Fep+Alp)/(Fed+Ald) ratio was initially introduced by US Soil Taxonomy as index for the total amount of Fe and Al which is potentially complexed with OM (USDA, 1999). We agree that this index is not any more state of the art and have removed it from the manuscript. As the pH values of the soils were apparently very high, I wondered why the occurrence of inorganic carbon in these soils was never discussed. We have tested all samples for inorganic carbon. Only in the samples from the East Siberian sites we found measurable amounts of inorganic carbon (<1% dw). Prior to total OC measurements, the inorganic carbon was removed by HCl fumigation. The high soil pH in the transient layer and permafrost horizons, however, derived from high electrolyte concentrations. Mainly Na and/or K salts accumulate within the subsoil and the frozen soil layers as result of impeded drainage. Due to the higher summer evapotranspiration than drainage, large amounts of salts accumulate within the active layer and the permafrost (Lopez et al., 2007). This is evident from the increase of exchangeable base cations (especially K⁺ and Na⁺) towards the permafrost. Additionally, the parent material derived from shallow marine sediments and may contribute to a higher salt concentration as well. This certainly interesting phenomenon was beyond the scope our story and we did not discuss it further. Instead we refer to Lopez et al. (2007), who discussed in detail the epigenetic salt accumulation in permafrost soils.

Heavy and light fractions are compared in terms of C/N. However, this may be not advisable, considering that the heavy fraction may always contain a substantial amount of inorganic N.

We agree that the bulk of the inorganic N (N_{min}) will be found within the heavy fraction and the C/N ratio have a different meaning compared to the LF. We emphasize this fact now more precisely in the manuscript. Both fractions have a different functionality in the soils. Based on the C/N ratio we can show that the HF is the principle source of

inorganic nitrogen and comprised the majority of the microbial resynthesized material. The HF may also be responsible for fixation of ammonium (e.g. in the interlayer of clay minerals). The LF, however, has very wide C/N ratios and is close to the C/N of the plant source and similar to the unfractionated O horizons (see Figure 6). We have measured the Nmin values (NH₄ + NO₃) only from a selected pool of samples. Thus we could not correct the whole TN data set for Nmin. The figure below is showing the TN as 100% and the proportion of organic N (ON), ammonia (NH₄), and nitrate (NO₃). NH₄ and NO₃ was measured from fresh soil, which was extract directly after sampling from two sites on Taimyr Peninsula. In general, the inorganic N was far below 1% of the TN in the bulk soil. Only in few samples Nmin exceeded 2% of TN. However, during density fractionation most of the Nmin is lost by exchange with sodium polytungstate. Taking into account that only ammonium in the interlayer of clay minerals can survive the density fractionation treatment, the proportion of Nmin to TN within the HF is definitely negligible.

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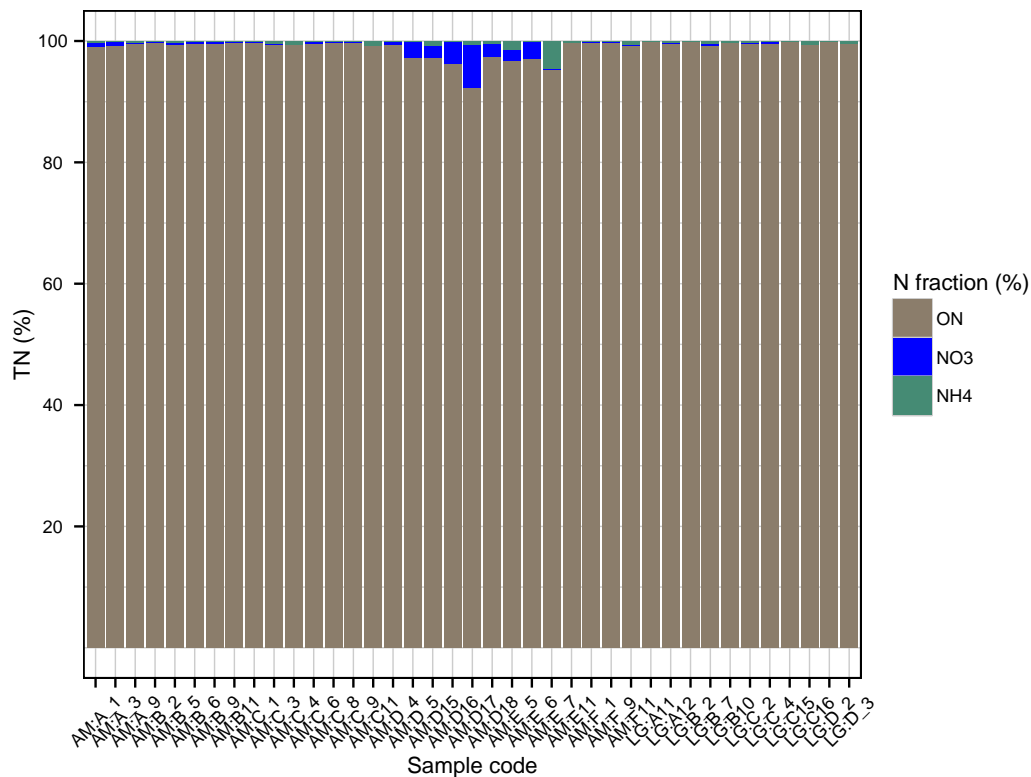


Fig. 1. Proportion of mineral N (NH₄+NO₃) to total N values (100%). Abbreviations: ON, organic nitrogen; NO₃, nitrate; NH₄, ammonia.

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