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Interactive comment on "Current, steady-state and historical weathering rates of base cations at two forest sites in northern and southern Sweden: A comparison of three methods" *by* Sophie Casetou-Gustafson et al.

Anonymous Referee #2

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The manuscript utilized three different methods and quantified weathering rates in two forested sites in Sweden. This study is very interesting, and I applause such efforts, as most studies focused on just one method. So this manuscript may be of interest to the community that Biogeosciences serves. However the manuscript, as currently written, made it difficult to understand exactly how three methods work, and evaluate the uncertainties from each method, in order to compare them for magnitude, depth gradients etc of such weathering rates, and provide recommendations how these methods are used for future studies. Below I provided ways to improve, followed by detailed

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comments.

(1) The title of the manuscript suggests that this study focuses on the comparison of three methods and examines how they are similar or different in quantifying the weathering rates. If so, the details of these three methods need to be explained in great details.

Historical weathering rates This is also called “long-term” weathering rate in the literature, and is estimated from soil chemistry/mineralogy. A few important considerations are missing from the paper.

The balance of chemical degradation versus physical erosion. What are the topographic features in the study sites? If the areas are flat and minimum physical erosion is present, this needs to be stated clearly in the paper. In contrast, if the erosion loss is important, then the top layer that was most depleted had been eroded away and the historical weathering rates will be underestimated.

The equations used need to be included in the paper, in addition to the citations (Marshall and Haseman (1943) and Brimhall et al. (1991)). For example, bulk density data were used as input data, but the method did not specify how BD was used. I am specifically interested in mass transfer coefficients and the volume change factors. For example, if the soil collapsed or expanded during chemical weathering, then the sample interval 10-20 cm, for example, may not be from 10-20 cm of original sediment before collapse or expansion. If so, the gradients or the total weathering rates may not be represented well. More importantly, the overall weathering rates, plotted in Figure 3, will be off.

QA/QC is needed for elemental data, including Zr, as this is important to evaluate the mobility of base cations as chemical weathering occurs. Zr concentration is extremely low as reported in Table 2, around 2 to 5 ppm. What is the precision in these low concentrations?

Line 254-Line 257 and Line261-Line262: How is the soil/sediment from a certain depth chosen as parent for a weathering profile needs more discussion. The manuscript assumed constant Zr concentrations and explored this by plotting Zr/Ti ratios in Figure 1. This is okay, but what about the homogeneous nature of these glacial sediments, in terms of base cations? For example, does major elemental chemistry remain constant after the 60-70 cm? This is critical to evaluate the error bars for mass transfer coefficients and weathering rates. By looking at data from Table 2, parent chemistry is different among all sites. Does that imply glacial sediments have varible chemistry with depth too?

Age: time used for quantifying historical weathering rates is the age of the landscape, i.e., the time since glacial retreat. However this is the age of the soil at the surface, and soils at deeper depths should be much younger. Indeed, as weathering proceeds, soil thickness increases ($\sim$70 cm according to this manuscript in southern and northern Sweden). If so, the age of soils decreases with depth. At the soil/parent boundary, the soil age should be zero. If so, how can release rates of cations be quantified using one age? This probably also explains partially why weathering rates are much higher at surface than at depth in Figure 2.

PROFILE model I understand that several other manuscripts are under review on the PROFILE model in the same issue. However since this manuscript stands on its own, and the PROFILE model is compared to other methods. It is reasonable to provide enough details for PROFILE model in this manuscript too.

What is a steady state weathering rate? Can you define it and also justify why steady-state is assumed? The introduction mentioned S emission and forest acidification etc. Would this allow a steady-state status at this?

Some default values, including pCO2, soil moisture etc are used for PROFILE modelling. Can you make a table to show how these variables are different or similar among all sites? This is very important as you start to compare sites for different weathering

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rates in Results and Discussion.

For sensitivity analysis, in section 2.4.3, three groups of variables are listed. Can you list values or ranges of these variables in the table above? A homogeneous soil profile is used. Can you write a couple of sentences to explain why such a scenario is chosen? I am also interested in the residence time of soil water at each depth interval.

Base cation mass balance I think it is critical to explain how much uncertainty is induced by different assumptions. For example, in quantifying the uptake in biomass (BBC), mass of fine roots was assumed and below ground biomass were estimated. How much error is this in the overall BBC?

The canopy budget method was used to quantify the inputs from atmospheric deposition (introduced between Line 304-Line 310). However, I am not sure I understand how it is done. Can you elaborate? How is dry deposition data used to estimate "dissolved" load of base cations?

Leaching (LBC) is estimated using three soil water samples collected at 50 cm. Is this for one year only, or multiple years? This is not an optimum method as soil water chemistry is known to vary significantly over seasons (e.g., a function of soil water residence time, biological uptake etc). Can you explain how different water chemistry is and when exactly the samples were collected? The evapotranspiration is estimated by CoupModel. This is entirely model-based, and is there any way to validate this?

Does plagioclase or amphibole weather to form smectite or other clay minerals and thus retain the cations?

Table 4 is a great effort to assess the data quality and evaluate the uncertainties in quantifying WBC using mass balance approach. Some are already discussed in the Method section, in terms of data source and spatial/temporal scales of data collection, and the only column added is the quality of term quantification. However the term quantification is so qualitative, and what is the cumulative errors in WBC? The leach-

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ing is listed as high temporal resolution. I do not think 3 sampling over one year is considered high temporal resolution though.

(2) Discussion Line 521-Line 529: I am not sure I understand this discussion. The weathering rates at pedon scales are compared to others. Should they be similar or different and Why? These statements are not useful if they are not put into some context where sites can be compared, in terms of soil age, types of parents, etc.

Line 542-555: similarly, this discussion cited several studies on different Wprofile/Wdepletion ratios, but did not specify where these ratios are above or below 1. If so, what do we learn?

Line 586-Line 587: The correlation is observed between weathering rates and bulk density. What does this mean? How does bulk density change the mineral dissolution kinetics? Why is it linear? Also according to the method, bulk density is estimated and it increases with depth. If so, is this correlation between weathering rates and bulk density an artifact?

Line 598-Line 620: It is frustrating that the depletion method was introduced and weathering rates were calculated and discussed, and then here the authors explained that Zr may not work as an immobile element, and the depletion method is not working.

(3) In Figure 3, weathering rates by three methods for two sites are compared. Error bars are added to represent the uncertainties for each rate. However it is not explained exactly how error bar is derived. This is very important.

Minor comments: Acid silicate bedrock: I have never seen this phrase before. Do you mean siliceous or felsic? Or do you really mean the bedrock is low in pH?

Line 94: recovery is driven mainly by silicate rocks? What about carbonate rocks? Line 181: different font used here. Line 183: Missing “rates” after weathering. Line 197-Line 200: What nutrients were added as solid fertilizers? Are there base cations added as well? This is important to know for mass balance calculation. Line 216: Use either 143

000 and 10 150 years, or 143 and 10 thousand years. Line 255: space between “and” and “above”. Line 267: Figure 5 is cited before Figures 2-4? Can you renumber them? Line 425: Misspelling: Weatherable? Avoid paragraphs with just one sentence, such as those in Line 487-Line 489.

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