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# Reply on RC1

Attila Buzás et al.

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Author comment on "Revisiting the long-term decreasing trend of atmospheric electric potential gradient measured at Nagycenk, Hungary, Central Europe" by Attila Buzás et al., Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2021-7-AC1, 2021

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**Authors' response to the 1st review**

First of all, we would like to thank the Referees for their thorough and constructive comments and the positive reception of our manuscript. Their precious work contributes to refinement of the manuscript and hopefully, ultimately to the publication of the revised paper.

Quotation from the review:

"*The attention to detail in the current study is impressive, with deep knowledge of the site evident. It is valuable as it includes a more accurate representation of the site, to account for the changes which have occurred there, and it should ultimately be published. A problem, however, with the current manuscript is that various uncertainties in the data are incompletely considered. This is important, as after all the corrections, users will want to know what level of accuracy can be assumed in the final corrected PG. And, following the points made in the conclusions about the need to understand a site fully, can the authors indicate how detailed a knowledge of a site is needed to obtain e.g. 10% or 1% accuracy? Another point is that the method of data selection is not to use the independent fair weather definition, but to select on the magnitude of the data following the long term conventions at the site. This may be a fundamental difficulty. Will the variations in this sampling between years also introduce further uncertainties?*"

We understand that the major problems with the paper according to the first referee were the inappropriate handling of various uncertainties and the ineligible method of the fair weather data selection. Indeed, these are flaws in the article that should be revised.

Firstly, we pay more attention to the error propagation throughout the data processing. In the revised form of the paper, we will present in detail how various uncertainties affect our conclusions and how do they propagate through the different operations (e.g., the uncertainty of the measuring instruments, the error of the uni- and multivariate linear fits, etc.). However, we are not able to exactly quantify the total accuracy of the PG (atmospheric electric potential gradient) measurements at the measurement site. We lack the appropriate supplementary measurements (such as the meteorological and air conductivity measurements for instance) that is why we can not account for various other

processes (e.g., local turbulent air motions, soil radioactivity, aerosol size distribution and concentration, ion mobility and conductivity, cloud heights, etc.) that could affect the uncertainty of the PG measurements. Please, mind that the principal aim of this paper is to correct for the shielding effect alone.

Secondly, we change the fair weather data selection method to a more appropriate one. Please note that we are confined to the usage of a fair weather data selection method based on the magnitude and statistical distribution of the data as we lack meteorological information that are commonly used to identify fair weather conditions for data selection (as for instance in *Harrison&Nicoll, 2018*). As there are long-term variation in the data, the application of the same fair weather boundary value to all the years can indeed introduce unwanted uncertanties. The reason to use this method was to preserve consistency with the *Märcz&Harrison, 2003* paper. Nevertheless, we will adopt the data selection method as in *Lucas et al., 2017* and use a varying upper fair weather boundary value (the lower one remains to be 0 V/m) that is calculated based on the statistical distribution of the data in each year to exclude unwanted year-to-year variations.

**Major points**

**Major point 1:**

**Review:**

"*L195. Add the uncertainty to the experimental points. Derive the mean (red line) from the data by allowing for the uncertainty rather than just removing the data from 4th Aug. Through doing this more rigorously it may become clear that the experimental values are not inconsistent with the model. Merely excluding the inconvenient data is unsatisfactory.*"

**Authors' response:**

L195. Even with taking into consideration the uncertainties, we are afraid that some unwanted effects (e.g., inappropriate handling of the instruments, unconsidered temporary changes in the environmental conditions, etc.) influenced the measurements on 4$^{th}$ August so that the profiles recorded on that day do not reflect the true shielding effect and thus they would bias the model. Please note that, compared to the measurements of the 3$^{rd}$ August, the shielding profile should not have changed so much (the difference between the two measurements is only one day). The outlier along line VI. at 16 m from the fence on 4$^{th}$ August (see Fig. 4/b in the manuscript) is there because the two instruments were put too close to each other and thus they altered the ambient electric field. That is an erroneous value that should not to be taken into consideration during the model setup. The other outlier at 22 m is again too high, we do not see such a sharp jump in the profiles measured on the other three days. Therefore, we are confident in that those values are specifically and incurably biased, unfortunately just in the vicinity of the critical locations so we choose to exclude these two, erroneous values from the investigation and to use the values from 4$^{th}$ August without them. The reasoning of this decision will be clarified more in the revised manuscript.

**Major point 2:**

**Review:**

"*L260 (and Table 3). Uncertainties on the annual percentage changes, propagated through, would be useful. Convention for p values is just to give an inequality and one significant figure (e.g. $p<0.05$, $p<0.001$).*"

**Authors' response:**

L260 (and Table 3). Thank you very much. We will implement the suggested changes.

**Major point 3:**

**Review:**

"*L276 The PG and aerosol number concentration are generally found to be positively correlated. It may be that there is an aerosol size effect here and/or a number concentration effect. More explanation is needed.*"

**Authors' response:**

L276 Unfortunately, the aerosol particle size is not measured systematically in Swider therefore we can not account for possible variation in the aeorosol size. On long time scales, aerosol concentration and PG are mainly positively correlated at Swider but this relation is not unambiguous. As we do not have information about how the size of the aerosols changed during the years we can not assure that there is not a size effect at play there. We will explain this issue more carefully in the revised paper. Please note, that recently a paper about the long-term PG measurements at Swider has been published (*Kubicki et al., 2021*) with more extended time series in the aerosol concentration data as well. We will refer to these longer time series in our revised work.

**Major point 4:**

**Review:**

"*L355. One important implication of this work is that local, site-specific effects may have a large influence on PG measurements and can entirely suppress global signals. How should this be considered in general? The need to see similar variations at displaced sites would seem important. On what timescales could this be expected?*"

**Authors' response:**

L355. This study focuses on the site-specific electrostatic shielding effect of local, conducting objects. However, there are other local processes that alter the PG. Considering the shielding effect generally, one should carefully evaluate each PG measurement site whether there are conducting objects near the PG instrument and perform similar parallel PG measurements to quantify the shielding effect. According to analytic calculations, thin conducting objects (such as a metallic pole or a fence) can distort the ambient atmospheic electric field up to 5% at adistance of 3 times their height and up to 1% at a distance of 10 times their height (*Lees, 1915*). If the obejct is more thick (like a forest or a bigger building) the distortion is around 5% at a distance of 5 times the height of the object and 1% at a distance of 33 times the height of the object (*Benndorf, 1900, Lees, 1915*). These values can help to locate PG instruments at any site. We will refer to them in the revised paper. Nonetheless, in our research, we were able to justify our results by finding similar changes in the PG on long time scales (ca. 5-10 years) recorded at a station (i.e., Swider) in the same region (at ca. 600 km). To find similar variations on shorter time scales and/or at more distant stations is out of the scope of this paper. We will note this more explicitly in the revised text.

**Minor points**

**Minor point 1:**

**Review:**

"*L12. Start the sentence differently "In this work it is found…""*

**Authors' response:**

L12. Thank you, we will revise this part.

**Minor point 2:**

**Review:**

"*L125. Fig2. The repeated points as stripes are confusing. Average them into a single value, with an uncertainty range. Also, the axes would be easier to read if the units were V/m.*"

**Authors' response:**

L125. Fig2. This figure shows the data points that were measured by the mobile and stationary field mills. The linear fit was done based on all the points, that is why we do not agree on averaging them. They can resemble stripes on the plot because the field mill can record PG values only in a precision of 10 V/m. On Fig. 2, PG values were averaged in every second (the original data sampling frequency was 2 Hz). Because of the averaging, PG values between every 10 V/m values can appear as well but they are grouped around certain values. Ultimately, we will change the unit to V/m, thank you.

**Minor point 3:**

**Review:**

"*L143 arose --> arise*"

**Authors' response:**

L143 Thank you, the word will be corrected.

**Minor point 4:**

**Review:**

"*L145 (and fig2). The calibrations on different days have different uncertainties. It is worth deriving them and including them on the plot, particular because of the apparently anomalous 4th Aug data in fig 1a.*"

**Authors' response:**

L145 (and fig2). We will include the uncertainty.

**Minor point 5:**

**Review:**

"*L154 What is the basis for the 1m uncertainty in annual tree height?*"

**Authors' response:**

L154 To acquire more accurate tree height curves one should have a detailed knowledge about the soil, climate and ecological environment of the measurement site. As we lack these information, we are confined to determine the tree heights based on national averages. The uncertainty of 1 m is an expectable uncertainty of these national averages as the local conditions may differ from the average. This will be explained in the revised text.

**Minor point 6:**

**Review:**

"*L235 Table 1. It is likely that the precision given is too great. It should be based on an assessment of the combined uncertainties in the calibration, and the validity of the model.*"

**Authors' response:**

L235 Table 1. Thank you, you are right. We will revise the precision of the values in the table.

**Minor point 7:**

**Review:**

"*L285 Conditions local to the site are likely to be the cause. However, it does suggest some doubt about what the absolute value should be at either site.*"

**Authors' response:**

L285 The Geophysical Observatory of Swider is located near (ca. 15 km away) Warsaw, the capital of Poland and is surrounded by settlements. The anthropogenic pollution is likely to be higher at Swider than at Nagycenk as it is located in a Natural Park and only a smaller city is located near it. Higher pollution decreases the air conductivity thus resulting in higher PG values. Air conductivity at Swider after the perturbed period of atmospheric nuclear weapon tests is around $3\text{-}4*10^{-15}$ S/m whereas the average fair weather air conductivity is greater by one order of magnitude (around $1.3*10^{-14}$ S/m) according to *Rycroft et al., 2000*. Please note that PG measured at different sites can have highly different magnitude. For instance, in a paper where 17 PG stations were compared, the non-disturbed PG median of all the investigated data ranged from 21 V/m to 404 V/m (Nicoll et al., 2019). The high variability of PG at different sites, alongside with the different sensitivity of instruments at NCK and Swider, are likely to be the reason behind the different absolute PG values at the two sites.

**Minor point 8:**

**Review:**

"*L355. This is too general a statement as written, as it does not consider the timescales that are relevant. What is probably meant here is on long timescales. But even so these are used for comparison with the KSC and Swider data.*"

**Authors' response:**

L355. Yes, this sentence is indeed too general. We will rewrite this paragraph to focus

more on the electrostatic shielding effect and to point out the relevance of making comparisons between relatively close PG measuring sites, wherever this can be done.

**Minor point 9:**

**Review:**

"*Fig 6. What is the aerosol size? The change in aerosol size with time (as well as number) will also affect the conductivity.*"

**Authors' response:**

Fig 6. Please, see our answer that was given to the third major point (L276).

**Minor point 10:**

**Review:**

"*L308. Describe winter as "December, January, February""*

**Authors' response:**

L308. Thank you, we will add the description.

**Minor point 11:**

**Review:**

"*L309. Replace " This behavior is in agreement with the general theory of atmospheric electricity" with "This is frequently found at continental sites".*"

**Authors' response:**

L309. Thank you, we will rewrite it.

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