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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "On the role of non-electrified clouds in the Global Electric Circuit" *by* A. J. G. Baumgaertner et al.

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We thank the reviewer for the comments on the manuscript, which helped to improve the revised version.

1. **p9817, l21: Move ZT10 to l18 where the paper is mentioned first.**

Reply Changed as suggested.

2. **p9819, l9 : Include page number for reference to Pruppacher and Klett.**

Reply We included "chapter 18.3.1" for the reference.

3. **p9821, l20: Quantify 'local area' and 'high resolution'.**

Reply The resolution has to be chosen such that the cloud can be resolved, therefore we included "that can resolve the considered clouds". Further, the section on the model was extended by a discussion of model resolution and domain size.

4. **p9823, l18: Explain what is meant by the 'fixed potential of the Earth'. What is used as a reference?**

Reply Mathematically, the choice of potential for the Earth is arbitrary, but was chosen to be 0 V. This is now mentioned in the manuscript.

5. **p9824, l5:For S=0, eq. 14 becomes the Laplace equation such that it is not clear why the term 'Poisson equation' is used.**

Reply As to the request of reviewer 1, the derivation of the equation is now in more detail. While mathematically the concerned PDE is of Poisson-type, strictly speaking it is neither Poisson's equation or the Laplace equation of electrodynamics, because conductivity is not constant. Therefore, the PDE is not named, but refered to as the "current continuity approach", as the PDE is based on the current continuity equation.

6. **p9 82 3, l23: Shower clouds can also be electrified. Convective clouds typically become electrified when they reach a height of 4-6 km when charge separation starts to occur in the mixed phase region, well before deep convection has developed.**

Reply Indeed there is still insufficient data, on a global scale, as to which types of clouds contribute current to the GEC, which leads to an uncertainty in the global resistance results here. This is pointed out in the revised discussion and conclusions.

7. **p98272, eq23: There seems to be an r^2 in the integrand missing to fit the units.**

Reply The integration over latitude and longitude, yielding a horizontal area, is matched by the division of cloud area A, so the units are correct.

8. **p9829, eq25: Why not use 0.3 instead of 2-beta, beta =1.7? What is the physical significance of 2000 km cloud size?**

Reply The notation 2-beta is used to follow the notation as in Wood and Field (2011), and for comparison with this paper we followed that paper as strictly as possible. We added that for clouds larger than 2000 km a scale break occurs. However, the model resolution is much better than 2000 km, so this does not affect the results here.

9. **p9831, l2: Up to this point, no result of the global resistance calculation has been reported such that it is not clear what the quoted percentages relate to. The wording 'overestimate' and 'underestimate' implies a deviation from a 'true' global resistance.**

Reply We clarified this in the revised manuscript: "...underestimates total resistance by 39% compared to the current continuity approach ...". The current continuity approach values referred to are discussed on the previous page (Table 1).

10. **p9833, l14-22: Give a range of values for n to enable an assessment of the degree of non-linearity introduced by gamma. Would it not be more straightforward to use a Taylor expansion of the denominator in eq29? Why is only the largest gamma physically meaningful? Does a sensitivity analysis for the inversion of gamma indicate a unique solution without competing relative minima? How is the reliability of the solution tested, e.g. with a set of forward models?**

Reply The number of levels n is 88 in the CESM simulations. In fact the Newton method does use the first order Taylor expansion. We did not use higher-order Taylor expansion because of the function's singularities (see Fig. 1 and 2 below). Only the largest gamma yields positive conductivity profiles, meaning that this is the only physically meaningful solution.

11. **p9834, l17: Perhaps best to start a new section named 'Discussion'.**

Reply The error discussion focuses on the parametrization introduced in this section, and not to the sections beforehand, therefore we left the error discussion in this section.

12. **p9834, l27: I think there is only a superposition of fields, but no mutual coupling.**

Reply In fact, it is a form of mutual coupling and not just superposition. Consider the following example: The domain in the figure below has a total resistance of 3.20e12 Ohm if only one of the clouds is present. When two clouds are present, the total domain resistance increases by 7.2% (3.43e12 Ohm) if the second cloud is far away from the first cloud (left Fig. 3a below), but increases by 8.4% for a horizontal distance of 1km (Fig. 3b below). The right figure shows that the two clouds behave as one cloud above 8 km, and thus non-linearly increasing the resistance. This is noted in the revised manuscript: "Note that the coupling is not a superposition, as can be shown from comparisons of the total resistance of the domain, which increases with decreasing distance between clouds. The cloud distance required for mutual coupling varies by cloud type and diameter."

13. **P9844, Fig.5: Perhaps better to use 10^{15} instead of the rather unusual P.**

Reply We added (PΩm^2=10$^{15}\Omega$m^2) to the Figure caption

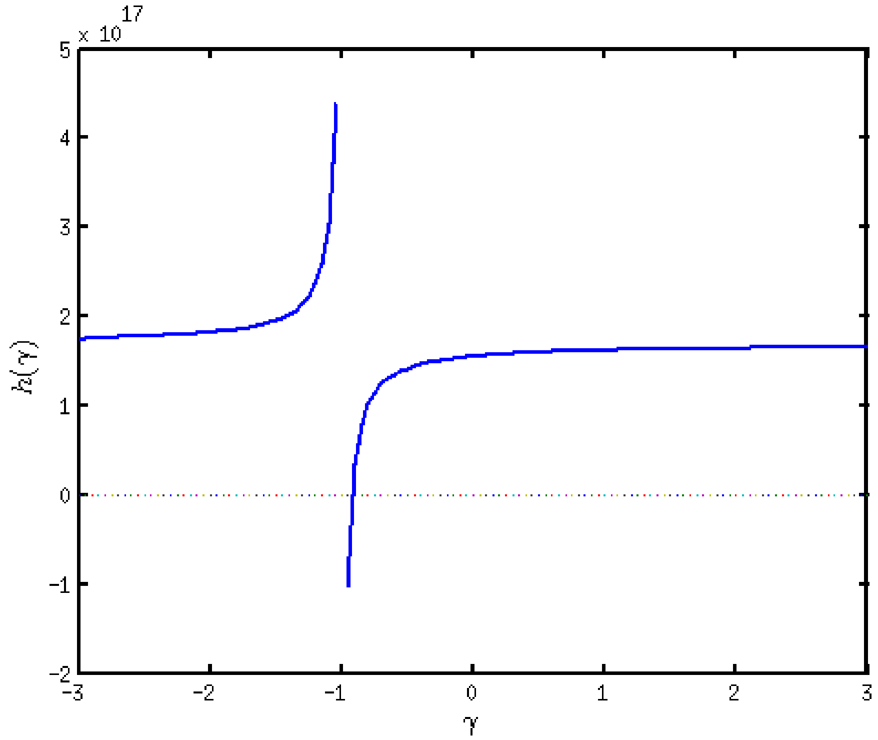

Fig. 1. h(gamma) for 50% cloud cover at 10-12 km using an exponential conductivity profile.

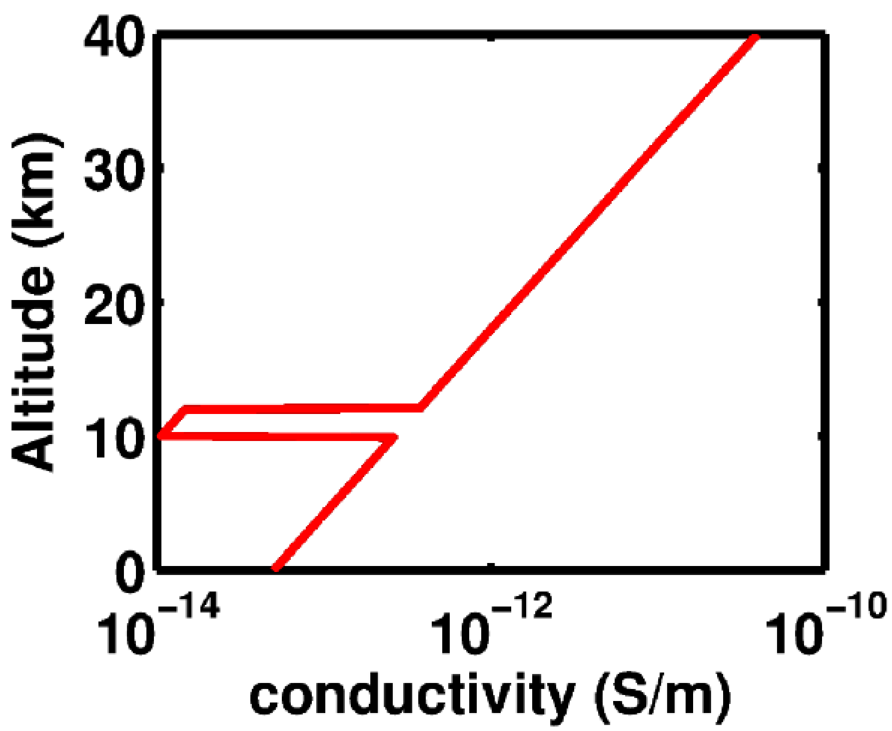

Fig. 2. Resulting conductivity profile

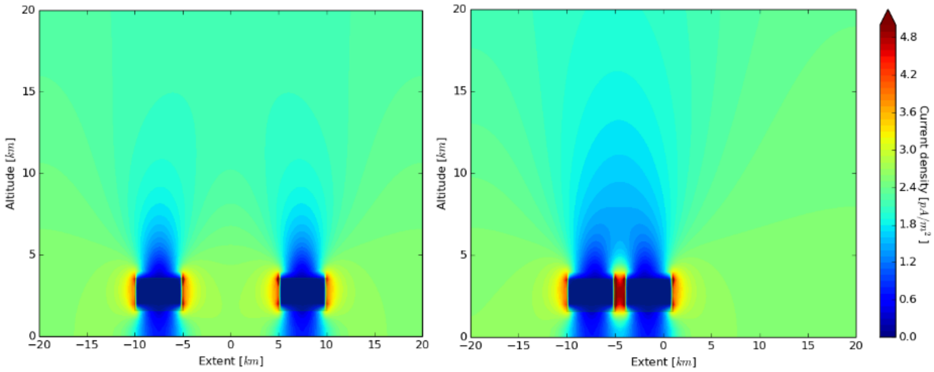

Fig. 3. Current density around two clouds