Review of "Lightning in global chemistry-climate models: A review of parameterizations, evaluations, and future projections" by Krause et al.

This paper reviews the lightning parametrisations used in chemistry-climate models, along with the trends in their changing use, evaluations of skill, and the climate projections made in the literature.

I like this review. I think it is fairly straightforward but plenty of work has gone into it and it is valuable. More importantly, it is timely. Much development and evaluation of lightning parametrisations has happened over the low-earth orbit observation era that we've just had. Now we are moving into a geostationary satellite observation era for lightning, and this review takes stock of where we got to with those datasets. There is also increasing use of machine learning models, and this model takes stock of where (largely) traditional parametrisation techniques got to, given the data available. Finally, storm-resolving models on global and regional scales are now becoming useful for climate change projections. Whilst, they're unlikely to be used in chemistry-climate models soon, they can contribute to our understanding of how lightning will change in future.

All my comments are minor, even the major one. Once the authors have considered them, I consider this paper is ready for publication.

Yours sincerely,

Declan Finney

(sort of) Major comment

Possible ways forward (or lack of) – This work is a useful stock-take, I just wonder if the authors have ideas for how to push its value further by proposing recommendations to the community of how to make progress? The article touches on machine-learning approaches, and on the new geostationary satellites, but doesn't provide any specific directions for how to overcome the large uncertainties in, not only projecting lightning changes, but even parameterising it in the present-day.

I provide a few examples of the kinds of things that come to my mind, but I do not consider necessary to include any of these. If the authors don't have their own thoughts, then the paper can be published without enhancing the recommendations.

- It is great that Cecil2026 has developed a new OTD/TRMM-LIS/ISS-LIS dataset, which kind of is the final thing from LEO satellites for now. Great progress has been made because of the ease of use (i.e. gridded, well characterised, netcdfs) of the LIS/OTD data. I would say we need the same coherent datasets from the lightning-observing GEO satellites now. Something that merges the datasets into something that's easy to pick up and evaluate or create parametrisations with.

It's ok if there's missing data – we now have the opportunity to get to relevant storm timescales (daily or 3-hourly). Evaluating at these scales allows us to properly start questioning the physics connecting the input variables and the lightning diagnostic.

- Something that I think can benefit projections is to break apart lightning intensity from storm occurrence. Finney2020 fig2 provides an example of this – I haven't seen it very often in other climate-lightning studies. This can be done fairly easily in models by outputting one more diagnostic of lightning-days, or lightning-hours, as well as total monthly lightning. Then you can talk about lightning-days, lightning intensity (fl/day), and total monthly lightning. Again this gets down closer to the timescale that storms actually exist upon, even if not the process timescales. I think we'll find lightning intensity more reliably increases with climate change across the world, and is tied to thermodynamic profiles and boundary layer conditions. Lightning-days is probably the complicated one, as it will depend more on synoptic patterns and global circulation changes. But pulling the metrics apart is a useful starting point for knowing how to build confidence in projections.

Minor comments

L9 – I see no requirement for chemistry to be present in a climate model in order to project lightning activity. I suggest you change this this to "Climate models…" and add a sentence or two to explain that chemistry is one of the main motivations for inclusion of lightning params in climate models, and that much of the evaluation is done from that perspective. Therefore it's useful to look at chemistry-climate models.

L13 – "times" seems a bit colloquial. I think either just list the two variables, or say the "the product of.."

L43 – Is "strong influence on…" "..climate" justified? The radiative effects resulting from lightning effects on ozone and methane are opposing, so I'm not sure how certain we are of the climate effect. Certainly atmospheric chemistry is strongly influenced.

L57 – I find the ", while…." part of this sentence to be odd. As I understand it, this is not a caveat to the charge separation statement, but just one of the papers in the debate mentioned at the beginning of the sentence. Why just mention one paper in the debate? If you want to get into it, then I suggest you'll need to give a couple of sentences to it. Or you could just include a number of citations at the point of "debate".

L59 – Whilst I am happy with the term "electrification", I wonder if you would keep better connection to the earlier part of the paragraph to say "explanation for charge separation"

L127 – Need to check nothing missed from “parametrization” and “parametrisation”. I imagine WoS is smart enough to return them anyway, but you should check. https://trends.google.com/trends/explore?date=all&q=parameterisation,parameterization,parametrization,parametrisation and https://english.stackexchange.com/questions/79847/parametrise-or-parameterise-a-curve

L132 - There is no need for them to be global. You can use regional models to project regional lightning changes. I think you might need to give a paragraph to tighten up you discussion of models. All kinds of *climate* model can be used to study this including GCMs and ESMs, and they may or may not include chemistry. Convection-permitting or cloud-resolving models on global or regional domains could be used (e.g. Romps2019 or Finney2020). So please have a think about how you want to describe what tools are used for projecting lightning.

L237 – Finney2018 supplementary fig S1 also shows that they attempted to account for shifting isotherms under warming climate.

L300 – I’d say this statement is already out of date but certainly wont stand the test of time well. I think you’d be best acknowledging that convection-permitting models are becoming more feasible for use in climate projection (there is no reason that they have to be applied globally anyway). E.G. I don’t know if the ICON simulations had a lightning parameterisation but it would be lightweight so there’s no reason they couldn’t https://link.springer.com/article/10.1007/s00382-026-08235-8 I don’t think you have to change your scope, just define it well. You could say that you are focusing on studies that have included a lightning param and a chemistry model. Then you just need to acknowledge that there could be higher resolution simulations in the near future, but that this is the state-of-the-art in CCMs.

Section 2 – this is lengthy, I think dividing it into 2-3 subsections would be pleasant. Perhaps one for CTH-related params, one for other non-microphysical params, and one for microphysics-based params. But whatever is fine, just break it up a bit.

L335 – “…though it doesn’t distinguish between whether a flash is CG or IC” or something like that? Current sentence might imply the satellite measurement sees them as different

L350 – I feel like this sentence is leading to a “..and therefore…” there is not high confidence in their ability to simulate such trends?

L369 – “Related to…” sounds odd here. The extratropical underestimate introduced in the previous sentence is not really to do with this intra-tropical differences. I think you mean “The tropical underestimation occurs primarily over central Africa, with compensating overestimation from the Amazon and martime continent”?

L551 – I don't know if you want to comment on potential reason for this insensitivity but I would hypothesise that it is heavily determined by the tropopause shift, which is reasonably well understood radiative response. Given it is a fairly direct response (at least in the tropics) to GHGs/water vapour, it probably is fairly similar across models. I suspect it's something that is checked a lot for whether it sensible, and may well be part of the model tuning process. The cloud top height baseline may also be something that's tuned to observations across models in the present-day simulations – that well-established baseline might also help achieve similar projected changes in CTH/lightning.

L600 – "presumably" – If you don't feel confident to make a robust statement, then I would change this to "for a more complex, 2-moment scheme".

Technical comments

L107 – "sensitivities" typo?

L377 – "intermediate"?

L534 – "sensitive" typo?