Review of Radiative sensitivity quantified by a new set of radiation flux kernels based on the ERA5 reanalysis
By Huang and Huang
essd-2022-474

Summary
The authors have improved the paper relative to its previous version and I am mostly satisfied with the changes they have made in response to my and other reviewers' comments. There remain a few places where further revisions are needed, which I detail below.

Specific Comments

- When making use of these kernels, I initially struggled to get good closure at the surface. The issue is that the surface temperature and humidity kernels peak at the lowest atmospheric level, but in many models this level is below ground. Thus even if the kernel is nonzero and large, the radiative impact is zero because that level has no change in temperature or humidity (because it is underground). The solution I found was to set the atmospheric temperature and humidity values equal to their surface values anywhere that they were zero or undefined at the lowest levels of the atmosphere. This correction ensures that there is something nonzero to multiply the kernel by at the near-surface level where the kernel peaks. I think you may need to provide this methodological detail somewhere in the paper in order for people to correctly implement these kernels.
- Figure 5: I don't feel as though the results shown in the right column of this figure are adequately explained. I think the statement on L370 is incorrect: Rather, the figure indicates that the negative surface temperature kernel has strengthened in ERA5. Why has this happened? I cannot rationalize this from looking at the changes in Figure 5g,h,i. I would have thought the moister atmosphere might weaken the surface temperature kernel (the opposite of what happens). I also am not sure what is being referred to on L373 regarding the linkage between the discrepancy noted in Figure 4i and the SW WV kernel results. Please elaborate on this.
- Figure 6: This is also not explained particularly well. It is stated on L391-392 that "the reduction of sea ice in the Arctic region leads to a significant decrease of radiative sensitivity to surface albedo". If this statement is taken at face value, one would expect panels d and f to look like mirror images of panel a, but there is little correspondence at all. But I don't think there is any reason to expect the albedo kernel to depend on surface albedo since it is defined as the SW impact of a 1% increase in albedo. This kernel mainly varies with insolation and cloud cover. So the change in total cloud cover (panel b) actually explains most of the geographical structure in the change in surface albedo kernel (rather than "also contributing" as the authors state).
- Figures 8: I find it very hard to reconcile the very small SW residuals in Figure 8 with the quite substantial zonal mean residuals shown in the bottom row of Figure 7. Please double check this calculation. I also suggest removing the substantial white space at the top and bottom of this figure, since no values extend above about 2 W/m2/K or below about -3.5 W/m2/K. In the caption, "list" should be "listed", and "pentagrams" should probably be "stars."

- Abstract: There is no mention of the analysis regarding dependence of the kernel on mean state (as examined in Section 3.3)
- L22: seems odd to not mention climate change in addition to variability here.
- L65: should be “approximate”
- L81: you may also consider citing Figure S2 of Zelinka et al (2020)
- L87: I don’t think “calls into question” is the right phrase here. Perhaps “…this warrants investigating whether…”
- L108: should be “set” (singular)
- L147-156: This methodological description is still awkward. You are not performing separate simulations, right? There is one control simulation, and within that simulation you perform multiple radiative calculations, each time with a small perturbation in a field. I think “simulations” should be replaced with “calculations” in most cases.
- L152: should be “calculate **the** radiative”
- L172-173: Many analyses in the paper use monthly resolved kernels, but I don’t think this is stated when it occurs.
- L180: I think you should explain explicitly what atmospheric kernels are here, since it may not be obvious what they are or how they are computed
- Figure 1 and others: Need to notify the reader that the colorbar ranges vary among panels
- L258: I understand why the authors refer to the Kramer et al (2019) kernels as CloudSat/CALIPSO, but this could possibly confuse readers who might think they are cloud radiative kernels. My understanding is that these make use of thermodynamic fields from ECMWF, so they actually use similar inputs as the ERA kernels developed here. I think a brief clarification of what these kernels are is warranted to avoid confusion.
- Table 1: Suggest renaming the third column as “Vertical levels” or something, since the resolution is not shown
- L289: should be “fractional”
- L299,308,404 and elsewhere: The word “biases” still shows up in the revision even though these are not biases.
- L323: 10% of what? Please specify
- L426-427: commas are not needed after the experiment names, and “and” should be inserted after “1850,”
- L432: Rather than “following the previous studies” this methodology deviates in a fairly significant way from Zelinka et al and Smith et al (and most studies that use abrupt-4xCO2 experiments). Namely, the conventional way is to difference piControl and abrupt over the duration of the abrupt run, compute annual mean values, and regress on annual mean surface temperature anomalies (the Gregory method). The method used here is quite different and needs to be explained and motivated better. Note – I am not criticizing the method. I just want you to explain and motivate it better, and to delete the phrase about it following previous studies. One nice motivation is that it obviates the need to worry about rapid adjustments.
- L441: “notre” should be “note”
- L447: delete “atmospheric” since it includes surface temperature and albedo

- L449: Somewhere in this section you need to note that the kernels and the climate fields they are multiplied with are at monthly resolution
- L460-471: For any casual reader, this description of how to compute cloud feedbacks is probably inadequate and bewildering. As another reviewer noted, the math ends up the same, but the physical connection of the equations to how it relates to clouds is lost. Suggest re-doing this (or appending discussion onto it), perhaps adhering more closely to Eqs. 22-25 in Soden et al (2008).
- Figure 7: The figure panels are too small, partly because there is so much redundant information that is repeated. All colorbars are identical, so there is no need to show them near each panel – this would clear up a lot of space. You could also label each row once and each column once rather than putting a title on each panel.
- Figure 10: The ERA5 kernels produce anomalously large Ts and Ta feedbacks relative to the other kernels, but I don't think this is discussed at all. Please discuss.
- L579: should be "containing." Also I would suggest noting in this section (rather than earlier in the text) that the multi-kernel dataset is also provided at this link. Thank you for providing this.
- L587: I don't think "including the kernel values" is needed here as this is obvious
- L594: should be "Antarctic" or "over Antarctica"
- L598, L617: 30%/10% of what?
- L600: suggest pointing the reader to the Appendix here.
- L605: I think you should say this "might explain" the discrepancies, since you have not established this across kernels (which also differ in other ways including radiative transfer codes)
- L618 and elsewhere: The word "affirm" appears 10 times in the manuscript; suggest using a synonym occasionally.
- L807: "the multiply of" is not the correct phrasing

References

Kramer, R. J., Matus, A. V., Soden, B. J., & L'Ecuyer, T. S. (2019). Observation-Based Radiative Kernels From CloudSat/CALIPSO. *Journal of Geophysical Research: Atmospheres*, *124*(10), 5431–5444. https://doi.org/10.1029/2018JD029021

Soden, B. J., Held, I. M., Colman, R., Shell, K. M., Kiehl, J. T., & Shields, C. A. (2008). Quantifying Climate Feedbacks Using Radiative Kernels. *J. Climate*, *21*, 3504–3520. https://doi.org/10.1175/2007JCLI2110.1

Zelinka, M. D., Myers, T. A., McCoy, D. T., Po-Chedley, S., Caldwell, P. M., Ceppi, P., et al. (2020). Causes of Higher Climate Sensitivity in CMIP6 Models. *Geophysical Research Letters*, *47*(1), e2019GL085782. https://doi.org/10.1029/2019GL085782