Review of "Influence of Cloud Retrieval Errors Due to Three Dimensional Radiative Effects on Calculations of Broadband Cloud Radiative Effect" by Ademakinwa et al.

27 October 2023

General comments

This paper examines how retrieved cloud properties, which are biased due to 3D radiative effects, affect the broadband shortwave cloud radiative effect. This is achieved by running 1D radiative transfer using either the true or retrieved cloud properties, and comparing with 3D radiative transfer using the true cloud properties ("truth"). It is found that, while retrieved cloud properties are biased, the corresponding cloud radiative effect from 1D radiative transfer remains close to the truth, and sometimes even closer to the truth than when using the true clouds with 1D radiative transfer.

The study is novel, interesting, and the paper is mostly well written. I found the text rather lengthy, and I worry that this could deter readers. The early classic papers on 3D radiative effects are well acknowledged, but some key literature on this topic within the last 5-10 years is not as well represented. There are also some areas where I think the physical interpretation of the results can be improved, and care should be taken to draw conclusions objectively from the results. These are all minor concerns and are outlined in my specific comments below. I congratulate the authors on a nice piece of work and, after addressing these comments, I recommend prompt publication in ACP.

Specific comments

Length: At 32 pages with single line spacing, the manuscript is certainly on the longer side. To ensure that this study receives the attention that it deserves, it is important to be as concise as possible. While I found the paper interesting throughout, I believe almost all of the novelty is coming from SQ3. I wonder if many of the results from SQ1 (3DRT compared to 1DRT) and SQ2 (retrieval biases) can be referred to the literature, since these are both questions that are already extensively covered in other studies. I will not insist on this, but I highly recommend the authors consider if they can make the manuscript more concise by focusing on the novel aspects, which will likely increase the impact of their work.

Title: I think the title needs to include "shortwave" since this study only addresses the shortwave portion of the cloud radiative effect. Suggestion: "Influence of Cloud Retrieval Errors Due to Three Dimensional Radiative Effects on Calculations of Broadband Shortwave Cloud Radiative Effect". Similarly, when the CRE is first mentioned in the abstract and body text, it should be clarified that only shortwave is considered.

L61: There is another recent study that used ML to retrieve cloud optical properties based on 3DRT: https://doi.org/10.5194/amt-15-5181-2022. I recommend adding this reference.

L63-72: A distinct mechanism, named "entrapment", has recently been proposed to play a key role in the 3D radiative effect of clouds: https://doi.org/10.1175/JAS-D-18-0366.1. I recommend adding this reference to the discussion in this paragraph.

L87-90: Another more recent study explored the TOA albedo bias associated with 3D effects: https://doi.org/10.1175/JAS-D-21-0032.1. I recommend adding this reference to the discussion here.

L93: I am not convinced that "more reasonable" is appropriate here. The comparison of 1D and 3D fluxes from true clouds or retrieved clouds provides insights into different science questions. If the goal is fundamental understanding of 3D effects and mechanisms, it makes more sense to consider true clouds. For assessing the impact of cloud retrieval errors on CRE estimation and ESM evaluation, as is the goal here, using the retrieved clouds makes more sense. So, to say that one approach is more reasonable that the other is not correct. Both approaches are valid depending on the application.

Fig. 1: I like this figure a lot. It really helps to follow the descriptions in the text. Two comments:

1. I am not convinced that Box B should be called "Radiance observations". The radiance obtained from 1DRT on true cloud properties is something that can only ever be simulated, not observed. It is not possible to observe this quantity because, as already mentioned in the paper, reality is inherently 3D. I would suggest renaming Box B to "radiance simulations" or simply just "radiance".
2. The notation "δf" is used for both the difference between Box F&G and the difference between Box E&F. Since these differences are not the same, I suggest adding some notation to distinguish them. Perhaps "δf_1" and "δf_2", or "$\delta f_{retrieved}$" and "δf_{true}".

L97-101: This text is just repeating what was already said at the beginning of the previous paragraph. To keep the manuscript concise, I suggest removing these sentences and starting this paragraph with something like "To determine whether biased retrievals of cloud properties can still provide an observational basis for CRE, we focus on three important scientific questions (SQs) as illustrated in Fig. 1:"

L160: Are CBH and CTH also mean values over the domain?

L142-144: The case selection and justification are OK, but some important limitations exist from only considering these two snapshots from LASSO. For example, there are other cloud regimes where 3D effects can be substantial such as deep convection (eg. https://doi.org/10.1029/2003JD003392). In the case of deep convection, the 3D retrieval biases and relative importance of 3D mechanisms are quite different. The two snapshots are also from the same location over land. Different surface reflection in other regions of the globe could lead to different 3D retrieval and 3D flux biases. In short, the limited generalizability of results obtained from these two snapshots should be acknowledged. (I now see that these caveats are mentioned at the end of the conclusions. Still, I think it is best to add the caveats to the text where the decisions about case selection are first discussed.)

L167-171: Is there a good reason to use a combination of SHDOM and Monte Carlo for radiance and flux calculations? It would seem to be more consistent if all calculations were

performed with one or the other. If the argument is efficiency, it should be the case that SHDOM is more efficient at computing radiances, while the two approaches are comparable for calculating fluxes in cumulus scenes (https://doi.org/10.1175/2009JAS3137.1), yet they appear to be used the opposite way around here.

L175-176: It has recently been shown that ambient aerosols can have a significant impact on the 3D radiative effect of cumulus scenes such as those considered: https://doi.org/10.1029/2022JD036822. Since aerosols are neglected here, a caveat should be added with reference to this study.

L189-190 and Fig. 3 caption: If the viewing zenith angle is 0° then the relative azimuth angle should be irrelevant, correct?

L192: I do not understand the comment "Coarser spatial resolution will be applied in future studies." What advantage will coarser resolution bring in future studies?

L214-215: The surface albedo of 0.07 seems quite low. Typical broadband albedo at the SGP side is close to 0.2. Perhaps the albedo at these two wavelengths is much lower than the broadband value but it is hard to tell because the surface spectral albedo described on L181-184 is not shown. One suggestion is to include a figure of the surface spectral albedo in the text or supporting information so that the reader can see the value close to 0.07 at the retrieval wavelengths.

Figure 6: What is the assumed standard deviation of the gaussian curves?

L386: I do not follow the explanation of larger droplet sizes. Shouldn't the 3DRT and 1DRT use the same droplet sizes? Please clarify.

L460-461: The leaking from optically thick to thin cloud mentioned here and in several other places suggests a horizontal redistribution of the photons, but it is not sufficient to explain the overall darkening. What I suspect is happening is that photons are leaking out of the sides of the clouds and are being preferentially absorbed at the surface in the 3D result. This is because, for photon trajectories where the number of scattering events is low and the sun is high, photons leaking out of the cloud side are statistically more likely to still be travelling downward toward the surface, causing a net loss of photons in the 3D result. Compare this with the low sun result where the net loss of photons is much lower. Following the same logic, for the photons with a low number of scattering events, relatively fewer photons will be absorbed at the surface because the original direction of travel was not directly downwards. I think this physical interpretation is missing in the paper, and can help to explain some of the features seen in these figures. This may also help to explain the misunderstanding in the previous comment.

L490-496: Can a physical interpretation be provided for the increased failure rates at low sun?

L570-582: The increased transmitted flux at high sun and decreased at low sun for 3D+true clouds has been examined for LASSO cases: https://doi.org/10.1175/JAS-D-19-0261.1. Their Figure 6b shows that the 3D transmitted flux was higher than 1D during the afternoon (high

sun) but lower than 1D at the end of the day (low sun). I think the results of that paper are more directly relevant to the discussion here than the others already cited, so I recommend that paper is referenced and compared to the results found here. (I noticed that the LASSO case study chosen in that study - 27 June 2015 - is the same as one of the snapshots chosen here. Despite the different simulation setups, their Figure 5d is statistically very similar to Figure 9e here, which is reassuring!)

L669-672: The claim that cloud properties from 1D retrievals provide a reasonable observational basis to estimate CRE is first made here, and is repeated in the abstract and conclusions. I find the wording of this claim rather subjective. There could exist applications where the magnitude of the CRE biases (1D-RT + retrieved clouds) relative to truth (3D-RT + true clouds) is still not good enough. I think the manuscript would be better served by replacing these statements with an objective concluding statement, something like "CRE calculated with 1DRT using retrieved cloud properties that are biased due to 3D effects is found to be comparable or better than CRE calculated with 1DRT using the true cloud properties". A statement like this is still interesting and novel, and it follows directly from the results, rather than extrapolating the results to a sweeping statement that is open to interpretation.

L709-717: Does the sensitivity of the results to excluding the failed retrievals concern the authors? Thinking back to their original motivation, which includes assessing the impact of cloud retrieval errors on CRE estimation and ESM evaluation: wouldn't users of cloud retrievals in these cases already screen out failed retrievals? As such, are the results that do not include failed retrievals (in the appendix) more relevant to scientists interested in this problem? I suggest adding a sentence or two with some perspectives on these points to the end of this paragraph.

Technical corrections

L139: Replace "June 27 June" with "27 June".

L180: Replace "over each RRTM spectral bands" with "over each of the RRTM spectral bands"

L190: Remove "The"

L303-310: This sentence spans 8 lines and is difficult to follow. I suggest breaking it up into multiple separate sentences.

L699: Replace "showed that although," with "showed that, although"

L702: Replace "7s%" with "7%"