Responses to reviewers' comments

We thank both reviewers for carefully reading and providing insightful feedback to our paper, which helped us improve the manuscript. The major changes to the manuscript are listed below.

1. We modified the title to include "shortwave" since we focused on the shortwave portion of the cloud radiative effect.

2. As recommended by one of the reviewers, for easy understanding and readability, we have used symbols consistent with our main figure (Figure 1) to drive our explanations all through the text.

3. Additional explanations were provided for why the darkening effects are predominant in the reflectance bias for the high sun as well as the brightening and darkening observed for the low sun reflectance bias cases.

4. The rest of the minor suggestions from the two reviewers were addressed accordingly throughout the manuscript.

Please find our point-by-point response to the referee's comments as well as changes made below (Comments in black and responses in blue). We believe these revisions have adequately addressed the reviewer's comments and welcome any additional suggestions or comments from the referees and editor.

Reply to Reviewer 1:

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.

Reply: Thank you for the comment. We agree that most of the novelty of this study comes from the SQ 3, however, we feel SQs 1 and 2 are still important to establish a relationship in order to explain SQ3. We have therefore trimmed a little part of the manuscript in SQs 1 and 2, but retained other aspects because we believe that they are relevant in explaining results in SQ 3.

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.

Reply: Thank you for your suggestion, the title has been modified to include "shortwave" as suggested. Also, "shortwave" has been included when the CRE is first mentioned in the abstract (L14) as well as in the first sentence on the scope of our study in the text (L71 -73) in the revised manuscript.

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.

Reply: Thank you for the recommendation, the study has been added as a reference in L58 in the revised manuscript.

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.
Reply: A sentence introducing entrapment as well as the reference has been added to the text in L65-66.

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.
Reply: The study has been added as suggested in L88-90.

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.
Reply: Thank you for this comment, we have reframed the sentence to reflect that comparing the radiative flux derived from the retrieved cloud properties using 1D RT with those derived from the true cloud fields using 3D RT enables us to measure the impact of cloud retrieval errors on the radiative flux estimates and CRE. L92-95.

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”.
   Reply: For simplicity and to use symbols all through the text, both Box B and Box C have been relabeled to “reflectance” with mathematical representations R_{3D} (for Observed or 3D RT simulated reflectance) and R_{1D}(for simulated reflectance from 1D RT) in the updated fig. 1 in the revised manuscript. This also enables us to easily use these symbols in the running text in the manuscript.

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 “δfretrieved” and “δftrue”.
   Reply: Thank you for pointing this out. To differentiate between the two notations for flux comparisons, the differences between Box E&F has been denoted with “δF_1” while the difference between Box E&G have been denoted with “δF_2” in the updated fig. 1.

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:”
Reply: Thank you for the suggestion, the text has been modified as suggested in L103-104 in the updated manuscript.

L160: Are CBH and CTH also mean values over the domain?
Reply: The cloud base height (CBH) and cloud top height (CTH) presented initially in the table were the minimum and maximum Cloud altitude respectively for the whole cloud field (see plot of CTH and CBH distribution across the LES for both 27 June and 18 August cases). The table 1 in the updated manuscript has been updated with the mean CTH and mean CBH respectively, this information have also been provided in the table's caption.

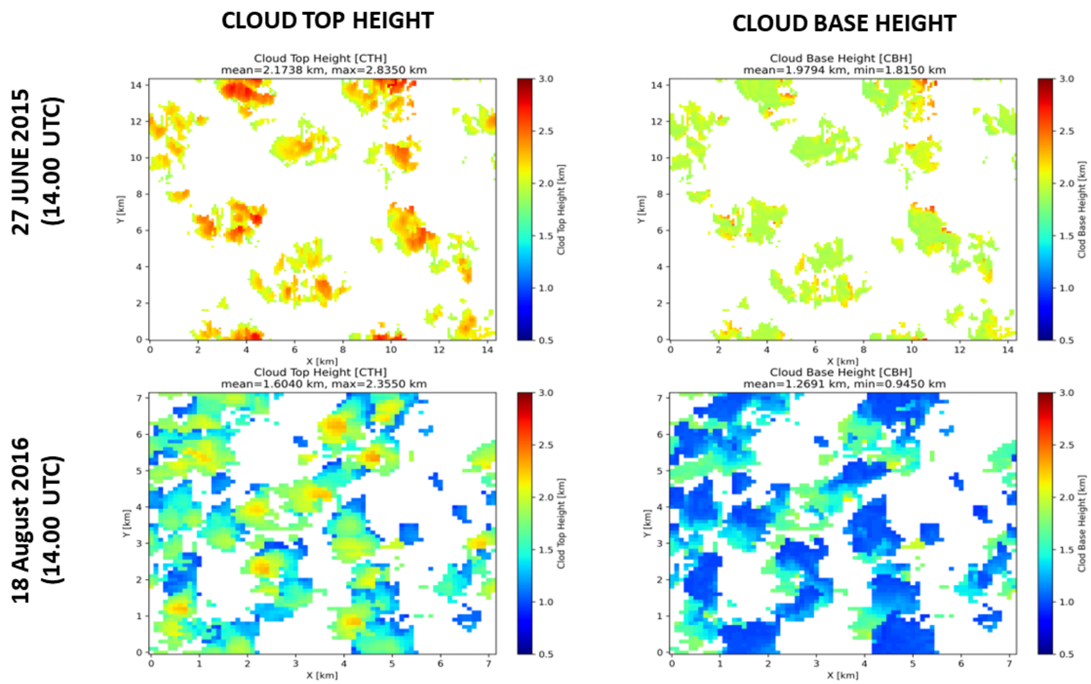

Fig showing the cloud top height (CTH) and cloud base height (CBH) distribution across the LES for both 27 June and 18 August cases

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 (e.g., 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.)
Reply: Thank you for this suggestion, the caveats have been included in the revised manuscript in L151-154.

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.
Reply: It is true that the SHDOM is more efficient for computing radiances, thus, it was utilized for our radiance computation (as was stated in L169 and L179). While it is efficient for pixel scale radiance computation, we had a hard time to achieve an energy conservation when using the SHDOM for broadband flux solutions for these large LES scenes (used in our study). The problem is that the domain average of the Reflected flux + Transmitted flux + Absorbed flux ≠ Solar flux at the top of the domain. We do not know if this is our problem (e.g., wrong configurations of the model) or a fundamental problem of SHDOM. Nevertheless, because energy conservation is critical for our study, we decided not to use SHDOM. In contrast, the Monte Carlo (only counting number of photons) handles flux computation well and satisfies the conservation of energy criteria on the domain scale, while the SHDOM is better for radiance computation. Hence we adopted the SHDOM for radiance computations and Monte Carlo for Flux computations.

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.
Reply: Thank you for this suggestion, this Caveat and reference to the study have been added as suggested. L186-188

L189-190 and Fig. 3 caption:, If the viewing zenith angle is 0° then the relative azimuth angle should be irrelevant. correct?
Reply: True. The relative azimuth angle (RAA) in the sentence has been replaced by the solar azimuth angle (SAA) in L204 as well as in the caption and label of Fig. 3.

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?
Reply: Since our study was conducted at the native LES resolution of 100m, several remote sensing instruments like MODIS have a coarser footprint and thus will have different 3D effects impacts on retrievals and radiative flux. Thus, future studies will investigate how 3D effects retrieval errors for different spatial resolutions affect the radiative flux estimates. This explanation has been added to the revised manuscript in L206-209.

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.
Reply: For this study, the central wavelength for each RRTM band was used to obtain the surface albedo. By this, corresponding surface albedo for each central wavelength was inferred from fig. 3 (curve for SGP albedo May 2003) in Coddington et al., 2013 for λ < 2.5 μm and fig. 4. (for a vegetative surface) In

Zhuravleva et al., 2009 for $\lambda > 2.5$ µm. The surface spectral albedo plot for each band center from the 14 RRTM spectral band has been included in the appendix of the manuscript.

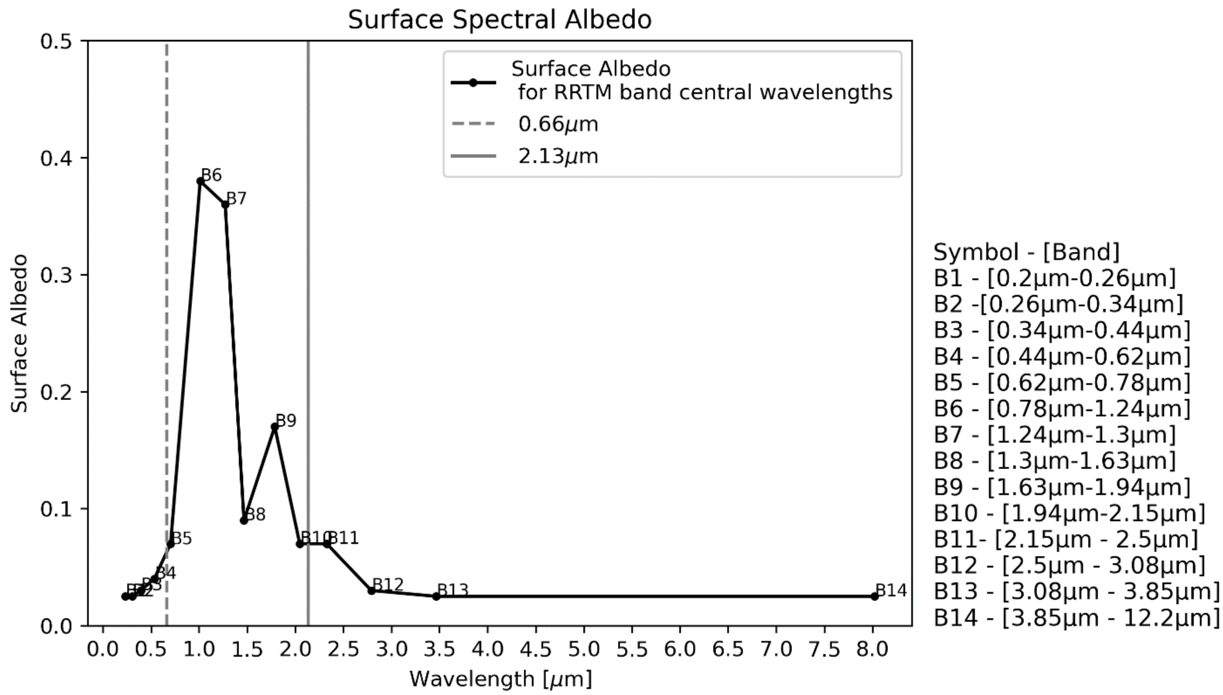

Figure: showing the surface spectral albedo used for the broadband calculation. Vertical lines denote the wavelength used for bispectral retrievals.

Figure 6: What is the assumed standard deviation of the gaussian curves?
Reply: The standard deviation (std) of the gaussian curves is the std value of the VNIR band at SZA 5 degrees.

L386: I do not follow the explanation of larger droplet sizes. Shouldn't the 3DRT and 1DRT use the same droplet sizes? Please clarify.
Reply: Sorry for the confusion, the sentence meant that even though the same cloud fields are feed into the RT solver (i.e.,the 1D and 3D RT solvers have the same input and thus will have the same droplet sizes), the 14 August cloud has larger droplet sizes compared to the 27 June cloud field (see Table 1). In 3D RT, the horizontal transport of photons across columns makes it more likely for photons to be absorbed by clouds in the 3D RT (due to increased pathlength) as compared to 1D RT where movement is confined to the vertical (Having agreed with the explanation regarding the reason for the darkening effect experienced in the high sun case (next comment), this sentence has been excluded from the revised manuscript).

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.
Reply: Thank you. This comment is insightful, and we agree with the suggested explanation. Sentences explaining this process have been added to the text. L338-L347 also in L442

L490-496: Can a physical interpretation be provided for the increased failure rates at low sun?
Reply: Possible reasons (such as multiple scattering, shadowed observation) for retrieval failure for the low sun have been provided in L460 -L466 in the revised manuscript.

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!)
Reply: Thank you for the suggestion. The study has been referenced and their findings compared to our results in L537 - L544 and also, the domain mean results were compared in L593 -L597 in the revised manuscript.

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.
Reply: We agree with the reviewer, the statements have been modified as suggested in L626-L628 and throughout the manuscript.

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.

Reply: A sentence with these perspectives have been added to the revised manuscript in L670 - L676

Technical corrections

L139: Replace “June 27 June” with “27 June”.
Reply: Modified as suggested.

L180: Replace “over each RRTM spectral bands” with “over each of the RRTM spectral bands”
Reply: Modified as suggested.

L190: Remove “The”
Reply: “The” has been removed from the text.

L303-310: This sentence spans 8 lines and is difficult to follow. I suggest breaking it up into multiple separate sentences.
Reply: Thank you. The sentence has been divided into multiple sentences.

L699: Replace “showed that although,” with “showed that, although”
Reply: Thank you. It has been corrected

L702: Replace “7s%” with “7%
Reply: Corrected. Thank you

Reply to Reviewer 2:

1 General

The paper is investigating the influence of 3D radiative transfer effects on cloud radiative forcing. To pin down various sources of errors it establishes a framework starting with a LES cloud field, then using a simulated radiance sensor which feeds into a Nakajima King type inversion to gain retrieved optical properties and finally computes broadband fluxes from the retrieved cloud optical properties. Along the way this study evaluates the effects of 3D vs 1D radiative transfer methods. The study is novel, the approach is sound, and the manuscript is well written. The scope of the study is limited to cumulus clouds with small aspect ratios and shortwave CRE. These limits should be presented in the title or abstract. One ingredient in the study is the 3D distribution of clouds which is here taken as granted (coming from the LES output) but in reality is usually not readily available. There are groups working on the 3D reconstruction of cloud scenes (sometimes also called Atmospheric Tomography) and I think it is still an active research field. I would hope that you add a statement that the 3D distribution of clouds is used from the LES and briefly discuss how one could get such info from observations, be it tomography, space carving or stereo methods. Also, I was wondering if you could add yet another flux comparison, namely $F_{3D}^{*} = g_{3D}\ (X^{*})$. I think it would be interesting to see how a 3D flux computation on the retrieved cloud properties would fare. At the same time, I concur with the first anonymous reviewer that the effects on 1D vs 3D RT (δY=$Y_{3D} - Y_{1D}$) and δF=$F_{1D} - F_{3D}$) has been the subject of previous studies. The length of the study did not bother me and I enjoyed the read throughout but I concur that the respective parts could be trimmed if need be.

There have been moments where I found myself needing to go back and forth looking up details scattered within the manuscript. Hence I have some minor remarks to enhance the readability, see below. After these have been considered, I recommend prompt publication.

Reply: Thank you for the comment. The limits of the study such as the ‘’focus on the shortwave portion of the spectrum“ has been added to the title. We also added these limits alongside the constraint of our study to shallow cumulus clouds to the abstract in L14 as well as the text in L151 in the revised manuscript.

A statement on how the 3D distribution of clouds from atmospheric tomography have been added to the revised manuscript in L131-L136.

A 3D flux computation on the retrieved cloud properties ($F_{3D}^{*} = g_{3D}\ (X^{*})$) was performed and results shown in the table below. From these results, it is clear that for the high sun case, the reflected flux at top of the domain for F_{3D}^{*} is underestimated compared to the benchmark F_{3D}. while the transmitted flux at the surface is overestimated compared to F_{3D}. This is expected because the darkening effect is predominant in the reflectance bias and thus underestimated cloud optical thickness (thinner clouds) dominates the retrievals which are used as inputs for the F_{3D}^{*} calculations. The bias between the F_{3D}^{*} and F_{3D} is more pronounced for the 18 August case because it consists of a large distribution of underestimated cloud optical thickness in its retrievals (from strong darkening effects). for the low sun case, there is no clear relationship between the reflected flux of F_{3D}^{*} and F_{3D}. The F_{3D}^{*} overestimates the reflected flux compared to the F_{3D} in the 27 June case, while the opposite is true for the 18 August case. Because we didn’t observe an obvious improvement of F_{3D}^{*} in comparison with F_{1D}^{*}, these results have not been included in the revised manuscript.

Case Name		SZA 5 degrees F_{1D}^{*} (Wm^{-2})	F_{3D} (Wm^{-2})	F_{1D} (Wm^{-2})	F_{3D}^{*} (Wm^{-2})	SZA 60 degrees F_{1D}^{*} (Wm^{-2})	F_{3D} (Wm^{-2})	F_{1D} (Wm^{-2})	F_{3D}^{*} (Wm^{-2})
27 June 2015 (14:00 UTC)	$F^{\uparrow}$	215.44 (213.94)	215.93	225.37 (223.52)	209.45	134.22 (111.21)	137.87	133.04 (112.01)	147.21
	$F^{\downarrow}$	918.97 (920.68)	918.79	910.76 (912.88)	924.00	419.60 (441.77)	414.36	420.97 (441.34)	404.51
	F^{abs}	228.56 (228.37)	228.23	226.82 (226.60)	229.51	130.25 (131.13)	131.82	130.11 (130.79)	132.27
18 Aug. 2016 (14:00 UTC)	$F^{\uparrow}$	315.16 (316.82)	308.68	355.26 (357.12)	288.71	209.74 (174.40)	218.62	211.54 (171.59)	208.40
	$F^{\downarrow}$	805.34 (803.59)	812.25	770.21 (768.26)	830.13	342.50 (378.46)	326.53	341.92 (382.68)	377.02
	F^{abs}	242.36 (242.48)	241.95	237.36 (237.46)	244.10	131.74 (131.20)	138.86	130.55 (129.76)	138.64

Note: Values before the parentheses are calculated from the combination of failed and successful retrievals representing the total cloudy population, while values in parentheses are calculated from successful retrievals only representing the total cloudy population. clear-sky pixels values have been included in all calculations.

2 Specific comments

- Fig 1. really helped to understand the flow of the study. However, I have some suggestions... I recommend to use the notation (symbols like "Y_{3D}" or "F_{1D}") throughout the text. Furthermore, the figure would be easier to follow if you introduced a legend for the symbols in the caption.
  Reply: Thank you for this comment. We have modified Fig 1 as well as the manuscript text using notations such as δR to represent the reflectance bias, δF_1 and δF_2 to represent radiative flux bias e.t.c. A caption briefly explaining the symbols have been added to Fig. 1.

- l. 164: Why use SHDOM and MonteCarlo. Is there a particular reason why you would want to use multiple software packages?
  Reply: It is true that the SHDOM is more efficient for computing radiances thus, it was utilized for our radiance computation (as was stated in L169 and L179 in initial manuscript). While it is efficient for pixel scale radiance computation, the SHDOM flux solutions for these large LES scenes fail the Conservation of energy criteria on the domain scale. Reflected + Transmitted + Absorbed ≠ Solar flux at Top of the domain. The Monte Carlo handles flux computation well and satisfies the conservation of energy criteria on the domain scale, while the SHDOM is better for radiance computation.

- l. 192: I guess using 100m horizontal resolution is convenient because it fits your LES from which you derive the 3D cloud structure etc. but it does not really fit the resolution of the current generation of satellites. I would encourage to spend a couple of sentences to discuss this in more detail as I would expect that the resolution would potentially alter the impact of 3D effects quite strongly in the framework you proposed.
  Reply: Since our study was conducted at the native LES resolution of 100m, several remote sensing instruments like MODIS have a coarser footprint and thus will have different 3D effects impacts on retrievals and radiative flux. Thus, future studies will investigate how 3D effects retrieval errors

for different spatial resolutions affect the radiative flux estimates. This explanation has been added to the revised manuscript in L206-209.

- l. 214: 0.07 surface albedo seems quite low for the single wavelengths as well as for the broadband values over vegetation. I was curious and could not understand the choice of 0.07 given the reference of Trishchenko.2003. Please elaborate in more detail where this value comes from.
  Reply: For this study, the central wavelength for each RRTM band was used to obtain the surface albedo. The corresponding surface albedo for each central wavelength was inferred from fig. 3 (curve for SGP albedo May 2003) in Coddington et al., 2013 for λ < 2.5 µm and fig. 4. (for a vegetative surface) In Zhuravleva et al., 2009 for λ > 2.5 µm . The surface spectral albedo plot for each band center from the 14 RRTM spectral band has been included in the appendix of the manuscript.

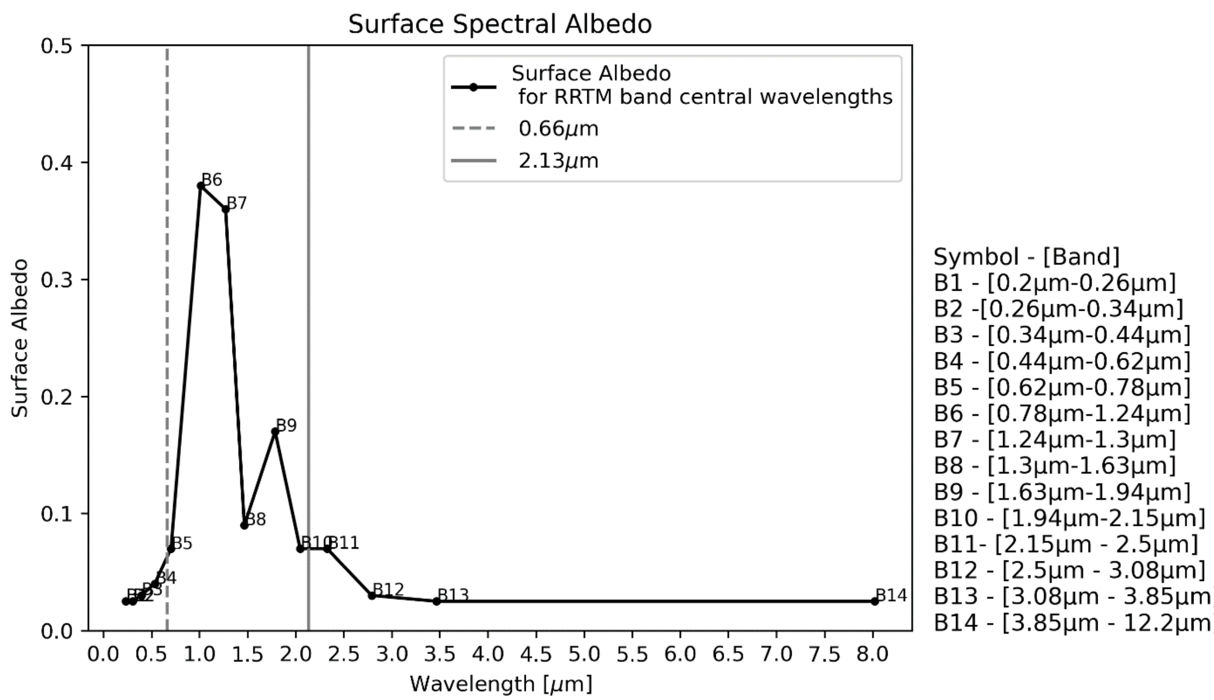

Figure: showing the surface spectral albedo used for the broadband calculation. Vertical lines denote the wavelength used for bispectral retrievals.

- l. 276: see general comments section. The vertical structure of the LES is usually not available. Please discuss the need for 3D cloud structure.
  Reply: Cloud properties e.g., the cloud droplet effective radius in the LES has a vertical profile, and remote sensing satellite instruments are strongly sensitive to the cloud top effective radius. thus the need to try to match the reconstructed cloud properties as much as possible to the original LES vertical structure. Thus, we distribute the retrieved cloud properties in layers where the original LES indicates such.

- l. 324: it would be easy to imagine a scene that would produce a wrong shadow label due to 3D radiation leakage. E.g. imagine the following: A clear sky domain, one cloud stripe along the y

axis, i.e. cld at (x0,y=:,z=z0), sun shining along the y axis with inclined sun. The 3D radiance will probably be lower than the 1D radiance, but it is certainly not shadowed. I am not saying that it is not a reasonable choice on your part, and I guess it works in most cases but I am curious why you wouldn't use an easier and probably more robust shadow mask. E.g. you could use a ray tracer or just the direct radiation component of flux computations.
Reply: The illuminated and shadowed pixels classification used for the illustration of reflectance between 1D and 3D reflectance does not necessarily mean that all shadowing cases are cast by a cloud. It could be as you described, photons leaking from the cloud sides in the 3D (which is absent in 1D RT) and therefore reduces the 3D cloud reflectance. To avoid this ambiguity, a less rigid term "darkened" has been used to replace the term "shadowed" for pixel reflectance comparison describing the 3D effects. Additionally, the term "illuminated" has been replaced by "brightened" for pixels where the 3D RT based reflectance is greater than its 1D counterpart. L319 - L322 in the revised manuscript.

- l. 507: This is just an example where you could use the symbol notation from fig.1. I think it would be more concise and easier to read e.g. add symbols like F_{3D} or F^{*}_{1D}. I think it would be great to use these symbols all throughout the text.
  Reply: Thank you. The manuscript has been modified using symbols consistent with Fig. 1. as suggested.

- l. 689: photon should be plural. Also, Sun should not be in caps - this would be the case everywhere (I am not a native speaker so I am just not sure)?
  Reply: This has been corrected. Thank you.

- l. 702: 7s% should be 7%
  Reply: This has been corrected

- l. 725: typo: studies should be study, affects should be affect
  Reply: This has been corrected

- l. 728: need should be needs?
  Reply: This has been corrected.

References

Coddington, O., Pilewskie, P., Schmidt, K. S., McBride, P. J., and Vukicevic, T.: Characterizing a New Surface-Based Shortwave Cloud Retrieval Technique, Based on Transmitted Radiance for Soil and Vegetated Surface Types, https://doi.org/10.3390/atmos4010048, 2013.
Zhuravleva, T. B., Kabanov, D. M., Sakerin, S. M., and Firsov, K. M.: Simulation of aerosol direct radiative forcing under typical summer conditions of Siberia. Part 1. Method of calculation and choice of input parameters, Atmospheric and Oceanic Optics, 22, 63-73, https://doi.org/10.1134/S1024856009010102, 2009.