

Review of the paper “Mechanisms of surface solar irradiance variability under broken clouds” by Wouter Mol and Chiel van Heerwaarden, DOI: 10.5194/egusphere-2024-2396

This paper focuses on surface solar irradiance (SSI) variability in broken cloud situations and investigates mechanism for SSI enhancements in presence of broken clouds. Therefore, 3D radiative transfer simulations for idealized and non-idealized clouds were performed and resulting irradiance fields are systematically evaluated to explore the involved mechanisms.

This paper is generally well written, presents new insights and can be a valuable basis for further studies in this field. I believe it is suited for publication after addressing my comments below and major changes to the introduction.

General comments

L. 15-30: The introduction is currently not matching the overall quality of this paper and seems to be suitable only if placed within a larger academic work (“thesis”, L.17). For this article, I would suggest a general introduction to the overall topic including its importance, placing this study in the context of prior work and describing the scope and additional value of this study instead of starting with a description of the content of the introduction chapter.

While chapter 1.2 gives some references to previous work, it also introduces a concept for separating relevant mechanisms and gives fundamental definitions for this work. I would therefore suggest to move this to a separate chapter outside the introduction.

Overall, the language and figure descriptions seem unprecise in multiple occasions. Some important information and details for reproducibility are missing. Although the provided source code and data could give some hints, I think the quality of the paper would profit from some thorough revision. In the specific comments below, I give examples, where in my opinion improvements could be easily adapted.

I encountered problems opening the “model_data.zip” provided through your zenodo data publication on a linux computer. Please double-check the file is usable.

Irradiances obtained with MCRT are subject to uncertainty. While this uncertainty might not be crucial for the results presented in this study, at least an order of magnitude should be mentioned in appropriate places of this paper. This could at least be a general upper limit desired for all experiments or experiment specific. The uncertainty/noise is well visible in ,e.g., Figs. 8, 9 and following.

Specific comments

L. 3: “surface solar irradiance extremes”: This work and the mechanisms are about *maxima*, minima are also extremal but not discussed. While I do not see this as critical in this occasion, please think about more precise wording in general. This would apply also the the title, as “variability” includes a lot more than the irradiance enhancement mainly discussed in this paper.

L. 4: Missing word after “and” (low?)

L. 29: Missing mention and description of Section 4 and 5

Fig. 1: Missing legend for color coding of lines

L. 48: Is there any previous work or citable resource, on increased cloud cover fraction of altocumulus compared to shallow cumulus? If yes, please include a reference else I do comply with this feeling and see that this is more of a definition for this work, but you may think about a less general formulation.

L. 75: “clear-sky to overcast conditions” seems misinterpretable to me, potentially including all conditions in between. I would suggest ‘the transition from clear-sky to overcast conditions’ instead

L.76: “Example[s]”

Fig. 2: Colorbar label is “Normalized” while “normalised” is used in the caption and mostly throughout the document.

Fig. 2: The axes do not really match what the figure describes, as the independent patches do not have an obvious spatial relation on x- and y-axis. I would suggest just scales in “cross-wind” and “along-wind” direction for more clarity.

L. 88: Probable typo: “[n] all cases”

L. 94: The “region” of optical thickness seems misinterpretable to me as a spatial description, as area and value range are important throughout this study. Possibly, using ‘range’ instead could clarify this a bit more.

L. 102: “optically thin area”: “area” (L. 97) refers to surface area and “parts of” (L. 100) as well as “sections” (L. 101) refer to spatial distribution of optical thickness. More stringent nomenclature could benefit readability a little bit here.

L. 105: What is the “upper limit of optical thickness” referring to here?

L. 107: “creat[ing]”

L. 150: As longwave is not used for this study to my understanding, the mention of the “128 set for longwave” seems irrelevant. I suggest either not mentioning it, in case you did not use and potentially also did not compute it or explaining why you needed to compute it, as neglecting it would have saved significant amount of computational effort.

L. 181–184: The text should mention that the cloud is only populating half of the domain. Information like domain size and horizontal resolution is also missing in the text. Also information on solar azimuth would clarify the setup. There is no information on atmospheric properties apart from clouds. For clear-sky SSI values (which then could be mentioned for example here) and reproducibility, this is a necessary information. Also the (periodic?) boundary conditions of the MCRT are only mentioned later on for the Cb-case.

L. 185: Fig. 4 suggests the domain is 12.8km x 12.8km for stratus, but 6.4km x 6.4km for cloud gap. Is this “the same configuration” and only an excerpt shown or do the domain sizes differ? Please

clarify.

L. 189: Two times “manually”: I suggest deleting the later occurrence

L. 196-201: As later use of this case suggests, the domain size here is not 12.8km x 12.8km (or 6.4km x 6.4km), but larger to isolate the towering cumulus. Please mention the actual domain size also here. While it is later on (Section 4.5) noted, that the optical thickness is ensured to be large enough, a thorough documentation of your scaling of optical thickness with increasing cloud depth is missing and should be added, for example here.

L. 208-209: Repetitive use of “altocumulus”, e.g., the second occurrence could be replaced by ‘This’.

Fig. 6: As cloud depth is later on (e.g. Fig. 13) used to distinguish cases, it would be nice if this would be given for the displayed snapshots for a better association.

L. 244: I am unsure whether there should be a second “in” in “for the scattering regime we are [in] in terms of mechanism”.

Fig. 9: The domain cross-section used for this plot could be indicated in Fig. 4 to get a feeling of the averaged region in y-direction, especially in the checkerboard case. This would also give a hint on sun direction there. Otherwise “(part of)” (Fig. 9, caption L. 2) is a very vague definition.

Fig. 9: While theoretically reconstructable from Norm. SSI (-), AE (W/m^2) and AE as % of IE for the reader, it would be helpful for the reader to have clear-sky SSI (dir/dif/tot) values given at least for this figure or more in general in the text.

Fig. 9 g-i: The extremal values on the shadow borders are a striking feature and should at least briefly assessed in the text. Also, there is no explanation of the grey regions here.

Fig. 9 i: In the case of sun zenith angle $SZA=30^\circ$ the gray shaded area including the border grid boxes do have an x-extent of about 2x the extent of the valid data area excluding the border grid boxes with extremal values. To my understanding, of the text, the cloud disks are 500m in diameter with a maximum distance of 150m in between (L. 193-195). This would suggest a ratio of > 3:1. I guess this is due to the selected and averaged y-axis range, but this needs more explanation.

L. 304-310: A full description of the setup would in my opinion include albedo and SZA in the text, not just in Fig. 10

Fig. 10 and Section 4.4.1:

Is the SSI summed/averaged over the entire domain (almost) constant for all cloud altitudes and therefore the power only redistributed or is there a significant difference in surface solar power based on cloud altitude? To me, this would be a nice additional information and support the previous explanation of checkerboard case SSI.

L. 326: Can omit the “in” in “very small [in] for the simulated altocumulus”

L. 336: “There are two exceptions where forward escape still occurs”: In a statistical sense, individual photons/rays can always be scattered only once or twice and therefore there is always some fraction of forward escape. While the meaning is fully understandable in this context, please

consider rephrasing to avoid the impression of exclusivity of the mechanisms. I would suggest replacing “occurs” by ‘plays a significant role’ or ‘contributes significantly’.

Fig. 13 caption:

Neither a nor b do directly show SSI patterns as indicated by the caption. Please make the caption, especially the first sentence, more precise.

Fig. 13 a: Are 17.2 and 18.4 ordered on purpose like this in the legend?

L. 371: There is still a maximum in IE in these cases, it is just spatially shifted and/or decreased. Please rephrase “disappearance” or specify the “peak irradiance enhancement” you mean more in detail.

L. 377: For example ‘hinder’ or ‘obstruct’ would describe the process more factual than “takes over the side escape mechanism”. At the moment this sentence does not reflect the actual process to me.

Fig. 14: Cb cases were before referenced by LES time or cloud depth. For better orientation, it would be helpful to get this information here as well.

Fig 15 caption, L.3:

“The [S]un”

L. 399-400: The regions meant here are the ones away from ‘cloud shadows’ and not from “clouds”, I suggest? Please consider rephrasing.

L. 409: “sunlit cloud base” sounds to me only possible with $SZA > 90^\circ$. Please clarify.

L. 427: Also for clouds with optical depth > 6 , a (small) fraction of light is scattered only once or twice. Therefore I suggest adding “irradiance is [predominantly] scattered uniformly downward”.

L. 427: To my knowledge, the downward radiance distribution underneath optically thick clouds is not “uniform”. Please clarify.

This can be looked up, e.g., in theory and simulation in Sobolev (2017), Grant et al. (1995), in measurements in Nagata et al. (1997) or simply using a 1D-RT calculation with an optically thick cloud.

L. 439: “onto” seems the wrong word here to me. Perhaps use ‘of’ instead?

L. 460: Can omit “out”.

L. 469: Following the sentence structure, I believe it should be ‘maximally complex’ instead of “maximum complexity”.

References

Sobolev, V. V. (2017). *Light scattering in planetary atmospheres: international series of monographs in natural philosophy* (Vol. 76). Elsevier.

Grant, R. H., Heisler, G. M., & Gao, W. (1996). Photosynthetically-active radiation: sky radiance distributions under clear and overcast conditions. *Agricultural and Forest Meteorology*, 82(1-4), 267-292.

Nagata, T. (1997). Radiance distribution on stable overcast skies. *Journal of Light & Visual Environment*, 21(1).