Decoupling the effects of clear atmosphere and clouds to simplify calculations of the broadband solar irradiance at ground level, by A. Oumbe

LETTER TO THE EDITOR, LISTING ANSWERS TO COMMENTS

Dear Editor,

to our opinion, we have answered all comments, concerns and suggestions made on our paper. We have made additional computations to better answer and additional graphs to be included in the revised text. We are confident that we have satisfactorily addressed all comments and that the revised manuscript will meet the high quality standards of GMD.

ANSWERS TO REVIEWER 1

Comment 1. The paper could be published almost as it is but it has to be noted (in the title too) that it is not a scientific paper but a technical note.

We fully agree. The title has been changed and is now "Technical Note - Decoupling the effects of clear atmosphere and clouds to simplify calculations of the broadband solar irradiance at ground level". In introduction, we also change "This article aims at holding…" by "This Technical Note aims at holding…" (page 2009, line 15). Title of section 2 is now "Objective" instead of "Objective of the article" (page 2009, line 20). Finally, the first sentence of the conclusion is "This Technical Note analyses…" instead of "This article analyses…".

Comment 2. Page 3, line 11: the authors could consider to add or replace the papers about the cloud modification factor with two papers that provide more coherent descriptions about how this factor is being used in UV or PAR studies. These papers are

from J. Calbo (Reviews of Geophysics, 2005) and den Outer et al. (Journal of Geophysical Research, 2010)

We fully agree. We have replaced the previous references (page 2010, line 5).

Comment 3. Figures 3, 4 and relevant text: the authors could provide some information about the behavior of rRm of variance of Kc for solar zenith angles greater than 60 degrees. Probably, this effect is related to the reduction (70, 80 degrees) and diminishing (90 degrees) of the direct component.

We made further analysis. We observe that for a given cloud optical depth τ_c, and for θ_S >50°, the RM of variance of *Kc*, *RM(v(K*$_c$*))*, increases with θ_S with a maximum at θ_S=80°. This happens for all studied τ_c. As the direct component is extinguished for τ_c>3-4, it is believed that the decrease of the direct component is not the main cause of this behaviour. Changes in ground albedo ρ_g do not change this behaviour: it is observed for all studied ρ_g. Other sources of variability than the ground albedo and the cloud optical depth have a greater relative importance when θ_S increases. We found that the increase in relative influence with large θ_S is mostly due to the increase of the optical path in the atmosphere due to greater θ_S and therefore a greater influence of *Pc* and notably the aerosols.

The text has been changed accordingly to account for these additional findings. It reads now "All three quantities increase sharply for θ_S>60°. The relative median, respectively P95, reaches a maximum of approximately 8-9%, respectively 11-12% for θ_S=80°. Then, a decrease is observed for θ_S>80°. Further computations show that the increase in relative influence with large θ_S is mostly due to the increase of the optical path in the atmosphere due to greater θ_S and therefore a greater influence of P_c and notably the aerosols."

Technical correction 4. Replace "Oumber" by "Oumbe"

Done

ANSWERS TO REVIEWER 2

Comment 1. The authors do a nice job of ensuring realistic combinations of model parameters. Nevertheless I wonder if 20 cases of P_c are enough, considering that each P_c is comprised of 7 parameters. Especially since statistics over these 20 cases are the key measure of whether the separability assumption is satisfied (the 95th percentile will separate a single case from all of the rest). If computational burden is an issue, perhaps fewer steps could have been used in some of the other parameters. Nevertheless the quality of the results, such as shown by their consistency between solar zenith angles, demonstrates that the set of cases studied is sufficient to support the conclusions made.

We fully agree. Actually, we made the computations twice independently at two different institutes by different persons, plus another one with the STREAMER model. Because they are randomly selected, the 20 cases of Pc were different in each study. Conclusions were similar, which is in agreement with the last sentence of the comment by the reviewer. Practically, it was difficult to concatenate all computations to get 60 random selected cases of Pc. We have opted to present the results of one of these three computation series. In addition, numerous additional runs were made to better understand the results. For example, new computations were made to better answer comments.

Comment 2. P2011, L26: A fixed value is used for the cloud droplet effective radius (r_eff) for each of water and ice cloud. What is the sensitivity to variations in r_eff? For instance, the near-infrared cloud reflectance would be expected to change with r_eff, and Nakajima and King (1990, Journal of the Atmospheric Sciences, 47, 1878-1893) studied the retrieval of r_eff over a range of at least 2 to 32 micrometres.

We have used the values of 10 µm for water cloud, and 20 µm for ice cloud for effective radius of droplets. In a preliminary study (PhD of A. Oumbe 2009), the influence of the changes in effective radius, from 3 to 50 µm was found negligible for ice clouds. For water clouds, the smaller the radius, the greater the influence, though this influence is still negligible with respect to other variables. We acknowledge that the study could be completed by taking into account changes in effective radius.

Oumbe, A.: Exploitation des nouvelles capacités d'observation de la terre pour évaluer le rayonnement solaire incident au sol (Assessment of solar surface radiation using new earth observation capabilities). PhD thesis, MINES ParisTech, 9 November 2009 (128 pages). Figure 4.6, p. 53.

Text has been revised accordingly. It is now: “Default values in libRadtran for cloud liquid content and droplet effective radius are used: 1.0 g m^{-3} and 10 µm for water cloud, and 0.005 g m^{-3} and 20 µm for ice cloud. In a preliminary study (Oumbe, 2009, Fig. 4.6, p. 53), the influence of the changes in effective radius, from 3 to 50 µm was found negligible for ice clouds. For water clouds, the smaller the radius, the greater the influence, though this influence is still negligible with respect to other variables.”

Comment 3. P2019, L2: The authors might consider noting the maximum albedo expected for desert regions (no more than around 0.5 I think), since many users of downstream products will be interested in the performance in snow-free arid regions.

We fully agree. Northern Africa and Arabia are desert areas and exhibit large ground albedo up to approximately 0.5 (Tsvetsinskaya et al., 2002; Wendler and Eaton, 1983).

Text has been revised accordingly, page 2015, lines 16-17. It is now: “The diffuse irradiance D and therefore G are strongly influenced by ρ_g. The influence of changes in P_c on K_c increases with ρ_g. Deserts such as Northern Africa and Arabia exhibit large ground albedo up to approximately 0.5 (Tsvetsinskaya et al., 2002; Wendler and Eaton, 1983); the error (P95) on G is of order of 10 W m^{-2}. Fresh snow-covered or ice-covered areas may exhibit very large ρ_g. For ρ_g=0.9, the error on G can be large for small θ_S, i.e. 30 W m^{-2}. One has to be cautious in using Eq. 3 in such extreme cases.”

Tsvetsinskaya, E. A., Schaaf, C. B., Gao, F., Strahler, A. H., Dickinson, R. E., Zeng, X., and Lucht, W.: Relating MODIS-derived surface albedo to soils and rock types over Northern Africa and the Arabian peninsula, *Geophysical Research Letters*, 29(9), 1353, 10.1029/2001GL014096, 2002.

Wendler, G., and Eaton, F.: On the desertification of the Sahel zone, *Climatic Change*, 5, 365-380, 1983.

Comment 4. Figures 3 and 4 plot results in relative terms. Consider plotting the results in absolute terms as well, since as you point out the absolute errors are important to consider in practice. Perhaps a second panel could be added to Figure 4 showing the same results as the current Figure 4 plot but in absolute terms.

Done for Figs 3 and 4.

Comment 5. P2016, L11-12: It is true that the uncertainty contributed by the assumption that changes in Pc can be neglected is within the WMO criterion of high quality measurements. However, in application there will be other contributions such as uncertainties in cloud property retrievals, aerosol amount and type, satellite calibration, radiative transfer model approximations, etc. The total uncertainty of output from any system using this assumption will be higher and probably outside the WMO high quality threshold.

Text has been changed and is now: "These results match the WMO requirements for high quality measurements. However, in applications as discussed in the following section, there will be other sources of uncertainties, and the total uncertainty of any model using Eq. 3 will be greater and probably exceeding these WMO requirements."

Technical correction 6. P2019, L4: Change "pyranometer" to "pyrheliometer".

Done

Technical correction 7. P2019, L28: The authors intend to mean a reduction for each of points (i), (ii) and (iii). Therefore, "reducing" should be moved before "(i)" to say this.

Done