Dear Referee #1,

Thank you for your suggestions and remarks. Consideration of these comments have helped improve the manuscript. Below you will find the answers to each comment.

In this study by Chesnoiu et al. the variability of surface solar irradiance and its components (direct and diffuse) is investigated for the period 2010-2022 over Lille, France, relying on ground-based measurements and radiative transfer simulations. Based on the classification of the sky conditions (for clouds and aerosols) they quantified the contribution of the different parameters on the variability and trends of the different solar irradiance components, and they obtained also climatologies for their site. The objectives of the study are quite straightforward and are addressed by a thorough analysis. The surface solar radiation climatology and trends that the authors provide here for Lille considering also the atmospheric parameters that can impact the calculated changes is of significance for assessing and understand changes in surface solar radiation. I consider the topic and results of this manuscript to fit the scope of ACP. However, I have some general and major comments (please see below 1-5) which should be addressed prior to publication.

1) My major comment concerning this study has to do with Section 4. Authors should rename the section, correct it and state clearer the objectives regarding this analysis. The analysis performed is a quantification of the direct (scattering and absorption) impact of aerosols in downwelling surface solar irradiance. Changes in downwelling surface solar irradiance due to aerosols calculated using eq. 29 are always negative (attenuation) due to their direct interactions of incoming solar radiation which is of relevance for surface related applications like solar energy as stated in the manuscript. The relative change (expressed in %) in downwelling surface solar irradiance due to aerosols presence was calculated with respect to an aerosol-free atmosphere using eq. 27. However, the radiative effect due to aerosol-radiation interactions REari according to IPCC report formerly known as direct radiative effect (DRE), is the change in radiative fluxes caused by combined scattering and absorption of radiation by anthropogenic and natural aerosols (Boucher et al., 2013). DREs are climate related quantities which are calculated at surface and top of the atmosphere (TOA) using net fluxes (downwelling minus upwelling) for shortwave and longwave radiation, for clear sky and all skies conditions, in order to assess the warming of cooling of the earth-atmosphere system. Authors should address which is the objective of this study, make the appropriate changes in section 4 including related references where applicable.

Boucher, O., D. Randall, P. Artaxo, C. Bretherton, G. Feingold, P. Forster, V.-M. Kerminen, Y. Kondo, H. Liao, U. Lohmann, P. Rasch, S.K. Satheesh, S. Sherwood, B. Stevens and X.Y. Zhang, 2013: Clouds and Aerosols. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

To improve clarity, we followed the recommendations of the reviewer both to change the title of Section 4 and to favor the use of "radiative effect" instead of 'direct radiative effect' in the manuscript. Thus, in the revised manuscript the new title of Section 4 is "Radiative effects of atmospheric components on SSI". Section 4.1 has been renamed "Clear-sky conditions" and Section 4.2 "Clear-sun-with-clouds conditions".

In addition, the acronym "DRE" has been replaced by "RE_d" (***R***adiative ***E***ffect on the ***d***ownwelling surface solar irradiance). These changes aim to avoid any confusion with the climate related quantity that indeed consider the net radiative effect, generally both at the surface and the top of the atmosphere.

Paragraphs introducing Section 4 (lines 782 to 804) have been rewritten to clarify our objectives and approach (lines 736 to 748 of the revised manuscript):

"In this section we assess atmospheric component's, especially aerosols, radiative effects on the downwelling surface solar irradiances (called RE_d for ***R***adiative ***E***ffect on the ***d***ownwelling SSI), consistently with our ground-based dataset, and in relevance for surface related applications (such as photovoltaic solar systems) and surface processes (e.g. photosynthesis). Note that only a few studies have assessed the direct radiative impact of aerosols specifically on downward surface solar radiation, as for example done in Papadimas et al. (2012) over the Mediterranean basin. Furthermore, our approach encompasses the shortwave radiative effects of atmospheric particles on both global (GHI), direct (BHI) and diffuse (DHI) components of the downwelling SSI, as in Witthuhn et al. (2021). In Section 4.1 our analysis of the RE_d focus on clear-sky conditions, through a statistical investigation of the aerosol radiative effects on all downwelling SSI components (GHI, BHI, DHI) over the whole period 2010-2022. In addition, Section 4.2 provides an analysis of aerosols and clouds radiative effects in CSWC conditions. This approach relies on two sets of pristine (i.e., aerosol-and- cloud free) and cloud-free simulations, which by comparison with ground-based measurements that include the effect of clouds on SSI, allow the quantification of both aerosols and clouds' RE_d in CSWC conditions. Finally, the respective and cumulative RE_d of clouds (on DHI) and aerosols (on DHI and BHI) can be quantified over all CSUN (CSKY and CSWC) situations, that represent on average 33% of sky conditions in Lille."

2) It is stated at Lines 273-274 that AOD440, AOD550, AE440-870 and relative humidity are the "remaining inputs" to SOLARTDECO. I think that this gives the wrong impression that these are the inputs in RT, while these values are used to select and adjust the new optical properties for the specific aerosol mixture. Please clarify and adjust 2.3.1 and 2.3.2 accordingly. For example, in Lines 343-344 it should be clarified that it is not only the fact that Mie calculations are time consuming that were not performed for every RT simulation, but the fact that inversion data are not always available, which has already stated earlier in the manuscript. In addition, while it is described in detail how the new aerosol optical properties are derived for each simulation, it is not clear the vertical structure of the aerosol layer (only notes in Lines 654-655 and 672-673) and how the extinction is scaled to measured aerosol load in the total column. Please clarify which are the parameters to be set (are those in Table 4?) apart from defining the new aerosol optical properties based on the Mie calculations. Another confusing part is Lines 383-384. SSA, g and ff are "estimates of optical properties derived from SOLARTDECO"? How this information is consistent with what is stated in Sections 2.3.1 and 2.3.2 regarding the inputs in RT?

In order to clarify all these aspects describing our use of the radiative simulations with SOLARTDECO, Sections 2.3.1 and 2.3.2 have been extensively modified.

The classification of aerosol properties, which was initially in Section 2.3.2, has been moved to Section 2.2 ("Classification of atmospheric conditions in Lille"). Section 2.2 now includes classifications of both the sky conditions (2.2.1) and aerosol conditions (2.2.2).

The description of SOLARTDECO (Section 2.3) has been improved: a flux diagram has been added for clarity (new Figure 2 in the revised manuscript), especially on the input parameters.

The motivation behind the pre-computed aerosol optical properties has been rewritten more clearly in Section 2.3 (lines 256-259).

The vertical structure of aerosols has been defined more carefully (exponential decay of the aerosol density with a 2 km scale height, lines 286-287), and the definition of the scaling of the extinction to the measured aerosol load has been added to the main text (Section 2.3, lines 279-284).

It has been made clear that the estimates of aerosol optical properties are not products of SOLARTDECO but rather outputs of a related routine, which mixes pre-computed aerosols optical properties of the fine and coarse modes to produce inputs (Cext, SSA, phase function) for DISORT (lines 254-256). Lines 383-384 appeared awkward and redundant and have been removed.

3) Consider to move 3.2.1 and 3.2.2 to the methodology Section.

This change in the organization of the paper has been done in the revised version. Sections 3.2.1 and 3.2.2 are now included as part of Section 2 "Data and Methods", in Section 2.4 titled "Multivariate analysis of the SSI variability". Section 2.4.1 describes the methodology, Section 2.4.2 the sensitivity study of clear-sky SSI.

Specific comments

Line 10: Change “all sky” to “all skies” throughout the manuscript.

This expression is widely used to describe all skies situations, encompassing both cloudy and clear conditions (Boers et al., 2017; Wild, 2009; Xie et al., 2016). In the present work, our approach is similar, although the distinction involves three categories of sky conditions (clear-sky, clear-sun with clouds and cloudy-sun) instead of two (cloudy or clear).

In the submitted version line 10 of the abstract, the "-" was missing in the "all-sky" expression. This has been corrected in the revised manuscript. But the use of this expression is adopted and rather conventional in earlier publications, as that of "Clear-sky", or "Clear-sun-with-cloud".

References:

Boers et al. (2017): Impact of aerosols and clouds on decadal trends in all-sky solar radiation over the Netherlands (1966–2015). (DOI: 10.5194/acp-17-8081-2017)

Wild (2009) : Global dimming and brightening: A review. (DOI: 10.1029/2008JD011470)

Xie et al. (2016): A Fast All-sky Radiation Model for Solar applications (FARMS): Algorithm and performance evaluation. (DOI: 10.1016/j.solener.2016.06.003)

Line 47: I am not following those "increase" and "decrease" descriptions inside the parenthesis where are referred to?

There was a mistake in the descriptions inside the parentheses. Aerosols and clouds lead to a decrease in direct radiation while increasing the diffuse component.

For clarity, the sentence was changed to:

“***However, depending on their optical properties, aerosols and clouds influence incident radiation by reducing the direct component while enhancing the diffuse component.*** “

Line 49: I suggest including also here the importance of direct normal irradiance to concentrating solar power systems providing also references (e.g. Sengupta et al., 2021, https://www.nrel.gov/docs/fy21osti/77635.pdf)

Thanks for this suggestion, the provided reference has been added in the revised version of the manuscript.

Lines 271: Please remove the 500 in “of respectively 407 and 209 500 ppmv”.

The concentration of oxygen has been changed from 209 500 ppmv to 209 000.

Lines 273-274: These sentences are confusing, regarding the geometry. The only geometry to be determined is the sun position through solar zenith angle and regarding viewing angle the whole dome is considered, right? It is stated explicitly in Line 283 that the “horizontal irradiances” were calculated, so please clarify if the other geometries are important at this part since no computations for tilted surfaces were performed.

Indeed, in this work only horizontal surface irradiances were computed by integration over the whole dome, with only the solar zenith angle as a geometrical input.

Nonetheless, SOLARTDECO is also able to compute radiances for specific viewing zenith and azimuth angles.

However, as such computations were not involved in the present study, we chose for clarity to remove the mention of geometrical inputs other than the SZA.

Line 281: Please consider the change from "of the incoming and outgoing spectral irradiances" to "of the incoming and outgoing spectral solar irradiances"

The adjective "solar" was added.

Line 367: These are absolute differences? Please, clarify.

The sentence was not quite clear and the indicated threshold was not correct.

It was changed as follows, lines 306-310 of the revised manuscript:

"Moreover, the performances of SOLARTDECO are well within the error margins expected for network-operational instruments (Meteorological Organization, 2008) **as mean absolute differences (MAD) are close to the resolution of network instruments (5 W/m²)** for all irradiance components and more than 95% of the comparisons have **mean differences** lower than ±20 W/m².”

Line 439: Is 435 W/m2 the correct number for clear-sky? The grey line is below 400 in Fig. 4 (h).

Indeed, 435 W/m^2 corresponds to the mean climatological value obtained by averaging all 1-minute measurements over the period 2010-2022. For consistency, we modified the text to fit Figure 4h, which reports the averages computed based on the monthly values.

The modified sentence is : "In comparison, the measured surface flux in clear-sky conditions is twice as high, with an average value around 375 W/m2." (lines 506-507 of the revised manuscript).

Line 451: Is 69% correct in summer for all-sky conditions according to Fig.4 (e)?

The diffuse proportions of irradiance were not consistent with those shown on Fig. 4e due to differences in averaged calculations, as explained in the previous comment. The text has been updated to match Fig. 4e: the averages are computed based on the monthly values. The new sentence is : "Moreover, the variability of the optical air mass has a great influence on the proportion of diffuse irradiance, which varies, under all-sky conditions, between 51% in summer to more than 65% in winter (lines 518-520 of the revised manuscript).

Lines 653-654 and 658-662: It would be helpful to provide also those mean values used as refence.

SZA (°)	AOD_{550}	SSA_{550}	**ff**	H_{aer} (km)	**RH (%)**	**PWV (cm)**	O_3 (DU)	O_2 (ppmv)	CO_2 (ppmv)	α
61.71	0.13	0.93	0.72	2	55	1.46	341	209 000	407	0.15

As shown line 405 of the revised manuscript, the above table describing the mean values used for each parameter involved in the sensitivity study has been added to the supplements (new Table S1).

Line 660: Remove "logically".

"Logically" has been removed (line 413 of the revised manuscript).

Figure 7: Last 3 lines of caption need to be clarified better.

The caption was clarified as follows:

"The additional decomposition of BHI_{CSWC} and BHI_{CSKY} with respect to the scene's parameters is illustrated in panel (b). The orange and blue columns from panel (a), which represent the intrinsic variability of the BHI under CSWC and CSKY conditions, respectively, are represented as dashed lines of the same color in panel (b). The pink dashed lines represent the values estimated from the decomposition of the BHI according to the scene's parameters as in Equation 6. The latter decomposition is also illustrated by the colored columns, which represent the contributions of the variability in the frequency of occurrence of aerosol classes ($freq_{aer}$, black column), as well as the variability of the AOD (green column), ff (violet column), PWV (blue column), and SZA (brown column)."

Line 724: F_{CSUN} here is BHI_{CSWC}?

F_{CSUN} corresponds to the sum of BHI_{CSWC} and BHI_{CSKY} from Figure 7.

For clarity, "[…] overall increase of F_{CSUN}." has been replaced with "[…] overall increase in BHI under clear-sun conditions." as shown line 679 of the revised text.

Technical corrections

Line 386: Replace 2020 with 2010.

Done.

Figure 4: In (e), (f) and (h) percentages that reflect the contribution of the DHI to the overall mean yearly GHI are missing. For (b) and clear-sky this is "blue line" or green? In addition in the 6th line AERONET is twice.

Percentages have been added in Figures 4e, f, and h.

For panel (b), the color of clear-sky conditions is indeed green. The caption of Figure 4 has been modified accordingly in the revised manuscript.

The first « AERONET » of the sixth line has also been removed.

Lines 507-508: Change the color of the lines insides parenthesis according to Fig. 5b and 6b.

Colors mentioned inside parenthesis have been modified, as shown lines 577-578 of the revised text.

Line 623: Replace "dFclear/dt" with dFi/dt

The subscript was changed accordingly, as shown line 375 of the revised text.

Line 626: In eq. 22 probably this "Fclear" is F?

« Fclear » is indeed F, the subscript has been removed (eq. 8 of the revised manuscript, line 378).

Line 791: Word "surface" is twice

One iteration of "surface" has been replaced by "solar", although the text of this paragraph has been modified.

Figures 7, 8, 9: Should be enlarge and brown columns better solid than shaded.

The size of each figure was modified while keeping panels (a) and (b) on the same page.

Brown columns are now solid.