Reply to report of reviewer #1
"Validating global horizontal irradiance retrievals from Meteosat SEVIRI at increased spatial resolution against a dense network of ground-based observations by Wiltink et. al."

bold italic font = reviewer's comment
regular font = authors' reply
red regular font = adjustments in manuscript

The authors present a methodology to downscale GHI retrievals from MSG imagery which is validated againts the HOPE field campaign (a set os 99 solar radiation sensors distributed along 10 × 12 km2). The paper is rather good and the results also are. I think that it has enough quality to be accepted for publication and also interest in the community. I have only a few minor comments and/or doubts.

We thank the reviewer for the comments and suggestions aimed at improving the quality of the manuscript. Please find a response to the review below to see how the reviewer's concerns were handled.

1) ***It is not quite clear to me what is the time scale of the GHI retrievals, since Meteosat Second Generation imagery is disseminated in 15-minutes how the authors estimate 5-minute GHI?***

   The primary service of MSG SEVIRI indeed has a repeat cycle of 15 minutes. However, here, the Rapid Scan Service (RSS) is used instead of the primary service. In 2013, the RSS was mainly performed by Meteosat-9. With the RSS, only the part of the SEVIRI disk covering Northern Africa and Europe is scanned, which enables a 5-minute repeat cycle instead of the 15-minute repeat cycle of the primary service. In the manuscript, we rearranged the following sentence to make it clear to readers less familiar with the RSS how a 5-minute temporal resolution can be achieved.

   page 6, lines 115-116: ~~Using the rapid scan service of SEVIRI (RSS), a single scan covering Europe is completed every five minutes.~~ → Using the Rapid scan service (RSS), only part of the SEVIRI disk covering Northern Africa and Europe is scanned, enabling a 5-minute repeat cycle.

2) ***would need a clearer explanation, I don't see why the use of residuals istead of reflectance and it is not completeley clear (at least to me) how this method is used or affect to the GHI retrieval. How afect the reflectance?***

   The high frequency residuals are used in the retrieval to update the SR reflectances of the 0.6 μm channel that do not include HR information to reflectances where the HR information is included. This is done by adding the high frequency residuals to the original (SR) reflectances. This was not explicitly mentioned in the manuscript. We have included the following line in the updated manuscript to clarify this aspect.

   page 7, Line 180: "... first estimation of δr_{06}. The high-frequency residuals of the 0.6 μm channel are then added to the original 0.6 μm reflectances, providing updated values of reflectances for the 0.6 μm channel that include HRV information. Using CPP LUTs and the bi-spectral retrieval method ..."

   We have also extended the explanation on how the conservation of retrieval accuracy of CER at HR is performred.

   page 7, line 182-183: ~~Therefore, the adjustment of $\delta r_{1.6}$ is iteratively determined from the LUT to conserve the SR value of CER (Werner and Deneke 2020).~~ → To restore the accuracy of the retrieved CER at HR,
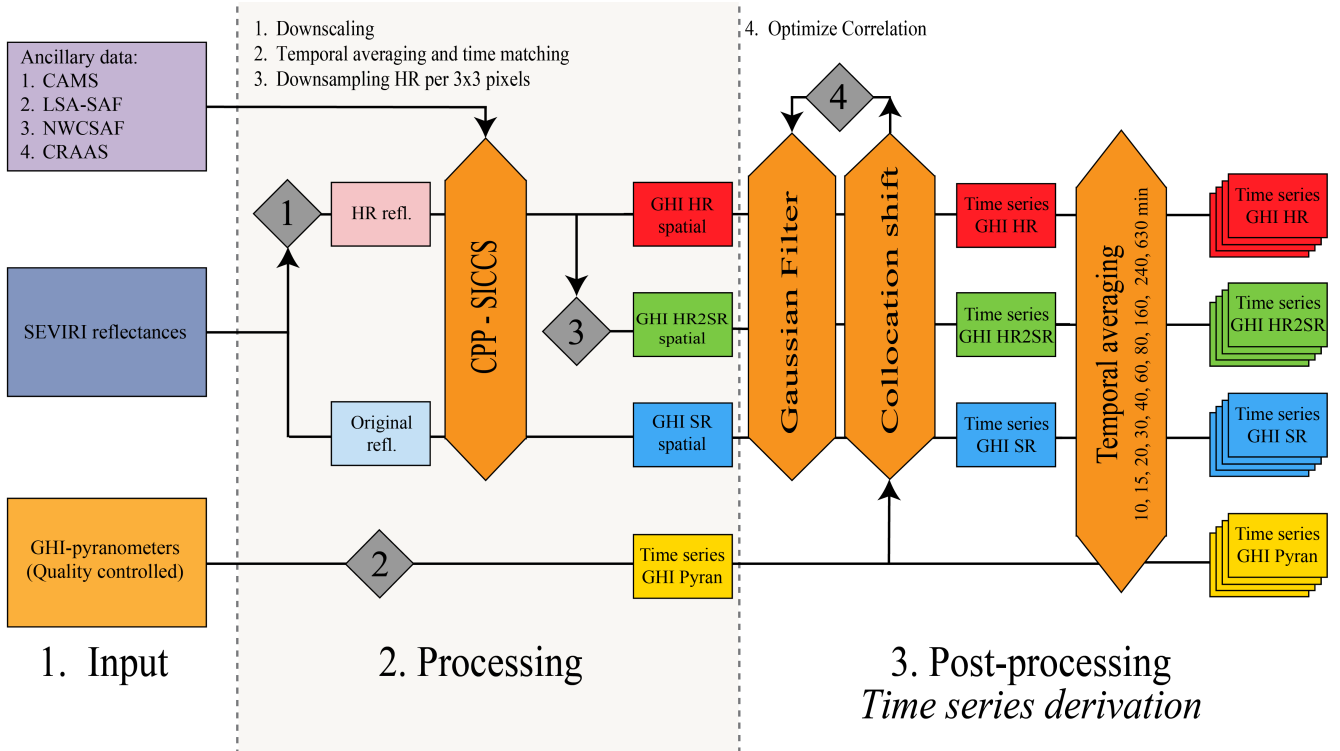
Figure 2: Flow diagram illustrating the required steps to derive time series of GHI from SEVIRI reflectances. The input data and processing are explained in Section 2 while the post-processing is explained in Section 3.

a local slope adjustment is performed. The slope adjustment determines where the high-frequency residual of $r_{1.6}$ equals zero, meaning the SR value of CER is restored. However, since the slope adjustment is based on the tangent of the COT contour at the location of the SR reflectances in the LUT, the HR CER retrieval does not precisely have to match the SR value (Werner and Deneke, 2020).

More details on the downscaling algorithm and the high-frequency residuals are presented in Werner and Deneke (2020). Their Figure 4c graphically shows how residuals are used to derive HR cloud optical thickness and effective radius from the 0.6/1.6 μm bispectral reflectance, which are then used to calculate GHI.

3) *I think that it would be eneficial a scheme or flow diagrama explaining or indicating the different steps and products used in the methodology in order to get easier for the reader the understanding.*

We have added a flow diagram (Fig. 2) to Section 2.2 of the manuscript, graphically illustrating the steps required to go from input data to satellite-derived time series. The figure is introduced as follows:

page 5, line 124 '... is presented in Deneke et al. (2021), and shown in a more compact form in the left hand side of Figure 2.

Note that a detailed flow diagram for the CPP-SICCS algorithm is presented in Deneke et al. (2021).

References

Deneke, H., Barrientos-Velasco, C., Bley, S., Hunerbein, A., Lenk, S., Macke, A., Meirink, J. F., Schroedter-Homscheidt, M., Senf, F., Wang, P., Werner, F., and Witthuhn, J.: Increasing the spatial resolution of cloud property retrievals from Meteosat SEVIRI by use of its high-resolution visible channel: Implementation and examples, Atmospheric Measurement Techniques, 14, 5107–5126, https://doi.org/10.5194/amt-14-5107-2021, 2021.

Werner, F. and Deneke, H.: Increasing the spatial resolution of cloud property retrievals from Meteosat SEVIRI

by use of its high-resolution visible channel: Evaluation of candidate approaches with MODIS observations, Atmospheric Measurement Techniques, 13, 1089–1111, https://doi.org/10.5194/amt-13-1089-2020, 2020.

Reply to report of reviewer #2
"Validating global horizontal irradiance retrievals from Meteosat SEVIRI at increased spatial resolution against a dense network of ground-based observations by Wiltink et. al."

bold italic font = reviewer's comment
regular font = authors' reply
red regular font = adjustments in manuscript

Summary and contributions

The authors present a global horizontal irradiance (GHI) retrieval based on measurements with the MSG-SEVIRI at high resolution (HR) of $1 \times 1 \ km^2$ compared to its standard resolution (SR) of $3 \times 3 \ km^2$. With the aid of MSG-SEVIRIs High-Resolution Visible (HRV) channel GHI is downscaled. The ac-curacy of the HR retrieval compared to its SR retrieval is validated against a dense network of ground-based pyranometer observations. Additionally, the sensitivity of the results to temporal and spatial averaging and its dependence on cloud regimes is studied in detail. Various algorithms to retrieve GHI from satellite measurements exist, to my knowledge however, incorporating the spatial information of the HRV channel to increase resolution of GRI retrieval was never considered. The results are sufficient to support the most interpretations/conclusions and are likely to be highly relevant for solar photovoltaic applications, climate and weather evaluations, as well as for scientific applications as cloud-radiation studies. The manuscript provides a contribution to methodology that can be trans-ferred to other satellite instruments, e.g. the Advanced Baseline Imager or the Advanced Himawari Imager. It is well-organized and scientific results and conclusions are presented in a clear, concise, and well-structured way. In my view after some minor changes, the presented work is worth publishing in 'Atmospheric Measurement Techniques'. Please find my detailed comments below.

We thank the reviewer for taking the time to write a comprehensive review of our manuscript. What follows is our reply to the review to show how the reviewer's comments and suggestions were handled.

General Comments

1) ***The authors introduce abbreviations such as SR, which stands for standard resolution, HR (high resolution). Please check text and be consistent using the abbreviations. Also, different abbreviation versions appear but mean the same, eg:***

    i) ***MSG SEVIRI***
    ii) ***MSG-SEVIRI***
    iii) ***SEVIRI***
    iv) ***Meteosat SEVIRI***

    We have attempted to bring some further consistency in how Meteosat SEVIRI is mentioned within the manuscript. For recognition in the title, abstract and for the first mention in the conclusion we entirely write

out Meteosat in combination with SEVIRI. The fully written version is also used when we refer to one of the satellites in specific (e.g. Meteosat-8, Meteosat-11). We now use the abbreviation MSG when referring to the second generation of Meteosat satellites in general. The term "SEVIRI" is now used in most other cases when we refer to the instrument itself.

We also attempted to more consistently use the abbreviations HR and SR. In the abstract and conclusion we do not use the abbreviations for clarity. For all other cases we now use either HR or SR. In the Figure captions we indeed used a slightly different abbreviation: SEVIRI-HR and SEVIRI-SR. We made this decision to let the figures stand out on their own while it remains clear what the source of the data is (i.e. SEVIRI). To be more consistent with the abbreviations used in the rest of the manuscript we have changed SEVIRI-HR, SEVIRI-HR2SR and SEVIRI-SR to SEVIRI: HR, SEVIRI: HR2SR and SEVIRI: SR.

2) *Following international agreements (IUAP document U.I.P.20 and others), the representation of physical units has been defined by corresponding standards. Correct practice for representing units in figure is using round brackets. Square brackets around a unit are incorrect, although this is still a widespread custom. Please take this standard into account in all figures. If a physical quantity has no unit remove brackets.*

We were not aware of this convention and thank the reviewer for pointing it out. In all the figures, the square brackets have been replaced with round ones, and the brackets around unitless quantities have been removed.

3) *The first paragraph in subsection 4.1 (lines 246-250) describes methodology. Lines 274-284 (subsection 4.1) as well as lines 404-411 (subsection 4.4) discuss findings. Please, consider moving the paragraphs to their respective sections.*

Lines 246-250 indeed describe the methodology and, therefore, have been incorporated in Section 3.1.

page 7, line 188-189: "~~To compare the ground-based ... SR and HR retrieval~~ → To validate the SEVIRI retrievals against ground-based observations, GHI time series are generated. The derivation of satellite-based time series is performed at the location of each of the 99 pyranometer stations, both at HR and SR. Besides the HR and SR SEVIRI GHI time series, an additional set of time series (HR2SR) are computed to study the effect of the downscaling algorithm in more detail. These time series are generated using HR SEVIRI GHI but are averaged over 3×3 pixels to match the SR.

Lines 273-293, which discuss the results of Figure 4, have been moved from the results section to a dedicated discussion section, now called: "Section 5.3: Dependence on temporal averaging length scale".We agree with the reviewer that in lines 404-411 results are discussed (subsection 4.4). Yet, we have decided not to move these lines to a discussion section as we believe it is too small for a dedicated subsection in the discussion, and, despite being discussion, we believe it fits better in the flow of the text in the results.

4) *Captions of Figures 3, 4, 5, 8, and 10 describe mostly the same (box-and-whisker plots of ...) Please consider to shorten the captions. For example: "The same as in Figure 3 but for ...*

Figure 3 shows SEVIRI: HR2SR, which is not shown by the other boxplots. Besides, for this Figure, all results are statistically significant (See reply to "Comments referring to figures: #3."). Therefore, what is shown in these boxplots distinctly differs from those shown later in the manuscript. The captions of Figures 4, 8 and 10 have been shortened and now refer to the caption of Figure 5 (Because of a rearrangement in the order of Figures, see reply to General comment #3, Figure 5 will be the first boxplot after Figure 3 in the updated manuscript)

Specific Comments

1) *page 1, line 6: ground observation → ground-based observations*
The reviewer's comment has been modified accordingly.

2) *page 2, line 29: "... from national measurement networks." Please give a citation or an example*
We have added a citation to the manuscript: "... from national measurement networks (Krähenmann et al., 2018)."

3) *page 2, line 38: (MSG) → (MSG; Schmetz et al., 2002)*
The reviewer's comment has been modified accordingly.

4) *page 3, line 61: "... HR SEVIRI retrieval ..." → HR retrieval*
The reviewer's comment has been modified accordingly.

5) *page 3, line 72: HD(CP)^2 stands for?*
HD(CP)^2 stands for "High Definition Clouds and Precipitation for advancing Climate Prediction", we have added the meaning of the acronym to the manuscript.

6) *page 4, line 87: globel horizontal irradiance = GRI*
The reviewer's comment has been modified accordingly.

7) *page 4, line 88: extremely rare limit (ERL; give citation)*
We have added a citation to the manuscript: "... extremely rare limit (ERL; Long and Dutton, 2002). ..."

8) *page 4, line 88-89: "...used, given ..." → used, and given*
The reviewer's comment has been modified accordingly.

9) *page 4, equation 1: punctuation mark*
The reviewer's comment has been modified accordingly.

10) *page 4, line 91: "... are not plausible ... " give some reasons*
This statement is mainly based on the visual inspection. For instance, in the time series shown by Figure A1, several pyranometer stations can be identified that have consistently lower irradiance than the majority of stations, while still being within the ERL. The shown date (07-07-2013) is largely clear sky and therefore major deviations are not expected between the stations. Possible reasons for the observed deviations are further explained in Discussion Section 5.1 and could be related to soiling, horizontal alignment and interference of (local) shadows due to nearby structures.

11) *page 4, line 94: "... reduction of roughly 5 to 10 % in the number of valid sensors." I wonder how all the 99 sensors (data points referring to e.g. Fig.3) can be in one box-and-whisker plot?*
The reduction of 5 to 10 % in number of valid sensors is determined for daily timescales (see Appendix A and Figure A2). For each pyranometer station only the days with valid data are considered. Many pyranometers have some missing data for various dates during the field campaign (see Figure A3). However, when the full range of the field campaign is considered, the data from each of the 99 pyranometers can still be used.

In line 94 we now stress that the reduction of roughly 5 to 10 % in the number of valid sensors concerns a daily reduction and not one over the full length of the field campaign:

page 4, line 94: "After performing the quality control, we observe a daily reduction of roughly 5 to 10 % in the number of valid sensors."

12) *page 4, line 97: Satellite data → Geostationary satellite data*
The reviewer's comment has been modified accordingly.

13) *page 4, line 98: ... we make use of the data from the MSG weather satellites ...*
The reviewer's comment has been modified accordingly.

14) *page 5, line 104-105: insert the sentence "The Meteosat satellites ..." inbetween "(EUMET-SAT)." and "Four satellites" on page 4 line 99*
The reviewer's comment has been modified accordingly.

15) *page 5, line 112: Please consider highlighting the 31 HR pixels in Fig. 1 or at least mention in section 2.2 that only those HR pixels have been used that include valid pyranometers.*
In the manuscript, we note the value of 31 HR pixels mainly to indicate the size of the HOPE pyranometer

network. Satellite GHI at the location of each pyranometer is determined by (spatial) Gaussian filtering. This implies that a collection of surrounding pixels is used. This could also include pixels that do not overlap with one of the pyranometer stations, which makes it difficult to highlight precisely which HR pixels have been used. Therefore, we think it is more correct to omit highlighting of pixels in Figure 1. Yet, we agree that it is worth mentioning, more precisely, in section 2.2 which pixels are used for the GHI derivation. Therefore, we have added the following sentence to line 112:

"... 31 HR pixels (see Fig. 1). Note that for the retrieval of satellite derived GHI at the locations of the pyranometer stations, a collection of surrounding pixels is used, possibly including pixels that do not contain a pyranometer station (see Sect. 3.1). Using the rapid scan ... "

16) **page 5, line 124: GEO stands for?**
GEO stands for "geostationary", we have added the meaning of the acronym to the manuscript.

17) **page 5, line 127: NWP stand for?**
NWP stands for "Numerical weather prediction", since the word is only used once in the manuscript we decided not to use the acronym anymore.

18) **page 5, line 128: 2.2.2 Cloud Physical Properties (CPP)**
The reviewer's comment has been modified accordingly.

19) **page 5, line 129: write only CPP algorithm**
The reviewer's comment has been modified accordingly.

20) **page 6, line 142: 2.2.3 Solar Irradiance under Clear and Cloudy Skies (SICCS)**
The reviewer's comment has been modified accordingly.

21) **page 6, line 143: write only SICCS**
The reviewer's comment has been modified accordingly.

22) **page 7, line 168: punctuation mark**
The reviewer's comment has been modified accordingly.

23) **page 7, line 185: SEVIRI retrievals → MSG-retrievals or satellite retrievals?Check the following pages.**
Also see the reply to main comment #1. We will mainly use "SEVIRI retrieval" in the updated manuscript. The term "MSG-retrieval" is not used anymore. The term "satellite retrieval" is now only used when referring to satellites in a broader sense (i.e. not just SEVIRI)

24) **page 8, Table 1: shift to section 3.2.1**
Table 1 has been shifted to Section 3.2.1. We also tried to place the other Tables and Figures as close as possible to their respective Sections.

25) **page 11, line 247: The authors described, by visual inspection the amount of valid sensors is reduced by roughly 5-10 %. I wonder how the RMSE was computed for each of the 99 sensors?**
Please see our reply to specific comment #11. The quality control is performed on a daily basis. The RMSE is computed for each pyranometer station over all (selected, in case of CRAAS or VI classification,) time slots with valid data.

26) **page 13, line 278: is diminished → diminishes?**
The reviewer's comment has been modified accordingly.

27) **page 13, line 286: "... half daily averages." A day has 24 hours. Half a day has 12 hours. There is no half-daily average. The authors maybe like to highlight on the approx. 6-hourly average. Furthermore, the averaging time 'daily' in Fig. 4 refers probably to the daytime average?**
The reviewer raises a valid point, daily and half-daily averages are indeed not considered here since only the times between 06:15 and 16:45 UTC are studied. To be more correct, we have updated the terminology in the manuscript.

page 13, line 286: "...half daily ..." → "... approximately 5 hours averaging time."
page 24, line 15: "... half-daily"→ "... approximately 5 hours."

We decided to replace the term "daily averages" with the term "daytime average," where we define daytime as the period from 06:15 to 16:45 UTC. Note that this time range does not exactly match the daytime definition (the time between sunrise and sunset). Yet, we do not expect this to lead to much confusion since we have stated that only the times between 06:15 and 16:45 are considered.

page 13, line 269: "... daily averages ..." → "... daytime-averages (06:15 – 16:45 UTC) . ... ".
page 24, line 287: "... daily averages"→ "... daytime-averages ... ".
Figure 4 x-axis: daily → daytime
Caption Figure 4: daily-averages → daytime-averages

28) **page 15, line 307: The clear sky (Fig. 5a) and overcast (Fig. 5c) days ...**
The reviewer's comment has been modified accordingly.

29) **page 15, line 313: non-significant vs insignificant (e.g. figure captions)**
We decided to consistently use the term 'non-significant' instead of using the term 'insignificant'.

30) **page 15, line 333: ... Belgium (not shown)**
The reviewer's comment has been modified accordingly.

31) **page 18, line 359: ... reach values above ...**
The reviewer's comment has been modified accordingly.

32) **page 19, line 381: judge → decide**
The reviewer's comment has been modified accordingly.

33) **page 19, line 385: Separating → Sorting**
The reviewer's comment has been modified accordingly.

34) **page 19, lines 389-390: I wonder what your expectations were?**
With higher clouds, like cirrostratus, we expected a smaller effect on surface GHI than lower-level clouds. Moreover, we would have expected the spatial variability of the cirrostratus regime to be more comparable to the cirrus regime. As a result, initially, we were not expecting to observe much difference between HR and SR for this cloud regime.

However, further inspection of the cloud regime, using the NWCSAF cloud types, showed that for about 20 % of the timeslots that were classified as cirrostratus, semi-transparent clouds above medium- or low-level clouds were occurring. Therefore, in the manuscript we argue that the observed resolution differences in this regime is mainly due to underlying lower-level clouds.

35) **page 20, lines 392-393: So basically it is not the cirrostratus cloud regime itself, which is the most spatially and temporally varying one (page 19, lines 389-390). It is due to the variability of underlying clouds, if I understand correctly? May the authors add a comment on that..**
This is indeed how we explain the observed improvement in accuracy between HR and SR for the cirrostratus regime. Please also see the reply to specific comment #34

36) **page 20, line 412: "When the different CRAAS regimes are compared, ..." → Comparing the different CRAAS regimes, ...**
The reviewer's comment has been modified accordingly.

37) **page 21, line 431: either write (Madhavan et al, 2016) or ... by Madhavan et al. (2016).**
We will cite the article in the following format: (Madhavan et al, 2016)

38) **page 21, line 452: remove "anyway"**
The reviewer's comment has been modified accordingly.

39) **page 22, line 457: "... is much smaller ..." → neglectible**
The reviewer's comment has been modified accordingly.

40) *page 23, line 474: "The relative ..." The meaning of the sentence is unclear to me.*

An incorrect word order was used in this sentence which might have caused the confusion. The correct word order should be:

page 23, line 474-475: "The ~~relative~~ median increases of relative RMSE between HR and SR are 3.23, 2.50 and 4.96 %, respectively."

41) *page 23, line 479: ... as is explained next.*
The reviewer's comment has been modified accordingly.

42) *page 24, line 516: the RMSE of the HR retrieval is smaller than the SR retrieval?*
The reviewer's comment has been modified accordingly.

43) *For the latter condition, ... ?*
For clarification, the sentence has been adjusted in the following way:

"For the ~~latter conditions~~ fully overcast conditions, it is suggested that the pyranometer measurements are representative of scales of at least 5 km ..."

44) *page 26, 555 The authors describe they examined the probability density distribution of daily averaged irradiances for many days, but it seems to me they show in Fig. A1 (upper right panel) the absolute frequency of observations (Count). Please clarify.*
The visual inspection of the HOPE pyranometer network is performed separately for each day of the field campaign. Figure A1 shows an example of the plots used to conduct a visible inspection for day 81 (i.e. 7 July 2013) of the field campaign. The PDF shown in the upper right panel shows the absolute count of the pyranometer stations (for this day, summing up to 89 stations due to missing data at 10 stations).

With the words "For many days," we tried to stress that after the visual inspection, which is thus performed for every day separately, in many cases, additional stations are removed from the dataset. Since this seems to raise some confusion, we have removed the words 'for many days' from line 555 of the manuscript.

45) *page 30, line 565: remove "presented in this paper"*
The reviewer's comment has been modified accordingly.

46) *"page 30, line 567: Meteosat SEVIRI vs. MSG-SEVIRI"*
For consistency we have decided to use the term "SEVIRI". Please see the reply to general comment # 1.

47) *page 30, line 569: remove Schmetz et al. (2002)*
The reviewer's comment has been modified accordingly.

48) *page 30, line 570: remove NWCSAF (2021)*
The reviewer's comment has been modified accordingly.

49) *page 30, line 571: remove Carrer et al. (2018)*
The reviewer's comment has been modified accordingly.

50) *page 30, line 572: remove Gschwind et al. (2019); Inness et al. (2019)*
The reviewer's comment has been modified accordingly.

51) *page 30, line 574: remove Tzallas et al. (2022)*
The reviewer's comment has been modified accordingly.

52) *page 31, line 602: Check hyperlink*
A hyperlink has been added to the reference.
Hyperlink: https://www.cmsaf.eu/SharedDocs/Literatur/document/2022/saf_cm_knmi_atbd_sev_cpp_3_3_pdf.pdf (last access: 01-07-2024)

53) *page 31, line 609: provie the DOI*
We were not able to identify a DOI for this specific article, alternatively we have added a url with a link to a PDF of the paper.
Hyperlink: https://ui.adsabs.harvard.edu/abs/1987A%26A...183..371D/abstract (last access: 01-07-2024)

54) *page 32, line 626: provide a hyperlink or DOI*
A hyperlink has been added to the reference.
`https://user.eumetsat.int/s3/eup-strapi-media/pdf_ten_05105_msg_img_data_e7c8b315e6.pdf` (last access: 01-07-2024)

55) *page 33, line 690: Journal or publisher is missing*
The journal and publisher were added to the reference. The updated reference is:
Michalsky, J., Dutton, E., Rubes, M., Nelson, D., Stoffel, T., Wesley, M., Splitt, M., and DeLuisi, J.: Optimal Measurement of Surface Shortwave Irradiance Using Current Instrumentation, Journal of Atmospheric and Oceanic Technology, 16, 55 − 69, `https://doi.org/10.1175/1520-0426(1999)016<0055:OMOSSI>2.0.CO;2`, 1999.

56) *page 33, line 697-699: Journal or publisher is missing*
For the paper of Nakajima and King (1990), we have added the publisher and a DOI. The updated reference is:

Nakajima, T. and King, M. D.: Determination of the Optical Thickness and Effective Particle Radius of Clouds from Reflected Solar Radiation Measurements. Part I: Theory, Journal of Atmospheric Sciences, 47, 1878 − 1893, `https://doi.org/10.1175/1520-0469(1990)047<1878:DOTOTA>2.0.CO;2`, 1990.

Unfortunately we were not able to find a DOI for the Mood (1950) paper.

57) *page 34, line 701: Provide a hiperling to the ATBD*
A hyperlink has been added to the reference. `https://www.nwcsaf.org/Downloads/GEO/2021/Documents/Scientific_Docs/NWC-CDOP3-GEO-MFL-SCI-ATBD-Cloud_v1.0.1.pdf` (last access: 01-07-2024)

58) *page 34, line 713: proof if the publication is still a preprint*
To the best of our knowledge, to date (03-07-2024), this article still is only available a preprint

Comments refering to Figures

1) *Figure 1: at the lower bound the SR and HR pixels are cropped. Please show the pixels*
Figure 1 has been adjusted so that is not cropped anymore halfway the HR subpixels.

2) *Figure 2: On a printout the light-green and green dots are hardly to distinguish. The authors perhaps make use of different markers, e.g. dots vs triangles*
We now use different markers for significant (dots) and non-significant results (triangles).

3) *Figure 3, caption: The authors describe that dotted lines around the annotation boxes indicate that the difference between HR and SR is insignificant at a 95 % confidence level according to the Mood median test. However in the figure there is no dotted line visible at all.*
Since in Figure 3 the differences between HR and SR remain statistically significant up to hourly averaging periods the dotted lines indicating non-significance are not shown in Figure 3. For clarification the caption of Figure 3 has been adjusted removing the explanation of the non-significance:

Caption Figure 3: "~~Dotted lines around the annotation boxes indicate that the difference between HR and SR is non-significant at a 95 % confidence level according to the Mood median test, while continuous lines indicate a statistically significant difference between both resolutions.~~" → For all the averaging periods, the differences between HR and SR are significant at a 95 % confidence level according to the Mood median test, which is indicated by the continuous lines around the annotation boxes.

4) *Figure 5, caption: High-Resolution (SEVIRI-HR) and ... see comment on abbreviations*
See reply to general comment #1.

5) *Figure 6, upper left and lower right panel: I wonder if the yaxis (upper left panel) and the xaxis (lower right panel) shows the relative or the absolute frequency? What do the dashed curves stand for? Is it probability? The authors may consider removing the dashed curves, because they are not described in the text*
The upper left and lower right panels show the relative frequency or probability density and not the absolute frequency. To clarify, the axis labels have been adjusted accordingly:

Figure 6, ~~"Frequency"~~ → "Probability density"
The dashed lines show the Gaussian distributions for the HR/SR bias and SDE. The solid black lines show the mean and standard deviation of the distributions. We believe this can be valuable information and therefore we included an explanation about this in the caption.

"The contineous black lines indicate the mean and standard deviation of the respective histograms.The dashed lines show the corresponding Gaussian distributions."

6) *Figure 6, upper right panel: The authors my consider adjusting the colorbar limits to the extrema of the difference in correlation between HR and SR in order to use the full color range. Also, there is difference between*

   i) *Correlation HR-SR, and*
   ii) *difference in correlation between HR and SR*

   Please clarify

The colour bar of Figure 6 has been narrowed (from -0.005 to 0.05) to better exploit the range of available colours.

What is shown in Figure 6 is the difference in correlation between HR and SR (ii) and not the correlation between HR and SR (i).

To take away the confusion the colourbar title has been updated:

page 16, Figure 6: ~~Correlation HR-SR~~ ⇒ Correlation HR - correlation SR

7) *) Figure 7, panels b, f, j, n: The JA~̈lich domain is hardly visible. The authors my consider to mark it in green or red.*
Compared to the size of the Western Europe domain, the Jülich domain is indeed hardly visible due to the limited extent. We have changed the colour of the Jülich domain in panels b, f, j, n from orange to light green, to try to make it better visible and updated the caption accordingly:

page 17, caption Figure 7: "... spatial resolution (d, h, l, p), respectively. The Jülich domain is highlighted in the Western Europe domain plots by light green pixels. Values of GHI ..."

8) *Figure 8, xaxis labels: The authors mix in the labels the number of observations (Nobs - absolute frequency) with relative frequency (given in percent). Please clarify*
Since the values below the x-axis of Figure 8 do not concern absolute amounts but percentages it is indeed not correct to speak of number of observations (Nobs). We have decided to use the term Relative Frequency of Occurrence (RFO) instead.

9) *9) Figure 9, caption: see comment on Figure 5*
See reply to general comment #1.

10) *Figure 9, caption: Last sentence, remove "adopted elsewhere in this study"*
We have decided not to remove the last part of the sentence 'adopted elsewhere in this study'. The reason for this is that we find it important to stress/ remind the reader that the filter width of 1 km is the used reference.

With a filter width of 1 km, the HR improvement is optimal or close to optimal when taken over all dates or the variable dates only. Yet, for overcast days, the selected filter width of 1 km is sub-optimal. By removing and not restating that 1 km is the used reference, we believe the above message might be lost.

11) *Figure 10, caption: see comment on Figure 5 and 9*
See reply to general comment #1.

12) *Figure 10: The authors may consider to adjust the yaxis limits in order to increase the box-and-whiskers, e.g. [10 60]. Figure A1, upper right panel: Please clarify which quantity is shown, the absolute, relative frequency or the probability density (unit?).*
In this case the figure A1 shows the absolute quantity (not PDF) of the number of stations (and is therefore unitless), we have rectified this in the manuscript. The y-axis limits have been narrowed from [10,50].

13) ***Figure A2: The authors my consider to remove the xaxis label, because the tick-labels show a date. There is no need to mention Time [-]***
The x-label with "Time [-]" has been removed from the figure.

14) ***Figure A3: see comment on Figure A2. Also, the authors my consider using white instead of black to illustrate invalid data.***
We have tried plotting Figure A3 using white for invalid data. However, in our opinion using black for invalid data results in a clearer contrast with the valid data. Therefore, we have decided not to change the color of invalid data from black to white.

References

Krähenmann, S., Walter, A., Brienen, S., Imbery, F., and Matzarakis, A.: High-resolution grids of hourly meteorological variables for Germany, Theoretical and Applied Climatology, 131, 899–926, https://doi.org/10.1007/S00704-016-2003-7/FIGURES/13, 2018.

Long, C. and Dutton, E.: BSRN Global Network recommended QC tests, V2.0, BSRN Technical Report, https://doi.org/hdl:10013/epic.38770.d001, 2002.

2nd review on

"Validating global horizontal irradiance retrievals
from Meteosat SEVIRI at increased spatial
resolution against a dense network of
ground-based observations" by Wiltink et. al.

bold italic font = reviewer's comment
regular font = authors' reply
red regular font = adjustments in manuscript

We thank the reviewer for the additional comments. Please find our response below to see how the comments were addressed.

Minor comments

1) ***page 3, line 77: exchange x with \times***
   The manuscript has been modified accordingly.

2) ***page 8, line 186: remove (SWIR) because it is not used in the paper otherwise***
   The manuscript has been modified accordingly.

3) ***page 9, line 223: The abbreviation RMSE is well-known in the community, however, please introduce the abbreviation for consistency in the paper.***
   The manuscript has been modified accordingly.

4) ***colourbar label: either write Correlation HR - Correlation SR or correlation HR - correlation SR***
   The text for the colourbar label is now written as "Correlation HR - Correlation SR".

5) ***page 16, line 322: The authors write that the 21st of July 2013 was for large parts of western Europe a persistent clear-sky day and refer to Fig 7a-d. However, Fig. 7b shows Central Europe (Be-Ne-Lux, FRA, GER). Maybe the authors change western Europe to Central Europe.***
   Initially, we decided to name the domain shown in Figure 7 b, f, j, n, the Western Europe domain because of the inclusion of the Benelux and parts of France. While there is not a fixed definition of European regions, the Benelux is often not considered Central Europe. However, since the domain is centred around Germany and includes limited parts of Poland and the Czech Republic, referring to it as Western Europe might also not be entirely correct. We have considered the reviewer's comments and now refer to the domain shown in Figure 7 b, f, j, n as the Central Europe domain.

6) ***page 17, caption to Fig 7: "... over western Europe ..." and "... in the Western Europe domain ...". See the comment before.***
   The manuscript has been modified accordingly. See our reply to minor comment 5.

7) ***page 17, Fig 7a,e,i,m: Remove [-] after Cloud Optickal Thickness. Correct Optickal to Optical in each figure, and on the colourbar below Fig. 7m***
   The manuscript has been modified accordingly.

8) **page 21, line 421: angels → angles**
The manuscript has been modified accordingly.

9) **page 28, Figure A1 (title of the lower panel): measurment → measurement**
The manuscript has been modified accordingly.