Reply to: RC C4483, Referee Roger Clay

Dear Roger Clay,

Thank you very much for your review. We improved the paper following your comments and hope that we solved all open issues with these updates. Your comments certainly helped us to improve the paper. Please find below detailed answers for each comment with explanations of the corresponding changes in the revised version of the paper. We included your original comments in blue color and quotation marks.
The updated version of the manuscript can be found in our separate comment AC C5550.

Best regards
Wilko Jessen and co authors

"1. Does the paper address relevant scientific questions within the scope of AMT?
Probably. But the paper uses procedures introduced elsewhere (in the reference papers) to study only one specific site. Hence, it is not clear to the reviewer that the paper is of interest to the general community. It is true that the techniques are generally described well and in detail but the conclusions related to evaluating the calibration duration are clearly site (meteorological) specific and would not be likely to be applicable elsewhere. "

Since only calibrations from one site (PSA) were evaluated the conclusions are partially site specific. However, although meteorological parameters may differ from site to site the effect of fluctuating calibration results in accordance to seasonal influences is a general problem in outdoor calibration of Si-Pyranometers. This said, similar results can be expected at sites with similar latitude and comparable (semi-arid) climate conditions.
The issue of the required calibration length itself is of general interest, since Si pyranometers are widely used by many readers of AMT. As there are no standards for the calibration of Si-pyranometers the detailed description and analysis of the calibration procedures is valuable. The site dependence of the performance is discussed in Geuder et al., 2010 (and the now accepted revision of the paper Geuder et al., 2016, Journal of Solar Energy Engineering).

We added the following text at the end of section 1:
"It should be mentioned that only calibrations from one site (PSA) are evaluated and the conclusions are therefore partially site specific. However, although meteorological parameters may differ from site to site the effect of fluctuating calibration results in accordance to seasonal influences is a general problem in outdoor calibration of Si-Pyranometers. This said, similar results can be expected at sites with similar latitude and comparable (semi-arid) climate conditions. The site dependence of the performance is discussed in [Geuder et al., 2016]."

"2. Does the paper present novel concepts, ideas, tools, or data?
Possibly. The techniques could be found in other papers and their application is rather site-specific so the novelty and applicability are limited. "
Along with the evaluation of (site specific) seasonal influences and calibration duration this paper was written with the intention to give an unpreceded detailed account of the calibration methods. Although some prominent features of these methods have been briefly discussed in previous publications, a detailed description of the procedures was lacking until now.
The paper also presents so far unpublished evaluations and data from five RSIs and noticeably 6.5 years. The tools described for the evaluation are also newly created for the study.
Hence, we presented several novel concepts.

“3. Are substantial conclusions reached?
Yes. Again site-specific. “

“4. Are the scientific methods and assumptions valid and clearly outlined?
Yes, although I would have expected comment on the level of accuracy required for the calibration method. Otherwise, it is not clear that appropriate calibrations are being achieved. This makes it difficult to assess the quality of the scientific method. Also, there is reference to an ’expert’ who checks when calibrations may be in error. How the expert makes the necessary decisions may be obvious in practice, but it is not clearly a good ’scientific method’. Additionally, the data are subjected to selection effects, ’calibration limits’, which are presented in Table 2 such that some data are flagged as ’potentially erroneous’. It appears that such data are actually ’marked for exclusion’. “

Excluding data from calibrations based on expert decisions is a common procedure that is also included in ISO standards for thermopile pyrheliometer and pyranometer calibration. Also automatic sort out is used in the presented calibration methods and the ISO standards. Data that are marked as “potentially erroneous” are without exception excluded from the calibration. The limits for the automatic exclusion are set under consideration of the reference and test sensor performance. E.g. under very high solar zenith angles (sunrise and sunset) the errors can negatively affect the calibration quality. Furthermore, such zenith angles typically are not used in CSP plants due to shading effects and lower limits for the required absorbed radiation for plant operation. Thus, there is no point in trying to calibrate the instrument for accuracy during solar zenith angles ≥85° (see Table 2 in the AMTD version of the document, now Table 4 in the revised version).
The focus of our calibration lies in calibrating for accuracy under conditions in which CSP plants operate.

We discuss this in the revised text as follows (section 3.1.2):
“The found calibration accuracy should also be related to the required accuracy for typical RSI applications. RSIs are usually applied for solar resource assessment that involves the combination of ground and satellite data. The uncertainty of the satellite data is typically much higher than the uncertainty of the ground measurements if best practices are followed for the measurements. An estimate of the required uncertainty of the combined data set from [Meyer et al., 2008] is 4.5 %. According to this publication this can be reached with two satellite data sets of moderate quality and an uncertainty of 4 % for the ground measurements. The achieved calibration uncertainty is therefore sufficient. The reached accuracy is also regarded as sufficient for other applications, e.g. the validation of forecasted irradiance data [Schenk et al., 2015].”

Meyer, R., J. Torres-Buron, G. Marquardt, M. Schwandt, N. Geuder, C. Hoyer-Klick, E. Lorenz, A. Hammer, and H.G. Beyer. 2008. Combining solar irradiance measurements and various satellite-derived products to a site-specific best estimate. Paper read at SolarPACES Symposium, March, at Las Vegas, USA.

Schenk, H., T. Hirsch, M. Wittmann, S. Wilbert, L. Keller, and C. Prahl. 2015. "Design and Operation of an Irradiance Measurement Network." *Energy Procedia* no. 69 (0):2019-2030. doi: http://dx.doi.org/10.1016/j.egypro.2015.03.212.

“Together with expert intervention, it seems likely that systematic errors could be introduced into the calibration process through the discarding of data. The level of such a (potentially important) error is not discussed. It is true that figure 2 shows improvement of statistical fluctuations with increasing calibration durations but one needs confirmation that the calibration approaches the desired ’correct’ value. I think that the neglect of possible systematic errors is not best scientific practice. “

We added the following text for clarification (page 7, line 24 in the version with the tracked changes):
"The manual discarding of data by expert intervention only excludes typically less than 1 % of the calibration data set. In the improbable case that erroneous data is not excluded or that valid data is excluded only small effects on the calibration results occur."

"5. Are the results sufficient to support the interpretations and conclusions? Yes, for this site.

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? Yes

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Yes

8. Does the title clearly reflect the contents of the paper?
Maybe.
Perhaps "optimising the calibration duration." "

From our perspective we are quite content with the present title. Since up to this date it includes the most detailed description of the calibration methods, we believe that the first part of the title should in any case remain the same.
In consideration of your suggestion we have now changed the title to:
"Calibration Methods for Rotating Shadowband Irradiometers and Optimising the Calibration Duration"

"9. Does the abstract provide a concise and complete summary? Yes

10. Is the overall presentation well structured and clear? Yes

11. Is the language fluent and precise? Sufficiently so.

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? Yes

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? No

14. Are the number and quality of references appropriate? Yes

15.Is the amount and quality of supplementary material appropriate? N/A

General Comments
This paper discusses the application of calibration methods (two) to shadowband irradiometers at the PSA site in Spain. The paper gives sufficient information and references for the reader to understand the calibration process, and this is a strength of the paper. Such shadowband irradiometers are generally calibrated for use when assessing potential solar power station sites and it is clearly important that their calibration process is well understood. An important part of that process is to know what length of dataset is necessary for evaluating a site. This issue is addressed for the PSA site. The problem with this is that the evaluation result is not obviously transportable for use at any other site with different meteorological variability. This would seem to limit the interest in the results presented in the paper. As noted above, there is no discussion of systematic errors in the process and this, together with the lack of a statement on the required level of uncertainty, is a significant problem for this reviewer. "
In above general comments we underlined the three critical points we would like to address in the following:

"the evaluation result is not obviously transportable"
We now discussed the applicability at other sites as explained above (see reply to comment 1).

"there is no discussion of systematic errors in the process"
In the updated version of the manuscript we included a short paragraph on systematic errors below equation 15 (new numbering).
"The calibration error can have a systematic component. The calibration error of the reference instruments causes a similar calibration error for the RSI calibration. The contribution of the soiling to the error is small doe to the maintenance efforts at PSA and the soiling correction for the reference data. If less frequent cleaning is provided and no or insufficient soiling corrections are applied additional systematic errors can occur, as the reference instruments are more sensitive to soiling than the RSIs under calibration."

"required level of uncertainty"
We added a paragraph concerning the required uncertainty in the revised text as stated above (see reply to comment 4).

"I thought that equation 12 was un-necessarily trivial."
--- now Eq 13
We decided to include every step of the calculation for the purpose of clarity. Actually the second reviewer pointed out a possible misunderstanding concerning L_DNI and we decided to keep the equation in the text in slightly enhanced version with the set A_{acc}:

$$L_{\mathrm{DNI}} = \frac{1}{m} \cdot \sum_t R_{\mathrm{DNI}}(t) \qquad \text{with} \qquad t \in A_{acc} \qquad (13)$$

"The paper is generally free of major expression errors. Although some of the english expression isn't elegant, it is perfectly satisfactory for the reader.
Line 14 of page 10267 should read "two tables were constructed which allow one to choose..." "
Thank you. The new version of the manuscript has been corrected accordingly.