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Interactive comment on "Compatibility of different measurement techniques. Long-term global solar radiation observations at Izaña Observatory" by R. D. García et al.

Anonymous Referee #2

The study presents an inter-comparison of different measurement techniques of global solar radiation. The authors demonstrate consistency and analyze uncertainties between the measurements by old and modern instruments using one year (July 2014 to July 2015) of simultaneous observations at the high altitude Izaña Atmospheric Observatory, Tenerife, Spain. The uncertainties were analyzed as a function of different seasons, intensity of solar irradiance, ambient temperature, relative humidity (RH), aerosol optical depth (AOD), and solar zenith angle (SZA). The obtained results are then applied for validation of a long-term data series started in 1977. This is an interesting study on compatibility of different measurement techniques that also has an application of extending the global solar radiation time series. However, while graphical presentation of the results is quite clear, I found that the text of the manuscript might be improved prior the possible publication in AMT. In particular the "Introduction" and "Results" sections need more work. I think that the authors could spend more efforts on revision of the text, clarity and completeness of the presentation. Below please find my general and specific comments.

***Authors**: We acknowledge the referee's constructive comments. The main text of the manuscript, and specifically "Introduction" and "Results" sections, have been reviewed and smoothed, and in the following we discuss and respond to the general and specific comments.*

1. **The authors claim to analyze performance of the measurements as a function of AOD, but I think that observations in this high altitude (2400 m a.s.l.) atmospheric observatory does not appropriate for this type of analysis. The range of the AOD variability is very small and the site is characterized by very low atmospheric aerosol loading. In fact, 67 % of the observations are for AOD (500nm) < 0.03. Only observations correspond to AOD > 0.6, and I suspect these observations are from a couple of consequent days and belonging to the same aerosol event (probably a case of dust transport). Therefore, the conclusions derived regarding compatibility of different measurement techniques under varying aerosol conditions maybe not solid enough.**

   ***Authors**: We agree. Following the Referee's recommendation, the authors have removed this analysis given that the range of the AOD variability is rather small (i.e. only 2% (N: 5 days) of the days present AOD>0.6). Accordingly the Figure 5 has been removed.*

However the authors consider interesting to include a short assessment on the bias found among BSRN GSR and the rest of measurements (PYR, CS, CSD and MFRSR) considering both background conditions (AOD<0.10) and dust conditions (AOD≥0.10) based on García et al. (2014c). This analysis was added in the manuscript as follows:

"As aforementioned, some of the analysis instruments and methods are sensitive to different factors and atmospheric conditions. We have analyze GSR the differences with respect to the BSRN GSR_H in function of the solar irradiance (Figure 3a), the average temperature and relative humidity (RH) (Figure 3b and 3c, respectively), the FCS, and AOD."

"We have also studied the differences with respect to FCS and AOD (not shown here). No dependence with FCS was found, although it should be noted that 85% of the days (N: 232 days) presented FCS>75% while only 1% (N: 4 days) showed FCS<25%. Concerning the dependence on AOD only background conditions (AOD<0.10) and dust conditions (AOD≥0.10) have been considered based on García et al. (2014b). No dependence on AOD is found, although we must highlight the fact that 87% of the days (N: 231 days) presented AOD<0.10 and 13% of the days (N: 33 days) showed AOD≥0.10. The GSR_H measurements most affected by AOD were those obtained with the CSD, which shows a monotonic dependence in the bias, being negative for pristine skies and positive for dust conditions."

2. **Inter-comparison of the measurement techniques is also presented as a function of seasons. What seasonal characteristic is expected to influence performance of the instruments? The inter-comparison is then presented as a function of temperature. I have strong impression that the results for summer months are similar to the results for temperature range of 15-20 and >20 degree; same for winter and <10 degree. I think that the analysis vs. seasons is redundant with the analysis vs. temperature.**

Authors: The referee is indeed right. So, the authors have decided to remove the inter-comparison presented as a function of seasons, given that this information is redundant with that provided by the inter-comparison as a function of temperature. Corresponding text to these results in Section 4.1 has been rewritten.

3. **p9, line 9 it is written: "underestimated for all sensors and instruments except for GSR MFRSR in winter and autumn". Why it could be, what is special in this case? An explanation/hypothesis?**

Authors: MFRSR presents a dependence with respect to the temperature and relative humidity. As remarked before the analysis respect to the season is identical to the analysis with respect to the temperature. This sentence has been rephrased as follows: "…underestimated for all sensors and instruments except for MFRSR GSR for low temperature values". The MFRSR is thermally controlled in order to operate at its optimal working-temperature, that is, 40°C. Thus, if the temperature is below this value the instrument head is heated until the working-temperature is reached, and then the heating is switched off. Therefore, when the difference between ambient temperature and 40 ° C is very large, the heating system is continuously working at 100% effort, creating in this former version of MFRSR instrument an electromagnetic

frequency interference with the irradiance measurements leading to inaccurate measurements (Harrison, 1994; Hodges and Michalsky, 2011).

The authors have added this information in the final manuscript as follows:

"Finally the MFRSR is the instrument that shows the best performance, with a bias close to zero through the whole year, and the lowest scatter (Figure 3). We observe, in general, an overestimation in MFRSR GSR_H, unlike the rest of the compared instruments. The MFRSR GSR_H has a clear positive dependence with irradiance (Figure 3a). There is not temperature dependence for temperatures >15°C, (Figure 3c) and a slight dependence, for lower temperatures. The MFRSR is thermally controlled at around 40°C. Thus, when the difference between ambient temperature and 40°C is very large, the heating system is continuously working at 100% effort, creating in the former versions of MFRSR instrument an electromagnetic frequency interference with the irradiance measurements, leading to higher measurement inaccuracies (Harrison, 1994; Hodges and Michalsky, 2011). The MFRSR GSR_H measurements show a slight positive dependence with relative humidity (Figure 3c)."

4. **The introduction section could include a review on the previous inter-comparison and compatibility works. What is similar or different/new in the suggested here study? Several references are mentioned in "Summary and conclusions" section reporting and 20 % uncertainties obtained in previous studies. The authors report much lower uncertainties. Is it due to different measurement conditions, quality of the reference instrument? A discussion or analysis can be useful.**

Authors: Following the Referee's recommendations, the authors have added the following information in the Introduction:

"In order to complete and extend the GSR_H time series, ancillary measurements are often used to estimate the GSR_H. However, it is necessary to know the accuracy than estimations by comparison with GSR_H measurements simultaneity performed with modern instruments. The sunshine duration (SD) has been widely used by applying the well-known Ångström-Prescott equation (Angstrom, 1924, 1956; Prescott, 1940) to estimate the GSR_H. Several authors as Almorox et al. (2005), Yorukoglu and Celik (2006) and García et al. (2014c) have used this method in different regions obtaining very similar results. Regarding the bimetallic pyranometer (PYR), designed in the early 1920s (Robitzsch, 1926) and widely used until the late 1960s, the GSR_H is obtained from an equation involving the recorded area and the ambient temperature (Robitzsch, 32). Stravisi (1986) performed a posteriori calibration of a PYR over a 3-year period obtaining hourly, daily and monthly correction factors. Later, Esteves and de Rosa (1989) proposed a correction method to improve the accuracy of daily averaged GSR_H readings, reducing the error from 20% to ~4%. Maxwell et al. (1999) performed a comparison between GSR_H estimations from a PYR and GSR_H measurements with an Eppley PSP radiometer. They applied an automatized process to scan the PYR charts finding differences in daily GSR_H values ranging between 2% and 10% over the course of a year."

However, all these partial intercomparisons were performed in several sites with different environmental conditions, and different instruments and time periods. On the contrary, what we propose in this study is to know the performance of different instruments running in parallel in a testbed site where the environmental conditions show a wide range of variation throughout the year. This allows us to obtain a comprehensive and consistent assessments on the GSR_H differences obtained with these instruments."

5. **It is mentioned in the abstract that fraction of the clear sky is among the factors that were found to affect the global solar radiation. It is mention among such factors as temperature, RH, and SZA. While I see analysis vs. temperature, RH and SZA, it is not**

clear for me what the authors mean by fraction of the clear sky and where it is in the manuscript.

Authors: There was an error in the abstract and it should say *"…Factors such as temperature, relative humidity (RH) or the solar zenith angle (SZA) have shown to moderately affect the GSR_H observations…"*

The authors have defined the fraction of clear sky (FCS) in Equation 6 (p7) of the manuscript as the ratio between the maximum daily sunshine duration and sunshine duration performed with CS recorder (García et al. (2014 a,b)). No significant bias between GSR BSRN and the rest of measurements (PYR, CS, CSD and MFRSR) respect to the fraction of clear sky (FCS) has been found despite 85% of the days in the year intercomparison (N: 232 days; 85%) showed FCS>75%

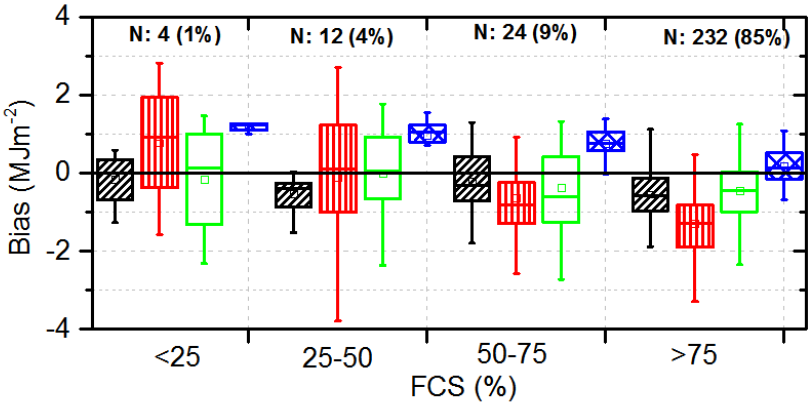

Figure 1.- Box plot of bias (PYR: black; CS: red; CSD: green and MFRSR: blue) versus fraction clear sky (FCS) in % between July 17, 2014 and July 12, 2015 at IZO.

Specific comments:

p1, line 12: "By comparing with: " the sentence is not clear.

Authors: The sentence has been modified as follows:

"…As an application of the methodology developed in this work, we have re-evaluated the GSR_H time series performed at IZO with two PYRs between 1977 and 1991. Their high consistency and temporal stability have been stated by comparing with GSR_H estimates obtained from SD observations…"

P2, line1: Should not the reference to [Stanhill and Cohen 2001] be cited separately from others and just after word "dimming"?
Authors: Done

Please check. p8, line 8: "solar irradiation" to "solar irradiance"?
Authors: Done

p8, line 12: "July, 17 2014" to "July 17, 2014" etc.

Authors: Done

p9, line 12: "There is not dependence: "to "There is no dependence…"

Authors: Done

p9, line 20: "It is clear a dependence with the irradiance level, the larger BSRN GSR values the larger bias." please revise the sentence construction.

Authors: The sentence has been modified as follows:

"The CS GSR_H estimations present a clear dependence with the irradiance, with higher bias for higher BSRN GSR_H values."

p9, line 21: "A slightly dependence with:" to "A slight dependence with:

Authors: Done

Section 5, in the beginning: It can facilitate the reading if some principles of the applied artificial neural networks will be shortly described in the text, instead to address the readers to the bibliography.

Authors: The artificial neural networks methodology was already published by García et al. (2016), and it is not specifically used in this study.

p. 11, line 18: I think that the next sentence can be reformulated, also "goodness" does not sound in this context. "However, the intercept is significantly higher in the 1977-1991 period than in the 2014-2015 period that might be likely due to, after reinstallation a correction in the bias, to instrument cleaning and fit. The goodness of the fit is noticeable during the whole period: "

Authors: The sentence has been modified as follows:

"…The intercept in the period 1977-1991 is higher than in the 2014-2015 period, while the R values are of about 0.95 in the whole period, and 0.98 in the 2014-2015 period. This improvement is likely due to the cleaning and fitting of the instrument before being re-installed for the 2014-2015 inter-comparison."

Finally, this is only a suggestion, but the authors may reconsider the title and indicate already in the first sentence that it is about measurements techniques of global solar radiation, otherwise "Compatibility of different measurement techniques." sounds too general. For example, "Compatibility of different measurement techniques of global solar radiation and application for long-term observations at Izaña Observatory"

Authors: The tittle proposed by the Referee has been accepted.