Reply to: RC C4813, Referee Frank Vignola

Dear Frank Vignola,

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

General comments:
"The paper discusses an interesting worthwhile approach. However, it is not a calibration in the normal sense that is traceable to the world reference radiometer since these instruments are used for calibration under stable weather conditions. By calculating the ratio under all weather conditions (assuming that statement is correct) the ratio is heavily influenced by the extreme solar zenith angles where the cosine of the solar zenith angles is small and hence small deviations can lead to large differences in the DNI values. In addition when the DNI values are small, the ratios can be very large.

By calculating the ratio over large time periods, much of the detailed characteristics of RSI problems can be obscured by the averaging process.

That said, longer term trends such as seasonal variations in the ratio can be uncovered as shown in the article. Note that seasonal variation in the aerosol composition of the atmosphere can show up in many instruments, but are particularly interesting when photodiodes are used for pyranometers because the aerosol load and water vapor content of the atmosphere affect the spectral distribution of the incoming solar radiation. Properly assessing the magnitude of these affects is very useful especially since the seasonal affects caused by atmospheric constituents might also be encountered in location with different atmospheric constituents."
Unstable weather conditions are also used in pyranometer calibrations following ISO 9847. The weather conditions do not affect the traceability. The presented calibrations are traceable to the WRR as the reference pyrheliometers and pyranometers have either been calibrated on site by using WRR traceable references and in accordance to ISO standards or have been calibrated by Kipp&Zonen with their traceable sensors.
We agree with your point concerning the problematic effect of extreme solar zenith angles. This is the motivation for using so called "calibration limits" which exclude data from such conditions. These are detailed in Table 2 (now Table 4 in the updated version).

Specific comments:
"GHIRSI = CFG x GHIcor eq. 1
Eq. 1 is slightly confusing. If GHIRSI is the GHI as measured by the RSI instrument and GHIcor is the reference GHI obtained from the reference instrument, then the equation looks like one is trying to calculate GHIRSI instead of correcting GHIRSI. It would seem more logical if one was trying to obtain GHIcos from GHIRSI instead."
Thank you for bringing this to our attention. In order to avoid confusion and possible misunderstandings (also in other equations or contexts) we decided to add a parameter list and a subscript list to the final version of the manuscript. (see Tables 1 and 2 in the updated version.)

As to the meaning of eq.1 (now eq.2 in updated version): The reference GHI is not used in this equation. It solely describes that the functionally corrected GHI from the RSI (GHI_{cor}) is multiplied with the calibration factor specific to GHI (CFG) in order to obtain the RSI's final GHI value, GHI_{RSI}. The calibration factor CFG has already been determined beforehand during the calibration process. Maybe this was not very clear in the description of said equation. Therefore we applied slight changes to the wording:
"After calibration the final irradiance values measured by the RSI ($GHI_{RSI,}$ DHI_{RSI} and DNI_{RSI}) are obtained as described in the following. GHI_{RSI} is obtained by multiplying the calibration factor *CFG* to the functionally corrected global horizontal irradiance (GHI_{cor}):
$GHI_{RSI} = CFG \times GHI_{cor}$ *eq. 2*"

"This would lead to GHIcor = RSCFG * GHIRSI where RSCFG is the Responsivity Correction Function for Global (this is just to avoid confusion with CFG). The responsivity is 1 over the calibration factor, so I it is up to the author to decide what to call and label the correction function."
This should be clarified with the above explanations.

"A reference GHI value is more accurately obtained from DNI * Cos(SZA) + DHI than is measured with a pyranometer. If one has high quality DHI measurements, one usually has the capability of making reference DNI measurements."
The reference GHI value used in our calibrations is obtained as described above. Please see line 27 on page 10253 to line 4 on page 10254:
"The reference global horizontal irradiance (GHI_{Ref}) is calculated from both reference instruments since this yields higher accuracy than GHI measurement by a pyranometer (see ISO 9060). Nonetheless, a second pyranometer that measures GHI directly is used to control the reference measurements by redundancy check."

"both reference instruments" refers to a pyrheliometer and a shaded pyranometer.
However, we now include the equation into the manuscript (now Eq. 1)

"Pages 10257 and 10258. One has RMSD for DHI measurements and RMSD for DNI measurements. Differentiate the labels. "
From our perspective using specific labels for different RMSD in this context would make it look more complicated than it is. The iterative calculation of calibration factors is carried by algorithms which minimize the RMDS between the RSI and the reference. This is done separately for the different irradiance components (GHI and DHI in DLR2008 and GHI, DHI and DNI in VigKing).

"Look into CFn
DNIRSI = CFn* (GHIRSI – DHIRSI)/cos(SZA) "
We included tables 1 and 2 in order to clarify the definition of the used variables.

"Equation 10- Usually the reference is in the denominator. "
We agree that it might be more intuitive to define the parameter R in the reciprocal way. However, later only the parameter Π is used which is calculated based on R. Hence, it is not of high importance to define R in the most intuitive way. The formulation and the evaluation are correct and changing the complete following results doesn't seem appropriate to us at this point.

"It is not clear from the description what is being taken for the calibration (eqs. 10 to 13). "
The calibration duration is represented by the duration T of the moving intervals for calculation of the moving average M. We now included a clarification for the meaning of T in the text after equation 12 (11 in the previous version).

"The motivation for the moving average is not clear. It seems that all the data for the period is being used. That is usually not the case as some DNI values are new zero. This requires a more complete explanation. "

Thank you for pointing this out. Actually, the same data exclusions as during calibrations are used. This includes the application of so called "calibration limits" (Table 2, now Table 4). These define a minimum of required irradiance (especially DNI) and zenith angles. Only data which is within these limits is used.

In order to be more specific in the section under discussion we changed the wording:

> First the instrument is calibrated over the entire available long-term measuring period by either method from section 2. The thereby derived calibration factors are applied to the functionally corrected 10 minute mean values of RSI measured irradiance from the calibration period. For the following steps the~~The~~ same manual and automatic data exclusions and the application of calibration limits (Table 4) as applied during the calibration process are kept in place. ~~including the calibration limits as applied during the calibration process are kept in place while calculating the~~The remaining data is used to calculate the ratio R_{DNI} of reference to the calibrated RSI irradiance along equation. (10). The timestamp t indicates the 10 minutes interval.
>
> $$R_{\mathrm{DNI}}(t) = \frac{DNI_{\mathrm{Ref}}(t)}{DNI_{\mathrm{RSI}}(t)} \qquad (10)$$
>
> Thereafter, the moving average (here: moving in steps of 24 hours) of R_{DNI} is calculated as

We also included the set A_{acc} in equations 12 and 13 (new numbering).

"My guess is that the calculation is for the entire period of data (-T/2 to T/2) at a given time td. In other words you are doing this for 10:50 each day for the entire period of record. Then you calculate another value for 11:00, and so on. Is that correct?"

This is only partially correct. We only use t_d at noon. So in your example we would not select 10:50 but 12:00 (UTC+1). And the next timestamp for which the moving average is calculated is not 10min later but one day later. This is the moving average M (now Eq. 12). Each individual value of M represents a calibration of duration T with data from t_d -T/2 to t_d +T/2. To clarify this we added the following to the text (page 11 line 18 of marked up version):

"As t_d is always noon (UTC+1) of a given day we calculate only one moving average $M_{\mathrm{DNI}}(T, t_d)$ for each day."

"It seems to be the average of all values over all times. This doesn't make since to me because the values at 8:00 will be different from 12:00 and they should not be thrown together. This is especially true because the ratio is dependent on the solar zenith angle, particularly at the beginning and end of the day."

The problem of different solar zenith angles is avoided as we only calculate one value per day around noon and for an integer number of days T as explained above. We added "T is an integer number of days." to clarify the procedure.

"Another way to do this would be to bin the DNI values and do this procedure for all DNI values at time td between say 900 and 1000 W/m2, etc."

Binning the DNI and evaluating different data sets is an option that we might test in the future. We think this is only an additional option that is not required to be discussed in the paper as the issue of solar zenith angles does not affect the moving averages (see last two comments).