Thanks for the reviewer's efforts to review this paper. The point-by-point responses are included below with the reviewer's comments in black and our replies in blue.

Reviewer #2

This paper reports on the performance a new radiometer, HSR1, that measures total and diffuse spectral irradiance. HSR1 measured irradiances, diffuse ratio, and derived aerosol optical depths are compared to other spectral and broadband radiometer systems: MFRSRs, SASHe, a Cimel sunphotometer, the RadFlux data product. The instruments operated at the ARM Southern Great Plains site for two months in spring/summer of 2022. The conclusion is that HSR1 measurements of total and diffuse spectral irradiance well in relation to the other instruments, however significant biases exist for irradiance measurements near the tails of the instruments spectral range.

This paper does a reasonable job with the statistical comparison between the HSR1 data and the data collected by the reference instruments at the SGP site. However, for a paper that aims to detail the functionality of a new instrument, key components of the manuscript are lacking. These include: details about the HSR1 instrument hardware, calibration procedures, and the study design that are necessary for an instrument paper of this sort. A discussion of the measurement biases in the context of the unique instrument design features. The role measurement uncertainty has on the analysis is not sufficiently addressed. Further, the quality of the writing, both with respect to grammar and structure of the paper, is not at an appropriate level for publication. I've highlighted a few examples of writing quality issues in the following comments. Given these issues I do not recommend this manuscript for publication in AMT at this time.

Thanks for the reviewer's efforts to review this paper. See our replies below.

Comments:
Lines 23-25 – "The HSR1 quantities are also compared at other wavelengths to the collocated instruments, where similar agreement is found for the spectral irradiances, although relatively larger disagreement is found at higher wavelengths, especially for spectral AODs." To me this sentence reads awkwardly. I recommend that it be reworked.

We have revised the text to improve clarity (Abstract): "The comparisons are within ~10% for the spectral irradiances, except for 940 nm where there is relatively larger disagreement. The AOD comparisons are within ~10% at 415 and 440 nm, however, a relatively larger disagreement in the AOD comparison is found for higher wavelengths."

Line 44 – It is worth pointing out somewhere in the manuscript that HSR1 measures total and diffuse irradiance simultaneously, which is in contrast to rotating shadowband systems.

Thank you for the suggestion. We have revised the text to make this point (Section 1): "Due to the nature of the measurements, the F_{total} and $F_{diffuse}$ are measured simultaneously. This is in contrast to rotating shadowband systems which must make the total and diffuse measurements separately and therefore at different times."

Line 45-59 – Much of the contents of this paragraph that detail characteristics of HSR1 should be moved out of the introduction to a section that overviews the hardware and calibration procedures of the instrument.

We have decided to keep this information in the introduction following a suggestion from the editor's initial review.

Line 55 – "As the sun moves across the sky throughout the day..." It is also worth mentioning here that the same holds true if the instrument position moves. Again, this seems to be a unique feature of the shadowmask design of the HSR1.

Thank you for the suggestion. We have revised the text to clarify this point (Section 1): "The HSR1 was designed with seven spectral sensors: six sensors placed on a hexagonal grid, one sensor at the center, under a complex static shading mask (see Figs. 1 in Badosa et al., 2014 and Wood et al., 2017). The shading mask design is to ensure that, at any time, for any location: (1) at least one sensor is always exposed to the full solar beam; (2) at least one sensor is always completely shaded and; (3) the solid angle of the shading mask is equal to π thus corresponding to half of the hemispherical solid angle. With no moving parts or specific azimuthal alignment, the instrument is ideal for deployment on moving platforms such as ships and remote locations where regular maintenance is difficult."

Line 57-59 – "The measured diffuse assumes that the diffuse light is scattered equally angular, i.e., isotropic. The isotropic assumption may not be applicable due to the scattering properties of aerosols and clouds which may have a preferential scattering angle." Here is an example of where the writing quality needs to be improved. This paragraph would read more clearly if the writing were more concise, e.g.: The measurement of diffuse irradiance assumes the scattered light is isotropic. Then the following discussion of the implications of assuming isotropic diffuse light is important (and necessary), but it does not fit in this section of the paper.

We have revised the text to clarify this point (Section 1). We have decided to keep this information in the introduction following a suggestion from the editor's initial review.

Line 71 – This section describing HSR1 is insufficient. Here is where some of the content from the introduction should go – describe the shadow mask, the specifics of the HSR1 design including a description of the spectrometers used, the theory behind the diffuse and total irradiance measurements, what is new about HSR1 specifically compared to past iterations of the instrument, briefly overview the calculation of the direct irradiance, etc.. Second, how is HSR1 calibrated? At the very end of the manuscript in the Discussion section it is noted that the HSR1 is calibrated against a lamp standard -- why is that procedure not described here? Why is there no discussion of the cosine response of the HSR1? Field-of-view issues, and lensing effects of the dome are briefly mentioned but that discussions lacks detail. It is useful to understand the limitations of the HSR1 instrument so the results of this intercomparison can be interpreted.

We have revised the text (Section 1 and 2) by adding in more details and specifics on the HSR1 including the shadowmask, spectrometers, theory behind the diffuse and total measurements, what is new to this instrument design, calibration information, cosine response, and field of view.

Line 74 – what is the native sampling rate of HSR1? Or how many data points are getting smoothed over in 1 minute?

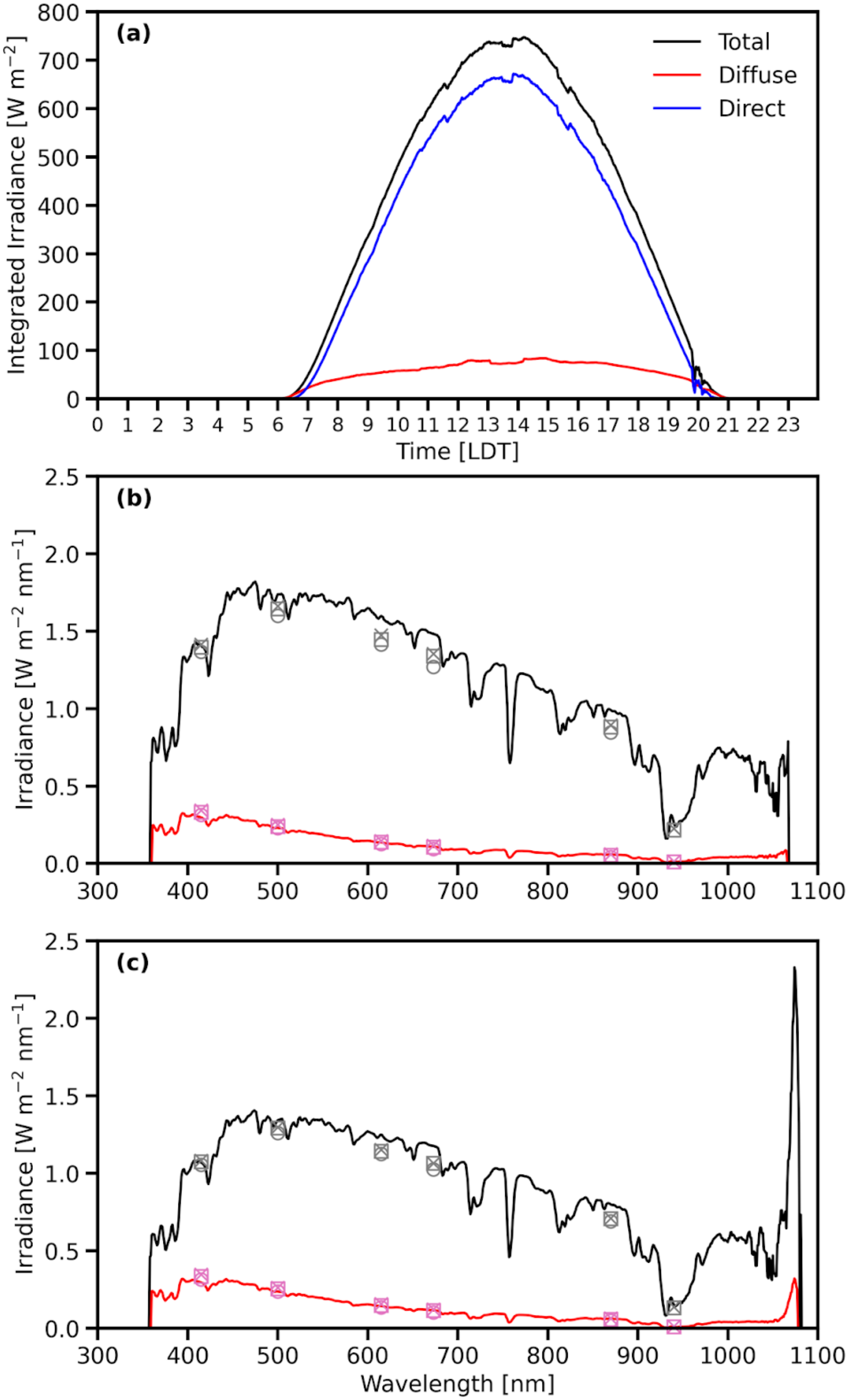
We have revised the text to include more details on the sampling rate and temporal resolution (Section 2.1): "The HSR1 spectrometer achieves an optical resolution of 3 nm over the range 350 nm to 1050 nm, and can take a measurement in as little as 200 ms. However, to improve the dynamic range of the instrument over the spectral range, and also capture the range of diurnal irradiances, readings are taken over a series of different integration times, and merged into a single high-dynamic-range measurement. This typically gives a measurement time of around 1 s. There is a trade-off between speed and dynamic range. In this study, measurements were made every 10 s, then averaged and stored every minute to match common solar radiation datasets."

Line 78 – roughly how far apart are the different instruments from each other? It is not easy to infer this from the reported coordinates. A map detailing the locations of the various instruments would be useful.

Thank you for the suggestion. We have added in a map of the instruments' locations across the site in new Figure 1 (see below), which indicates that the physical distance is 170 m or less.

Line 79 – I would move Figure 1 that shows an example of HSR1 irradiance data to a later part of the paper. Also, why not include the comparable irradiance measurements from the other instruments?

Thank you for the suggestion. We have revised Section 2.1 so now Figure 2 (previously Figure 1) is later in the text. We have also updated Figure 2 to include the irradiance measurements from the MFRSRs and SASHe (see revised figure below). Note that the figure has been updated to a different time when all instruments were available.



(a)
Total
Diffuse
Direct
Integrated Irradiance [W m^{-2}]
Time [LDT]
(b)
Irradiance [W m^{-2} nm^{-1}]
(c)
Irradiance [W m^{-2} nm^{-1}]
Wavelength [nm]

Line 90-95 – This discussion of the cause of the downtime seems unnecessary.

We have shortened the HSR1 downtime information by removing the paragraph description and only including in the text (Section 2.1): "The HSR1 exhibited excellent uptime and near-autonomous data collection over the two-month test period with an uptime of 97.5%."

Line 98 – How was it determined that stray light is causing the noise at the tails of the spectrum?

We have revised the text to include that the straylight issues are known based on lab tests (Section 2.1): "In particular, considerable noise was noted for wavelengths greater than 1000 nm (Fig. 2c) as the measurements were contaminated by second-order stray light as identified in the lab using a monochromator. As with all spectrometers, measurements at the two extremes of the spectrum have low sensitivity, and therefore additional noise is apparent."

Line 102-103 – the comment on future designs of the HSR1 is better suited for a discussion section later in the paper.

Thank you for the suggestion. We have moved this text to the discussion section (Section 5).

Line 110-111 – "We consider how the dome lensing effect corrected total and diffuse spectral irradiances may affect the results in Sect. 5." I do not believe that this was ever done in Section 5.

We are working on expanding the discussion of the dome lensing effect in the discussion section (Section 5). We plan to include this in a revised version of the manuscript.

Line 115 – throughout the manuscript I am not sure it is necessary to refer to measured or derived quantities at a specific wavelength as "spectral". As far as my knowledge goes this is not standard practice. It is more readable to just say the AOD at 500 nm, for example.

Thank you for the suggestion. We have revised the text to remove "spectral AOD" and instead refer to AOD at specific wavelengths. We have kept "spectral irradiance" to distinguish from broadband irradiance.

Line 130 – again, I am not sure the discussion of data reprocessing is necessary.

Thank you for the suggestion. We have revised the text to reduce the detail of the SASHe data reprocessing (Section 2.2.3).

General comment – there needs to be more discussion of the magnitude and sources of measurement uncertainty for HSR1 and the reference instruments. This will help the reader better understand the significance of the differences between the measurements.

We have added into the text uncertainty estimates where available (Section 2). We are working on uncertainty estimates for the HSR1 AOD to include in a revised version of the manuscript. We also plan to include discussion of the measurement differences in the context of the uncertainty in a revised version of the manuscript.

Line 145 – how do visible and sub-visible cirrus impact the determination of clear-sky periods? Cirrus can significantly bias the diffuse irradiance measurement.

We have added into the text an expanded description of RADFLUX to clarify how clear-sky periods are identified (Section 2.2.4): "RADFLUX processing first identifies clear sky time periods using the magnitude and variability of the $F_{broadband,\ diffuse}$ and $F_{broadband,\ total}$ that have been normalized to remove the impacts of the diurnal cycle. Clear sky estimates are determined at all times using empirical fits to those data points (Long & Ackerman, 2000). Finally, cloud fraction (CF) is calculated based on a relationship with the normalized diffuse cloud effect (Diffuse measured - diffuse clear sky/total clear sky). Care is taken to distinguish between optically thin and thick clouds in the CF calculations using statistics on the magnitude and variability of the irradiance measurements and the diffuse ratio (see Long et al. 2006 for more details)."

Because the RADFLUX clear sky identification methods are based on the variability of the $F_{broadband,\ diffuse}$, they capture optically thin cirrus quite well. It compares well to both sky imagers and human observers in its ability to identify optically thin clouds. It is possible that sub-visible cirrus that doesn't have a significant impact on the variability of the diffuse will not be captured in the clear sky estimates. However, if subvisible cirrus is missed in the HSR1 AOD retrieval, then it is also likely missed in all of the AOD retrievals as they all use some kind of measure of the scatter of SW irradiance to determine when skies are cloud-free.

Line 149 – what does this manuscript gain by including the comparison of PAR? I recommend removing this portion of the analysis.

The PAR comparison shows an application of the HSR1 that is possible with hyperspectral information. We have moved the PAR comparison to new section Appendix B.

Line 170 – it should be made clear that in equation 2 the optical depths have a spectral dependence.

We have updated Eqs. 4 and 5 (previously Eqs. 2 and 3) to indicate that the optical depths have a spectral dependence by adding in that these quantities are a function of wavelength, λ (Section 3):

$$DNI(\lambda) = DNI_0(\lambda)exp[-\left(\tau_{Rayleigh}(\lambda) + \tau_{aerosol}(\lambda) + \tau_{gas}(\lambda)\right)m] \quad (4)$$

$$\ln(DNI(\lambda)) = \ln\left(DNI_0(\lambda)\right) - \left(\tau_{Rayleigh}(\lambda) + \tau_{aerosol}(\lambda) + \tau_{gas}(\lambda)\right)m \quad (5)$$

Line 192 – what is the rational for kicking out half of the data points when deriving the TOA DNI?

We consider the interquartile range to eliminate outliers and reduce noise as is done by other AOD retrievals that the retrieval in this study is based on. We have revised the text to make this point clearer (Section 3): "The TOA DNI are then filtered by only considering the interquartile range (i.e., 25^{th}-75^{th} percentile) to eliminate outliers and reduce noise (Koontz et al., 2013; Ermold et al., 2013)."

Line 227 – "Therefore, portions of the surface downwelling diffuse light are not measured by the HSR1 and..." It seems like this light is measured by the HSR1, but it is just attributed to being direct irradiance?

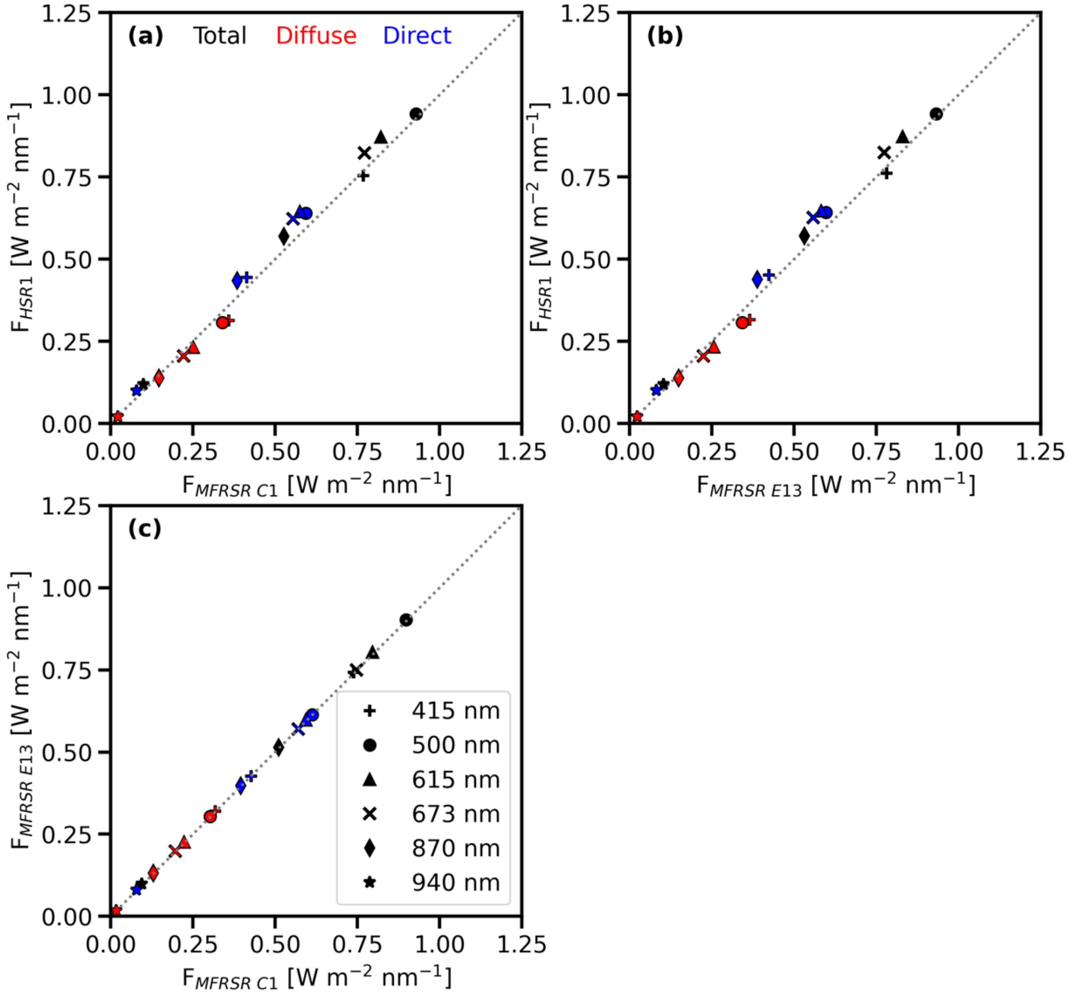
Yes, this is correct. We have revised the text to clarify this point (Section 4.1): "Therefore, portions of the $F_{diffuse}$ are measured by the HSR1 as the F_{direct} and may explain the underestimation $F_{diffuse}$ observed in this comparison study."

Line 228 – Throughout the paper comparisons are done between the various reference instruments. As currently written, this seems unnecessary as I do not see what value it adds to the analysis, and it distracts from the main topic which is the evaluation of the HRS1.

The comparison results between the other instruments provide a reference for the HSR1 comparison. We have revised the text to highlight this point for why the other instruments are compared. For the irradiance, the text is revised to (Section 4.1): "The MFRSR C1 and MFRSR E13 spectral irradiances are also compared to each other in Fig. 5 and Fig. 6 to provide context to the HSR1 comparison by considering the comparison of established instruments that are also the same instrument in nearly the same location." For the AOD comparison, the text is revised to (Section 4.2): "The CSPHOT, MFRSR C1, MFRSR E13, and SASHe AODs were also compared for AOD at 500 nm to provide context to the HSR1 AOD comparison based on the comparison of established instruments and AOD retrievals." We have also removed the tables and reduced the text to clarify the story.

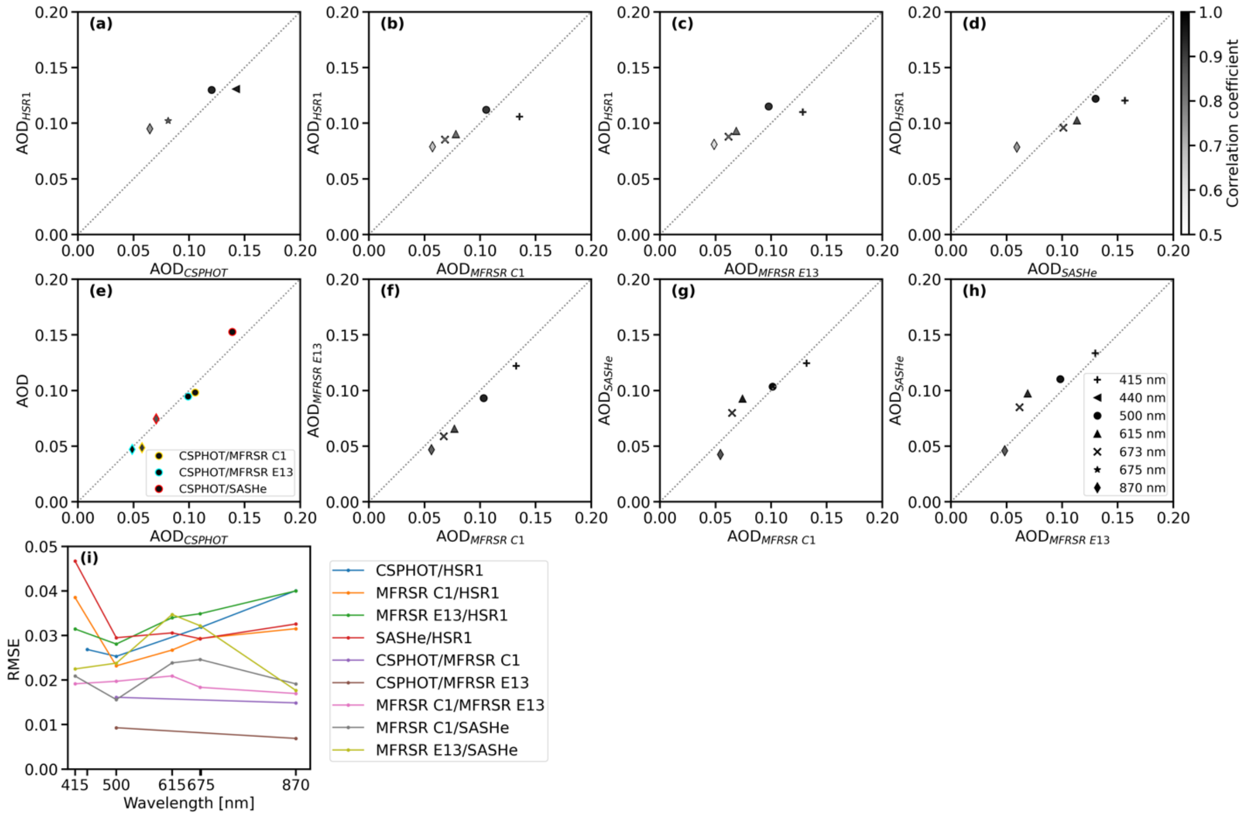
Line 251 – In Figure 4 why not also include the direct irradiance?

We decided to focus on the total and diffuse since this is what is measured by the HSR1. The direct can be inferred by what is included in new Figure 7 (i.e., direct = total-diffuse). We have also plotted the direct irradiance comparison (blue) for your reference.



Line 255 – This table is hard to read and interpret and does not hold a lot of utility to the reader. Much of this information is already stated in the text, so I'd either omit the table or present the data in a graphical format.

Thank you for the suggestion. We have removed the tables. For the irradiance comparison, we have presented the correlation coefficients in the text as the values are nearly the same. For the AOD comparison, we have instead presented the correlation coefficients as the color shading in Figure 10a-h (see below).



Line 271-273 – "Similar to the total spectral irradiance, the MFRSR C1 and MFRSR E13 diffuse spectral irradiance comparison at 940 nm is the largest relative difference, which is nearly an order of magnitude larger than all other wavelengths (0.9-1.9%). This further highlights the challenges in measuring the spectral irradiance at 940 nm." I found this wording confusing and suggest it be revised.

We have revised the text for clarity (Section 4.1): "Interestingly, the mean $F_{diffuse}$ for the HSR1 compared to those from the MFRSR C1 at 940 nm agree better than the MFRSR C1 and MFRSR E13 $F_{diffuse}$ at 940 nm of 9.8%. However, the mean differences for the $F_{diffuse}$ at 940 nm are small in magnitude at only 0.001-0.003 W m^{-2} nm^{-1}. Similar to the F_{total} comparison, the MFRSR C1 and MFRSR E13 $F_{diffuse}$ relative difference is largest at 940 nm compared to the relative differences at other MFRSR wavelengths. For context, the relative difference at 940 nm is nearly an order of magnitude larger than all other wavelengths (0.9-1.9%). This further highlights the challenges in measuring the spectral irradiance at 940 nm as two of the same instruments in the same location differ the most at this channel."

Line 279 – the details about the MFRSR spectral channel widths seems better suited for Section 2.

Thank you for the suggestion. We have moved the MFRSR narrowband filter details to Section 2.

Line 287 – what is the motivation for comparing HSR1 to SASHe under clear sky-conditions. As is this manuscript is only presenting statistical quantities of HSR1 versus other instruments with little justification for doing so or interpretation of the results. For example, how might the shadowmask design of HSR1 influence this comparison with a shadowband type instrument?

The SASHe comparison is limited to clear-sky due to SASHe data issues during this time period as discussed in Section 2.2.3. We have revised the SASHe data section to clarify this point. We plan to add in text on how the shadowmask influences comparison with the shadowband systems in a revised version.

Line 304-312 – again, what about the instruments or experimental setup is driving these differences.

We plan to add in text on how the instrumental designs are potentially driving the differences seen in the comparison analysis in a revised version.

Line 325 – this sentence should be reworded: AODs are not collected, they are calculated.

We believe that this is a typo as the text says that the AODs are collocated and not collected (Section 4.2).

Line 340 – again, I do not see the value in the comparison of the AOD derived from the reference instruments.

The comparison results between the other instruments provide a reference for the HSR1 comparison. We have revised the text to highlight this point for why the other instruments are compared. For the AOD comparison, the text is revised to (Section 4.2): "The CSPHOT, MFRSR C1, MFRSR E13, and SASHe AODs were also compared for AOD at 500 nm to provide context to the HSR1 AOD comparison based on the comparison of established instruments and AOD retrievals."

Line 375 – it may be worthwhile to include a timeseries figure or two of irradiance and AOD that illustrates under what solar zenith angle and cloud conditions there is good and poor agreement between HSR1 and the reference instruments.

Thank you for the suggestion. We are also working on a new figure to a revised version of the manuscript that is a timeseries of the irradiance(500 nm) and AOD(500 nm) with a clear-sky marker.

Line 423 – "Noting the measurement uncertainty of ±3% in the diffuse flux (Michalsky and Long, 2016), only 16.5% (all times) and 18.3% (clear-sky times) of the diffuse flux errors due to considering the HSR1 diffuse ratio are within measurement uncertainty." I had a hard time understanding this sentence and would recommend rewording it.

We have revised this sentence for clarity (Section 4.3.2): "The measurement uncertainty of the $F_{broadband,diffuse}$ is ±3% (Sect. 2.2.4). If the $F_{broadband,diffuse}$ is determined by the DR_{HSR1}, then the $F_{diffuse,error}$ considering the DR_{HSR1} are within the $F_{broadband,diffuse}$ measurement uncertainty only 16.5% (all times) and 18.3% (clear-sky times) of the time."

Line 509 – This section is not a discussion section but it is a summary. Here is a good place to discuss how the design of the HSR1 impacts its ability to measure irradiance relative to the reference instruments. Under what conditions does is perform well (e.g., clear-sky, cloudy-sky)? And when there are biases in the data HSR1 produces, why? For example, what impact does the wide field-of-view, the cosine response of the sensor, the assumption that the diffuse light is isotropic, etc., have on the measurements.

Thank you for the suggestions. We are working on expanding the discussion section to include further discussion on how the HSR1 performance and evaluation relates to instrument design in a revised version.