Author response to referee comment #2

December 4, 2020

We thank referee #2 for the time spent reading the manuscript and the productive and helpful comments. We have addressed the referee's comments on a point to point basis as below for consideration. All page and line numbers refer to the first version of the manuscript.

1 General comments

R2: *The developed model is physically sound and has been validated using laboratory measurements at two wavelengths. While the technical content is complete and well explained, I miss some motivation and explanation of the effect in the Introduction and an illustration and discussion of the practical relevance in the Results and Discussion section. I recommend publication after these minor revisions are made.*

Response: We will add more detailed explanations and motivations regarding speckle effect into the introduction and extend the discussion in order to better illustrate our results.

2 Specific comments

R2: *The modeled effect is not well known in the scientific community. It is difficult to believe that sunlight induces noticeable interference effect in solids because speckles are typical for lasers, but not for natural light. You should mention in the Introduction the puzzling spectral wiggles in the order of a few percent discovered in data of the SCIAMACHY and OMI instruments (described and illustrated by van Brug et al., 2004).*

Response: We will clarify these aspects in the introduction.

R2: *Interference effects require that the coherence length is larger than the size of material inhomogeneities, thus you should quantify the coherence length of sunlight and compare it with the typical scale of inhomogeneities in diffuser material. According to Divitt and Novotny (2015) the coherence length of sunlight* *is 80 x wavelength, which corresponds to 62 μm and 126 μm at the wavelengths of your measurements (777 nm, 1570 nm).*

Response: According to the specifications given by the manufacturer the scattering centers of the diffuser material have a maximum diameter of 20 microns. We will add a comparison in Section 3.2.

R2: *The importance of the effect and the model for practical applications should be graphically illustrated in the Results and Discussion sections. In particular a plot of the wavelength dependency should be added due to its high relevance for spectral measurements. The wavelength dependency cannot be assessed from the equations, thus a graphical illustration would help the reader to grasp the importance of the described effect. Furthermore, such a plot would allow comparing at least qualitatively the modelled spectral dependency with observed spectral patterns, e.g. as in Fig. 1 of van Brug et al. (2004).*

Response: We will add plots of the wavelength dependence for both bands in the discussion.

R2: *You should also mention that the effect is not restricted to diffusers, but occurs for all static measurements of a solid. Point out its relevance for laboratory calibration of spectrometers and spectral measurements using a fixed set-up of target, spectrometer and light source; and explain that the effect vanishes if one of these is moved or tilted during the measurement, as in case of remote sensing.*

Response: We will introduce the reader more broadly into the subject of speckle and some mitigation methodes in the introduction. However, we would like to point out, that the movement or the tilting of parts in the optical system are usually not implemented in space applications, since they would involve additional moving parts, which is usually to be avoided. The only change of the geometry would be the angle of incident due to the movement of the instrument relativ to the sun. Angular averaging effects, however, are not part of this work.

Line 21f: R2: *"Since Spectral Features are of statistical nature and cannot be mitigated by any post-processing steps". Correction may indeed be difficult, but not because the effect is of statistical nature, but because the intensity of the pattern and its position on the focal plane are difficult to calculate accurately because they depend on a number of parameters which are difficult to measure with sufficient accuracy (temperature, pressure, isotropy of incident light field).*

Response: We will adapt this passage regarding the term "statistical".

3 Technical corrections

Line 18: R2: *: "diffuser introduces a statistical interference phenomenon" I suggest to delete statistical (as it is a geometric effect, not a statistical one) and replace "phenomenon" by "pattern".*

Response: We see the argument of the Referee here and will follow his suggestion to remove "statistical" for this specific formulation. However, we still see the need for a quasi statistical treatment of the effect, because the resulting intensity of the speckle pattern seen by the detector is essentially unpredictable.

Line 50: R2: *: unwanted "features". Unclear: What do you mean with unwanted? Unexplained?.*

Response: What is meant here, are the "features", that are caused solely by the diffuser. They are "unwanted" in the sense, that they alter the solar reference spectrum, which is recorded during calibration. We will change this sentence to clarify this.

Line 51f: R2: *: The SFA value is then calculated as the standard deviation of the normalized signal over a certain spectral width, that includes multiple features." The definition of SFA is unclear: normalized to what? What means "certain spectral width"? Is standard deviation calculated over time or over wavelength? The definition only gets clear at line 106f together with Eq. (3). Improve here the explanation and refer for details to Eq. (3).*

Response: We will replace "certain wavelength range" by "multiple spectral channels". The standard deviation is taken over the normalized detector signal, which essentially is calculating it over wavelength. We will clarify this.

Line 76f: R2: *: "Sun's light... is assumed to be spatially coherent giving the distance from the Sun to the Earth and the limited acceptance angle of the spectrometer." The coherence of light from a spatially incoherent spherical source is in fact valid immediately beyond a distance of a few wavelengths (Agarwal et al. 2004), thus the spatial coherence of sunlight has nothing to do with the Earth-sun distance. Quantify instead the coherence length, e.g. by citing the result 80 * Lambda by Divitt and Novotny (2015). Also the influence of the acceptance angle of the spectrometer is not clear. Either explain or remove it.*

Response: We wanted to point out that the spatially coherent Sun light incident on the diffuser can be treated as collimated under the mentioned conditions, which is also matched by our experimental setup. We will rework this part.

Line 77f: R2: *: "the temporal coherence is very short compared to the detector integration time, which is in the order of seconds" Quantify the temporal coherence and replace seconds by milli-seconds. The sunlight coherence time is 3* *fs according to Herman et al. (2014) who cite the "Optics" book of Hecht (2016).*

Response: We will rework this part.

Line 120: R2: *: add a reference for Eq. (4).*

Response: Done.

Line 233f: R2: *: "the fitted mean free path length of our diffuser sample is determined as ls = 53µm". Explain how you fitted the free path length. The mean free path length depends on wavelength as the scattering probability is wavelength-dependent. Hence, add the wavelength.*

Response: We will use different values for l_s for each band. We will add an explanation on how this values were obtained. The reference value of $l_s = 56\mu m$ given by the manufacturer is for $\lambda = 500nm$. We obtained more realistic values for l_s at the employed wavelengths using the approach by Zhu et al. (1991) of calculating the frequency correlation function $F(\Delta f)$.

Line 300: R2: *: Coernicus → Copernicus.*

Response: Done.

4 References

Zhu, J. X., Pine, D. J., and Weitz, D. A.: Internal reflection of diffusive light in random media, Phys. Rev. A, 44, 3948–3959, https://doi.org/10.1103/PhysRevA.44.3948, https://link.aps.org/doi/10.1103/PhysRevA.44.3948, 1991.