Response to comment of Anonymous Referee #1 on “Restoring the top-of-atmosphere reflectance during solar eclipses: a proof of concept with the UV Absorbing Aerosol Index measured by TROPOMI” by Victor Trees et al.

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We thank the reviewer for his/her careful reading and for the comments and suggestions, which have improved the manuscript. Below, we give in *black italic* the reviewer’s comment, in black our response, and in red the changed text in the manuscript.

General comments:

The manuscript by Trees et al. describes a technique to correct for the change in the top-of-atmosphere (TOA) solar spectral irradiance during a partial or annual solar eclipse. The technique is based on earlier works by Koepke et al. (2001), Bernhard and Petkov (2019) and Ockenfuß et al. (2020). However, the authors generalized these calculations by also including the case of an annular eclipse (The formulas presented by Koepke et al. (2001) only consider partial and total eclipses). The method makes satellite measurements collected during a solar eclipse available for the retrieval of properties of the Earth’s atmosphere. The technique is sound and the validation results show convincingly that it is working. The topic is suitable for Atmospheric Chemistry and Physics.

My main issue is that a solar eclipse is a very rare event and applicability of the method is therefore limited. If data from one or two satellite orbits have to be discarded because of contamination by the Moon’s shadow, the data loss is minor and interpolations using data from adjacent orbits should satisfy most needs. The more interesting question is whether the technique is accurate enough to detect changes in atmospheric properties during an eclipse and could help to evaluate atmospheric processes initiated by an eclipse. For example, there could potentially be a change in aerosol properties during the eclipse because aerosol hygroscopic growth is likely affected by the reduced air temperature (and the resulting effect on relative humidity) during an eclipse. For the correction method described by the authors to be useful, the uncertainty of the correction must be smaller than the expected change in aerosol properties induced by an eclipse. What is the evidence that the uncertainty is indeed sufficiently small? The authors should try to estimate the uncertainty of their correction as it applies to the ultraviolet (UV) Absorbing Aerosol Index (AAI). This would further demonstrate the strength of their method and increase the scientific *relevance of the paper.*

We thank the reviewer for her/his critical comment on the applicability and accuracy of the eclipse correction method. We address the points mentioned in the above comment separately:

– *My main issue is that a solar eclipse is a very rare event and applicability of the method is therefore limited. If data from one or two satellite orbits have to be discarded because of contamination by the Moon's shadow, the data loss is minor and interpolations using data from adjacent orbits should satisfy most needs.*

  Every year, there are about 2 to 3 solar eclipses (with a yearly average of 2.4 solar eclipses)[1]. Since the start of the nominal operational mode of TROPOMI in May 2018, 7 solar eclipses occurred, 6 of which have been measured by TROPOMI. In the paper, in the second paragraph of the Introduction, we mention that, sometimes, such eclipse anomalies propagate into anomalies in temporal average maps without raising an eclipse flag, potentially resulting in false conclusions about the mean aerosol effect in that time period. An example of a *monthly average* AAI map of the GOME-2 satellite instrument that is distorted by a solar eclipse can be found on https://d1qb6yzwaaq4he.cloudfront.net/airpollution/absaai/GOME2B/monthly/images/2019/GOME-2B_AAI_map_201912.png. The formulae in the Appendix of this paper can also be used to only compute an eclipse flag. Indeed, an eclipse flag computation is not new and the eclipse anomalies could be omitted by raising an eclipse flag and discarding the data, however, the advantage of a correction is that data is not lost and can potentially be used to study solar eclipses from space. In addition, the successful correction shows that the physics of the shadow is understood.

  We have added the following sentence to the second paragraph of the Introduction:

  l.28: "Since the start of the nominal operational mode of the TROPOMI spectrometer instrument on board the S5P satellite in May 2018, 7 solar eclipses occurred, 6 of which have been measured by TROPOMI."

  We have changed the last sentence in the second paragraph of the Introduction:

  l.36: "Sometimes, such eclipse anomalies propagate into anomalies in temporal average maps without raising an eclipse flag, potentially resulting in false conclusions about the mean aerosol effect in that time period." -> "TROPOMI data contains an eclipse flag indicating the eclipse occurrence at a ground pixel. For satellite instruments that do not contain an eclipse flag, such as the GOME-2 instrument, these eclipse anomalies propagate into anomalies in temporal average maps, potentially resulting in false conclusions about the mean aerosol effect in that time period."

  Also, we have added the following footnote to the second paragraph of the Introduction:

  l.40: An example of a *monthly average* AAI map of the GOME-2 satellite instrument that is distorted by a solar eclipse can be found on https://d1qb6yzwaaq4he.cloudfront.net/airpollution/absaai/GOME2B/monthly/images/2019/GOME-2B_AAI_map_201912.png, visited on 22 February 2021.

[1] https://eclipse.gsfc.nasa.gov/SEpubs/5MCSE.html

– *The more interesting question is whether the technique is accurate enough to detect changes in atmospheric properties during an eclipse and could help to evaluate atmospheric processes initiated by an eclipse. For example, there could potentially be a change in aerosol properties dur- ing the eclipse because aerosol hygroscopic growth is likely affected by the reduced air temperature (and the resulting effect on relative humidity) during an eclipse.*

Evaluating atmospheric processes initiated by the eclipse would, besides the measurement and correction accuracy, also require an estimation of the 'non-eclipse state', i.e. the situation if no eclipse would have occurred, which is unknown. However, if changes are detected that are spatially correlated with the recent eclipse ground track, atmospheric processes initiated by an eclipse could potentially be identified. In this paper, we did not find an indication of a change of the absorbing aerosol effect that was spatially correlated with the recent eclipse ground track. Montornès et al. (2016) modeled a local surface temperature response of ∼-1K to ∼-3K. We speculate that aerosol properties do not rapidly change in a the few hours of reduced temperature during the eclipse. We speculate, however, that chemical processes requiring sunlight could possibly change in a few hours during the eclipse, such as NO2 or tropospheric ozone, but this should be investigated in a future study. We added the following sentence to the Abstract:

l.15: "No indication of local absorbing aerosol changes caused by the eclipses was found."

We added the following sentence to the Conclusion:

l.489: "In this paper, we did not find an indication of absorbing aerosol changes in the Moon shadow (e.g. which are spatially correlated with the recent eclipse ground track)."

– *For the correction method described by the authors to be useful, the uncertainty of the correction must be smaller than the expected change in aerosol properties induced by an eclipse. What is the evidence that the uncertainty is indeed sufficiently small? The authors should try to estimate the uncertainty of their correction as it applies to the ultraviolet (UV) Absorbing Aerosol Index (AAI). This would further demonstrate the strength of their method and increase the scientific relevance of the paper.*

We agree with the reviewer that a detection of an eclipse-initiated phenomenon only can be done when its signal is significantly stronger than the noise of the corrected product itself. For the two eclipse cases discussed in this paper, we did not find significant features in the corrected AAI product that could indicate eclipse-initiated phenomena. In the new Appendix B of this document, which we also added to the paper, we analyze the effect of the solar irradiance correction on the AAI precision.

We also added the following sentences:

l.316: "In Appendix B we provide an analysis of the precision of the AAI during the solar eclipses studied in this paper."

l.394: "Note that this AAI change is larger than the maximum standard AAI error in orbit 13930 of 0.40 (see Appendix B)."

The authors chose to validate their method by comparing retrievals of the UV AAI with and without correction for the Moon's shadow. The UV AAI is a hard-to-interpret indicator of aerosol absorption properties. An alternative metric would be the aerosol absorption optical depth (AAOD), which is similarly defined as the widely-used aerosol optical depth (AOD), except that optical depth refers to the absorbing part of aerosols only and not to the extinction (from absorption and scattering), as it is the case for the AOD. Hence the AAOD is a more useful quantity to describe aerosol absorption properties than the AAI. It would be helpful if the authors could briefly explain how the AAI relates to the AAOD and/or provide a reference.

The aerosol absorption optical depth is defined as AAOD = AOD (1- SSA) (Sun et al., 2019). The AAI depends on various parameters such as the AOD, SSA and height (de Graaf et al., 2005). Therefore, the AAOD is not retrievable from AAI unless a value for SSA and height is assumed or taken from a model. We have added a sentence to the AAI description:

l.314: "In the next paragraph, we provide a brief introduction to the AAI. For more details about the sensitivity of the AAI to atmosphere and surface parameters, we refer to..." -> "In the next paragraph, we provide a brief introduction to the AAI. The AAI depends on various parameters such as the aerosol optical depth (AOD), single scattering albedo (SSA) and aerosol layer height (ALH). For more details about the sensitivity of the AAI to atmosphere and surface parameters, we refer to..."

Specific comments:
The abstract should be improved for clarity. Technical terms that are not commonly used should be avoided or defined. For example:

- *L7: "eclipse obscuration fraction" is not a commonly used term. While I don't object to its use after it is properly defined, it might be better to either avoid this term in the abstract, or provide a short verbal definition.*

  We changed the sentence:

  L7: "... how to compute the eclipse obscuration fraction ..." -> "... how to compute the obscuration during a solar eclipse ..."

- *L9: The sentence "We verify the calculated obscuration with the observed obscuration using an uneclipsed orbit." is misleading. The paper compares *data products* obtained with and without obscurations, not obscurations per se.*

  We have changed the sentences as follows:

  l.10: "We verify the calculated obscuration with the observed obscuration using an uneclipsed orbit." -> "We compare the calculated obscuration to the estimated obscuration using an uneclipsed orbit."

  l.76: "...and we show how the calculated obscuration fraction can be verified by using measurements in an uneclipsed orbit..." -> "...and we show how the calculated obscuration fraction can be compared to the estimated obscuration fraction from measurements in an uneclipsed orbit..."

l.219: "We use the example of 26 December 2019 to verify the calculated obscuration fractions..." -> "We use the example of 26 December 2019 to compare the calculated obscuration fractions to the estimated obscuration fractions from observations in an uneclipsed orbit..."

l.472: "...we compared the calculated obscuration fractions to the observed obscuration fractions at the ground pixels using measurements of the previous orbit... " -> "...we compared the calculated obscuration fractions to the estimated obscuration fractions at the ground pixels using measurements of the previous orbit..."

– *L12: The sentence "...would result in [...] in a maximum Moon shadow signature in the AAI of 6.7 points increase." is difficult to understand without reading the paper first and should either be reworded or deleted.*

We simplified this part in the abstract as follows:

L10: "In the corrected products, the signature of the Moon shadow disappeared. Not taking into account solar limb darkening, however, would result in a maximum underestimation of the obscuration fraction of 0.06 at 380 nm on 26 December 2019, and in a maximum Moon shadow signature in the AAI of 6.7 increase." -> "In the corrected products, the signature of the Moon shadow disappeared, but only if wavelength-dependent solar limb darkening is taken into account."

– *L54: Regarding: "Such wavelength-independent approximations of the eclipse obscuration fraction based on the the overlapping disks indeed could work well to estimate the shortwave fluxes." "works well" should be quantified. Weather an approximation "works well" depends on the desired accuracy. Also, the word "the" before "overlapping" is repeated.*

We agree that the succesfulness of such an approximation will depend on the accuracy of the results versus the desired accuracy, which explains our usage of the word "could" in this sentence. How accurate the results using such an approximation are, depends on the assumptions made. We did not study and so quantify the effect of neglecting the wavelength dependence of the obscuration on the accuracy of shortwave fluxes (i.e. integrated over the spectral domain), because we study the reflectances as functions of wavelength. We changed the sentence as follows:

L58: "Such wavelength-independent approximations of the eclipse obscuration fraction based on the the overlapping disks indeed could work well to estimate the shortwave fluxes." -> "Such wavelength-independent approximations of the eclipse obscuration fraction based on the the overlapping disks indeed could work well to estimate the shortwave fluxes, depending on the desired accuracy."

– *L90: Regarding "I depends on mu = cos(theta) where theta is the viewing zenith angle," This is misleading as it could be interpreted that I(theta) = I (0) * cos(theta). If the Earth were a Lambertian Reflector, the radiance would be independent of the viewing angle theta (i.e.: I(theta) = I(0)). Since the Earth is not a Lambertian Reflector, the radiance *will* depend on the viewing angle. While this dependency could be expressed as a *function* of cos(theta), this is not clear from the sentence. I suggest to just mention that I depends on the viewing angle without mentioning cos(theta).*

We changed the sentence as follows:

L95: "Also, I depends on $\mu = \cos\theta$ where θ is the viewing zenith angle, on $\mu_0 = \cos\theta_0$ where θ_0 is the solar zenith angle, on the viewing azimuth angle φ and on the solar azimuth angle φ_0." -> "Also, I depends on the viewing zenith angle θ, the solar zenith angle θ_0, the viewing azimuth angle φ and the solar azimuth angle φ_0. Furthermore, we use the definitions $\mu = \cos\theta$ and $\mu_0 = \cos\theta_0$."

- *L94: " The fraction of sunlight that is blocked by the Moon is the eclipse obscuration fraction, f_o." This is not a good definition as "sunlight" is not a physical quantity. Furthermore, because of solar limb darkening, f_o is not defined by the geometric area of the solar disk that is blocked by the moon, but depends on wavelength – see for example Figure 7. This should already be mentioned here. To emphasize the wavelength dependence, the symbol $f_o(\lambda)$ should be used instead of f_o. So I would say: "The fraction of the TOA spectral irradiance $E_o(\lambda)$ that is blocked by the Moon is the wavelength-dependent eclipse obscuration fraction, $f_o(\lambda)$. The remaining solar spectral irradiance at TOA is $(1-f_o(\lambda))E_o(\lambda)$." In general, it would be helpful to add "(λ)" after all spectral quantities that depend on wavelength.*

We have changed the sentence as suggested:

L99: "The fraction of sunlight that is blocked by the Moon is the eclipse obscuration fraction, f_o. The remaining solar irradiance at TOA is $(1-f_\mathrm{o})E_0$." -> "The fraction of the TOA spectral irradiance $E_0(\lambda)$ that is blocked by the Moon is the wavelength-dependent eclipse obscuration fraction, $f_\mathrm{o}(\lambda)$. The remaining spectral irradiance at TOA is [1-$f_\mathrm{o}(\lambda)$]$E_0(\lambda)$."

We added (λ) to f_o and E_0 in Eqs. 1, 2, 3, 6, and 7, and in the text where relevant.

- *Eqs. (6) and (7). Please replace E_0 and f_o with $E_0(\lambda)$ and $f_o(\lambda)$ to emphasize that these are spectral quantities like $I(\lambda)$. See also Figure 7.*

We added (λ) to f_o and E_0 in Eqs. 1, 2, 3, 6, and 7, and in the text where relevant.

- *L290: Before explaining how to interpret the AAI, its definition (i.e., Eq. (16)) should be presented and explained.*

We thank the reviewer for this suggestion. We swapped the first and second paragraph of Section 3.1.3.

- *L292: While it may be possible to calculate the AAI in the present of clouds, is the result of any value? Absorbing aerosols are typically close to the surface (at least in the vicinity of urban centers) and cannot be "seen" by a satellite below a moderately thick cloud. Adding to my general comment, it is beyond the scope of the paper to discuss the value of the AAI to characterize aerosol absorption. Still, the authors should better explain why they chose this parameter to validate their correction method. For example, Eq. (16) could lead to a AAI different from 0 for the case of non-absorbing small aerosol particles. Hence the AAI could potentially indicate absorbing aerosols when in fact non-absorbing aerosol was present.*

The AAI can particularly indicate absorbing aerosols when they are located above the clouds. In that case, the AAI is equivalent to the AAI for an aerosol layer above a bright surface (see de Graaf et al., 2005). When the aerosol layer is below the cloud, the AAI is indeed determined by the cloud scattering properties yielding near-zero or negative AAI (de Graaf et al., 2005). We changed the following sentence:

l. 310: "The AAI generally increases in the presence of absorbing aerosols and can, unlike the aerosol optical depth, also be computed in the presence of clouds." -> "The AAI generally increases in the presence of absorbing aerosols and can, unlike the aerosol optical depth, also be computed when the aerosol layer is above clouds."

We chose the AAI to apply the correction to because the signature of a solar eclipse in the AAI is significant in value and spatial size. The AAI application is relatively straightforward because the AAI depends on the absolute reflectances at only the two wavelengths 340 and 380 nm (rather than differential features on a fitted polynomial) and therefore is directly affected by the eclipse obscuration. In a future study, the correction could be tested on products that are derived from the reflectance at more than two wavelengths. We added the following sentence to the Introduction:

l.33: "The AAI is retrieved from TOA reflectance measurements at two wavelengths in the UV-range, hence the AAI may directly be affected by the obscuration during a solar eclipse."

– *Figure 15: The scatter is rather large. So the figure's value to validate the correction method is rather limited for X > 0.7. This could be mentioned.*

Although we have carefully selected the reflectances in orbit 11403 and 11404 to calculate the obscuration factors, the selected reflectances in the orbit 11403 cannot be the same as the reflectances in orbit 11404, due to natural variation across the Earth's surface. There are indeed some points that are scattered, however, most points are located around the calculated results (represented by the opacity of the points in the plot). Making the filter of Equation 15 more strict (e.g. $R_{340}^{\text{meas}} > 0.75 \cdot R_{380}^{\text{meas}}$), decreases the scatter but also decreases the number of points. The scatter is less for small X, because the number of points roughly decreases with decreasing X simply because X is directly related to the circumference of the surface area centered at the shadow axis (where $X = 0$) for which the solar to lunar disk center separation is smaller than X. We have added a footnote to line 291:

The density of points increases with increasing X because the Earth's surface area for which a certain value of X applies increases with increasing X. Making the filter of Equation 15 more strict (e.g. $R_{340}^{\text{meas}} > 0.75 \cdot R_{380}^{\text{meas}}$), decreases the scatter but also decreases the number of points.

Technical comments

– L41: "have been taken," > "have been observed,"

We do not agree. The measurements have been taken.

– L51: Why "instead"? The verb "approximated" already implies that this is a simplification.

Montornès et al. (2016) used a different approximation than mentioned in the former sentence. We removed the word "instead", and changed the font type of the word "diameter" to italic:

L51: "The eclipse obscuration at a point in the shadow can be approximated by the fraction of the area of the apparent solar disk occulted by the Moon (Seidelmann, 1992). Montornès et al. (2016) instead approximated the eclipse obscuration by the fraction of the solar disk diameter occulted by the Moon ..." -> "The eclipse obscuration at a point in the shadow can be approximated by the fraction of the area of the apparent solar disk occulted by the Moon (Seidelmann, 1992). Montornès et al. (2016) approximated the eclipse obscuration by the fraction of the solar disk *diameter* occulted by the Moon ..."

- L168: low > small

  We changed the text as suggested:

  L168: "... a relatively low r_m, ..." -> "... a relatively small r_m, ..."

- L241: For clarity, please explain “scanline”. (E.g., the line at Earth’s surface defined by the satellite swath that is roughly oriented East-West)

  We have added a footnote after the word "scanline":

  L241: The line at the Earth’s surface perpendicular to the flight direction defined by the satellite swath which is roughly oriented West-East.

- L275: “Sect..” > “section.”

  According to https://www.atmospheric-chemistry-and-physics.net/submission.html#templates": "The abbreviation "Sect." should be used when it appears in running text and should be followed by a number unless it comes at the beginning of a sentence." Here, indeed, "Sect." is not followed by a number, because the sentence reads " in this Sect.." Therefore, we think the reviewer correctly states that "Sect." should be written as "section". We thank the reviewer for pointing this out and changed the sentence:

  L275: "... in this Sect.." -> "... in this section."

  Similarly, we changed:

  L403: "In this Sect., we reflect back on the assumptions ..." -> "In this section, we reflect back on the assumptions ..."

- L317 Moon > Moon’s

  We think that both Moon’s shadow and Moon shadow are correct. To be consistent with the the terminology in rest of the paper, we leave term "Moon shadow" here.

- L331: 110405 > 11405

  We changed the sentence as suggested. We thank the reviewer for pointing out this typo.

  "... orbits 11403 and 110405 ..." -> "... orbits 11403 and 11405..."

– L358: delete “still”

We changed the sentence as suggested:

L358: "... still in too low ..." -> "... in too low ..."

– L415: What is “chord”?

We changed "chord" into "straight line":

L415: "... at the chord ... " -> "... at the straight line ..."

The following appendix is added to the paper:

Appendix B: Error propagation

In this appendix, we show the effect of the solar irradiance correction on the precision of the AAI. It should be recalled from Equation 3 that the corrected measured TOA reflectance, $R^{\text{int}}(\lambda)$, is computed from the measured TOA reflectance by TROPOMI, $R^{\text{meas}}(\lambda)$, and the calculated obscuration fraction, $f_{\text{o}}(\lambda)$. We assume that the noise of $R^{\text{meas}}(\lambda)$ and the noise of $f_{\text{o}}(\lambda)$ are normally distributed with standard deviations $\sigma_{R^{\text{meas}}(\lambda)}$ and $\sigma_{f_o(\lambda)}$, respectively. Also, we assume that the noise of $R^{\text{meas}}(\lambda)$ is not correlated with the noise of $f_{\text{o}}(\lambda)$. Then, we may compute the precision of $R^{\text{int}}(\lambda)$ as follows

$$\sigma_{R^{\text{int}}} = R^{\text{int}} \cdot \sqrt{\left(\frac{\sigma_{R^{\text{meas}}}}{R^{\text{meas}}}\right)^2 + \left(\frac{\sigma_{f_{\text{o}}}}{1 - f_{\text{o}}}\right)^2} \qquad \text{(B1)}$$

$\sigma_{R^{\text{meas}}(\lambda)}$ is provided in the current operational TROPOMI L2 AAI product for $\lambda = 340$ nm and $\lambda = 380$ nm. $\sigma_{f_{\text{o}}(\lambda)}$ depends on the precision of the geometrical eclipse prediction, i.e. α in Equation 9, and the precision of the solar limb darkening function, Γ. The geometrical eclipse prediction was verified with the predictions by NASA (see Section 2.4). The largest source of uncertainty for α in the present era (1800 CE to present) is the Moon’s surface topography, which causes the lunar disk circumference to deviate from a perfect circle.[2] Our and NASA’s eclipse predictions do not include these effects of mountains and valleys along the edge of the Moon, which may shift the limits of the eclipse path north or south by $\sim$ 1 to 3 kilometers, and may change the eclipse duration by $\sim$ 1 to 3 seconds.[3] For the solar eclipse of 21 June 2020, we added a time increment of 3 seconds to estimate the effect of a local eclipse timing error due to the Moon’s topography on f_{o} and the AAI. At the ground pixels for which $f_{\text{o}} > 0$, the average absolute changes in f_{o} and the AAI were 0.00049 and 0.00588, respectively. Hence, in what follows in this appendix, we assume that there is no error in α.

Pierce and Slaughter (1977) provide the probable error, Pe, of the estimated solar limb darkening function $\Gamma(\lambda, r)$ for the tabulated set of λ’s, which is independent of r. We assume that the measurement noise of Γ was normally distributed with

[2] See https://eclipse.gsfc.nasa.gov/SEhelp/limb.html, visited on 27 March 2021.

[3] See https://eclipse.gsfc.nasa.gov/SEpath/SEpath2001/SE2020Jun21Apath.html, visited on 27 March 2021.

standard deviation $\sigma_\Gamma(\lambda) = Pe(\lambda)/0.6745$. We also assume that the noise of Γ was uncorrelated in r-space. We performed a Monte Carlo error propagation simulation to estimate the error of the obscuration fraction, $\sigma_{f_\mathrm{o}}(\lambda)$. That is, to each $\Gamma(\lambda, r)$ at $\lambda = 340$ nm and 380 nm, we added 100 times a randomly generated normally distributed error $\sigma_\Gamma(\lambda)$, repeated the computation of f_o (Equation 9) for each sample, and computed σ_{f_o} as the standard deviation of f_o. The precision of the AAI can be computed as follows

$$\sigma_\mathrm{AAI} = 100\sqrt{\left(\frac{\sigma_{R_{340}^\mathrm{model}}}{\ln(10)R_{340}^\mathrm{model}}\right)^2 + \left(\frac{\sigma_{R_{340}^\mathrm{int}}}{\ln(10)R_{340}^\mathrm{int}}\right)^2} \tag{B2}$$

The expression for the precision of the modeled reflectance at 340 nm, $\sigma_{R_{340}^\mathrm{model}}$, as a function of $\sigma_{R_{380}^\mathrm{int}}$, can readily be derived by analytically solving $\sigma_{R_{340}^\mathrm{model}} = \sigma_{A_\mathrm{s}}|\partial R_{340}^\mathrm{model}/\partial A_\mathrm{s}|$ and $\sigma_{A_\mathrm{s}} = \sigma_{R_{380}^\mathrm{int}}|\partial A_\mathrm{s}/\partial R_{380}^\mathrm{int}|$. Possible calibration (offset) errors of TROPOMI and model uncertainties of DAK are excluded from this analysis.

Figure B1 shows σ_AAI at the ground pixels of the eclipsed TROPOMI orbits during the solar eclipses that were discussed in this paper. The results are presented as a function of obscuration fraction f_o at 380 nm, with solar irradiance correction applied (semi-transparent blue dots) and without solar irradiance correction applied (semi-transparent black dots). In the absence of a solar eclipse ($f_\mathrm{o} = 0$), σ_AAI for with and without solar irradiance correction is identical, since $R^\mathrm{int} = R^\mathrm{meas}$ and $\sigma_{R^\mathrm{int}} = \sigma_{R^\mathrm{meas}}$ (see Equation B1). In the presence of a solar eclipse, σ_AAI increases with increasing f_o. When no solar irradiance correction is applied, again $R^\mathrm{int} = R^\mathrm{meas}$, but R^int is decreased at both 340 and 380 nm in the Moon shadow, which increases σ_AAI through the division by R_{340}^int and through the increased σ_{A_s} and $\sigma_{R_{340}^\mathrm{model}}$ (Equation B2). When a solar irradiance correction is applied, $R^\mathrm{int} > R^\mathrm{meas}$ and is not decreased anymore by the eclipse. However, the additional solar limb darkening noise term in Equation B1 increases σ_AAI, which is most significant at relatively large f_o resulting from the division by $1 - f_\mathrm{o}$. The maximum AAI precisions, after a solar irradiance correction in the TROPOMI orbits on 26 December 2019 and 21 June 2016, are 0.26 and 0.40 respectively. The precisions in the uncorrected case are respectively ~ 0.05 and ~ 0.10 better, but the uncorrected AAI value itself is off by many points as shown in for example Figure 17.

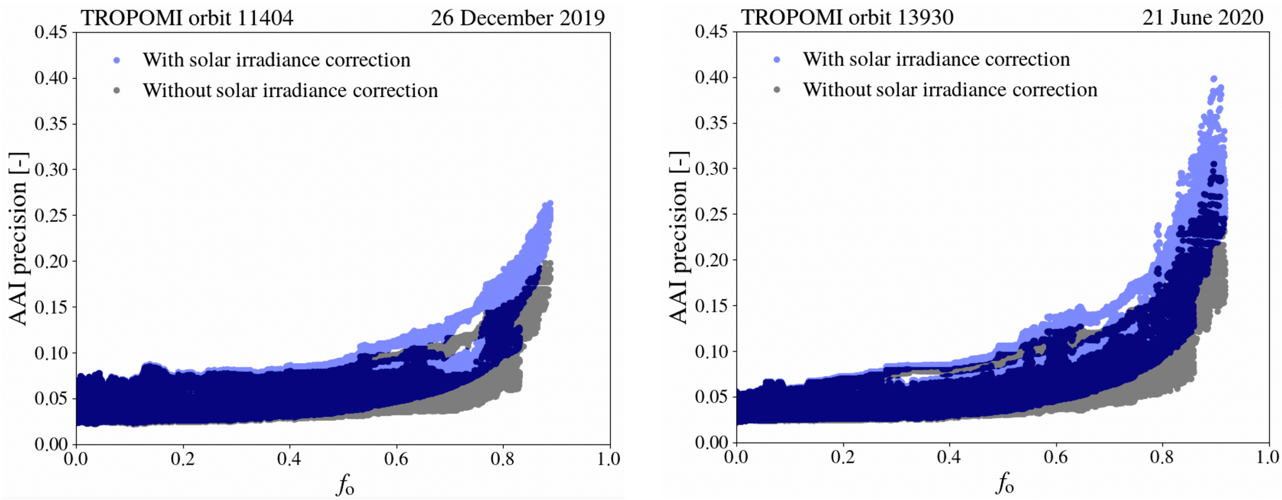

Figure B1. Precision of the AAI in the eclipsed TROPOMI orbits on 26 December 2019 (left) and 21 June 2020 (right) as a function of obscuration fraction f_o at 380 nm, with solar irradiance correction such that both $\sigma_{R^{meas}}$ and σ_{Γ} are propagated (semi-transparent blue dots) and without solar irradiance correction such that only $\sigma_{R^{meas}}$ is propagated (semi-transparent black dots).

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