Answers to the interactive comments by anonymous Referee #2 on "On the absolute calibration of SO_2 cameras" by P. Lübcke et al.

The comments of the Referee are printed in usual black font and our answers are printed in bold font. Text that was changed or added to the revised manuscript is printed in italic.

Anonymous Referee #2
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This paper concerning the calibration of SO2 cameras is a timely contribution to the literature. Such cameras are growing more and more popular as a means of measuring volcanic SO2 emissions and the examination of calibrations that this paper addresses will be of value to the scientific community. It is critical that errors associated with such cameras are better known prior to more widespread use. The authors carefully address a number of possible errors with the 'calibration cell-only' method, effectively highlighting the need for integrated DOAS measurements for accurate quantification of SO2 emissions.

The main item I see as lacking in this paper is more of a mention of the fact that, while important, merely ensuring a good camera calibration does not mean that the end emission rate will be accurate. If accurate emission rates (and not just calibration) are the goal of such camera measurements, issues like grounded/partially visible plumes, as the authors encountered in their own field work, will need to be addressed as well. That is not to say that the authors need to tackle those problems for this paper, but they are relevant and should be mentioned as a caveat to readers new to SO2 camera usage.

- The authors agree with the referee, that partly visible plumes should be addressed. This was done on P.6213, Line 22.
We also added on P.6216, Line 10: *"On two of the measurement days, the plume was partly hidden behind the volcano, in this case, even a careful calibration does not allow accurate emission rate measurements."*

In general, this is a good paper with sound and valuable science and should be published, given some small changes. One minor thing to be careful of is mixed usage of British and American English. Clarify which one is the journal's preference and check for consistency. In particular, page 6195 has successive paragraphs with different spellings of characterize/characterise. Favorable/favourable and center/centre were also noted throughout text. In addition, certain parts are wordy or ill-worded (e.g., pages 6188 and 6204), which may lead to confusion on the part of readers.

- We revised the manuscript to improve the readability and changed the instances of American English we found to British English. These changes are listed at the end of this text.

Below are constructive suggestions for minor changes that would improve the reader's experience. I thank the editors and authors for the privilege of reviewing this paper.

We thank Referee #2 for the detailed and constructive review of the manuscript. We feel that the comments helped to improve the manuscript. Detailed changes are shown in the following:

Page 6184

Lines 7/8: Multiple uses of “two-dimensional.” Could substitute “synoptic” or similar word.
- **Text in line 7-21 was rephrased, to shorten the manuscript, “two-dimensional” is not used multiple times anymore.**

Page 6186

Lines 10 & 13 and elsewhere: Mixed usage of “flux” and “emission rate.” While flux has often been used in literature pertaining to volcanic emissions, it actually pertains to a property with an areal component, i.e., flow (per unit time) per unit area. As volcanic emissions are not reported per square inch or square kilometer, but as unit mass per unit time, the term “emission rate” is preferable.
- Although we note that in the comment the referee referred to "flux density" (which we never calculated) rather than "flux" we agree with the referee that using different terms for the same quantity may be confusing to the reader. Therefore we replaced “emission flux” or “flux” by “emission rate” throughout the manuscript.

Line 2: Spell out “field of view” before first abbreviation of FOV in main text.
- Line 7: Replaced FOV with “field-of-view (FOV)”, narrow field-of-view is introduced as NFOV earlier now.

Lines 4-5: Sentence about NOVAC approach is irrelevant; remove.
- Lines 4-5: We removed the sentence about the NOVAC network.

Lines 11-13: Is there evidence/testing showing error related to summation of the wideangle FOV intensities? Otherwise, it’s just speculation on the part of the author with no supporting reason.
- The error related to the summation was described in the Appendix of Boichu et al. (2009). However, the authors agree, that the remark does not add additional information to the manuscript, thus we removed the sentence: “While the wide FOV method has a time resolution…broad range of intensities in the FOV.” from Line 10-13.

Line 18: McGonigle is the correct spelling of the first author citation.
- The typo in the name McGonigle was corrected in the reference.

Line 24: Not clear whether 22.4 degrees is the FOV of the IDOAS or camera.
- We changed “(22.4°)” to “(the camera has a FOV of 22.4°)”

Line 27: Change “like” to “e.g.,”

- changed “like” to *“e.g.”* **and added a definition of the light dilution effect (see Referee #3 Comments).**

Page 6187

Lines 3-13: Combine these paragraphs.

- The two paragraphs were combined.

Page 6188

Lines 1-19: This section is very choppy and disjointed, which could cause confusion or misunderstanding. Most points are important, but could be written much better in order to have a stronger end to the introduction section. The entire first paragraph should be rearranged to flow more logically and smoothly. For example, the first two sentences could be combined. The third sentence is awkward, as it describes the “differential optical density” being the “difference between the optical densities.”

- We rewrote the section according to the referee’s suggestions. The second and the third sentence of the first paragraph were removed to shorten the manuscript. The term "apparent absorbance" is explained later in the manuscript. At this point it is important, that the camera measures optical densities not column densities.

The final two sentences of the first paragraph are also awkwardly worded and don’t flow well together.

- The final two sentences were combined to “*For the calculation of SO_2 emission rates the first crucial step is to calibrate the SO_2 camera: the optical densities have to be converted to SO_2 CDs, i.e., the number density of SO_2 integrated over the light path (Mori and Burton, 2006, Bluth et al., 2007, Kern et al.,2010b).***”**

The third paragraph is out of place and could perhaps be integrated with text on the previous page.

- The third paragraph (Line 13-15) was moved to the first paragraph. It is now, directly following the sentence mentioning, that a calibration is important (to give an example, how a calibration could be performed), and before the paragraph that talks about errors from the calibration.

A better transition to the fourth paragraph is necessary; make it more clear in the previous paragraphs that the DOAS calibration of the camera is preferable but has yet to be adequately studied/constrained and that that is what your fieldwork/paper sets out to do.

- We added a sentence to that effect: *“While the DOAS calibration appears preferable, as it can detect ash and aerosol influences, it has not been studied adequately yet.”* **at the beginning of the last paragraph.**

Lines 3-4: Either “see Mori…” or “e.g., Mori…” but not both together.

- We changed the reference to *“e.g. Mori …”*

Line 21: Influenced in what ways? Mention specific examples.

- We changed the phrase “influenced” to “*scattered and absorbed***”**

Lines 22-23: Can you really call it differential optical density if you’re referring to a situation with only one band-pass filter?

- The authors agree with the referee, in the case of a single filter camera we only determine the optical density. “differential” was therefore deleted.

Line 25: Delete the word “still.” What is considered to be a “reasonable” exposure time? Why? There are issues related to the speed of the plume features through the field of view relative to the exposure time, and also to the exposure time relative to the opening/closing of the shutter. More explanation of which factors lend themselves to “reasonable” exposure times should be mentioned.

- **We deleted “still”**

We also added a footnote, to explain what we refer to by reasonable exposure times on P.6188 Line 25: The footnote reads:

“[1] *The choice of a reasonable exposure time is mainly influenced by two effects: On the one hand, the volcanic plume moves between two exposures. With our set-up and measurement geometry (Table 2) the distance between two pixels is approximately 2.5m. Assuming a wind-speed of 10* ms^{-1}*, this leads to a total exposure time of 0.25 s if plume features should not move more than by one pixel between subsequent images. On the other hand, the exposure time should be long compared to the shutter opening time. If the exposure time is of similar magnitude as the shutter opening time, this can lead to less exposure of e.g. the corners of the image (vignetting). This effect can lead to artefacts in the image, when different exposure times are used for background images and measurement images.”*

Lines 26-27: Delete “Therefore.”

- We deleted “Therefore”.

Page 6189

Line 9-10: More of a transition is needed than just a colon before introducing equation

- We changed the sentence to “*The optical density* τ_B *for Filter B, which is not influenced by* SO_2 *absorption, is given by:”*

Page 6190

Lines 17-21: The paragraph between lines 18 and 21 should be split into two, with the first sentence added to the preceding paragraph, which speaks about aperture. The second sentence should be in the paragraph below, which concentrates on the filters.

- The paragraph was split according to the referee's suggestion.

Page 6192

Line 13: Change to "... azimuth angle and, most importantly, changes ..."

- We changed the sentence accordingly.

Page 6193

Lines 9-11: Not necessary to include this reference to future discussion. Remove this paragraph.

- We removed lines 9-11.

Line 13: No comma after CD.

- The comma was removed.

Lines 13-17: Move to between other two paragraphs.

- Done.

Lines 15-16: Change to "Thus a calibration curve can be obtained for each pixel from AA/CD: : :"

- Done.

Lines 19-22: Delete "When calibration cells are place… can be obtained." The sentence is unnecessary if the above change is made. Also delete "However" from the next sentence.

- Done.

We also added an additional sentence on the main disadvantage of calibration cells:

"*A calibration curve obtained this way only shows the camera's reaction to pure SO_2. Additionally, it can usually not be performed with the same viewing direction as the plume measurements and needs to be repeated throughout the day, to assess changes in the incoming solar radiation.***"**

Page 6194

Line 11: Replace “which” with “though this issue”

- Line 10: Replaced “image, which can be corrected” with *“image, though this issue can be corrected”*

Line 12: Comma after “As mentioned above”

- The comma was added.

Line 26: No comma after “taken”; commas before and after “over time”

- Commas changed accordingly.

Page 6195

Line 16: Change “perpendicular” to “perpendicularly” Multiple British/American English issues on this page.

- Changed “perpendicular” to *“perpendicularly”***, changed “center” to** *“centre”***.**

Page 6200

Lines 5-6: No need to re-define AA; delete “the difference between tA and tB.” Also, expand on why the aerosol-induced effect is neglected, and why it is acceptable to neglect the effect.

- The re-definition of the AA was removed. The aerosol-induced effect usually has been neglected in published studies, since it was assumed that the second filter would completely remove it. The authors of this manuscript do not believe that it is acceptable to neglect aerosol-induced effects, we rather think it is important to note, that, while the second filter improves the situation, the calibration should be performed with a DOAS system. We therefore changed the sentence in Line 5-6: “*This means, while Filter B does certainly reduce the influence of aerosol on SO_2 camera measurements, it does not completely remove it.”*

Lines 7-8: Put AOD in parenthesis in line 7 after aerosol optical density, as the acronym is not yet defined prior to the usage in line 8.

- Done.

Line 14: Change “radiation on volcanic” to “radiation by volcanic”

- Done.

Page 6203

In reference to the convolution of absorption cross sections to instrument resolution, the past tense of this verb is “convolved,” not “convoluted”. Two instances on this page.

- Done.

Page 6204

Lines 6-7: Combine first two sentences of paragraph, change wording to make less confusing, e.g, Because the data from the NFOV-DOAS, together with the corresponding AA data from the SO2 camera, are used to create a calibration curve, it is important to know the exact area in the camera image at which the DOAS telescope is directed.

- The two sentences were combined to: *“It is important to exactly know the area to which the NFOV-DOAS telescope is directed, because the data from the DOAS together with the corresponding AA data from the SO_2 camera are used to create a calibration curve (e.g. Figure 7).”*

Lines 11-12: No paragraph break here.

- Paragraph break is removed.

Lines 12-21: Your use of FOV here could be quite confusing. There is the true FOV the DOAS telescope, but what you often refer to as FOV is actually the location of the footprint of the DOAS FOV in the camera image. The FOV of the DOAS did not change during transport; the location of the footprint did. Clarify this wording.

- The transport could also slightly change the size of the DOAS FOV, if for example, the light fibre was defocussed. We added the phrase ‘*the telescope, relative to the camera FOV,***’ in Line 14 to clarify the wording.**

Page 6205

Line 9: Change “extension” to “extent”

- Changed to “*extent***”.**

For the transformation matrix, presumably you only had fixed feature points in half (or less) of the image (i.e., the lower part, where the edifice was). What sort of errors might you be introducing by extending a transformation applicable to only a limited spatial extent of the image to the entire image?

- We estimated the error from the transformation, by looking at cross sections in the x-direction and the y-direction (see Figure 18, left panel). From these cross-sections we

estimated that the displacement is below Δx=1 pixel in the x-direction (which is a conservative estimate, as you can see in Figure 18) , and below Δy=2.5 pixels in the y-direction.

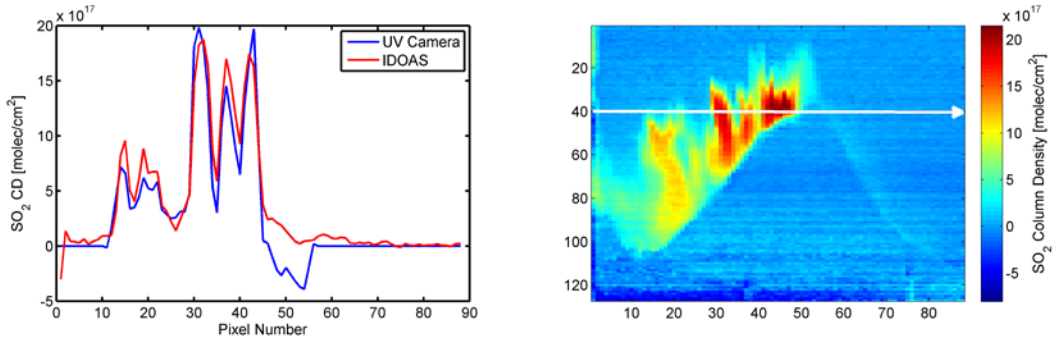

Figure 18: (a) Reduced resolution IDOAS image, the white error shows the cross-section shown on the right side.(b) Cross-section through the SO2 camera (blue) and the IDOAS (red) image in row 40.

As a next step, we calculated the gradients $\frac{\Delta\tau}{\Delta x}$ and $\frac{\Delta\tau}{\Delta y}$ for each pixel of the transformed apparent absorbance image, and calculated the error in τ arising from the image transformation using error propagation: $\Delta\tau\sqrt{\left(\frac{\Delta\tau}{\Delta x}\cdot\Delta x\right)^2+\left(\frac{\Delta\tau}{\Delta x}\cdot\Delta x\right)^2}$..

The resulting error-bars were added to Fig.7 (see Figure below), we also removed data points with large errors (with an error above an optical density of 0.05) from the plot, however, this did only negligibly change the calibration curve. This explanation was added to the "Comparison between SO_2 camera and IDOAS", which is now Appendix C.

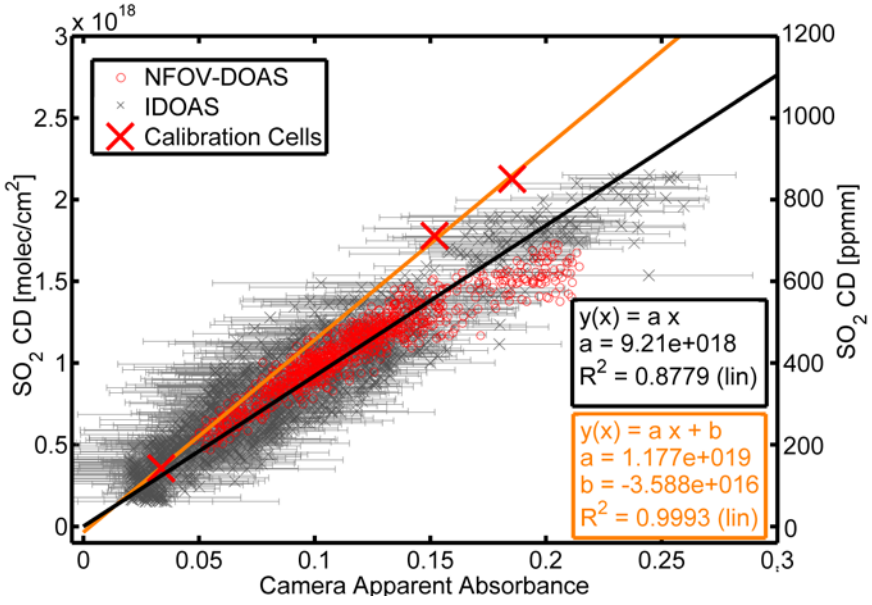

Figure 7: Error bars for the uncertainty of the camera apparent absorbance were added to the IDOAS datapoints.

Page 6206

Lines 9-10: Delete “The results will be discussed and interpreted in this chapter.” Unnecessary.
- The sentence was removed.

Page 6207

Did you investigate residuals between the polynomial images and the raw data? Are you left with just the ring structure, or are other effects that may cause issues with an accurate calibration?
- First of all we have to confess that there was an error in the manuscript. The 2D polynomials were fitted to the optical densities (rather than to the intensities) for both filters. When fitting a 2^{nd} order polynomial to the raw (intensity) images, the main influence is due to the lens vignetting, which would mask the weak structures we are interested in. The major effect in the residuals is the ring-like structure. The residuals are not complete noise, but the remaining structure is usually below 0.005, which would result in an uncertainty of the calibration curve of approximately 5%.

To correct the error about the fit, we rewrote text on P.6203, Line 1-8, P.6206, Line 26 – P.6207 Line 5, P.6208, Line 6-7:
P.6203, Line 1-8. Rewritten, the old text was: *“For the comparison with the CD obtained by the IDOAS and the calculation of the SO_2 fluxes all AA images were corrected for higher sensitivity towards the edges of the detector (Sect. 4.3). A 2^{nd} order polynomial was fitted to calibration cell images, not considering areas affected by reflections (Sects. 4.4 and 6.2). From these fits a reflection free AA image was simulated. The AA was normalised to 1 in the area were the DOAS telescope is pointing. Higher sensitivity towards the edges of the detector was corrected by dividing each pixel of the AA images by the corresponding pixel of the mask.”*
The new text is: *“For the comparison with the CD obtained by the IDOAS and the calculation of the SO_2 emission rates all AA images were corrected for higher sensitivity towards the edges of the detector by dividing each pixel of the AA images by the corresponding pixel of a correction mask. (Sect. 4.3). This mask was created by fitting 2^{nd} order polynomial to the optical densities τ_A and τ_B from calibration cell images, not considering areas affected by reflections (Sects. 4.4 and 6.2). From these fits a reflection free AA image of a calibration cell was calculated. The correction mask was then obtained by normalising the AA to 1 in the area were the DOAS telescope is pointing.”*

P.6206, Line 26 – P.6207, Line 5 : Changed the text to *“Figure 5b shows an AA image that was created by fitting two-dimensional 2nd order polynomials to the variation of intensity of the calibration cell optical densities τ_A and τ_B, without considering the area affected by the reflection features. The residual between the polynomial fit and the calibration cell images was usually below 0.005 (again, only in the area not affected by reflection).”*

P.6208, Line 6-7: Changed *"For calibration with cells, the calibration curves obtained during the three days (see Sects. 6.3.2, 6.3.3 and 6.3.4) differ very little for all of the measurements."* ***to*** *"For calibration with cells we fitted a 2nd order two-dimensional polynomial to the optical density images of the calibration cells (the areas with structures from reflections were removed from the fit, see Sect. 5.1), From these 2D-polynomials we created reflection free AA images. The residual between the 2D fits and the optical density images were usually below an optical density of 0.005 in the areas without reflection structures, thus leading to an uncertainty of approximately 5% for the calibration curves. The AA value for the calibration curves was then calculated in the same area as the DOAS FOV to be able to compare the two methods. The calibration curves obtained during the three days (see Sects. 6.3.2, 6.3.3 and 6.3.4) differ very little for all of the measurements."*

Page 6214

Line 8: Delete "with them"; switch "errors" and "associated" More British spellings on this page that are inconsistent with American spellings elsewhere.

- We tried to remove all American spellings throughout the text, as required by Copernicus. Deleted "with them" and switched "*errors***" and "***associated***".**

Page 6216

Line 18: Remove "first time." While the SO2 camera is offering more opportunities for capturing high temporal resolution emission rate fluctuations, it's certainly not the first time it has been done, as such variations have been captured at other volcanoes with everything from cameras to COSPEC. If you are referring to the first time at Popo, make that more clear. I suspect it wasn't even the first time at Popo; DOAS systems, FLYSPECs, and SO2 cameras from multiple institutions measured at Popo at the CCVG workshop in 2008.

- Removed "for the first time". However, this point is arguable, the time-resolution of the SO_2 camera is much higher than COSPEC or scanning DOAS instruments, therefore these measurements were the first ones with such a high time resolution.
The authors are not aware of published SO_2 camera measurement results from the CCVG workshop in 2008.

Additionally, after discussing this comment, we decided to rewrite P.6185, Line 13-15, since SO_2 has been monitored long before the NOVAC network was installed. The new sentence is:
"*SO_2 emission rates have long been routinely monitored at a considerable number of volcanoes for volcanic risk assessment. More recently, permanent Differential Optical Absorption Spectroscopy (DOAS, Platt and Stutz, 2008) systems were installed at a number of volcanoes in order to improve the temporal resolution of the datasets – largely by the Network for Observation of Volcanic and Atmospheric Change (NOVAC, Galle et al., 2010).***"**
Since DOAS is now introduced on P.6185, Line 13, we removed the re-definition on Page 6185, Line 22.

Figures 7, 10, 12, 13
Y-axis labels indicate "DOAS SO2 CD". If red "X"s on plots are SO_2 camera data only, then this axis label is not accurate and the DOAS portion of the label should be removed.
- The DOAS portion of the label was removed, and a second y-axis, indicating column densities in ppmm was added.

<u>Changes to reduce the text length as requested by the referee:</u>
Several changes were made, to reduce the length of the text, and improve the readability. These changes are listed below. However, they did not change the scientific meaning of the manuscript. Sections 5.3, Section 5.4 and the flux calculation from Section 6.5 were moved to the Appendix, to focus the reader more on the actual results, and less on the technical implementation.

P 6184, Lines 7-21 were rewritten and shortened. The old text was:
"While this approach is simple and delivers valuable insights into the two-dimensional SO_2 distribution, absolute calibration has proven to be difficult. An accurate calibration of the SO_2 camera (i.e., conversion from optical density to SO_2 column density, CD) is crucial to obtain correct SO_2 CDs and flux measurements that are comparable to other measurement techniques and can be used for volcanological applications. The most common approach for calibrating SO_2 camera measurements is based on inserting quartz cells (cuvettes) containing known amounts of SO_2 into the light path. It has been found, however, that reflections from the windows of the calibration cell can considerably affect the signal measured by the camera. Another possibility for calibration relies on performing simultaneous measurements in a small area of the camera's field-of-view (FOV) by a narrow-field-of-view Differential Optical Absorption Spectroscopy (NFOV-DOAS) system. This procedure combines the very good spatial and temporal resolution of the SO_2 camera technique with the more accurate column densities obtainable from DOAS measurements."
The new text is:
"One important step for correct SO_2 emission rate measurements, that can be compared with other measurement techniques, is a correct calibration. This requires conversion from the measured optical density to the desired SO_2 column density (CD). The conversion factor is most commonly determined by inserting quartz cells (cuvettes) with known amounts of SO_2 into the light path. Another calibration method uses an additional Narrow Field of View Differential Optical Absorption Spectroscopy system (NFOV-DOAS), which measures the column density simultaneously in a small area of the camera's field-of-view. This procedure combines the very good spatial and temporal resolution of the SO_2 camera technique with the more accurate column densities obtainable from DOAS measurements."

P.6185:

Line 1: Changed *"…calibration cells can lead…"* **to** *"…calibration cells, while working fine in some cases, can lead…"*

Line 4-8: We did not correct for radiation dilution or multiple scattering with the information from the DOAS. Therefore we removed the following lines, to reduce the length of the text: *"These effects can lead to an even more significant overestimation or, depending on the measurement conditions, an underestimation of the true CD. Previous investigations found that possible errors can be more than an order of magnitude. However, the spectral information from the DOAS measurements allows to correct for these radiative transfer effects."*

Line 8: Added an s to *"measurements"*

Line 24-26: The COSPEC is an obsolete instrument; the comparison with the price is bad, since COSPECs cannot be purchased anymore. We rewrote these lines. The text *"Apart from the advantage of lower cost of instruments when compared to the COSPEC, DOAS can be used…"* **was replaced by** *"In addition to small instrument size and thus easy portability, DOAS can be used…"*

Line 14-19: The paragraph about the wind-speed measurement is not necessary here. It is explained again in the flux measurement chapter. The following lines were removed: *"With the scanning DOAS, the wide FOV instrument and the SO_2 camera the wind speed can be calculated by comparing time series of SO_2 column densities at two different distances from the volcanic vent. The time the plume needs to travel between the two distances is found by using cross-correlation between time series of the respective measurements (e.g., McGonigle et al., 2005; Johansson et al., 2009; Galle et al., 2010; Boichu et al., 2010)."*

P.6187, Line 3-5: Reworded this sentence, changed: *"of 1 Hz with, however, extremely reduced spectral information."* **to:** *"of 1 Hz, but with extremely reduced spectral information."*

P.6189, Line 11: It was not stated, that τ is the apparent absorbance. We changed the sentence from *"The AA is the difference between the optical densities for Filter A and Filter B:"* **to** *"τ is the difference between the optical densities for Filter A and Filter B, it is also referred to as the apparent absorbance (AA):"*

P.6191, Line 3: Added *"both"*

P.6194:

Line 10: We added a clarification about the geometrical considerations: *"(i.e, calculating the length of the light path through the cell for different illumination angles)"*

Line 11: The main disadvantages of the calibration cell method were added here, to strengthen the message*: "A calibration curve obtained this way only shows the camera's reaction to pure SO_2. Additionally, it can usually not be performed with the same viewing direction as the plume measurements and needs to be repeated throughout the day, to assess changes in the incoming solar radiation."*

P.6195, Line 6: It was unclear, how the change of signal can be characterized with calibration cells, were therefore changed "e.g. with calibration cells" **to** *"e.g. by taking images with several calibration cells covering the complete FOV"***.**

P.6196, Line 23: Changed *"from"* **to** *"of"* **and added** *"and T_X is the transmittance."*

P.6198, Line 5: added *"for an empty calibration cell (S =0, and assuming $I_{X,M}(\lambda) = I_X(\lambda) + \Delta I_X(\lambda)$)"*

P6199 Line 4-6: The sentence was rephrased. The old text *was "Values between 0.13 and 2.42 have, e.g., been found in quiescent degassing volcanic plumes at Mt. Etna (Spinetti and Buongiorno, 2007)."* **The new text is** *"For example, values between 0.13 and 2.42 have been found in quiescent degassing volcanic plumes at Mt. Etna (Spinetti and Buongiorno, 2007)."*

P.6201, Line 7: The message was not clear, that we obtain a fake signal from light scattered into the FOV of the camera on aerosol in the volcanic plume. We changed the sentence from *"This roughly corresponds to an SO_2 CD of 2.5×10^{17} molec cm^{-2} or ~100 ppmm."* **to** *"This means one can obtain a signal equivalent to an SO_2 CD of $2.5x10^{17}$molec/cm^{-2} or 100 ppmm if 20 % of the measured light was scattered into the camera's FOV on aerosol in the volcanic plume."*

P6204:

Line 6-8: Changed *"The data from the NFOV-DOAS together with the corresponding AA data from the SO_2 camera were used to create a calibration curve. It is important to exactly know the area to which the DOAS telescope is directed."* **to** *"It is important to exactly know the area to which the NFOV-DOAS telescope is directed, because the data from the DOAS together with the corresponding AA data from the SO_2 camera are used to create a calibration curve (e.g. Figure 7)."*

Line 25: Added *'for each measurement period'*

P 6206:

Line 1: Changed *"rangers"* **to** "ranger's"

Line 19: Added *"and the calibration cell measurements are performed within 5 minutes"*

P.6207, Line 21: It was unclear here, what we wanted to say with the sentence. We changed the sentence from *"However we found changes of the slope of the calibration curve of up to 8% when fitting a first order polynomial in an area that includes correlation coefficient values within 1% of the maximum."* **to** *"To assess the uncertainty of the calibration due to the alignment of the instruments FOV's, we investigated the calibration curve for all areas that have a correlation coefficient within 1 % of the maximum correlation coefficient. For these areas found changes of the slope of the calibration curve of up to 8 % when fitting a first order polynomial to the data."*

P6209, Line 3-5: Rephrased the sentence *from "This time the calibration curves derived from the DOAS and the calibration cells show better agreement: they differ only by about 5.6% and the offset between the two calibration curves is only 3×10^{16} molec cm^{-2}."* **to** *"This time the calibration curves derived from the DOAS and the calibration cells show good agreement. The slope differs by only about 5.6 % well within the measurement uncertainty, and the offset between the two calibration curves is only $3x10^{16}$ molec/cm^2 (12 ppmm)."*

P.6211:

Line 8: Changed *"on Day 1 is indeed lower, as expected for a higher aerosol influence."* **to** *"on Day 1 is indeed lower than on Day 2, as expected for a higher aerosol influence on Day 1."*

Line 19-22: Had to be changed, since the flux calculation was moved to the appendix. The old text was changed from *"In order to test the influence of the calibration on the retrieved SO2 emission rate, SO2 fluxes for both calibration methods were determined the following manner: first, all AA values were converted to SO2 column densities using calibration curves derived from both the DOAS and from the calibration cells (see Figs. 7, 10, 12 and 13)."* **to** *"In order to test the influence of the calibration on the retrieved SO_2 emission rate, SO2 emission rates for both calibration methods were determined (see Appendix D) for details on the emission rate calculation)."*

P.6214, Line 5: We added a sentence, to clarify, that while we had 60% difference in the calibration curve, we had smaller differences in the resulting fluxes: "*The difference in the emission rate is significantly lower, than the maximum difference of 60% we found in the calibration curve on Day 3. This is due to the fact that for the emission rate measurements, we have both, high and low SO_2 CDs, at lower SO_2 CDs the two calibration methods differ less than 60% (see Fig.13)."*