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Reply to Anonymous Referee #1

In the following, referee comments are written in italics, our replies in normal font. Sections describing changes in the manuscript are indicated in blue. Figure and Table numbers refer to the original manuscript and supplement.

Referee comment on "Optical receiver characterisations and corrections for ground-based and airborne measurements of spectral actinic flux densities" by Birger Bohn and Insa Lohse, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-288-RC1, 2022

This study examines actinic flux density optical collectors and develops a new technique to quantify correction functions for angular imperfections. The detailed responses of a pair of 2 pi optics used for a Zeppelin and a second pair used on the HALO aircraft. They are examined individually as downwelling ground based detectors and in 4 pi pairs as they perform on the aircraft. These optics show significant differences in the azimuthal and zenith responses and thus differ in the corresponding correction functions.

I commend the authors for the rigorous and exhaustive examination of the optical collectors and the deep analysis to correct imperfections on their specific measurements. The tools developed provide a resource to the community to improve actinic flux measurements. Importantly, these corrections do not rely on knowledge of the atmospheric environment (e.g. clouds, aerosols, etc) but rather on the relative changes in the measurements themselves.

This work provides a call to all groups with measurements of actinic flux to consider optical accuracy and the impacts of the non-ideal response. While this may not be practical for all groups, I suggest experts in the community may support more detailed optical analyses.

That said, the corrections are not always large and depend on measurement requirements. The authors note that the magnitude of corrections depends on the optical quality and measurement geometries. Downwelling optics for ground-based UV measurements (e.g. spectrometers or filter radiometers) may have relatively minor corrections (e.g. Figure S28), particularly with lower surface albedo. Total actinic flux from optical pairs with a sufficiently accurate 4 pi response also have relatively small corrections (e.g. Figure 11 and the discussion Section 7). The authors note that mechanical adjustment can improve hemispherical measurements, though corrections may still be necessary.

In addition, the primary purpose for such measurements is the subsequent calculation of photolysis frequencies. The impacts of the corrections on photochemistry are reduced and the authors note this is beyond the scope of this work. Nevertheless, it is an important consideration in the larger picture. Most photolysis frequencies are driven by UV wavelengths and the UV corrections in this study were relatively minor. In addition, photolysis frequency calculations include large molecular parameter uncertainties that typically exceed the measurement uncertainties. Nevertheless, better measurements are in fact, better, and molecular uncertainties may be reduced in future studies. At longer wavelengths, the uncertainties were more significant affecting the photochemistry of NO3 and other molecules.

The paper is well written, relevant and fits well within the scope of AMT.

Reply: We thank the referee for the positive evaluation of our work, the supporting general statements and helpful comments.

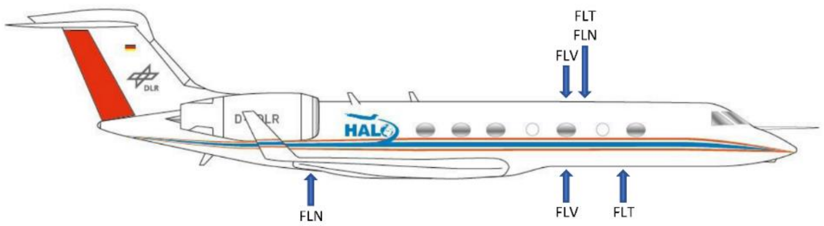
Minor comments and revisions:

Line 1 and/or line 28: UV/VIS to "ultraviolet and visible (UV/VIS)"

Reply: Was changed as recommended in both lines (in accordance with the journal rules).

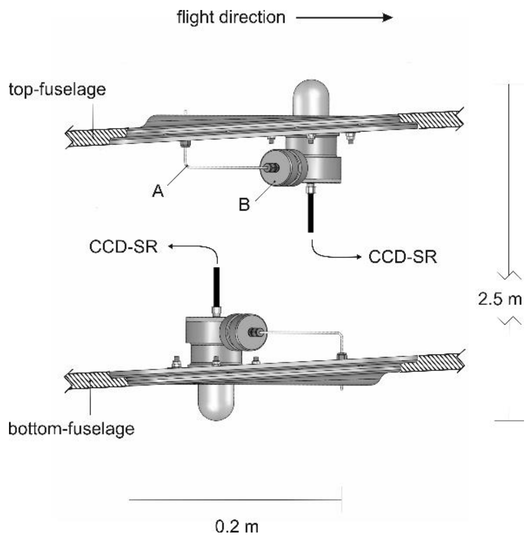
Lines 114-5: I do not see a description of FLT, FLV and FLN. Nor do I understand the acronyms. Figure S7 does give some information but does not distinguish between FLT and FLN.

Reply: The acronyms were originally chosen to distinguish between ground and airborne configurations: GRD for "ground" and FLT for "flight". In a subsequent deployment the "nadir" receiver position was changed, and this configuration was named FLN. In another campaign both receivers were placed in the larger "viewport" adapters (Fig. S7) of HALO which led to the acronym FLV. We don't think the reader should be bothered with this acronym history. On the other hand, we noticed that the acronyms GRD and ZEPP_FLT were not mentioned in the manuscript but are used in some of the file names in the online material. We therefore added a sentence in the Supplement, page 14 line 27 to clarify: "The configurations can be inferred from the filenames: GRD refers to corrections for the four receivers on the ground, ZEPP_FLT to the Zeppelin configuration, and HALO_FLT, HALO_FLN and HALO_FLV refer to the three HALO configurations."
Moreover, we added a new figure (see below) after Fig. 2 showing the receiver positions of the three HALO configurations and added one sentence in line 117: "The receiver positions of the three configurations are indicated by arrows in Fig. X."



New figure X: "Top and bottom receiver positions of the three HALO configurations FLT, FLN and FLV. Adapted from a figure used with permission by DLR, Germany."

In addition, we reversed the flight direction of the setup in Fig. 2 to match with the new figure above.



Revised Fig. 2.

Line 228: Typo. Change 'was' to 'were'

Reply: Was changed.

Figures 7, 8: The paper jumps between Zeppelin and HALO configurations. Be sure to distinguish the platform in each figure caption for clarity. In these two plots they are the Zeppelin optics.

Reply: Figures 7 and 8 show radiance distributions which are independent of the platform (although the 5 km data were only used for HALO). We checked all figures to ensure that the respective platform is mentioned if necessary and, as a precaution, added the information more explicitly in the captions of Figs. 6, S9, S11 and S13.

Line 358-60: Should this refer to Figures S4 and S5. Figure S11 does not show the azimuthal variability. Also, the variability of the nadir sensitivity looks to be about 5% based on the error bars in Figure S5. That does not seem to qualify as "small". Perhaps note it is an exception here.

Reply: The reference Fig. S11 was wrong, we meant Fig. S12 and changed it. Regarding the azimuthal variabilities of the Zeppelin setup: these are small compared to those resulting for HALO at polar angles >80° (e.g. Fig. 5, Fig. S8, Fig. S10). Nevertheless, the sensitivities can vary in a 5% range for different azimuth angles for some receivers. But this variability is not neglected when azimuthal-averaged corrections are used. They are covered by the uncertainties (derived by the rotations of radiance distributions as explained in the text). However, we noticed that the azimuth-dependent Z_P data of the four receivers was not included in the first version of the online material and added it.

Figure S5: Just a comment: The bottom optic for the Zeppelin seems to be a significantly inferior optic. Perhaps that is why it was placed in the less consequential upwelling position. Could this be improved through mechanical adjustments? If so, the corrections would be more in line with the other optics. In addition, both Zeppelin optics seem to encourage crosstalk as they show 80% sensitivities at 90 degrees. Optimizing the angular response is a balancing act but perhaps these could be adjusted to be closer to 50%.

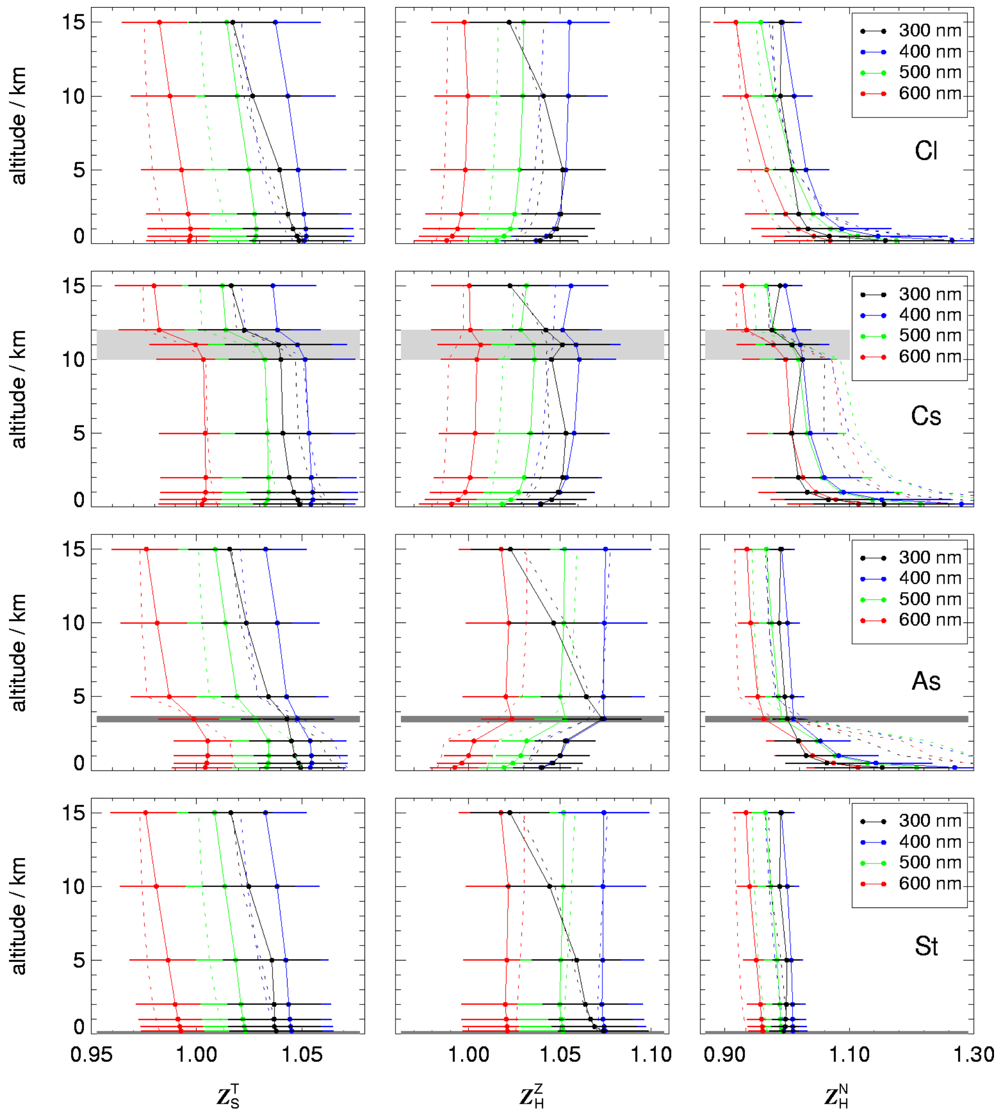
Reply: Readjustment of the receiver optics is indeed difficult. We have tried this in the past with mixed success. We therefore rely on the adjustment skills of the manufacturer who hopefully achieved the optimum properties for each receiver. The around 80% sensitivity at 90 degrees is in general a good result and important to avoid large corrections on the ground, especially at low sun and long wavelengths. On the other hand, for the Zeppelin configuration the sensitivity peak of around 1.7 results at 90 degrees (Fig. S13). However, this peak would become very narrow and would hardly affect the corrections if the bottom receiver would perform like the top receiver. So, the key to optimum response is a high sensitivity up to 90 degrees plus an efficient horizontal shielding which was suboptimal for the Zeppelin bottom receiver. If the receivers were adjusted for a sensitivity of 50% at 90 degrees, this would result in a depression of sensitivity at smaller and larger polar angles which again would have to be compensated by corrections.

Lines 370-380: I think this is an important place to note explicitly that the impact of the large upwelling correction near the surface has only a small impact on the total. Thus, the impact on total photolysis frequencies would be small.

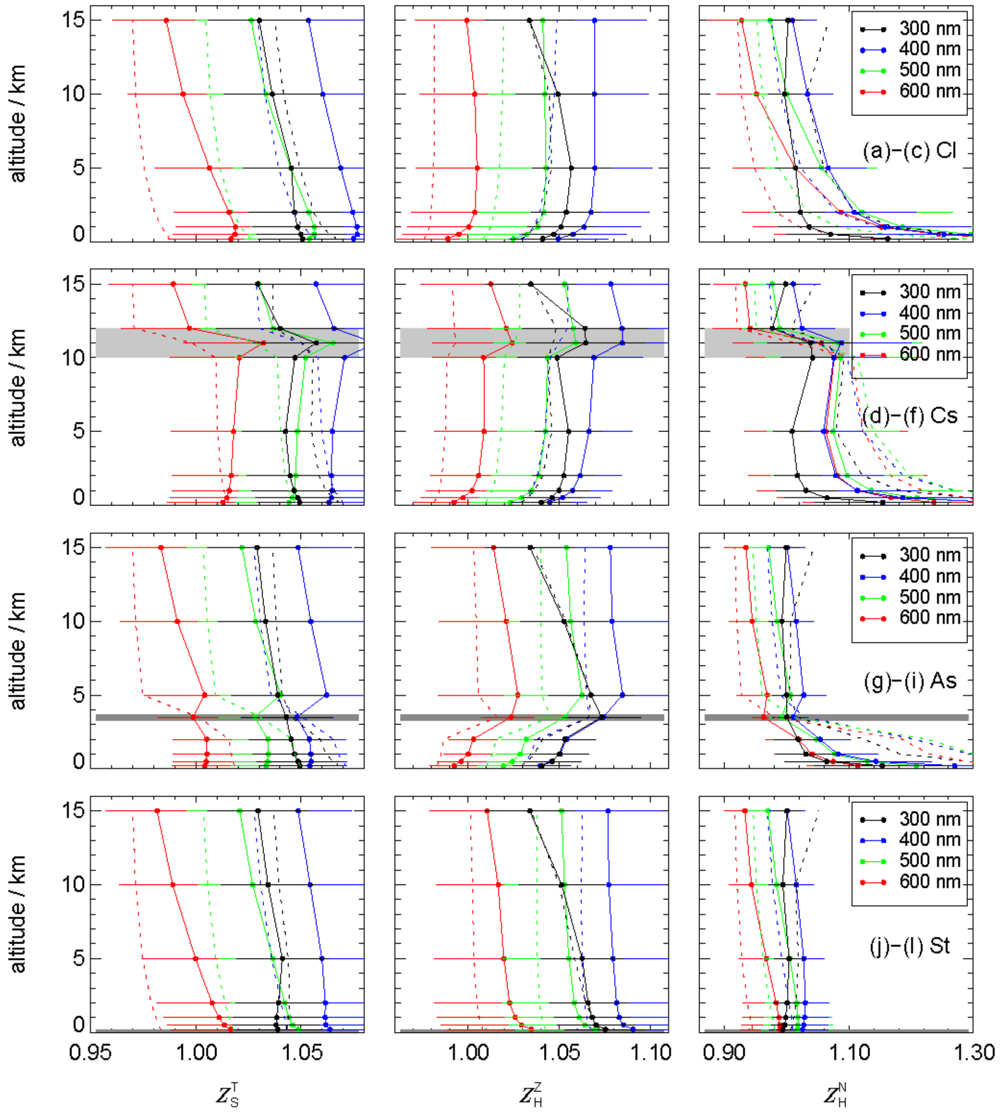
Reply: This is stated in line 500 where the Zeppelin measurement example is discussed. But it can be mentioned here already. We added one sentence in line 375: "However, the Z_S^T are hardly affected by the greater Z_H^N because the contributions of upward radiation are small under such conditions."

Figures 11 and S27: The grey bars for the Cs cloud in these figures are deceiving. The cloud ranges from 10-12 km but is shown as a thin line at 11 km. I also suggest adding a point at 12 km to show the correction from the bottom to the top of the cloud.

Reply: As suggested, we made additional simulations and derived corrections for the cirrus cloud case at 12 km. The figures were revised, and the cloud covers were included more realistically by grey areas indicating their depths (see revised Fig. 11 and Fig. S27 below). The 12 km corrections are close to those at 15 km and will not be used for the parameterizations (like the in-cloud corrections). In line 472 we added: "…at the intermediate altitudes of 3.5 km (As) and 11 km (Cs) as well as from above-cloud at 12 km (Cs) were not considered…" The 12 km data were included in version 2 of the online material.



Revised Fig. 11: "… Cloud layers are indicated by grey-shaded areas.…"



Revised Fig. S27: "… Cloud layers are indicated by grey-shaded areas.…"

Note that Fig. S27 will be removed from the Supplement following a comment by referee #2.

Line 374: "Because of insufficient,…". This line is vague. If I am interpreting the meaning correctly, you could modify the end to, "Because of insufficient field-of-view limitations of the bottom receiver, significant cross talk to the upper hemisphere occurs and the Z(NH) are generally greater than unity".

Reply: The sentence was changed as suggested.

Line 410: Typo. I think you mean "contain the uncertainties"

Reply: The referee is right, "content" was the wrong word. We changed to "confine the uncertainties" to clarify. We used a similar phrase in line 470 where we changed "helps to contain" to "again confines".

Line 420: Typo. "final"

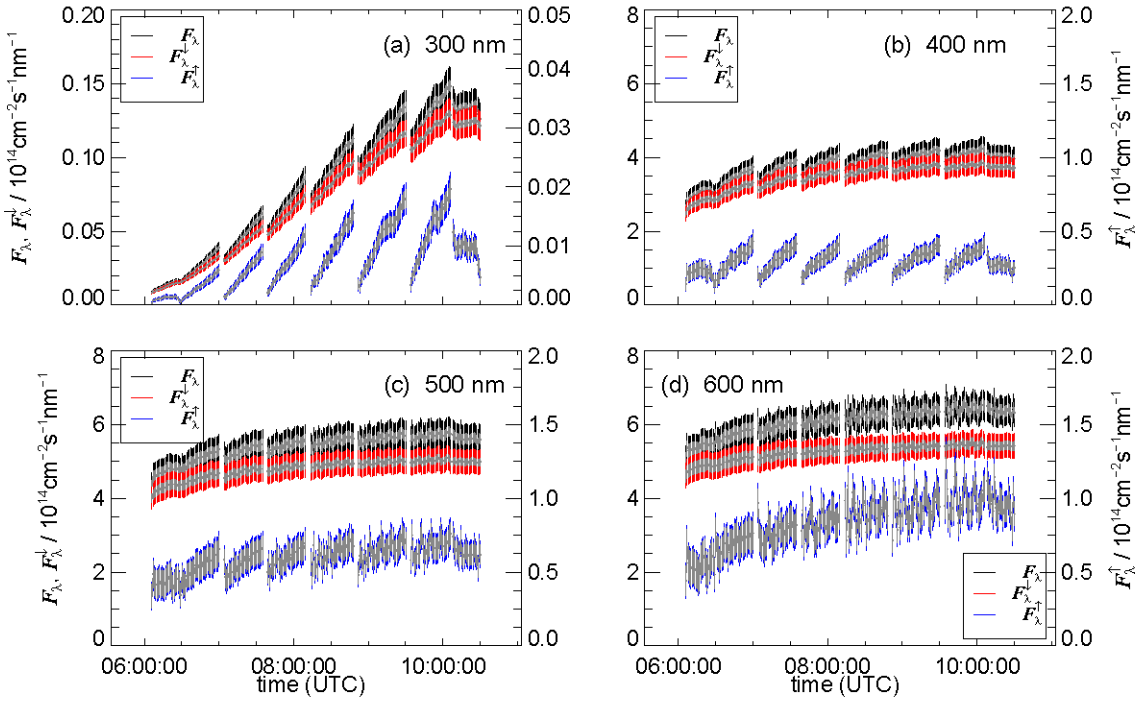
Reply: That was a typo. We changed to "the finally applied".

Line 504-5: The main source of the increase in upwelling flux from 300 to 600 nm is the orders of magnitude increase in the solar spectral shape. The albedo effect is secondary.

Reply: Yes, this statement was wrong. We changed the sentence: "The increase of the $F_\lambda^\uparrow$ compared to the $F_\lambda^\downarrow$ from 300 nm to 600 nm at the lowest altitudes is caused by increasing ground albedos."

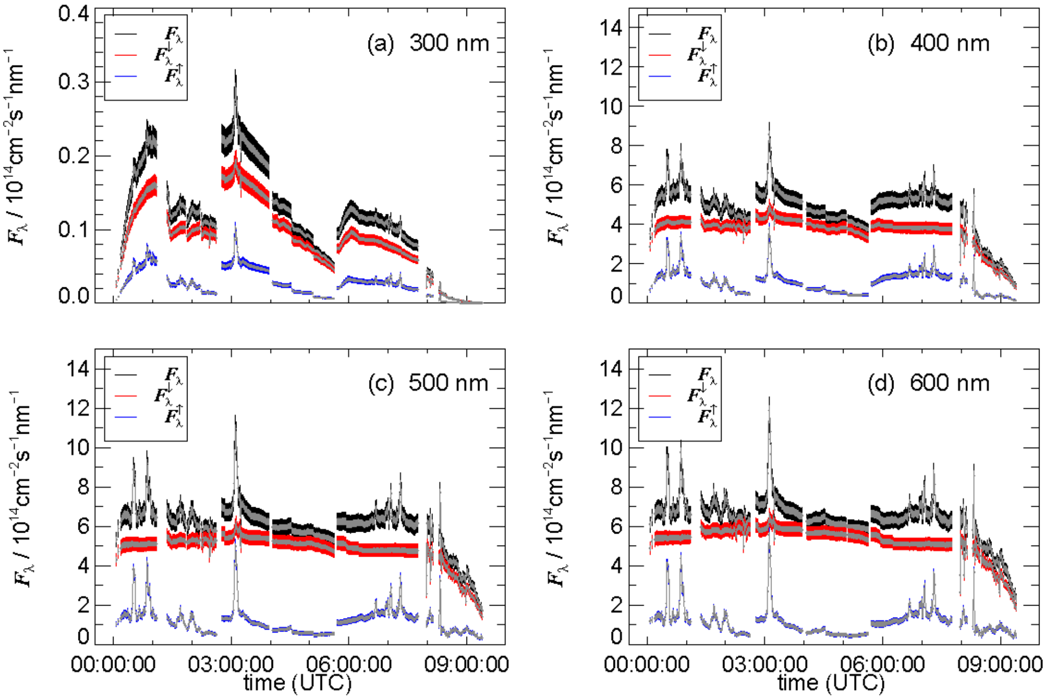
Figure 17: The error bars show the uncertainties from the corrections and calibrations. I was disappointed not to see the impact of the corrections alone as that is the point of the entire paper. It should be shown in this figure (or another) and well explained in the text. The fact that they may be relatively small (especially on this HALO flight) is important.

Reply: The uncertainties of the corrections are shown separately in Figs. 14 and 16 where they can be examined in greater detail. In Figs. 15 and 17 they are difficult to see for smaller values of the flux densities. Anyway, we now show both, total errors and those of the corrections alone as grey overlays. In the text we now write (line 502): "The finally derived total, downward and upward spectral actinic flux densities are shown in Fig. 15 together with their total uncertainties and those resulting from the corrections. The latter are dominant for the upward component and less significant for the total and downward." And in line 520 for HALO: "The finally derived spectral actinic flux densities and their uncertainties are shown in Fig. 17. The uncertainties from the corrections are again more significant for the $F_\lambda^\uparrow$ especially at low altitudes. Flux densities …"



Revised Fig. 15: …" The color-coded error bars correspond to total uncertainties including those from corrections and calibrations (Sect. S7, Supplement). The overlying grey error bars indicate the uncertainties from the corrections alone. …"

Note that the date was removed from the x-axis ("time (UTC)" was added instead), the x-range was changed, y-ranges for 400, 500 and 600 nm are the same now and panels are labelled (a)-(d) in response to referee #2.



Revised Fig. 17: "… The color-coded error bars correspond to total uncertainties including those from corrections and calibrations (Sect. S7, Supplement). The overlying grey error bars indicate the uncertainties from the corrections alone."

Note that the date was removed from the x-axis ("time (UTC)" was added instead), y-ranges for 400, 500 and 600 nm are the same now and panels are labelled (a)-(d) in response to referee #2.

Section S3.4: Note that the relative contributions apply at 400 nm. That is stated in the figure captions but not the text.

Reply: We added the information "for 400 nm" in the first sentence of the paragraph.