Reviewer 1:

This work tested multiple actinic flux optical designs based on commercially accessible materials for field use. Actinic flux optics are generally in short supply. Thus, the efforts in this work to produce low-cost actinic flux optics would greatly benefit the scientific community. Unfortunately, the paper lacks sufficient detail to assess the designs and quality of the resulting measurements. Most importantly:

- The 6 hours of field day under clear sky conditions near midday is insufficient to assess the optics.
- The angular response of the optics does not appear to be sufficient for accurate actinic flux measurements, except near midday where the response is relatively flat.
- Stray light is not properly assessed. The analysis of the UV-B spectra and jO3 is expected to be invalid. UV-A and jNO2 may be feasible.
- The language and references imply some confusion between radiative measurements of actinic flux, cosine response (irradiance) and radiance.
- The model results do not appear to be consistent between jNO2 and jO3.

The work requires major corrections and additional analysis to be considered for publication. However, I do encourage these additional efforts to examine and further improve the actinic flux optical design.

We appreciate the reviewer's careful and technically detailed evaluation. The concerns raised regarding angular response characterization, stray-light performance, field-test duration, radiometric terminology, and model consistency were taken seriously and resulted in substantial revisions and additional analysis.

In response:

The radiometric terminology throughout the manuscript has been revised to clearly distinguish hemispheric spectral actinic flux from planar irradiance and radiance, and all references to cosine-response corrections have been removed or replaced with appropriate angular-response characterization language.

The angular-response section has been rewritten to explicitly define the ideal hemispheric (2π) actinic-flux response and to clarify that the goniometric measurements quantify deviation from this target response. Additional discussion has been added regarding angular limitations at large solar zenith angles and potential design improvements.

A quantitative UV-B stray-light assessment was performed using the long-pass filter method of Jäkel et al. (2007). The residual UV-B stray-light contribution is now bounded at <0.16% (after dark correction), and this value is explicitly reported. This directly addresses concerns regarding the validity of $J(O_3)$ analysis.

The scope of the six-hour field deployment has been clarified. The experiment is now explicitly described as a short-duration radiometric validation and model-consistency check conducted under controlled clear-sky, near-noon conditions, rather than a comprehensive field qualification study. Limitations at large solar zenith angles are acknowledged, and extended deployments and intercomparisons are identified as future work.

The model configuration has been clarified, including the use of total actinic flux output and the correct surface albedo. The solar-zenith-angle dependence of the J-value comparison is now explicitly described to resolve the apparent discrepancy between $J(NO_2)$ and $J(O_3)$.

We believe these revisions address the major concerns raised and substantially strengthen the manuscript in terms of radiometric rigor, methodological transparency, and clarity of interpretation.

Major comments

Line 25: Here is one more formative, peer-reviewed reference for photochemical rates:

- Turco, R. P., Photodissociation rates in the atmosphere below 100 km, Geophys. Surv.,2 , 153-192, 1975.

We appreciate you pointing out this reference, it has been added.

Line 33: Add Bohn and Lohse, 2023.

This has been added.

Lines 38-41: These references do not apply to “instrumentation for actinic flux”. They are radiance and irradiances measurements and not directly relevant to photochemistry. The irradiance measurements have a cosine response which falls to zero at the horizon. This does not represent the full 4 pi steradian (actinic flux) response of molecules to the light environment. Also, those referenced instruments are not generally optimized for the UV and visible light that drives photochemistry. Perhaps a careful read of Madronich, 1987 (not the same 1987 article referenced in this article) could help with the apparent disconnect between irradiance and photochemistry.

- Madronich, S., Intercomparison of NO_2 photodissociation and U.V. radiometer measurements, Atmos. Environ., 213, 569–578, 1987.

We appreciate this clarification. The Introduction has been revised to remove references to irradiance-based instrumentation where not directly relevant to actinic-flux measurements. The radiometric terminology now follows Madronich (1987), and the distinctions between radiance, planar irradiance, and hemispheric actinic flux are explicitly defined. The instrumentation references have been updated accordingly.

Here are suggested references for double-monochromators with PMTs for actinic flux

- Kraus, A., and A. Hofzumahaus (1998), Field measurements of atmospheric photolysis frequencies for O3 , NO2 , HCHO, H2O2 and HONO by UV spectroradiometry, J. Atmos. Chem., 31, 161–180, doi:10.1023/A:1005888220949.

- Hofzumahaus, A., A. Kraus, and M. Mueller, Solar actinic flux spectroradiometry: A technique for measuring photolysis frequencies in the atmosphere, Appl. Opt., 38, 4443–4460, 1999.
- Müller, M., A. Kraus, and A. Hofzumahaus (1995), O 3 O(1 D) photolysis frequencies determined from spectroradiometric measurements of solar actinic UV-radiation: Comparison with chemical actinometer measurements, Geophys. Res. Lett., 22, 679–682, doi:10.1029/95GL00203
- Shetter, R. E. and Müller, M.: Photolysis frequency measurements using actinic flux spectroradiometry during the PEM-Tropics mission: Instrumentation description and some results, Journal of Geophysical Research-Atmospheres, 104, 5647–5661, https://doi.org/10.1029/98JD01381, 1999.

For diode arrays:

- Jakel, E., Wendisch, M., & Lefer, B. (2006). Parameterization of ozone photolysis frequency in the lower troposphere using data from photodiode array detector spectrometers. Journal of Atmospheric Chemistry, 54, 67-87. https://doi.org/10.1007/s10874-006-9014-1

For CCDs

- Eckstein, E., Perner, D., Bruhl, C., and Trautmann, T., 2003: A new actinic flux 4 pi-spectroradiometer: Instrument design and application to clear sky and broken cloud conditions, Atmos. Chem. Phys. 3, 1965–1979.
- Jakel et al, 2007
- Petropavlovskikh, I., Shetter, R., Hall, S., Ullmann, K., and Bhartia, P. K.: Algorithm for the charge-coupled-device scanning actinic flux spectroradiometer ozone retrieval in support of the Aura satellite validation, J. Appl. Remote Sens., 1, 013540–013540–22, https://doi.org/10.1117/1.2802563, 2007.
- Stark, H., Lerner, B. M., Schmitt, R., Jakoubek, R., Williams, E. J., Ryerson, T. B., Sueper, D. T., Parrish, D. D., and Fehsenfeld, F. C.: Atmospheric in situ measurement of nitrate radical (NO3) and other photolysis rates using spectroradiometry and filter radiometry, J. Geophys. Res., 112, D10S04, https://doi.org/10.1029/2006JD007578, 2007.

The suggested references have been incorporated into the Introduction to better situate this work within established actinic-flux spectroradiometry literature.

Line 44: Bohn and Lohse 2023 do not provide “cosine error corrections” because they are not using cosine weighted (irradiance) optics. The introduction in this work correctly notes the complex optical corrections to achieve the “isotropic angular response across all zenith and azimuth angles” for actinic flux.

The original wording incorrectly implied that Bohn and Lohse (2023) addressed cosine-error corrections. The manuscript has been revised to remove this implication and to replace references to cosine correction with angular-response characterization, which more accurately reflects both the cited literature and the radiometric quantity measured.

The Introduction now describes spectral responsivity and angular-response characterization rather than cosine-error assessment, and clarifies that 2π actinic-flux receivers are characterized via goniometric angular testing rather than cosine-weighted optics. These revisions align the manuscript with established actinic-flux measurement literature and resolve the inconsistency identified by the reviewer.

Line 54: Again, these references do not describe photochemically relevant instruments. The instrument papers noted above in this review include more appropriate angular calibration techniques (e.g. Fig 2 of Shetter and Mueller. 1999)

The reviewer is correct that the originally cited references were not directly relevant to actinic-flux instrumentation. These citations, which pertained to the goniometer apparatus rather than photochemically relevant receivers, have been removed. The Introduction now incorporates Shetter and Müller (1999) and related actinic-flux spectroradiometry literature to better reflect appropriate angular-characterization techniques used for photochemical measurements.

Line 83 and in Figures 2 and 3: The angle range of 0 – 180 deg is traditionally aligned to be -90 to 90. That is, 0 deg is the zenith position, directly above the optic. This relates back to "cosine" optics. These irradiance optics collect overhead light fully (i.e. cos(0 deg) = 1) and collect no light at the horizon (i.e., cos(90 deg)=0). Actinic flux optics follow the same tradition but ideally collect light fully at all angles from -90 to 90 degrees. See instrument references noted above (e.g. Jakel, Hofzumahaus, Shetter, etc).

The angular coordinate convention has been revised to follow the traditional zenith-centered representation used in actinic-flux spectroradiometry. Figures 2 and 3 and the associated text now use a –90° to 90° range, with 0° defined as the zenith position directly above the optic and ±90° corresponding to the horizon. The figure captions and Methods section have been updated accordingly to clearly define this convention. This revision aligns the manuscript with established actinic-flux instrumentation literature (e.g., Jäkel, Hofzumahaus, Shetter)..

Line 89 More details about the power meter are required, including model number, calibration details, etc.

Additional details of the optical power measurement system have been added to the Methods section. The LED light was focused onto a calibrated optical power detector (Newport 818-UV/DB) connected to a NIST-traceable calibration module (Newport DB15) and power meter (Newport Model 2935-C). The same focusing lens was used during calibration to ensure that the beam filled the detector aperture. Calibration traceability and instrument configuration are now explicitly stated in the manuscript.

Line 100: Humidity and breeze do not directly affect radiometric measurements in the UV/VIS range. They do indirectly affect cloud formation and dust aerosols, respectively.

The statement has been removed to avoid implying a direct radiometric effect of humidity or breeze on UV/VIS measurements. The text now limits discussion to radiatively relevant atmospheric factors.

Line 107: Was the albedo really set at 0.9999 or is that a typo. That is brighter than fresh snow. Perhaps 0.09999 was used?

The reviewer is correct that an albedo value of 0.9999 would be unrealistic for the deployment conditions. This value was not used in the analysis. The surface albedo applied in the TUV configuration was 0.4, selected to represent the reflective rooftop surface at the measurement site. The manuscript has been revised to clearly state the correct albedo value and remove any ambiguity.

Line 109-10 Perhaps I missed it but I do not see the model outputs in the paper or data output at the BYU Scholar archive.

The measurement datasets have been deposited in the BYU Scholar archive. The TUV model outputs were not originally included but have now been added to the archive to ensure full transparency and reproducibility. The model configuration parameters are fully described in Section 2.4, including solar geometry, albedo, wavelength limits, and cross-section inputs. The archive now contains both the measured spectra and the corresponding TUV outputs used in the J-value comparison.

Line 116-7: I would not expect the 265 and 523 nm LEDs to show the same response because the scattering efficiency of the material will have a wavelength dependence. Perhaps a plot of the response as a function of wavelength for one of the optics would be helpful.

The reviewer is correct that the scattering efficiency of PTFE is wavelength dependent, and identical absolute responses at 265 and 523 nm are not physically expected. The calibration LEDs were used primarily to assess geometric and detector-response stability of the receiver rather than to demonstrate wavelength-independent angular sensitivity.

The manuscript has been revised to clarify that while absolute collection efficiency varies with wavelength due to diffuser optical properties, the overall angular-response shape was qualitatively similar across the calibration wavelengths tested. Because the focus of the angular characterization was geometric acceptance rather than spectral scattering properties, a wavelength-resolved angular-response plot has not been added. The text now explicitly notes that wavelength-dependent variations are expected.

Line 117: There are seven led lamps used in the calibration. Where only six used for the angular response calibrations?

The reviewer is correct that seven LEDs were initially included in the calibration setup. Some LEDs were later found to exhibit unstable output and was therefore excluded from the angular-response analysis. The manuscript has been revised to clarify this point and remove any ambiguity.

Fig 2: The angular response of the optics is not addressed properly. I presume the "phase angle" is the angular response of the optics to a point source. If so, none of the optics have a flat actinic flux response across the hemisphere (0-180 deg). The response shown is neither a square wave (for actinic flux), or a cosine response (for irradiance).

The authors mention they could perform a "cosine" correction this is not the correct terminology. A cosine correction accounts for deviations from a cosine weighted angular response, as used for irradiance. Actinic flux optical corrections aim to approximate a flat hemispherical response. As shown, these optics have significant diurnal biases that could strongly impact the daily measurement cycles and introduce biases into subsequent chemical analyses.

Finally, more discussion would be helpful to understand the differences between the optical designs. What could be done to further improve the design? What is the response beyond the 180 degree range of this graph?

The angular-response section has been substantially revised to clarify the physical interpretation of Fig. 2 and to remove ambiguity regarding cosine-response terminology. The figure represents the receiver sensitivity to a directional source under controlled laboratory conditions and is now explicitly described as quantifying deviation from an ideal hemispheric (2π) actinic-flux acceptance function.

All references to cosine correction have been removed and replaced with angular-response characterization language appropriate for actinic-flux measurements. The manuscript now clearly states that the instrument directly measures hemispheric actinic flux through diffuse collection rather than converting from a cosine-weighted irradiance measurement.

Additional discussion has been added to address the implications of non-ideal angular response. The revised text notes that deviations from a uniform hemispheric response can introduce biases at larger solar-zenith angles, while the near-midday deployment conditions minimize this effect in the presented dataset. Differences between the optical designs are now described in greater detail, including how diffuser geometry and shielding influence angular acceptance. Potential design improvements, such as modified diffuser curvature and optimized sidewall shielding, are also discussed.

Finally, the angular-response plots now use the conventional –90° to 90° zenith-centered representation, and the manuscript clarifies that sensitivity below the receiving plane is negligible due to the opaque mounting plate, which blocks radiation from below.

Lines 121-122: The discussion of the <10% asymmetry of the 90 deg azimuthal rotation would seem to be insufficient as each of the receivers clearly show significant azimuthal asymmetries between 0 and 180 deg. For example, the variable cone design has a relative response of ~58% at 0 degrees and 35% at 180 deg. Additionally, the peak of the Uni Dome appears to be ~10 degrees offset from the zenith position at 90 deg. This needs to be explained and I recommend showing the results at 90 deg (and perhaps additional angles) for at least one optic.

The <10% value refers specifically to rotational symmetry of the receiver about its vertical axis. The 90° rotation test evaluates whether the measured response depends on instrument orientation (e.g., fibre coupling or mechanical asymmetry) rather than on the direction of incident illumination. The manuscript has been revised to clarify this distinction.

The differences between opposing azimuthal illumination angles (e.g., 0° and 180°) arise from directional laboratory illumination and partial self-shadowing of the housing and diffuser geometry. These differences reflect finite angular acceptance of the receiver under single-direction illumination, not orientation bias. In atmospheric conditions, actinic flux represents the hemispheric integral of radiance from many directions simultaneously, and is therefore less sensitive to directional anisotropy than a point-source measurement.

Additional text has been added to explain the small zenith offset observed in the Uni Dome design. This offset is attributed to minor asymmetry in fibre positioning and internal scattering paths within the diffuser material. The Results section has been updated accordingly to clarify these effects.

Figs 2 and 3: Grid lines at 0, 90 and 180 deg should be included as key angles in this analysis. (As noted above, I would first rotate the coordinates to -90, 0, 90 deg).

These figures have been updated.

Figs 2-4: Define and discuss the marker uncertainties

Error was propagated through on absolute measurements, but because these are shown as relative measurements the uncertainty has been omitted.

Line 122: Actinic flux does not have a cosine response. Please review the angular response sections in Hofzumahaus, 1999, Jakel, 2005 and Shetter and Mueller 1999. They all show angular response curves with relatively flat responses out to ~85 deg, as needed for actinic flux. A cosine response is limiting for actinic flux because it underrepresents the area close to the horizon. If aiming for a cosine response, how do you convert to actinic flux? If aiming for a flat actinic flux response, more discussion is needed to assess what could be done to create a more uniform actinic flux response across the hemisphere (0-180 deg).

The original wording unintentionally suggested a cosine-response objective, which was not the intent of the instrument design. The radiometer is not designed to measure planar irradiance, and no cosine-based conversion to actinic flux is performed. Instead, the PTFE diffuser is intended to approximate a hemispheric (2π) actinic-flux collector, for which the ideal angular response has uniform sensitivity for radiation incident from all directions above the horizon.

The manuscript has been revised to remove all references to cosine response and to explicitly define the target response as uniform hemispheric sensitivity. The angular characterization section now clearly states that the goniometric measurements quantify deviation from this idealized actinic-flux response. It is also clarified that actinic flux is measured directly from the hemispheric response of the diffuser and not derived from an irradiance measurement.

Additional discussion has been added to place the design within the context of established actinic-flux instrumentation (e.g., Hofzumahaus, Jäkel, Shetter) and to outline potential geometric refinements that could improve hemispheric uniformity in future iterations.

Fig 4: Define and describe the red markers and error bars for the data collected.

The following was added to the manuscript: The x- and y-error bars indicate the error in the wavelength (0.5%) and power reading (5%) for each point.

Lines 136-40: The stray light assumptions are not correct and the claim of insignificant stray light from the low-cost spectrometer in this experiment is highly improbable. Stray light correction is vital for atmospheric single monochromators measurements in the UV-B. The issue lies in the 4-5 orders of magnitude difference in light intensity between 300 and 400 nm. A fraction of a percent of the visible light scattered inside the spectrometer (stray light) and hitting the 300 nm pixel easily overwhelms the signal. Thus, careful UV-B stray light characterization is necessary to measure actinic flux and calculate UV-B sensitive photolysis frequencies, particularly jO_3.

Jakel et al., 2007 provides an analysis technique using a series of long pass filters that demonstrate the influence of broad spectral regions on UV-B signals. Unfortunately, this work relied on thin, isolated mercury lines that are insufficient to demonstrate the effect. I am unclear if the current analysis even includes a dark correction to remove the electronic offset inherent in CCD spectrometers. The only clue is in the data files that log the "Electric dark correction enabled" is labeled "true".

Unless convincingly proven otherwise, this small spectrometer should be presumed to have a significant or overwhelming stray light effect in the UV-B. I would strongly recommend foregoing UV-B and jO_3 analysis with this spectrometer without a full consideration of stray light and dark current. Unfortunately, the TUV comparison for jO_3 does not alleviate the concerns (see comments below). Again, direct comparison with established instrumentation would definitively determine the accuracy and appropriateness of this system for jO_3 measurements.

The reviewer is correct that UV-B actinic-flux measurements are particularly sensitive to stray light in single-monochromator/CCD systems because visible and UV-A radiance can exceed UV-B by several orders of magnitude. The original manuscript description, which referenced isolated Hg lines, was insufficient to rigorously bound UV-B stray light.

A quantitative stray-light assessment was therefore performed using the long-pass filter technique described by Jäkel et al. (2007). A series of long-pass edge filters was applied under identical acquisition settings, and the residual signal recorded below each cut-on wavelength was used to establish a wavelength-resolved upper bound on out-of-band contributions. After dark correction, the maximum stray-light contribution in the UV-B region was <0.16% of the in-band signal under the tested conditions.

The Methods section now explicitly states that electronic dark correction was enabled during acquisition and that all spectra were dark-corrected prior to conversion to actinic flux. The long-pass filter spectra used to derive this bound are provided as Figure R1 in the response package.

These additions directly address the UV-B stray-light concern and support inclusion of the $J(O_3)$ analysis within the stated uncertainty and bias limits.

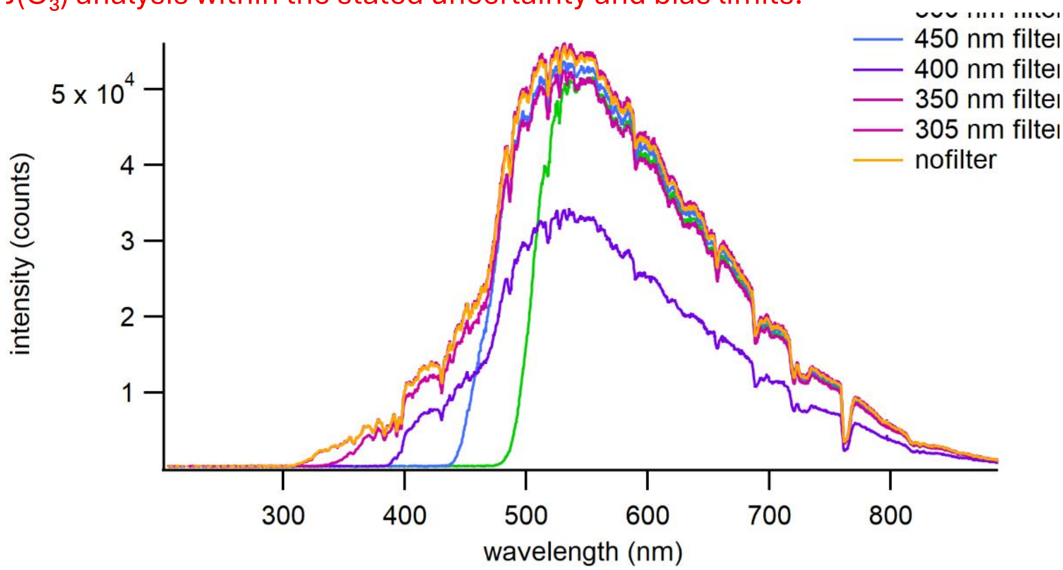

Fig 4 and line 143: What fitting was used to generate this line and what is the reasoning behind a 10% uncertainty?

The manuscript has been revised to clarify the fitting procedure and the stated uncertainty. The line shown in Fig. 4 represents a least-squares linear regression between the measured and modeled J-values over the comparison period. The purpose of the fit is to illustrate proportional agreement and systematic deviation between datasets rather than to provide a predictive model.

The originally stated 10% value has been updated. The current radiometric uncertainty is 15%, reflecting the combined calibration uncertainty associated with the wavelength-dependent detector responsivity. This uncertainty arises from convolution of the CCD quantum-efficiency curve, wavelength-dependent transmission of the PTFE diffuser, and fiber coupling efficiency, as described in the Methods section.

The manuscript now explicitly states the 15% radiometric uncertainty and clarifies its physical basis in the detector responsivity calibration rather than presenting it as an arbitrary fitting tolerance.

Section 3.2: The uncertainty analysis neglects the uncertainties inherent stray light or angular response (“cosine”) corrections. Admittedly, many of the past analyses in the literature have not fully considered these factors, but they should be noted here.

Also, the cross-section and quantum yield uncertainties are better described as biases and not correctly added in quadrature. Fortunately, both measurement and model are using the same cross-sections and quantum yields to calculate photolysis frequencies (this should be noted here and then the references do not need to be repeated in sections 3.2 and 3.4). Thus, these biases do not affect the comparison to TUV.

Section 3.2 has been revised to clearly distinguish between random measurement uncertainty and systematic bias. Angular-response deviations and potential stray-light contributions are now treated explicitly as sources of systematic bias rather than statistical uncertainty and are not included in the quadrature uncertainty. The quadrature value now reflects only the radiometric calibration uncertainty associated with detector responsivity.

The treatment of absorption cross-sections and quantum yields has also been clarified. These parameters introduce systematic bias in calculated photolysis frequencies and are therefore not combined in quadrature with radiometric uncertainty. Because identical cross-sections and quantum yields are used in both the measurement-derived J calculations and the TUV model, they do not affect the measurement–model comparison. This clarification has been incorporated into both the uncertainty discussion and the model-comparison section, and redundant references have been removed.

Section 3.3: I am not certain of the scientific or technical value of this section. Please further explain the purpose of the graph which only demonstrates the measured mercury lamp spectrum through an FEP chamber film. The chamber may indeed be “sufficiently strong for photochemical studies” but I am not sure of the contribution to this work.

Section 3.3 has been revised to clarify its scientific purpose. The spectrally integrated 300–888 nm flux is now explicitly described as a radiometric diagnostic used to verify instrument consistency and is not used in any photochemical calculations. All photolysis frequencies are derived exclusively from wavelength-resolved spectral actinic flux within the relevant absorption bands.

The purpose of the mercury lamp/FEP chamber experiment is to demonstrate the instrument’s capability to measure wavelength-resolved actinic flux in controlled laboratory photochemical environments. In environmental chambers, discrete lamp emission features and transmission characteristics of chamber materials directly influence photolysis rates. The revised text now explicitly states that this experiment demonstrates the ability of the radiometer to resolve discrete emission lines and quantify attenuation through FEP film, enabling determination of photolysis conditions in chamber-based oxidation studies.

These clarifications have been added to improve the scientific framing of Section 3.3..

Line 148: The atmospheric UV-B signal is significantly lower than UV-A and thus I would expect a higher uncertainty for $jO3$ (even neglecting stray light). This is not accounted for when using strong UV-B LED lamps for calibration.

The reported 15% uncertainty represents the radiometric calibration uncertainty of the instrument responsivity rather than photon-counting noise. Although atmospheric UV-B flux is lower than UV-A, each reported spectrum is the average of 20,000 exposures, yielding sufficient signal-to-noise that detector noise is negligible across both the J(NO_2) and J(O_3) wavelength regions under the measurement conditions.

The calibration LEDs establish the wavelength-dependent detector responsivity, but the stated uncertainty reflects the calibration transfer and responsivity convolution (including detector quantum efficiency, PTFE transmission, and fiber coupling), not the absolute brightness of the calibration source. The manuscript has been revised to clarify that the uncertainty is dominated by radiometric calibration factors rather than spectral signal level.

Section 3.4 The duration of the field study is insufficient. To properly assess the optics requires multiple full sampling days under varying atmospheric conditions. However, the field data only covers ~6 hours near mid-day under relatively clear sky conditions. While the data is shown to be in rough agreement with the clear-sky model, this comparison is too simplistic. For one, the angular response is relatively flat at the low solar zenith angles during the measurements. The dataset should include low sun angles where optical design is most critical. For another, cloud and aerosol conditions change the direct solar beam and diffuse fraction of light and the optic needs to represent all conditions. Finally, if these new optics are to be considered as a cheap alternative to established optics, they should be directly intercompared (though that could be deferred to a later study).

Extended field testing across a broad range of atmospheric conditions is indeed necessary for full operational qualification of a field-deployable actinic-flux radiometer. The outdoor measurements presented here were intended as a short-duration radiometric validation and model-consistency check rather than a comprehensive field characterization.

The measurements were conducted near local solar noon under clear-sky conditions to provide a stable and well-characterized radiative environment for comparison with the clear-sky radiative-transfer model. As noted by the reviewer, these conditions correspond to relatively small solar-zenith angles and therefore do not test the receiver under low-sun or strongly diffuse illumination, where angular-response effects may be more significant.

The manuscript has been revised to explicitly state this limitation and to clarify that performance under large solar-zenith angles, variable cloud cover, and enhanced aerosol loading remains to be evaluated. We also note that direct intercomparison with established actinic-flux radiometers was beyond the scope of the present study. Multi-day deployments and instrument intercomparison are planned in future work to assess operational field performance.

These revisions better define the present study as a calibration validation and proof-of-performance assessment rather than a full field qualification.

Fig 6a: The spectra do not resemble surface atmospheric spectra above ~500 nm. The strong peak centered around 550 nm and a very low value at 900nm is not expected in either surface actinic flux or irradiance spectra. To demonstrate, I compared this data with TUV model (out to 700 nm). The model shows approximately 10% drop in signal from 500 to 700 nm for actinic flux and ~25% drop for irradiance. The corresponding drop in this figure is much larger at ~50%.

The spectral comparison to the extraterrestrial flux (ASTM G-173 AM 1.5 G) is noted in the text for the unit change wavelength offset but does not account for the unusual surface atmospheric shape. Perhaps this is a calibration issue at higher wavelengths. A calibration with NIST-traceable sources or intercomparison with an established actinic flux instrument would help determine if the LED light calibration is sufficient across the spectral range.

I recommend replacing this plot with a single spectrum in comparison with TUV.

The reviewer is correct that the full 300–888 nm spectrum is not required for the photochemical analysis presented here. Photolysis frequencies were calculated exclusively from the UV portion of the spectrum (≤ ~420 nm), and the radiometric responsivity characterization was independently constrained in this wavelength region.

To avoid overinterpretation of wavelengths outside the calibrated and photochemically relevant range, Figure 6 has been revised to present a single representative measured spectrum restricted to the UV window used for the J-value calculations, overlaid with the corresponding TUV model spectrum. This revision ensures that the comparison focuses on the wavelength region that directly influences $J(NO_2)$ and $J(O_3)$ and for which the instrument responsivity is independently characterized.

The text has been updated accordingly to clarify that longer wavelengths were not used in the photochemical analysis.

Line 166: What is the value of the total summed flux from the spectrometer at one moment in time. This is only a function of the instrument wavelength range and not of atmospheric or photochemical relevance.

The reviewer is correct that the total spectrally integrated flux over the detector wavelength range is primarily a function of the instrument bandpass and is not directly photochemically meaningful. The manuscript has been revised to clarify that the integrated 300–888 nm flux is reported only as a radiometric consistency check and is not used in any photolysis-rate calculations. All J-value analyses are based exclusively on wavelength-resolved spectral actinic flux within the relevant absorption bands.

Line 180: AtChem is mentioned but why are no AtChem results shown? This should be expanded or removed.

AtChem was not used as an independent radiative-transfer comparison tool and was not intended to provide a quantitative validation dataset. It was employed solely as a chemical plausibility check to verify that the calculated J-values produced physically reasonable photochemical behavior within a box-model framework.

The manuscript has been revised to clarify this limited role and to remove any implication that AtChem results represent a separate comparison to the measurements or to TUV. No standalone AtChem dataset is presented because it was not used as an independent validation benchmark.

Lines 180-1: Where is the factor of 3? A factor of 3 is quite large if the uncertainty is only 15.3% for the measurements. What is the reason for this discrepancy?

The original wording was unclear and has been revised. The factor-of-three deviation occurs only at large solar-zenith angles (early morning and late afternoon), whereas near local solar noon the measurements agree with the TUV model within the propagated ±15% radiometric uncertainty.

The increased deviation at large solar-zenith angles is attributed to the combined effects of finite angular-response sensitivity of the receiver and the limitations of the clear-sky radiative-transfer assumptions used in the model under low-sun conditions. The manuscript now explicitly describes this solar-zenith-angle dependence and removes the earlier implication of uniform agreement.

Lines 183-4: Perhaps the morning measurement is too low because of the uncorrected angular response.

This is a plausible interpretation. The manuscript has been revised to clarify that deviations observed during early morning and late afternoon likely reflect the combined influence of finite angular-response sensitivity at large solar-zenith angles and simplified clear-sky assumptions in the radiative-transfer model. The instrument response was not corrected for angular deviations beyond the measured characterization; therefore, increased discrepancy under low-sun conditions is expected and is now explicitly acknowledged in the discussion.

Lines 186-7: The cross-sections and quantum yields in the model and measurement are described as identical in the paper. Perhaps the authors mean that the implantation of the cross-sections and quantum yields in the data and in the model may have slight discrepancies.

The manuscript has been revised to clarify this point. Identical absorption cross-sections and quantum yields were used in both the measurement-derived J calculations and the TUV model configuration. There were no differences in parameter implementation between the two calculations; therefore, discrepancies between modeled and measured values cannot be attributed to cross-section or quantum-yield selection.

The remaining differences are instead attributed to factors influencing the radiative field rather than the photochemical parameters, including simplified clear-sky assumptions in the model (e.g., omission of aerosol or cloud scattering), finite angular-response sensitivity of the receiver at larger solar-zenith angles, and minor effects associated with wavelength interpolation and spectral binning. The manuscript has been revised accordingly.

Fig 6B: This 311 nm actinic flux plot would benefit from a TUV model comparison to help address the jO3 questions below. Perhaps add an additional wavelength to represent jNO2 (e.g. 380 nm).

Fig 6C and 6D. I attempted to reproduce the TUV model results using the parameters specified in Section 2.4. However, this was complicated by two factors.

- The text does not specify if the model is set to output total actinic flux or downwelling-only (solar direct + downwelling diffuse). I believe it should be downwelling-only as that is what appears to be measured during the field deployment, although that was not explicitly specified.
- I am unsure of the albedo used as the text notes the unreasonable value of 0.9999. I used 0.09999, assuming a typo

I was able to approximately calculate the same JNO2 in Fig 6a if I assumed a total actinic flux output. The downwelling-only would reduce the values by ~10%.

I cannot, with any combination of factors, reproduce the JO3 shown in Fig 6b. Applying the same parameters used to match total JNO2, the corresponding total modeled JO3 is a factor of ~3 higher than shown in the figure. I suggest the authors revisit this analysis and clearly define all parameters used in the calculations.

In addition, the figure includes the uncertainty from the cross-sections and quantum yield uncertainties in the measurements. Identical references were noted in both measurement and model so they are not relevant to the measurement/model comparison. The more fundamental comparison is between the measured and modeled actinic flux where the uncertainty is not tied to these molecular parameters. As mentioned above, a spectral comparison and a plot of individual wavelengths vs time would be revealing.

The manuscript has been substantially revised to address these points.

TUV Configuration and Reproducibility

Section 2.4 has been clarified to explicitly state that TUV was configured to output total downwelling actinic flux (direct beam + downwelling diffuse), excluding upwelling radiation, to match the 2π hemispheric measurement geometry of the instrument. The surface albedo is now clearly specified as 0.4, correcting the earlier ambiguous value.

The wavelength integration limits used for $J(O_3)$ and $J(NO_2)$ calculations are now explicitly stated in the Methods section to ensure reproducibility. In particular, $J(O_3)$ was calculated over the calibrated UV range consistent with the measured responsivity window. These clarifications resolve the earlier ambiguity that could lead to differences in reproduced values.

$J(O_3)$ Discrepancy

The factor-of-three deviation occurs primarily at larger solar-zenith angles. Near local solar noon, measured and modeled values agree within the stated radiometric uncertainty. The manuscript now explicitly describes the solar-zenith-angle dependence of this deviation and attributes it to the combined effects of finite angular-response sensitivity of the receiver and simplified clear-sky model assumptions at low solar elevations.

Uncertainty Treatment

The uncertainty discussion has been revised to separate radiometric calibration uncertainty from systematic biases. Absorption cross-sections and quantum yields are now explicitly treated as systematic parameters applied identically in both the measurement-derived J calculations and the TUV model; therefore, they do not influence the measurement–model comparison. The quadrature uncertainty shown in the figure now reflects only the radiometric calibration uncertainty.

Spectral Comparison

In response to the reviewer's suggestion, Figure 6 has been revised to include a direct spectral comparison between measured actinic flux and TUV output within the photochemically relevant UV window. This allows evaluation at specific wavelengths (e.g., 311 nm and 380 nm) without overinterpretation of longer wavelengths outside the calibrated range.

These revisions clarify model configuration, improve reproducibility, and ensure that the measurement–model comparison is presented in a physically consistent and transparent manner.

Line 212: What is the relevance of "wavelength range" and "low saturation levels" to stray light?

The reviewer is correct that wavelength range and detector saturation level are not direct indicators of stray-light rejection. The original wording was imprecise and has been revised.

The Conclusions section now refers explicitly to the quantitative stray-light characterization performed using the long-pass filter method described in the Methods. Residual out-of-band signal in the UV-B region was bounded to <0.16% of the visible signal after dark correction, providing a wavelength-resolved upper limit on stray-light contamination. The revised text removes the earlier implication that spectral range or saturation behavior alone demonstrate stray-light suppression.

Line 214: This paper describes spectrally-resolved spectrometer measurements. They are not "broadband" measurements that average over a spectral range. Perhaps this refers only to the optics. They could indeed be used in broadband instruments and stability would be crucial.

The reviewer is correct that the instrument described here performs spectrally resolved measurements rather than broadband integrated measurements. The original wording was imprecise. The term "broadband" has been replaced with "spectrally resolved" throughout the manuscript where appropriate. In cases where broadband applicability was mentioned, this now explicitly refers only to the potential use of the optical designs in broadband radiometric instruments rather than to the spectrometer measurements presented in this work.

Technical corrections

Line 35: Typo on references, “Bohn et al.(Jäkel et al., 2007)” . Note, the two referenced Bohn papers and Jakel et al., 2007 do not mention cosine corrections as each study used 2 pi steradian optics that do not require such corrections.

We thank the reviewer for identifying both the citation error and the incorrect implication. The malformed reference has been corrected to Jäkel et al. (2007). We also revised the surrounding text to remove the statement implying cosine correction for 2π actinic-flux receivers. The Introduction now correctly describes that such instruments rely on goniometric angular-response characterization rather than cosine correction, consistent with Jäkel et al. (2007) and Bohn and Lohse (2023). These changes align the manuscript with the established actinic-flux measurement literature.

Line 49: What does “Quality, 2021, 2023” refer to in the references?

Apologies, these have been corrected.