

Interactive comment on “Calibration and evaluation of CCD spectroradiometers for airborne measurements of spectral actinic flux densities” by Birger Bohn and Insa Lohse

Anonymous Referee #1

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Calibration and evaluation of CCD spectroradiometers for airborne measurements of spectral actinic flux densities

This manuscript describes the calibration procedures and data evaluation of a CCD spectroradiometer (CCD-SR). The instrumental characteristics are partly compared with results from other publications. The performance of the CCD-SR is demonstrated for airborne and ground-based observations.

The manuscript is very technical and gives a lot of details. It is well-written but could be shortened at some points, since it is no new instrumental techniques described here. The benefits for the reader should be pointed out more clearly in the introduction. What is new compared to former publications? The manuscript is recommended for

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publication in AMT. Nevertheless, the following comments should be addressed first.

General comments:

1. The CCD-SR shows good performance also for ground-based observations. The disadvantage of less sensitivity and impact of stray light in the UV spectral range can be avoided by careful calibrations and some corrections as written in the paper. The comparison with the DM-SR has shown sufficient agreement. This precise scanning instrument, however, has much lower time resolution than the CCD-SR which is not sufficient for fast changing atmospheric conditions (as cloudy sky). For this reason I suggest to change the title: “Calibration and evaluation of CCD spectroradiometers for ground-based and airborne measurements of spectral actinic flux densities”. There is no need to restrict the application of the CCD-SR to airborne measurements. That could be made clear by extending the ground-based comparison (see comment #41).
2. Since the angular response of the entrance optics is highly affecting the quality of the data it would be worthwhile to implement it in this paper. In this case some changes to the text and text cuts should be made not to overload the manuscript when adding the discussion about the angular response. That would give the reader a full description of the instrumental performance in one paper.

Specific comments:

3. Give wavelength range of the CCD-SR in the abstract.
4. p117: “flux densities in a 300 nm range” – What does it mean? Is it the detection limit at 300 nm wavelength?
5. p117: “below cutoff wavelength” – Not knowing the manuscript, the reader will not know what “cutoff wavelength” means. Better write something like that “below atmospheric cutoff wavelength which was simulated depending on solar zenith angle, ozone column, ...”
6. p117: “with reference instrument data” – Which instrument? Tell the reader that is

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a high sensitive double monochromator.

7. p1119: “Overall, the investigated instruments are clearly . . .” – already mentioned in the beginning of the abstract (l3).

8. p2: Please discuss the dependence on temperature and pressure of molecular parameters.

9. p211: Explain shortly what is meant by “stray light”. Furthermore, mention the lower sensitivity in the UV-B.

10. p313: “upward radiation in the UV range can often be neglected” – only valid over dark surfaces

11. p3114: “have low time resolution” – What means low? Please give numbers.

12. p516: “The idea is to piece together . . .” – I am wondering if there is mismatch between the spectra sampled over different integration times, because the measurement volume is different. In particular for fast changing atmospheric conditions in combination with the speed of HALO, I would expect some differences. Did the authors compare the spectra for some examples without oversaturation? Furthermore, the linearity of the detectors should be shortly discussed.

13. p518: “.. calculation of final actinic flux . . .” – In fact, these data are only a kind of quicklook. Post-processing is required as mentioned in the subsequent sentence.

14. p5112: Maybe a flow chart of the following calibrations would be helpful.

15. p5122: “dark spectra” – Explain shortly.

16. p5123: “were fitted with an “ – Why did the authors did not use also the Neon emission lamp which covers the longer wavelengths greater than 546 nm?

17. p914: “Noise levels were found to increase with the square root of signals . . .” - Can you show a plot for illustration, maybe for different wavelengths?

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18. p10l1: “example of signal-to-noise ratios” – Give equation. I am wondering if it is correct to illustrate the wavelength dependence of the SNR this way. Since the SNR depends on the magnitude of the signal itself, a constant signal should be used for all wavelengths (however feasible) to demonstrate the pure wavelength dependence. As suggested in comment #17, plot the SNR as a function of the signal for different wavelengths.
19. p10l8: “Laboratory calibration” – include radiometric
20. p10l16 “shows little wavelength dependence” – What means little, give numbers.
21. p11 Fig. 5: What is the gain of information showing the procedure for two integration times? The reader might be more interested in the stray light fraction than showing each step of the data evaluation.
22. p12l12: “WG320, WG360” – Please refer to Schott, otherwise it is not clear where the “WG” comes from.
23. p12l23: “. . . stray light quickly diminishes with increasing wavelength. . .” As mentioned in comment #21, this would be good to see in a plot for all spectroradiometers.
24. p13 Fig. 6: Here, a test of the linearity could be implemented.
25. p13l14: It is suggested to delete the paragraph. After introducing the spectral calibration, the reader assumes that the wavelength shift is considered in the radiometric calibration.
26. p14l11: Also here, delete the paragraph. The reader will not be interested in the Metcon software.
27. p16l14: “in total uncertainties between . . .” - The error due to angular response is not included here as it should be when talking about the total uncertainty.
28. p17l12: “Detection limits are usually defined as the three-fold . . .” – Please give a reference.

29. p17I20: “the noise limits correspond to 0.1% and 0.0001%...” – Are these values derived from the table? Give the reference (typical maximum) values. Tab. 3 lists also noise equivalent photolysis frequency for a limited spectral range above 300 nm in brackets. A better motivation might be to give the results for two situations (low SZA, low total ozone column vs. high SZA, high total ozone column). Note the conditions in the table caption. It would give the reader a smooth introduction to the cutoff wavelength paragraph.

30. p17I24-p17I31: This paragraph could be deleted. It was already stated in the introduction that in the UV-B the ozone photolysis is more affected than the NO₂-photolysis.

31. p17I32: “cutoff-wavelength” - atmospheric cutoff wavelength. The authors created some look-up-tables (as mentioned on p18I3). A contour plot showing the dependence of the cutoff wavelength on SZA and total ozone column would be nice to see.

32. p19I14: How are temperature and pressure variations considered in the look-up-tables? There should be some sensitivity in particular for ozone photolysis.

33. p19I21-p21I23: This section can be shortened. A flow chart summarizing the steps to create a spectrum from raw data might be helpful.

34. p19I25 Is the dark signal taken from laboratory measurements? If yes, how are changes be considered during the campaign (p8I1)?

35. p20 Fig. 10: The upper two panels are sufficient to illustrate the stray light and offset correction for field measurements. An additional subfigure showing the stray light fraction would be more interesting than the remaining six panels (supporting also p22I2).

36. p21 Fig. 11: Combine with Fig.10., the logarithmic representation would be sufficient. Could the authors add a comparison with simulations for the downward actinic flux density?

37. p22I8: “starting with the longest available...” – As mentioned earlier the reader

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might be more convinced of this combination method by showing spectra measured for different integration times in one plot with indication at which wavelengths the final spectrum were merged.

38. p23l3: The reader probably expects the results of the photolysis frequency right here.

39. p23l16: One example is sufficient, either 62000 or 62001. When comparing with DM-RS add the measurement uncertainty for both instruments in Fig. 12.

40. p24 Fig.12: The lower left panel would be sufficient. Could the authors here also some simulated spectrum?

41. p25l1: The authors compare j -values derived from CCD-SR and DM-SR for two days including cloud periods. Here the advantage of the better time resolution could be directly shown by a time series for of j -values with best temporal resolution for each instrument. Furthermore, filtering these cloud events from Fig. 13 might be worthwhile to exclude the data sampled during variable conditions within the time frame of one DM-SR measurement.

42. p29 Fig. 14: Show a map instead of the time series of latitude and longitude. Combine SZA and total ozone column in one panel. Remove date in x-axis in the lower panels. Add some simulated j -values for downward components.

Technical comments:

43. p2l13, p2l22: “spectral actinic photon flux density” – delete “photon”

44. p2l26: “easyness” - easiness

45. p3l1: “stray-light” - stray light

46. p3l16: “maneuvers in flight” - flight maneuvers

47. p4l7: “properties” - characteristics

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48. p4l14: “lengths” - length
49. p5l6: “The idea is to piece together . . .” - combine
50. p5l12: “characterisation” - characterization
51. p6 Fig. 2: Rearrange plot to save some space. Maybe one combined color coded plot is sufficient showing the spectra as function of wavelength difference referred to center wavelength (± 4 nm). Otherwise, please give labels for each subfigure (a) –(e).
52. p8 Fig. 3: Unit of signal? Counts?
53. p8l13: “is considered a combination” - “is considered as a combination”
54. p9 Tab. 2: Numbers in Counts?
55. p9 Fig. 4: Label subfigures and use larger points. Plot subfigures in two columns.
56. p12l8 and hereafter: Maybe better to use the index “stray” instead of “scat” in the S-variable.
57. p16 Fig. 8: Figure caption “hangar measurements” - field measurements, label the subfigures with (a) - (d)
58. p16l2: “Firstly by the . . .” – no sentence, link it to the sentence before by using “;”
59. p17l14: “be considered a theoretical” - as a theoretical
60. p17l18: “are listed in Tab. 2” - Tab. 3
61. p17l25: “Tab. 2” - Tab. 3

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