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Interactive comment on "Analysis of actinic flux profiles measured from an ozone sonde balloon" *by* P. Wang et al.

Anonymous Referee #1

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The actinic flux drives the photochemistry of the atmosphere. As such its behaviour and understanding of the processes that affect it, is of great importance. Surprisingly there are very few measurements of this quantity under varying atmospheric conditions. The work presented in this paper describes a new instrument that have the potential to greatly improve this lack of measurements of this important quantity. It may be noted that an equally important radiative quantity, the net radiative heating/cooling rate that drives the atmospheric circulation, is on an even worse footing when it comes to atmospheric profile measurements.

Considering that the instrument is uncalibrated the authors are able to obtain a lot of useful insight by including ancillary satellite and ground-based information in their analysis. The main weakness of the paper is the assumptions used in the radiative transfer modelling. A single wavelength is used to represent the broad-band response of the diode detector. This may have implications for the model/measurement comparison as shown below for Fig. 11d. Also the use of a single layer cloud sometimes precludes a deeper understanding of the measurements, see remarks about Fig. 7d below. The authors are encouraged to redo the model simulations with the improvements suggested below before final publication of the manuscript.

Specific remarks

- **Page 31171, line 4**: It is stated that actinic flux profiles have been measured by tethered balloons and aircrafts. It might also be mentioned that actinic flux relevant radiation profiles have been measured by balloons in the stratosphere (Schiller et al, 1994) and the troposphere and stratosphere (Kylling et al., 2003). Furthermore, accurate spectral actinic flux measurements were made by Hofzumahaus et al., 2002.
- **Page 31171, lines 23-24**: The Junkermann (1994) and Palancar et al. (2011) papers are mentioned, but the results they obtained are not summarised as is done for the other cited papers. For completeness please also do so for these two references.
- **Page 31172, lines 4-20**: The wavelength dependence of the actinic flux should be further emphasized. The vertical profile of the actinic fluxes relevant for ozone and nitrogen dioxide are very different due to the processes that affect them. This should be discussed in connection to what the diode instrument measures.
- **Page 31172, lines 21-28**: It might be mentioned that the CMF is wavelength dependent as demonstrated by Seckmeyer et al. (1996).
- **Page 31172, line 24**: It is stated that the CMF is the “ratio between UV radiation

...”. Clearly the CMF is not restricted to UV radiation. Please remove “UV” from the sentence.

- **Page 31173, line 5**: A plot showing the spectral response of the diode should be included. This is important documentation of the instrument and makes it easier to understand what it is actually measuring. See also comments to Fig. 11d below.
- **Page 31173, lines 5-27**: Please include following information:
  - If you measured the angular response of the instrument, please include plot.
  - A picture showing the instrument would be helpful.
  - What is the temporal sampling frequency?
  - Where in the ballon payload is the instrument located? Please discuss possible effects of shadow from the balloon and/or the payload.
- **Page 31174, lines 12-25**: Which ozone cross section and Rayleigh scattering cross section were used?
- **Page 31174, line 21**: What is the justification for using a single wavelength in the radiative transfer modelling and not doing it correctly by calculating a spectrum and convolving the spectrum with the spectral response of the diode? See also comments to Fig. 11d below.
- **Page 31175, line 9**: is the 3 km$\times$6 km SEVIRI resolution latitude$\times$longitude or vice versa?
- **Page 31176, line 15**: The albedo used in 1D radiative transfer models is an effective albedo. As the altitude of the instrument increases the effective albedo “seen” by the instrument will change as the instrument “sees” a larger and larger area including the ocean to the west. While the effect is probably minor due to the low surface albedo, it might be worthwhile to mention.

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- **Page 31177, line 24**: How was it determined that the sky was clear? Are contrails allowed in clear-sky profiles?

- **Page 31177, line 24, Fig. 2a and Fig. 3**: The clear-sky actinic flux profiles have some periodic small scale variability. This may be caused by rotation of the balloon and hence the payload. It might be interesting to calculate the frequency of this variability in the actinic flux and see if it is consistent with the expected period for rotation of the payload. The periodic variability in the actinic flux should be larger when the instrument is exposed to the direct sun and less or absent when the instrument is inside a cloud. This is so because imperfections in the angular response are more evident in an inhomogeneous light field. Evidence for this behaviour is seen in Figs. 3a-e where little or no small-scale variability is seen inside and below the cloud and then it appears ones the instrument is above the cloud and exposed to the direct sun.

- **Page 31177, lines 11-12**: May also sub-visible cirrus and far away clouds contribute here?

- **Page 31177, lines 21-22**: It is stated that the "altitude dependence of the internal radiation field in a scattering atmosphere depends mainly on the optical depth". It is not defined what is meant by "internal radiation". Also, depending on the wavelength, altitude distribution of the optical thickness and the magnitude of the optical depth, the amount of overlying atmosphere and its properties, possible pollution in the cloud (single scattering albedo smaller than 1.0) and surface albedo may play a role. The phase function may also be of importance depending on the phase of the cloud. Thus, this sentence appears to oversimplify as it stands. Finally, the expression within the parenthesis may be omitted. It is trivial that "$\tau = 0$ at TOA.." etc.

- **Page 31180, line 25**: Please state what the magnitude of the SEVIRI COT negative bias is.

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- **Page 31183, lines 6-8**: It is stated that "COT values in the maps are averaged over $0.1^{\circ} \times 0.1^{\circ}$ grids, while the COT values are given for single pixels". But in the caption of Fig. 7c the single pixel values are from $0.1^{\circ} \times 0.1^{\circ}$ pixels. Are there two types of $0.1^{\circ} \times 0.1^{\circ}$ pixel values? What are they and what are the differences? Please clarify.

- **Page 31183, line 17**: It is straightforward with a radiative transfer model to include several cloud layers and this should be done to better reproduce the measurements. In Fig. 1 (this review) single cloud layer (red) and two cloud layers (green) simulations are included. The total optical depth was 25 in both cases and the solar zenith angle as in Fig. 7d. The wavelength is 550 nm, the surface albedo 0.15 and no aerosols were included. Clearly the two layers simulation better resembles the measurements in Fig. 7d.

  The really intriguing feature with the measurements shown in Fig. 7d is the decrease in radiation as the altitude increase from about 0.5 to 2.0 km, that is between the two cloud layers. Below a sufficently thick cloud little of no vertical variation is expected as shown by the model results in Fig. 1 (this review), green line. The behaviour of the measurements in this altitude range is unexpected. Aerosols may play a role, but it is not at all clear to this referee what the reason is for this behaviour.

- **Page 31184, line 18**: Should it be 0.1-degree box instead of 1-degree?

- **Page 31184, lines 21-22**: It is stated the balloon passed through the cloud top resulting in a sharp peak in the actinic flux at 3 km. In the next sentence it is stated that the "COT increased again at about 4 km". But then the balloon was above the cloud? Or was there another cloud? Or was the ballon flying at 4 km and the COT of the underlying cloud increased? Please clarify.

- **Page 31184, line 24**: The measured and simulated profiles are said to follow

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each other “very well”. May you please quantify “very well” by providing rms-differences or similar?

- **Page 31184, lines 25-26**: Please prove your conclusion by varying the extinction coefficient with altitude and thus make the simulated actinic flux agree with the measurements.

- **Page 31185, line 5**: What is meant by “properly simulated”?

- **Page 31185, lines 6-23**: For large solar zenith angles a difference between the measured and simulated actinic flux is seen below about 10 km in Fig. 11d. It is speculated that full spherical geometry is needed to explain this discrepancy. However, the DAK simulations are made for the single wavelength of 550 nm under the assumption that this single wavelength best describes the broad band response of the diode. This assumption may hold for small solar zenith angles, but not necessarily for large solar zenith angles. The clear-sky actinic flux varies with wavelength (Rayleigh scattering). To investigate this effect the actinic flux was calculated as a function of altitude for wavelengths of 450, 550 and 650 nm for a solar zenith angle of 75°. A water cloud with optical thickness of 30 evenly distributed between 0.1 and 1.0 km, was included in the simulations. Pseudo-spherical geometry was assumed. In Fig. 2 (this review) the actinic flux normalised to its value at 30 km is shown for the three wavelenghts. It is seen that the actinic flux varies considerably with wavelength below about 15 km and that a wavelength of 650 nm resonably well resembles the measurement presented in Fig. 11d. Thus the choice of 550 nm in the DAK simulations is not representative for large solar zenith angles. This example very clearly demonstrates the danger involved when using a single wavelength to simulate an instrument with a broad spectral response. Rather then using a single wavelength, the DAK simulations should be made for all wavelengths covered by the diode and the resulting spectrum convolved with the spectral response of the diode.

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Finally note the difference between the black and green lines in Fig. 2 (this review). For the green (black) line the cloud optical depth was evenly distributed between 0.1 (0.8) and 1.0 km. The black line best reproduces the red line in Fig. 11d of the manuscript, but it is not clear from the text how the vertical distribution of the optical depth was for the calculation presented in the manuscript.

- **Page 31187, line 5**: After the simulations have been redone accounting for the spectral response of the diode instrument, the shapes of measured and simulated actinic fluxes will most likely agree for SZA $> 75^\circ$ and the conclusions may be changed accordingly.
- **Page 31194, Fig. 4a-b**: Have you tried to use log-scale on both the x- and y-axes in Fig. 4a? And have you tried to use log-scale on the x-axis of Fig. 4b?
- **Page 31195, Fig. 5a-b**: Please mark the launch site in Fig. 5a or even better include a square marking the region shown in Fig. 5b. Fig. 5a looks like a MODIS image obtained directly from the MODIS web site. A little more work is warranted to make the presentation clearer.
- **Page 31195, Fig. 5c**: It is not marked which lines correspond to the measurement and the model. Also, it would be interesting to include a model/measurement ratio or difference plot.

Technical remarks

- **Page 31172, line 12**: The sentence "the photodissociation of nitrogen ...." is unclear, please rewrite.
- **Page 31175, lines 12-18**: The sentences in this part are hard to read; please rewrite.
- **Page 31186, line 15**: Replace "an large" with "a large".

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References

- Hofzumahaus A., A. Kraus, A. Kylling and C. Zerefos, Solar actinic radiation (280-420 nm) in the cloud-free troposphere between ground and 12 km altitude: Measurements and model results, J. Geophys. Res., 107, doi=10.1029/2001JD900142, 2002.
- Kylling, A., T. Danielsen, M. Blumthaler, J. Schreder and B. Johnsen, Twilight tropospheric and stratospheric photodissociation rates derived from balloon borne radiation measurements, Atmos. Chem. Phys. 3, 377-385, 2003.
- Schiller, C., A. Hofzumahaus, M. Müller, E. Klein, E.–P. Röth, and U. Schmidt, Ultraviolet actinic flux in the stratosphere: An overview of balloon-borne measurements during EASOE, 1991/92, Geophys. Res. Lett., 21, 1239–1242, 1994.

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Interactive Comment

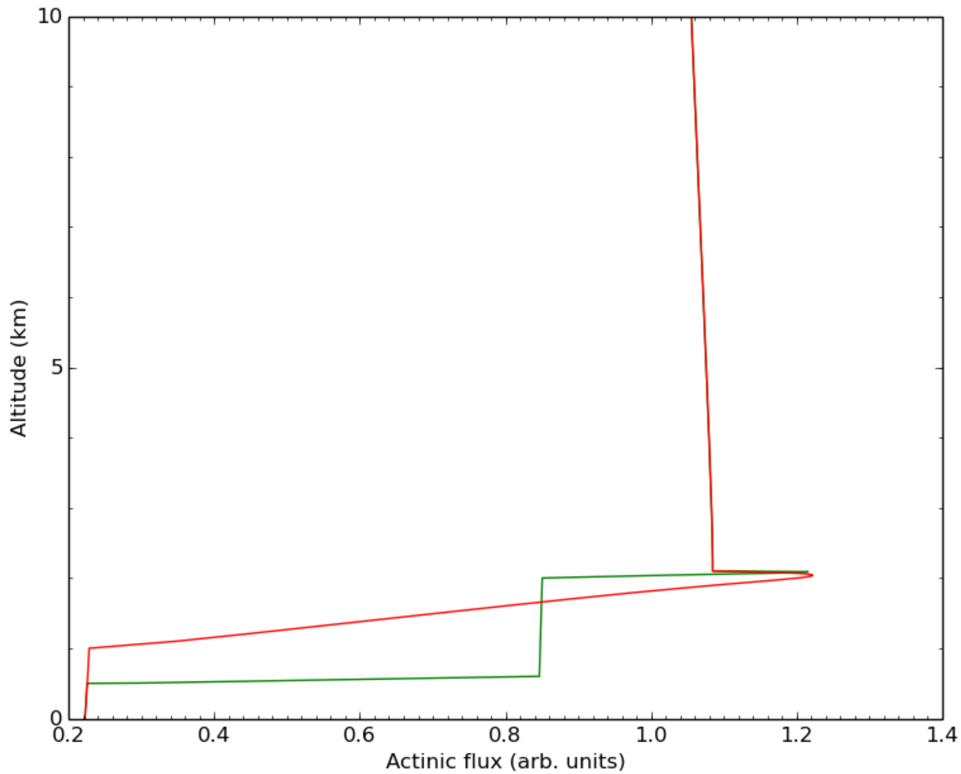

Fig. 1. Similar to Fig. 7d in the manuscript. Both single layer (red) and two layers (green) cloud simulations are shown.

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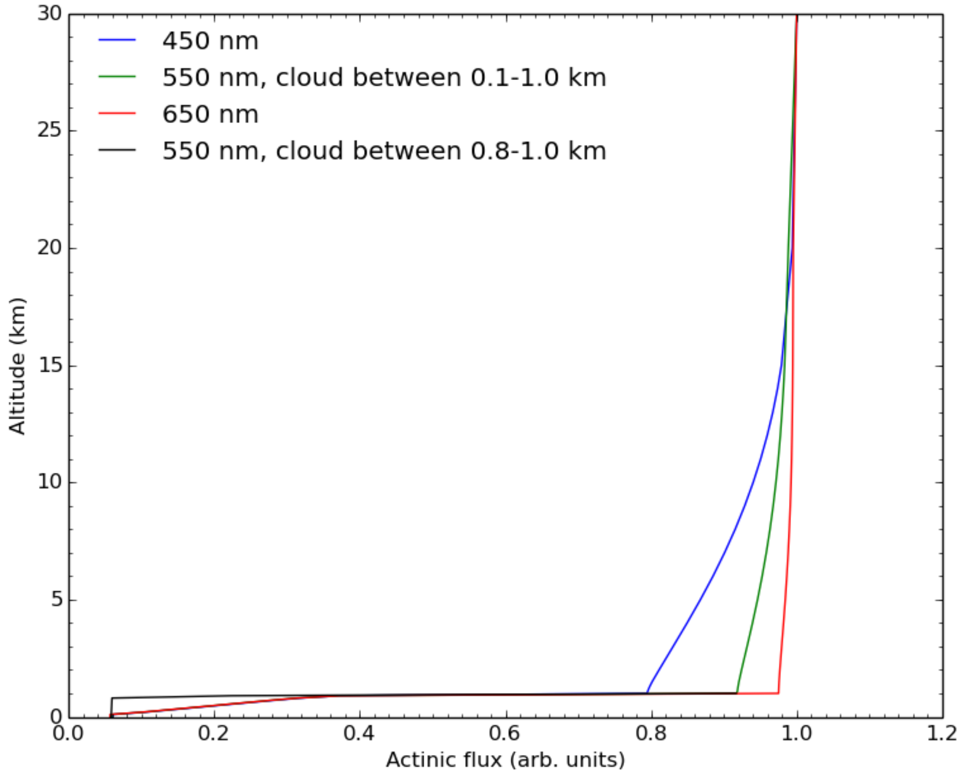

Fig. 2. Similar to Fig. 11d in the manuscript. Note how the normalised actinic flux profiles change with wavelength below 15 km.

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