Interactive comment on:

"Ultraviolet actinic flux in clear and cloudy atmospheres: Model calculations and aircraft-based measurements"

by G. G. Palancar et al.

Anonymous Referee #1

We thank the referee for the insightful and helpful suggestions which resulted in an improved manuscript.

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General Comments

Palancar et al. describe an interpretation of aircraft measurements of actinic flux densities with TUV model calculations and a simplified analytical approach to deal with closed and broken cloud fields. This is a useful attempt so sort out the great complexity associated with cloud influence on actinic flux to eventually improve the quality of photolysis frequencies entering chemistry transport models. The paper is well written and should be published after minor corrections.

Specific Comments

*** Page 3322, line 6:** Avoid decimal places of ozone columns. Such details imply a precision that is neither realistic nor necessary for this work. The same applies for aircraft positions and altitudes given in section 2.1.

Answer: the numbers for the mentioned parameters have been corrected throughout the text.

*** Page 3322, line 13:** In the abstract a quantitative statement is missing on the magnitudeof the observed enhancements or reductions induced by clouds. Otherwise the onlynumbers in the abstract give the impression of an almost perfect agreement betweenmodeled and measured data. For example in Fig. 2 total actinic flux is affected by thepresence of clouds by at least a factor of two in both directions compared to clear skyconditions.

Answer: The abstract was modified as follow to include quantitative statements about the effects of clouds relative to the clear sky model calculations.

"For cloud-free conditions, the ratio of observed to clear-sky-model actinic flux (integrated from 298 to 422 nm) was 1.01 ± 0.04, i.e. in good agreement with observations. The agreement improved to 1.00 ± 0.03 for the down-welling component under clear sky conditions. In the presence of clouds and depending on their position relative to the aircraft, the up-welling

component was frequently enhanced (by as much as a factor of 8 relative to cloud-free values) while the down-welling component showed both reductions and enhancements of up to a few tens of percent. Including all conditions, the ratio of the observed actinic flux to the cloud-free model value was 1.1 ± 0.3 for the total, or separately 1.0 ± 0.2 for the down-welling and 1.5 ± 0.8 for the up-welling components."

*** Page 3326, line 8:** There should be a statement on the accuracy of the measurements considering calibration standards and potential drifts during the campaign.

Answer: As stated in section 2.1, a complete description of the instruments, calibration procedures and installation on the aircraft is given by Shetter and Müller (1999) and Shetter et al. (2003).To explicitly state this in the manuscript we added the following sentence in section 2.1:

"The accuracy of the measurements is estimated to be 6% in the UV-B and 5% in the visible (including drift during the campaign) while the optical angular responses of the instruments are ±3% for solar zenith angles less than 80º."

Page 3326, line 24: Please use UTC instead of GMT and UT throughout the text and in Figs. 1, 2.

Answer: UTC is now used throughout the text and also in Figures 1 and 2.

*** Page 3332 ff:** In Section 4.2 an analytical model for actinic flux received above, within, and below clouds with simplifications is presented. However, the relation of this model to the measured data or the TUV model calculations remains rather vague. Merely the lower limit of 0.5 derived for the slope of the correlations in Fig. 6 was rationalized. If the authors want to promote the use of these formulas they should show that their use yields reasonable estimates, e.g. in terms of a factor Qtot. For the aircraft measurements the necessary parameters are not available, so a comparison is difficult, but what about the TUV calculations that were made for the data in Fig. 7? Because up-welling,down-welling and direct radiation were considered, I assume that the necessary input parameters are available directly (c, μ) or indirectly (A, R, T)?

Answer: This section has been moved to the appendix A.

*** Page 3337, line 15:** I don't understand how Eq. 23 was derived from Eq. 22.

*** Page 3338, line 3:** I don't understand how Eq. 25 was derived from Eq. 24.

Answer: In general, for x much smaller than 1, $(1+x)^{-1}$ can be approximated as:

$$\frac{1}{1+x} \approx 1 - x$$

Also, as i increases the contribution of the high power terms is increasingly smaller so that they can be usually neglected.

As $2\mu A_o$ is much smaller than unity, equation 22 was expanded in a Taylor series, where only the terms which were first order in A_o were kept. After operating, equation 23 is obtained.

$$\frac{1+2\mu A}{1+2\mu A_o} = (1+2\mu A)(1-2\mu A_o)$$

$$= 1 - 2\mu A_o + 2\mu A - (2\mu)^2 AA_o$$

$$= 1 + 2\mu A\left(1 - 2\mu A_o - \frac{A_o}{A}\right) \qquad \text{Eq. 23}$$

The same apply to equations 24-25.

* **Table 1:** The selected wavelength range should be repeated in the caption.

Answer: The Table 1 caption was changed as follows:

Table 1. Average ratios of the integrated actinic fluxes (298-422 nm) measured to those calculated with the cloud-free model, for all INTEX-NA flights.

* **Table 2:** Use $Q^{\downarrow}$ and $Q^{\uparrow}$ instead of "Downwelling" and "Upwelling".

Answer: $Q^{\downarrow}$ and $Q^{\uparrow}$ are now used in table 2.

* **Figs. 1 and 2:** Indicate in the captions that Fig. 1 shows cloud free data and Fig. 2 data influenced by clouds. In addition to aircraft altitude in panel (a) you could plot solar zenith angles in panel (b), because this is the most important input parameter for the model calculations.

Answer: The corresponding SZA variations were plotted in panels (b) of Fig. 1 and Fig. 2. Captions for Fig. 1 and Fig. 2 were changed as follows:

Figure 1: Time series of measured (clear-sky) and cloud-free modeled (a) total and (b) down-welling and up-welling actinic flux for 13 August. Aircraft altitude and SZA variations are also shown in panels (a) and (b), respectively.

Figure 2: Time series of measured (cloudy) and cloud-free modeled (a) total, (b) down-welling, and (c) up-welling actinic flux for 7 August. Aircraft altitude and SZA variations are also shown in panels (a) and (b), respectively.

* **Figs. 4 and 5:** Perhaps it would be more intuitive to exchange panels (a) and (b)consistent with Figs. 1-3 and to avoid confusion of "up" with the upper hemisphere.

Answer: Panels (a) and (b) were exchanged in figures 4 and 5.

*** In Figs. 3-7** four different notations or symbols are used for the ratios Q, all different from the symbols used in the text, Qtot, $Q^{\downarrow}$, $Q^{\uparrow}$. The drawing program is certainly able to create arrows pointing up and down.

Answer: To be consistent with the text, the notation Q^{tot}, $Q^{\downarrow}$ and $Q^{\uparrow}$ was used in all figures.

*** Fig. 6:** The meaning of the colour coding is not clear. I assume it refers to fixed Δx and Δy intervals? Fig. 7 shows that not all data points are represented in Fig. 6?

Answer: As stated in the text (page 3330, line 25), the color scale indicates the frequency of occurrence of the x and y values. In other words, the most common values occur near 1,1 which is clear skies.

*** Fig. 7:** This figure is really hard to digest. In particular the positions of the bold numbersappear arbitrary. The dashed upper limit is different from Fig. 6. The exact meaning of the upper limit remains unclear.

Answer: Table 2 lists the sky conditions that could be present above and below the aircraft, with their likely effect (perturbations) on up-welling and down-welling radiation. The bold numbers in figure 7 represents the zones where the corresponding perturbations can, in average, be found. As the magnitude of the upwelling and downwelling perturbations depend on many parameters these zones have, of course, no well-defined limits. In contrast with the lower limit, the upper limit is not well defined and its meaning is unclear. Thus, we deleted the upper limit line from figures 6 and 7. We think that this limit is determined by unlikely situations. Both TUV model and the simple analytical model show that this limit could be higher than the one shown in figure 6, but these values are mostly found for unlikely and very specific combination of values for the used parameters (e.g.large cloud optical depth with a small cloud cover, high albedo, and low surface elevation). As all these situations were likely not found during the flights these ratios do not appear in figures 6 and 7.