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 #2

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

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General Comments

The manuscript compares spectral actinic flux (see specific comments) measurements made from an aircraft platform over a range of conditions with a radiative transfer model simulating the same conditions. The agreement is good in clear sky conditions, especially for the down welling component of the total actinic flux, as one might expect for this model which has been widely tested and used. Once clouds are included the situation becomes far more complex and the resulting actinic flux depends on where the clouds are in relation to the aircraft, and whether the direct beam is obscured or not, as well as the macro- and micro-physical properties of the clouds which determine the reflection and transmission of radiation. This makes for a complex set of possible changes from the clear sky situation. Observations from the aircraft provide the spatial distribution of clouds, but cloud properties are generally not available. The model can only deal with one dimensional clouds and then use a cloud fraction to deal with broken clouds. Typical values were used for cloud properties. While for a single observation the absolute discrepancy between model and measurement increases enormously in the presence of clouds, the model does manage to reproduce the general pattern of observations, and for a large set of data provides some statistical correlation with the observations. As the authors point out, chemistry-transport models are in need of better understanding of cloud-radiative interactions to increase confidence in their ability to predict photolysis processes when clouds are present, and this work begins to address that need, producing a simplified analytical model as a start to disentangling the complexities involved. The paper is well written and suitable for ACP, but requires some minor corrections.

Specific comments

The term "Actinic flux" is widely used in atmospheric science for what is the radiant fluence rate (W(or photons s-1)m-2), also sometimes called spherical irradiance or scalar irradiance. Radiant flux (W, or photons s-1) is the power emitted, transmitted or received in the form of radiation, while actinic simply means capable of producing a photochemical effect. It is clear how the term actinic flux developed as a shorthand for "radiation arriving at a molecule in the atmosphere and capable of causing a photochemical effect" when atmospheric chemistry is the interest. However the term is at odds with its mathematical definition (as given in equation 2) and with accepted lighting/radiation terminology. While the authors cannot be criticised for using the accepted, albeit incorrect, terminology in their field, perhaps they can start a move to use a more widely understood and technically correct term e.g. actinic fluence rate retains the sense that this quantity is appropriate to photochemistry, but is also clearly understood in general radiation terms.

Answer: The reviewer is absolutely correct that actinic flux is inconsistent with currently accepted radiation nomenclature. However, we are not sure that fluence rate is the most widely used alternative. For example, the ocean optics community uses the term scalar irradiance, for precisely the same quantity. Thus we are reluctant to champion a specific change in this paper. Instead, after the first occurrence of actinic flux, we will add (fluence rate) to indicate that perhaps this discussion should be re-opened.

Abstract – this gives the impression that the model and measurements agree almost perfectly. The level of enhancement or reduction in the observations, and captured by the model, should be quantified.

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."

P3326 How well do the input optics represent the theoretical directionally independent response to radiation? How are the SAFS calibrated, and how well do they compare with each other? What is the overall uncertainty in the measurements? This is alluded to later (p3329 line 17), but is never actually stated.

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."

P3328 /P3333 What is the effective albedo of the cloud in the TUV model / its contribution to the total albedo in the analytical model? Measurements of cloud and surface albedo in the UV can be found in Webb, A.R., Kylling, A., Wendisch, M and Jakel,E.(2004) Airborne measurements of ground and cloud spectral albedos. J. Geophys.Res. 109, doi:10.1029/2004JD004768.

Answer: In the analytic model, the cloud albedo is simply specified. In the TUV, the cloud optical depth is specified and the cloud albedo is calculated (depending on the sza). In most situations considered, the cloud albedo is much larger than the ground albedo.

P3328 What is the uncertainty in the model output for clear skies (based on the uncertainty of inputs)? Again this is mentioned later, but only in terms of "within the uncertainties". Please state what these are.

Answer: The biggest uncertainty in model input is the extraterrestrial solar flux. The absolute radiometric calibrations are of order 1-2% which is probably approached when integrating over a fairly broad band, as we do. In any smaller band, the relative errors will be larger. Rayleigh scattering contributes a little, but the cross sections are very well known, and the atmospheric pressure is usually measured well.

P3332 Section 4.2 provides a very simple approach to understanding a complex problem. However, it is almost divorced from the rest of the paper in that the simple analytical model is not systematically compared with either the measurements or the TUV model. If the same input parameters were used as for the TUV model then it would show whether the conceptual ideas in the simple model are realistic enough to be useful. For example, Rayleigh scattering is ignored – is this viable in the UV where Rayleigh scattering is especially strong?

Answer: This section has been moved to appendix A.

Technical:

- P3325 line 19/20 Sect. should be Section.

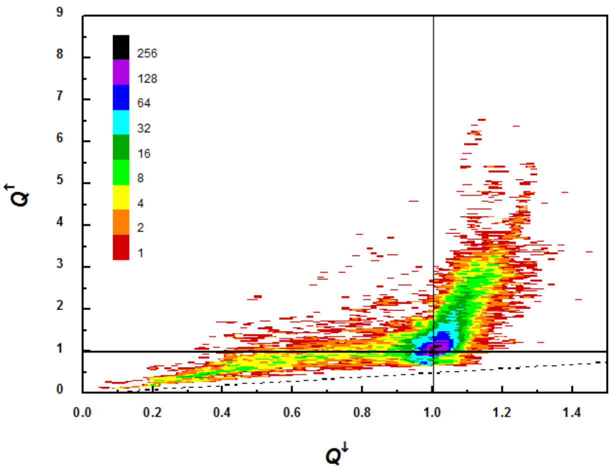
- Time should be expressed as UTC throughout.

- Figure 7 caption states correlation of cloudy model to clear sky model, yet the axes arelabelled observation/model. They should state model (cloud)/model (clear).

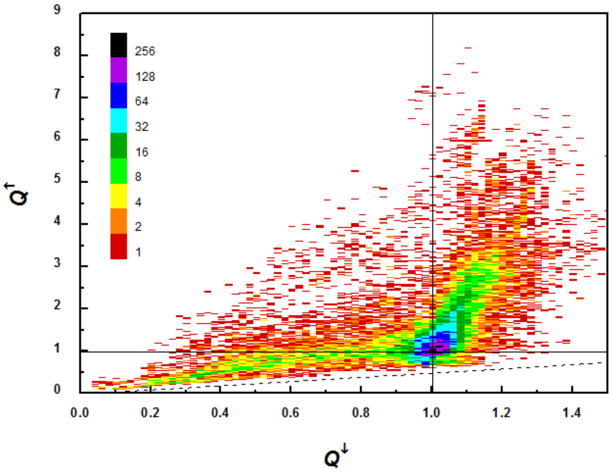
- Figures 3-7 are inconsistent in the notation used (Q up, or just UP) and both these aredifferent to the text. Please use one notation throughout.

- Fig 6 and 7. Why are the scales, and the number of points (observations) different onthese two figures? There are more grey spots in Fig 7 than are represented in Fig 6.

Answer: All the technical comments were addressed. To be consistent with the text, the notation Q^{tot}, $Q^{\downarrow}$ and $Q^{\uparrow}$ was used in all the figures. Scales in figures 6 and 7 were corrected to show the same range. Please, note that the data sets plotted in figures 6 and 7 are identical. The observed difference in the number of points between figures 6 and 7 arises as a consequence of the "Color Fill Control" used in the drawing program. Figure 6 is a contour plot created using the "Fill to contour Lines" option which produces the following kind of plot:



The other available option is "Fill to Grid Lines" which produces the following plot:



On the other hand, Figure 7 is an XY (scatter) plot created with a different drawing program.
We still think that, with the first option, the most important feature in the plot (i.e. the two regimes and the fact that the most common values occur near 1,1 which is clear skies), can be seen in a clearer way. Also, the fact that the program "ignores" some points changes neither the

visualization nor the interpretation of the figure. As the meaning of the upper limit is not clear, the corresponding lines were deleted from figures 6 and 7.