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Professor Andreas Hofzumhaus
Editor
Atmospheric Chemistry and Physics

Dear Prof. Hofzumhaus,

Once again I am indebted to the reviewer for some thoughtful feedback. Listed below are the comments from the reviewer. For each point raised I include *my response* to the comment, and where possible a line number reference for where a change has been made. For the supplementary material, these refer to the "diff" file line numbers which is appended to this response.

*****General Remarks*****

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*****Specific comments pertaining to the main text of the paper *****

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P5, L13: Change "of with" to "combined with"

Done

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P8, L21: Change "the irradiance measures are estimated to have a calibration uncertainty (1sigma) of 5.5 %." to "the irradiance measurements have a calibration uncertainty (1sigma) of 5.5 %." Note that I suggest to replace "measure" with "measurements"

Done

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Some uncertainties provided in the main text need adjustment, based on my comments below.

List of points where changes have been made:

Abstract altered (Page 2, L4) Uncertainty estimate.

Page 8, L19 Altered bias wording

Page 8, L 24. Altered wording to incorporate changes in uncertainty estimate.

Page 13, L21. Added sentence referring to the dependence of uncertainty on solar zenith angle.

*****Specific comments pertaining to uncertainty estimate (supplement)*****

In the version available to me (acp-2014-394-supplement-version2.pdf), references in the text are indicated by a question mark. The document has to be re-compiled with the correct citations.

Apologies - Corrected in this version. Because of the desire to allow comparability with previous versions I have kept the supplementary document separate. I believe that this text needs to be embedded in the main text as an appendix using the new style sheet once accepted?

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P1, L16: Change “whereas the direct beam irradiance is derived from measurements of global and diffuse signals.” to “whereas the direct beam irradiance deferred from SRAD measurements is derived from measurements of global and diffuse signals.”

Derived changed to inferred, which I believe to be the suggestion here. L16

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P2, L33: Change “that ratio” to “the ratio”

Done. L34

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Equation 2: The subscripts should be changed from lower case “o” to zero to be consistent with the other equations.

In addition, a bit more information should be provided how $S_0^T(lambda)$ and $S_0^T(lambda_r)$ are derived. For example, is $S_0^T(lambda)$ derived by first calculating $S_0(lambda, airmass)$ from the SRAD’s diffuse and global measurement for different airmasses and then extrapolated to airmass = 0 using the standard Langley technique?

Lower case o to 0 - done. An extra paragraph has been added to specify how the technique is implemented. L40 – L43

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Equation 3: It took me some time to verify that equation 3 is indeed correct. The second term of the equation contains the term $S_0^T(lambda_r)$ both in the numerator and denominator. For clarity, it might be better to rearrange the second term of the equation as follows:

$S_0(lambda) * (E_0^T(lambda)/S_0^T(lambda)) * (S_0^T(lambda_r)/S_0^T(lambda_r))$

and have a break in the line of the fraction between:

$(E_0^T(lambda)/S_0^T(lambda))$, and

$(S_0^T(lambda_r)/S_0^T(lambda_r))$.

The suggested change would break the link to c_{RL} in the line above. I have therefore left the expression as it was, but added an intermediate expression, leaving out $S_0^T(lambda_r)$ (which is duplicated, as the reviewer comments), to make the identity more explicit. I believe that this satisfies the intent of the reviewer. L46.

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P2, L54: change “equation S3” to “equation S1”

Done. L58

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Equation 4: The first and second term of this equation is basically a re-arrangement of the second and third term of equation 1. For clarity, the subscript “SRAD” should also be added to the first term of Equation 4 and the first factor of the second term of equation 4. (I use the term “term” here for expressions between equal signs).

Agreed. L61

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P3, L81: Change “of the ratio is less than 2% were” to “of the ratio of less than 2% was”

Agreed. L86

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P3, L84: Regarding "a value of 1% has been used": The value in Table 1 is actually 2%. Please make consistent.

Value in the table was cumulative, which was misleading and unclear. This has been altered in the table.

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P3, L87. All uncertainty components discussed so far refer to the 1-sigma confidence interval. To be consistent, the 5% uncertainty of the TOA spectrum quoted here should therefore also refer to 1-sigma. Please double check whether this is the case, and adjust value here and in Table 1 if necessary.

The wording in the reference is not clear. I have used their terminology more closely and stated that this is assumed to be a 1σ *estimate. L93*

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Section 1.4.: I am puzzled why the uncertainty of $S_0(lambda)$ has not been included in the uncertainty budget summarized in Table 1. It is the ultimate goal to estimate the uncertainty of an individual measurement of J(O1D). For example, some of the variability quantified by the box-whisker plots shown in Figure 4 and 5 is caused by the uncertainty of $S_0(lambda)$. $S_0(lambda)$ should therefore be part of the overall uncertainty as this quantity is part of Equation (3) like the other quantities discussed above.

Perhaps it could be pointed out that the uncertainty of $S_0(lambda)$ is a "Type A uncertainty" (see: http://physics.nist.gov/Pubs/guidelines /TN1297/ tn1297s.pdf), which decreases when individual measurements are averaged (for example, to calculate a monthly average).

Also, I assume that that uncertainty of $S_0(lambda)$ is much smaller during clear sky periods than cloudy periods as the interpolation of global and diffuse irradiance is not affected by varying clouds. This should be stated.

Lastly, I think this section should also be re-arranged. First it should be pointed out that the uncertainty of $S_0(lambda)$ is dominated by the uncertainty in deriving $S_0(lambda)$ from global and diffuse measurements because those measurements are performed sequentially and need to be interpolated. Second, it should be clearly stated that the uncertainty is estimated based on the ratio

$(S_0(lambda_r)SRAD)/(S_0(lambda_r)sunp)$

and that this approach was chosen because $S0(lambda_r)sunp$ does not require interpolation. Hence, the uncertainty of $S0(lambda_r)sunp$ is much smaller than the uncertainty resulting from the interpolation of global and diffuse data to derive $S0(lambda_r)SRAD$ and, in turn, this ratio. Third, it should be pointed out that the ratio is assumed to be independent of wavelength (i.e., the uncertainty of $S0(lambda)SRAD$ is equal to the uncertainty of $S0(lambda_r)SRAD$.

The comments are valid. I have taken the opportunity to recast the section which is evidently too brief - and to cover the points raised. I have also included the comments on Type A uncertainty estimates.

I note that the measurement uncertainty will become less important once multiple measurements are averaged. This was my original (but unfortunately unstated!) reason for not including it in the uncertainty estimate. I have now made this explicit in the the table by including both the single measurement uncertainty and the limiting (many measurement) limit.

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P4, L100: According to Equation 5 of the main text, F depends on E_0, alpha and E. the uncertainty of E_0 has been assessed in Section 1, the uncertainty of alpha is being addressed here, but the uncertainty of E (spectral global irradiance) is not assessed anywhere. Since the cosine error is corrected, the uncertainties of E and E_0 should be comparable, but because E and E_0 are not independent, their uncertainty components cannot be summed up in quadrature. I encourage the author to assess this problem and give his best estimate of the uncertainty component that could be attributed to E, and the effect on the uncertainty of F.

The global irradiance is somewhat different, in that it is measured directly rather than by difference. However, it is also an interpolated value for half of the measurements (when diffuse is being measured).

Regarding alpha: By assuming that alpha is between 1.73 and 1.96 with equal probability within this range and zero probability outside, the 1-sigma uncertainty calculates to

$(1.96 - 1.73)/2/sqrt(3) = 0.066,$

according to Section 4.4 of http://physics.nist.gov/Pubs/guidelines/ TN1297/ tn1297s.pdf. So the relative uncertainty is 0.06639 / [(1.96 + 1.73) / 2] = 0.0359 or 3.5%. According to the text, a 10% change in alpha results in a 8% change in F. Hence, the 1-sigma uncertainty of F is 3.5% * 8 / 10 = 2.8%. This value should replace the current value of 10% in Table 1. So the combined uncertainty of F should be $u(F) = sqrt(5.5\%^2 + 2.8\%^2) = 6.2\%$, assuming that the contribution u(E) of the spectral global irradiance E is negligible.

I have followed the reviewers suggestion on the uncertainty of α, and this is included in the text. (Using an equivalent reference). Following the warnings of this approach, I have also included an assessment of the importance of this estimate in the overall uncertainty.

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P4, L108: Again, is 10% a 1-sigma or 2-sigma uncertainty? For Table 1, a 1-sigma uncertainty is required, but research papers typically give a 2-sigma uncertainty, so I suspect that 10% is 2-sigma. I realize that authors are sometimes sloppy, so it may not be possible to determine the confidence interval of product of cross section and quantum yield.

Following the suggestion of the reviewer I have revisited Sander et al. and note that the uncertainty estimate is 1σ. I have noted this in the relevant line in the text.

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P4, L110: It seems that measurements may be biased low by a maximum of 5% because of the limited wavelength range. Ideally, data should be corrected by the best estimate of the bias, e.g., by 2.5%. If that would be done, the corrected measurements would be off by a maximum of 2.5% in either direction, and the 1-sigma uncertainty calculated with the approach above would be $(2.5\% - (-2.5\%))/2/sqrt(3) = 5\%/2/sqrt(3) = 1.4\%$. Since no correction was applied, I suggest to double this uncertainty to 2*1.4% = 2.8%, even though including a known systematic error in the uncertainty budget is not good practice. Note that this uncertainty is still smaller than the 5% currently given in Table 1.

I had considered including a correction for this as a bias, but had not considered treating it in this way. Thank you! I have now corrected all measurements by 2.5%, altered all figures and tables and included an estimate of the uncertainty of 1.4% as suggested. This is also mentioned in the main text.

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Table 1: Please adjust values in Table based on my comments above. State that these numbers refer to a confidence interval of 1 sigma, and consider providing an "expanded" uncertainty as described in Section 6 of http://physics.nist.gov

/Pubs /guidelines /TN1297/ tn1297s.pdf.

I have included the clarification of the nature of the uncertainties reported in the heading of the table.

Also, every line of the table should have a label, e.g., the label of the 5.5 value should read: "Combined uncertainty of $E_0(lambda)$".

The structure of the table has been modified.

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Please note that the "diff" file does not have complete references, but they can be found in the new version of the appendix.

Regards

A/Prof. Stephen WIlson

cc:

encl: Latexdiff file for appendix

Manuscript prepared for Atmos. Chem. Phys.
with version 2014/09/16 7.15 Copernicus papers of the LaTeX class copernicus.cls.
Date: 16 June 2015

Uncertainty Estimates for $J(\mathrm{O}^1\mathrm{D})$ Measurement

S.R. Wilson

In this supplementary material an estimate of the uncertainty in the measurements using SRAD is presented. Given the unusual nature of the calibration used for this instrument, this analysis is preceded by a description of the calibration method, followed by estimates of the uncertainties in the components of the calibration to derive an uncertainty in the determination of the irradiance. This is then used to derive an uncertainty in the spectral actinic flux. Then the uncertainty in $J(\mathrm{O}^1\mathrm{D})$ is considered.

1 Calibration Strategy

The strategy for calibration of the spectral radiometer (SRAD) has been described elsewhere (**?**). The method will be summarised here at least partially to harmonise the different symbols and terminology used. The key principle is to use the sun as the reference calibration source. This equates to a knowledge of the solar direct beam irradiance as a function of wavelength $E_0^T(\lambda)$, where T here indicates the top of the atmosphere. For this work the spectrum of **?** has been used. The initial focus is on the calibration of direct beam irradiance. Once this has been completed, the calibration of diffuse irradiance is determined and then direct and diffuse combined to derive the global spectral irradiance. It should be noted that the direct beam irradiance is measured by sunphotometers directly, whereas the direct beam irradiance is ~~derived~~ inferred from measurements of global and diffuse signals.

Atmospheric transmittance can be expressed in terms of the signal at ground level $S_0(\lambda)$ and top of the atmosphere $S_0^T(\lambda)$ or in terms of the direct beam irradiance (E_0). For measurements at a particular (reference) wavelength (λ_r) this can be expressed as:

$$\frac{E_0(\lambda_r)}{E_0^T(\lambda_r)} = \left(\frac{S_0(\lambda_r)}{S_0^T(\lambda_r)}\right)_{sunp} = \left(\frac{S_0(\lambda_r)}{S_0^T(\lambda_r)}\right)_{SRAD} \tag{1}$$

Here, the subscript $sunp$ refers to measurements made with a sunphotometer and $SRAD$ to measurements made with a spectral radiometer. For the calibration of sunphotometers, various techniques have been developed to determine $S_0^T(\lambda_r)$, as aerosol optical depth (AOD) is determined from the atmospheric transmittance. A calibrated sunphotometer therefore provides a measure of the transmittance at a particular measurement time, allowing an estimate of the SRAD top of the atmosphere signal $S_0^T(\lambda_r)$. A knowledge of $E_0^T(\lambda)$ then permits the derivation of the direct beam irradiance at ground level.

For other wavelengths we can determine the relative calibration using the ratio-Langley technique. The Langley technique is a well known implementation of the Beer-Lambert law where the top of the atmosphere signal is derived from direct beam solar measurements at a range of solar zenith angles. Fundamental to this method is the assumption that during the period of the analysis the atmospheric optical depth does not change. Alternative methods have been developed, such as the ratio-Langley (**?**). The ratio-Langley technique determines ~~that~~ the ratio in the top of the atmosphere signal between two wavelengths, assuming that the difference in optical depth between the two wavelengths does not change during the calibration, which is a much less stringent requirement, particularly when the two wavelengths being compared are close.

The ratio-Langley technique provides estimates of the ratio of top of the atmosphere signals, with this information derived from the spectral radiometer measurements:

$$c_{RL}(\lambda) = \frac{S_o^T(\lambda)}{S_o^T(\lambda_r)} \frac{S_0^T(\lambda)}{S_0^T(\lambda_r)} \tag{2}$$

In practice this means dividing the direct beam irradiance spectrum (from SRAD) by the direct beam irradiance at λ_r for a series of clear–sun measurements, and then extrapolating these ratios back to an airmass of zero using the standard Langley technique.

With the calibration at λ_r from above (equation S1), the direct beam irradiance can be derived at other wavelengths:

$$E_0(\lambda) = S_0(\lambda)\frac{E_0^T(\lambda)}{S_0^T(\lambda)} = S_0(\lambda)\frac{S_0^T(\lambda_r)}{S_0^T(\lambda)}\frac{E_0^T(\lambda)}{S_0^T(\lambda_r)} = \frac{S_0(\lambda)}{c_{RL}(\lambda)}\frac{E_0^T(\lambda)}{S_0^T(\lambda_r)} \tag{3}$$

The derived direct beam irradiance depends therefore on four independent factors as given on the right hand side of this equation, including the measurement itself. Each term will therefore now be considered, and then combined to produce an overall uncertainty estimate.

1.1 Estimate of $S_0^T(\lambda_r)$ and uncertainty

The sunphotometer measures the solar direct beam irradiance at a range of visible and UV wavelengths chosen to be relatively free from the influence of molecular absorption. The wavelength relevant for these measurements is 342 nm. This wavelength has been calibrated *in situ* through the use of the General method (**?**). This method, is also an extension of the Langley technique, assuming that the relative size distribution of the aerosols is constant for the time period being used for calibration, and results in significantly improved reproducibility (factor of 5) of the calibration values (**?**).

From equation S3S1, the SRAD top of the atmosphere signal at the reference wavelength is given by:

$$S_0^T(\lambda_r)_{SRAD} = S_0(\lambda_r)_{SRAD}\left(\frac{S_0^T(\lambda_r)}{S_0(\lambda_r)}\right)_{sunp} = S_0^T(\lambda_r)_{sunp}\left(\frac{S_0(\lambda_r)_{SRAD}}{S_0(\lambda_r)_{sunp}}\right) \quad (4)$$

$$S_0^T(\lambda_r) = S_0(\lambda_r)\left(\frac{S_0^T(\lambda_r)}{S_0(\lambda_r)}\right)_{sunp} = S_0^T(\lambda_r)_{sunp}\left(\frac{S_0(\lambda_r)_{SRAD}}{S_0(\lambda_r)_{sunp}}\right)$$

The ratio of the direct beam signal from SRAD and the sunphotometer can be determined every time there are valid coincident measurements of the direct sun.

In determining the calibration of the Carter-Scott SPO1A sunphotometer ($S_0^T(\lambda_r)_{sunp}$), the full 8 years of the operation of the has been analysed. During this time there were over 900 periods were available for calibration of this instrument (periods of observations with a solar zenith angle in the range 60 – 74 degrees following the removal of measurements impacted by clouds). The top of the atmosphere sunphotometer signal derived from this has an experimental standard deviation of the mean of less than 0.3%.

The ratio of the direct beam signals of the two instruments (last term in eq. S4) depends on both the absolute sensitivity of SRAD, which varied during the time period, and any non–ideal solar zenith angle response of the SRAD diffuser (which did not alter significantly during the measurements reported here). This solar zenith angle dependance (cosine error) has been assessed by determining the solar zenith angle dependence of the ratio of SRAD to the sunphotometer and corrected. the uncertainty in the cosine correction, determined by the scatter around a smooth curve, is of the order of 1% at solar zenith angles less than 80°.

Following the correction for the solar zenith dependence, the ratio of the direct beam irradiance signals are quite stable, except when there have been significant instrument changes. In the period 2003 – 2005 when the instruments were not changed the estimated central value derived from the median has a standard deviation of 0.5%.

1.2 $c_{RL}(\lambda)$

The accuracy of Ratio-Langley derived ratio has been assessed for sunphotometers (**?**), where single day calibrations had a relative standard deviation of < 1% and an accuracy consistent with this, using the Langley derived values as the true value (measurements were made at a high altitude site (Mauna Loa), where the Langley approximations are more valid). Using data from sunphotometers operating at Cape Grim with stable channels a standard deviation of the ratio is of less than 2%

were was observed. For the SRAD analysis, the scatter of the retrieved calibrations $c_{RL}(\lambda)$ has been determined for each calendar year. For wavelengths above 300 nm the standard deviation of the mean is <1%, but climbs rapidly to 2% by 298 nm. For the purposes of the uncertainty estimate, a value of 1% has been used.

1.3 $E_0^T(\lambda)$ and overall calibration uncertainty

The irradiance at the top of the atmosphere is taken from **?**. In this work they report an uncertainty of less accuracy of better than 5%. For the purposes of this analysis their estimate is assumed to be 1σ and this value has been used for the determination of the calibration uncertainty. When combined with the other uncertainties listed above for the terms in equation S3 , the total uncertainty of the direct beam calibration is estimated to be 5.5%.

1.4 $S_0(\lambda)$

The uncertainty in the determination of individual values of direct beam irradiance signal ($S_0(\lambda)$ from the measurements of spectral is derived from sequential measurements of global and diffuse irradiance from SRAD can also be estimated. The scatter in the values of separated by several minutes. Further, the direct beam irradiance is derived as the difference between measurements of the global and diffuse signal and hence there is significant uncertainty introduced by this process. As the sunphotometer is not subject to these limitations, scatter in $\frac{S_0(\lambda_r)_{SRAD}}{S_0(\lambda_r)_{sunp}}$ will be dominated by the SRAD uncertainty unless this ratio approaches the standard deviation in the sunphotometer measurements, which is less than 1%. (It should be noted that SRAD returns measurements of global and diffuse irradiance with a standard deviation of 1% as measured by repeated measurement).

The observed scatter in $\frac{S_0(\lambda_r)_{SRAD}}{S_0(\lambda_r)_{sunp}}$ (determined from the Median Absolute Deviation scaled by 1.48 which equates to standard deviation for a normal distribution) is 12%. Both the sunphotometer and SRAD return measurements with a standard deviation of < 1% This much larger scatter in the ratio results from the need to interpolate values over periods of several minutes, and that the direct beam irradiance is derived as the difference between measurements of the global and diffuse signal. This uncertainty will be reflected in While this estimate is based on measurements of "clear sun", this does not mean clear sky but rather observations where the sun is not obscured by cloud. This variability will dominate other errors. For example, at large zenith angles (low signal) the wavelength of maximum contribution to $J(O^1D)$ around 310 – 320 nm has a signal intensity at least 100 fold greater than the noise. As a Type A estimate of uncertainty **?** , estimates derived from multiple measurements will have a smaller uncertainty.

1.5 $S, S_\downarrow$

The uncertainty in the diffuse and global signals can be estimated from the relationship given in Eq. (4) (main text) with an assumption in the relative uncertainty in the diffuse and global measurement. Since both measurements need to be interpolated, both are subject to the same error sources. If the % scatter is the ~~variation in the derived quantities and not directly in the calibration itself~~same for both diffuse and global, the implied uncertainty in both is approximately 8%. Note that these two quantities are independently measured. The wavelength dependence of this uncertainty in S and $S_{\downarrow}$ is difficult to quantify but it seems unlikely to be significant.

For E and $E_{\downarrow}$, the uncertainty is the combination of measurement and calibration uncertainties, which for a single measurement is 10%.

2 Uncertainty in F

The uncertainty in F as derived from ~~equation~~ Eq. 5 (main text) will contain the calibration uncertainty discussed above, ~~and~~ the measurement uncertainty in the global and diffuse irradiance and the uncertainty in α. First, Eq. 5 is recast in terms of the measured quantities:

$$F = E_{\downarrow}(\alpha - 1/\mu) + E/\mu \tag{5}$$

Assuming that the correlation between variables is small (Section 5.1.2, **?**), so that the higher order terms can be ignored, the uncertainty in F can be written as:

$$\sigma_F{}^2 = (\sigma_{E_{\downarrow}}(\alpha - 1/\mu))^2 + (\sigma_\alpha E_{\downarrow})^2 + (\sigma_E/\mu)^2 \tag{6}$$

The remaining quantity to be estimated is the uncertainty in α. Based on the work of **?** α should lie in a range 1.73 (cloud) – 1.96 (clear sky). ~~This represents~~ The distribution of conditions are probably not normally distributed within these limits. Following Section 4.3.7 **?** , with no knowledge of the distribution, a uniform distribution is assumed between these limits, giving an uncertainty of ~~the order of 10% . A 10% change in α results in an 8% change in~~ 3.5% (1σ).

Eq. S6 gives an uncertainty that is dependent upon the solar zenith angle. At around 56 degrees the first term is close to zero, and given the estimates given above, the second term is a few percent of the final term. It is informative to consider the case when it is overcast. Then $E_0 = 0$ and the expression for F ~~, determined from this data set. This results in an overall uncertainty in the determination of F of~~ becomes $F = E_{\downarrow}\alpha$. However, as E_0 is determined by difference between the global and diffuse spectral irradiance, the uncertainty remains dependent upon μ. Therefore, for all viewing conditions the uncertainty in F increases with increasing solar zenith angle.

Eqn. S6 has been evaluated for the whole dataset presented here. On average, it is found that the final term is 80% of the total uncertainty, with the other two terms being around 10% ~~(due to the calibration plus~~ each. The derived median uncertainty for F is 12% for a single measurement.

When considering averages of measurements, the importance of the signal uncertainty will decrease, and the uncertainty in E and $E_{\downarrow}$ should approach the calibration uncertainty. Under these conditions the uncertainty remains dominated by the final term in Eq. S6, with a median uncertainty of 7%.

Given that the uncertainty term involving σ_α is relatively small, the assumption of the form of the distribution of α ~~estimate)~~is not critical.

3 Determination of $J(\mathrm{O^1D})$

To evaluate the uncertainty in the integral given in equation 2 (main text) it is necessary to consider all terms over an extended wavelength range. For the combined uncertainty of the cross section and quantum yield for the production of $J(\mathrm{O^1D})$ from ozone is estimated to be 10% (1σ by **?** for the relevant wavelengths here.

The UV-B measurements span the region 298 - 335 nm, and this can lead to an underestimate of the photolysis rate. A study by **?** found that cut-offs below 298 nm did not perturb the estimate of $J(\mathrm{O^1D})$ by more than 5%, with the maximum error at times of low column ozone and high sun. Test measurements using spectra measuring out to 340 nm found that including the region between 335 – 340 nm altered $J(\mathrm{O^1D})$ by less than 1%. There is no recommended quantum yield for $\mathrm{O(^1D)}$ production above 340 nm (**?**). The estimates presented here will therefore be biased low by the limited wavelength coverage by typically less than 5%. The estimates of $J(\mathrm{O^1D})$ have therefore been increased to correct for this bias by 2.5%, and the 1σ uncertainty in this is estimates to be 1.4%, using the distribution logic applied to σ_α given above.

The resultant estimated uncertainties are summarised in Table ~~s1~~S1. It should be noted that this does not include any estimate of the impact of model assumptions including the assumption of isotropic diffuse irradiance or the assumption of the surface albedo equal to zero.

For comparison with the model TUV 5.0 (**?**) some of the uncertainties are common, as the same spectral data are used and the comparison is with clear skies, where the uncertainty in α is much smaller. Therefore in this case the relevant uncertainty is close to the calibration uncertainty (5.5%), although the ozone column, taken from TOMS satellite measurements is an assumed parameter in this comparison.

Table 1. Summary of the percentage uncertainties (1σ) in determining the irradiance, the estimation of the spectral actinic flux and $J(\mathrm{O^1D})$. The "limiting" uncertainties are calculated for estimates based on averaging numerous measurements. In this case the measurement uncertainty is no longer significant.

Quantity	Component	% Uncert.
Calibration $(E_0(\lambda))$	Cosine Corr.	1
	$S_0^T(\lambda_r)$	0.5
	$c_{RL}(\lambda)$	2
	$E_0^T(\lambda)$	5
Overall Calibration Uncertainty		5.5
Measurement Uncertainty	(S_0)	12
	$(S,S_\downarrow)$	8
Overall Uncertainty	E, E_0	10
F	α	~~10~~3.5
Combined uncertainty	1 meas.	~~10~~12
"	limiting	7
Ozone properties	Φ,σ	10
Limited wavelength range		~~5~~1.4
$J(\mathrm{O^1D})$	1 meas.	~~15~~16
"	limiting	12